Information for NZIER Report on Oil Security

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1.0 Introduction

The Ministry of Economic Development (MED) is updating the 2004/2005 study into New Zealand's oil security (the "2005 Report")[1]. They have contracted NZIER to undertake this review and have asked them to work with Hale & Twomey (H&T) to complete this task. As in the 2005 Report, MED wants the review to cover both international disruption events and domestic events which would be caused by infrastructure disruption.

The 2005 Report assessed the value of holding stock to mitigate disruptions. This review reassesses the value of holding stock as well as other mitigation options. H&T's input to the review is to:

- Calculate the disruption impact from the various scenarios being assessed
- Investigate and update the probabilities for each disruption scenario
- Assess the direct costs involved in mitigating the disruption
- Review and agree the findings with NZIER following their analysis of the economic impact from the disruptions

This report summarises the scenarios, details the possible disruption, outlines the direct costs and estimates the probability of each event.

2.0 Scenarios

The scenarios are similar to those in the 2005 Report. Rather than repeat that work, this report provides an update and explanation of how the disruption is now calculated when different from the 2005 Report. Two new scenarios covering disruption to the Wellington and Lyttelton distribution terminals have been added to this review.

In order to create a significant disruption the scenarios are low risk but high impact events. The petroleum industry carries sufficient stock and safety buffers to manage disruptions that are more likely to happen. There has not been an incident along the lines of those outlined in these scenarios in the actual petroleum supply to New Zealand to the knowledge of the authors.

2.1 International disruption

2.1.1 Probability of event

The 2005 Report used disruption probabilities data taken from a Paul Leiby presentation to develop an international scenario. The base data giving annual probabilities is shown in the following table from the 2005 Report.

Study	Disruption of 10% or more of World Supply	Disruption of 15% or more of World Supply
EMF 1996	5.3%	2.5%
DOE 1990 High Risk	3.1%	1.4%

[1]Covec and Hale and Twomey Limited (2005) Oil Security, Report prepared for Ministry of Economic Development, Wellington

DOE 1990 Midcase	2.4%	1.0%
DOE 1990 Low Risk	1.5%	0.5%
CIA-hosted Panel 1999	1.1%	0.4%

The disruption data was originally used in a report on The Value of Expanding the U.S. Strategic Petroleum Reserve (2000).[2] The EMF study refers to a study by the Energy Modelling Forum at Stanford University. In 2005 they updated this work using new methodology and more detailed build-up of the probabilities of disruption[3]. This study used a risk assessment framework with input from workshops including leading geopolitical, military and oil market experts. The primary output from the study was:

At least once during the 10-year timeframe 2005-2014:

- The probability of a net (of offsets)[4] disruption of 2 MMBD (million barrels per day) or more lasting at least 1 month is approximately 80%.
- The probability of a net (of offsets) disruption of 2 MMBD or more lasting at least 6 months is approximately 70%.
- The probability of a net (of offsets) 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 ore more is about 50%.

These disruption probabilities cover much smaller disruptions than the 10% (~8.5 MMBD) and 15% (~12.8 MMBD) disruption probabilities in the above table, although as the disruption is at 2 MMBD or more, the larger events are included. The review also noted:

> *"A similar risk assessment was conducted by EMF in 1996. The current assessment covers four regions of the world instead of two regions, has updated probabilities to reflect current world conditions, and has modified excess capacity and oil supply forecasts. The net effect of these changes shows an increased likelihood of disruptions for all sizes up to 10 MMBD, but the same estimate as 1996 for disruption sizes of greater than 10 MMBD (7-8% or lower)."*

The 2005 EMF study shows the new results against their 1996 study. The 1996 study numbers are lower (when converted into annual probability) than the numbers shown for the same study (EMF 1996) in the Leiby table (and as used in the 2005 Report). A 10 MMBD disruption is about a 12% disruption (on 2004 world consumption) and the EMF studies (both 1996 and 2005) assess this as a 7-8% risk in a 10-year period (0.7-0.8% per annum). This is a lot lower than a 5.3% for 10% and a 2.5% for 15% disruption shown in the table from Leiby's paper.

The 2005 EMF study now appears to be the most thorough study that other papers use for disruption risk[5] so we have used this paper for updating the international disruption estimates.

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[2] Paul N. Leiby, David Bowman, 2000; The Value of Expanding the U.S. Strategic Petroleum Reserve by Oak Ridge National Laboratory (pg. 16).

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

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

These probabilities are given for events of a certain size or more and for a certain time period range. For modelling we use a specific event as a representation of a range of likely events. To do this we use the probability curves given in Figure 13 in the paper (copied in Appendix 2). While the disruption impacts have taken account of any spare capacity in supply when calculating the disruption impact, they have accounted for the use of emergency stocks in response.

For the analysis we take an event that causes a disruption of 7MMBD or more which has probability of approximately 25% (2.5% per annum) for an event of 6 months duration (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 these events is around an 8.4 MMBD disruption which is a 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

2.1.2 Market response

While the normal supply to the market 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). In addition the price will increase, which will have the effect of stimulating supply (i.e. rising prices will stimulate additional supply in addition to use of normal spare capacity) and reducing demand.

The price rise will be a result of the net price elasticity's of supply and demand. There is a thorough discussion of these elasticity's given in the paper by Brown et al. (2010)[6]. These elasticity's are also in line with similar papers reviewed. In summary the combination of the supply and demand elasticity's yields a midpoint elasticity of -0.136. That is oil prices will rise by 7.35 per cent (=1/0.136) for every 1 per cent reduction in oil supply.

To calculate any price and disruption impact, the response of countries that hold emergency stock needs to be taken into account. A 10% disruption for 6 months is a total disruption of approximately 1,600 MMB. This is a similar size to the government and public emergency stocks held in IEA countries[7]. However given a disruption will 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 a 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%. This has the following impact on international and local prices.

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[5] For example: Oak Ridge National Laboratory, Paul N. Leiby, 2007. "Estimating the Energy Security Benefits of Reduced U.S. Oil Imports", February 28 and Resources for the Future, Stephen P.A. Brown and Hillard G. Huntington, 2010. "Reassessing the Oil Security Premium", February.

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

[7] Based on an update of Table 2 in the paper by Leiby et al. (2000)

		Initial response (10%)	Likely settled response (5%)
Increase in base price		74%	37%
Crude oil price (assuming base price US$120/bbl)	US/bbl	$208	$165
NZ petrol price increase	Cpl (%)	+91 (42%)	+46 (21%)
NZ diesel price increase	Cpl (%)	+91 (64%)	+46 (32%)
NZ jet fuel price increase	Cpl (%)	+91 (71%)	+46 (36%)

Notes: NZ price increases assume 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. Exchange rate assumption US/NZ 0.8200.

