New Zealand Lifelines Council

New Zealand Lifelines Infrastructure Vulnerability Assessment: Stage 1

September 2017

New Zealand Lifelines Council Members

Ministry of Civil Defence & Emergency Management

NZ Transport Agency

EQC Earthquake Commission

GNS Science

Transpower

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Ministry of Business, Innovation & Employment

Water New Zealand

Preface

This Stage 1 report provides a summary of information on New Zealand's critical lifelines infrastructure and vulnerability to hazards gathered from existing reports and inputs from New Zealand Lifelines Council (NZLC) members.

This report is intended to; provide strategic oversight of all infrastructure services (energy, transport, telecommunications, water) in New Zealand, raise awareness particularly with regard to inter-dependencies, and contribute to raising the resilience of infrastructure to meet our community needs. During 2017/18 Stage 2 will seek to address the knowledge gaps that are considered high priority and /or relatively easy to address.

The use of this report by others and suggested enhancements is welcomed and encouraged. This report will be a live document with regular updates as new information comes to hand. In depth assessment of particular subjects will be contained in separate reports.

The report is general in its application and subjective in its recommendations. While every effort has been made to ensure the accuracy of the report, no liability whatsoever can be accepted for any error.

Roger Fairclough
Chair, New Zealand Lifelines Council

DISCLAIMER

The findings in this report are derived from general investigation and do not necessarily reflect official policy or position of any agency. Examples presented within this report are for the purpose of demonstration.

It is recommended that users exercise their own skill and care with respect to their use of the information contained in this report and that users carefully evaluate the accuracy, currency, completeness and relevance of the material for their purposes. This information is not a substitute for independent professional advice and users should obtain any appropriate professional advice relevant to their particular circumstances.

Acknowledgements

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New Zealand Lifelines Council

Contents

1. Summary

Lifelines infrastructure includes the transport, energy, communications and water services sectors that are fundamental to New Zealand's communities and economy.

Through the New Zealand Lifelines Council (NZLC) and 16 regional lifelines groups, New Zealand's lifelines organisations work together on projects to understand and identify ways to mitigate impacts of hazards on lifelines infrastructure. This report is a first pass at collating and summarising key findings from regional lifelines studies and other major national hazard studies such as DeVoRA, AF8 and WENIRP[1]. It aims to provide insights on New Zealand's critical lifelines infrastructure and its resilience (and conversely its vulnerability) to major hazards and identifies a number of knowledge gaps in our understanding and mitigation of New Zealand's critical infrastructure vulnerabilities.

The longer-term goal, to be delivered through Stages 2 and 3 of this project, is to provide government and industry with a strategic understanding of nationally significant infrastructure, its vulnerability and resilience to hazards, and strategies to mitigate risks to a nationally agreed 'acceptable' level.

1.1 Nationally Significant Infrastructure

Recent lifelines projects have followed a criticality assessment approach which identifies lifelines infrastructure within the region as *nationally*, *regionally* or *locally* significant. Nationally significant infrastructure assets are often where there are 'pinchpoints' in the supply chain – sometimes these are single sites which would cause a significant loss of national service. Examples include:

- Marsden Refinery, refines around 70% of New Zealand's fuel, the jetty for importing/exporting fuel and the pipeline to / depot at Wiri supplying Auckland and surrounds and jet fuel for Auckland Airport.
- The main telecommunications exchanges in Auckland, Wellington, Christchurch, Hamilton and Porirua.
- Ports of Auckland and Tauranga (largest by throughput volume), Wellington and Picton roll on-off ports (inter-island connection and fuel terminals) and Lyttelton Port (major fuel supplier to the South Island).
- The Taranaki gas fields – source of NZ's natural gas and supplying some electricity generators.
- Auckland Airport – the gateway to 75% of international visitors - as well as Wellington, Christchurch and Queenstown airports, the next largest by visitor volume.

Other sectors have nationally significant assets which are *lineal* pinchpoints. For roads, examples include high volume roads such as SH1 in Auckland and Wellington and other highways (such as the coastal Kaikoura highway and other parts of SH 1 in the South Island) which have economic significance and/or long detour times.

In the national electricity grid, the transmission lines (and connecting substations) from Bunnythorpe to Whakamaru transmit a large proportion of electricity to the central/upper North Island, though the highest capacity line is the HVDC line transmitting power between the North and South Island. Clyde and Roxburgh Power Generation Dams provide 35-40% of New Zealand's power.

While water supply does not have a national supply network, the Hunua Dam and Ardmore Treatment Plant in Auckland are probably the most critical water supply sites in New Zealand in terms of the numbers of people affected by a failure of supply from those assets. There are nationally significant assets in other cities such as the Hutt River waters supplies in Wellington and the main water treatment plant treating Waikato River water for Hamilton.

1.2 Interdependencies and Hotpots

Along with key sector pinchpoints such as those described above, many regional lifelines projects look at risks associated with infrastructure 'hotspots' where critical assets from a number of sectors converge with a

[1] Determining Volcanic Risk in Auckland (DeVoRA, www.devora.org.nz), Alpine Fault Study (AF8, http://projectaf8.co.nz/), Wellington Earthquake National Initial Response Plan v1.1 (WENIRP). http://www.civildefence.govt.nz/cdem-sector/cdem-framework/guidelines/wellington-earthquake-national-initial-response-plan/

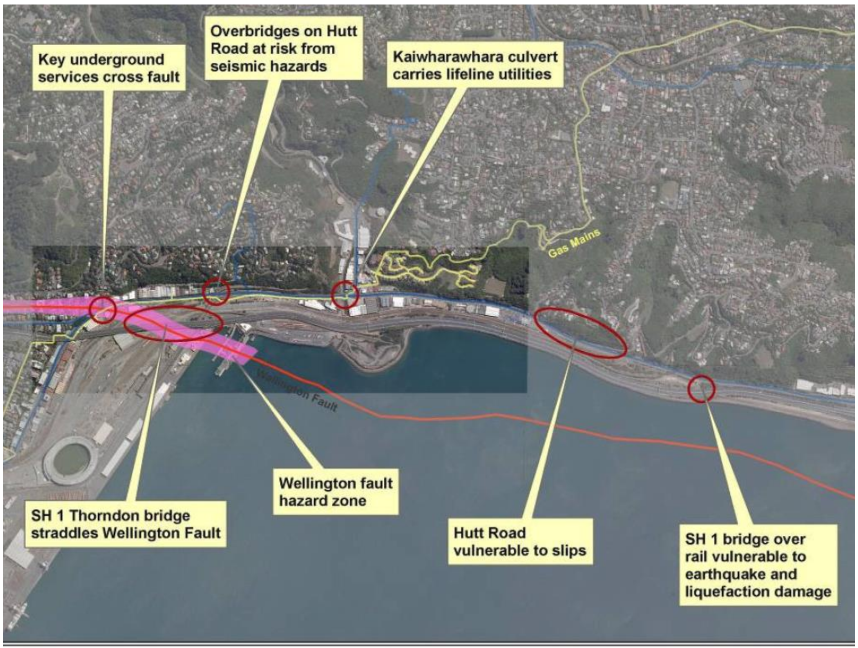

Figure 1-1: Infrastructure Hotspot in Thorndon, Wellington

high consequence of failure associated with cumulative loss of services at that site. Examples include Thorndon in Wellington (pictured right), Auckland's Harbour Bridge, which carries a number of critical utility pipes/cables, and Kawarau Gorge – a key transport and electricity transmission route for Queenstown.

The 'interdependency' aspects of lifelines networks are another important consideration and are a major driver for collective projects by lifelines sectors. Electricity is (arguably) the service that is most critical for the normal operations of most other lifelines (and if the electricity fails, fuel for generators and roads for transporting generators and fuel). Roads and telecommunications are vital to the everyday functioning of our communities, as well as facilitating access to sites for restoration and communications during readiness, response and recovery. The interdependencies in the lifelines networks are numerous and complex.

1.3 Major Hazards to National Infrastructure

The resilience of New Zealand's infrastructure has been the focus of regional lifelines projects since the first project in Christchurch in the late 1980s. This project 'Risks and Realities' was credited with driving a number of seismic mitigation programmes, the benefits of which were realised many times over in the Canterbury earthquakes in 2010/11 *(Ref: CAE Lifelines Lessons from Natural Hazards December 2012)*. Since then many other regional projects have been undertaken and continue to inform lifeline utility risk mitigation programmes.

A major earthquake affecting Wellington justifiably continues to receive a lot of attention as it has the potential to isolate the Wellington region by road and rail and cut off water supply, electricity, gas and telecommunications for several weeks to months. Major power disruptions would in turn impact telecommunications capability and fuel terminals at the Port are likely to be inoperable immediately following a major quake. There are many other potential local tsunami and seismic hazards to the region.

The Alpine Fault runs 400km up the South Island and a major rupture would have devastating consequences. In the scenario modelled for the Alpine Fault Study *Project AF8*, which has an expected return period of 300 years, tens of thousands of landslides are expected isolating many areas by road (the West Coast is particularly vulnerable) and likely damaging electricity, telecommunications, water/wastewater networks and many other lifelines. There are many issues being identified around the potential isolation of Queenstown and surrounding communities which are such a major component of New Zealand's tourism.

Volcanic hazards are prevalent in the North Island and the Taupo zone and Taranaki volcanoes are near major electricity and gas production sites. Impacts of Volcanos are not geographically isolated as ash has the potential to ground air traffic and disrupt almost all types of infrastructure services to some extent.

There is no 'good' location for an Auckland volcanic eruption from an infrastructure perspective. The two most catastrophic scenarios for Auckland are somewhere near the narrow part of the isthmus through Otahuhu/Sylvia Park, a major transmission path for most lifeline utilities, or the CBD with the Harbour Bridge, major telecommunication exchanges, Ports of Auckland, Brittomart and critical water reservoirs.

A national tsunami exercise in 2016 'Exercise Tangaroa' brought attention to the fact that New Zealand's main fuel refinery and most of the major fuel terminals are on the east coast. There has been limited planning as to how fuel will be offloaded and transported if ports/wharves/roads suffer significant damage (though some is occurring as part of WENIRP).

Aside from these specific hazard scenarios there are many other natural and technological hazards such as human pandemic, criminal attack and asset failures due to causes such as condition, third party damage and fires. The potential impacts of technology failure (both unintended events and cyber-attack) are increasing as lifelines networks increasingly rely on technology. It is well known that roads are highly vulnerable to landslides, both rain and earthquake induced, and our distributed lineal asset networks (pipes and cables) are vulnerable to earthquakes.

1.4 Building Resilience into Infrastructure Networks

While the national hazardscape is complex, New Zealand's infrastructure networks have all been designed to be resilient to varying degrees. Technical resilience is inherent in many networks through redundancy (multiple paths of supply) and robustness (design codes for strength). However, there are geographical and other constraints in providing alternative supply routes and100% security of supply is neither feasible nor affordable. There are different funding constraints and regimes both between and within the public and private sectors and many organisations require a commercial return on resilience investment projects.

Billions of dollars have been and are continuing to be invested in projects that will increase the resilience of nationally significant infrastructure. These include major projects such as Wellington Transmission's Gully and a second major water supply pipeline from Auckland's Ardmore Treatment Plant to the City. The Christchurch and other recovery programmes have a vital role in 'building back better' with more resilient networks, such as creating 'loop' redundancy in the Christchurch electricity supply and use of ductile pipe materials. Incremental improvements in all sectors occur as renewal programmes replace older assets with newer modern materials and design.

There are a number of legislative and regulatory requirements requiring lifelines to plan for hazards and restore services quickly (to pre-identified emergency service levels) following an event. However, there are no nationally consistent standards for resilience applied to New Zealand's critical infrastructure as these are defined by each lifeline utility. Additionally, there is no national picture or monitoring of planned investment in infrastructure resilience or understanding of societal risk tolerance.

Growth is a strategic issue for New Zealand's infrastructure resilience. It can enable resilient infrastructure investment– many major national projects provide for growth but also provide additional redundancy in the networks. Conversely if infrastructure upgrades do not keep pace with growth it contributes to a reduction in infrastructure redundant capacity and resilience.

1.5 Conclusion

A number of knowledge gaps have been identified and suggested projects to support ongoing resilience improvements are presented in Section 7. Coming out of work in the 'lifelines' sector, these projects are focussed on aspects such as improving our understanding of critical infrastructure, major hazards and the intersection between the two. Further work is also needed to understand the dependence of critical community sectors (health, emergency services, Fast Moving Consumer Goods, etc) on lifelines services and backup arrangements if those services fail.

Outside of regional lifelines projects, there are other major initiatives underway seeking to improve New Zealand's infrastructure resilience, both by individual lifelines and through other forums. These include initiatives such as the Built Environment Leaders Forum and National Science Challenge (MBIE), National Disaster Resilience Strategy (MCDEM), National Infrastructure Plan (National Infrastructure Unit / NIU Treasury) and many others discussed in Section 7.

It is proposed that NZLC will meet with MBIE, NIU and MCDEM to agree on the next steps, which should as a minimum include:

1. Progress with Stage 2 of this report, as outlined in Section 7.
2. Continue to provide oversight and input to major national resilience programmes to ensure they are connected and, where NZLC has been assigned accountability, that they are progressing to plan.

2. Introduction

2.1 Background

Many regional lifelines groups in New Zealand have undertaken studies to assess the vulnerability of lifelines infrastructure to natural hazards. These studies generally aim to understand service impacts of natural disasters such that they can be minimised and recovery times reduced. The outputs from this work are used by lifeline utilities to support investment in risk mitigation work (such as seismic strengthening) as well as to support planning for response and recovery activities (lifelines coordination processes).

2.2 Purpose

As more regional level studies have been completed and updated, cross-boundary and 'national picture' infrastructure vulnerability issues are often raised. This has been one of many drivers for this national level vulnerability assessment projects.

The aim of this Stage 1 assessment is to provide a national view of critical infrastructure and vulnerabilities. It is intended to inform a range of activities, including:

- Regional lifelines projects, to provide an understanding of the cross-boundary issues that need to be considered in regional vulnerability assessments (impacts within the region impacting outside the region and vice versa).
- Lifeline utility resilience planning (eg: support prioritisation of resilience projects with consideration of wider infrastructure impacts).
- National policy and strategy setting, such as the National Disaster Resilience Strategy and future review of the National Infrastructure Plan.
- Future infrastructure and hazard research priorities.

The longer-term goal, to be delivered through Stages 2 and 3 of this project, is to provide government and industry with a strategic understanding of nationally significant infrastructure, its vulnerability and resilience to hazards and strategies to mitigate risks to a nationally agreed 'acceptable' level.

2.3 Key Audience

The primary audience for this work is regional lifelines groups and lifeline utilities. Other potential users are:

- Government agencies and CDEM Groups involved in emergency management and infrastructure policy.
- Research agencies.
- Infrastructure funding agencies.

2.4 Approach

This report presents an initial view of national infrastructure vulnerability, drawing on existing regional vulnerability study reports and key hazard and regional specific studies such as the Wellington Earthquake National Initial Response Plan (WENIRP V1.1), Determining Volcanic Risk in Auckland (DeVoRA) and the Alpine Fault Magnitude 8 Project (AF8). A range of other ongoing programmes are acknowledged in

National Lifelines

This first stage of the study focuses on the 'nationally significant' networks of the following organisations.

Energy

- Transpower (national grid)
- Generators (Meridian Energy, Contact Energy, Mercury, Genesis Energy and TrustPower)
- First Gas Holdings (gas transmission North Island)
- Electricity Distribution companies
- Refining NZ (Marsden Refinery and Pipeline to Wiri, Auckland).
- Wiri Oil Services Limited.
- Fuel companies (BP, Z, Mobil, Gull).

Transport

- New Zealand Transport Agency (national highways)
- Kiwirail (rail network)
- Auckland Airport
- Wellington Airport
- Christchurch Airport
- Ports of Auckland Ltd
- Ports of Tauranga Ltd
- CentrePort (Wellington)
- Lyttelton Port
- Picton (ferries)
- Local authority road networks

Telecommunications

- Chorus
- Spark
- Vodafone
- 2degrees
- Kordia

*Water**

- Watercare
- Wellington Water
- Christchurch City Council Water

** While these largest cities have been the focus for Stage 1, further input from other major cities and towns will be sought during Stage 2.*

Section 6.2, such as the National Science Challenge, and outputs from these will be used to inform this project as work continues.

This desktop assessment was supplemented by information gathered from a workshop at the 2016 *National Lifelines Forum,* attended by a wide range of lifeline utility, hazards, research and government experts and sector representatives, and input to report drafts by regional lifelines groups, lifeline utilities and central government agencies involved in infrastructure resilience.

Regional lifelines groups have traditionally focussed on major natural hazards, with varying attention given to other hazards such as pandemic, criminal attacks, space weather and technology failure (both deliberate cyber-attacks and unplanned disruptive events). This report is therefore more comprehensive with respect to the major natural hazards including earthquake, tsunami, volcano and severe weather. Further work will be undertaken on a wider range of hazards in Stage 2 and 3.

2.5 Vulnerability Assessment Methodology

Figure 2-1 illustrates the general methodology used to assess infrastructure vulnerability in several recent regional lifelines projects. The interdependency of the networks and services is a key consideration in assessing infrastructure vulnerability. Firstly, when assessing the criticality of its own network, each organisation considers which assets supply critical customers that depend on them (other lifelines, hospitals, etc). Secondly, when considering service impacts and recovery times, consideration is given to the impact from other lifelines failures, eg: road access, telecommunication disruptions.

The extent to which quantitative scoring systems are used in regional lifelines projects varies. Many of the original lifelines projects carried out in the 1990s and 2000s included an individual analysis of asset components using a spreadsheet and a multi-criteria analysis risk scoring approach. This provided a useful multi-hazard ranking of the region's highest risk assets but was very time-intensive. The higher-level approach taken for more recent projects provides a more strategic view of the potential infrastructure impacts from natural hazards. It is envisaged that as asset and hazard data improves, this will support more quantitative modelling using damage assessment and economic impact tools and enhancement of the risk and vulnerability assessment process shown in Figure 2-1. There is also the opportunity to widen the vulnerability assessment process beyond the traditional natural hazards focus of lifelines groups.

While information on infrastructure vulnerabilities for this report was drawn largely from sources referenced in Section 2.4 (ie a 'bottom up' approach), a national level 'top down' assessment will be scoped as part of Stage 2 and potentially undertaken in Stage 3.

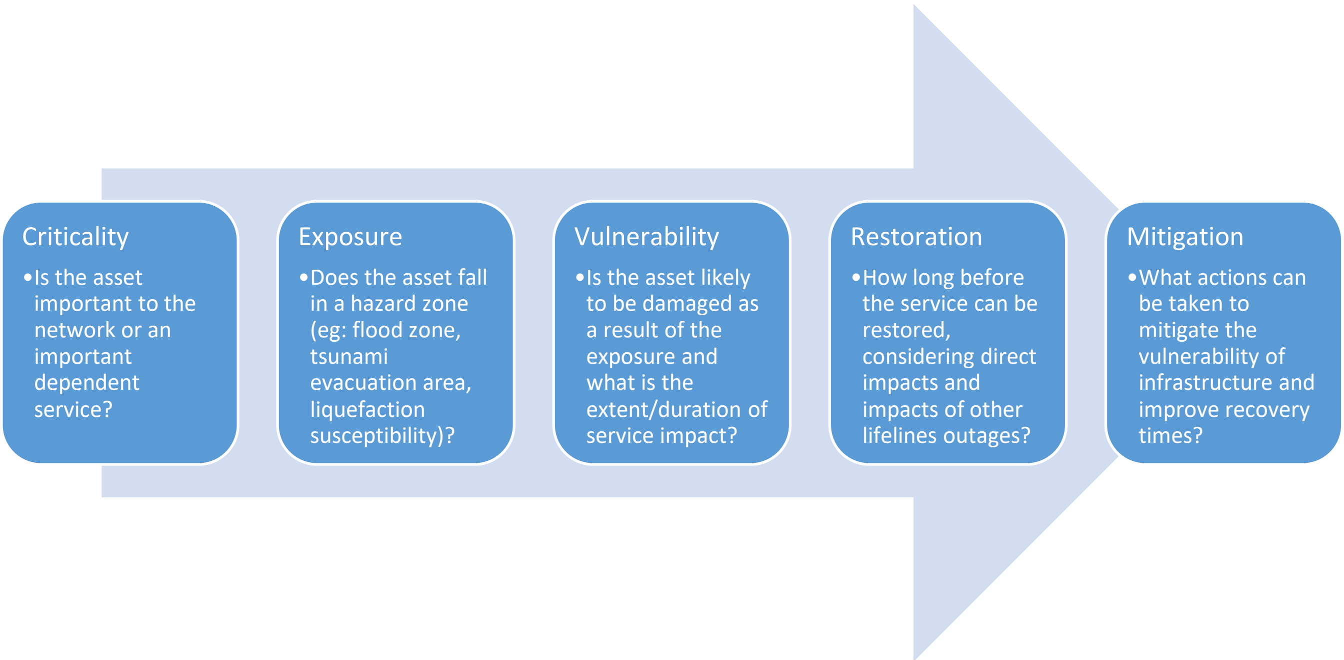

Figure 2-1: Overview of the Vulnerability Assessment Process

2.6 Defining Critical Infrastructure Assets

The approach to defining critical lifelines infrastructure assets in recent regional lifelines projects is illustrated in the diagram below[2]. The rating system requires a two-step process for identifying critical assets:

- Identifying critical infrastructure assets and community sites based on sector outage numbers and extent.
- Reviewing critical infrastructure assets considering whether the asset supplies another critical infrastructure or community site that is dependent (ie considering the wider service impacts of an asset failure).

For the purposes of this Stage 1 report, information has been collected from regional lifelines reports and groups and lifeline utilities to identify 'nationally significant' infrastructure assets for each sector. A more structured framework and methodology for criticality assessment using a 'top down' national approach will be undertaken in Stage 2.

