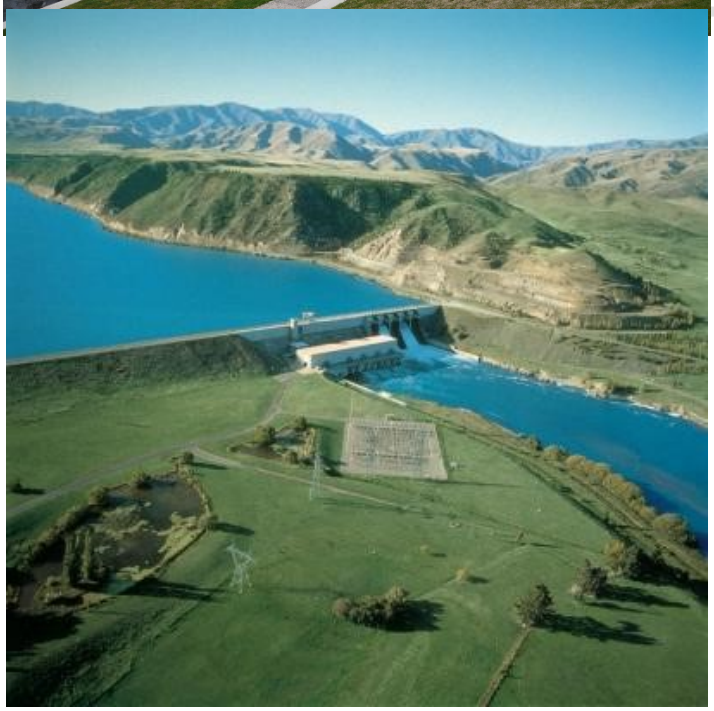
Emergency Management Otago
Te Rākau Whakamarumaru Ōtākou

Otago Lifelines Programme

Vulnerability and Interdependency Update of Otago's Lifelines infrastructure



OLG (Version 7) 2018 February

Preface

Acknowledgements

This project has been convened and administered by the Emergency Management Otago (previously identified as: Otago Civil Defence Emergency Management Group).

The 2017 Programme was managed and completed by the following project team:

- Project Sponsor: Emergency Management Otago: Chris Hawker (Director and Group Controller)
- 2016/2017 Project Manager and Editor: Emergency Management Otago: Sarah Hexamer (Planning & Development Manager) and also (Lifelines Utilities Committee Coordinator/Emergency Management Otago Strategic Representative)
- Acknowledgment to Ewen Graham - Emergency Management Otago (Waitaki District) for final proofreading support of V6

2014 Project Manager and 2016 Workshop Facilitator: Lisa Roberts (Infrastructure Decisions Limited). This update *was adapted and updated using original content from the 2014 assessment written by Lisa Roberts, new information and data received via the 2016 and 2017 workshops and meetings* & the 2017 National Lifelines Vulnerability Assessment Final Version.

The National Vulnerability Study 2017 completed by Lisa Roberts from Infrastructure Decisions and Lifelines Groups from around New Zealand have contributed significantly to the collation of information used within this document.

Block 7 completed the Otago Risk Register April 2017 which is referred to and supports this document.

In addition to the original contributors in 2014, Emergency Management Otago would like to further acknowledge the contribution of time and effort in 2016 & 2017 by the following lifelines organisations and staff:

- Allied Petroleum (James (Jim) Hill, Kevin Sim)
- Aurora/Delta (John Campbell)
- Central Otago District Council (Murray Hasler, Julie Muir, Quinten Adams)
- Chorus (Ross Hunt)
- Clutha District Council (Jules Witt, David Campbell)
- Contact Energy (Mike Craighead, Ken Roberts)
- Dunedin Airport (Stu Casey)
- Dunedin City Council (Mick Ball, Michael Tannock)
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- Nova Energy (Colin Anderson)
- Network Waitaki (David Paterson, Matthew Hawtin)
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- Waitaki District Council (Martin Pacey, Neil Jorgensen, Michael Voss)
- Whitestone Contracting (Julian Hardy)

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- NZDF (Ray McLellan)
- Chamber of Commerce (Dougal McGowen)
- Emergency Management Otago Risk Reduction Project Consultant (Block 7)
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- New Zealand Fire Service (Rodger Smith, Laurence Voight, Peter Amyes)
- Project AF8 Manager (Jon Mitchell)
- Southern District Health Board (Paul McNamara, Owen Black)
- St John (Doug Third)
- Wanaka Airport (Ralph Feagan)

Disclaimer

This 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 or misprint. This is a 'living' document and will be updated as often as changes are identified. Each subsequent version will be in the following format YYYY/Version X (numerical) and a notification will be emailed out to all partners that a change has been made to the core document and it will be resent to you for you to replace your current version with.

Most of the hazard information used for this programme has been prepared at a regional or national level and does not replace any requirement for detailed site-specific geological, geotechnical or other investigation. Readers of the report are advised to consult with Otago Regional Council team as to the suitability of hazard information used in this report for other applications.

Infrastructure information in this report is current at the time of application but ongoing changes will occur. Information in this report may not necessarily indicate the current state of hazard vulnerability or preparedness of the lifeline utilities described other than on the date this report was issued. We are reliant on our Lifelines Partners and Critical Users updating us as regularly as new information arises.

The lifelines infrastructure information in this report was provided by lifelines organisations themselves and the Emergency Management Otago, Otago Regional Council is not responsible for the disclosures made or withheld. The decision as to which information to disclose was the responsibility of each individual utility.

Much of the content was taken from the 2017 National Lifelines Vulnerability Assessment and this is available as a separate document to support this programme

While looking through this programme you will find some of the queries you may have are answered in Section 7. It is recommended that all readers of this document (whether in full or in part) also read section 7 as this identifies future projects and priorities

Document History

2017 Versions	Issue Date	Notes
0.5	August 2014	Final draft report following July workshop circulated for final review.
1.0	September 2014	Review comments incorporated and final report issued.
2.0	November 2016	Workshop held in Dunedin
2.0	January 2017	Meeting held in Dunedin
2.0	February 2017	Draft of version 2 completed with information provided at workshop and meetings held in 2016 and 2017
3.0	April 2017	Following updates received post meetings in February and April
4.0	June 2017	Further updates on community response locations
5.0	September 2017	Updates following Flood Event July 2017
6.0	December 2017	Version 6 completed with Risk Reduction and National Lifelines Vulnerability Assessment included as supporting documents (linked items) Version 6 Approved by LUC on 1 December 2017
7.0	February 2018	Changes to Heath Section, from SDHB to Health Facilities as not all are SDHB facilities - pg 39 and fig 3.2

Table of Contents

SEPARATE DOCUMENTS to support this programme are available on request

- **Otago Risk Register**
- **National Lifelines Vulnerability Assessment**
- **AF8 SAFER Project**

List of Figures

List of Tables

Forward by The Director for Emergency Management Otago and Group Controller

Former Prime Minister Sir Geoffrey Palmer once said:

"Sometimes it does us a power of good to remind ourselves that we live on two volcanic rocks, where two tectonic plates meet, in a somewhat lonely stretch of windswept ocean, just above the Roaring Forties.

If you want drama – you've come to the right place."

We live in a wonderfully diverse land offering both overwhelming beauty, and at the same time, significant risk. Over the past 6 years we have been provided with some uncomfortable lessons about our vulnerabilities and the challenges we know we will face when major events occur. Floods, earthquakes, extreme weather events, significant fires, and the limited road corridors we know will be affected by each of these, underlines the reasons why we need to have robust plans in place to, as far as possible, mitigate adverse effects from an event, but also to support an effective response and rapid recovery after the fact. The Ministry of Civil Defence & Emergency Management's new promotional line of *"Never Happens, Happens"* is prophetic in that although we do not know what will happen "next", we know something will.

This multi-disciplinary and collaborative programme is another step along the road to being prepared and able for when the ***Never Happens*** does, and as a coordinated and mutually supportive team, the Otago Lifelines Group are committed to contributing positively to the developing resilience of the Otago Region.

Chris Hawker
Director/Group Controller
Emergency Management Otago
April 2017

Executive Summary

Programme Overview

Lifeline utility organisations provide important services to the community, including telecommunications, transport, water and energy services. Following a major disaster, restoration of lifelines services are critical to a community's ability to recover from the event.

This programme update presents the outcomes of an assessment of the potential impacts on Otago's critical lifeline utility assets from failure of another lifelines service and/or following a natural hazard event. This includes an analysis of 'hotspots' (where a number of critical assets are co-located) and 'pinchpoints' (single points of vulnerability in individual networks). Potential mitigation measures to improve resilience in the lifelines sector are presented in **Section 7.**

The programme follows on from many other lifelines projects undertaken in the last 25 years in New Zealand, including Dunedin City in 1998. The approach for this programme has been to take a strategic, qualitative assessment of hazard-related lifelines risk focused on the region's most critical assets. The hazard information is available to individual lifelines organisations to undertake more detailed quantitative risk assessment and mitigation option development, as appropriate.

The Region's Critical Lifelines Infrastructure

For this programme, lifelines organisations rated the criticality of their assets as nationally, regionally or locally significant, as defined in **Section 2**. Key points in relation to Otago's critical lifelines infrastructure include:

- Otago is a significant generator of electricity, providing between 35 and 40% of New Zealand's electricity requirements from the Clutha and Waitaki Rivers. 'Nationally significant' sites include Benmore, Roxburgh and Clyde switchyards, which are all a critical part of the national grid, and Halfway Bush substation which supplies a large part of Dunedin, including the CBD.
- Many parts of the State Highway network have long detour times, for example if SH 6 from Cromwell to Queenstown is closed, the alternative State Highway route adds around 4 hours to the journey. Where local roads offer alternatives these are often highly limited in terms of capacity.
- The telecommunications sector is complex with a high level of inter-connectivity between various providers which share parts of the network and exchange messages between networks. The Otago region is supplied via several fibre cables along a coastal and inland route shared by a number of providers.
- While there is a single point of supply of fuel into the region (via Ports of Otago), fuel can be trucked from other major South Island ports if they are operational.
- Water supply and wastewater networks are different from other sectors in that there are stand-alone schemes in Dunedin City and many of the region's towns. Many of these schemes are reliant on single water sources, notably a large amount of Dunedin's water supply comes from a raw water line from Deep Creek and Deep Stream (though projects are underway to provide redundancy for these critical assets).

Figure 4.1, page 43 *illustrates the region's infrastructure 'hotspots' and 'pinchpoints'.*

Two of the most significant areas include:

- The low lying South Dunedin and harbourside area, which is at risk of flooding, storm surge, tsunami and liquefaction. It contains a number of critical utilities, including the South Dunedin sub-station and Grid Exit Point (GXP) which services the South Dunedin area, the Dunedin telecommunications exchange, the Tahuna wastewater treatment plant and the Musselburgh pumping station which pumps all of Dunedin's wastewater to the treatment plant.
- The Kawarau Gorge has numerous locations prone to alluvial fan activity, rock fall and landslides, many of which interact with the areas appreciable seismic risk. The electricity transmission lines to Queenstown run along or near the Gorge as does SH6 and the main inland fibre cable owned by Chorus.

Lifelines Infrastructure Interdependencies

Many past hazard events have demonstrated the interdependencies that occur in the lifelines sector. In a widespread electricity failure, most fuel stations cannot pump fuel, port operations cease, wastewater pump stations start overflowing within hours and, as the duration of outage lengthens, telecommunications and water supplies are disrupted.

In a major disaster, telecommunications and transport services become critical for other lifelines to coordinate and undertake response activities. Broadcasting and the internet is important for disseminating important public information.

Most lifelines organisations have contingency arrangements for power failure, however, as indicated these typically do not enable full service delivery after a few days.

Figure 0.1 Lifelines Sector Interdependencies

Lifelines Sector	*Dependant on*	Airport	Broadcasting	Electricity	Fuel	Gas	Ports	Rail	Roads	Telecomms	Wastewater	Water Supply
Airport		0	3	2	2	3	3	3	1	3	2	2
Broadcasting		2	0	2	3	3	3	3	2	3	3	3
Electricity		2	3	1	2	3	3	3	1	1	3	3
Fuel		3	3	2	3	3	1	2	1	2	3	2
Gas		3	3	2	3	3	1	2	1	2	3	1
Ports		3	3	1	2	3	0	1	1	2	3	2
Rail		3	3	2	1	3	3	0	3	1	3	3
Roads		3	3	3	2	3	3	3	0	3	3	2
Telecomms		2	3	1	1	3	3	3	1	1	3	3
Wastewater		3	3	1	2	3	3	3	2	3	0	2
Water Supply		3	3	2	2	3	3	3	2	3	2	0

Note: *This figure illustrates the impact on lifelines services following 1 week of outage of another lifelines service, in an emergency response situation. Dependence levels may be different in business-as-usual or shorter/longer duration outages.*

1 – Critical for services to function

2 – Critical for service to function but some backup or bart function

3 – Not required for service to function

0 – not applicable

Lifelines Infrastructure Vulnerability to Hazards

The potentially most damaging natural hazards for the region, from an infrastructure perspective, are major storms (with associated flooding, high winds and landslides) and earthquakes (with associated ground shaking, liquefaction and landslides).

Storms and Flooding:

Taieri Bridge carries critical water pipes for Dunedin

All State Highways have flood prone areas and many wastewater and water pump stations and treatment plants are in flood prone areas along the coast or rivers.

However flooding tends to cause disruption to most lifelines infrastructure only during the event itself, with services restoring once the flood waters recede. The exception is fast moving river flood waters which have the potential to scour abutments and damage bridges as well as assets carried under bridges.

Apart from this type of flood damage, it is the high winds and landslides associated with some storms that can cause more costly damage and longer recovery times.

Long duration, high wind events will typically cause electricity disruption and associated knock-on impacts to other lifeline networks.

Major landslides can close roads for weeks to months, also causing delays to recovery of other lifelines networks. Otago's sparsely populated region means that detour routes can add hours when State highways are closed.

More specifically, a storm causing major flooding and landslides through the Kawarau Gorge could potentially cause loss of electricity supply to Queenstown for days to weeks, and cause major disruption to road transport.

Earthquakes:

There is earthquake risk across the region with a number of areas considered susceptible to liquefaction such as the Taieri basin and embayments of coastal Otago.

Most critical infrastructure sites have been designed to withstand seismic events. However a major earthquake is likely to cause significant damage to underground local distribution networks, particularly in liquefaction prone areas and for older and brittle assets.

The potential regional impacts associated with these and other natural hazards are further described in Section 5. **Section 5.**

Mitigating Lifelines Infrastructure Vulnerabilities

Through the development of this programme, lifelines organisations identified the following programmes to enable a more effective response and recovery from a major disaster.

1. *Otago Southland Integrated Fuel Contingency Plan – to facilitate access to fuel by lifeline utilities and other key CDEM response agencies in a significant fuel shortage.*
2. *Otago Southland Strategic Air Operations and Reconnaissance Plan – to optimise the use of limited helicopter/drone resources for rapid damage assessment and logistical support.*
3. *Regional Emergency Generator Management Plan – to assess the available resources in the region and recommend how these are most effectively allocated.*
4. *Lifelines – CDEM Sector Communication Protocols – protocols for lifelines organisations and CDEM to communicate and coordinate during response and recovery.*
5. *Lifelines – CDEM Sector Communication Systems – to consider the use of alternative communications systems in the event of a major failure of normal communication methods.*

As well as these recommended collective projects, all lifelines organisations have ongoing programmes to mitigate the potential impact of hazards on their own networks, such as seismic screening programmes and regular critical asset inspections. How effective Lifelines Groups through the completion of significant projects planned help mitigate risk of infrastructure failures are demonstrated in Section 7**.**

The Goals of the Otago CDEM Group

Goal 1 Increasing community readiness by ensuring awareness, understanding, preparedness and participation in Civil Defence Emergency Management through public education initiatives and community-led CDEM planning.