2.2 Major Refinery Outage

The Marsden Point refinery, owned and operated by Refining New Zealand (Refining NZ), remains a vital link in the New Zealand petroleum supply chain. Since 2004 the refinery has expanded its middle distillate producing units so it now produces a larger proportion of the market demand (close to 100% for jet fuel and ~80% for diesel). The refinery has also announced a project to expand its petrol producing capacity which will take Refining NZ's typical share of the petrol market from 55% to 65%.[8]

The refinery continues to target (and achieve) first quartile performance for operational availability (reliability) for refineries in the Asia-Pacific region as benchmarked by Solomon Associates[9]. The Refining NZ CEO also reported in the 2010 Annual report:

> *"We have a very good track record and have received the highest ratings from our insurer".*

Based on their performance since 2004 and their continued high performance on external benchmarking we can conclude, as with the 2004 report, 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.

2.2.1 Outage scenario

The scenario assumes that some incident (be it a natural disaster or internal event) takes the refinery out of action for an extended period such that the refinery customers have to re-establish their supply routes using 100% import supply. While the refinery is off line, the scenario assumes that within a relatively short period of time (1 to 2 weeks) the refinery tankage and RAP will be able to be used for import cargoes. Any delay in using these facilities will not change the overall shortage of product (from a national perspective), rather concentrate the shortage on the Auckland region.

The scenario calculation assumes the following:

- Imports already planned will continue to meet some of the market demand (42% petrol, 2% jet and 25% diesel based on 2011 data).
- That it will take 6 weeks (42 days) for companies to re-establish full supply via imports.

[8] Refining NZ, Notice of Annual Meeting Explanatory Notes 2012

[9] Refining NZ Annual Report: page 7.

- Given the size and reach of the companies operating in New Zealand, we expect some will be able to secure additional short term imports by diverting cargoes from other destinations or securing very prompt cargoes (it is assumed that two additional cargoes can be secured in 2 to 3 weeks and two more in 4 to 5 weeks).
- Companies will draw down the normal buffer stocks they carry to manage normal operational variation along with their safety stocks. We estimate this to be about 9-10 days consumption at normal rates. There is a lot more stock than this in the system but the system requires it to operate - if this stock is drawn down it will minimise the immediate shortage but there will be a delay when the stock is rebuilt before supply can be re-established - the net short to market will be the same.

The net impact over a two month period is shown in Appendix A. Over the 42 day period about 24% of normal petrol and diesel demand cannot be met. While the shortage is shown at its worst in the first two weeks, this can be smoothed across the period by drawing down on inventories faster in the initial period (this assumes inventories are drawn evenly over 42 days).We have assumed that the shortage is evenly spread over the country and the shortages given for petrol/diesel are about 50/50.

The jet shortage is worse as Refining NZ supplies virtually all the market so there are no imports to meet some demand. Nearly 50% of normal demand can't be met over the period. Jet demand in New Zealand is approximately 30% domestic with the rest international - it will primarily be international demand that will be affected. The expectation is that there will be some rationalisation to flight timetables to better load aircraft and reduce fights (both domestically and internationally). For international flights it will mean that many flights will tanker in fuel for their return journey when they fly to New Zealand to minimise fuel pick up in New Zealand. For example, any plane larger than an A320 or Boeing 737 flying the Tasman can load enough fuel to avoid lifting any fuel in New Zealand. Long haul traffic (NZ to/from Asia/North America) does not have this option so it is likely they will need to stop outside New Zealand (e.g. Brisbane, Nadi) either before or after their visit to load additional fuel to minimise the jet use locally. Alternatively the international flights will be rationalised and long haul passengers may need to go out through Australia.

The summary of the assumptions for the jet shortage impacts are:

- 52% still met (1.81 ml/day)
- 10% lower demand (0.35 ml/day) by rationalising flights[10]
- 15% bunkered from Australia for trans-Tasman flights (0.52 ml/day) - i.e. normal demand shifted to Australia[11]
- Remainder (23% or 0.80 ml/day) would need to be bunkered in on other international flights (i.e. there would only be about half the normal jet availability for long haul flights)

2.2.2 Probability

The probabilities assessed in the 2005 Report still appear valid based on the updated information and the reliability benchmarking of the refinery noted above. The Major Accidents Reporting System (MARS) database was again reviewed for the last 10 years to assess incidents for petrochemicals and refining. There were a slightly higher number of incidents reported compared

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

[11]Based on discussions with Air New Zealand and the Board of Airline Representatives New Zealand during the work on RAP contingency options.

to the 2005 Report (46 incidents of which 40 appeared to be related to refineries although some of these were refineries with petrochemical units so may have been petrochemical related).

The incident mix was similar to the last review 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 leaks of vapours causing fire and explosions. While some incidents were very severe (involving fatalities) there were few that had a significant impact on production (an 8 week shutdown was the longest noted although many cases did not specify shutdown periods). In virtually all cases where there was detail given, the facilities involved did not have a good record in terms of safety and reliability leading up to the incident.

Taken on face value with this sample, there are approximately 100 refineries in Europe so 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 as noted there may have been other shutdowns not detailed. Given Refinery NZ reliability and safety performance you 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.

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. These were covered in the earlier report and in terms of natural disasters, it should be noted that one of the reasons the Marsden Point site was chosen was for the regions lower risk to natural disasters (e.g. lowest earthquake risk within New Zealand).

Hale & Twomey has reviewed the Northland Lifelines Group Infrastructure Resilience Plan[12]. This review identifies the co-dependences of the infrastructure including, for example, the refineries dependence of electricity and water supply. They then assess infrastructure failure scenarios and the risk posed by natural hazards. For this report the relevant information is the risk posed by natural disasters to the probability assessment (as we have covered single site fire/technological failure in the probability assessment above).

The major natural disaster risk (both for electricity network and the refinery) is identified as a tsunami or volcano. Cyclone/flooding is assessed at much higher probability although the disruption caused by these events are likely to be shorter term (covered in the next scenario) rather than the long term disruption being assessed here. The report assesses tsunami at a higher probability than volcano.

The tsunami risk is further assessed in Part D: Lifelines Tsunami Plan[13] and the report Review of Tsunami Hazard and Risk in New Zealand.[14] The refinery is coastal and is well within the area covered by the orange and yellow zones which are assessed as the maximum credible regional/distant tsunami and maximum credible local source tsunami. However it would not be affected by the red zone - an event impacting on the direct shoreline. If the refinery was inundated and suffered major damage the assessment is that it would take months to recover - consistent with this scenario. While it is clear that the refinery could be affected by a major tsunami the issue is the probability. The probability is more clearly shown in the GNS report (Section 9: Results of Risk Modelling). The refinery is not in a high risk area and while it would

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

[13] Northlands Lifelines Group: Infrastructure Resilience Plan (January 2012). Part D: Lifelines Tsunami Plan.