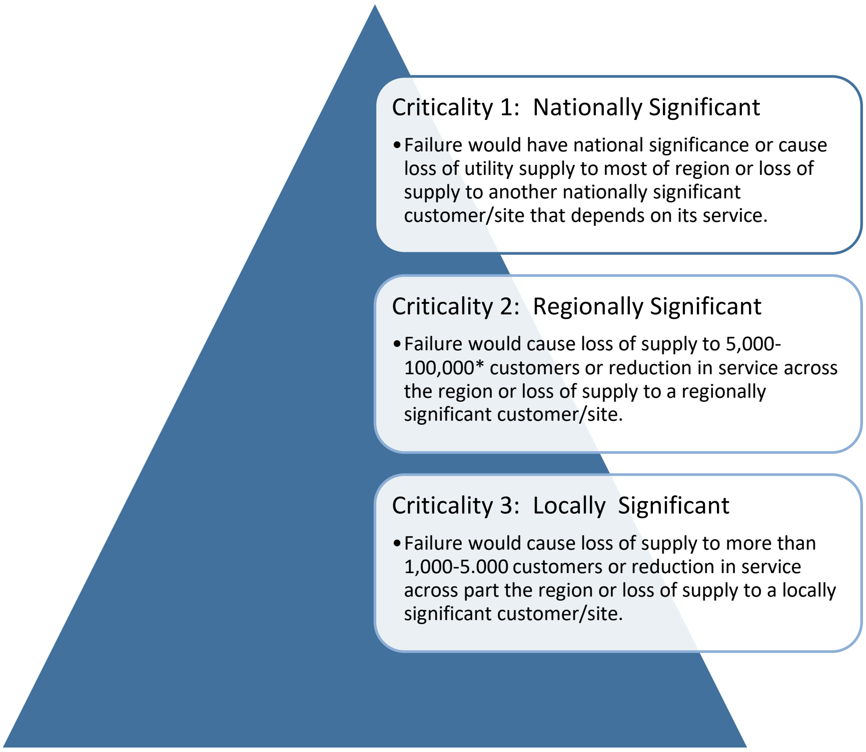

Figure 2-2: Assessing Infrastructure Asset Criticality

Notes:

- *These definitions are intended to represent the service impact of an asset or service failing – both in terms of the numbers of customers with affected services and the impact of services of those customers (eg: hospitals).*
- *The definitions do not attempt to rank sectors (eg: whether an electricity asset supplying 100,000 customers is more important than a gas asset supplying the same).*
- *The numbers are meant to be indicative rather than specifically followed, allowing for some judgement in the application considering factors such as length of time to restore an alternative supply (or detour route) and the social implications, eg: isolated communities.*
- *Regions have used different thresholds for regionally and locally significant – reflecting the regional context.*
- *Further refinement of these definitions will be undertaken in Stage 2.*

[2] It has been used in lifelines projects in Otago, Northland, Auckland, Manawatu-Wanganui, Nelson-Tasman and Gisborne and in slightly modified format in Waikato and Bay of Plenty.

3. New Zealand's Critical Infrastructure

3.1 Electricity

New Zealand's electricity network broadly comprises:

- generation stations;
- national transmission grid;
- electricity lines distributors which connect to the national grid and distribute to consumers;
- electricity retailers - which buy wholesale electricity and sell to consumers; and
- main load centres.

The transmission grid, generation sources and load centres are illustrated in Figure 3-2.

Electricity Generation

There are some major generation schemes that provide single points of faiure - the largest capacity sites include:

- The Clyde and Roxburgh generation schemes on the Clutha river and the Benmore generation scheme on the Waitaki river provide between 35 and 40% of New Zealand's electricity requirements.
- The Waikato River schemes, which provide around 10% supply (operating at maximum capacity, all sources in Waikato region including hydro can potentially generate 50% of NZ's demand.
- Huntly and Manapouri are the largest capacity individual stations (not necessarily reflective of relative amount of actual production in any one year).

Actual generation from each source varies by time and season and is managed by Transpower as Network Operator.

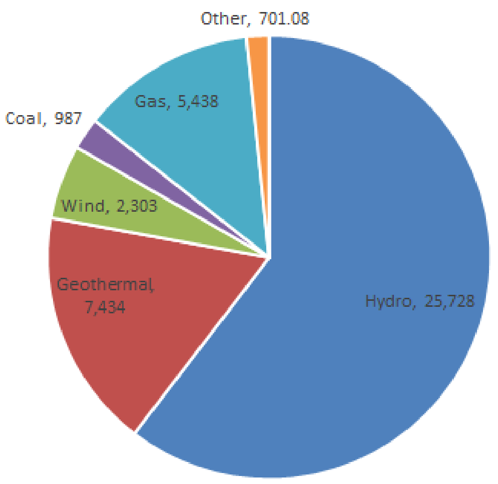

Figure 3-1: New Zealand's Electricity Generation by Type (MBIE website).

Providing a reliable electricity supply

Electricity is an important lifeline from an interdependency perspective. It is needed for refining and distributing fuel and gas, treating and distributing water, operating telecommunications networks, ports, railways and many other lifelines. Backup electricity (generators and batteries) is in place at many key sites, but generally not sufficient to maintain full services in a widespread power outage.

Maintaining a reliable electricity supply is core to the business of electricity generators and distributors. Key facets of resilience include:

- The National Grid connects most generation sources, such that isolation of any single generation source may result in lower security, but probably not loss of supply.
- Most of the critical parts of the transmission and distribution network operate with at least n-1 security (have alternate paths of supply), again meaning that asset failure generally causes minimal loss of supply.
- Critical assets are designed to avoid or withstand natural hazard impacts.
- Rapid response plans and critical spares are a key part of the resilience strategy.

In recent years around 1500MW of coal and gas-fired thermal generation plant has exited the market due to economic reasons, of which more than 500MW was in urban Auckland (Southdown and Otahuhu). With increasing push for renewables, gas and coal are likely to continue to exit the market and the sector continues to investigate alternative energy options such as solar PV and storage.

Another potential strategic resilience issue is that the coal capable generation plant at Huntly Power Station may cease operating in 2022, with implications for national electricity supply during an extended period of low hydro inflows and for supply security in the upper North Island.

Transpower's *Transmission Tomorrow* outlines the strategic changes in the industry and their proposed responses.

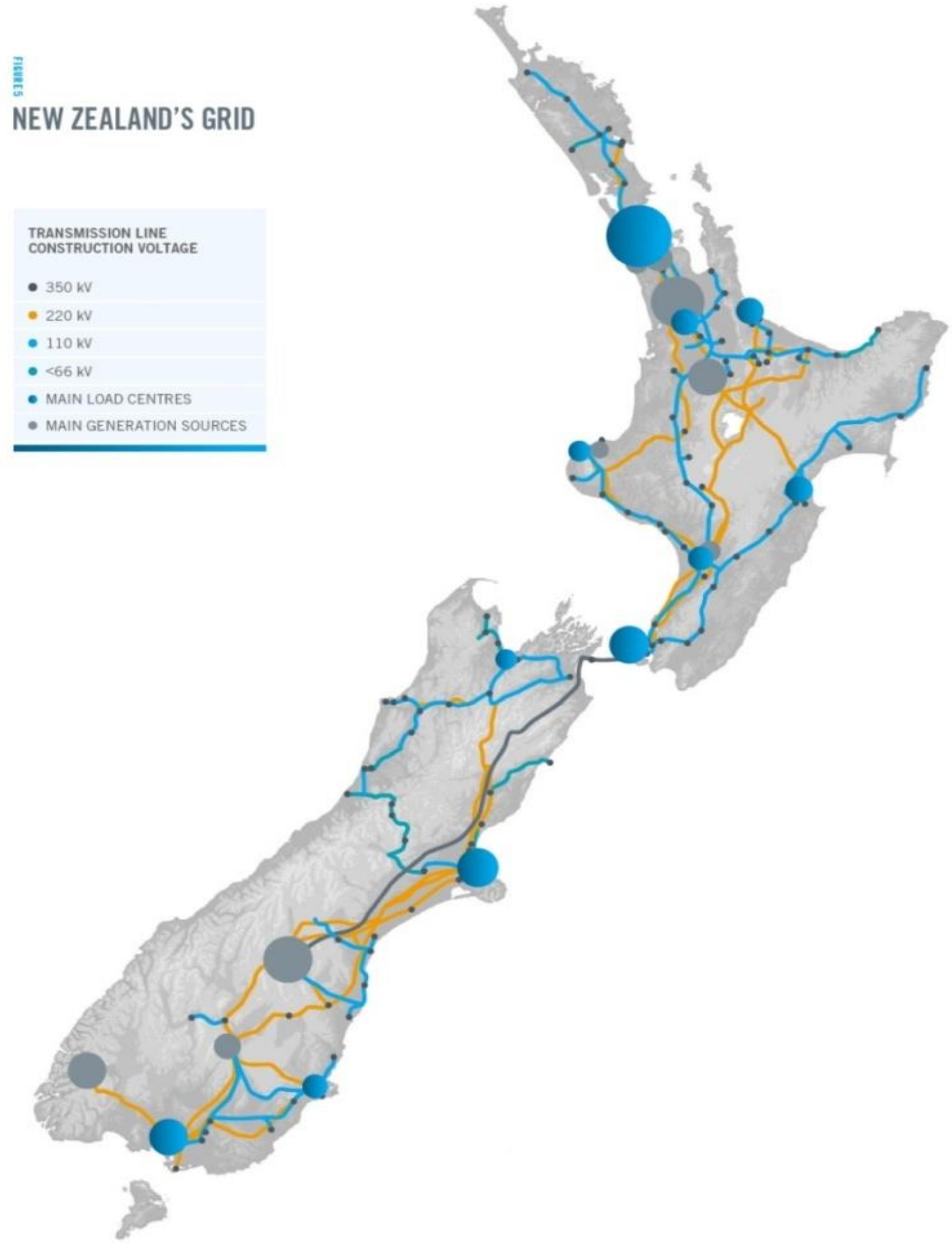

Figure 3-2: The National Grid

Electricity Transmission – the 'National Grid'

The National Grid transmits electricity from generation sites to electricity distribution companies and some major consumers supplied directly from the grid.

The most critical components of the transmission and distribution network are generally those that transmit the largest volume of electricity and/or have limited redundancy and/or which supply critical customers. Regional lifelines projects and groups have identified the following 'nationally significant' components of the National Grid (refer also Figure 3-3):

1. The transmission line to Northland and substation supplying the Marsden Refinery (the Refinery cannot operate without supply from the national grid).
2. The highest capacity transmission line in New Zealand is the 350kV HVDC line from Benmore to Haywards (Wellington), loss of which would result in loss of transmission capacity between the North and South Islands (when all generators are operating, each island is able to generate sufficient capacity to meet demand within the island, however there is likely to be constraints in the North Island at peak loads and the line is particularly critical when drought or other conditions impact generation in either island).
3. Haywards substation[3] is important as part of this link as well as being the main substation supplying Wellington.
4. Bunnythorpe substation, which is a key switching point between South Island generation and North Island demand (and sometimes vice versa), and the transmission lines from Bunnythorpe to Haywards substation.
5. Whakamaru substation which is a key point of supply to Waikato, Auckland and Northland (and the transmission lines from Hamilton and Wairakei to Whakamaru).
6. Benmore, is a major hub which supplies power through 350kV HVDC transmission line to Haywards (Wellington) and the national grid.
7. The Roxburgh and Clyde substations are key transmission hubs on the National Grid.
8. A number of Auckland's substations service greater than 50,000 customers, including Penrose, Otahuhu, Mt Roskill and Albany.
9. South Island transmission lines north of Christchurch from Islington substation into Kikiwa and Stoke substations (supplying the upper South Island).
10. Plus a number of areas that receive a single line of supply, including Queenstown (transmission lines through Kawarau Gorge), double circuit transmission from Wairakei in to the Hawkes Bay and north, circuits from Stratford to Opunake and New Plymouth which service the onshore gas fields (which rely on the National Grid to operate).

System Operation

As well as managing the national grid, Transpower is the national System Operator, responsible for managing the real-time power system and operating the wholesale electricity market. In this role it aims to balance supply and demand – as a last resort to avoid system-wide blackouts it can respond to major imbalances through mechanisms such as AUFLS (Automated Under Frequency Load Shedding). The main control room in Wellington is a critical site for the System Operator with a hot standby site in Hamilton.

The system operation relies heavily on automated processes and digital technologies and cyber terrorism / space weather / other causes of technological failure are a major risk in this area.

[3] While the term substation is used as an overarching term, some of these sites are more commonly referenced as switchyards.

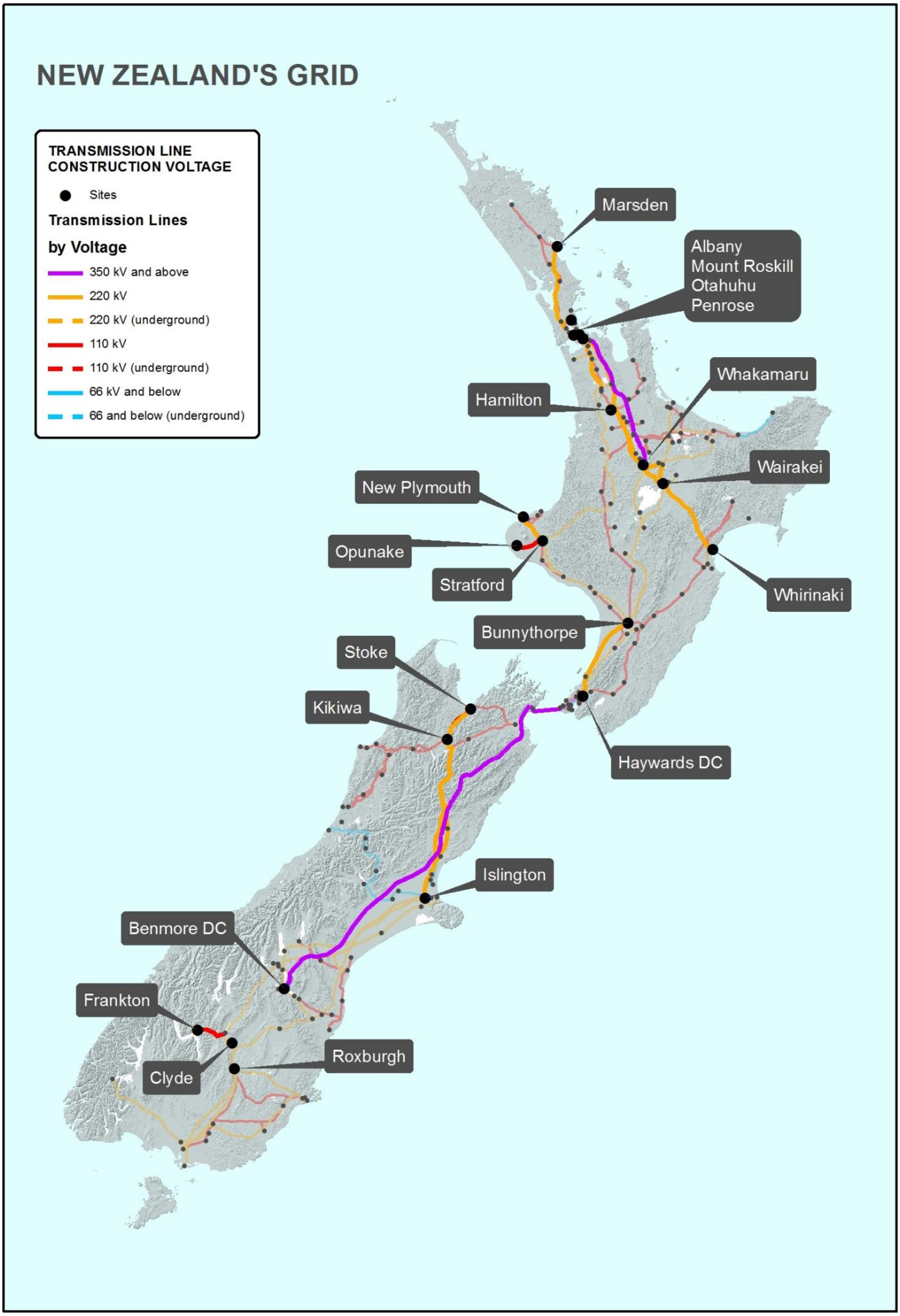

Figure 3-3: Nationally Significant Assets in National Grid (identified in regional lifelines studies)

Electricity Distribution

Around 30 electricity distribution companies take power from the National Grid at Grid Exit Points (GXPs) and distribute them to customers via a network of substations, cables and lines.

Nationally significant distribution assets are generally those that supply critical sites dependant on electricity, though many of these sites have more than one line of supply as well as some form of on-site backup generation. There are other specific examples of nationally significant assets such as the Vector tunnel to Auckland CBD.

Major Customers

Most businesses rely on electricity supply to function. From a consumption perspective, Tiwai Point is the largest electricity user in the country and there are many other major industrial users in the steel, wood, pulp, paper and printing sectors. However, while the cost implications of a major industrial shutdown are significant, from a wider community and economic perspective the most critical large user of electricity is probably Marsden Refinery (refer Section 3.2), followed by the Maui onshore gas fields in Taranaki, which also cannot operate without the national grid. Fonterra is also a major customer with most dairy processing facilities relying on mains electricity supply and having limited on-site generation backup. Other critical community customers are discussed in Section 4.

Resilience to Hazards

The national grid passes through areas vulnerable to all New Zealand's major natural hazards. The majority of the South Island's generation sources have proximity to the Alpine Fault. Some major substations are in tsunami zones, such as Bream Bay which supplies Marsden Refinery. Critical transmission lines pass through many areas of slip-prone terrain.

Most transmission lines span lattice steel towers which are robust and not expected to incur damage from seismic or flood activity unless there is major ground rupture or landslip at the foundation. Furthermore, as noted earlier, most of the network can be supplied from more than one line (though sometimes the second circuit is on the same tower). However, there are a number of places where space is constrained and towers are being replaced by pole structures.

The smaller distribution networks are a combination of overhead lines and underground cables – the former tend to be more resilient to seismic activity and faults are relatively easy to find whilst underground cables are more resilient to wind/flood risk but can break with seismic movement and take more time to repair. Some are older and less resilient to ground movements.

Transmission substations are subject to high design standards and are likely to survive an earthquake or at least be repairable, though distribution substations are more variable. Tsunami waves are considered more potentially damaging for substations and overhead lines, though in many cases the area supplied by those assets would be damaged and resupply could be prioritised accordingly. Volcanic ash can cause flashover and disrupt electricity supplies.

Hydro generation is vulnerable to drought and there are potentially impacts on security of supply, particularly with the planned closures of non-hydro generation discussed earlier. Another potential vulnerability is the impact of an earthquake on lake sediment and water turbidity which has the potential to close generation plants. Further information on these resilience issues will be sourced as part of Stage 2.

Some distribution companies have assets in commercial premises and are reliant on access to maintain these, for example, a building demolished in Molesworth Street in Wellington following a Kaikoura earthquake.

Regulation and Funding

While most parts of the electricity supply chain operate as a commercial business, resilience is also influenced by sector regulation. In general, investment in transmission and distribution services is governed by the Commerce Commission and other parts of the supply chain are governed by the Electricity Authority. Both regulators have statutory objectives to promote reliability. The Security and Reliability Council is a special-purpose advisory group with a mandate to identify risks affecting the sector and make recommendations to the Electricity Authority.

Transmission investment is, in part, driven by the grid reliability standards (GRS) administered by the Electricity Authority under the Electricity Industry Act. The standards are rules that incentivise investment meeting an economic cost-benefit test. Economic evaluation typically takes into account the 'value of lost load' (VOLL) (an estimate of the economic hardship from non-supply) and the probability of disruption events. Assessment involving 'high impact low probability events is challenging (as for all infrastructure).

The VOLL is an estimated default figure that may not accurately reflect the relative cost of interruptions to different customers nor the impacts of longer term outages (such as major ashfall disruptions). Transpower can proposed to employ alternative VOLL estimates and is undertaking further work in this area.

The Commerce Commission regulates maximum revenues for 17 distribution businesses (of 29 in total), incorporating incentives for them to maintain or improve reliability (relative to performance over the last ten years). But in general, distributors make their own investment decisions about resilience levels.

Hydro generation (dams and canals) are subject to specific safety provisions in the Building Act.

Other general regulation and funding constraints for lifelines are discussed in Section 6.1.

3.2 Fuel

Overview of the National Supply Chain

Around 70% of New Zealand's fuel is refined at the Marsden Refinery, south of Whangarei, including all aviation and shipping fuel. All fuel into New Zealand is imported by BP, Mobil and Z (which refine fuel at Marsden) and Gull (directly imports refined fuel to ports in the North Island).

Two ships distribute fuel from Marsden Refinery to ports around New Zealand, the majority of Auckland usage is supplied to Auckland's Wiri facility by pipeline, with the remainder transported by road from Marsden to Northland and North Auckland. Other ships bring in refined fuel from international ports. The quantity and type of fuel varies, for example, only diesel gets shipped into Taranaki while other types of fuels are supplied by road.

A number of transport companies distribute fuel from ports to customer supply points.

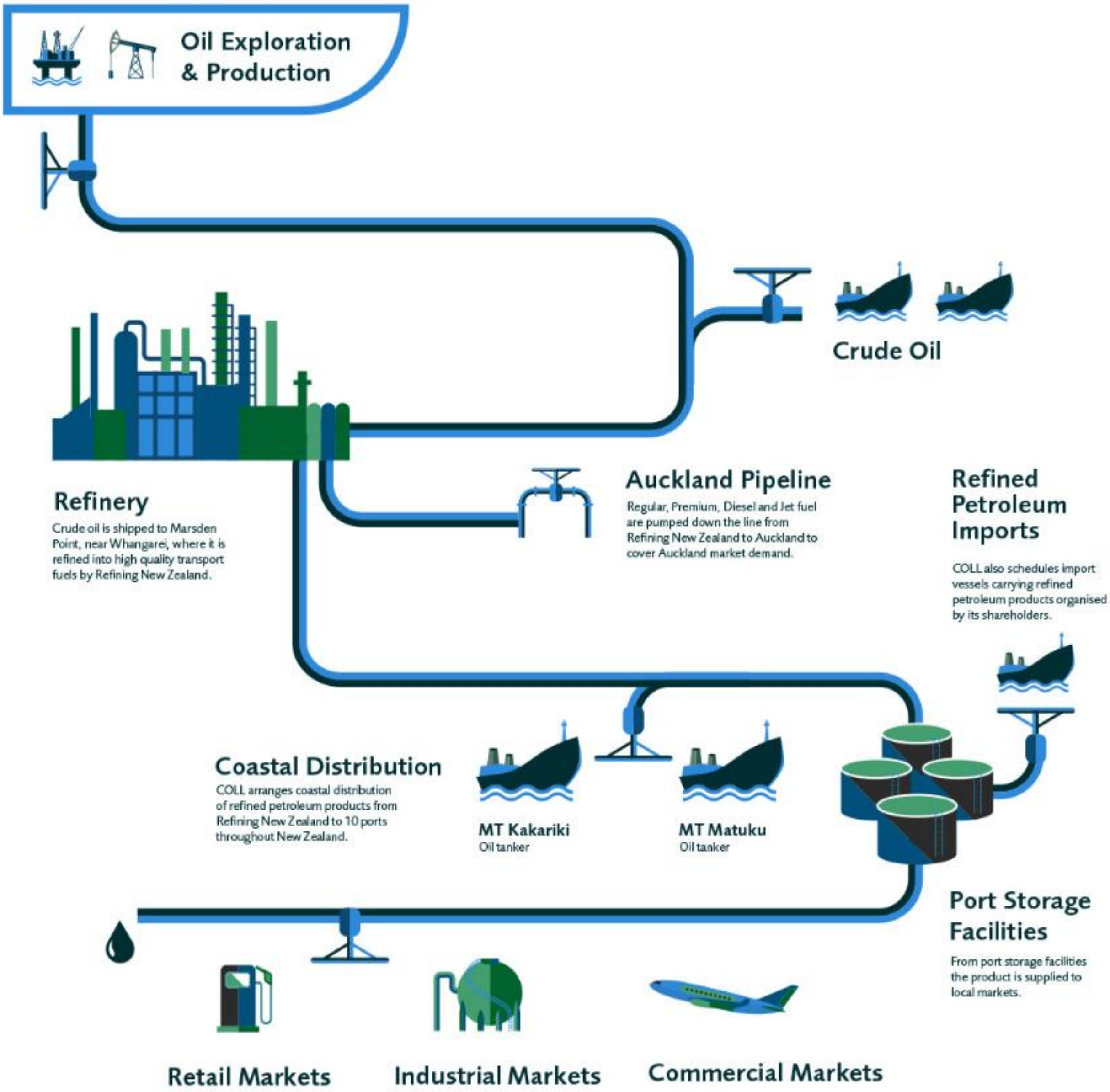

Figure 3-4: New Zealand's Fuel Supply Chain (www.coll.co.nz)

Taranaki is an important region for the production and refining of petrochemicals. Currently, most of the high quality petroleum products are sold into the international market while New Zealand imports and refines cheaper fuel for domestic use.