Goal 2 Reducing the risks from hazards in the Group area by improving the Group's understanding of hazards and by developing and monitoring a Group-wide risk reduction programme which demonstrates how individual agency initiatives contribute to overall regional risk reduction.

Goal 3 Enhancing the Group area's ability to respond to civil defence emergencies through developing sufficient numbers and capability of CDEM staff and by having effective plans, systems and procedures in place to respond to emergencies.

Goal 4 Enhancing the Group area's ability to recover from civil defence emergencies through a continued focus on recovery plans, training and exercises.

The National Lifelines Sector Going Forward

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. 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.

A number of knowledge gaps have been identified and suggested projects to support ongoing resilience improvements. 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.

In many regions, lifelines projects have been followed on by the establishment of Lifelines Groups, to maintain the relationships that have been developed and progress the collective projects identified the National standard for Lifelines groups is demonstrated in Appendix 7.

Section 0 provides a brief overview of the current progress of Emergency Management Otago's Lifelines Committee as of the completion of this **Version 6 OLGP 2017**

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.**

Risk Reduction

A complete review of the Risks and Hazards to Otago was undertaken in the first quarter of 2017 and a workshop held to establish the risk to agencies, industries and businesses from a non-natural hazard event. The updated Risk Register was completed in April 2017 and the full version supports this programme as **separate document.** The table on the next page gives an insight into the perceived risk to each sector by risk. *This chart should be used as a brief overview and the full context of the scales used and the risks perceived are contained in the detailed report*

Given the uncertain nature of risk, it is not possible to identify every hazard and source of risk across the Otago region. This updated risk register has, however, given an important cross-section of risk, risk perception, and risk interactions over the social, natural, economic and built environments.

A feature of the risk profile of the region is that perception of risk is not always matched by preparedness to manage or mitigate risk. This is especially the case for the economic environment and tourism sector, which has a high perception of risk but has a concerning lack of comprehensive crisis planning. Conversely, agriculture also has a high perception of risk, which is matched by a high level of preparedness and strategic planning to deal with the worst-case scenarios – in the case of agriculture this could be a major biosecurity incursion.

The social environment, including health and education has a medium to high perception of risk and is less concerned about biosecurity risk and more concerned with potential pandemic, natural hazard and man-made disasters.

The built environment (comprising lifelines and ports) had the lowest perception of risk among the different sectors. This is possibly due to the confidence that these sectors have in their measures for containing health, biosecurity and economic crises.

The most consistently high-risk hazard was man-made disaster. This was an interesting result, as outside of the built environment respondents, other sectors gave few examples of possible man-made hazards.

As has been set out clearly in the AF8 Project and in the previous version of the Otago CDEM Group Plan risk register, the likelihood and consequences of a major earthquake event make this the major risk to the Otago region. This has been largely corroborated by the data gathered in this updated register in terms of consistent high risk associated with natural hazards.

There does appear a need, however, for the Otago CDEM to continue to increase awareness of the risk posed by an AF8 event in terms of fostering an integrated response across sectors to provide the maximum possible resilience for the Otago region.

It is noted that new information will be produced throughout the lifespan of the Otago CDEM Group Plan (2017-2022), in regards to hazards and risk across the Otago Region. The Group Plan should ensure that monitoring is undertaken by stakeholders to ensure they understand the risks within their areas of responsibility, so that, where necessary, action can be taken to mitigate that risk. A process of collating this information should also be determined, so that changes in the state of risks over time can be tracked.

Risk Perception per Sector (adapted from the Emergency Management Otago Risk Register 2017)

	Hazards>	Pandemic	Natural Hazard / AF8	Biosecurity	Economic Crisis	Political Instability	Man-Made Disaster	Risk/ theme
Environment	Sector	*Risk*	*Risk*	*Risk*	*Risk*	*Risk*	*Risk*	*Risk*
Social	Health	High (1)	High (1)	Medium (2)	Medium (2)	Medium (2)	High (1)	Medium-High (1.5)
	Education	High (1)	Medium-High (1.5)	Low (3)	Low (3)	Medium (2)	High (1)	
Natural	*Agriculture*	Medium- High (1.5)	High (1)	High (1)	Medium-High (1.5))	Medium (2)	High (1)	High (1)
Economic	*Business*	Medium- High (1.5)	High (1)	High (1)	High (1)	Medium (2)	High (1)	High (1)
	Tourism	Medium (2)	High (1)	Medium (2)	High (1)	Medium (2)	High (1)	
Built /Lifelines	*Air ports*	Medium- High (1.5)	High (1)	Low (3)	High (1)	Low (3)	High (1)	Medium (2.0)
	Sea ports	Low (3)	High (1)	Low-Medium (2.5)	Low (3)	Low (3)	High (1)	

Score	3	2.5	2	1.5	1
	Low	Low-Med	Medium	Med-High	High

Recent work to describe lifeline vulnerability and hazard characteristics in Otago.

Note that this is not a complete list, and does not include knowledge held by agencies such as territorial authorities, lifeline providers, and major industry groups (e.g., Otago Chamber of Commerce).

- Otago Lifelines Project (2014). Prepared for the Otago CDEM Group.
- Natural hazards investigations prepared for the Dunedin City District, including for the review of the District Plan.
    1. The Natural Hazards of South Dunedin, ORC, 2016.
    2. Active landslides in the Dunedin area, ORC, 2015.
    3. Flood hazard on the Taieri Plain (revised), ORC, 2015.
    4. Identification of areas possibly susceptible to landsliding in the coastal sector of the Dunedin City district, GNS Science, 2015.
    5. Extent and characteristics of alluvial fans in the northeastern sector of the Taieri Plain, GNS Science, 2015.
    6. Flood hazard of Dunedin's urban streams, ORC, 2014.
    7. Review of Dunedin City District Plan: Natural Hazards, ORC, 2014.
    8. Coastal hazards of the Dunedin City District, ORC, 2014.
    9. Assessment of liquefaction hazards in the Dunedin City District, GNS Science, 2014.
    10. The hazard significance of landslides in and around Dunedin City, GNS Science, 2014.
    11. Attributing and reconciling source of landslide data within the Dunedin City Council area, GNS Science, 2012.
    12. Natural hazards on the Taieri Plains, Otago, ORC, 2012.
- Natural hazards reports prepared for other districts within the Otago Region, and available from the Otago Natural Hazards Database (www.orc.govt.nz).
    1. Seismic hazard in Queenstown Lakes District, ORC, 2015.
    2. Coastal Otago Flood event 3 June 2015, ORC, 2015.
    3. Lake Wakatipu / Queenstown CBD flood hazard, ORC, 2015.
    4. Lake Wanaka flood hazard, ORC, 2015.
    5. Kingston flood hazard, ORC, 2015.
    6. Glenorchy flood hazard, ORC, 2015
    7. Flood and erosion hazard in the Arrow River at Arrowtown, ORC, 2015.
    8. Flood and erosion hazard in the Clutha River/Mata-Au between Queensberry and Lake Dunstan ORC, 2014.
    9. Coastal morphology of South Otago, ORC, 2014.
    10. Community vulnerability to elevated sea levels and coastal tsunami events in Otago, ORC, 2012.
    11. Otago alluvial fans: high hazard investigation, ORC, 2011.
- River morphology and riparian management strategies and reports (assessing potential for riverbank erosion and morphological change)
    1. Pomahaka River, ORC, 2016.
    2. Taieri River, ORC, 2016.
    3. Pomahaka River, ORC, 2016.
    4. Kakanui River, ORC, 2015.
    5. Channel morphology of the Kakanui and Kauru rivers, North Otago, ORC, 2015.
    6. Channel morphology of the Waianakarua River, North Otago, ORC, 2015.
    7. Channel morphology of the Shag River, North Otago, ORC, 2014
    8. Channel morphology of the Rees River, ORC, 2013
- Otago Tier 2 Oil Spill Response Plan (reviewed in 2016).

Milton 2060 Flood Risk Management Strategy, ORC & CDC, 2012.

1. Introduction

Scope and Purpose

Regional lifelines projects have been carried out across many regions in New Zealand.

In Otago, the first lifelines project focused on the Dunedin City area and was completed in 1998. The last review was completed in 2014.

This programme covers the jurisdiction of the Emergency Management Otago (Otago Civil Defence Emergency Management (CDEM) Group), **Figure 1.1.** Otago CDEM Group Area.

Lifelines programmes aim to assess the potential impacts of hazards on the region's lifelines infrastructure and identify mitigation strategies to reduce that risk.

However the purpose of undertaking lifelines programmes is not just to carry out an engineering assessment of risk and identify risk reduction strategies. The other purpose is perhaps best expressed in the mission of the National Lifelines Committee (which coordinates and supports the regional lifelines programmes and groups):

"Enhancing the connectivity of lifeline utility organizations in order to improve critical infrastructure resilience."

In other words, the collaboration that occurs between lifelines organisations during the programme enhances the understanding of each other's networks and operations and improves coordination across the sector in both preparedness and response to major hazards.

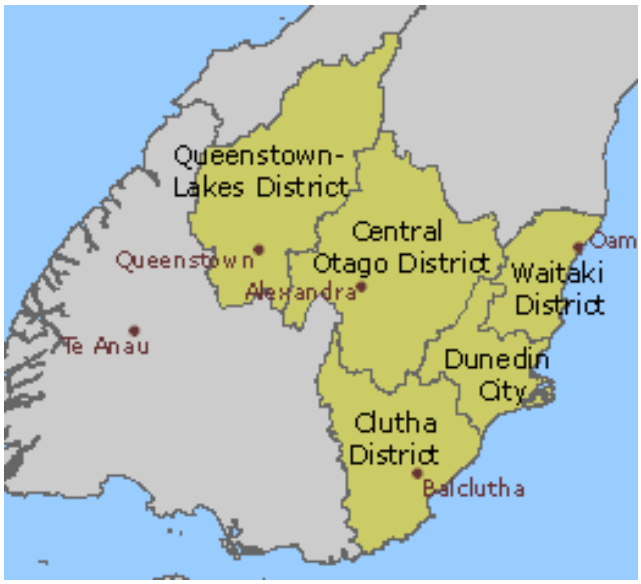
The development of this programme also provided the opportunity for lifelines organisations to engage with key stakeholders including CDEM agencies and critical community service providers such as health and emergency services.

Water of Leith Flooding

New Flood Prevention System 2016

Figure 1.1 Otago CDEM Group Area

The CDEM Group area includes the Otago Region as well as all of the Waitaki District Council area (some of which is in the Canterbury Region). In this report, references to the Otago Region are inclusive of the whole CDEM Group area.



Total Otago CDEM Area Size	**36,446 sq km**
Queenstown Lakes District	**9,446 sq km**
Central Otago District	**10,034 sq km**
Waitaki District	**7,258 sq km**
Dunedin District	**3,305 sq km**
Clutha District	**6,403 sq km**

Programme Approach

The 2014 project had been undertaken with updates in this 2017 programme as follows:

1. Identification and mapping of critical lifelines infrastructure and community facilities in the region **(Section 2),** including the identification of 'hotspots' and 'pinchpoints' (defined in **Section 4**).
2. Assessment of the interdependencies between the lifelines sectors (the extent to which each utility relies on other utilities for them to function), summarised in **Section 3.**
3. Spatial mapping of critical infrastructure overlaid with the region's significant natural hazards.
4. An assessment of the likely impact of those hazards on the critical lifelines infrastructure (summarised in **Section 5**).
5. Development of response and restoration principles and priorities (**Section 6**).
6. Identification of potential mitigation options to reduce the impacts identified and a future improvement action plan aimed at improving the region's infrastructure resilience **(Section 7**).
7. The inclusion of Project AF8 (Alpine Fault Magnitude 8 Earthquake) **Appendix 4a** as a 'whole of South Island' approach.
8. Risk Register and Non Natural Hazards Vulnerability Assessment Tool 2017

Lifeline Infrastructure *(In this report the term 'lifelines organisation' is used synonymously with 'lifeline utilities' as defined in the Act)*

Lifelines organisations provide important infrastructure services to the community. The CDEM Act 2002 defines lifeline utilities as providers of water, wastewater, telecommunications, gas, electricity, fuel, road, rail plus some other specified entities including, in the Otago region, Dunedin and Queenstown Airport and Port Otago.

The region's lifeline utility providers include:

- Allied Petroleum (Fuel)
- Aurora/Delta (Electricity)
- BP (Fuel)
- Caltex (Fuel)
- Central Otago District Council (Transport and Water)
- Chorus (Telecommunications)
- Clutha District Council (Transport and Water)
- Contact Energy (Electricity Generator)
- Dunedin Airport (Air Transport)
- Dunedin City Council (Transport and Water)
- Kiwi Rail (Rail Transport)
- Kordia (Broadcasting and Telecommunications)
- Liquigas (Gas)
- Meridian Energy (Electricity Generator)
- Mobil (Fuel)
- Network Waitaki (Electricity Distributor)
- New Zealand Transport Agency (Road Transport)
- Nova Energy (Gas)
- OtagoNet Ltd (Electricity Distributor)
- Pioneer Generation (Electricity Generator)
- Port Otago (Sea Transport)
- Queenstown Airport (Air Transport)
- Queenstown Lakes District Council (Transport and Water)
- Spark
- Transpower (National electricity transmission)
- Trustpower (Electricity Generator)
- Vodafone (Telecommunications)
- Waitaki District Council (Transport and Water)
- Wanaka Airport
- Z (Fuel)
- 2 Degrees

Programme Benefits

Through participation in the Otago Lifelines Programme, lifelines infrastructure providers achieve the following benefits - they:

- have the latest regional hazard information available (in GIS files where available);
- have maps of critical lifelines and community sites in the region (to enable them to take into account supply to these sites when prioritising their response and recovery);
- understand the likely impact of natural hazards on their assets and services;
- understand the impact of these hazards on other utilities that they rely on, and therefore the knock-on impact to their own services (interdependency impacts);
- gain knowledge of potential mitigation measures to reduce vulnerability to hazards that can feed into long term asset management plans; and
- have the opportunity to facilitate communication with other lifelines organisations and critical community service providers about hazard mitigation and to establish 'pre-event' relationships.

The programme outputs therefore support an improved, coordinated response to major hazards by and between CDEM agencies and lifeline utilities. However it is noted that the scope of this programme does not include development of operational response processes.