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

expect to receive a significant wave (over 4 metres) on a 1 in 2500 year analysis; on a 1 in 500 year analysis the wave height expected would be under 4 metres and unlikely to cause major damage. Therefore tsunami risk taking out the refinery for an extended period would be assessed at between 0.04-0.20% in line with our prior assessment of risk for this scenario (when added to the internal risks).

The 2005 Report gave the probability for a complete refinery outage (including all facilities) as 0.1-0.2% and for a complete plant outage (but not jetties, tanks and pipelines) 0.25-0.35%. This scenario is a combination of both, although it assumes the jetties tanks and pipelines will be available again in a relatively short period of time. There is no reason to change these probabilities from the updated analysis so we recommend using the same a range of 0.20-0.25% (1 in 400 to 500 years) to represent this scenario.

2.2.3 Cost of disruption

This section covers additional costs incurred by the suppliers to minimise the disruption rather than the cost of not meeting demand which is covered in the NZIER work. In this scenario the oil companies re-establish supply using imports. While they are likely to face some increased costs to access prompt cargoes, ultimately supply via import is 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 do carry business interruption insurance) nor do we consider loss of refining margin to the refinery users.

2.3 Short refinery disruption

This scenario assesses a shorter duration outage of the refinery when it will commence operation again with a timeframe that it is not worth establishing full re-supply using imports. In effect this is a significantly more severe version of refinery upsets that happen from time to time and are managed by companies using inventories that they carry.[15]

While the scenario assumes a full outage of the refinery for a three week period, in practice it may be a shorter total refinery outage with one unit down for an extended period (e.g. if there had been an incident on one unit). The impact on product shortage is likely to be similar although there may be a larger impact on one product rather than across all products as assumed in this scenario.

2.3.1 Outage scenario

The scenario assumes that some incident (be it a natural disaster or internal event) takes the refinery out of action for three weeks. While it won't be known immediately, it is expected that the approximate timeframe for restart would be known within a few days after the incident so industry know they are not switching to a complete import supply. It is assumed in this scenario that, other than for a relatively short outage (up to a few days), the refinery tankage and RAP pipeline will be operational.

The scenario calculation assumes the following:

- Imports already planned will continue to meet some of the market demand (42% petrol, 2% jet and 25% diesel based on 2011 data)

[15] Refinery NZ reported 1.4% unplanned downtime (5 days) for 2011 performance (Annual Report 2011)

- Given the size and reach of the companies active in New Zealand, we expect some will be able to secure additional short term imports by diverting cargoes intended for other destinations (it is assume that two additional cargoes can be secured in 2 to 3 weeks)
- Companies will draw down on the normal buffer stocks they carry to manage normal operational variation along with their safety stocks. Because of the shorter duration these will likely be drawn down more quickly than the long term disruption.

The net impact over a two month period is shown in Appendix A. Use of inventories and a couple of very prompt imports can mean that the actual stock shortages will be minimised (approximately 2% for petrol and diesel and about 24% for jet). In practice there will be stock outs in certain areas for short periods as the suppliers ration the available product around the country - this scenario assumes all buffer and safety stock is being used. It is likely the shortages will actually be in week 2 through to weeks 4 and 5 rather than over the immediate three week period as shown in Appendix A (magnitude will be similar).

The shortage of jet fuel will require action to be taken. It is assumed it can largely be managed by short term rationalisation of flights and tankering fuel from Australia for trans-Tasman flights.

2.3.2 Probability

The probability of a shorter term outage is higher than an extended outage. A number of the incidents reported in the MARS database on refineries involved short term refinery shutdowns or extended shutdowns of some units (approximately 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 in the last scenario, their performance is significantly better than an average refinery.

Natural disasters would also be a higher probability in that cyclone/flooding could cause this scenario especially severe disruption to the electricity network.

The 2005 Report did not explicitly cover this scenario. The probability would be higher than the extended outage but certainly better than the average European performance. Added to this is the risk from natural events and dependent infrastructure (e.g. electricity network).

Given these factors our estimate for a short term (three week) outage is 0.5-1.0% (1 in 100 to 200 years).

2.3.3 Cost of disruption

In this scenario the oil companies are likely to face some 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.

2.4 Long term disruption to RAP/Wiri

This scenario is a regional infrastructure disruption rather than a national disruption. There will be product available in the country – the difficultly will be getting it to where it is needed (Auckland). This scenario is based on work done by H&T in the RAP Contingency Review.[16] Based on feedback from the oil companies during the review, the most severe contingency analysed here is a long term disruption to the Wiri terminal that removes both the terminal and the stock in the terminal

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

from use for market supply for an extended period. There is short term market demand (one to two months) that cannot be met as the companies re-establish supply from neighbouring terminals. Ultimately more trucking and driver resource will be needed from overseas to meet the increased distribution task. Reestablishment of jet fuel supply will be managed separately.

2.4.1 Outage scenario

The scenario assumes that some incident (most likely to be an event that destroys a significant part of the asset) takes the Wiri terminal out of action for an extended period such that the companies that use Wiri need to re-establish supply into Auckland from neighbouring terminals. For petrol and diesel ultimately 100% of the supply can be met from neighbouring terminals although it will take some time to put the assets in place (specifically trucks and drivers) to enable all the supply to be met. Jet fuel is covered separately.

The scenario calculation assumes the following[17]:

- While Auckland itself faces the shortage, the transportation assets from Northland and Bay of Plenty/Waikato will also be used to assist in the resupply. This means that rather than have normal supply in those regions and a serious shortage in Auckland, the shortage will be spread across the region, although the shortage in Auckland will still be a little more severe. While this results in a slightly higher shortfall volume (because the assets are being employed to do longer journeys), we expect it is economically rational as the cost will increase as the shortage becomes more severe in a region (i.e. the cost of reducing Auckland availability by 1 million litres if it is already short 5 million litres will be a lot higher than shorting the other markets 1 million litres from a full supply situation).
- Over the first week any spare trucks in the country (10 assumed) are relocated and assigned to the new task.
- Permission to allow trucks to load over the current road weight limits (allows increased volumes to be transported) is given after a week and that increases to maximum capability over the following 9 days.
- Other measures (e.g. demand shift from region, improved distributor fleet utilisation, loading efficiencies) 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.
- 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) .
- In this case there is little stock to cushion the impact so the impact of the disruption will be felt within a couple of days (there is likely to be 1-2 days of jet supply at the airport).

The petrol and diesel 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 12% (of the upper North Island demand) or 63 million litres, although taken over the first two weeks the short is 28% (33 million litres).

The jet shortage is more severe as Wiri terminal provides the only means of getting jet fuel to Auckland Airport. This is approximately 77% of the national demand. The impact will be almost immediate as the airport facility only carries one to two days stock.