Supply Chain Vulnerabilities

Marsden Refinery

The Marsden Refinery and jetty are the most critical points in the national fuel supply chain. Without Marsden, or its jetty, operating, the country would suffer fuel shortages unless demand was constrained. It would take several weeks to bring supplementary refined fuel in from Singapore[4] (both BP and Mobil operate in Australia but there is currently no guarantee that ships could be diverted if required). If the jetty was damaged this would impact on ability to import refined fuels to the Port and the Wiri Pipeline as well as the ability to export refined fuel to other ports.

Marsden Refinery holds on average 11 days supply of crude oil and around 8 days of finished product.

Fuel Storage Facilities

In an isolated failure of a single port (or associated fuel storage facility) in most cases normal demand could largely be met by surging capacity at surrounding ports and trucking fuel supplies in. This is dependent on roads being open and the capacity in the trucking fleet (which is likely to be a constraint). Terminal fuel storage by Port is illustrated in Figure 3-5.

After Marsden, Wiri Oil Depot is considered the most critical facility (and the pipeline supplying it from Marsden is also a nationally significant asset) and it has been estimated that only a portion of Auckland's demand could be met by truck from Tauranga and Marsden (and not jet fuel as there is no truck-loading facility for this at Marsden). The availability of suitable trucks, drivers and a functional road network, to distribute fuel is the key constraint, not the ability to divert fuel to alternative ports.

In recent years, jet fuel demand and Auckland regional fuel demand has increased significantly. While the Wiri Oil Depot used to hold up to one week's demand, fuel supply is increasingly 'just in time', increasing the fuel shortage risks associated with a pipeline or refinery failure. Pipeline capacity is being increased to mitigate this risk to some extent.

The other most critical fuel supply facilities are in Mt Maunganui, Christchurch and Wellington. Lyttelton is important for the whole South Island - the next largest terminal is a third the size. Wellington's Seaview Wharf is seismically vulnerable and dependent on road access and the facilities at Kaiwharawhara (supplying marine diesel to inter-island ships) and Burnham (jet fuel supply) have vulnerabilities as well.

Further south, both Dunedin and Invercargill terminals would be critical supply points following a major earthquake as road and rail links will likely be compromised.

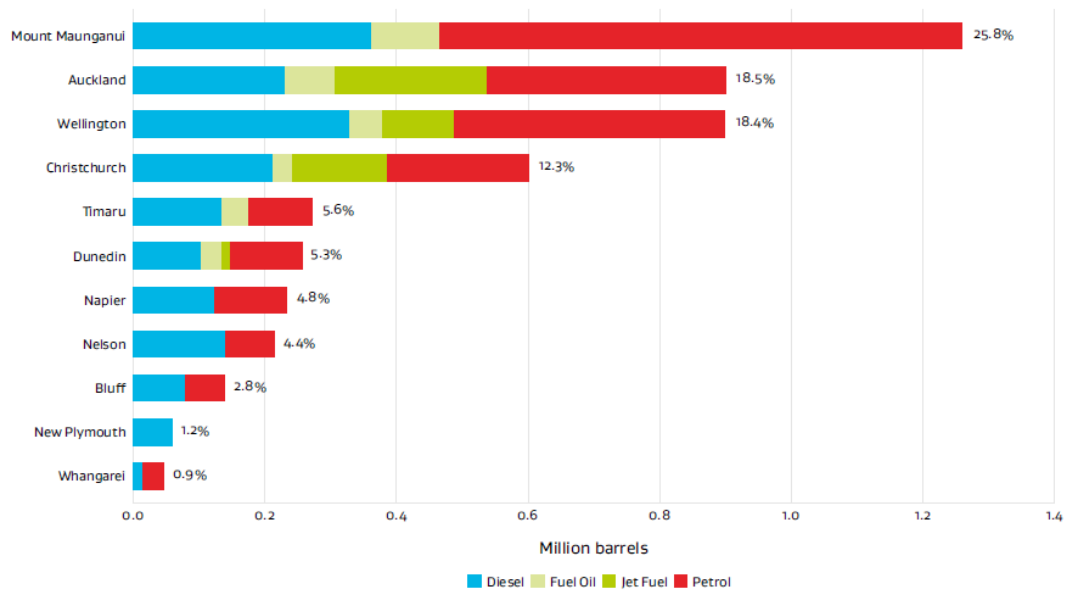

Figure 3-5: Terminal Fuel Storage by Port in 2015 (data in gross capacity), Ref MBIE Energy in NZ 2016

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[4] MED1348187 - Hale & Twomey: Information for NZIER Report on Oil Security.

Wiri-Oil Pipeline and Lyttelton to Woolston Pipeline

As with the gas transmission network, these oil pipeline is designed to withstand seismic events but is at risk from major land movement. Regular inspections, testing, spares and contingency planning are all undertaken to mitigate the risk of failure and facilitate a quick restoration if failure does occur.

Risks of facility outages

The operators of fuel storage facilities take risk very seriously, however there are many potential hazards that are challenging to mitigate. Marsden Refinery and many fuel terminals are in a tsunami zone (refer box on previous page) and is the Refinery is dependent on the electricity supply which is in itself vulnerable to hazards. Fire is another risk for oil terminals. The fuel pipeline is at risk from major landslides, third party damage / explosion and loss of electricity supply to pump stations along the line. Wiri Oil depot is in a major flight path to Auckland Airport.

Constraints in the Road Network

Fuel distribution in New Zealand is highly road dependent, in fact some regions, such as the West Coast of the South Island, Taranaki and Manawatu-Wanganui, are totally dependent on trucked fuel. For these areas, isolation by road essentially means loss of fuel supply into that area until the logistics to enable air or sea transport can be put in place.

Customer Supply Points

Fuel is stored for supply at retail outlets supplied by the four oil companies (Mobil, BP, Gull, Z). Some of these are oil company owned and managed, some independently owned and managed. The re-fuelling rates vary and it is impossible to give a definitive view on the amount of storage held at these sites, though it is typically in the range of 'days' during normal levels of use.

The key vulnerability in the retail outlet network is the dependence on electricity to pump fuel. Only a few stations in New Zealand have on-site standby generation, though some new fuel stations are increasingly being built with 'plug in' generator capability. Regional and local fuel plans are being developed that both highlight and seek to address this key resilience issue.

Many farms and industries also have their own diesel storage, though there is no national picture of such stockholdings and there is some anecdotal information that on-site storage facilities are reducing due to the high installation and maintenance costs. Further collection of information on fuel storage in New Zealand is intended in Stage 2.

Fuel Supply and Tsunami

In 2016, a national CDEM Exercise 'Tangaroa' tested the nation's ability to respond to a tsunami exercise event. The event was triggered by an earthquake near the Kermadec Trench and generated waves on the NZ coast of up to around 10m.

Exercise Tangaroa highlighted some aspects of NZ's fuel supply that make it vulnerable to disruption.

The refinery and most of the fuel storage and offloading facilities are on the east coast, the coast most vulnerable to tsunami. The exercise scenario is likely to have caused significant damage to this infrastructure. There are currently no alternative plans to get fuel to shore if there is major damage to wharves and tanks.

NZ's jet fuel is refined at Marsden with the majority going by pipeline to Wiri and then to Auckland Airport. There is only a few days demand of jet fuel stored in New Zealand and there are understood to be constraints on the ability to import refined jet fuel to alternative Ports (further information will be gathered in Stage 2).

While the above vulnerabilities in the are discussed here mainly in relation to tsunami, acknowledged as a very low probability hazard, there are other potential hazards as discussed Section 5. Liquefaction damage to facilities is a key risk, particularly in more seismically active areas.

New Zealand Lifelines Council

Regulation and Funding

The entire fuel chain is operated on a commercial basis with competition amongst suppliers. Like the telco sector, supply resilience is largely driven by businesses' motivations to maintain and promote market share and corporate reputation. There is no sector regulation specifically relating to resilience but the regulation of workplace safety and hazardous substances has a significant influence on fuel resilience.

As a member of the IEA International Energy Programme, New Zealand is required to hold 90 day's stock to promote resilience to very significant global supply disruptions (such as Hurricane Katrina and the Gulf War). However, as stockholdings fall short of this, the Government makes up the short 'ticket' contracts (an option to purchase stock in an IEA declared emergency).

There has been some discussion about whether the amount of stock stored in NZ is sufficient to ensure the right level of resilience, given possible impedance to uplifting stock options in a global crisis. This is anecdotal discussion only that needs to be subject to further enquiry.

MBIE's most recent Petroleum Supply Security Review (*ref Hale and Twomey 2017*) concluded that the cost of holding additional supply in NZ was not justified by the mitigated risk cost. However, it also concluded further work was needed on mitigating jet fuel supply risks (including possible additional storage in Auckland) and noted the importance of Wynyard Wharf as a backup option for Auckland.

Decisions on resilience considerations in matters such as location of fuel terminals, minimum storage volumes and backup generators at facilities are made by the fuel companies on a commercial basis. MBIE's national oil security reviews aim to identify and address any risk and resilience issues. However, the Wellington Resilience Programme is flagging concerns about the vulnerability the Seaview Terminal and the impact on both normal and response and recovery operations. It is unclear would be accountable for setting up temporary offloading facilities and the like (in Wellington or elsewhere) – while the lifeline duties in the CDEM Act are clear, there are questions about how far those duties extend or are commonly understood.

Fuel terminals are also regulated through Health and Safety at Work (Major Hazard Facilities) which requires operators to identify and eliminate / minimise risks and hazards.

Two key documents – the MCDEM National Fuel Contingency Plan and MBIE Oil Response Strategy cover matters relating to managing post-event fuel shortages, but not risk mitigation (reduction) aspects.

Other general regulation and funding constraints for lifelines are discussed in Section 6.1.

3.3 Gas

Natural Gas

Natural gas is an important source of energy in the New Zealand, comprising around 14% of energy demand[5].

Production

Natural gas in New Zealand is largely sourced from three gas fields in the Taranaki – Maui, Pohokura and Kupe. Product is piped to on-shore production stations and from there condensate is piped to the Omata Tank Farm for shipping to Marsden and offshore refineries. Gas is fed into the national network.

The Maui production pipeline and Omata Tank Farm are both rated as nationally significant assets.

Transmission

The national transmission network owned by First Gas supplies a number of cities and towns across the North Island, as shown in Figure 3-6. The main north-south line on the west side of the North Island supplies Auckland, Hamilton and Wellington and is considered a nationally significant asset.

Unlike many other national transmission networks (roads, electricity, telecommunications), there is little loop redundancy in the network. Short term pipeline disruptions do not necessarily affect supply continuity as gas pressure is maintained in the pipeline that can be drawn down to a limited extent. There are contingency arrangements in place to reduce demand through demand curtailment measures and details for the critical contingency operation can be found at www.cco.org.nz .

The primary focus of the contingency arrangements is maintaining a minimum pressure in the piped gas network. Once pressure drops below a certain level the process to restore supply can take weeks or months as it requires manual reconnection.

The transmission network is a pressurised pipe network designed and operated to the AS/NZS 2885 suite of standards and can withstand significant seismic shaking, though there is a risk of gas pressure loss. Risks mainly relate to major land movement from differential ground movement (fault rupture, liquefaction) local weather-related land slips, coastal erosion and significantly the impact of urban encroachment.

Some LPG is also transported by ship, road and rail around the country.

MBIE commissioned a report on gas disruption risks in 2014 which concluded that the significant risks in the industry were well understood and managed (*ref Worley Parsons 2014)*.

Maui Pipeline Outage 2011

This 5-day pipeline outage resulted from a slow-moving land-slide and saw curtailment measures instigated for all consumers apart from essential services and residential consumers. The outage had a significant effect on many sectors – from restaurants to crematorium but long-term impacts were avoided by protecting the system through these contingency curtailment measures. http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-security/documents-image-library/Review-Maui-pipeline-outage-october-2011.pdf

Landslides in general are a key hazard for gas lines, mitigated by careful monitoring and land stability management. Also spare lengths of pipe are available to quickly repair any pipeline breaches.

[5] MINISTRY OF BUSINESS, INNOVATION AND EMPLOYMENT ENERGY NEW ZEALAND: 2016

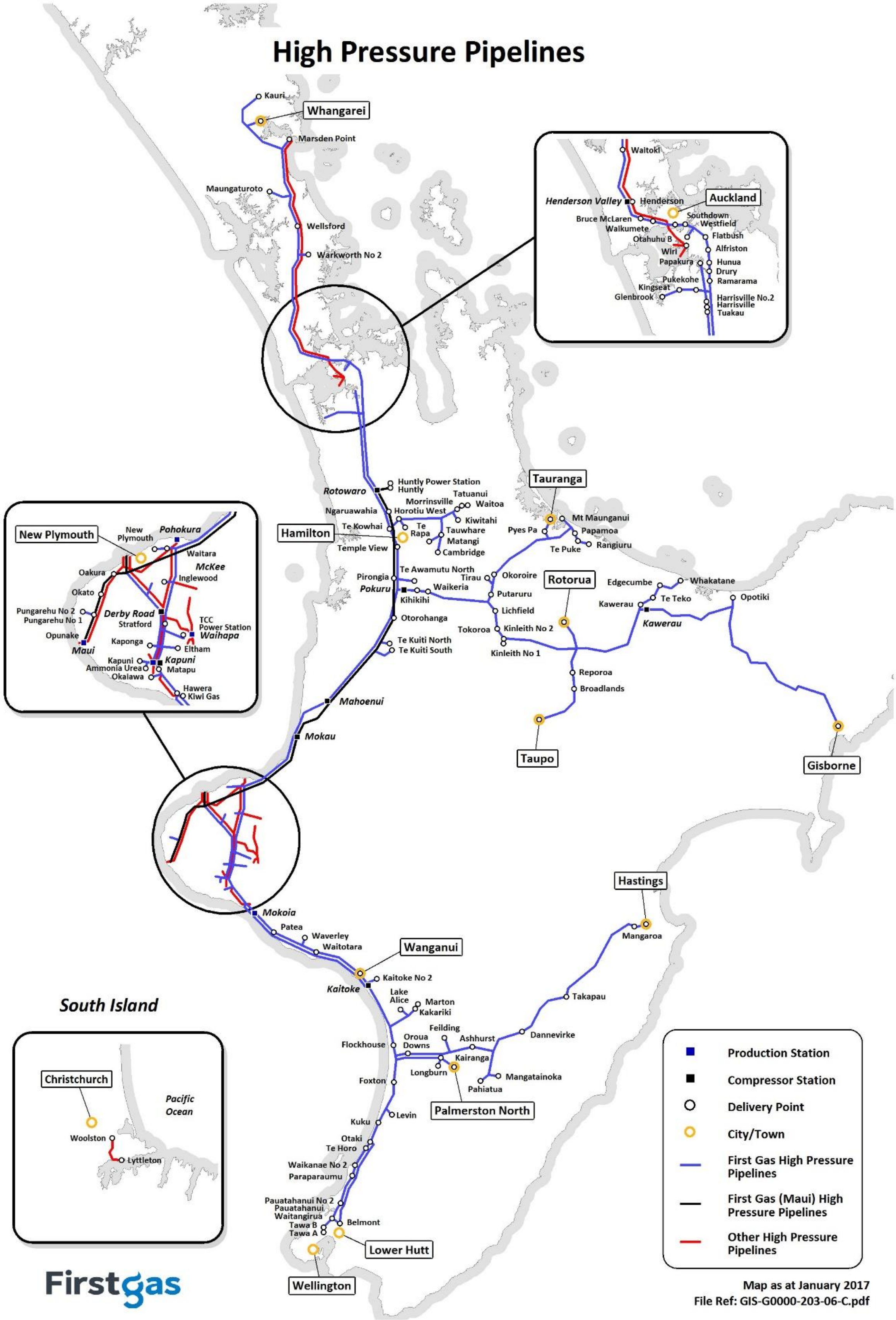


Figure 3-6: Gas Transmission in the North Island

Distribution

Open access distribution networks are owned by First Gas, Vector, Powerco, and GasNet, while Nova Energy owns a number of small private pipelines.

Because of the time-consuming process to restore service if gas supply shuts down, there is a trade-off between the number of shut off valves (to isolate the network) and time to reinstate if shut off.

Major customers

While household consumers only use a small amount of the gas produced (<5%), gas is critical to the electricity generation, horticultural and petrochemical industries as well as hospitals. It provides a significant energy source for commercial enterprises such as dairy plants and other energy intensive enterprises.

Vulnerability to Hazards

Along with the supply chain vulnerabilities discussed above, the potential for cascading impacts of gas breaks need to be recognised – they are a major fuel source for fire following earthquakes. In areas such as Wellington, breakage of pipes at terminal points (eg: buildings) is the site of most likely breakages.

LPG

LPG is supplied into New Zealand from Taranaki – a combination of imports and sourced from the NZ gas fields. Around 180,000 tonne of LPG are consumed in New Zealand each year.

LPG is shipped to the South Island ports of Lyttleton and Dunedin by coastal tankers from where it is distributed by road tanker to downstream wholesalers who have their own bulk storage facilities throughout the South Island.

The North Island is supplied by road tanker from bulk storage facilities at Taranaki and Wiri. An import terminal at Manukau is being mothballed as it is too expensive to maintain and operate (the harbour can only take small coastal tankers).

Liquigas provide a tolling service for the bulk supply of LPG into, out of and around New Zealand, though they do not own the LPG they transport. Downstream companies include Elgas, Ongas, Contact and Genesis.

Use of LPT for car fuel is decreasing and few petrol stations are maintaining LPG facilities.

Regulation and Funding

The regime is broadly the same for electricity, except that there are no codified reliability standards and no regulated investment test for gas transmission.

Gas Industry Company (GIC) is the co-regulatory body to develop arrangements, including regulations where appropriate, which improve the operation of gas markets, access to infrastructure, and consumer outcomes. The GIC's report on Gas Transmission Security and Reliability (*A Gas Industry Co Issues Paper – April 2016*) provides a good summary of the various regulatory and non-regulatory drivers of resilience in the sector.

Other general regulation and funding constraints for lifelines are discussed in Section 6.1.

3.4 Roads

Nationally Significant Assets

New Zealand road authorities use the One Network Road Classification (ONRC) system which divides New Zealand's roads into six categories. The categorisation is based on factors such as how busy they are (traffic volumes) whether they connect to important destinations, or are the only route available.

This classification provides a useful baseline for criticality assessments for vulnerabilities studies, whereby most Roads of National Significance are those categorised as 'High Volume' or 'National'. However not all are. Road controlling authorities participating in regional lifelines projects have in some cases classified roads as nationally or regionally significant that aren't rated as 'High Volume' or 'National' under ONRC criteria. For example, NZTA recognises two 'local' roads as nationally significant – the roads to Ports of Auckland and the Marsden Refinery.

Vulnerability to Hazards

A key challenge for those involved in road resilience is the ability to predict where rain and earthquake induced landslips will occur and the high cost of remediating potential large landslips. Potential seismic damage to structures is easier to identify and remediate and seismic inspections and upgrading of critical bridges is ongoing.

Roads are also highly vulnerable to volcanic ash – while generally ash does not cause long term damage it can render the road temporarily impassable and result in a costly clean-up regime. Low lying coastal roads are obviously vulnerable in both tsunami and storm surge prone areas.

Traffic on the road is also a hazard – illustrated by recent bridge strikes in Auckland and the near gridlock caused by the most severe traffic incidents.

Bridges on roads often carry critical infrastructure assets of other lifelines organisations, making the consequence of their failure even more severe.

Nationally significant, vulnerable roads identified in available regional vulnerability study reports and the 2016 NLF workshop include:

- SH 1 Brynderwyns (floods / slips).
- SH1 and 16 in Auckland are both vulnerable to tsunami in places, notably the onramps to the Harbour Bridge and the causeway along SH 16.
- The SH1 High Productivity Freight Network is vulnerable to earthquakes in Pokeno and Tuakau and flooding at Huntley.

NZTA's Resilience Programme

Road networks have been shown to be vulnerable to both high frequency (floods) and low frequency (earthquake) events with long recovery times following some events. Treasury's National Infrastructure Plan (2015) identifies improving road resilience as a high national priority.

This is not to suggest that road resilience hasn't been given attention both at a local authority and state highway level. NZTA's *Resilience Programme* has been underway for many years. Key projects undertaken include:

- A national scan of exposure to low frequency hazards and expected impacts on the road network. A series of maps showing hazard risk are at https://nzta.maps.arcgis.com/apps/MapSeries/index.html?appid=5a6163ead34e4fdab638e4a0d6282bd2
- A framework for criticality of the road network.
- A map of road resilience 'hotspots' considering low and high frequency events and road criticality.
- A consortium led by GNS Science developed a Risk Evaluation Tool for the State Highway Network, which evaluates the service disruption to the network following hazard disruption. This was tested on a pilot study route in Wellington.
- A number of business continuity and emergency response projects, including development of an online detour route tool for road closures.