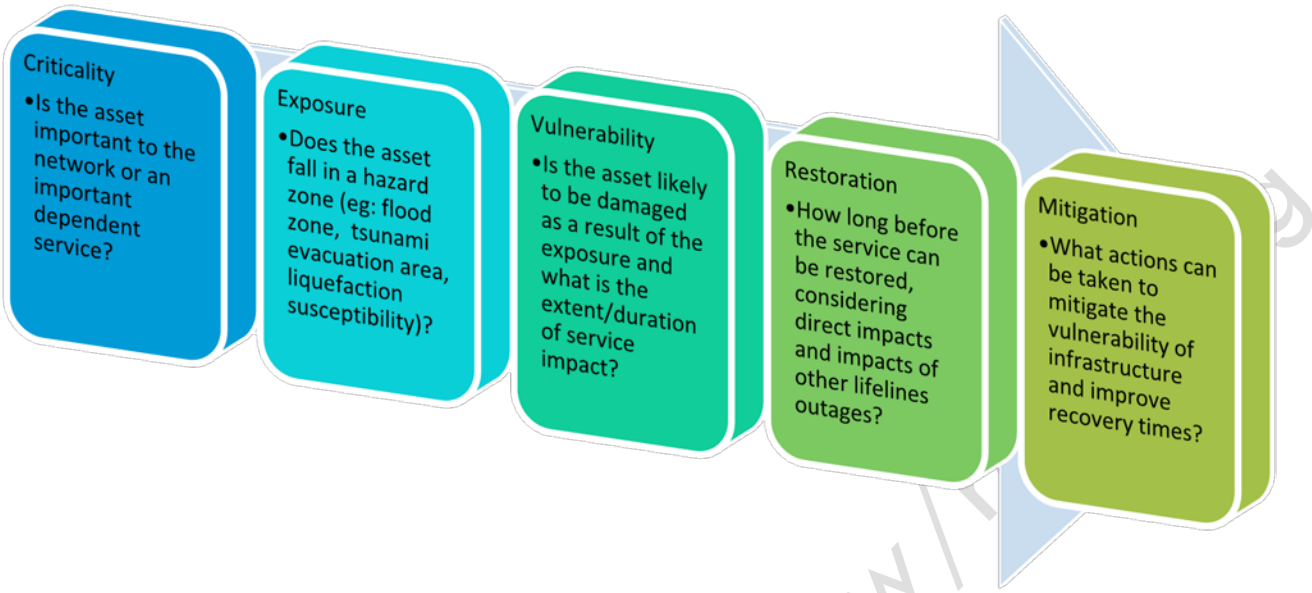
Finally, participation in the programme helps lifeline utilities in meeting the requirements of the CDEM Act 2002, which include that each lifeline utility organisation must:

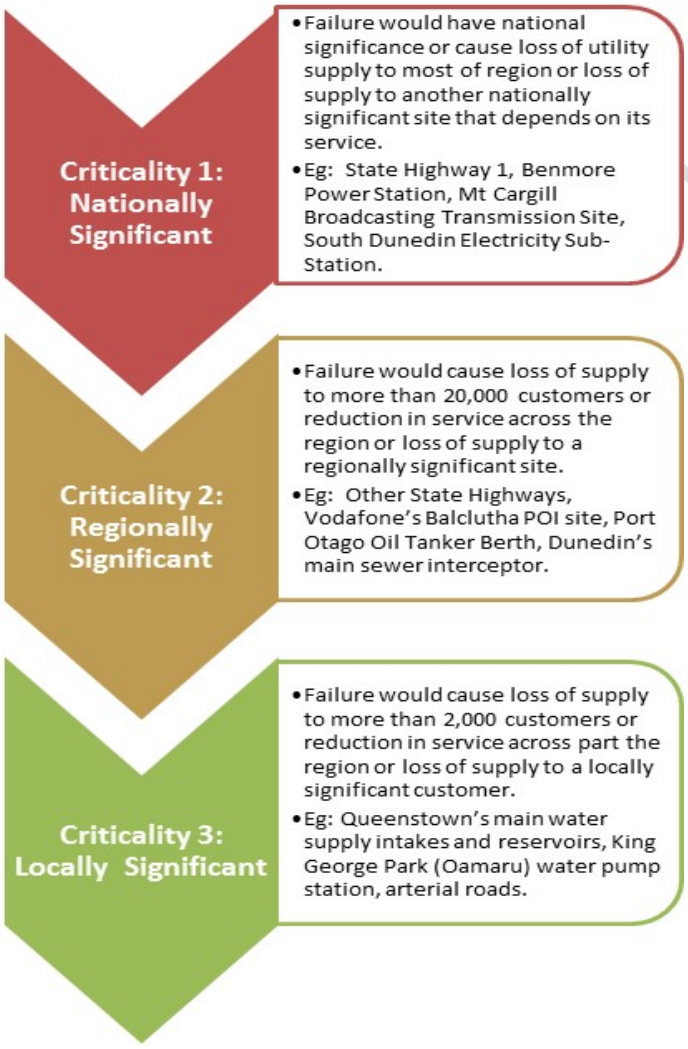
- ensure that it is able to function to the fullest possible extent, even though this may be at a reduced level, during and after an emergency;
- make available to the Director in writing, on request, its plan for functioning during and after an emergency;
- participate in the development of the national CDEM strategy and CDEM plans.

The Director's Guidelines for Lifeline Utilities and CDEM Groups (DGL 16/14) published June 2014 expand on these legislative requirement.

2. Otago's Lifeline Infrastructure Sectors

This section provides an overview of the lifeline utilities in the Otago region, how they operate and critical areas of the network, rated according as shown below.





Critical Lifelines Infrastructure Assets

Each lifelines organization in the Otago region has categorized its assets as Criticality 1, 2 or 3 (***nationally, regionally*** or ***locally*** significant). The approach is summarized in **Figure 2.1**. In general, the criticality approach takes into account the number and type of customers affected, both directly and indirectly, if an asset fails. The criticality rating reflects the consequences of failure, not the likelihood of failure under various hazard scenarios.

Figure 2.1 Defining Critical Lifelines Infrastructure Assets

Electricity

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.

2.1.1 Sector Overview

New Zealand's national electricity grid is illustrated in **Figure 2.2.** Transmission voltage in **Figure 2.3**.

Electricity networks are broadly comprised of:

- Generation sources (grey nodes);
- Transpower's national transmission grid;
- Electricity lines distributors which connect to the Transpower grid and distribute to consumers;
- Electricity retailers – which buy wholesale electricity and sell to consumers (not part of the scope of the programme as they do not operate network assets); and
- Consumers (demand nodes shown in blue in **Figure 2.2**.).

Figure 2.2 also clearly illustrates that while Otago is not a major consumer of electricity on a national scale, a significant amount of NZ's electricity is generated in the region (primarily hydro power generation).

2.1.2 Electricity Generation

Otago's electricity generation sites include:

- Contact Energy's Clyde (432MW) and Roxburgh (320MW) Hydro Power Stations on the Clutha River, which together produce nearly 10% of NZ's electricity. The Clyde Power Station is most critical as it houses the control centre for the Roxburgh and Hawea Dams as well.
- Meridian's six hydro power stations on the Waitaki River, generating a maximum of 1540MW from Ohau, Benmore, Aviemore and Waitaki stations and supplying a further 25-30% of NZ's electricity demand. Benmore is New Zealand's second largest power generation site.
- Trustpower supplies around 130MW from 4 schemes (combination of wind and hydro), the largest being Waipori Falls generating 72MW.
- Pioneer Generation's 15 generation sites (a combination of hydro, gas and wind), generating a total of 43MW, with no single site producing over 10MW.

Most of the electricity generated is transmitted into Transpower's national grid at switchyards, the exception being Trustpower's generators which are embedded in the Dunedin electricity distribution network.

Loss of any single power generation dam or station would not cause a loss of supply to end customers unless it occurred concurrently with other major generation failures in the country. However loss of one of the larger stations would cause a reduction in national security of supply.
Therefore Meridian's and Contact's stations are rated criticality 1 (except for Lake Hawea rating a 2) and Trustpower's stations are rated 3. **Figure 2.5.** Otago Region's Critical Electricity Infrastructure.

Figure 2.2 New Zealand's National Electricity Grid

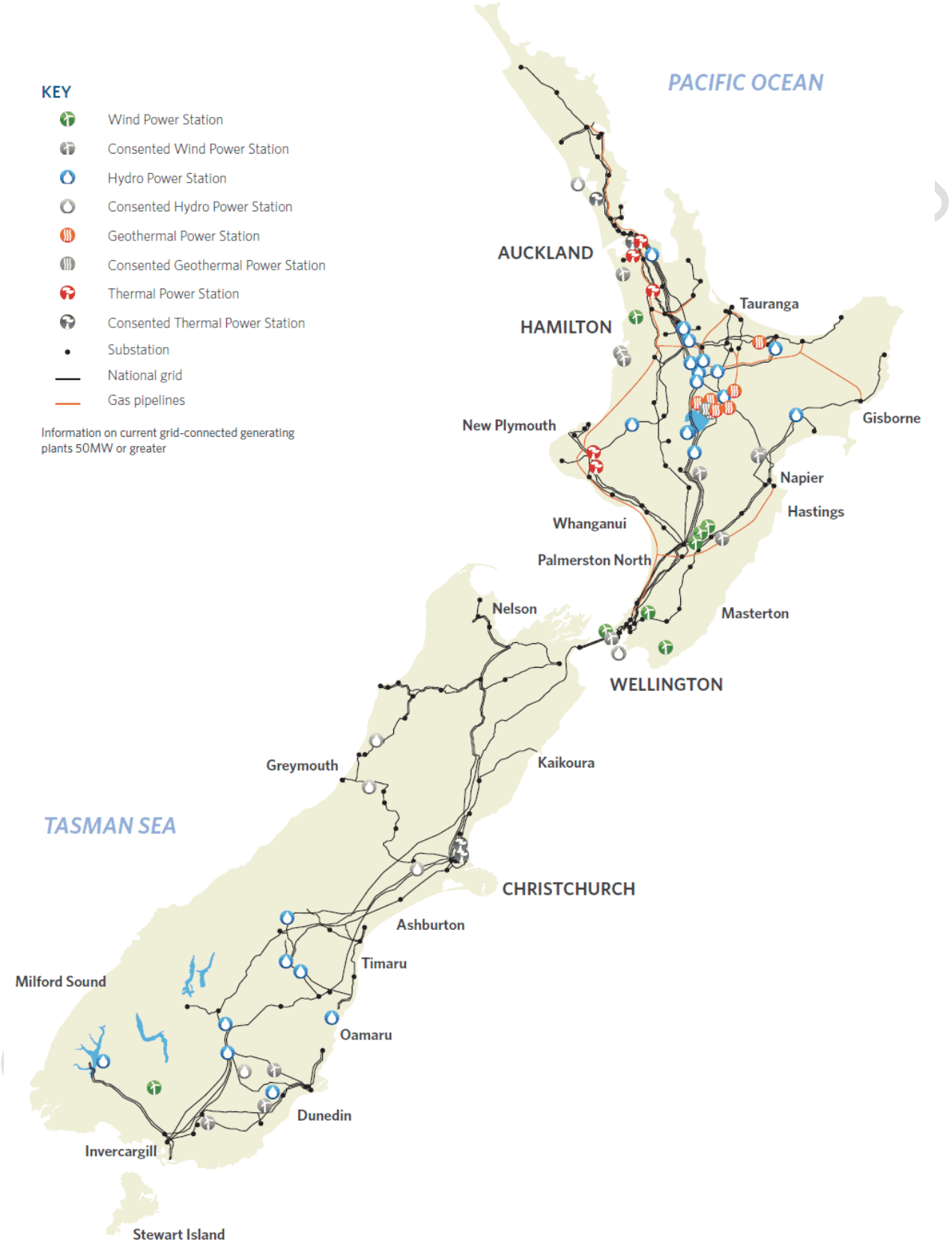
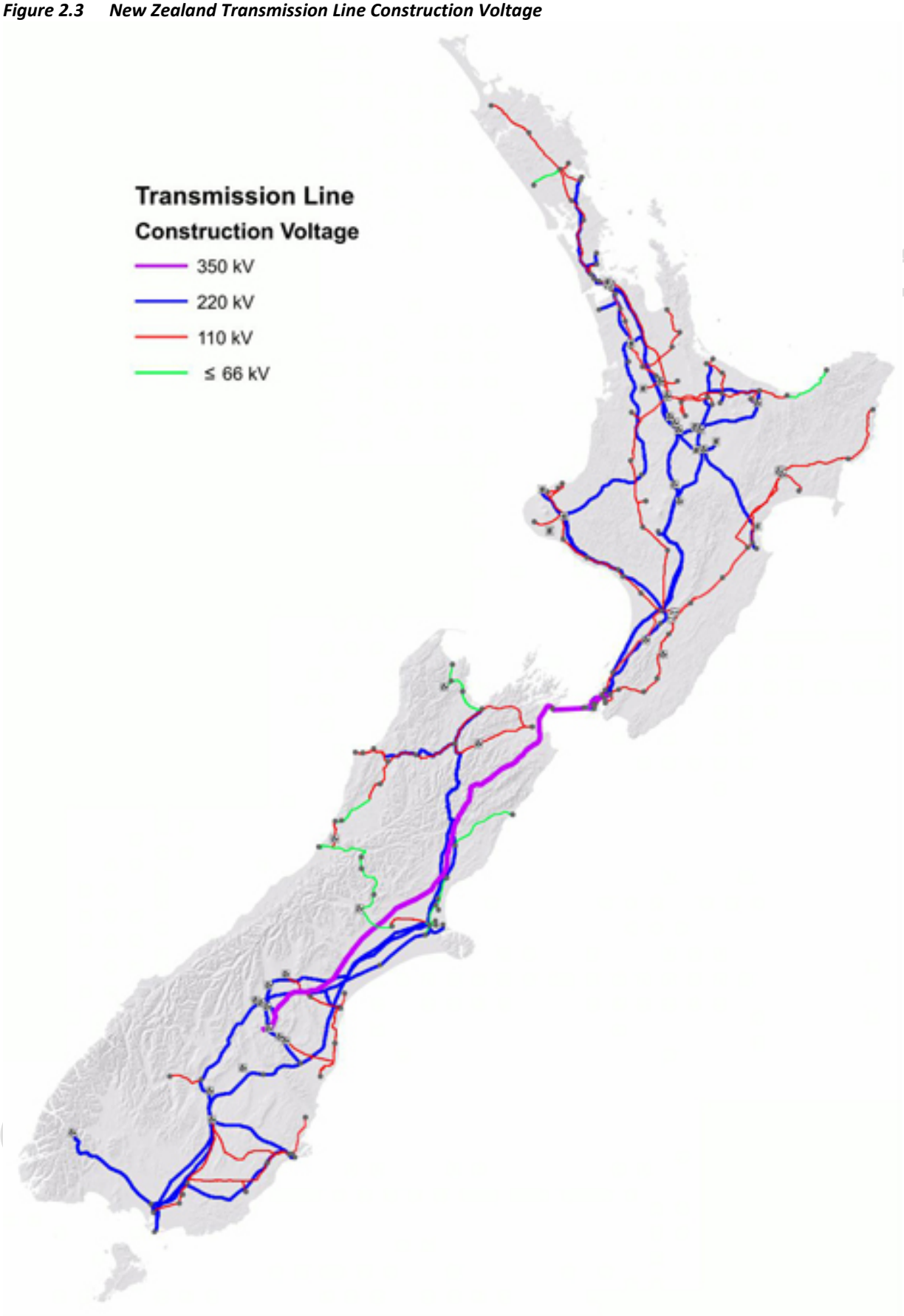


Figure 2.3 New Zealand Transmission Line Construction Voltage



2.1.3 Electricity Transmission and Distribution

Transpower manages and operates the national grid, supplying to three electricity lines companies in the Otago Region: Error! Reference source not found. illustrates New Zealand Wide Main Electricity Sites.

1. Aurora Energy
    - 6th largest electricity lines distributor in NZ
    - supplies to around 84,000 customers in Dunedin and Central Otago
    - delivers around 1400GWh annually
    - network of around 5,500km of lines and cables and 36 zone substations
    - Transpower supplies into network at 5 GXPs, the most critical being Halfway Bush which supplies nearly 40,000 customers in Dunedin.
2. OtagoNet
    - supplies around 14,800 customers
    - covers a large area with a network of around 4400km of lines and cables and 32 zone substations
    - delivers around 420GWh annually
    - Transpower supplies network at 3 GXPs at Balclutha, Naseby and Halfway Bush.
3. Network Waitaki
    - supplies approximately 12,000 consumer connections
    - network of 1,800km of power lines
    - delivers around 230GWh annually
    - Transpower supplies into network at 4 GXPs, the most critical being Oamaru GXP supplying around 10,500 people. The Weston Switching Station (Network Waitaki) is also critical to the supply of electricity to these people.
    - Network Waitaki has identified some 33kV lines as critical because of lack of alternate distribution routes.

For this programme, Transpower's transmission lines have been rated as criticality 1 (>200MW), criticality 2 (>50MW) and criticality 3 (all other lines). The highest capacity line 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. However when all generators are operating, each island is able to generate sufficient capacity to meet demand within the island.