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

[17] All assumptions are more fully explained in the RAP contingency report

- 3% for regional airports will be met from Wellington (0.08 ml/day)
- 12% for domestic aircraft will be shifted to Wellington and Christchurch (0.32 ml/day)
- 20% will be shifted to Christchurch to meet shifted international demand (0.54 ml/day)
- 15% will be tinkered in from Australia for trans-Tasman flights (0.41 ml/day)
- 10% will be reduced through flight rationalisation (0.27 ml/day)
- 40% will need to be tankered in on international flights (1.09 ml/day)

In summary, this means only 35% of the normal Wiri demand will be met (through other New Zealand airports) whereas the rest will either be avoided through rationalisation or shifted offshore. A requirement to meet 40% of normal demand by tankering in on international flights is possibly more than can be managed (as this is more than a 50% reduction in normal availability). It may be that serious changes to the schedules (e.g. nearly all flights coming through Australia) will need to be made with many long-haul travellers needing to fly in/out through Australia.

Unlike petrol and diesel, the jet problem doesn't reduce overtime and continues until a solution can be put in place. From the RAP Contingency Study the best option to restore the jet fuel supply was to put in place a system to directly connect the RAP to the WAP (pipeline between Wiri and the airport). While this would restore 100% of supply, estimates are that it would take from 3 to 6 months to put in place. If may be less if preparatory work is done – this is analysed in the NZIER report.

2.4.2 Probability

The 2004 report assessed the probability of a Wiri terminal outage (although that was a four week outage with a similar impact) at 0.2-0.4%. A further review of the MARS database shows that it is not very comprehensive for terminal incidents so not a good indicator of probability.

The most significant terminal incident in the last 10 years was a major terminal explosion and fire at Buncefield in the United Kingdom (December 2005). This incident resulted in standards for all terminals to be re-evaluated both for design/construction and operation. During the RAP Contingency Review, the owners of the Wiri terminal advised that the lessons learned from Buncefield have been applied to the Wiri terminal (such as upgrading the fire water systems).

The upgrades would have the impact of reducing the probability of incidents. We reflect this by reducing the end of the range of likelihood for this analysis. This gives a range of 0.2-0.3% for this event (1 in 333 to 1 in 500 years). While this seems low in fact it can be regarded as relatively generous when analysing terminal performance in New Zealand. This is discussed further in Section 2.8. We note also from the tsunami risk assessment that Wiri is unlikely to be affected by a tsunami given its location.

2.4.3 Cost of 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 $90,000/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. While there will be extra shipping cost this should be largely offset by not paying pipeline fees.

There is no estimate of the cost of disruption to the airlines for the jet disruption. At this stage we are using a preliminary estimate of $0.5-1.0 million/day relating to the extra costs involved in tankering fuel. The disruption to flights would be additional.

2.5 Short Term Disruption to RAP/Wiri

This scenario reflects disruption to the RAP pipeline rather than the Wiri terminal. During the RAP Contingency Review, discussions with Refining NZ (owners of RAP) and the Wiri terminal operators gave comfort that RAP disruptions should be able to be resolved in a short period of time (less than 7 days). Scenarios which might take the pipeline out for longer periods involve severe natural disasters that would also remove much of the demand (e.g. a volcano that would force the evacuation of Auckland and closure of Auckland airport). Therefore to model a severe scenario we assume a 9 day shutdown of the RAP.

2.5.1 Outage scenario

The scenario assumes that some incident or natural disaster causes such damage to RAP that is would take 9 days to restore operation.

The scenario calculation assumes the following:

- Unlike the long term outage (Wiri disruption), the stock at Wiri at the time of the incident will still be available to market. While typically there is around 6 days stock held at Wiri, we assume not all of this can be accessed without causing disruption when trying to build stock again. On average we assume only 4 days of each product can be drawn down (at any one time some products will have more and others less).
- Over the first week any spare trucks in the country (10 assumed) are relocated and assigned to the extra task (trucking fuel into Auckland from neighbouring terminals).
- Some of the normal fleet servicing Wiri will remain there accessing the existing stock (about 50%), with the remainder moving to neighbouring terminals to transport extra product into the region.
- Spare RAP capacity means stocks can be rebuilt at Wiri in the period following the shutdown.

While the stock at Wiri can be used to smooth the disruption, in theory 17% of the normal petrol and diesel demand won't be able to be met over the 9 day period. This disruption could be minimised by encouraging consumers to defer demand - product will be available, just in a few days' time. Given stock normally in the system (e.g. service station stocks) it could be that the main impact from the outage will be that some service stations run out of stock for a limited period rather than a severe market outage.

The jet disruption will be more severe as there is no ability to supplement the available inventories with supply from neighbouring terminals or to defer demand. Given inventories normally held at Wiri and Auckland Airport we assume a little over 5 days normal demand can be met (it may be a little higher if the normal testing cycle can be expedited). The summary of the assumptions for the jet shortage impacts are:

- 55% still met (1.43 ml/day)
- 10% lower demand (0.26 ml/day) by rationalising flights
- 12% demand shift (0.31 ml/day) by shifting domestic demand to Wellington/Christchurch
- 15% tankered from Australia for trans-Tasman flights (0.39 ml/day) - i.e. normal demand shifted to Australia
- Remainder (8% or 0.21 ml/day) would need to be tankered in on other international flights

In effect, 67% of normal demand will still be met from New Zealand airports.

2.5.2 Probability

In the 2004 report the probability of a three week RAP outage was assessed at 1-2%. In hindsight the outage is very unlikely to be that long so this probability is high. Updated statistics from the US for pipeline incidents translated to RAP would be for an incident once every 15-20 years rather than once every 12 years with the 2004 data. In practice many of these outages and short term spills rather than significant outages.

The European data available from CONCAWE[18] also shows a declining trend for pipeline incidents with 2010 data being 0.12 spills per 100km down from the 5-year average of 0.25. For RAP this is equivalent to a spill every 50 years.

Given the statistics, and despite the shorter incident length being analysed, we believe if anything the probability should be lower than assumed in the previous study. Natural disasters likely to cause damage to the pipeline are also expected to be repaired within this timeframe. The recommendation is to use a range of 0.5-1.0% (1 every 100 to 200 years) for this scenario.

2.5.3 Cost of 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 $40,000/day once all contingencies are in place or around $180,000 for the 9 day disruption taking account of the ramp up in resource use and cost.

2.6 Long term disruption at Wellington

As with Wiri this scenario is a regional infrastructure disruption rather than a national disruption. Damage to the distribution facilities in Wellington would mean product would need to be trucked into the region from neighbouring terminals. There are actually three different berths and terminal locations in Wellington - Seaview for the main transportation products (petrol, diesel and a small amount of jet), Kaiwharawhara for marine fuels (diesel - no truck loading, and fuel oil) and Miramar for jet fuel. In addition, at Seaview there are four completely different terminals all with significant separation. Other than a natural disaster (e.g. major earthquake and/or tsunami) it is difficult to see how all facilities at one location could be taken out of service. With natural disasters, demand may be affected as much as supply so the scenario is often less severe.