At this stage the programme is being provided to regional NZTA and local road authorities to inform local level planning. Eventually the intention is to develop a nationally prioritised programme of resilience improvements.

- SH 1 through Dessert Road, with exposure to both volcanic and meteorological hazards.
- SH 1 and 2 into Wellington are vulnerable, particularly to seismic activity and flooding (SH 2 between Petone and Ngauranga was identified in a 2017 NZTA / GWRC study as the most vulnerable stretch of road in Wellington).
- SH 1 Kaikoura Corridor (road and rail in narrow corridor vulnerable to slips both rain and earthquake induced)
- SH1, 6 and 8 in Otago are critical and has a high risk of seismic/alluvial activity and severe weather events. SH1 is vulnerable to tsunami along several stretches.
- SH 3 Manawatu Gorge (seismic and flood hazards).
- SH 3 Taranaki North (important oil, gas, freight and evacuation route).
- SH6 Hokitika-Haast Pass and SH94 Milford Sounds (important tourist routes)
- SH6 Kawerau Gorge (seismic and flood hazards, alternate route adds 4 hours)
- SH6, 7 & 73 provide the only links to the West Coast and damage to one, or all of these is highly likely in a major earthquake event potentially isolating the West Coast completely.
- SH 29 is important as part of the FMCG and fuel supply chains in and out of Port of Tauranga.
- SH88 (link to Port Chalmers)
- Lyttelton Tunnel and access roads.
- Plus other local roads to nationally significant sites referenced on the previous page.

For many of these roads, the alternate routes are also prone to the same hazards. Project AF8 highlights this risk in the South Island and the subsequent isolation of many communities.

Figure 3-7: State Highway, Kaikoura

Regulation and Funding

NZTA allocates government funding for both State Highways and local roads using a prescribed business case model. The model has been reviewed in terms of how it supports investment in resilience and proformas for fund applications for resilience projects are available. Further work needs to be done on supporting less resourced regions to be able to monitor, report and progress resilience programmes.

There is no specific regulation relating to minimum resilience standards, outside the CDEM Act. However, the ONRC performance measures, which are likely to set benchmark standards for funding applications, do include some relating to resilience.

Other general regulation and funding constraints for lifelines are discussed in Section 6.1.

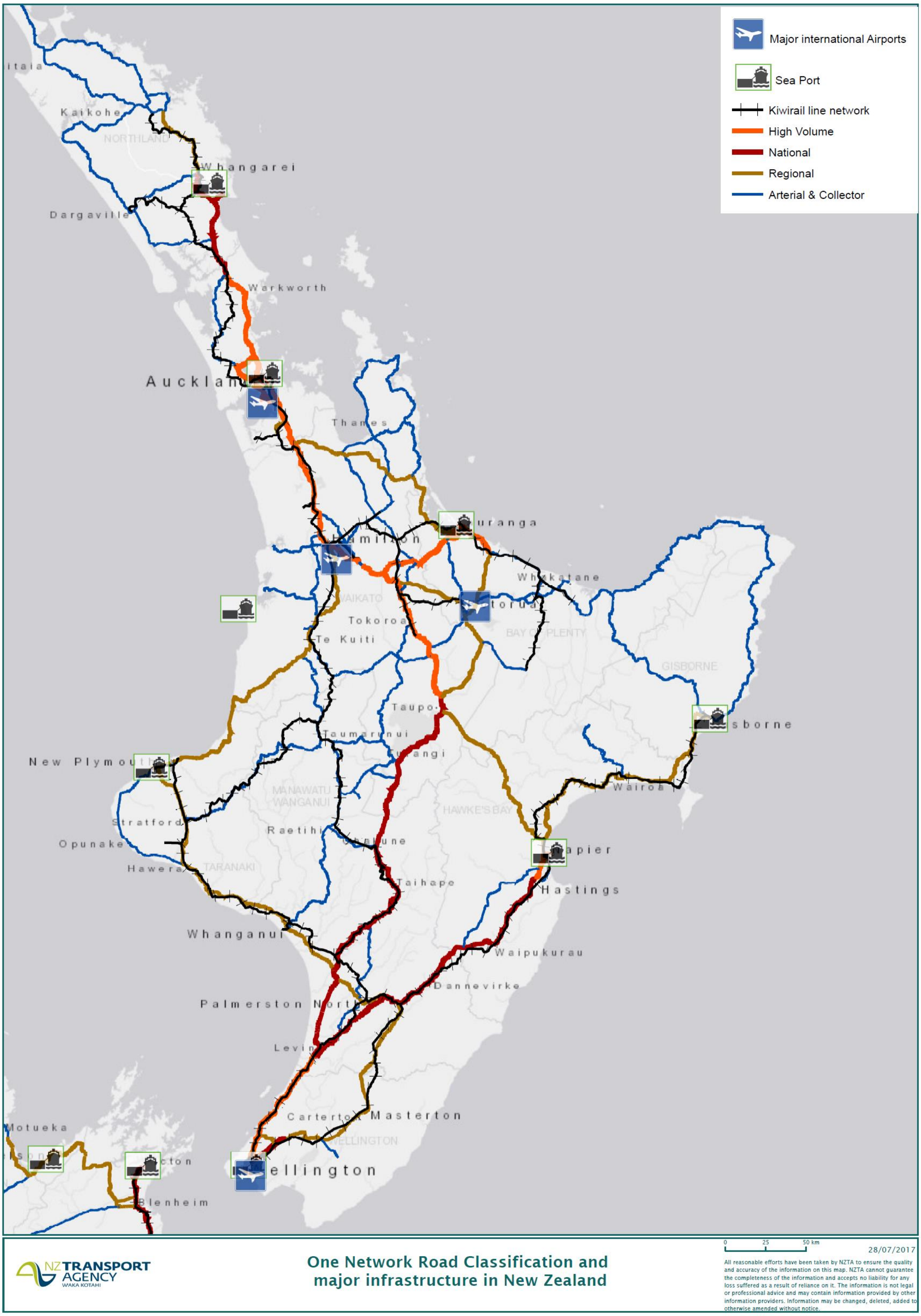


Figure 3-8: North Island Transport Infrastructure

Figure 3-9: South Island State Highways

3.5 Air Transport

There are 5 international airports (Wellington, Christchurch, Rotorua, Dunedin and Queenstown) plus the RNZAF base at Ohakea. Auckland Airport carries 75% of international passenger traffic while Christchurch is the main gateway into the South Island. Auckland and Christchurch are the only two hubs for international USAR assistance.

Regional airports service the balance of New Zealand and can have national significance, for example, Hokitika Airport potentially becomes highly critical for the West Coast if it is isolated by road.

Airports and runways are designed to withstand seismic events, however there is still likely to be damage in a major event. Queenstown is notably in an area of high seismic risk and some airports are prone to liquefaction (such as Wellington and Dunedin). With the potential for major road damage in an 'AF8' type scenario, this airport could be extremely important in the evacuation of tourists (and other people) and for bringing in emergency supplies and responders. The airport only holds 3 days of jet fuel which is transported by road from Dunedin.

Other vulnerabilities include:

- Volcanic ashfall disrupting flights
- Technological disruption, vulnerability to accidental or intentional technological failure
- Dependence on jet fuel. The loss of jet fuel supply to Auckland Airport would have a significant impact on international and domestic travel in the country and the Airport has a temporary fuel contingency plan for failure of Marsden of the fuel pipeline. It is understood that alternative supply from Mt Maunganui may not be viable given different quality standards (the issue of jet fuel contingency arrangements is being further explored during Stage 2). Some international flights could pre-load in Australia but the full impact of a prolonged jet fuel shortage is unclear.
- Aircraft accident (of many causes, including criminal / terrorism).
- Low lying airports near the coast vulnerable to tsunami and storm surge. Sea level rise associated with climate change will exacerbate those hazards.
- Hazard impacts on road access to airports – the majority of airports have single road access and many of these roads are vulnerable to flooding (eg: Dunedin) and other hazards.

Further information on this sector will be collated during Stage 2, including information on airport capacity and traffic volumes, capability to act as backup for other airports and jet fuel contingency arrangements. This will include information on the airline sector and roles including airports, airlines, NZ Defence, CAA and Airways as well as air surveillance and navigation assets.

Regulation and Funding

The Civil Aviation Authority (CAA) has primary regulatory responsibility for aviation safety and aviation security. Other general regulation and funding constraints for lifelines are discussed in Section 6.1.

3.6 Rail

The national rail network is primarily important from an economic perspective, moving significant amounts of freight around the country, along with commuter rail in Auckland and Wellington.

Parts of the network that were identified as being nationally significant in the 2016 National Lifelines Forum workshop are the North-South trunk line in the North Island, the inter-island rail route and the Kaikoura Corridor in the South Island (the workshop pre-dated the earthquake). There are many other places, such as SH1 through Otago, where the rail line runs alongside the state highway such that both are at risk from slips, flooding and other hazards.

There is little redundancy in the network from a route alternative perspective, for example, in Wellington, an outage of the rail network leads to heavy road congestion. Essentially the road and marine network is the main alternative for freight movement if the rail corridor is closed, noting that some road and rail lines follow the same route with no nearby alternative roads. The movement of freight by road following the closure of the Kaikoura Corridor caused significant logistical stress, both in terms of the trucking fleet and impact on the inland road between Picton and Christchurch.

Within two weeks following the Kaikoura earthquake, KiwiRail entered into coastal shipping freight market with a NZ Connect Service to quickly move domestic freight from Auckland to Christchurch. Extra capacities were opened at the ports, and by using rail in Auckland and Christchurch added benefits of reducing truck congestion from already busy roads.

Vulnerabilities in the rail network are similar to those discussed for roads.

Regulation and Funding

Information will be gathered in Stage 2 of this report.

3.7 Sea Transport

Ports are important economic hubs for our remote country, connecting New Zealand to international markets. In regions at risk of being isolated by road for long period (Wellington, Taranaki, West Coast), ports become critical for transport of emergency supplies.

A study was carried out by the University of Auckland in 2012 (*Ref: Vulnerability of New Zealand Ports to Natural Hazards*). The aim of this report was to review the exposure of New Zealand's coastal ports to natural hazards and examine aspects related to access routes to the port. Fourteen major ports in New Zealand were identified based on economic importance and level of infrastructure. These facilities facilitate billions of dollars of trade both internationally and nationally, and act as vital lifelines in the event of a natural hazard. All these facilities are owned and operated by private companies that are majority owned by local government.

The review demonstrated the wide range in exposure to seismic, tsunami and volcanic hazard throughout the port network. The conclusions are summarised in the box to the right.

Further work is intended in Stage 2 to collect information on the inland and coastal port network.

Vulnerability of NZ Ports to Natural Hazards

- Seismic hazard is closely aligned to the main faults that run through the centre of New Zealand, with Eastland Port, Port of Napier, CentrePort, Port Marlborough and Westport exposed to the highest seismic hazard over a range of return periods.
- The scenario most likely to affect several ports is a rupture in the northern section of the Alpine Fault with Westport, Port Nelson, Port Marlborough, Lyttelton Port, CentrePort and PrimePort expected to experience MM intensities of VII.
- Volcanic hazard in Taupo Volcanic Zone, Auckland Volcanic Field and Mount Taranaki. Taranaki and Ports of Auckland potentially directly impacted, with ash fall is identified as a hazard for most of the North Island ports and is dependent on prevailing wind directions.
- The primary tsunami hazard is from a South American source that will expose the east coast of the country, and most significantly Eastland Port on the North Island. The other main tsunami source is from a local subduction zone earthquake, with CentrePort experiencing a high tsunami hazard because of an event of this nature.
- The majority of the ports are located on reclaimed land that varies both in age of construction and quality.
- Access routes to most ports are susceptible to some level of damage as a result of one or more of the natural hazards identified here, potentially restricting access to the port.

Ref: Vulnerability of New Zealand ports to natural hazards, 2012. Ragued, B ; Wotherspoon, Liam ; Ingham, Jason.

Regulation and Funding

Maritime New Zealand has prime regulatory responsibility over the operation of vessels, ports and offshore installations as well as provision of navigation aids. Other general regulation and funding constraints for lifelines are discussed in Section 6.1.

3.8 Telecommunications

The telecommunications sector is one of the most complex of the lifelines sectors – technology changes rapidly and there is a high level of inter-connectedness between the various providers which share parts of the network and exchange messages between networks. As technology changes, so does consumer demand – increasing numbers of households have replaced 'land line' phones with cellular. Cellular is also particularly important for some more rural and isolated communities.

Fixed Line Networks

The brains of the fixed line networks are the main **Telephone Exchanges** which are connected to intermediate and local exchanges via links (increasingly fibre). The core fibre network connects the main exchanges and has very high capacity. If an exchange becomes isolated from the nationwide network of exchanges, it will in some cases continue to operate in local mode, meaning that local phones will be able to call local phones from the same network. 111 service may be rerouted to a local number, such as the local police station or answered by a technician at the exchange building.

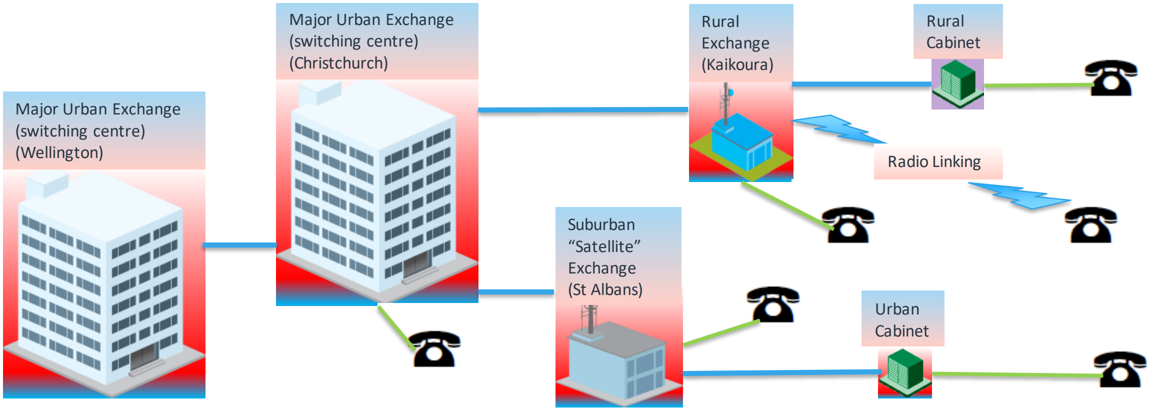


Figure 3-10: Traditional Network – copper links (courtesy of Chorus)

Mobile (Cellular) Networks

There are 4 major building blocks to cellular networks.

- The **Cell Site** provides the local coverage, and a mobile phone will connect to the cell site with the strongest signal, usually, but not always the nearest cell site.
- **Transmission** links connect the cell site to the Aggregation Node and the Aggregation Node to the Exchange. The transmission links are fibre, copper or microwave radio (increasingly, transmission links are moving to fibre connections).
- The **Aggregation / Intermediate Node** is linked by transmission links to the exchange.
- The exchange (**Mobile Telephony Exchange, or Strong Node**) is the brains of the operation; it makes the connection between the caller and the called. If the transmission links are broken, the call cannot be completed. It is not possible for a cell site to work in local mode.

The network operators in New Zealand operate several Exchanges (strong-nodes) and these are also connected by fibre transmission links. If these links are broken, the network functionality will be severely impacted. These links are therefore heavily protected with redundant links and automatic failovers.

Because of the dependence of telecommunication sites on electricity supply, there are a range of backups if mains supply fails:

- Strong-nodes are equipped with battery backup and fixed diesel generators
- Aggregation points are equipped with batteries and either a fixed generator or the facility for connecting portable generators.
- Cell sites are equipped with battery backup (typically between 4 and 12 hours depending on priority) and either fixed generators or generator plugs.
- The network operators hold their own portable generator stocks to maintain some basic coverage in a limited area.

Main Providers

The Telecom split in 2011 saw Chorus take ownership of all physical fibre and copper networks and most exchanges with Spark retaining ownership of a number of key exchanges and all cellular sites including a shared interest in specific inter-city fibre cable routes. Vodafone and 2degrees are the other providers identified as Tier 1 by the Telecommunications Carriers' Forum, with Vocus is becoming an increasingly large player in the market.

While Chorus took over most of the fixed line network at the time of the Telecom split, increasingly, other operators are installing fixed line exchange equipment as local loop unbundling[6] becomes the norm. Vocus, MyRepublic, 2Degrees, Mobile, Vodafone, Enable and Northpower are examples of these.

There are over 80 service providers now delivering services over fixed and mobile networks – the broad structure of the New Zealand Fixed Line market is illustrated below.

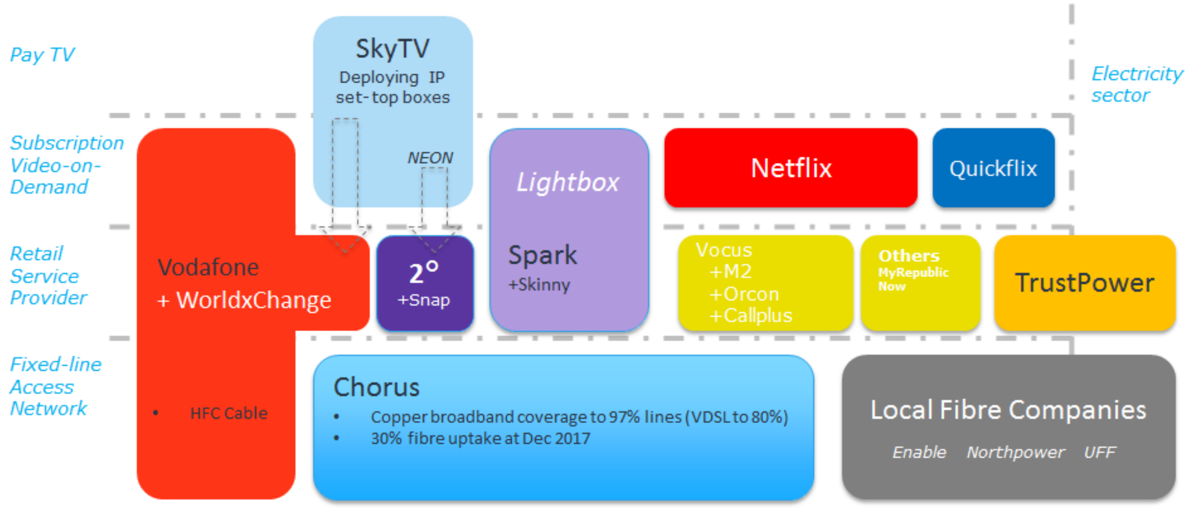


Figure 3-11: New Zealand Fixed Line Market

Nationally Significant Assets

Major Exchanges

Both Spark and Vodafone's main Exchanges are in Auckland, Wellington, Christchurch and Hamilton. Porirua is another critical exchange for Spark as it is the terminal for Spark's inter-island cable. Chorus retains a core network presence by co-locating in Spark exchanges but it is gradually diversifying its national network nodes into its own key sites. 2degrees has its major exchange for mobile in Auckland and Wellington, with a disaster recovery site in Hamilton. For the broadband (fixed), the major exchange is in Christchurch with disaster recovery in Auckland and Hamilton being built up.

Core Transmission Network

The international fibre links owned by Southern Cross Cable are nationally significant but the two main links (terminating at Muriwai and Takapuna) do provide redundancy for each other with a third cable into Raglan soon to provide even more diversity.

The Chorus core fibre network connecting the major Exchanges in both the North and South Islands includes three main north-south cables – broadly described the 'eastern', 'central' and 'western' cables. These are considered as nationally significant assets, though they do provide redundancy for each other if one fails through a 'ladder network' (illustrated in Figure 3-12). This core network carries all services (ie mobile/landline, voice/data). The relative criticality of various parts of the network has not been assessed (eg: assessing which components carry the highest traffic).

[6] Enabling multiple telco operators to use connections from the telephone exchange to the customer's premises.

Other providers such as Vodafone, Spark and Vocus have network, generally on high capacity routes such as inter-city core backhaul networks.

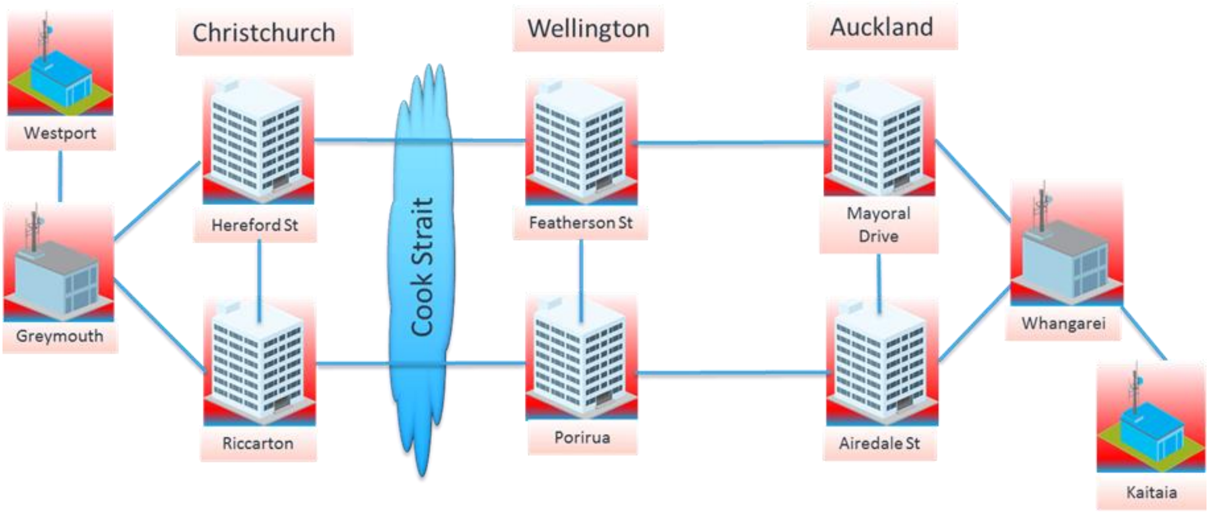


Figure 3-12: Ladder Network Diversity – courtesy of Chorus

Access Network

The 'access' networks include landline, cellular and broadband voice and data services. These all connect into the core networks and take services to the end user.

Network Vulnerability

The highly-interconnected nature of the telecommunications networks makes it complicated to predict the impact of specific asset outages, such as loss of a major Exchange. These sites are designed to 'fail over' to the remaining sites if one fails though there are some limitations.