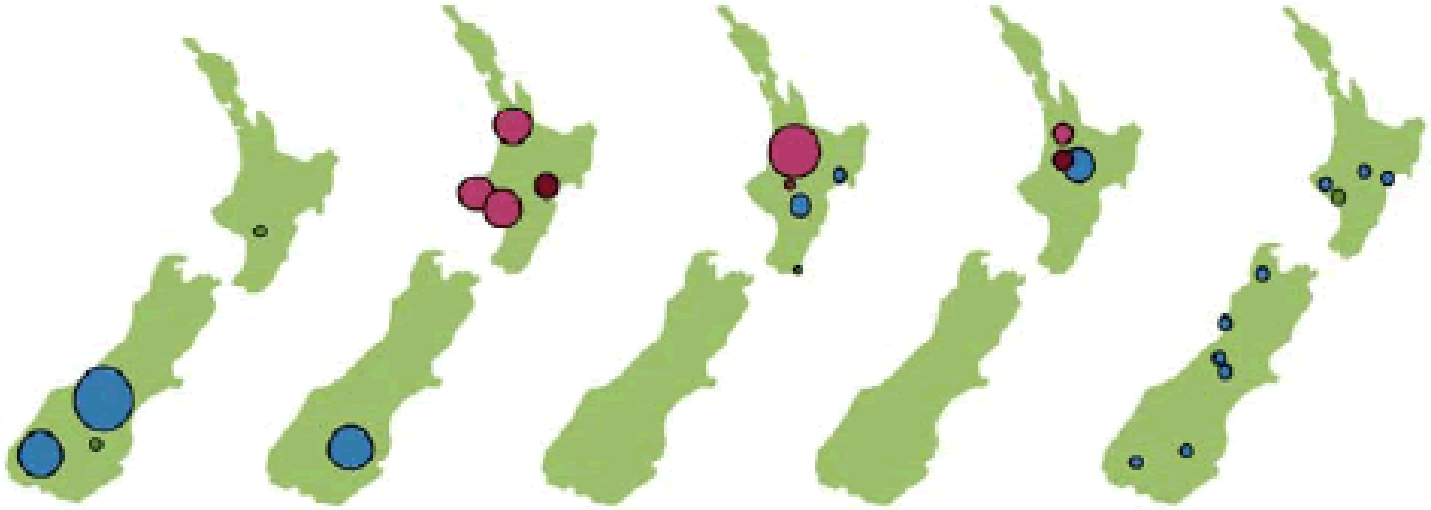
There are a number of highly critical switchyards and stations, most significantly:

- Benmore, a major hub which can supply the HVDC transmission line and the national grid.
- Halfway Bush substation, which supplies a large area of Dunedin, including the CBD.
- South Dunedin substation, servicing that area.
- Three Mile Hill, which is a key switching station supplying Halfway Bush and South Dunedin.
- Roxburgh and Clyde switchyards which are key transmission hubs on the national grid.
- Cromwell substation which supplies Queenstown.

Most of the larger switchyards have redundancy within the station, such that failure of single assets is likely to result in a reduction in capacity rather than total loss. The transmission and distribution companies also have their own communications networks which enable communications in remote areas where other services are unavailable and for remote control of the network.

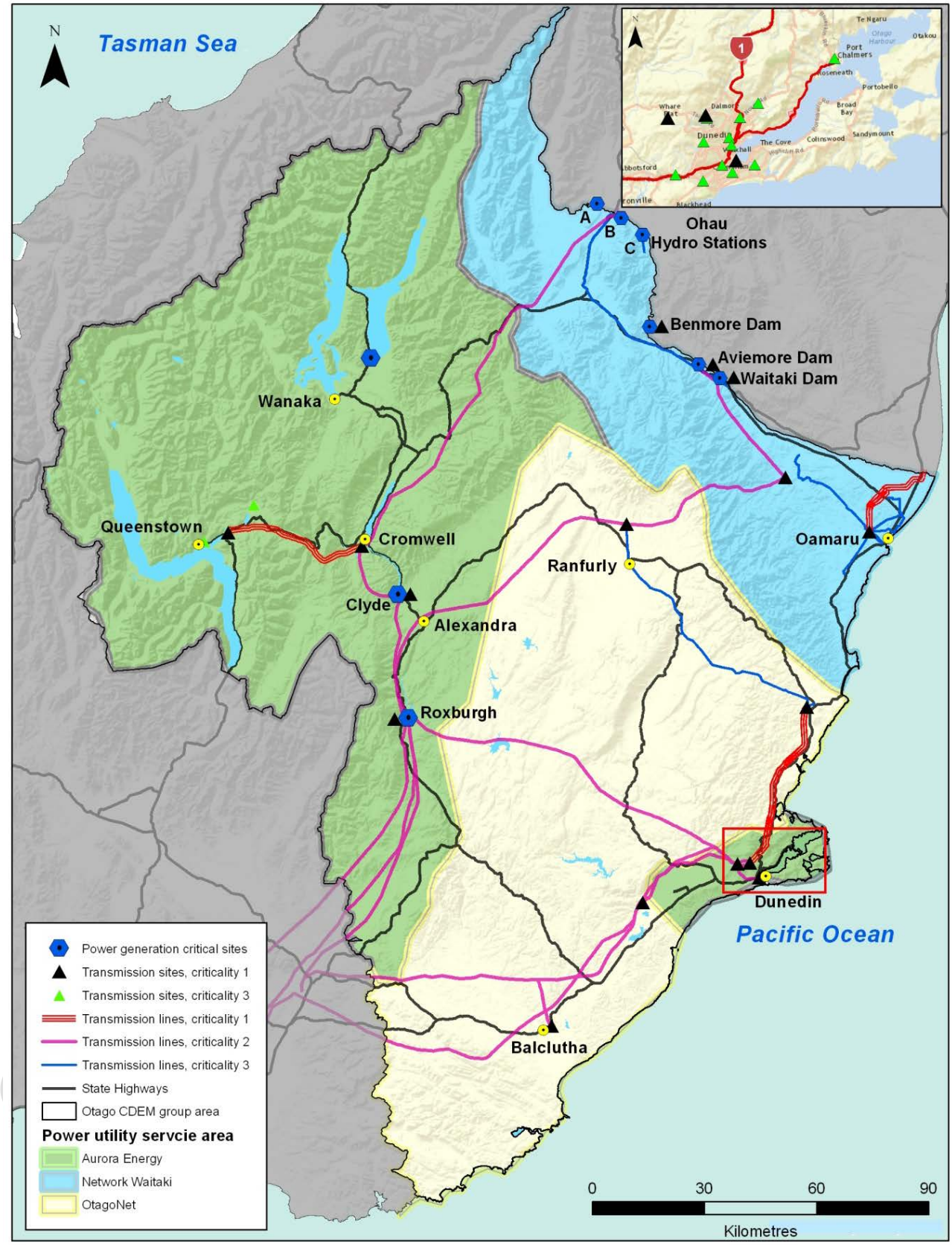
Figure 2.4 New Zealand Main Electricity Suppliers

North Island	Meridian Energy	Contact Energy	Genesis Energy	Mighty River Power	Trustpower	Other
Hydro MW			502	1,063	178	68
Thermal MW		780	1,415	122		179
Geothermal MW		324		115		70
Wind MW	92		7		161	
Other MW				7		



South Island						
Hydro	2,488	752			235	30
Wind	58					
NZ Total MW	2,580	2,294	1,603	1,217	445	347

Figure 2.5 Otago Region's Critical Electricity Infrastructure



Fuel

2.1.4 National Supply Chain

Around 70% of New Zealand's fuel is refined at the Marsden Refinery, south of Whangarei, and distributed by ship to ports around the country (and by pipeline to Auckland) as illustrated in
Figure *2.6*. The remainder is refined overseas and shipped directly to ports from overseas sources. Therefore Marsden Refinery, though it is not located in the region, is a critical fuel site for Otago and all of New Zealand.

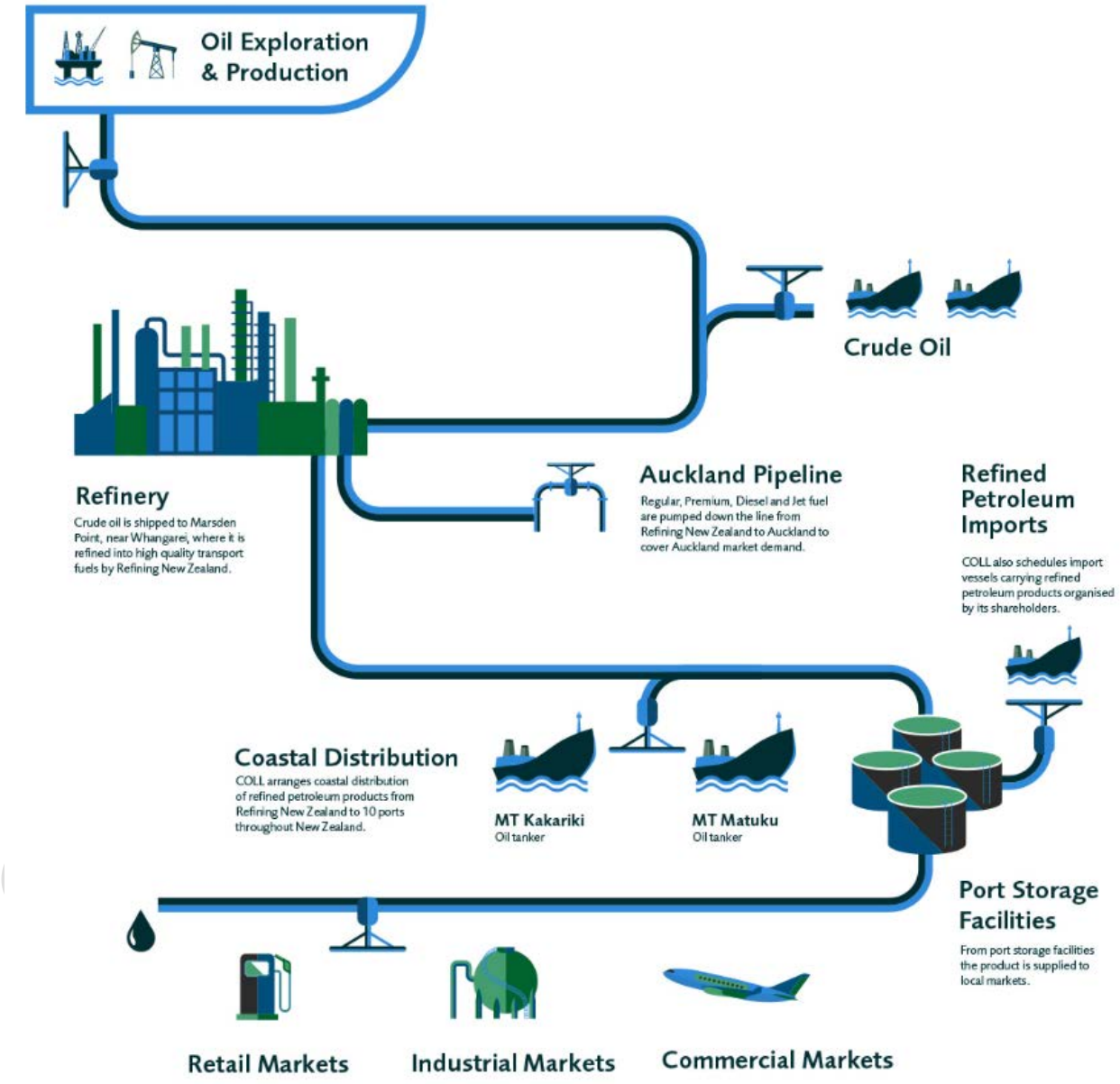
Figure 2.6 New Zealand's Fuel Supply Chain

Otago's fuel comes in via around 27-30 annual bulk fuel shipments to Port Otago's oil berth. It is piped from the berth to three terminals on the City waterfront: **Figure 2.8** Otago Critical Fuel and Gas Infrastructure.

- Chevron Terminal (10Ml petrol, 500kL diesel)
- Z Terminal, operated by NZ Oil Services (12Ml of diesel, 5Ml of light fuel for ship bunkering).
- BP Terminal, operated by NZ Oil Services Ltd (7Ml of petrol, 6Ml of diesel and 0.9Ml of jet) – the jet fuel supplies airports in the Otago and Southland regions. An additional 2ML of jet fuel storage capacity is in development for BP Dunedin.

Mobil have a terminal in Bluff. They supply their Southland sites from Bluff and Otago sites from the BP terminal in Dunedin. The terminals have capacity to hold around 2 weeks jet fuel demand and 1 month petrol/diesel demand, however the levels vary and the jet fuel tanks are run to near empty before re-filling.

All of Otago's fuel is normally supplied from these terminals, however if needed, Otago's fuel can be trucked in from Timaru, Lyttleton or Bluff. There is sufficient capacity in the trucking operations to do this.



2.1.5 Fuel Distribution

Fuel is distributed from Chevron and Z terminals by two operators (Pacific Fuel haul and Allied Petroleum) and two operators from BP (RD Petroleum and Allied Petroleum) to fuel stations and customers around the region.

There is no consolidated view of service station numbers and capacity, nor the extent of backup generation for pumping at these sites. This is an area for future work.

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 are discussed here are mainly in relation to tsunami, it is 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.

2.1.6 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[1] (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

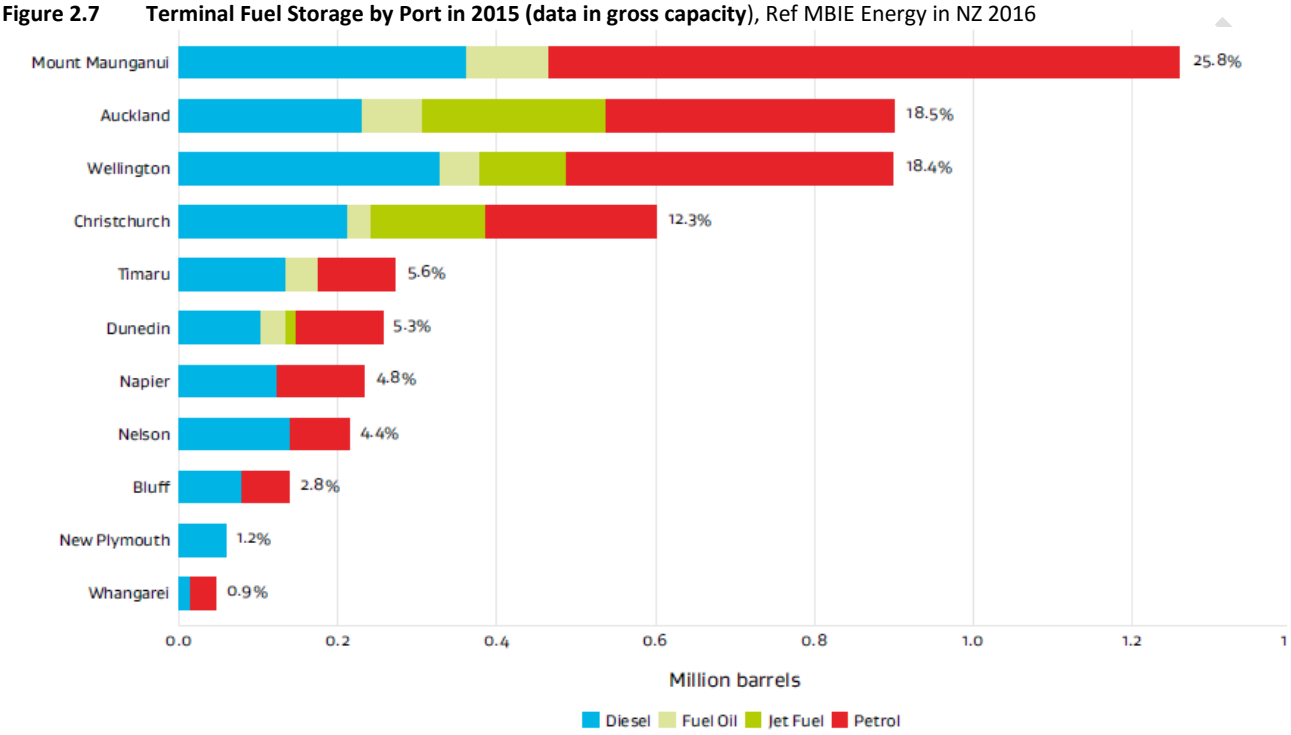
In an isolated failure of a single port (or associated fuel storage facility) in most cases normal demand could largely be met by surging capacity at surrounding ports and trucking fuel supplies in. This is dependent on roads being open and the capacity in the trucking fleet (which is likely to be a constraint). Terminal fuel storage by Port is illustrated in Figure 2.8 Otago's Critical Fuel and Gas Infrastructure

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.