To model a severe example we assume all of Seaview's terminals are taken out of operation, which given the dispersed terminals effectively means either an incident taking the jetty out of service or a natural disaster affecting all four facilities. We assume both the terminals and stock are unavailable so there will be market demand that cannot be met in the short term as the companies re-establish supply from neighbouring terminals. Ultimately more trucking and driver resource will need to be brought into the country from overseas.

2.6.1 Outage scenario

The scenario assumes that some incident takes the jetty out of action affecting all Seaview terminals (note in this case the existing stock would still be available) or a natural disaster affecting all Seaview terminals. Wellington (and Manawatu demand) would need to be transported from Napier (or Taranaki for diesel). This will require additional trucking resource which will take time to put in place. Severe pressure would be put on Napier terminal although we assume this

[18] European refiners' organisation.

can be managed by sending the import ships that would have been going to Wellington into Napier.

The scenario calculation assumes the following:

- Wellington normally supplies north into Manawatu, Wairarapa and Taranaki (for petrol) as well as Wellington. We assume that the product short is spread over the whole region rather than just Wellington (including Hawkes Bay and Taranaki which become the supplying terminals).
- Taranaki petrol demand will likely be switched to northern terminals (at least half of it is supplied from the north already) with only a minor increment to the trucking task.
- The northern reaches of current supply from Wellington, New Plymouth and Napier (e.g. southern central high country, Gisborne north) will be shifted to be supplied out of Mt Maunganui to ease pressure on throughput at Napier.
- Over the first week any spare trucks in the country (10 assumed) are relocated and assigned to the new task.
- Permission to allow trucks to load over the current road weight limits (allows increased volumes to be transported) is given after a week and that increases to maximum capability over the following 9 days.
- Other measures (e.g. demand shift from region, improved distributor fleet utilisation, loading efficiencies) 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 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 we assume the stock in the Seaview terminals is unavailable (pessimistic assumption) the impact would be almost immediate.
- As the trucking resource builds up we estimate Napier terminals (there are two) will be close to capacity for gantry throughput (24 hour operation). There would need to be a ship in port approximately every 10 days. While this would be infeasible for normal operations in this case it can be feasible as all import ships would now need to include Napier as a port drop (Seaview is normally an 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) until full supply is re-established the short is 15% (of the lower North Island demand) or 28.1 million litres, although taken over the first two weeks the short is 35% (15 million litres).

There is no jet issue as jet 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.

2.6.2 Probability

The probability of an outage on this scale would be lower than Wiri as it is difficult to come up with a scenario that takes out all Seaview terminals. Offsetting this is the natural disaster risk in Wellington due to earthquake and tsunami is higher than Wiri. The tsunami risk for Seaview is assessed in the GNS paper (2005) along with the Wellington Lifelines Group Petone/Seaview

'Critical Area' Report.[19]The GNS paper gives an expected wave height for Lower Hutt (Seaview) of 3.6m for a 1 in 500 year cycle. The Lifelines review assesses this as causing some minor damage to the berth and surrounding area but not causing major supply disruption. As with the Marsden Point refinery there could be a larger wave that causes significant damage (note this would also cause major infrastructure damage reducing fuel demand) but the probability is much lower.

On balance we assume a slightly lower probability than Wiri (0.15-0.25% or 1 in every 400 to 667 years).

2.6.3 Cost of 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 $77,000/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).

2.7 Long term disruption at Lyttelton

This scenario is the most major regional infrastructure disruption for the South Island as Lyttelton throughput is approximately three times the next largest South Island terminal. As with the other regional disruptions this is a distribution issue rather than a shortage of stock. Damage to the facilities in Lyttelton would mean product would need to be trucked in from Nelson, Timaru and Dunedin. There are actually three separate terminals at Lyttelton, along with 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.

For the assessment we assume the most severe case where all supply into Lyttelton is disrupted for a period (at least two months) while demand remains the same. We assume both the terminals and stock are unavailable so there will be market demand that cannot be met in the short term as the companies re-establish supply from neighbouring terminals. In practice some stock is likely to be available which would mitigate the initial shortage somewhat. Ultimately more trucking and driver resource will need to be brought into the country from overseas.

2.7.1 Outage scenario

The scenario assumes that some incident takes all Lyttelton terminals out of action (or the port) such that no product can be received in the port. The nearest terminal is Timaru but this terminal is relatively small so will quickly reach capacity (both from resupply and from gantry capacity)[20]. To the north, some demand can be shifted to Nelson but we would expect these terminals to reach capacity (there is only one gantry at Nelson). The balance would be met from Dunedin which is actually closer to Christchurch than Nelson. In practice Dunedin might supply in to South and Mid-Canterbury and all Timaru throughput would go north.

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[19] Wellington Lifelines Group, Hutt City; "Petone/Seaview 'Critical Area' Report on Information Gathering phase, December 2011.

[20] This scenario was developed before Chevron announced they were re-commissioning their Timaru terminal. This will increase Timaru capacity giving better back up to Lyttelton. This would reduce the total disruption volume and the cost of resupply against that evaluated in this report.

The scenario calculation assumes the following:

- 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 any spare trucks in the country (10 assumed) are relocated and assigned to the new task. This will take Timaru to capacity so some extra task will need to be shifted to Dunedin (e.g. supply into South Canterbury).
- Permission to allow trucks to load over the current road weight limits (allows increased volumes to be transported) is given after a week and that increases to maximum capability over the following 9 days. The incremental volume comes from Nelson (north Canterbury) and Dunedin.
- Other measures (e.g. demand shift from region, improved distributor fleet utilisation, loading efficiencies) 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.
- This trucking task is slightly more difficult than both Wellington and Wiri because of the longer distances between the terminals.
- In practice the impact of each action will overlap although the profile is likely to be similarly (unless the offshore trucks and drivers can be secured more quickly).
- As we assume the stock in both Lyttelton and Woolston terminals is unavailable (pessimistic assumption) 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 a normal 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 15% (of the Timaru north South Island demand)or 29.6 million litres, although taken over the first two weeks the short is 28% (13 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, Dunedin or Bluff). Most domestic demand would be shifted to Auckland/Wellington by tankering planes going to the South Island. International planes would either need to tanker in (from Australia) or also call at Auckland to refuel.

2.7.2 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 with all the earthquake activity in Canterbury over the past two years, including the February 22nd earthquake which was centred in Lyttelton, the terminals have only been out of service for periods of days, not weeks as assumed in this pessimistic scenario.