Further investigation of the implication of critical telco asset failures will be undertaken as part of Stage 2 of this project, in liaison with MBIE who is also doing work in this area.

Spark's Mayoral Drive Exchange (and nearby Airedale) is possibly the country's most significant telco site though the implications of a major failure have not been quantified. The worst case (though very low probability) is a volcanic eruption in this area, which also has the main Vodafone Exchange and the Sky Tower (a major communications hub) in the vicinity. There are of course many other potential hazards – a recent multi-storey building fire in Auckland was not far from the Mayoral Exchange.

As a network, the sector is most vulnerable to power outage. The main exchanges and cell sites have battery and diesel generators on site and all sites have battery backup which will operate from anywhere between a couple of hours and several days depending on factors such as traffic and battery age. In a major, prolonged power outage, fuel and access for re-fueling become critical. Even with the main telecommunications networks operating on backup power, many homes rely on power for phone and internet.

The other major hazards are seismic activity – land displacement snaps fibres and damages bridges carrying cables, fire, and volcanic ash impacting on air conditioning systems required to keep equipment cool.

Another risk which surfaced in Christchurch, and more recently in Wellington following the 2016 Kaikoura Quake, was the vulnerability of the building stock housing telco equipment.

Broadcasting

Kordia owns and manages the broadcasting network in New Zealand, which includes FM radio.

The major transmission sites are illustrated in Figure 3-13. Loss of these sites would impact transmission capability, sometimes to large areas and regions. For example, disruption of services from the site on Mount Cargill in Dunedin would cause almost total loss of services in Otago and Southland. For this reason, these sites are managed to very high standards of resilience.

Most sites are unmanned and are monitored from the Transmission Control Centre (TCC), located in Avalon, which is a 24/7 operation. Kordia provides a managed environment (watertight, ventilated, and powered) with associated towers for others to locate their transmission equipment such as Police, Ambulance, Transpower, Vodafone and Spark cellular. As such, many of their sites are critical to a number of other providers.

Radio

TeamTalk is the major provider of analogue and digital mobile radio in the country (used for handheld VHF communication devices) and provides services to a number of lifeline utilities and emergency services in the region including Ambulance Services and CDEM communities.

Regulation and Funding

The historical development of the core national 'ladder network' with robust core Exchanges was based on strong resilience principles driven by a Government owned sector (at the time).

Today, apart from the CDEM Act, there are no regulatory requirements to maintain resilience of the telecommunications infrastructure and service. The Building Code does mandate standards around critical buildings housing communications equipment though design standards for other components of the network are not prescribed (apart from as part of Government funded initiatives such as ultra-fast and rural broadband).

he New Zealand Telecommunications Forum (TCF) is a pan-industry body fostering cooperation among telecommunications service providers to develop standards and other industry wide solutions for ensuring the efficient supply of telecommunications equipment and services in the long-term interests of consumers. Its members include 2degrees, Chorus, Spark New Zealand, Vodafone New Zealand as well as a significant number of smaller players in the New Zealand telecommunications industry. The TCF is recognised by the government as the "Telecommunications Industry Forum" referred to in the Telecommunications Act 2001 as having authority to develop access codes for regulated services.

Telco Cooperation – Kaikoura 2016

The November 2016 earthquake cause significant damage to the eastern core fibre route used by Chorus, Spark and Vodafone. Kaikoura was effectively isolated from outside communications and the failure put a lot of pressure on the one remaining South Island fibre link to the west.

The only intact fibre link in the Kaikoura area was offshore - the Vodafone 'Aqualink' cable which provides express capacity from Christchurch to Wellington. As the result of collaboration between the three parties, the Aqualink was able to be modified to provide service into Kaikoura and restore some diversity in the core network.

The restoration of the eastern core fibre route occurred through cable overlays where the fault was inaccessible, some slung from helicopters for hundreds of metres. Chorus and Spark also brought forward plans for an inland fibre route to increase diversity.

The event highlighted how important telco sector and Lifelines / CDEM relationships are in an emergency, and how valuable regional lifelines groups are for fostering those relationships.

The commercial imperative to keep customers connected is the main driver for resilience investment. This has seen ongoing investment in seismic retrofitting and backup generation particularly since the Christchurch earthquake. As with the fuel sector, MBIE does maintain oversight of the resilience of the network as a whole. Other general regulation for lifelines is discussed in Section 6.1.

Figure 3-13: Kordia's Transmission Sites

3.9 Water

Water supply and wastewater services are fundamental to public health and firefighting. In urban areas, the absence of water and wastewater networks for long periods has the potential to render areas effectively uninhabitable.

New Zealand's public water supply and wastewater and stormwater networks are managed by local authorities or entities under their jurisdiction. Outside the metropolitan areas, schemes are typically locally sourced supplies to individual towns (or a number of towns in close proximity). It is not uncommon for a scheme to rely on a single water source and therefore that site, the trunk mains and reservoir that connect the source into the reticulation, become highly critical.

Water and wastewater scheme are vulnerable to a number of natural hazards, as discussed in the box right. But another key vulnerability is electricity which is required for treatment and pumping processes. Only the largest and most critical sites tend to have on-site backup generation. Also, water and wastewater systems are increasingly managed through automated computerised systems and many pumps and machinery can be operated remotely through the internet or telemetry. This advanced technology is dependent on electrical, telecommunications and internet integrity. Failure of these systems or malicious interference through cyber-attach may be a new hazard that has not yet been fully evaluated by many suppliers.

Water Supply

This section looks at the supply of potable water to communities. Potable water supplies are vulnerable to both water quantity and quality disruptions. In fact, most of the recent major incidents, such as 2016 Havelock North and 2017 Dunedin, Lower Hutt and Auckland Hunua supply issues related to quality rather than quantity issues.

The sector is complex in that there is no national provider and there are many parties involved in the provision of potable water and responding to disruptions, such as local government, Ministry of Health and MCDEM. Response roles are not always well understood by the wider sector.

A brief discussion on the water supply for the four largest cities follows. Other than key assets in these cities, another notable 'nationally significant' water supply scheme is owned by Whangarei District Council which supplies water critical for Marsden Refinery operations. While a number of other cities have schemes that supply over 100,000 people, there is sufficient redundancy in those networks such that loss of a single asset would impact a smaller number.

Natural Hazard Risks to Water Schemes

Water supply and wastewater distribution networks are highly vulnerable to seismic events, as evidenced in the long recovery times from the Christchurch earthquake.

The older pipes in NZ's water and wastewater reticulations commonly include materials that may be considered brittle such as asbestos cement and earthenware pipes. These materials performed poorly during ground shaking and deformation during the Christchurch and Kaikoura earthquakes. More modern materials such as PVC, steel and polyethylene performed better but were still vulnerable to major ground movements particularly at connection points to rigid structures such as manholes and pump stations.

Local authorities are systematically replacing the older pipes with the more resilient, ductile pipes through their renewal programmes. However, progress will be slow as there is a considerable legacy of old materials and other competing demands for infrastructure investment. Adoption of good asset management practice is helping to prioritise the most critical and vulnerable pipes through a risk based analysis and subsequently reduce the impact and increase the resilience of reticulation networks.

Cyclonic heavy rainfall / wind events are another challenge for the sector – many water sources are in slip prone catchments with erodible soils.

Other major natural hazard risks include tsunami (many wastewater treatment plants and some water supply plants are on the coast) and volcanic ash – which can impact treatment quality.

Catchment management and protection of water sources is another key area of risk for water supply managers.

Auckland

Auckland's water supply is supplied from the Hunua (around 60%), Waitakere Dams (around 25%) and the Waikato River (around 10%). Future regional growth and security will be met by development of the Waikato source and upgrades to existing treatment plants (there is around $5B in Watercare's asset management plan for renewals, growth and resilience projects).

There are a number of assets rated as 'nationally significant' which have the potential for major impacts on Auckland's water supply.

Failure of the major Hunua sources and/or Ardmore treatment plant for longer than 24 hours would cause major service disruption and restrictions. There are multiple hazards that could impact the operation of these sites, most recently experienced in early 2017 following upstream slips in the Hunuas highlighting catchment protection and activity risks.

Auckland's most critical main 'Hunua 3' brings water from the Hunuas into the central Auckland. A new main following a different route 'Hunua 4' will provide redundancy for Hunua 3 following completion. .

Wellington

Wellington is supplied from sources on the outskirts of the City and transmitted by trunk mains – around 20% from dams in Te Marua, 50% from the Hutt Aquifer and 30% from Wainuiomata. In Wellington, these mains pass through high risk fault areas and studies have been shown that a major Wellington Fault quake could cause damage taking up to three months for restoration of bulk supplies to parts of the City (further work is being undertaken to understand outage times). The work of the Wellington Lifelines Group through the Wellington Resilience Programme will sharpen attention on these risks and potential mitigation measures.

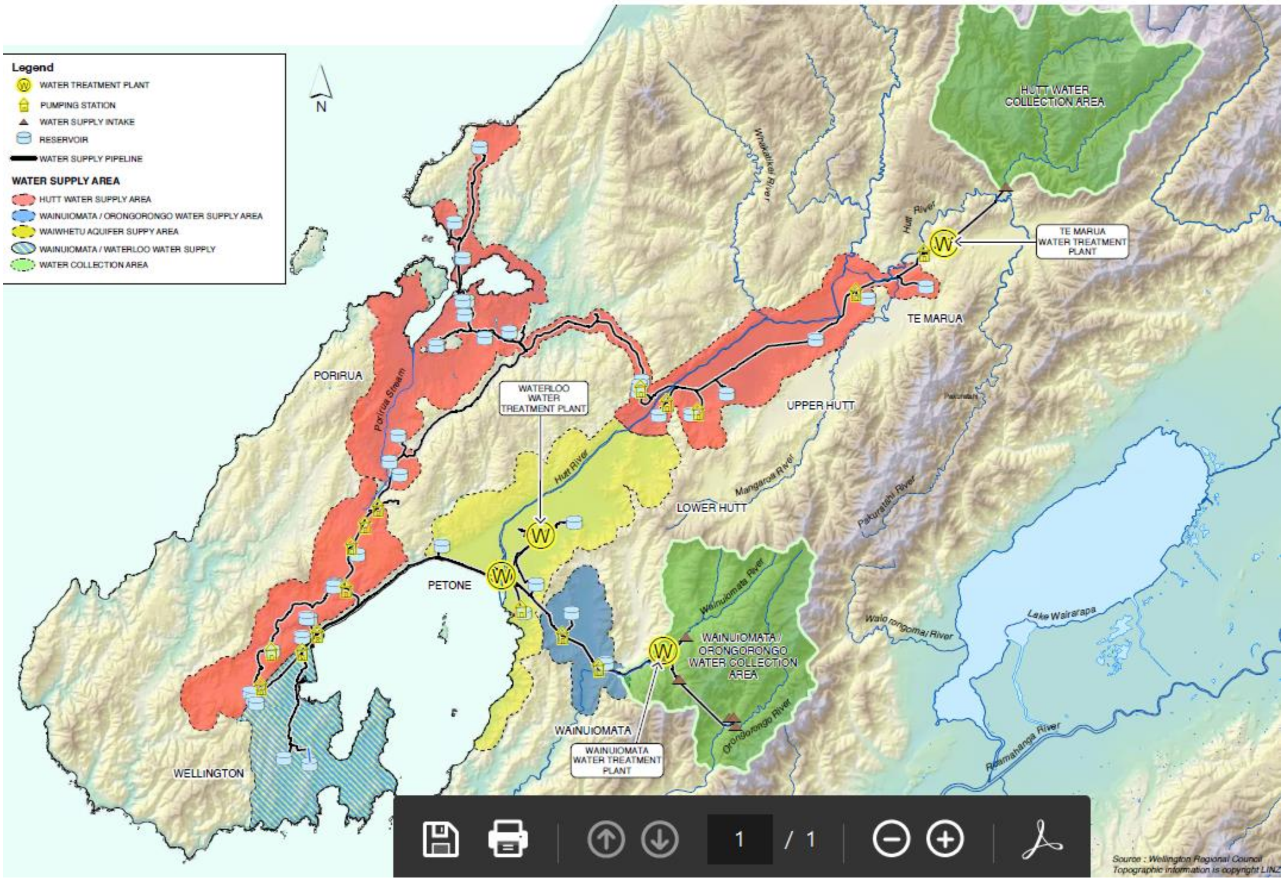


Figure 3-14: Diagrammatic of Wellington's water supply

Christchurch

Christchurch's water supply is more resilient than Auckland and Wellington in terms of having multiple bore sources (providing redundancy from each other) from deep, well protected aquifers. However, the supply is unchlorinated so is more vulnerable to contamination, as occurred in the Canterbury earthquakes. Those parts of the network damaged in the earthquakes have been replaced with more resilient materials and design standards (work is ongoing in this respect).

Hamilton

Hamilton's water supply comes from a single abstraction point on the Waikato River. The risk associated with failure of the single supply point is mitigated by a deployable pumping platform for abstraction and a multi barrier treatment process to ensure source water can be treated at most levels of contamination. The treatment infrastructure allows for redundancy to ensure ongoing resilience of the treatment processes. Multiple reservoirs and a ring main provide resilience if any part of the reticulation is damaged.

Wastewater

The largest wastewater asset in New Zealand is the Mangere Wastewater Treatment Plant, which services the western, southern and central Auckland areas and there are many critical interceptor mains bringing wastewater to the plant (a major upgrade will provide redundancy for these).

Recent modelling as part of the Wellington Resilience Programme indicates there will be lengthy outages of wastewater in some parts of Wellington following a Wellington Fault Rupture. Further information on this sector will be gathered in Stage 2.

Land Drainage and Stormwater

Stormwater networks are considered a lifeline utility under the CDEM Act 2002. Regional lifelines projects have not at this stage identified any specific 'nationally significant' stormwater infrastructure though attention is certainly given to it at a regional and local level.

Stage 2 will give further consideration to the inclusion of solid was and flood protection assets warranting attention as nationally significant assets.

Regulation and Funding

Water Supply is regulated through the NZ Drinking Water Standards which include requirements for water quality and reliability though do not explicitly require minimum emergency response standards.

Wastewater standards are imposed by Regional Councils through consent conditions for discharges (including overflows).

Stormwater standards for the whole network are not generally mandated, however primary systems are usually designed to pass a 1:10 year rainfall event and secondary systems (overland flow paths, detention areas) a 1:100 year event. The Building Act requires new houses and habitable buildings to be designed with the floor level above the 50-year ARI event. It also requires the 10-year ARI event not to cause nuisance to other properties. Urban stormwater systems need to be designed and managed to meet this requirement. These design standards are often at odds with planning for other hazard types which specify standards for much lower frequency events. Decisions on funding and levels of resilience are made by local authorities or their governing boards.

Other general regulation and funding constraints for lifelines are discussed in Section 6.1.

4. Lifelines Interdependencies

4.1 Lifelines Sector Interdependence

All lifelines services rely to some extent on some or all of the other lifelines services in order to operate. Figure 4-1 and Figure 4-2 summarise interdependencies between lifelines sectors during business-as-usual and major disaster events where disruption is expected to roads and electricity networks.

The ratings presented in this section are indicative only – obviously the extent of dependence in a response and recovery situation will depend on the specific scenario and there is some variation by region. The total dependency scores clearly illustrate the importance of electricity, roads, fuel and telecommunications to the other sectors, with air transport, VHF and broadcasting becoming more important in a major disaster event.

3: Required for Service to Function, 2: Important but can partially function and/or has full backup, 1: Minimal requirement for service to function.

The degree to which the utilities listed to the right are dependent on the utilities listed below	Roads	Rail	Sea Transport	Air Transport	Water Supply	Wastewater	Stormwater	Electricity	Gas	Fuel Supply	Broadcasting	VHF Radio	Telecomms	Total Dependency
Electricity	1	2	3	3	3	3	2		2	2	3	3	3	30
Roads		3	3	3	2	2	2	2	2	3	2	2	2	28
Fuel	2	3	3	3	2	2	2	2	2		2	2	2	27
Tele-comms	2	2	2	2	2	2	2	2	2	2	2	3		25
Water Supply	1	1	1	2		3	1	1	1	1	1	1	2	16
VHF Radio	2	2	2	2	1	1	1	1	1	1	1		1	16
Stormwater	2	1	1	2	1	1		1	1	1	1	1	1	14
Wastewater	1	1	1	2	1		1	1	1	1	1	1	1	13
Rail	1		1	1	1	1	1	1	1	1	1	1	1	12
Sea Transport	1	1		1	1	1	1	1	1	1	1	1	1	12
Air Transport	1	1	1		1	1	1	1	1	1	1	1	1	12
Gas	1	1	1	1	1	1	1	1		1	1	1	1	12
Broadcasting	1	1	1	1	1	1	1	1	1	1		1	1	12

Figure 4-1: Interdependency Matrix – Business As Usual

The degree to which the utilities listed to the right are dependent on the utilities listed below	Roads	Rail	Sea Transport	Air Transport	Water Supply	Wastewater	Stormwater	Electricity	Gas	Fuel Supply	Broadcasting	VHF Radio	Telecomms	Total Dependency
Fuel	3	3	3	3	3	3	3	3	3		3	3	3	36
Roads		3	3	3	3	3	3	3	3	3	2	2	3	34
Tele-comms	3	2	2	2	3	3	3	3	3	2	2	3		31
Electricity	1	2	3	3	3	3	2		2	2	3	3	3	30
VHF Radio	2	2	3	3	2	2	2	2	2	2	2		2	26
Broadcasting	2	2	2	2	2	2	2	2	2	2		2	2	24
Air Transport	2	1	1		2	2	2	2	2	2	2	2	2	22
Water Supply	1	1	1	2		3	1	1	1	1	1	1	2	16
Stormwater	2	1	1	2	1	1		1	1	1	1	1	1	14
Wastewater	1	1	1	2	1		1	1	1	1	1	1	1	13
Rail	1		1	1	1	1	1	1	1	1	1	1	1	12
Sea Transport	1	1		1	1	1	1	1	1	1	1	1	1	12
Gas	1	1	1	1	1	1	1	1		1	1	1	1	12

Figure 4-2: Interdependency Matrix – During / Post Disaster Event

Dependence on Electricity

During normal operations, electricity is required to operate most of the other lifeline utilities to some degree and, because of this dependence, typically utilities have backup generation at their most critical sites. However, a widespread regional power outage would, after varying periods of time, still impact on telecommunications, water supply, wastewater, gas, fuel supply and traffic management services.

Dependence on Telecommunications

A major telecommunications failure will impact the business sector and wider community and impede the efficiency of utility businesses; however most utilities could continue core services without telecommunications in the short term. Impacts on control systems would mean that some utilities would need to revert to manual operation and monitoring of facilities and response to service requests could be impaired. As technology enables more complex operations arrangements, the service impacts of reverting to manual operation may be significant.

The situation changes in an emergency because telecommunications become critical for coordinating response and recovery efforts. The cellular network may become overloaded during or shortly after an event. However, the copper, fibre and wireless infrastructure (including cellular) provides diversity. Most utilities use a combination of the above technologies and some have their own dedicated network of links and radio.

Dependence on Broadcasting

Broadcasting is not generally considered a critical supply to other utilities during business as usual. However in a response situation, particularly where other communications are impacted, broadcasting is a means of communicating public information such as road disruptions, public water supply warnings and advising of fuel shortages.

Dependence on Roads

The road network is important for all utilities to operate, particularly for sea/air/rail networks which are connected by road and for fuel distribution. Road failures during business-as-usual may affect response to service requests and asset failures. In an emergency, staff need to be able to access facilities and diesel and plant needs to be transported to construction sites.

Dependence on Air Transport

Air services also become important to other lifelines in a major disaster; to assess damage, bring in

The Interdependent Lifelines Sector

In 2006 an outage on the Transpower Otahuhu substation caused widespread loss of electricity service across Auckland and resulted in several other lifelines sector failures, even though supply was largely restored within 12 hours. While many years ago now, the event remains a useful example of the interdependencies in the lifelines networks with the following results.

- Approximately 20 sewerage pump stations overflowed at some stage.
- Most petrol stations in affected areas were unable to pump petrol.
- There was road congestion, mainly due to traffic light failures, which in turn impacted on other utility's ability to get generators to wastewater pump stations.
- All organisations reported difficulty making connections on both landlines and cell phones. Many offices had PABX failures and could not be contacted. The failure of PABX caused many people to revert to cell phones, causing overloading of that network. Some small areas, served by small cell sites without battery backup, lost cell phone service completely.
- The primary impact on train services was due to disruption at Brittomart (which has only limited power backup on site) due to local signalling being off and station services including fume ventilation fans bring off. *The subsequent electrification of the rail network is likely to have exacerbated impacts.*
- There was total plant-site shutdown at Wynyard Wharf, however the Wiri fuel depot was active so there was no need to load vehicles manually with diesel trailer pumps. Chemical and bitumen vehicles were also stranded.
- Some utilities, along with the wider business community, felt an impact in terms of loss of productive office time (those without backup generators / batteries on site).

responders, equipment and spares and access sites when there is significant road disruption. It may be the only source for critical supplies in the early days of an event where roads are heavily disrupted and can be critical for evacuations.

Dependence on Sea Transport

The fuel sector is reliant on shipping for distribution of fuel, though most other sectors do not have a major dependency on sea transport during BAU operations. In a major disaster, some regions may be heavily dependent on sea transport for provision of emergency supplies (for example, Wellington and West Coast of the South Island) or evacuation of people.

Dependence on Water Supply and Wastewater and stormwater

Water supply and wastewater services are critical for the community, both for public health and firefighting purposes, as well as some dependence on these services by other lifelines. For example:

- Fuel terminals require a high capacity water supply (or alternative firefighting capability).
- Building services require water and wastewater for health reasons, though alternative arrangements can be made such as re-location or using bottled water supplies and temporary wastewater facilities.
- Water supply is required for air-conditioning and plant cooling operations in some sectors.
- Air transport requires water supply at the airport (for passenger services for commercial flights), and telecommunications requires water for equipment cooling.
- Natural gas electricity generators require high quality water for cooling and compression.

Dependence on Petroleum

All utilities have some dependence on fuel for plant and vehicles for service personnel. If electricity is affected, diesel supply to critical sites to operate backup generators becomes more important. Even those sites with on-site diesel storage typically only hold a few days' supply. Refuelling of generators deployed to other critical facilities is likely to become a significant logistical issue.

Dependence on Gas

Lifelines networks are not generally reliant on gas for network operation, with the exception of gas powered electricity generators and Marsden Refinery (it can function without a gas supply but may not meet consent conditions).

4.2 Critical Community Facility Dependence on Lifelines

Lifeline utility services are important for the functioning of critical community facilities. These facilities and service providers maintain business continuity arrangements for backup services based on their own risk assessments and commercial imperatives.