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

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.

Figure 2.7 Terminal Fuel Storage by Port in 2015 (data in gross capacity), Ref MBIE Energy in NZ 2016



*Data is in gross capacity

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.

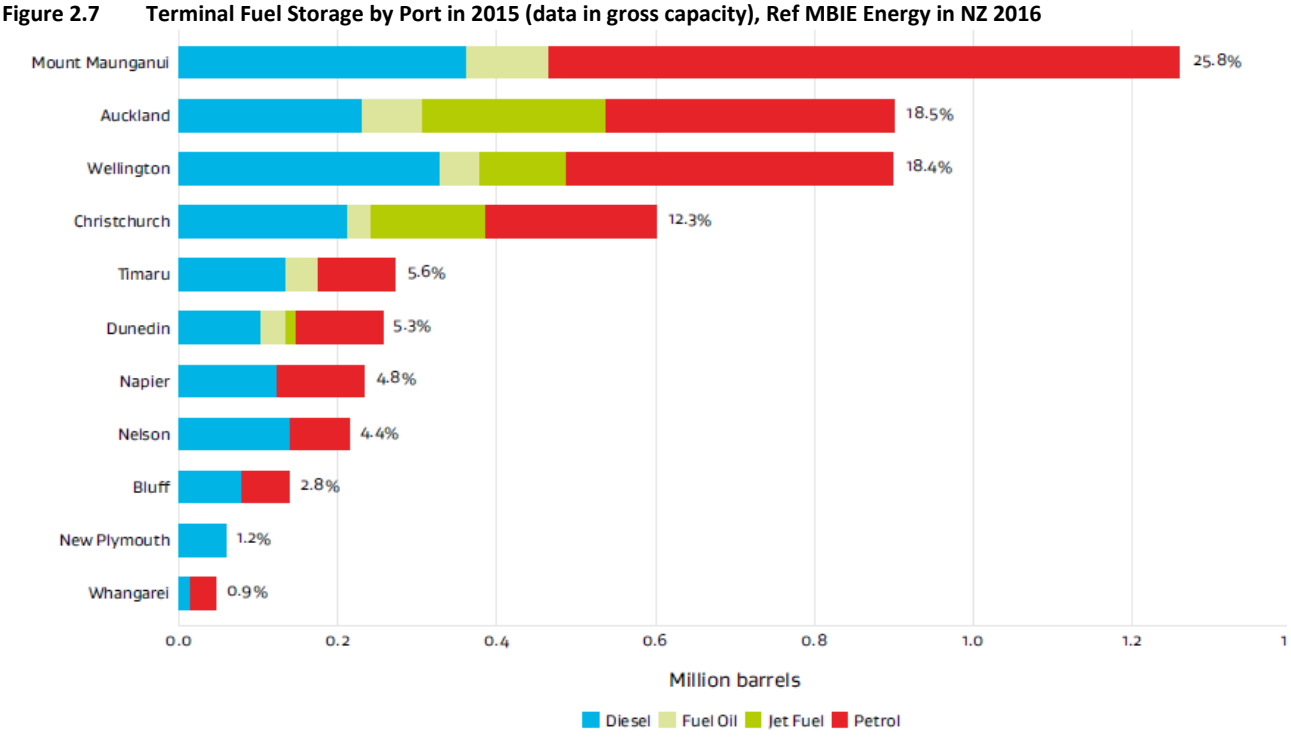
Wiri-Oil Pipeline and Lyttelton to Woolston Pipeline

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 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.

Figure 2.7 Terminal Fuel Storage by Port in 2015 (data in gross capacity), Ref MBIE Energy in NZ 2016



*Data is in gross capacity

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.

Gas

Gas is used in the Otago region for both industrial (e.g. Macraes Gold Mine) and domestic purposes. Gas is sourced from the Taranaki region and brought to Otago by rail and ship. If there is a failure in the supply chain or insufficient capacity to meet demand, typically in winter, gas can be imported from Australia within 1-3 weeks.

Liquigas Dunedin Site

Liquigas brings in 70% of the region's LPG supply by ship to Port Otago, with an annual throughput of 20,000 tonnes. This is stored at Liquigas's Dunedin depot which holds 1300 tonnes of bulk LPG before being distributed by road tankers to 4 LPG distributors in the region – Rockgas Contact, Ongas, Elgas and Nova Energy.

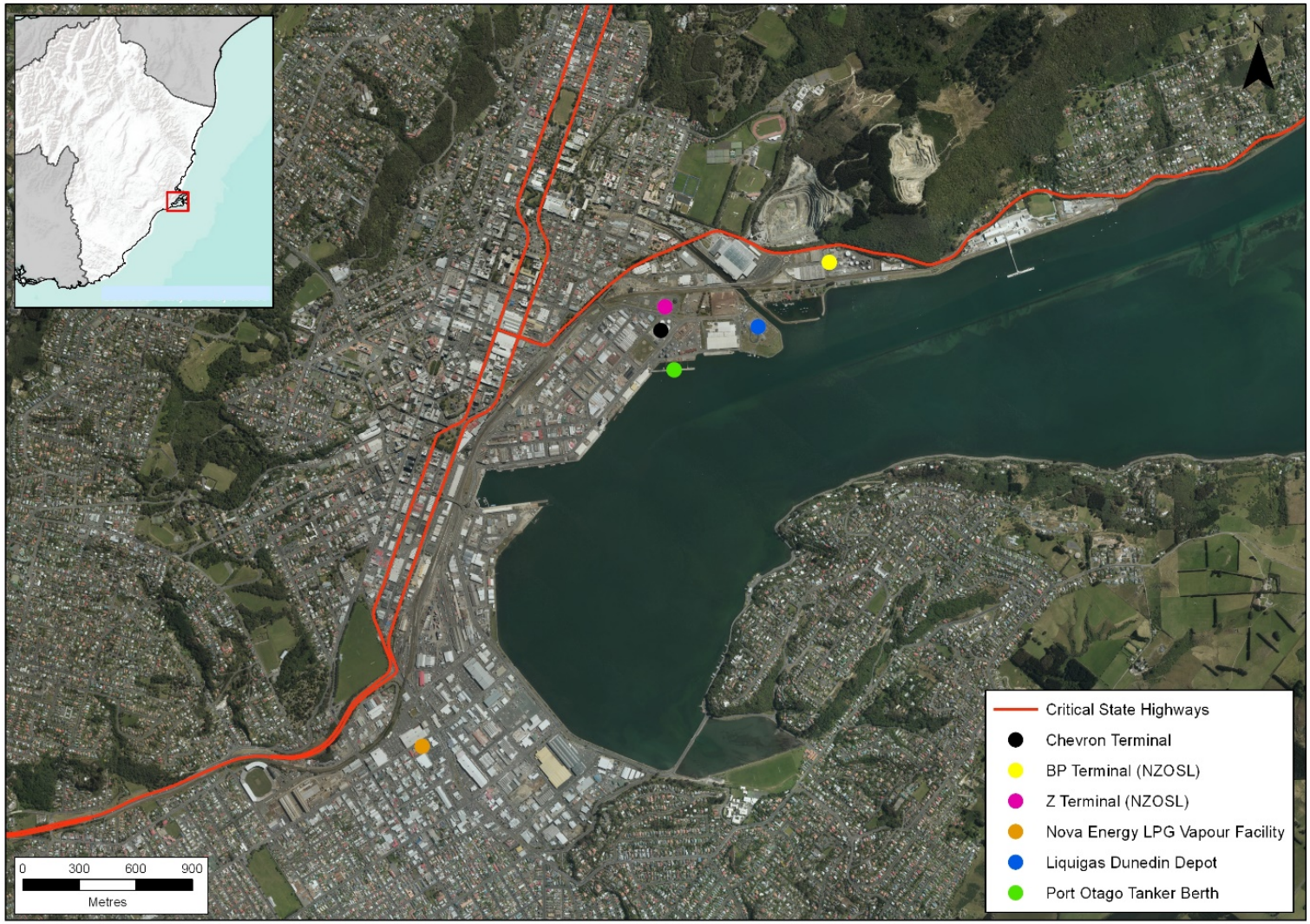
Nova Energy brings in the remaining 30% of gas to the region via rail from Taranaki. It is also a gas distributor, supplying LPG to reticulated customers in Dunedin (via over 33km of underground pipe) as well as to their cylinder customers.

The most critical sites for Nova Energy include the LPG Vapourisation Facility on Hillside Road and the 20 tonne tanks at Balclutha and South Dunedin, the latter supplying key industrial customers.

As well as Nova Gas, three other gas providers in the Otago region include:

- Rockgas, which provides a reticulated gas supply in Queenstown and cylinder distribution services.
- Ongas, which provides bulk support to service station outlets in Dunedin, a reticulated gas supply in Wanaka, mainly around the business district and cylinder distribution across the wider region (based in Wanaka).
- Elgas which provides bottled gas only

Figure 2.8 Otago's Critical Fuel and Gas Infrastructure

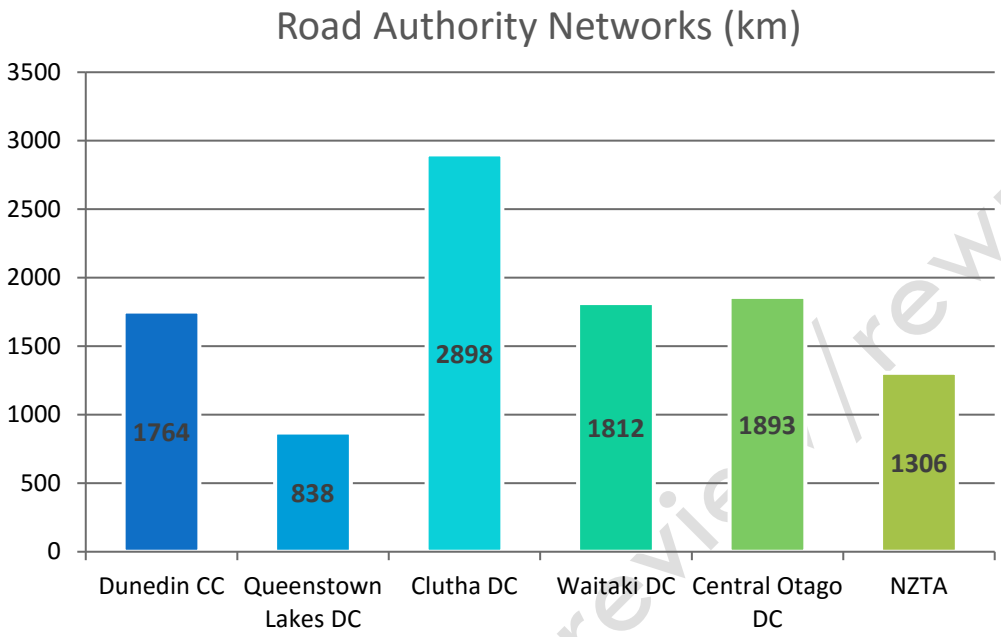


Transport

2.1.7 Roading

There is around 10,500 km of public road in the Otago CDEM region, owned and managed by the road authorities illustrated in **Figure 2.9.** The New Zealand Transport Agency (NZTA) operates the state highways and local authorities the public local roads.

Figure 2.9 Road Authority Networks



The topography is predominantly flat to rolling however there are some mountainous areas throughout the region making for challenging road alignments and increased exposure to severe weather events such as strong winds, ice, snowfall and heavy rain events.

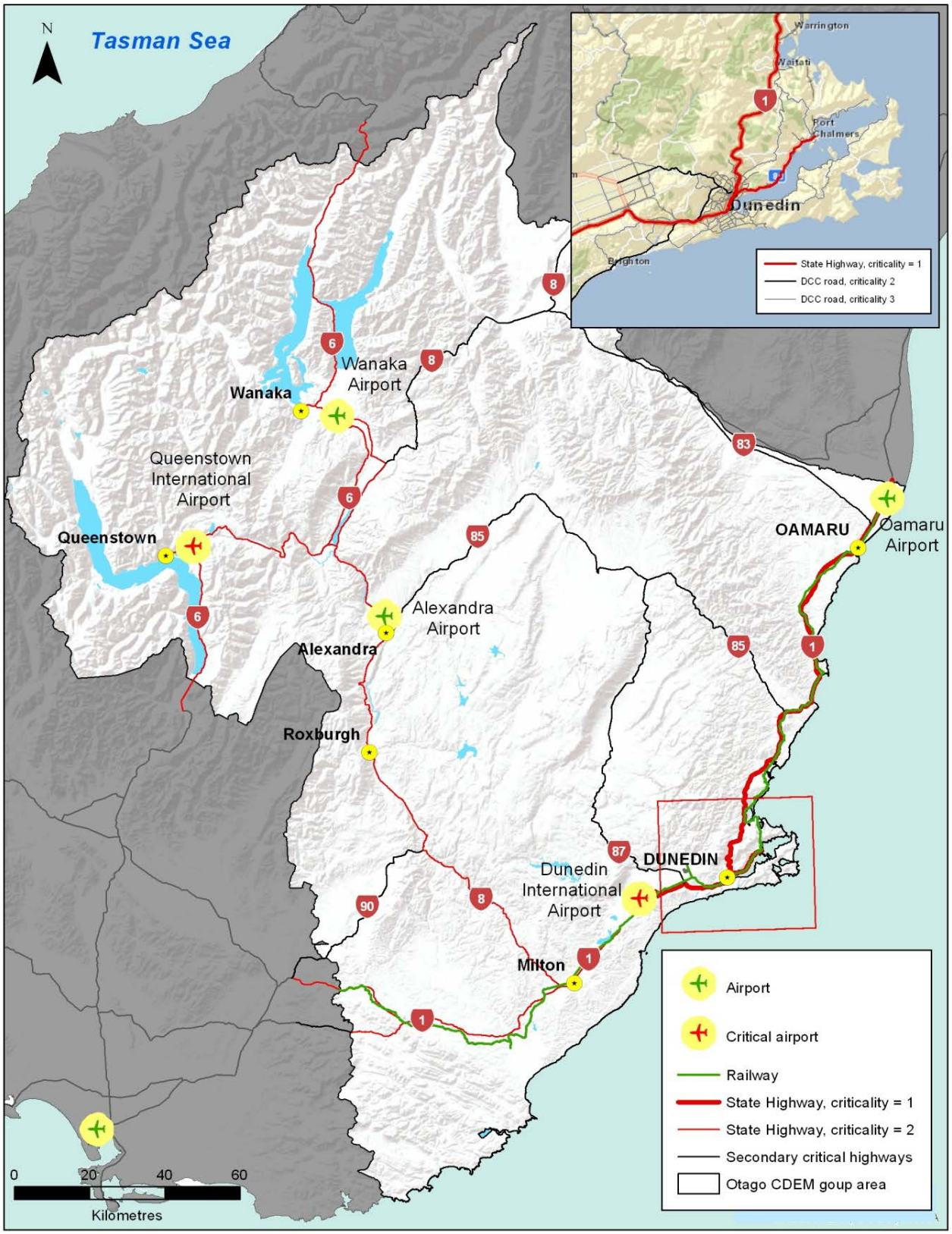
Figure 2	Sealed	Unsealed	Total
WDC	777	1035	1812 km
DCC	1070	694	1764 km
CDC	828	2070	2898 km
CODC	524	1369	1893 km
QLDC	490	348	838 km
NZTA	1306	0	1306 km

Many of the limited routes in and out of the region are highly susceptible to periodic closure due to natural hazards (snow, flooding, landslip). The One Network Road Classification (ONRC) is appropriate as a basis for ranking the road criticality for the purposes of this lifelines programme, as follows:

- Criticality 1 – 'National' ONRC roads (connect major population centres, ports or international airports and high traffic volumes).
- Criticality 2 – 'Regional' ONRC roads (make a significant contribution to the region, connect regionally important locations such as airports, tertiary hospitals)
- Criticality 3 – 'Arterial' (connect regionally important locations such as regional hospitals or may be critical due to lack of an alternate route).