The Canterbury Lifeline Utilities Group has looked at the risk associated with the fuel terminals[21]. For natural disasters they assess earthquake as the highest risk. As noted above the infrastructure

[21] Canterbury Lifeline Utilities Group Hazard Assessment for petroleum Storage, Transport and Supply - A summary (December 201)

has proved to be very resilient through recent earthquake activity. Tsunami is assessed at medium risk although from the GNS report we see the expected wave height in Christchurch (Lyttelton) or 4.0 meters over a 1 in 500 year assessment. This wave height may cause some damage (depending on the tide) so would be regarded as significant in the probability assessment.

On balance we assume a similar probability of outage as Wiri (0.20-0.30% or 1 to 333 to 500 years) with the lower dispersed terminal risk offset by a higher natural disaster risk.

2.7.3 Cost of 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 $94,000/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).

2.8 Terminal disruption probability discussion

While the probability assessment for individual disruption events 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 about 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). In fact over the past 20 to 30 years there has been a fairly low incidence of even minor incidents affecting terminal availability. This includes a period where a major earthquake was centred almost underneath the facilities (Lyttelton).

Viewed on this basis the assumptions for terminal risk are reasonable (possibly on the high side) 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.

2.9 Multiple terminal disruption

MED raised the issue of multiple terminals being disrupted by a common event (most likely a tsunami). The GNS risk assessment was reviewed to look at the risk assessments for the various terminal locations and the type of event that could cause multiple terminal outages. The terminal summary is below (based on the 1 in 500 year return period):

- Refining NZ: Covered in the above scenario (unlikely to be an issue with a reasonable probability of occurrence).
- Wiri: No issues as wave would be low (West Coast).
- Mt Maunganui: Above likely wave height so no issue – also position of terminals gives a lot of protection from wave front.
- Napier: Possible issue (likely cause primarily local but possible South American earthquake).
- New Plymouth: No issue as wave low and terminal up the hill.
- Wellington: Covered above - not likely with this probability assumption.
- Nelson: Relatively small wave expected no issues – primarily local event.

- Lyttelton: As covered above the wave height predicted could cause issues so is included in probability assessment. Main cause likely to be South American earthquake.
- Timaru: Higher wave than Lyttelton predicted so is vulnerable. Main cause likely to be South American earthquake.
- Dunedin: Relatively small wave predicted – terminal up harbour in Dunedin. No issues expected.
- Bluff: Assuming Invercargill data applies to Bluff, the wave height would not cause issues.

In summary, while an event could cause multiple terminal issues (e.g. a South American earthquake causing damage at Lyttelton, Timaru, Napier and possibly the refinery), the probability of such an event is very low (need to go to the 1 in every 2500 year return cycle). With the probability of 1 in every 500 years the only likely event is one that affected both the Lyttelton and Timaru terminals. This scenario is only a slightly more severe scenario than the Lyttelton outage we have already modelled. Given a tsunami of that size would also cause major infrastructure and population damage, it would also significantly reduce the demand for petroleum. On balance it may actually be a less severe scenario so it is not studied separately.

2.10 Additional Cases

Following the review of the draft report, MED requested to variation cases be evaluated. These are:

- Quicker response with additional trucking to solve the regional distribution issues (Wiri case used for the comparison)
- No allowance to load the fuel trucks over their legal limit in response to an emergency (Wiri case used for the comparison)

2.10.1 Quicker response with additional trucking

This variation on the Wiri disruption case (2.4) looks at the impact of getting additional trucking sooner than assumed. This is reflective of having a fleet of trucks (and some drivers) that would be available at relatively short notice within New Zealand or arrangements in place so that additional trucking can be brought in from offshore more quickly.

In this case we assume that the additional trucks required (12) will start to arrive after two weeks and there will be sufficient in the country to fully meet the requirement after one month (rather than two). The resulting shortage is shown in Appendix 1.

2.10.2 No overloading of trucks

This variation on the Wiri disruption case (2.4) assesses the impact if trucks can't be loaded above their legal limit. The ability to use this extra capacity in an emergency is a key recommendation of RAP Contingency Review as it increases the delivery efficiency and volumes without additional resource (trucks or drivers). If this cannot be done then more resources will need to be brought in from offshore. Our estimate is that instead of 12 trucks there will be an additional 29 trucks imported. This is a considerable number (not to mention the issue of additional driving resource required) and we expect that they will come from further afield (not just Australia) and take longer. While vehicles start to arrive after two weeks it would be three months before there were enough to fully meet the additional distribution the task. The resulting shortage is shown in Appendix 1.

3.0 Contingencies

3.1 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 all the other terminal disruptions, the impact of these outages is much smaller. To assess 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. 0.7% being the probability of any one event happening)

3.2 Storage location

Storage of crude or product to use in emergencies was the contingency assessed in the 2005 Report. Fuel storage also contributes to meeting New Zealand's IEA commitments which was the focus of that report. Storage of fuel could still be used as a contingency both for international events and to provide domestic security. However for consideration of storage 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 sense it is no more valuable than ticket stock held offshore and should be evaluated on that basis.
- Physical emergency stock held in New Zealand can also provide domestic security. The value of the security it provides needs to cover any cost 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 in an emergency but if a key vulnerability is a natural disaster affecting the Marsden Point area then it is not providing 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 Wiri) will provide security against both a refinery disruption and a Wiri terminal disruption. This may mean it is the most logical location (highest probability of being of use)
    - Emergency stock held in the other ports (e.g. Wellington or Lyttelton) could also be affected by the event affecting the location so may not provide additional security (it would provide security against a refinery event)

Appendix 1: Scenario impacts

	Long term disruption to NZRC				Short term disruption to NZRC			
	Petrol + Diesel		Jet		Petrol + Diesel		Jet	
Day	Total supply (kl/d)	Shortfall (kl/d)	Total supply (kl/d)	Shortfall (kl/d)	Total supply (kl/d)	Shortfall (kl/d)	Total supply (kl/d)	Shortfall (kl/d)
-6	16,890	0	3,480	0	16,890	0	3,480	0
-3	16,890	0	3,480	0	16,890	0	3,480	0
0	9,500	7,390	903	2,577	16,631	259	2,570	910
3	9,500	7,390	903	2,577	16,631	259	2,570	910
6	9,500	7,390	903	2,577	16,631	259	2,570	910
9	9,500	7,390	903	2,577	16,631	259	2,570	910
12	9,500	7,390	903	2,577	16,580	310	2,630	850
15	14,088	2,802	2,153	1,327	16,327	563	2,749	731
18	14,088	2,802	2,153	1,327	16,327	563	2,749	731
21	14,088	2,802	2,153	1,327	16,890	0	3,480	0
24	14,088	2,802	2,153	1,327	16,890	0	3,480	0
27	14,088	2,802	2,153	1,327	16,890	0	3,480	0
30	15,235	1,655	2,466	1,014	16,890	0	3,480	0
33	15,235	1,655	2,466	1,014	16,890	0	3,480	0
36	15,235	1,655	2,466	1,014	16,890	0	3,480	0
39	15,235	1,655	2,466	1,014	16,890	0	3,480	0
42	16,890	0	3,480	0	16,890	0	3,480	0
45	16,890	0	3,480	0	16,890	0	3,480	0
48	16,890	0	3,480	0	16,890	0	3,480	0
51	16,890	0	3,480	0	16,890	0	3,480	0
54	16,890	0	3,480	0	16,890	0	3,480	0
57	16,890	0	3,480	0	16,890	0	3,480	0
60	16,890	0	3,480	0	16,890	0	3,480	0
63	16,890	0	3,480	0	16,890	0	3,480	0
66	16,890	0	3,480	0	16,890	0	3,480	0
	Total shortfall	172,750		70,720	Total shortfall	7,416		17,860
	% of demand	24%		48%	% of demand	2%		24%