There is currently no national view on the extent to which these critical community sectors have alternative arrangements (such as radio/satellite or on-site backup generation). As part of regional lifelines studies, each region identifies what they see to be critically important sites for their community. CDEM Groups are an important facilitator of this process. This information then informs each lifelines criticality analysis in that an asset that services a critical site (such as a hospital) that depends on them, also becomes critical.

A brief overview of 'critical community' sectors and dependence on lifelines services is provided below. It is not complete, and as with all components of this report mainly draws on existing documented information. Further analysis and engagement with these sectors will be carried out in Stage 2 of this project.

Emergency Services

Emergency services (Police, Fire and Ambulance) are reliant of lifelines to operate, this includes telecommunications, fuel, water (potable and waste), electricity, and transport (road) access.

Emergency services have business continuity arrangements in place and can operate form alternate sites. However if multiple sites are effected by a lifelines service disruption e.g. a regional telecommunications outage; or if a lifelines service is disrupted for a significant period e.g. a fuel supply issue, emergency response will be impacted.

Health Services

All hospitals in New Zealand are considered to be critical community infrastructure. Hospitals are reliant on lifelines to operate, this includes electricity, water (potable and waste), telecommunications, transport, fuel, and gas. Hospitals have a range of business continuity plans in place including back up generation and stored water however this is generally only sufficient to maintain essential operations for a few days before resupply would be required. Due to their operating model it is not possible to deliver the majority of services from another location.

Critical health care services are also delivered off hospital campuses or by non-hospital providers. These include but are not exclusive to, primary care (general practice and pharmacies), public heath, dialysis centres, aged residential care facilities, and disability support services.

Many of these services must also be considered critical providers both due to the services they provide and the fact that if they are inoperable hospitals would not have the capacity and capability to look after their patients.

Hospital and health services also depend on suppliers that in turn were dependent on lifelines services (eg: food and linen suppliers reliant on gas supply).

Government

Government agencies are required to have and maintain business continuity arrangements. These arrangements are required to enable agencies to continue to deliver their critical functions in a disruption.

Business continuity arrangements may include, staff working from home, fail over to alternate sites or working from existing facilities with emergency generation.

Delivery of some of these arraignments requires access to lifelines e.g. water (potable and waste) or telecommunications; some may require access to continued fuel supply for generators.

Fast Moving Consumer Goods (Food and Grocery)

The Fast Moving Consumer Goods sector references groceries, many of which have a short shelf life. The major food depots are in Christchurch, Palmerston North and Auckland. These sites are considered nationally significant.

The majority of the nation’s food comes from, or passes through Auckland. The sector is heavily dependent on roads and rail for the movement of goods, in Wellington the potential to be isolated from the main supply chain in Palmerston North is a noted vulnerability for the region.

Banking

The headquarters of the major banks are located in Auckland and are rated as nationally significant. Banking services depend on power supply and telecommunications to operate and enable financial transactions.

Corrections Facilities

Prison facilities rely on lifeline utilities to function. They have business continuity plans in place for loss of this supply including limited (days) self-sufficiency for power and water. Prisons are dependent on roads and telecommunications to implement their business continuity plans i.e. re-supply for fuel, water, food and medical. They also have a dependency on wastewater services, which is critical from a Public Heath perspective.

Community Corrections have dependencies on telecommunications and roading to operate. Main sites also require water and power to support community corrections operations.

Solid Waste

Solid waste management services include collection from households and other sites, transfer and sorting (typically at refuse transfer stations) and disposal of non-recylable / useable waste to landfill. Most transfer stations and landfills rely on electricity and fuel powered plant and equipment. Road access is critical, particularly following an event with major debris (from built infrastructure damage or from the hazard itself, such as volcanic ash).

Major Industry

Many lifelines projects consider major industry as critical community sites as well, including the likes of Tiwai Point, major freezing works and dairy processing sites and major construction depots.

4.3 Infrastructure Hotspots

Infrastructure interdependence increases the overall risk and consequence of a potential failure of a single infrastructure type. Co-location of critical infrastructure assets also increases the risks of a damaging event at a single site, both in terms of the direct impact of a number of critical assets simultaneously failing (eg: a major landslide) and in terms of the potential hazards that some assets pose to others (major water main failure could wash away other assets in the area). These areas have been termed 'hotspots - where a number of critical infrastructure assets from different sectors converge in a single area. Major hotspots identified in regional vulnerability studies include:

- Petone / Seaview Critical Areas – includes fuel offloading / fuel storage for Wellington plus regionally significant assets for water, gas, electricity, wastewater and telecommunications.
- Thorndon Critical Area – a number of critical utilities within a narrow corridor traversing the Wellington Fault with much in liquefaction-prone reclaimed land.
- SH 6 Kawarau Gorge – primary road access and electricity transmission lines to Queenstown, along with one of the major South Island telecommunications fibre links – prone to alluvial activity, rock fall and landslides.
- Auckland Harbour Bridge and major road pinchpoint and carries a number of critical utility pipes/cables.
- Central Plateau (a hub of electricity generation transmission and highways in a volcanic risk area).
- SH20 near Mangere Bridge – the Marsden-Wiri fuel line, electricity main transmission lines north and a large wastewater interceptor are all in the area.
- Low lying South Dunedin area contains a number of critical utility sites for Dunedin (Dunedin exchange, Tahuna wastewater treatment plant, etc).
- The Cook Strait – a major transport route (ferry) and carries transmission cables for electricity and telecommunications between the islands.
- The Lyttelton Tunnel.
- Kaikoura Coast – state highway, railway, core telecommunications cables.

5. Infrastructure Vulnerability to Hazards

5.1 New Zealand's Hazardscape

New Zealand's on the collision zone between the Pacific and Australian plates and in the southern hemisphere westerly wind belt leads to numerous natural hazards.

Earthquakes are commonly thought of as our most potentially damaging hazard, but floods cause more frequent problems and tsunami threats are very real. Impacts from 'super-eruptions' in the central North Island have the potential to be even bigger than major earthquakes.

Regional lifelines projects tend to use regional CDEM Plans as a source of information for regional hazards. Table 5-1summarises the risk rating given to these hazards in current CDEM Plans (the most current as at March 2017). While the major natural hazards feature predominantly across all Plans, other hazards such as human pandemic and criminal acts are also rated highly in some regions.

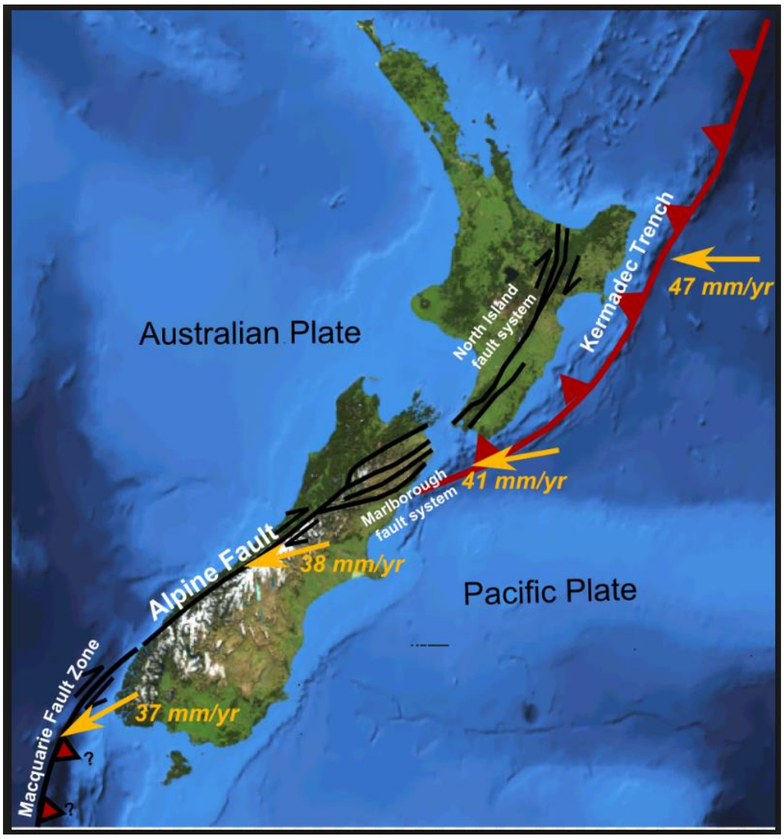


Figure 5-1: Major fault / plates in New Zealand

The following sections summarise information on the 'big 4' natural hazards that are most commonly the focus of regional lifelines studies. Emerging hazards that are starting to receive more attention, but as yet have limited vulnerability assessment information for lifelines projects, include:

- Space weather, and reliance on services such as GPS which are satellite based.
- Cyber attack, space weather or technological failures through other causes.
- Risks associated with urban encroachment on areas where significant lifelines infrastructure is built.

There are a number of features of hazards that make them challenging to understand.

The ***composite, cascading, cumulative*** nature of hazards is not always well captured in lifelines project analyses. The focus is often on direct impacts such as tsunami wave damage and landslips, not necessarily the cascading impacts such as increased flooding risk arising from ground movement (as occurred in Christchurch). Cumulative impacts can occur such as when a light rain accompanies volcanic ashfall increasing 'flashover' risks on electrical systems.

There is **a limited hazard event history** within our living memory and the low frequency events are not all well understood. There is not a good understanding of some medium term volcanic events as the geological records are relatively thin and have not been preserved in the geological record.

Availability of national hazard maps. For some hazards there are national datasets such as 'active faults', earthquakes (Geonet), tsunami and soil types. For others, hazard information has been developed at a regional or local scale and not always on a consistent basis. The challenge is often how to transfer raw data into usable form / product for studies such as lifelines projects.

Damage impacts cannot be accurately predicted. There are huge range of contributing factors and damage / loss assessments at best can be only expected to provide a broad-brush estimate.

Different hazard types are often assessed on different hazard levels, making it difficult to compare hazard risks. For various reasons, floods are typically analysed for much higher frequency events (1:100yr) than tsunami or earthquake (1:500 or 1:2500 years).

Table 5-1: Regional Hazard Risk Ratings (sourced from the regional CDEM Plans available online March 2017)
E: Extreme. VH: Very High. H: High. (lower rating hazards not shown)

Ratings have been developed using MCDEM Guidelines for CDEM Plans.

	Earthquake	**Volcano**	**Tsunami**	**Severe Storm / Flood**	**Infrastructure Failure[7]**	**Drought/Extreme Temp**	**Animal Pandemic**	**Human Pandemic**	**Rural Fire**	**Transport Accident**	**Other**
Northland			H	VH Flood / slips	H						
Auckland	H	H	H	VH	H			VH	H	H	Coastal erosion, hazardous spill, land instability, urban fire.
Waikato	H	VH	VH	H	H	VH	VH	VH			Marine Spill Land Instability
Bay of Plenty	H NI Shear Belt	E Local	H/W	E			H/E	E	E	E	Biological pests
Gisborne					H	H	H	VH	H	H	Criminal
Hawkes Bay	'top 10'	'top 10'	'top 10'	'top 10'	'to p 10'		'top 10'	'top 10'	'to p 10'		Multiple urban fire Hazardous Substance
Taranaki	H	E		H	VH			E			
Manawatu-Wanganui	VH		VH	VH		VH	VH	VH			
Wellington	VH		H	H				H			Landslide
Marlborough	E			E	H	E	VH	VH	VH	H	Pests and diseases, Terrorism Urban Fire, Hazardous Substance, Dam break, Landslide
Nelson-Tasman	VH			H				H	H		
West Coast	1st		4th	5th				2nd			*Risk rating not listed – SMG results used to prioritise*
Canterbury	VH		VH	H				VH			
Otago	E	-	H	VH	VH	VH	VH	VH	VH	H	*Snow, frost, landslides, wildfires*
Southland	VH		H	VH	VH	VH	VH				Snow, frost

[7] Where sector-specific failures were identified, electricity was most commonly referenced.

5.2 Earthquake

The Hazard

The Alpine Fault, the Wellington Fault and Hikorangi Subduction Zone are believed to pose the highest seismic risk to the country from a potential damage perspective. The Alpine Fault runs for some 400 km through the South Island and the Wellington Fault runs intersects the capital city, while the Subduction Zone could impact all of eastern North Island. The Hikorangi Fault has an associated high risk of generating a tsunami. There are numerous other active faults and many unknown faults both on and offshore.

Knowledge of Hazard

Earthquake hazards have been relatively well researched and there are a number of national datasets available (most are managed by GNS):

- The **NZ Earthquake Catalogue** is a list of known events compiled from oral and written history, and since the 1930s, from instrumental readings (Geonet).
- New Zealand's major known faults are mapped in the **Active Faults Database** (pictured below).
- The **National Seismic Hazard Model** provides probabilistic estimates of the strength of earthquake shaking that can be expected according to a user-defined time period and probability.
- An initiative spurned out of the Canterbury earthquakes is the **NZ Geotechnical Database** which aims to collect and make available geotechnical investigations from all sources. While originating in Canterbury, the model aims to grow into a full national data repository.
- The **NZ Landslide Database** holds data on historical major landslides including information such as triggering event and damage (Geonet).

Key areas of further research are the work on the probabilistic hazard and risk. Refined earthquake and tsunami forecasting, liquefaction hazards and landlides at a national scale are progressing.

Impacts on Lifelines Infrastructure

The expected effects from earthquakes that create a potential hazard to infrastructure includes:

- Surface fault rupture – can range in length from a few metres to hundreds of kilometres and with ground displacements of several meters possible. Shearing of assets can result where ground displacements occur.
- Land movements – in a moderate to large earthquake the ground in nearby areas maybe uplifted, dropped or tilted – again ground displacement can be several meters as experienced in the Edgecumbe earthquake (where a large part of the ground in the Rangitaiki Plain

Figure 5-2: Active Fault Database (GNS)

dropped by up to 2m) and more recently in Kaikoura.

- Strong shaking can cause damage to structures – the extent of damage can be mitigated through modern seismic design.
- The combination of ground shaking and earth movement can produce secondary effects including rockfall / landsliding, tsunami, ground settlement and liquefaction.
- Liquefaction was shown in the Canterbury earthquakes to be particularly devastating to underground, brittle assets due to the associated differential ground subsidence and lateral spreading. Liquefaction can occur in high risk soils at MM7.

Distributed, lineal assets are at most risk from seismic hazard and recovery times can be years.

The Wellington Lifelines Group has done a significant amount of work understanding the risk and recovery times associated with a major Wellington Fault event. *Priority Site Access* looks at the likelihood of access to critical sites (such as hospitals, water supply dams) being disrupted following various hazards. This work followed on from a study on regional access routes into Wellington and the likelihood of weeks to months before regional access to the CBD and Lower Hutt was re-established, following a major earthquake.

Project AF8 is another significant project aimed at understanding the risk and impacts associated with an Alpine Fault rupture and further information will be captured from this project as it progresses.

There is a growing awareness that slope stability in Wellington (and elsewhere) is possibly one of the bigger hazards caused by a large earthquake event.

Risks to Nationally Significant Assets

Nationally significant infrastructure considered to be most at risk from the seismic hazard are listed below (refer section 3 for information on impacts from failure of these assets). This list is by no means exhaustive and further information will be sourced from projects such as the Wellington Resilience Project as part of Stage 2.

Electricity:

- Transmission Substations at Haywards (Wellington), Islington (Christchurch), Manapouri and Bunnythorpe
- South Island and Central Plateau generation sites and infrastructure connecting to the national grid.
- Radio / fibre communications networks for system operation
- Sustained loss of power to critical sites exceeding their capacity for restart.

Water / Wastewater stormwater

- All schemes near active faults.
- Wellington Fault line can cut off bulk supply to Wellington City and much of the Metropolitan area (Porirua City, Upper Hutt City, Hutt City).
- Auckland's Watercare assets in Tuakau / Pokeno.

Transport

- Wellington fault – SH 1 and 2.
- Alpine Fault – State Highways to West Coast, Queenstown, Fiordland etc.
- Kaikoura Coastal Highway.
- SH1 in Otago – Landslips, weather, earthquakes
- SH1 in Tuakau / Pokeno
- SH6 Karawau Gorge - Landslips, weather, earthquakes
- SH6 Karawau gorge – loss of power and communications to Queenstown Lakes due to power lines and fibre cables in this area.

Telecommunications

- Many parts of the core fibre network pass through fault terrain. An example is Wellington along SH2 – which carries fibre and other services to Cook Strait crossing (Spark fibre alternate Levin-Nelson but not used by all operators)
- Building in Welington in tsunami zone (main exchange)?
- Older exchange buildings
- Bridge crossings – eg: Stillwater in West Coast, Grey Valley bridge sequence
- Anything that impacts on power supply

Fuel

- All fuel terminals in seismic hazard areas, potential isolation of West Coast of the South Island a major risk.

New Zealand Lifelines Council

5.3 Volcano

The Hazard

While the upper North Island has a relatively low seismic risk, central Auckland is uniquely (for a major city) located on a volcanic field and the central North Island has several large volcanoes.

Known, existing volcanic areas are shown in Figure 5-3.

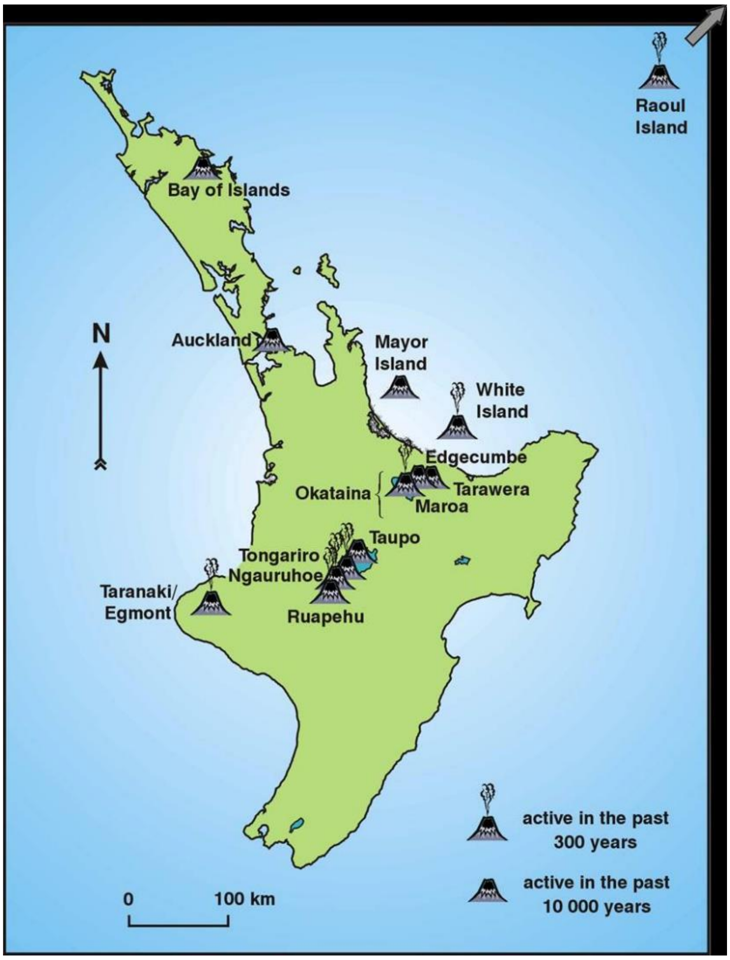


Figure 5-3: New Zealand's Volcanoes

Knowledge of Hazard

The eruption history of New Zealand has been well examined by the scientific community and return periods and ashfall projections have been analysed in depth through projects such as DeVoRA.

The volcanic risk to Auckland has been the subject of a major study, DeVoRA (Determining Volcanic Risk to Auckland). The field is believed to be 250,000 years old and there have been 55 recorded eruptions, the most recent being Rangitoto around 600 years ago.

The Taranaki, White Island and central north island volcanoes are more recently active. The Manawatu-Wanganui Lifelines Study recently developed a series of volcanic ashfall scenarios, an example is shown in Figure 5-4.

The Taupo Caldera Volcano is the largest in New Zealand, and has generated some of the largest known eruptions in the world's history. Lifelines studies have not really focussed on this risk because of its low probability yet potentially nationally catastrophic nature that makes it difficult to plan for.

Potential unmitigated impacts of volcanic ash include:

- Buildings rendered uninhabitable due to ash environment, impacts on air conditioning systems and, worst case, roof failure due to ash loading.
- Reduction in air cooling performance has the biggest potential impact in the telecommunications area which requires cooling for equipment to operate.
- Intake of ash into plant and equipment can damage (directly or via water sources) and impact operations of facilities such as power generation plants and water/wastewater treatment plants – hydro-electric turbines in the Tongariro Power Scheme were destroyed in the 1995 Ruapehu eruption.
- The potential for air transport disruption is significant, particularly as some volcanoes have a history of erupting for long periods of time.
- Roads will be unsafe to drive – both in terms of skid and visibility risks – and cleanup and disposal operations will be significant.

Risks to Nationally Significant Assets

In terms of direct major infrastructure damage from near proximity hazards, such as lava flows and ballistics, an Auckland volcanic eruption is probably the worst-case scenario (if we ignore a massive 'Taupo' type caldera eruption).

‘Exercise Ruaumoko’ in 2007 projected widespread infrastructure devastation from the region’s main oil depot and wastewater treatment plant, isolating both major highways from the south (SH 20 and 1). The estimated loss of an ‘Exercise Ruaumoko’ scenario was 43% of Auckland’s GDP (15% of NZ’s GDP) with a 5% in 50 years probability of occurrence. A volcano in the central city area, where the country’s major telephone exchanges are based along with Auckland’s transport hubs (Spaghetti Junction, Britomart, Ports of Auckland, Harbour Bridge) and major central water storage facilities (such as Khyber Reservoirs) would be even more devastating.

From a lifelines perspective, the major impact of a Taranaki eruption would be potential for isolation by road and damage to the country’s gas production facilities and transmission lines to the north. There would be likely significant and ongoing affects to North Island air transport, damage and/or curtailment of national oil and gas production and there would be major impacts on national poultry and milk supplies would be

A major central island eruption could potentially close and damage State Highways for lengthy periods of time as well as impact on the main electricity transmission lines bringing electricity from South Island sources. There is also a risk to electricity generation in the Waikato including Wairakei and Whakamaru.

A large rhyolite eruption from Taupo or Okataina Calderas could have a year of pre-cursory activity, this is a huge policy issue with respect to evacuation decisions.

Impacts on Lifelines Infrastructure

Volcanic ash is one of the major hazards associated with volcanoes. The Auckland Lifelines Group, through its sub-committee the ‘Volcanic Impacts Study Group’ has undertaken a significant body of work on the impacts of volcanic ash on lifelines infrastructure.