Road authorities have further refined their classifications taking into account criticality considerations outlined in **Figure** *2.10* which illustrates the region's critical roads categorised on this basis.

Figure 2.10 Critical Transport Infrastructure



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.

2.1.8 Airports

Significant air transport facilities in Otago include:

Dunedin Airport

Dunedin Airport services Air New Zealand, Virgin Australia and Jetstar, which fly to other regional airports around New Zealand and to Sydney, Brisbane and Melbourne. The nearest major airports are Invercargill (2.5 hours drive), Christchurch (4.5 hours drive) and Queenstown (3.5 hours drive). Dunedin is primarily a passenger airport and around 850,000 passengers and 500 tonnes of freight were transported through Dunedin Airport in 2013. The Airport is self-sufficient for 3-4 days with backup services . 'JetA1' (jet fuel) is trucked to the Airport from the BP terminal in Dunedin or from Christchurch.

Queenstown Airport

Queenstown Airport is New Zealand's 4th busiest airport by passenger numbers after Auckland, Christchurch and Wellington. Due to the popularity of the region as a visitor destination, the airport is considered a strategic national asset and a key driver of the region's tourism industry and broader economy.

Located 10 minutes from downtown Queenstown, the airport is the direct domestic and international entry point to the lower South Island, servicing more than 1.8 million passengers per year (2017) across four airlines - Air New Zealand, Jetstar, Qantas and Virgin Australia. The airlines operate daily direct scheduled services from New Zealand's main metropolitan ports of Auckland, Wellington and Christchurch which provide strong regional links throughout the country, as well as from the Australian cities of Brisbane, Coolangatta, Sydney and Melbourne. Auckland and Sydney airports are the major international hub airports for long haul visitors.

Queenstown Airport is New Zealand's busiest helicopter port and is heavily used for tourist 'flightseeing'. Private jets are also a growing market, both short and long haul, with aircraft flying direct from north Asia and the west coast of the United States.

The airport has 3 days' supply of Jet A1 fuel and more can be trucked to the Airport from the BP terminal in Dunedin or flown in as extra fuel on aircraft.

Queenstown Airport Corporation manages Queenstown Airport and is also contracted by Queenstown Lakes District Council to provide general airport and property management for Wanaka Airport and property maintenance for the Glenorchy Aerodrome. The nearest airports to Queenstown are Wanaka Airport (1 hour drive), Invercargill (2 hour drive), Dunedin (3.5 hour drive), and Alexandra Airport (1.5 hour drive).

Wanaka Airport

Wanaka Airport is a General Aviation airport which is primarily a base for flightseeing, flight training, private flights, aircraft maintenance operations, and some visitor attractions. It does not operate scheduled commercial services but could be used as an alternative to, or in conjunction with, Queenstown Airport in an emergency.

There are no terminal facilities but there are a number of general aviation aircraft, hangars, aircraft maintenance operations and a supply of Jet A1 and AVgas available on-site. Further information regarding Queenstown and Wanaka is available in **Appendix 3.**

Oamaru Airport

Larger aircraft such as 737s are able to land and this airport is only 1 hour drive from Dunedin. Oamaru airport has 20,000l fuel storage available for helicopter operations

Alexandra Airport

A small airfield with limited passenger facilities catering to scenic and charter flights. The terminal building is unmanned. The could be capacity to utilize this in a major event affecting Queenstown.

Dunedin Airport

Summary	
Airport type	Public
Owner	Dunedin City Council and the New Zealand Government (The Crown)
Operator	Dunedin International Airport Limited
Serves	Dunedin
Location	Momona, Dunedin, New Zealand
Built	1962
Elevation AMSL	1.2 m / 4 ft
Coordinates	45°55′41″S 170°11′54″E
Website	www.dunedinairport.co.nz

Map

Location of Dunedin Airport in New Zealand

Runways

Direction	Length		Surface
	m	ft	
03/21	1,900	6,234	Asphalt

Statistics (2016)

Passenger throughput	909,614[1](financial year)[2]
Aircraft movements	29,229[3]

Oamaru Airport

IATA: OAM · ICAO: NZOU

Summary	
Airport type	Public
Owner	Waitaki District Council
Operator	New Zealand CAA
Location	Oamaru
Elevation AMSL	99 ft / 30 m
Coordinates	44°58′12″S 171°04′54″E

Runways			
Direction	Length		Surface
	ft	m	
18/36	4,210	1,283	Asphalt
11/29	3,107	947	Grass
02/20	2,775	846	Grass

Alexandra Aerodrome

IATA: ALR · ICAO: NZLX

Summary	
Airport type	Public
Operator	Central Otago District Council
Serves	Alexandra, New Zealand
Elevation AMSL	752 ft / 229 m
Coordinates	45°12′42″S 169°22′24″E

Runways			
Direction	Length		Surface
	ft	m	
01/19	2,139	652	Grass
14R/32L	3,937	1,200	Asphalt
14L/32R	3,937	1,200	Grass

Wanaka Airport

Wanaka Airport terminal

IATA: WKA · ICAO: NZWF

Summary	
Airport type	Public
Operator	Wanaka Town Board and Management Committee
Location	Wanaka
Hub for	Aspiring Air
Elevation AMSL	1,142 ft / 348 m
Coordinates	44°43′21″S 169°14′45″E
Website	www.wanakaairport.com

Map

Location of airport in New Zealand

Runways			
Direction	Length		Surface
	ft	m	
11/29	3,937	1,200	Asphalt

Queenstown Airport

Summary	
Airport type	Public
Owner	Auckland Airport Corp, Queenstown Lakes District Council, Shareholders
Operator	Queenstown Airport Corporation Ltd.
Serves	Queenstown, Arrowtown
Location	Queenstown, New Zealand
Elevation AMSL	357 m / 1,171 ft
Coordinates	45°01′16″S 168°44′21″E
Website	queenstownairport.co.nz

Map

Location of Queenstown Airport within New Zealand

Runways

Direction	Length		Surface
	m	ft	
05/23	1,891	6,204	Grooved Bitumen
14/32	890	2,920	Bitumen[1]

Statistics (July 2014 to July 2015)

Passengers total	1,409,663[2]
Aircraft movements	41,769

2.1.9 Port Otago

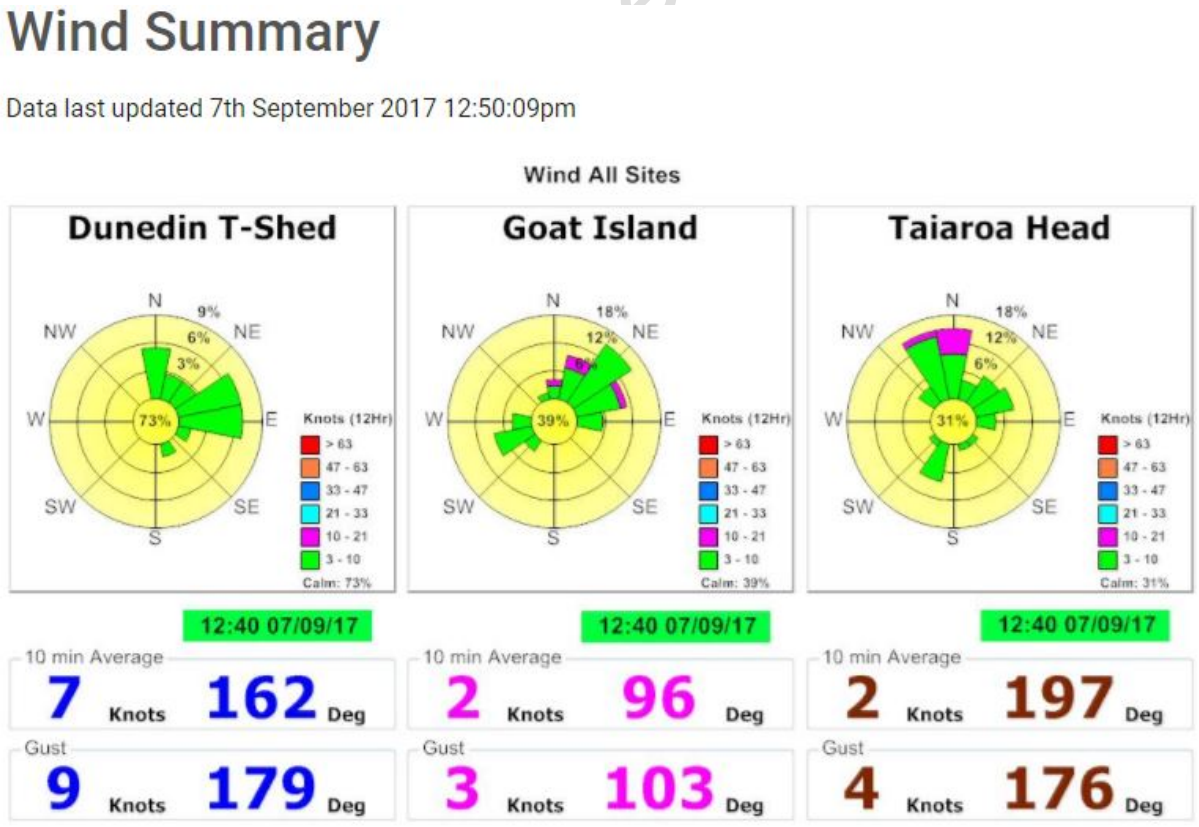
Port Otago is primarily an export port with 80% of freight exported – all logging from Southland and Otago is exported via ship. Most of the exported products are brought to the Port by rail and most of the imported product is fuel.

If the port were inoperable for any reason, some product could be transferred to Bluff or Timaru. The impact would be more significant in the food industry as products from dairy factories and meatworks are exported through Port Otago and it is more difficult to reduce production than, say, for logging.

The fuel wharf is considered the most critical of the 7 wharves in Dunedin.

Port Otago

Updated wind summaries are accessible via the Port Otago website
https://www.portotago.co.nz/our-harbour/harbour-conditions/wind-summary/



2.1.10 Kiwirail

There is around 300km of rail track in the Otago region and 8 tunnels.

Dunedin Railways (Taieri Gorge) covers 64km from Dunedin to Middlemarch and has 10 Tunnels and as we know it is high in Tourism passengers. This would put them in a high-risk zone if an event happened.

Most of Otago's rail network runs alongside the coastline and is susceptible to coastal erosion, damage through seismic activity and tsunami.

Rail doesn't carry any perishable goods but do freight most supermarket essentials for Mainfreight, Toll and Peter Baker Transport daily from Christchurch to Dunedin and onto Invercargill. Kiwirail also transports the bulk Gas into Dunedin for Nova.

Kiwirail rely heavily upon network communications to run their trains and services.

Kiwi Rail Transporting Logs along the East Coast

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.

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.

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. 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.

Figure 2.13 illustrates the number of consumer connections supplied from Council water supply schemes in the Otago Region.
Figure *2.11* illustrates the waste water connections.
Figure *2.12* illustrates Otago's urban water supply and waste water schemes

Figure 2.11 Number of Council Water Connections

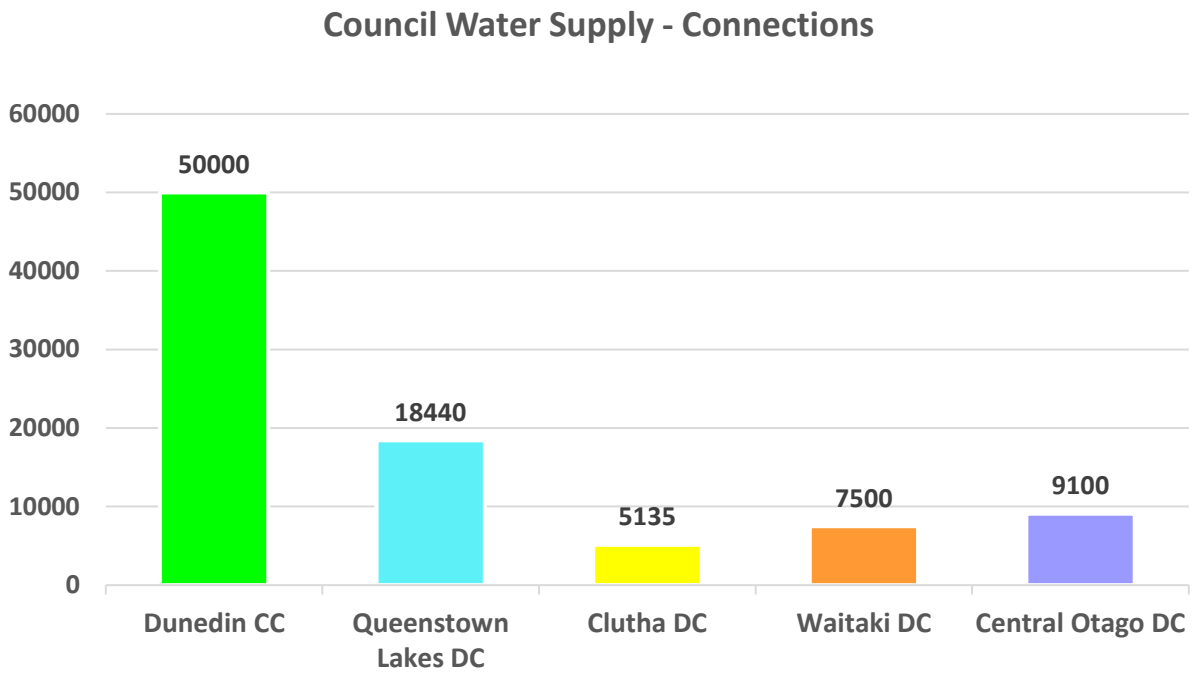
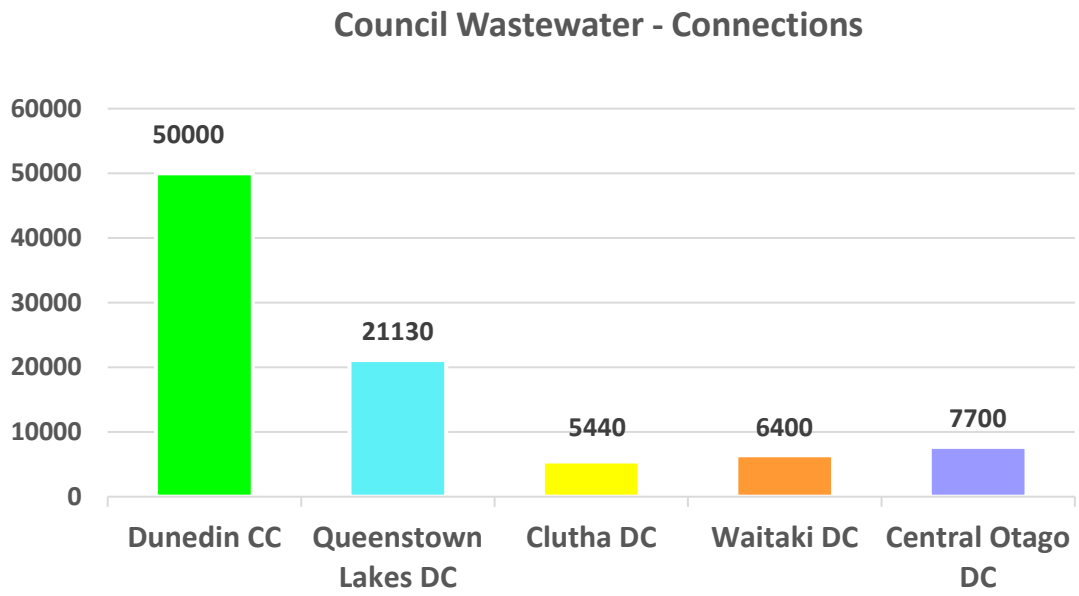


Figure 2.12 Otago Waste Water Schemes



2.1.11 Dunedin City Council

An overview of Dunedin City Council's water supply network is as follows:

- Raw water for Mount Grant is sourced from Deep Creek (around 20%) and Deep Stream (around 80% of supply) and piped to the Mount Grand Water Treatment Plant (WTP) – these pipes are highly critical for security of supply. A notable point of vulnerability is where both pipes cross the 80 year old Taieri River Bridge.
- Mount Grand WTP supplies between 40 and 70% of Dunedin's water and is therefore another significant critical asset.
- The Southern WTP supplies between 20 and 50% of Dunedin's Water, depending on water quality and electricity prices. It is supplied by Silverstream and the Taieri bore field, supplemented by Deep Creek/Deep Stream when electricity prices are high and/or raw water quality is low.
- Around 10% of supply is from smaller WTPs in Mosgiel (supplying the Mosgiel area) and Port Chalmers (mainly servicing cruise ships in summer).
- Water is mostly gravity fed from WTPs with some small areas supplied by booster pumps.