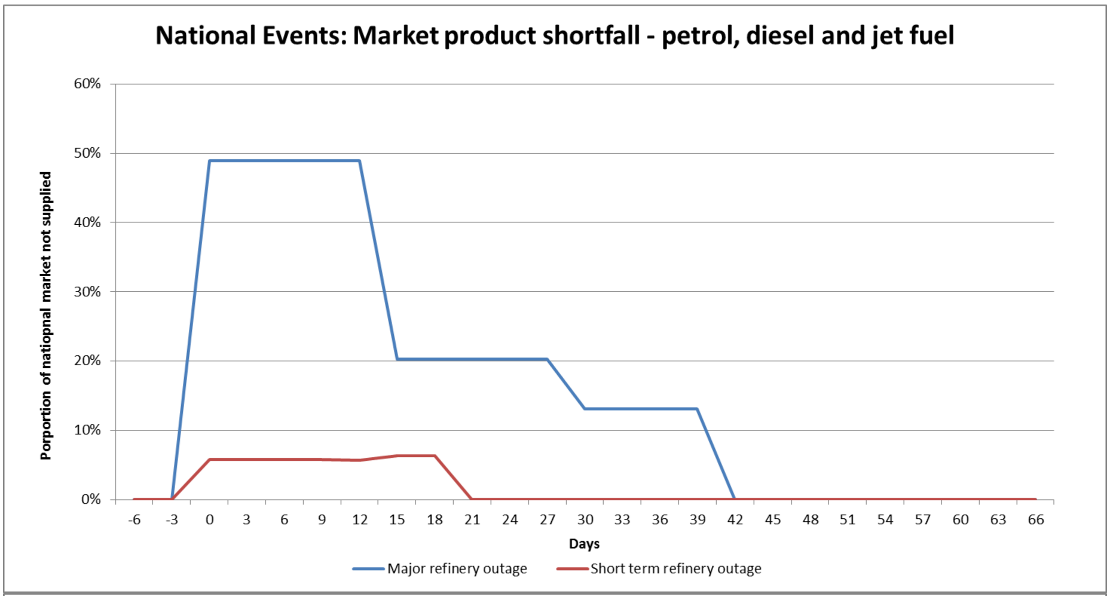
Source: H&T

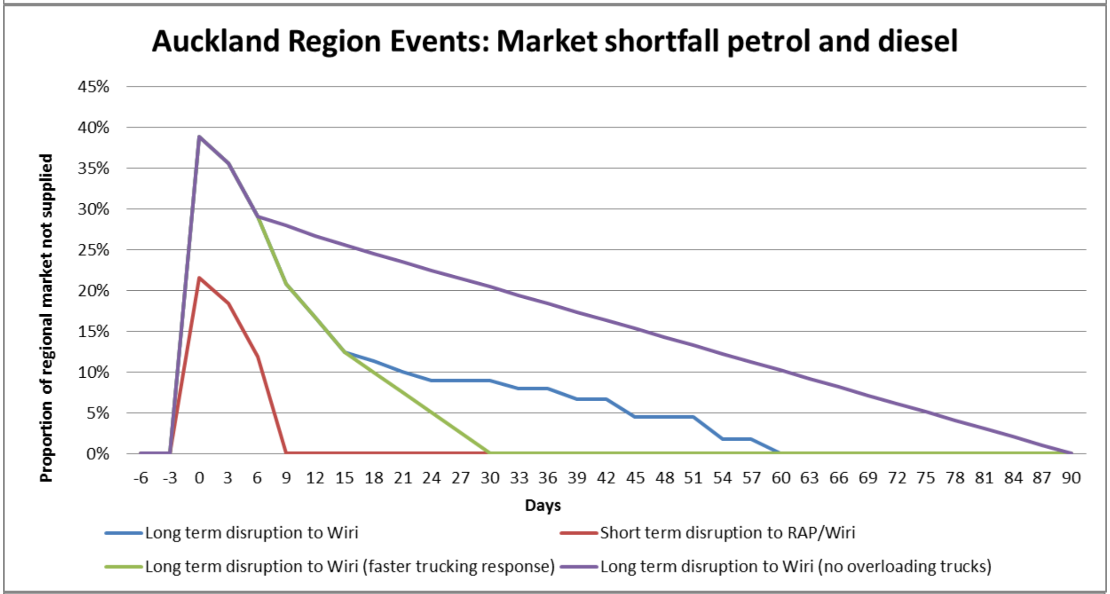
Note: Volumes shown are for 'that day', for the purposes of anlysing the total impact the two days following 'that day' can be assumed to be similar to 'that day'.