An example of a poster output from this work is shown on the following page. All posters can be downloaded at http://www.aelg.org.nz/document-library/volcanic-ash-impacts/.

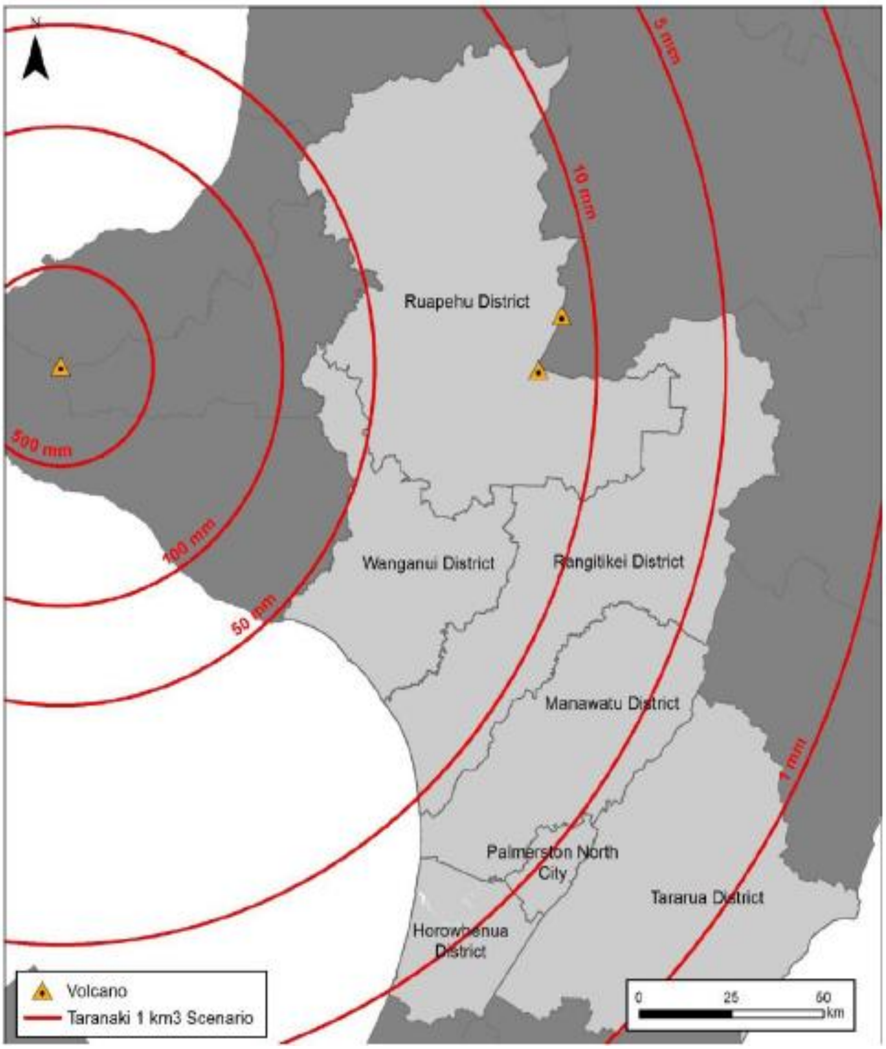


Figure 5-4: Volcanic Ash Modelling, Mt Taranaki (westerly, 1:2,500 yr event). Source Manawatu-Wanganui Lifelines Project 2016.

VOLCANIC ASHFALL

ADVICE FOR AIRPORT OPERATORS

VOLCANIC ASH IS: HARD, HIGHLY ABRASIVE, MILDLY CORROSIVE AND CONDUCTIVE WHEN WET.

ASH IMPACTS TO AIRPORTS

ASH IS HAZARDOUS TO AIRCRAFT.

- It can cause engine failure and severe abrasion to exposed surfaces

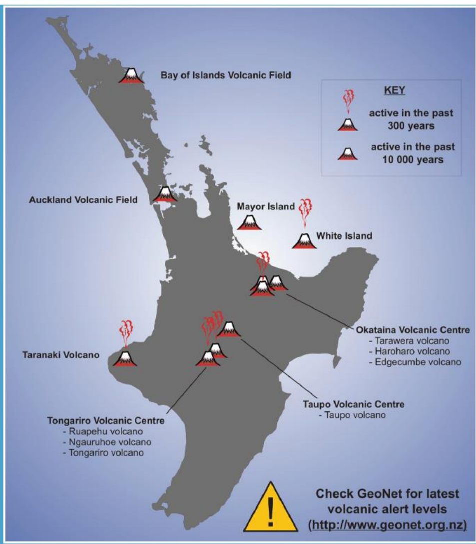
ASHFALL MAY REQUIRE AIRPORTS TO CLOSE. TYPICAL IMPACTS INCLUDE:

- Difficult landing conditions due to reduced runway friction, especially when ash is wet.
- Loss of local visibility when ash on the ground is disturbed by engine exhausts during takeoff and landing.
- Ingestion of remobilised ash into jet engines during taxi-ing, takeoff and landing.
- Deposition of ash on hangars and parked aircraft, with structural loading considerably worsened if ash becomes wet.
- Contaminated ground-support systems.

ASH ACCUMULATIONS OF LESS THAN 1 MILLIMETRE MAY BE SUFFICIENT TO TEMPORARILY CLOSE SOME AIRPORTS.

Cleaning up airports after an ashfall is a time-consuming, costly and resource intensive operation. The complexity and immensity of this task should not be underestimated.

ASH IN AIRSPACE IN THE VICINITY OF AIRPORTS MAY ALSO CAUSE DISRUPTIONS TO AIRPORTS EVEN IF IT DOES NOT ACCUMULATE ON THE GROUND.



3-5 mm of ash fall at Mariscal Sucre International Airport in Quito, Ecuador, following the 3 November 2002 eruption of Reventador volcano. The airport closed for 8 days due to the ash deposition on aircraft and runways.

5-10 mm of ash fall at San Carlos de Bariloche International Airport in Bariloche, Argentina, following the June 2011 eruption of Peyuhue Cordon-Caulle volcano in Chile. The airport closed for 31 days due to the on-going ash falls, remobilisation of ash and cleanup.

WARNING INFORMATION

WHERE TO FIND WARNING INFORMATION

- ASH CLOUD FORECAST (ash suspended in atmosphere): The Wellington Volcanic Ash Advisory Centre (VAAC) will issue Volcanic Ash Advisories (VAA) and Graphics (VAG) forecasts on suspended ash in the atmosphere affecting aviation. See: **http://vaac.metservice.com/**
- ASHFALL FORECAST (ash falling to ground): GeoNet (GNS Science) will provide ashfall forecasts in the event of an explosive eruption (see: **geonet.org.nz).**
- AVIATION COLOUR & VOLCANO ALERT LEVEL (ash falling to ground): GeoNet (GNS Science) sets the Aviation Colour Codes and Volcano Alert Level for New Zealand's volcanoes (see: **geonet.org.nz**).

RECOMMENDED ACTIONS

HOW TO PREPARE

At-risk airports should develop comprehensive operational plans for ashfall events (including cleanup – see companion "Advice for Urban Clean-Up Operations" poster). These plans should, where possible, be integrated with airline plans.

A more comprehensive summary of ashfall consequences to airports and detailed planning guidelines are available from:

- ICAO: **www.paris.icao.int/news/pdf/9691.pdf**

The ICAO resource provides guidance on:

a) standing arrangements prior to volcanic eruptions;

b) responses during an eruption

c) post-eruption cleanup and re-opening of the airport.

Field crews should use safe operating procedures when operating in an 'ashy' environment.

- Protective clothing (full-length clothing, face masks and goggles) should be worn and care must be taken on ash-covered surfaces, particularly roofs.
- See **www.IVHHN.org** for further advice on protecting people from ash hazards.

ROLES AND RESPONSIBILITIES

The NZ Civil Aviation Authority (CAA) has a comprehensive document outlining roles and responsibility in managing volcanic ash in New Zealand for the aviation sector.

- **www.caa.govt.nz/meteorology/living_with_volcanic_ash.pdf**

FURTHER INFORMATION ON DEALING WITH VOLCANIC ASH MAY BE FOUND IN THE FOLLOWING LOCATIONS:

http://www.geonet.org.nz
http://www.ivhhn.org
http://volcanoes.usgs.gov/ash/trans/index.php#airports
http://www.caa.govt.nz/

DRAFTED BY TOM WILSON AND CAROL STEWART.

7 February 2013

UC University of Canterbury — Air New Zealand — Auckland Engineering Life Lines — Auckland Airport — CAA Civil Aviation Authority of New Zealand — GNS Science

Figure 5-5: Example of a Volcanic Ash Management Poster (Auckland Lifelines Group, Volcanic Impacts Study Group).

New Zealand Lifelines Council

5.4 Tsunami

The Hazard

Tsunami are typically generated as a result of displacement of ocean water due to landslides, earthquakes, volcanic eruptions and meteorite impacts. Tsunami threats to New Zealand are broadly categorised as:

- Distant source; > 3 hours travel time to New Zealand from sources such as South America and to a lesser extent Cascadia (North America) and the Aleutian islands.
- Regional source; 1-3 hours travel time to New Zealand from sources such as the Solomon Islands New Hebrides and the Tonga-Kermadec trench. 'Exercise Tangaroa' in 2016 was considered a credible worst-case tsunami generated from a seismic event near the Kermadec islands (refer Figure 5-6).
- Local Source < 60 minutes travel time to the nearest New Zealand coast. Seismic activity on the southern end of the Tonga-Kermadec trench can cause tsunami to reach the Northland coast within 1 hour. Travel times from the adjacent Hikurangi subduction zone along eastern North Island could be as little as 15-20 minutes. Other sources include submarine landslides or a slump in the continental shelf.

The following is an example scenario used specifically for Exercise Tangaroa, it is not intended to be indicative of general tsunami arrival times.

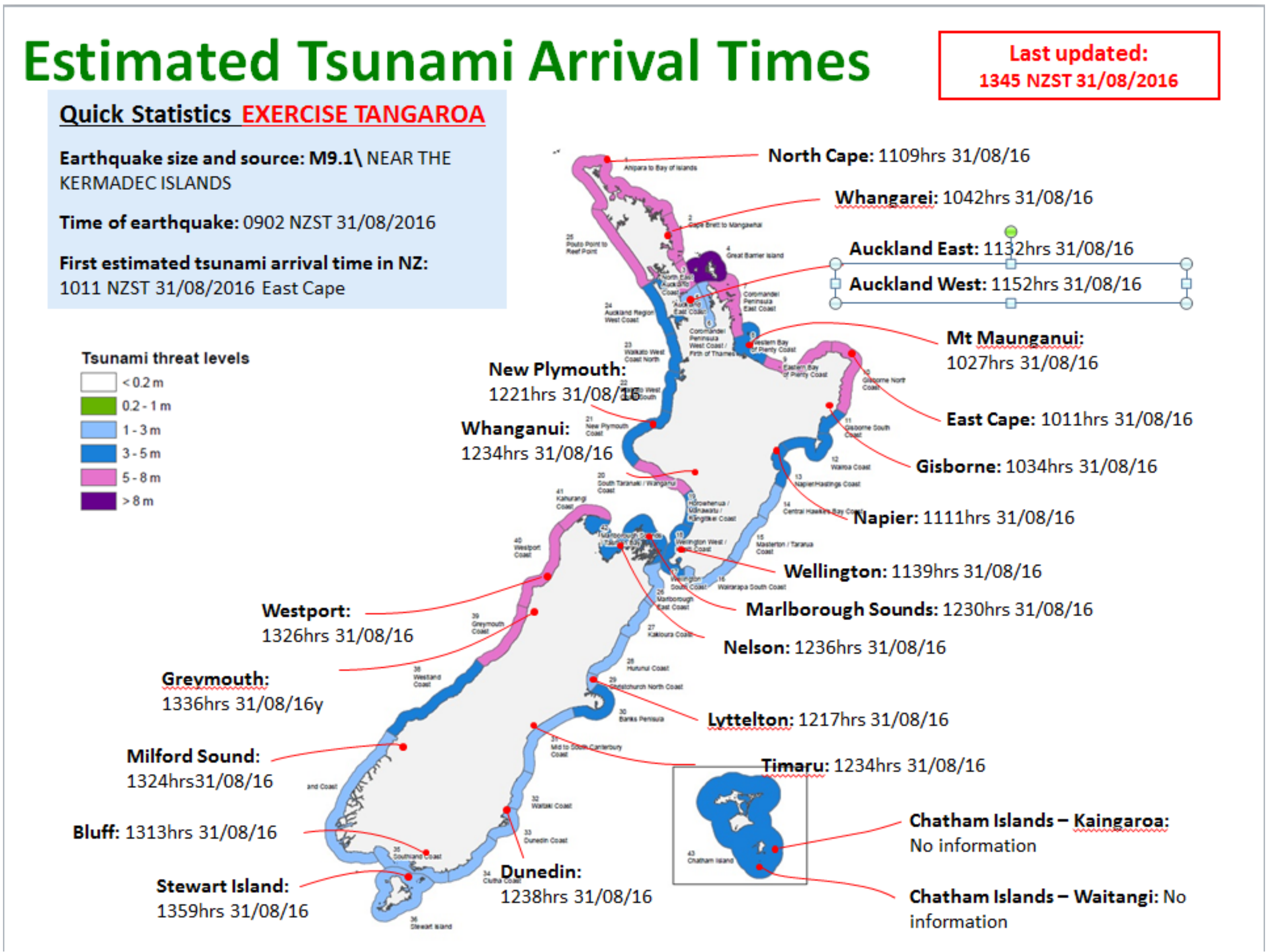


Figure 5-6: 'Exercise Tangaroa' Threat Map and Arrival Times since the earthquake

Knowledge of Hazard

There have been five events in the last 150 years which have produced moderate sized tsunami along New Zealand's coast as documented by historical observation. Prior to Kaikoura, the most recent event, the 1960 Chile earthquake magnitude 9.5, caused fluctuations up to 4.5m above sea level with damage confined to immediate coastal area.

There is a national probabilistic hazard model (Power et al) and an older probabilistic risk model (Berryman et al 2005).

Tsunami evacuation zones have been mapped for much of New Zealand's coastline in accordance with the Director's Guideline *MCDEM DGL 08-16* based on a 'level 2' rule-based methodology. This essentially models the height of the wave with GIS-calculated attenuation rules for open coast, harbours and rivers. Evacuation zones represent an envelope around all possible inundation from all known tsunami sources, taking into account all of the ways each of those sources may generate a tsunami (and therefore no one event is expected to inundate the majority of a zone). The zones have a significant factor of safety applied, reflecting the accuracy of the relatively simplistic empirical approach.

Further work is being done (as part of the 'Riskscape' project) to model average inundation areas for given return periods.

The availability of LIDAR datasets is a key enabler of more accurate tsunami modelling and the quality and completeness of these varies around the country.

Impacts on Lifelines Infrastructure

The Wellington and Auckland Lifelines Group (WeLG and ALG) collaborated on a project in 2015/16 to review knowledge of tsunami impacts on infrastructure drawing from research on recent events[8]. Briefly, the study found that:

- Transportation networks will likely be damaged by even small tsunami (tsunami depths ~ 1m) due to scouring and deposition of debris.
- Wastewater and potable water networks are particularly vulnerable to tsunami at their facility buildings and pipe intake and outflow sites. Contamination of drinking water supplies or sewerage containment ponds can occur with even small amounts of intrusion of seawater from a tsunami.
- Telecommunications networks will most likely be disrupted locally due to damage to buildings and electrical equipment at exchanges and failure of cellular sites
- Energy networks, particularly electricity, will be impacted due to shorting of buried cables if they become exposed to the water and have pre-existing casing damage. Also, overhead lines are susceptible to failure by toppling of poles, which can be damaged by debris strikes. Petroleum and gas terminals, often located in coastal areas may suffer damage to their pipe networks and tank farms in tsunami depths of 2m or greater.
- Back-up services, such as generators, are often located on the ground outside of buildings, on ground floors or in basements, putting them at risk.
- Bridges are a lifeline component that are vulnerable to tsunami and often have co-location of other lifeline services, which if damaged can cause failure of these other lifeline services.

[8] N.A. Horspool S. Fraser, An Analysis of Tsunami Impacts to Lifelines, Report 2016/22 May 2016

Risks to Nationally Significant Assets

Nationally significant infrastructure considered to be most at risk from the tsunami hazard include:

Fuel

- Refinery and fuel terminals on the East Coast – major impacts on the national supply chain as described in Section 3.2.

Electricity

- Bream Bay Substation (supplies Marsden Refinery) and Marsden substation (supplies Northland and the Refinery)
- Fighting Bay – DC termination
- Distribution zone substations in each CBD (eg: Quay Street Auckland, South Dunedin).

Water / Wastewater

- A number of wastewater treatment plants, township water sources and major pump stations are in inundation areas (the low lying South Dunedin area being one example).
- There will be a knock on impact from electricity impacts.

Transport

- Coastal State Highways – of particular significance where co-located with railway (eg: South Island) and national 'high volume roads' such as Wellington's SH 1 and 2 and Auckland SH1 through Tamaki, Harbour Bridge and SH 16 causeway.
- All ports
- Coastal airports

Telecommunications

- Low lying Exchanges (regional / local significance)
- Fibre crossings at bridges
- South Island East Coast Fibre route

5.5 Severe Weather

Hazard Overview

There are a number of hazards arising from New Zealand's climate. In the north, ex-tropical storms, such as Cyclone Bola, causing intense rainfall and/or high winds occur every few years. Further south, snow and ice add to the climate related hazards.

Hazard Knowledge

Most hazard information is managed by regional councils, developed using varying methodologies. Information in this area includes:

- rainfall history and probabilistic forecasting(NIWA).
- data of historic events (eg: mapped 'historic flood' areas).
- predicted inundation from river and urban stormwater flooding – eg: using hydrological models.
- for regional lifelines projects, rainfall-induced slope instability risk has sometimes been derived from contour and geological data, though accuracy is limited.

The impacts of climate change are expected to be increased intensity storms (both wind speeds and rainfall intensity) and increased droughts.

Some work is being done to standardise methodologies for flood modelling. Further work is also needed to improve understanding of lower frequency events (most is limited to 1:100 yr events) and quantify the impacts of climate change.

Figure 5-7: A broadcasting tower (continuing to function in ice / snow conditions)

Impacts on Lifelines Infrastructure

Broadly, the potential impacts from these hazards to infrastructure can be categorised as:

- Flooding – the damage can depend on whether this is ponded or flowing water (eg: rivers) but typically lifelines services are restored relatively quickly once flood waters recede, though in some cases damage can be more severe (floodwaters scouring bridges and attached pipes/cables). River / stream flooding and high turbidity can impact on the ability to treat water and infiltration of wastewater networks can cause overflows from the wastewater networks.
- High winds – a particular risk to overhead electricity lines (especially where trees are not managed away from lines) and restoration times can be weeks to months if there are widespread rural line outages.
- Rainfall induced landslides – typically closing roads (in some events in the last two decades single regions have counted thousands of slips) and recovery work may take years.
- Snow and ice – mainly a temporary hazard to roads though can damage overhead infrastructure if heavy.
- Drought – causing water supply constraints, increased fire risk.

Regional lifelines studies have not identified any nationally significant infrastructure vulnerable to floods. The low-lying Dunedin CBD area does contain a number of regionally important infrastructure sites.

5.6 Technological Disruption

Technological disruption is a threat to varying extents to most of New Zealand's infrastructure networks. Technology enables more complex operations and subsequently there will be more significant service impacts if technology fails and the backup is reversion to manual systems.

There are many potential causes of technological disruption – cyber-attack, space weather, system operator errors being examples.

Lifeline projects in New Zealand have historically focussed on natural hazards and the information available on this hazard for this report is limited. Further information on this will be collated and presented in this report as part of Stage 2.

Global Navigation Satellite Systems

There has been increasing discussion in lifeline group forums (and others) on the reliance on the Global Positioning System (GPS), which is one of a number of satellite-based positioning systems collectively known as the Global Navigation Satellite System (GNSS).

GNSS provides the positioning, navigation and the timing (PNT) of data exchange between/to users worldwide and is now used extensively in many of New Zealand's critical infrastructure sectors (e.g. transport and information and communications technology (ICT) networks). It is also a key component in many of the modern conveniences that people rely on or interact with on a daily basis, including banking financial services, aviation, maritime navigation and surveillance, surveying, vehicle navigation systems and other recreational activities.

GNSS disruption can come from a variety of unintentional or intentional sources, including space weather events (refer box to the right), radio spectrum encroachment (radio emissions matching GNSS frequencies), 'jamming' devices that intentionally block GNSS signals, or 'spoofing' devices which intentionally replace true GNSS signals to manipulate the computed position or time. New Zealand's increasing dependency on the GNSS, particularly for PNT with little or no backup services, leaves users potentially vulnerable to these disruptions (whether unintentional or intentional).

Space Weather Disruption to GNSS

Space weather events are rare and well monitored by international agencies. Overseas studies show that the other unintentional or intentional 'jamming' or 'spoofing' of GNSS signals may be more prevalent than expected, and in some countries, show that it is happening on a daily basis over limited areas (e.g. the blocking of signals from vehicle navigation systems to prevent the location of a vehicle being known).

There are now several documented cases of major airports worldwide being closed and air traffic being diverted due to GNSS disruptions from 'jamming' devices being used adjacent to the airport. There is currently no monitoring of 'jamming' or 'spoofing' devices in New Zealand.

Impacts on Lifelines

The whole of New Zealand is vulnerable to GNSS disruption. Water, electricity, transportation, ICT, and energy networks are particularly vulnerable, due to an increasing reliance on GPS/GNSS. Current risk reduction initiatives include:

- Advances in receiver and antenna design will reduce the impacts of space weather events;
- multiple GNSS constellations to reduce the incidence of 'jamming' or 'spoofing';
- advisory notices on the 'health' of systems/networks that rely on GNSS,
- upgrades if necessary
- awareness raising, and
- inclusion in business continuity plans for at-risk businesses

Future treatment options include implementation of a Satellite-Based Augmentation System (SBAS) and alternative timing being led by Land Information New Zealand (LINZ) in collaboration with Australia.

6. Programmes to Build Resilience

6.1 Regulation and Funding Drivers

Some lifelines services are competitive (electricity generation, gas production, fuel supply and telecommunications) some are natural monopolies (electricity and gas transmission and distribution, Airways corporation) and some are run as public services funded through taxes, levies or rates.