Dunedin City Council also provides smaller water supply schemes in Outram, West Taieri, Rocklands and Waikouaiti (also supplying Karitane and Merton).

2.1.12 Queenstown Lakes District Council

Queenstown Lakes District Council operates 8 water supply schemes (Queenstown, Wanaka, Arrowtown, Lake Hawea, Glenorchy, Lake Hayes, Luggate and Arthurs Point) supplying around 60% of the dwellings in the District. Water predominantly sourced from much of which is sourced from Lakes Wakatipu, Wanaka and Hawea. The intakes and treatment plants for all their schemes are rated as Criticality 3.

2.1.13 Waitaki District Council

Waitaki District Council operates 23 urban and rural water supply schemes supplying 20,000 people (95% of the District's population).

Two sites are considered critical from a local perspective:

- Oamaru's Redcastle Road Raw Water Pump Station which supplies around 15,000 people (there is 10 days of raw water storage); and
- The King George Park pump station which supplies around 4,000 people (there is around 1 day's treated water storage).

2.1.14 Central Otago District Council

Central Otago District Council operates 9 schemes, the two largest being Alexandra and Cromwell which each serve around 5,000 customers (approximately 6,150 connections). The treatment plant, bore fields and main pump station in these schemes have been rated Criticality 2 ('regionally significant').

Other schemes at Clyde, Roxburgh, Naseby, Omakau / Ophir, Ranfurly, Pisa Village and Patearoa supply a further 2,950 dwellings.

Water reservoirs in Cromwell, Alexandra, Ranfurly, Roxburgh and Little Roxburgh Village have been rated Criticality 3 (locally significant) as have the water source and treatment facilities in the remaining schemes.

2.1.15 Clutha District Council

The two largest schemes are Balclutha and Milton:

- Balclutha is sourced from the Balclutha River and has two offsite reservoirs and two smaller onsite reservoirs servicing around 2,000 properties.
- Milton is sourced from the Tokomariro River and has two reservoirs servicing around 1,000 properties including the Otago Corrections Facility.

The Council also runs 16 rural water schemes and 8 small town supplies.

Waste Water

2.1.16 Dunedin City Council

The Tahuna Wastewater Treatment Plant (WWTP) treats around 70% of Dunedin's wastewater, with a smaller wastewater treatment plant at Brighton Road. Tahuna WWTP is a highly critical facility, along with the Main Interceptor Sewer and the Musselburgh pump station which respectively collect and pump most of the City's wastewater to the Tahuna WWTP.

Primary treatment occurs at the Mosgiel WWTP and it is then pumped to Green Island for Secondary treatment. Smaller self-contained wastewater schemes are provided in Middlemarch, Seacliff, Waikouaiti and Warrington.

2.1.17 Queenstown Lakes District Council

Queenstown Lakes District Council provides wastewater reticulation to around 70% of the dwellings in the District, discharging to 4 treatment plants in Wanaka, Hawea, Luggate and Queenstown. The serviced areas include Queenstown-Frankton-Kelvin Heights-Arthurs Point-Lakes Hayes-Arrowtown, Wanaka, Hawea, Luggate and Glenorchy.

The treatment plants at Queenstown, Hawea and Wanaka are rated Criticality 3, along with a number of the largest pump stations.

2.1.18 Waitaki District Council

Waitaki District Council provides 10 reticulated wastewater schemes servicing around 16,000 people.

Of the 28 pump stations in the networks, 3 pump stations in Orwell Street, Beach Road and Regina Lane rate as Criticality 3, servicing between 3,000 and 9,000 people each.

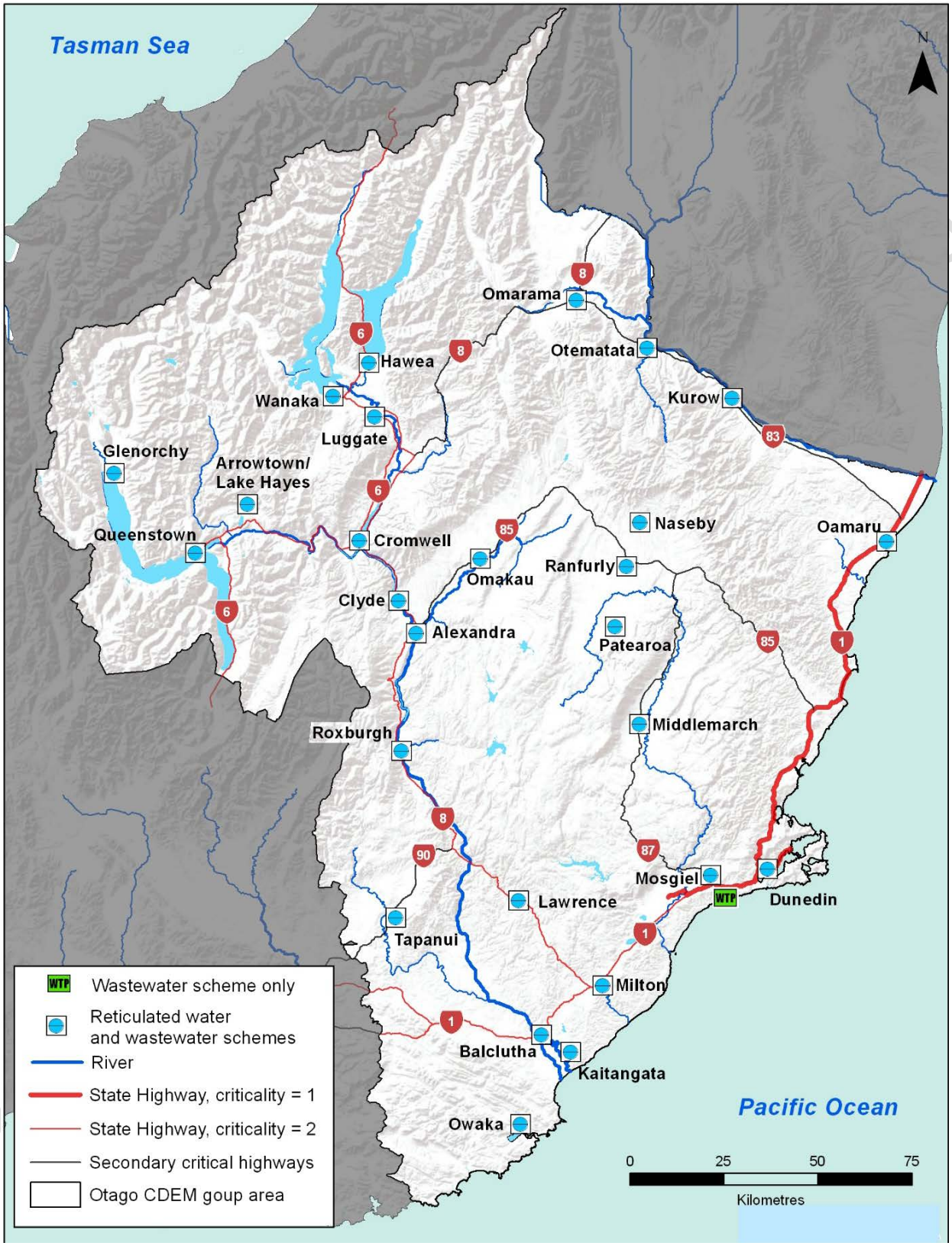
2.1.19 Central Otago District Council

Central Otago District Council provides a reticulated wastewater network to around 7,700 properties in 8 schemes – Alexandra, Cromwell, Bannockburn, Roxburgh, Naseby, Omakau, Lake Roxburgh Village and Ranfurly. From a wastewater perspective, the District's critical sites are the treatment plants in Alexandra and Cromwell together with large and terminal pump stations in those towns. In addition, wastewater pump stations in Roxburgh, Bannockburn and Pisa have been rated Criticality 3.

2.1.20 Clutha District Council

Clutha DC provides reticulated wastewater to around 5,500 properties across 11 wastewater schemes, the two largest being Balclutha and Milton, servicing the same population as the water suppl

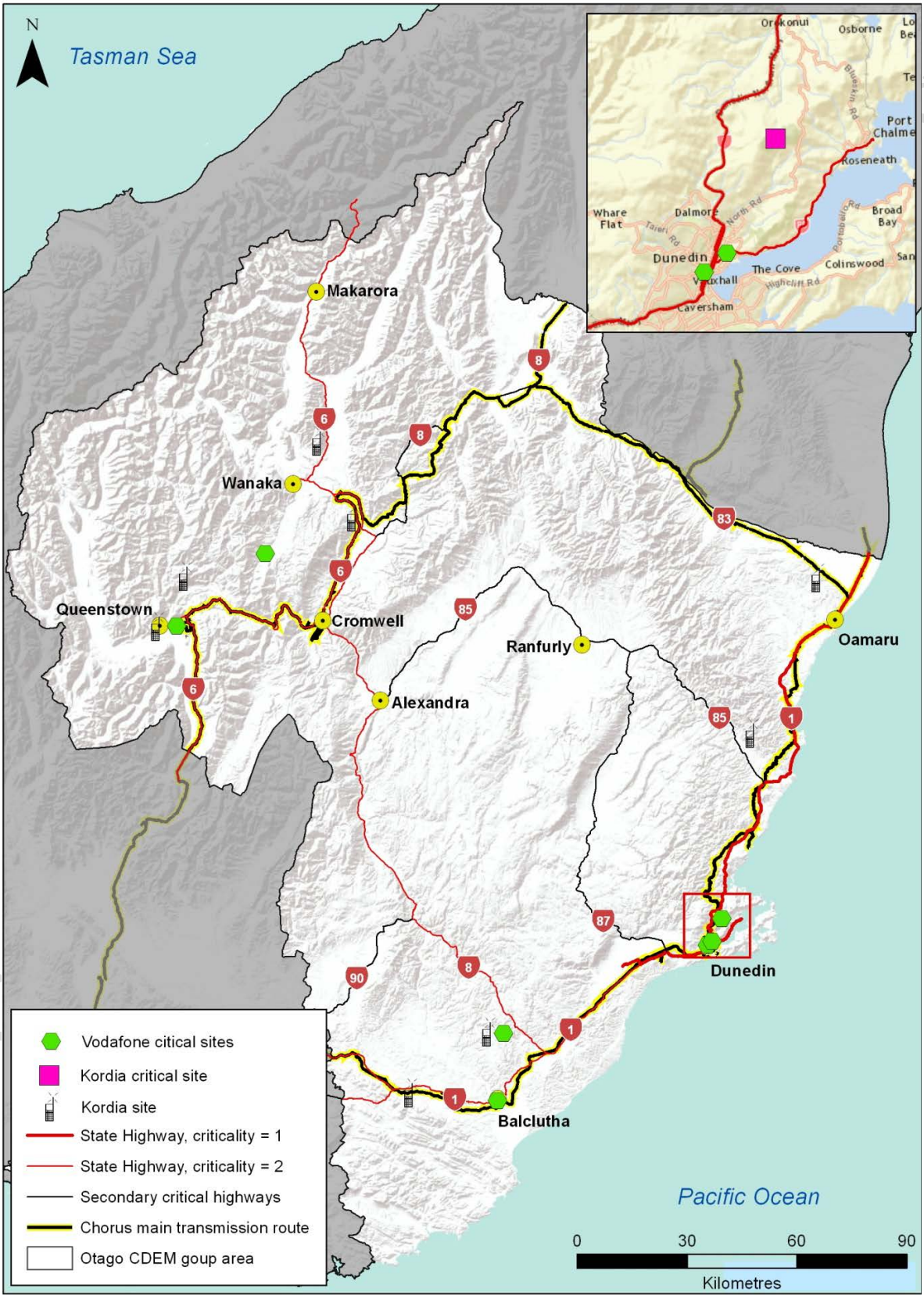
Figure 2.13 Otago's Urban Water Supply and Wastewater Schemes



Telecommunications

The telecommunications sector is one of the most complex of the lifelines sectors, partly because of the rapid change of technology, providers and user preferences, but also because of the level of inter-connectedness between the various providers which share parts of the network and exchange (voice and data) messages between networks.

Figure 2.14 Critical Communications Infrastructure



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 Node** is a Base Station Controller (BSC) for a 2G (GSM) phone or a Radio Network Controller (RNC) for a 3G phone. Transmission links then connect the aggregation point 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.

Exchanges/strong nodes are connected by fibre transmission links. If these links are broken, the network functionality will be severely impacted and they are therefore heavily protected with redundant links and automatic failovers.

Major Exchanges

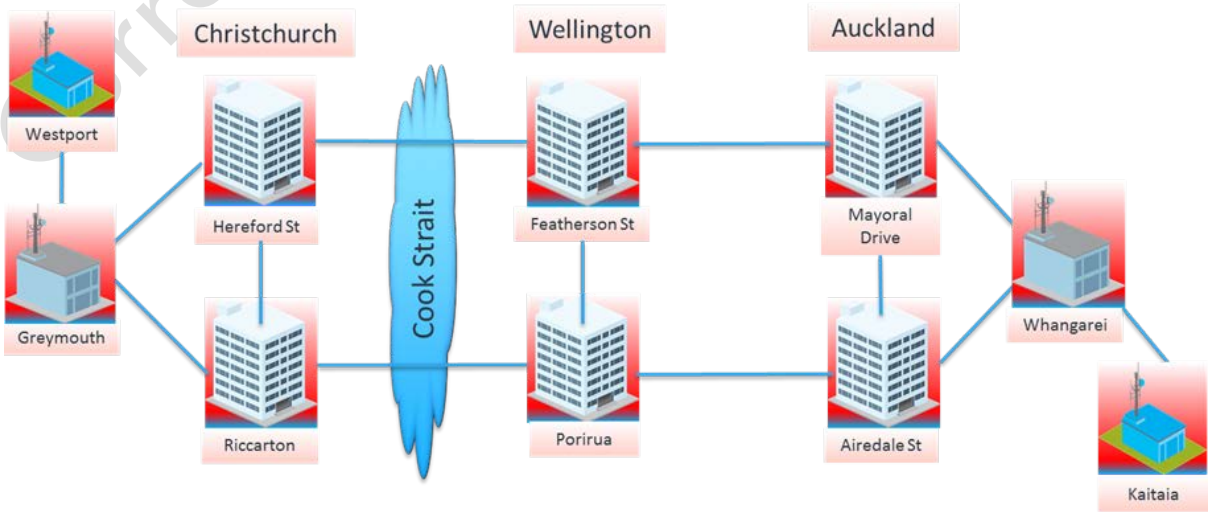
Both Spark and Vodafone's main Exchanges are in Auckland, Wellington, Christchurch and Hamilton. Porirua is another critical exchange for Spark as it is the terminal for Spark's inter-island cable. Chorus retains a core network presence by co-locating in Spark exchanges but it is gradually diversifying 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 **Error! Reference source not found.**). 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).