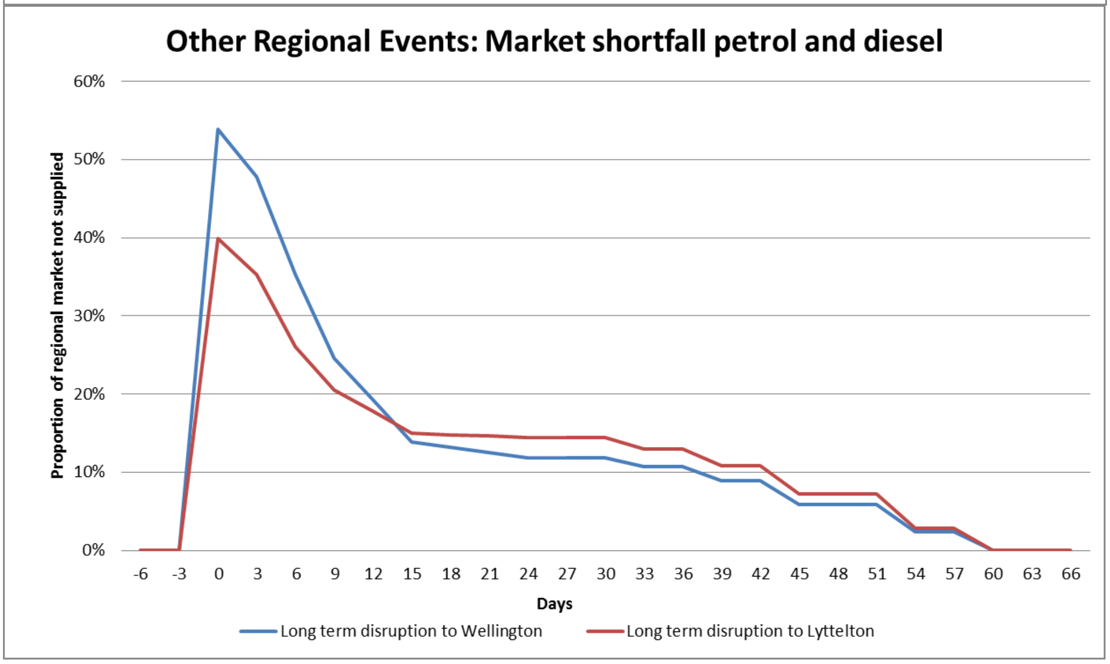
	Long term disruption to RAP/WIRI			Short term disruption to RAP/WIRI	
	Petrol + Diesel			Petrol + Diesel	
Day	Total supply (kl/d)	Shortfall (kl/d)		Total supply (kl/d)	Shortfall (kl/d)
-6	8,410	0		8,410	0
-3	8,410	0		8,410	0
0	5,140	3,270		6,593	1,817
3	5,411	2,999		6,864	1,546
6	5,960	2,450		7,413	997
9	6,660	1,750		8,410	0
12	7,010	1,400		9,500	0
15	7,360	1,050		9,500	0
18	7,459	951		9,500	0
21	7,561	849		9,500	0
24	7,660	750		8,410	0
27	7,660	750		8,410	0
30	7,660	750		8,410	0
33	7,735	675		8,410	0
36	7,735	675		8,410	0
39	7,848	563		8,410	0
42	7,848	563		8,410	0
45	8,035	375		8,410	0
48	8,035	375		8,410	0
51	8,035	375		8,410	0
54	8,260	150		8,410	0
57	8,260	150		8,410	0
60	8,410	0		8,410	0
63	8,410	0		8,410	0
66	8,410	0		8,410	0
	Total shortfall	62,608		Total shortfall	13,078
	% of demand	12%		% of demand	17%

	Long term disruption to Wellington		Long term disruption to Christchurch	
	Petrol + Diesel		Petrol + Diesel	
Day	Total supply (kl/d)	Shortfall (kl/d)	Total supply (kl/d)	Shortfall (kl/d)
-6	3,040	0	3,260	0
-3	3,040	0	3,260	0
0	1,360	1,590	1,960	1,300
3	1,542	1,409	2,109	1,152
6	1,910	1,040	2,410	850
9	2,225	725	2,590	670
12	2,383	568	2,680	580
15	2,540	410	2,770	490
18	2,560	390	2,777	483
21	2,580	370	2,783	477
24	2,600	350	2,790	470
27	2,600	350	2,790	470
30	2,600	350	2,790	470
33	2,635	315	2,837	423
36	2,635	315	2,837	423
39	2,688	263	2,908	353
42	2,688	263	2,908	353
45	2,775	175	3,025	235
48	2,775	175	3,025	235
51	2,775	175	3,025	235
54	2,880	70	3,166	94
57	2,880	70	3,166	94
60	2,950	0	3,260	0
63	2,950	0	3,260	0
66	2,950	0	3,260	0
	Total shortfall	28,113	Total shortfall	29,567
	% of demand	15%	% of demand	15%

	Long term disruption to RAP/WIRI (Additional cases)		
	Petrol + Diesel (shortfall comparison)		
Day	Original case(kl/d)	Faster additional trucking	No overloading of trucks (kl/d)
-6	0	0	0
-3	0	0	0
0	3,270	3,270	3,270
3	2,999	2,999	2,999
6	2,450	2,450	2,450
9	1,750	1,750	2,351
12	1,400	1,400	2,249
15	1,050	1,050	2,150
18	951	840	2,064
21	849	630	1,978
24	750	420	1,892
27	750	210	1,806
30	750	0	1,720
33	675	0	1,634
36	675	0	1,548
39	563	0	1,462
42	563	0	1,376
45	375	0	1,290
48	375	0	1,204
51	375	0	1,118
54	150	0	1,032
57	150	0	946
60	0	0	860
63	0	0	774
66	0	0	688
69	0	0	602
72	0	0	516
75	0	0	430
78	0	0	344
81	0	0	258
84	0	0	172
87	0	0	86
90	0	0	0
Total shortfall	62,608	45,058	123,808
% of demand (month 1)	19%	18%	28%

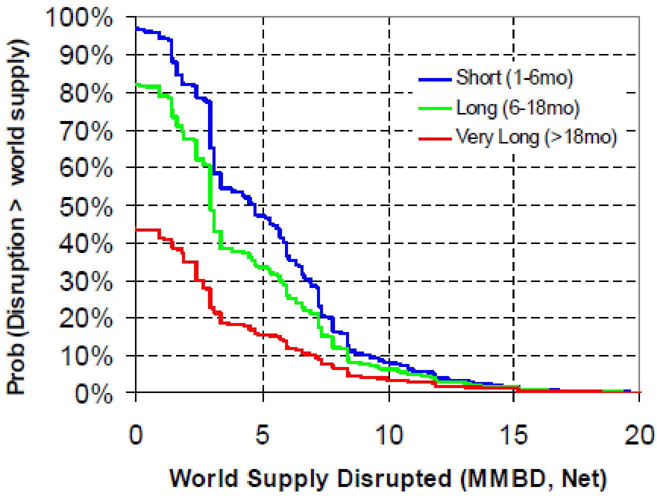

National Events: Market product shortfall - petrol, diesel and jet fuel
Porportion of natiopnal market not supplied
60%
50%
40%
30%
20%
10%
0%
-6 -3 0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66
Days
Major refinery outage
Short term refinery outage


Auckland Region Events: Market shortfall petrol and diesel
Proportion of regional market not supplied
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
-6 -3 0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90
Days
Long term disruption to Wiri
Short term disruption to RAP/Wiri
Long term disruption to Wiri (faster trucking response)
Long term disruption to Wiri (no overloading trucks)


Other Regional Events: Market shortfall petrol and diesel
Proportion of regional market not supplied
60%
50%
40%
30%
20%
10%
0%
-6 -3 0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66
Days
Long term disruption to Wellington
Long term disruption to Lyttelton

Appendix 2: Global oil market disruption risk

Figure 13. Probability of a Disruption for All Durations



Source: Energy Modeling Forum, Stanford University (2005)