These different business models give rise to different approaches to resilience investment. Investment decisions in some sectors are made on a purely commercial basis (will the investment provide financial gain) which may not necessarily reflect the best community outcomes. All sectors operate with some level of financial constraint and resilience projects complete with many others for funding.

There is however a range of regulation that aims to ensure that risks are being managed and that lifelines infrastructure is resilient. Regulation and regulatory bodies specific to each sector are discussed in Section 3. There are some requirements that have application across many or all sectors.

The CDEM Act, notably the requirement to function to the fullest possible extent following an emergency, is an important factor for justifying significant resilience investment in the lifelines sector. The CDEM Act gives effect to the National Civil Defence Emergency Management Plan 2015, which sets out the roles and responsibilities of lifelines (and others) in reducing risks and preparing for, responding to and recovering from emergencies. However, while the CDEM Act and National Plan may be used by utilities to support investment decisions, there has been no real compliance monitoring of this legislation to date.

Other relevant regulation includes:

- The Building Act, which sets standards for building quality and resilience, with higher standards for important sites.
- Some sites, such as fuel terminals, are regulated through Health and Safety at Work (Major Hazard Facilities) which requires operators to identify and eliminate / minimise risks and hazards.
- Consenting requirements under the RMA also consider risk mitigation in the location and design of infrastructure sites.
- The RMA which now recognises the management of significant risks from natural hazards as a new matter of national importance.

It is important to recognise that resilience does not just apply to the physical lifelines networks – the organisation's themselves need to be resilient, bringing many other aspects such as financial resilience, leadership, ability to adapt and change, etc. This report currently focussed on the physical networks but consideration to expanding that focus to organisational resilience of lifeline utilities will be given in Stage 2.

6.2 Regional Lifelines Groups

The first Lifelines Project was initiated in Wellington in the late 1980s by the Centre for Advanced Engineering. This was followed by the commencement of projects in Christchurch (1993) and Auckland (1995) with similar projects following in a number of cities and regions over the following decade. Each project typically culminated in the establishment of a Lifelines Group to progress and monitor recommendations arising from the Lifelines Projects.

The work that regional Lifelines Groups undertake provides a collective layer of risk management and resilience planning that builds upon and links across the work undertaken by individual lifeline utilities. Regional lifelines groups include representatives from lifeline utilities in the region and typically aim to:

- Encourage and support the work of all lifeline utility organisations in identifying hazards and mitigating the effects of hazards on lifeline utilities.
- Facilitate communication between all lifeline utility organisations and other organisations involved in mitigating the effects of hazards on lifelines, in order to increase awareness and understanding of interdependencies between organisations.

- Coordinate lifeline utilities input into Civil Defence Emergency Management (CDEM) planning activities.
- Create and maintain awareness of the importance of lifelines, and of reducing the vulnerability of lifelines, to the various communities reliant on lifelines services.

6.3 Lifelines Infrastructure Investment Programmes

New Zealand's infrastructure networks have all been designed to be resilient to varying degrees. Technical resilience is inherent in many networks through redundancy (multiple paths of supply) and robustness (design codes for strength). However geographical constraints and the size of our population makes redundancy in all networks impractical and unaffordable.

Most lifeline utilities have in place asset (or activity) management plans with medium to long term investment programmes to renew and improve the networks.

While recognising major infrastructure investment is ongoing, there is no national picture of required and planned investment specifically focussed at improving infrastructure resilience.

There are also no nationally consistent standards for resilience applied to New Zealand's critical infrastructure and little clarity on what acceptable levels of service are following different event scenarios.

Growth in some parts of New Zealand are both contributing to and reducing resilience. Growth has been a major driver for a number of investment programmes which will also add to network redundancy and resilience. However, it also reduces the spare capacity of existing infrastructure.

6.4 National Initiatives

Outside of regional lifelines projects, there are other major programmes underway seeking to improve New Zealand's infrastructure resilience, both by individual lifelines (such as NZTA's resilience programme) and through other forums. Major programmes include (noting this list is not exhaustive):

- Major national hazard studies such as DeVoRA, AF8 and WENIRP[9]
- The 'Built Environment Leaders Forum – Summary of Findings June 2017' has a range of actions to build a more resilient built environment. It covers a wide range of areas such as governance, leadership, decision making, public engagement and the evidence base.
- The National Disaster Resilience Strategy, currently in development by MCDEM, will also drive a major national resilience action plan.
- Treasury's 2015 National Infrastructure Plan identified a number of key actions in this area, including providing mandate and support for lifelines group activity. The Plan identified shortcomings in all sectors between the level of resilience that can be expected from a national perspective and identified a number of priority areas including ports, rail and national roads.
- Lifelines groups around the country continue to work on projects to improve regional infrastructure resilience. Wellington Lifelines Group is underway with a major infrastructure resilience programme to look at the economic impacts of an earthquake and the benefits of investment in mitigation projects.
- The National Asset Management Support Group (NAMS-IPWEA) continues to develop guidance and build industry capability in asset / infrastructure management of public infrastructure. Managing risk and resilience is an important component of this work.
- The National Science Challenges (mainly "Resilience to Nature's Challenges" and "Better Homes, Towns and Cities") are substantial multi-organisation research programmes including programmes of work aimed at infrastructure resilience.
- The Transport System Strategic Resilience project across all agencies of land, air and marine transport.

[9] Determining Volcanic Risk in Auckland (DeVoRA, www.devora.org.nz), Alpine Fault Study (AF8, http://projectaf8.co.nz/), Wellington Earthquake National Initial Response Plan v1.1 (WENIRP). http://www.civildefence.govt.nz/cdem-sector/cdem-framework/guidelines/wellington-earthquake-national-initial-response-plan/

- The Ministry for the Environment has recently done some work around developing a risk-based approach to natural hazards (Ref Tonkin and Taylor, 2016) as has Local Government New Zealand as part of the scoping work for a potential Local Government Risk Agency.
- Many other university research programmes including University of Canterbury Quake Centre, QuakeCORE, Resilient Organisations and others.

6.5 Potential Mitigation Projects

The following were identified as potential mitigation projects during the 2016 National Lifelines Forum workshop, some of which are already underway. During Stage 2 the NZLC will engage with each sector to review and expand this list.

Table 6-1: Potential Resilience Projects

Sector	Potential Projects
Electricity	▪ Undergrounding (reduced wind/flood risk, can increase seismic risk). ▪ Transmission cable over Harbour Bridge ▪ General, ongoing work – increased route diversity, cyber controls/SCADA protection, strategic spares, outage plans, blackout plans. ▪ Standardisation of operating procedures to enable sharing staff/equipment in disasters. ▪ Work to mitigate the reliance on the Central Park substation for a significant part of Wellington City's electricity supply.
Water / Wastewater stormwater?	▪ Increased water security (drought) ▪ Upgrading of watermains in the Wellington region to protect from the seismic hazard.
Transport	▪ Transmission Gully, Wellington (in progress). ▪ Construction of the Petone to Grenada motorway. ▪ Projects arising from NZTA resilience programme RoNS? ▪ Second Auckland Harbour crossing ▪ Alternative inter-island ferry berth
Telecommunications	▪ Raglan to Australia fibre ▪ Chorus fibre route surveys ▪ Mobile technologies emerging that will greatly increase voice capacity – voice over LTE, voice over Wi-fi ▪ UFB +RBI programme is contributing to better resilience of national fibre network (more meshing)
Fuel	▪ Planning for 'Exercise Tangaroa' scenario ▪ Review sufficiency of local storage volumes. ▪ Move terminals away from coastline ▪ Further development of regional fuel plans.
Other	▪ Translation of research (eg: tsunami impacts, volcanic ash) into design standards and codes. ▪ Business continuity planning (milking shed generators, zip-zap machines) ▪ Shift in business locations in Christchurch west to more resilient locations ▪ Satellite upload (Centre for Space Science Technology) ▪ Drone fleets for reconnaissance pre and post disaster ▪ LINZ advancing Satellite-Based Augmentation System (SBAS) with likely business case support needed from Lifelines Utilities.

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7. Gaps Identified and Next Steps

7.1 Knowledge Gaps

The following knowledge gaps were initially identified from the 2016 National Lifelines Forum workshop and in the development of this report. These have been added to through input from national utilities and regional lifelines groups who reviewed this report.

Natural Hazards

There are a number of national hazard datasets / maps to support vulnerability assessments. Potential areas for further work identified during this study include:

- National volcanic ashfall modelling scenarios.
- Updated tsunami inundation modelling supported by high resolution bathymetry and topographic data (while there are a number of initiatives underway not have national reach and are largely local to regional scale).
- Probabilistic seismic modelling.
- Prediction of earthquake-induced land instability.

Knowledge of Critical Lifelines and Community Infrastructure

Gaps identified in the knowledge of critical lifelines and community infrastructure include:

- Lack of a national view on nationally significant customers and their dependence on lifelines and backup arrangements (eg: alternate communications, backup generators). This is also a gap at a regional and local area in many places.
- Understanding of the community impacts of prolonged lifeline service outages.
- Limited representation by lifelines service providers in lifelines projects, National Lifelines Forum, land use planning and community resilience initiatives.
- Understanding of impacts of critical telco infrastructure failure.
- Understanding of the national electricity generation sector and minimum generator operation requirements.
- Understanding of how transport networks (supply chain) are used and implications of major failures.
- Understanding of the vulnerability of key supply chains for lifeline utilities (such as bitumin supply for roads).
- Impacts resulting from GNSS failure and mitigation strategies.

Understanding of Impacts of Hazards on Lifelines Infrastructure

Gaps identified in the knowledge of likely impacts of hazards on lifelines infrastructure include:

- In general, further work on translating research into practical guidance such as damage matrices and volcanic ash posters.
- Further work on earthquake and cascading impacts on electricity (eg: landslides / hydro lakes)
- Inclusion of other hazards – rural fires, disruptive technologies, cyber-attack, space weather, other criminal acts.
- Inclusion of supply chain impacts in transport vulnerability analysis – eg: bitumen plants/quarries, Bailey Bridge stocks.
- Understanding of dependence on satellite GPS and likelihood/impacts of failure.
- More collaboration cross-regional work to understand impacts and plan response.

7.2 Next Steps

This report represents the completion of Stage 1 of this project, which aims to present a strategic overview of nationally significant infrastructure and its vulnerability to hazards drawing largely on existing documented information.

Stage 2 is subject to funding availability and aims to address during 2018/19 the knowledge gaps identified in Stage 1 that are considered high priority and /or relatively easy to address.

1. Review the potential mitigation programmes/projects with each sector (Section 6.4).
2. Review and map knowledge gaps identified in Section 7.1 against existing research programmes to identify which are / are not being addressed.
3. Draw on outputs from major projects/programmes as they progress, such as DeVoRA, AF8, Wellington Resilience Programme, Science Challenge and the Ministry of Transport's strategic resilience project, to ensure strategic information (including economic impacts where available) is covered in this report.
4. Engage with the 'critical community' sectors identified in Section 4.2 to better understand their critical sites and supply chains (eg: FMCG), the impacts of failure of lifelines services and extent of backup arrangements.
5. Expand the range of hazards analysed in Section 5 (eg: pandemic, technology failure, cyber-attack, urban encroachment).
6. Include further analysis of the impact of new technologies as both resilience opportunities and challenges.
7. Develop maps of nationally significant infrastructure for each sector (possibly overlaid with national hazard datasets where practical).
8. Include further information on the airports, ports and fuel sectors (eg: fuel storage volumes around NZ, airport and ports capacity / traffic).
9. Consider inclusion of flood protection and solid waste assets.
10. Review / refine / expand the definitions of 'nationally', 'regionally' and 'locally' significant including possible guidance for lifeline utilities on assessing criticality and dependencies.
11. Include further information on the impacts of critical site / cable failures in the telco sector and contingency arrangements.
12. Include a more comprehensive list of reference material and improve referencing within the document.
13. Consider the inclusion of *organisational resilience* components of lifeline utilities as well as the physical network vulnerabilities.
14. Develop an action plan to address strategic issues and gaps, aligned to the Built Environment Leaders Forum Findings, the National Disaster Resilience Strategy and the National Infrastructure Plan.

    Some of these actions may be undertaken by NZLC. The active funding, support and contribution of others is necessary and encouraged.

Stage 3 work is as yet undefined but will seek to further progress work from Stage 1 and 2 and may include projects such as:

15. Further analysis of national critical infrastructure asset failure impacts and vulnerabilities.
16. Developing national level understanding of acceptable risk / service levels for nationally significant infrastructure. This could include establishing target resilience goals at local, regional and national levels to which infrastructure providers work towards (potentially leading to a national code).
17. Modelling economic impacts of nationally significant infrastructure failures (and cost/benefit of mitigation programmes).

Attachment 1: Glossary

Term	Definition
Asset	The physical hardware (eg. pipes, wires), software and systems to own, operate and manage Lifelines Utilities (energy, transport, telecommunications, water). In the broadest sense this includes utility business owners, operators and contractors.
Asset Management Plan	A document that specifies the activities, resources and timescales required for an individual asset, or a group of assets, to achieve the utility's asset management objectives.[10] *Note:* May extend to information on funding plans.
Business Continuity Planning	An organisational activity to build its ability to maintain its internal systems and operations, in order to promote service continuity to customers.
Consequence	The impact of a supply outage on direct customers, usually extending to include the downstream impacts of the outage on society as a whole.
Critical Assets (Sites / Facilities / Routes)	Assets that are especially significant to societal wellbeing and that therefore merit priority attention by utilities in emergency response and recovery. *Note:* Both Infrastructure and community sites / facilities will generally feature in regional lifelines group critical sites / facilities lists.[11] A broad criticality rating of *Nationally Significant, Regionally Significant and Locally Significant* has been used.
Critical Customer	An organisation that provides services deemed critical to the functioning of communities and that rely on lifelines services to function. For this report, these include organisations emergency services, health, banking, Fast Moving Consumer Goods and Corrections services, as well as the lifeline utilities themselves.
Emergency *This definition has been paraphrased from the Civil Defence Emergency Management Act 2002.*	A situation that • is the result of any happening, whether natural or otherwise, including natural hazard, technological failure, failure of or disruption to an emergency service or a lifeline utility; and • causes or may cause loss of life, injury, illness or distress, or endangers the safety of the public or property; and • cannot be dealt with by emergency services, or otherwise requires a significant and co-ordinated response under the Civil Defence Emergency Management Act 2002.
Event	An occurrence that results in, or may contribute substantially to, a utility supply outage (i.e. an inability to continue service delivery). *Notes:* This informal term is often used in by Lifeline Utilities to refer to the onset of a hazard or an emergency. Events can be 'external', i.e. something that happens to the utility, or 'internal', i.e. a breakdown within the utility.
Four R's	Categories that form a framework for emergency planning and post-event actions. New Zealand's civil defence emergency management framework breaks down into four such categories: *Reduction, Readiness, Response and Recovery*. • *Reduction* means identifying and analysing risks to life and property from hazards, taking steps to eliminate risks if practicable, and, if not, reducing the magnitude of their impact and/or the likelihood of occurrence • *Readiness* means developing systems and capabilities before an *event* happens to deal with *risks* remaining after *reduction* possibilities have been put in place, including self-help and response programmes for the general public and

[10] Based on the definition in the ISO Asset Management Standard.
[11] A list in *The Guide to the National CDEM Plan* identifies these and other sectors and areas that should be prioritised in *response* and *recovery*.

Term	Definition
	specific programmes for *lifeline utilities,* emergency services and other agencies. The term *preparation* is sometimes used • *Response* means actions taken immediately before, during, or directly after an *event* to save life and property and to help communities begin to recover • *Recovery* means efforts and processes to bring about the immediate, medium-term, and long-term holistic regeneration and enhancement of a community after an *event.* *Paraphrased from the National CDEM Plan*
Global Navigation Satellite Systems (GNSS)	GNSS provides the positioning, navigation and the timing (PNT) of data exchange between/to users worldwide and is now used extensively in many of New Zealand's critical infrastructure sectors (e.g. transport and information and communications technology (ICT) networks).
Hazard	Something that may cause, or contribute substantially to the cause of, a utility performance failure. *Adapted from the CDEM Act 2002.*
Hotspot	Place where especially significant assets of different infrastructure utilities or sectors are co-located. *Notes: It is envisaged that the 'location' will be 'tight' – the underlying principle is 'if a hazard strikes here, several asset-types will be affected'. Bridges often offer good examples. There doesn't need to be a 'supply' relationship between the assets for a hotspot to exist. Simple co-location is the test.*
Interdependence	Relationship between infrastructure types characterised by one's need for supply from another in order for their service to function. *Notes: The supply relationship need be in one direction only: if A needs B, that is an interdependency; B doesn't have to need A as well.* *In Vulnerability Studies, interdependence is usually identified at sector level, but interdependence can also be relevant at site level.*
Lifeline Utility	Lifeline utilities own and operate the assets and systems that provide foundational services enabling commercial and household functioning. *Notes:* Lifeline utilities are defined formally in the CDEM Act to include those operating in the following sectors: electricity, gas, petroleum, telecommunications, broadcast media organisations, ports, airports, roads, rail, water, and wastewater. The term 'critical infrastructure' is sometimes used.
Lifelines Groups	Regional collaborations, typically bringing together representatives of utilities, the science community, emergency managers, emergency services and other relevant professionals, with the objectives of improving the resilience of the region's lifeline utilities. Lifelines groups focus on the first two of CDEM's *Four R's*: *Reduction* and *Readiness*.
Likelihood	The probability that an event will occur. *Note:* Depending on the context, 'likelihood' can be applied either to natural hazard return periods (e.g. 1:100 year flood) irrespective of whether a supply outage results, and to *events* (essentially, outage-causing occurrences whatever the cause).
Locally Significant	An asset or facility that, if it failed, would cause a loss of service of local impact (broadly, loss of service to more than 2,000-5,000 customers, or partial loss of service across the country). *Note:* The threshold for 'locally significant' used in regional lifelines projects has varied.
Mitigation	The pre-event, asset-related, steps of a utility to reduce or eliminate supply outages. Notes: Use of the term mitigation is generally confined to asset- related risk reduction steps. Other steps to reduce or eliminate performance outages (e.g. ensuring access to spare parts, staff training for roles in outage events) are better described as readiness.

Term	Definition
Nationally Significant	An asset or facility that, if it failed, would cause a loss of service of national impact (broadly, loss of service to more than 100,000 customers, or partial loss of service across the country).
Pinchpoint	Utility asset or site where a satisfactory alternative is not available and which is therefore essential to service delivery to *critical sites or facilities*. *Note: Pinchpoint* is equivalent to a 'single point of failure' (a term sometimes used in telecommunications) or 'bottleneck' (a term often used in road transport).
Resilience	The state of being able to avoid utility supply outages, or maintain or quickly restore service delivery, when *events* occur. *Notes: It is sometimes helpful to distinguish:* • *'technical' or 'asset-related' resilience: i.e. the ability of physical system(s) to perform to an acceptable/desired level (and beyond the design event to prevent catastrophic failure) when subject to a hazard event* • *'organisational' resilience: i.e. the capacity of an organisation to make decisions and take actions to plan, manage and respond to a hazard event in order to achieve the desired resilient outcomes. Adaptation by the utility following an outage-threatening event can be an important aspect of resilience.* *Similarly, the broad 'service delivery' resilience focus adopted in this glossary draws attention to three components adopted by the New Zealand Lifelines Committee):* • *Robust assets (bringing in the engineering perspective)* • *Effective coordination pre-event and during response and recovery (participation in lifelines groups and sector coordination entities assist here)* • *Realistic end-user expectations (utilities have roles in fostering an appreciation that occasional outages will occur)* *The National Infrastructure Unit's (NIU's) description of resilience (one of its six 'guiding principles') is 'national infrastructure networks are able to deal with significant disruption and changing circumstances'. The extension to 'changing circumstances' broadens NIU's focus to pressures other than outage events.*
Regionally Significant	An asset or facility that, if it failed, would cause a loss of service of regional impact (broadly, loss of service to more than 20,000 customers, or partial loss of service across the region). *Note:* The threshold for 'regionally significant' used in regional lifelines projects has varied.
Risk	The effect of uncertainty in meeting objectives. Usually described as the combination of *likelihood* and *consequence*.
Risk Management	A **s**ystematic process to identify, analyse, evaluate, treat, monitor, and review *risks* that cannot be reduced. *Notes: Risk management is 'event-specific', i.e. addresses identified risks – likely to be those where the likelihood and consequence are greatest. In common with business continuity planning, risk management may be undertaken both by utilities and by organisations that consume infrastructure services.*
Vulnerability	The utility state of being susceptible to loss of utility service delivery / outages when *events* occur and being unable to recover quickly. *Notes: The serviceability loss could arise from a failure of the utility's assets or systems, or from any external event. Vulnerability and resilience can be regarded as opposite ends of a continuum.*
Vulnerability Study	A review of and report on utility *vulnerability*, generally done at regional level. *Notes: Vulnerability studies generally include description of interdependencies and may also identify hotspots and pinchpoints.*

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Attachment 2: References

Auckland Lifelines Project, Phase 2, 2013/14.

Centre for Advanced Engineering, LIFELINES, Lessons from Natural Hazards in Canterbury, Document Summaries December 2012.

Canterbury Lifelines Priority Sites for Recovery, 2010.

Hale and Twomey (for MBIE), New Zealand Petroleum Supply Security 2017 update.

Hawke's Bay Facing the Risks, 2001.

Manawatu-Wanganui Vulnerability Study 2016

Ministry of Business, Innovation and Employment, Energy in New Zealand 2016.

National Infrastructure Plan 2015, NZ Treasury.

Nelson-Tasman Vulnerability Study 2016

Northland Lifelines Project, 2009-14.

Otago Lifelines Vulnerability Study, 2014

Otago Lifelines Utilities Programme 2017 (development from the 2014 Study)

Southland Lifelines Vulnerability Project, 2014.

Tonkin and Taylor (for MfE), Risk Based Approach to Natural Hazards under the RMA, 2016.

Vulnerability of New Zealand ports to natural hazards, 2012. Ragued, B ; Wotherspoon, Liam ; Ingham, Jason.

WeLG/WREMO Lifelines Response Priorities 2015.

Wellington Earthquake National Initial Response Plan (SP 02/17), Version 1.1 May 2017.

Worley Parsons (for MBIE) Gas Disruption Study, Report On The Potential Impacts On The Nz Gas Market Public Issue, January 2014

Websites:

Determining Volcanic Risk in Auckland (DeVoRA, www.devora.org.nz)

Alpine Fault Study (AF8, http://projectaf8.co.nz/)

MBIE Energy Information (www.mbie.govt.nz)