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



Fixed Line Networks

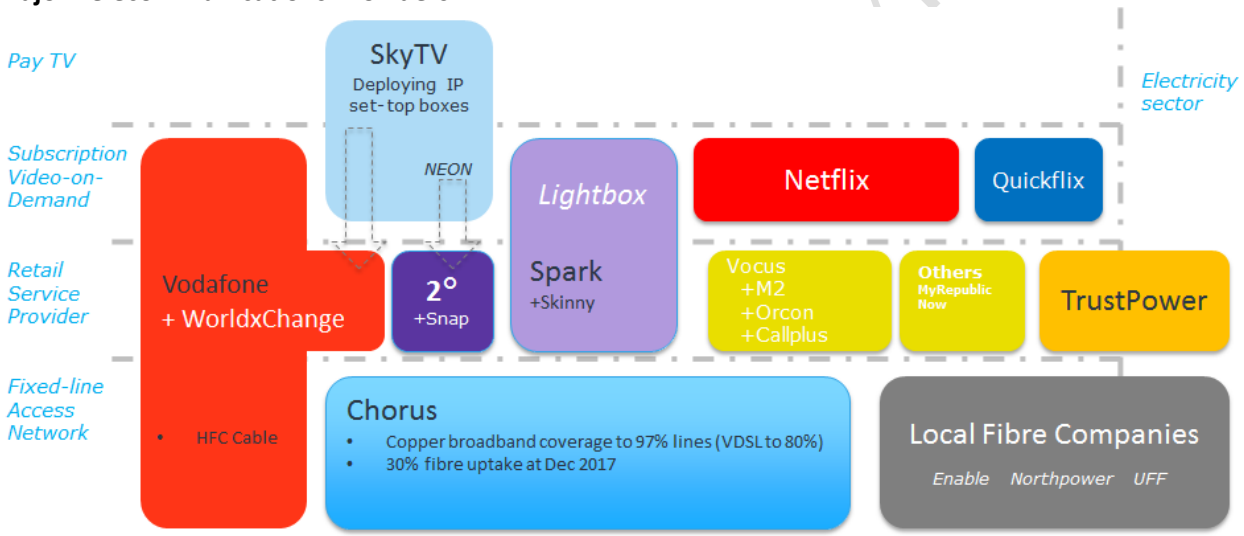
The Otago region is supplied via two main fibre routes – a coastal and inland route shared by a number of providers, shown in Figure 2.14.

Roadside Cabinets are the first aggregation point for Digital Subscriber Line (DSL) broadband connections and connection point for landline phone services.

Telephone exchange buildings (**Local Exchanges**) which operate direct copper pair connections to customer premises. If an exchange becomes isolated from the nationwide network of exchanges, it will 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 Chorus technician at the exchange building.

Links between exchanges are used for carrying long distance traffic such as tolls, fixed to mobile, international, 0800, 111 services etc. These links may be fibre cables, copper cables or microwave radio links. Increasingly, other operators are installing fixed line exchange equipment as local loop unbundling[2] becomes the norm.

Major Telecommunications Providers



Vodafone

Vodafone operates mobile network services in Otago providing 2G & 3G coverage across all of the region's major towns and highways and 4G (LTE) coverage in Dunedin city.

Fixed-line data and voice services for many business customers are provided via the "Blue network" (formerly TelstraClear network).

Vodafone also operates a high capacity fibre-optic transmission ring that passes through Dunedin in the east, south to Invercargill, and up through Queenstown in the west.

Vodafone-branded consumer fixed-line voice/data services are also provided through the region under wholesale from Chorus.

Vodafone have around 60 cell sites providing cellular services in the region and 200 fixed line service sites (exchanges and road side cabinets). They identified 3 sites as 'regionally critical', including:

- The Dunedin POP (Point of Presence) – from where fixed line services into Dunedin are provided.

[2] The process of allowing multiple telecommunications operators to use connections from the telephone exchange to the customer's premises.

- The Balclutha POI (Point of Interface) – provides a voice interconnect between Vodafone fixed-line and other networks in the region.
- North East Dunedin Radio Access Network transmission hub.

Chorus

Chorus provides fixed line services across the region to retail service providers who in turn supply value-add services to customers.

The network consists of a mixture of technologies including fibre, copper and radio and assets include fibre and copper cables and roadside cabinets.

Chorus owns and manages the lines that link from consumers to roadside cabinets, the roadside cabinets, and most of the links between cabinets and key network nodes.

Chorus also has a fibre optic trunk transmission ring that provides connectivity northwards with the rest of the country. The eastern side follows the coast through Dunedin and into Southland, the western side follows the Mackenzie Country, Lindis pass and into Central Otago before heading south along SH6 to Southland. Both sides of this network have elements of shared fibres with other national network providers.

Network control is based in Hamilton, with local contracting companies engaged for network augmentation and maintenance activities.

Spark

Spark owns cellular and landline exchanges plus some fibre trunks and links. Spark exchanges have duplicated processors on each site and there is diversity in the 'daisy chain' networks which allow some exchanges to be fed from the other direction if a cable fails.

Information on the criticality of these cell sites and exchanges was not made available for this programme.

Other Providers

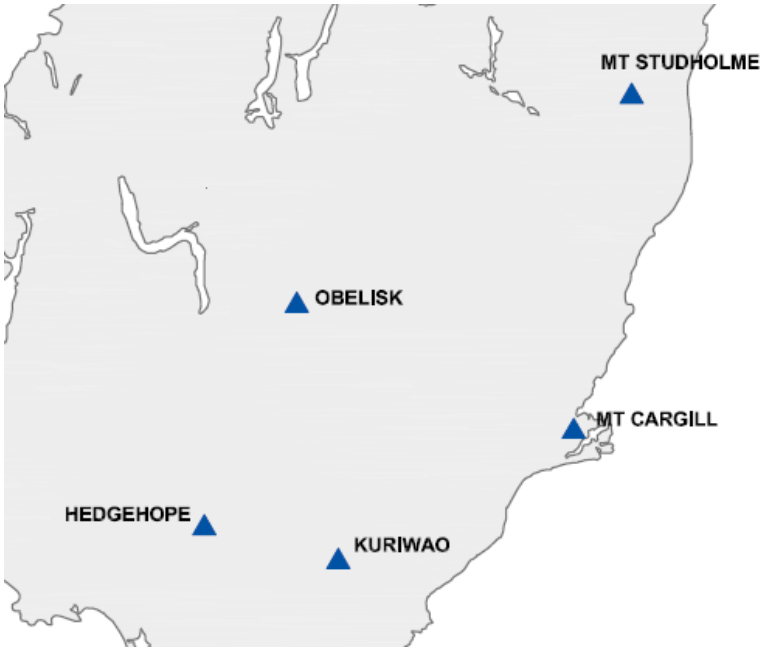
The telecommunications network is becoming more diverse. Other providers in Otago include (but are not limited to).

- 2degrees, which owns a number of cell sites in the region.
- Kordia – historically a broadcasting transmission business (TV and FM Radio) - its business is now 50% telecommunication services including wide area network (WAN), Internet access and phones.
- FX provides a fibre optic trunk network across New Zealand.
- Teamtalk – [provide trunk dispatch radio services (subject to a takeover by Spark))
- Vodafone trunk fibre networks (parallel and in some cases, shared with Chorus and Spark

Broadcasting

Kordia's Mt Cargill Transmission facility in Dunedin's North East Valley is the main broadcast transmission site for Otago providing Freeview Digital Terrestrial Television and all FM radio services. Loss of the site would cause almost total loss of these services in Otago and Southland, rating it as a Criticality 1 site. Other sites include Mt Studholme, Big Hill, Razorback, Otago Base, Mount Stuart, Kuriwao, Obelisk, Queensberry, Mt Maude, Coronet Peak and Queenstowm

Kordia provides a managed environment (watertight, ventilated, and powered) with associated towers (antenna aperture) for others to locate their transmission equipment such as Police, Ambulance, Transpower, Vodafone and Telecom cellular).



Kordia Transmission Sites in mid and Lower South Island

The Mt Cargill site is unmanned and is monitored from the Transmission Control Centre (TCC), located in Avalon, which is a 24/7 operation.

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.

Waste and Debris Spoil

Dunedin City Council

Green Island Landfill Site on Brighton Road, Green Island is the only active landfill site in Dunedin and the main Landfill for the region accepting hazardous waste. Moving putrescible waste (spoil) to landfill would be the first priority in an emergency event. Green Island can take Asbestos and sludges, contaminated soil plus some hazardous biological waste (i.e. dead animals)

Clutha District

Clutha District Council operates the only sanitary landfill in the district at Mount Cooee on the outskirts of Balclutha, on the Kaitangata Highway. Open almost every day of the year, the Mount Cooee landfill accepts most types of waste as well as recyclables and ewaste. This landfill would only be used if the others we inaccessible or expediency was demanded.

Queenstown Lakes District

The Victoria Flats Landfill is located 17km from Frankton on the East Side of State highway 6 between the Victoria Bridge and the Nevis Bluff. Scope Resources Limited is contracted to run the landfill on behalf of the Queenstown Lakes and Central Otago Districts. This landfill would only be used if the others we inaccessible or expediency was demanded.

The landfill which is not open to the public accepts the following from licensed contractors:

- Household Collection Waste
- Transfer Station Waste
- Commercial Waste
- Special Waste and Hazardous Waste.

Other commercial cleanfill sites which may be able to be used in an event are:

- Hall Transport – Kaikourai Valley
- Nash and Ross
- Transfer Stations: Timaru, Oamaru, Queenstown and smaller sites across the region
- Fulton Hogan Cleanfill

3. Lifelines Infrastructure & Sector Interdependence

All lifelines services rely to some extent on some or all of the other lifelines services in order to operate. Therefore, a hazard impacting on one lifelines network is likely to have a knock on effect on others. To mitigate the risk that arises from this interdependence, many lifelines have backup services should the lifelines service they rely on fail such as on-site generators and water tanks.

Figure 3.1 summarises the extent of interdependence between lifelines sectors and the level of backup arrangements in place. The figure reflects the impact on lifelines services following 1 week of outage of another lifelines service, in an emergency response situation. Dependence levels may be different during business-as-usual or during shorter/longer duration outages. It is noted that in some cases there is dependence within a sector. For example, lines companies are dependent on Transpower and local authority road agencies are dependent on NZTA.

2017 Update – Critical Actions

Fuel supply is critical to all – A sustained supply is essential. Stored diesel has a use by date. Each district needs to have a register of fuel storage.

Queenstown's interdependency with Otago needs recognition. Wanaka's interdependency with Otago is the same but less constrained than Queenstown

Plans need to be developed and implemented for back up generation to allow fuel to be accessed from underground tanks in times of major power failure. This is especially relevant for aviation fuel

Communications are also critical to most Lifelines Utilities.

3.1.1 Dependence on Electricity

During normal operations, electricity is the utility that most others are dependent upon, and is required to operate all the other lifeline utilities to some degree. Because of this dependence, most utilities have backup generation at their 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.

2017 Update – Critical Actions

Independent power supply via generator is essential for many of our critical infrastructure and dependent community facilities. A Regional Generator Plan needs to be completed indicating where vulnerabilities are and where generators can be utilized and prioritized for fuel supply.

3.1.2 Dependence on Telecommunications and Broadcasting

A major telecommunications failure is likely to have major impacts on the business sector, however most utilities could continue services at near full capacity without telecommunications in the short term. Some utilities would need to revert to manual operation and monitoring of facilities. Response to service requests would be impaired and there may be a reduction in water supply and wastewater effluent quality.

However the situation changes in an emergency because telecommunications become critical for coordinating response activities. There is a high reliance on the cellular network for voice communications and this network may become overloaded during or shortly after an event. However the copper, fibre and wireless infrastructure (including cellular) provides diversity and is very resilient. Most of Otago's utilities use a combination of the above technologies to monitor their own infrastructure and some have their own dedicated network of links and radio. Broadcasting services also become more critical in an emergency for providing important public information

Figure 3.1 Interdependancy Matrix

Lifelines Sector	*Dependant on*	Air Services	Broadcasting	Electricity	Fuel	Gas	Ports	Rail	Roads	Telecomms	Wastewater	Water Supply	**Comments Note: This reflects the impact on lifelines services following 1 week of outage of another lifelines service, in an emergency response situation. Dependence levels may be different in business-as-usual or shorter/longer duration outage**
Air Services		0	3	2	2	3	3	3	1	3	2	2	Dunedin Airport self sufficient 3-4 days with backup generators for terminal building and control tower plus 500,000l water, and on site wastewater treatment/disposal. Fuel critical but 3-4 days storage and larger aircraft could refuel at destination airports. Road access critical but airport serviced from 3 directions providing alternates if one closed.
Broadcasting		2	0	2	3	3	3	3	2	3	3	3	Mt Cargill Transmission Facility is self sufficient for generators / fuel for 20 + day. Reliance on helicopters for access if there is road closures to sites.
Electricity		2	3	1	2	3	3	3	1	1	3	3	Distributors and generators rely on Transpower network being operational. Fuel, roads and telecoms become more critical in coordinating and emergency response situation. Reliance on helicopters for access if there is road closures to sites.
Fuel		3	3	1	1	3	1	3	1	2	3	2	Can gravity feed or use air compressors/pumps to supply from terminals (could also be used at fuel stations but would be unmetered supply) if electricity failure. Water required at flammable sites (petrol) but self contained water supplies being installed in terminals. All fuel comes in via ship and distributed via roads.
Gas		3	3	2	3	3	1	2	1	2	3	1	Gas comes in via rail and port and is distributed by pipe and road - Fryatt Street is the main road to and from the terminal. Water supply required for fire fighting, though alternatives are sea water pump (if electricity operating) or fire service appliance (if available).
Ports		3	3	1	2	3	0	1	1	2	3	2	Electricity backup on for emergency functions, > 24 hours would have significant impact on operations. 2/3 of cargo is transported to / from the port by rail, the rest by road. Road also required for staff access. Fuel required for ship bunkering. Water supply required for staff but could bring in.
Rail		3	3	2	1	3	3	0	3	1	3	3	Roads critical for transfer of freight and passengers. Electricity critical for network control. Fuel required to operate trains.
Roads		2	3	3	1	3	3	3	1	2	3	3	Main dependency is between NZTA and local road authorities. While traffic lights require electricity, manual traffic management can occur and in other places traffic should revert to normal road rules. Reliance on helicopters for access if there is road closures to sites.
Telecomms		2	3	1	1	3	3	3	1	1	3	3	Require electricity but main sites have generator backup while smaller sites have battery backup that can operate 4-60 hours. Telecommunications network is highly interconnected meaning many telcos rely on other's assets. Roads required for access to sites (or helicopters if roads closed)- more critical in emergenies.
Wastewater		3	3	1	2	3	3	3	1	2	0	2	Dunedin's main Musselburgh PS is the only sewer PS with backup generation on site (diesel). Most PS have emergency storage in dry conditions of between 2 and 8 hours and designed spill structures to discharge overflows safely to waterways. Treatment plants do not have backup generation though some biological treatment would still occur in ponds/wetlands.
Water Supply		2	3	1	3	3	3	3	2	2	3	0	Water pump stations and treatment plants do not have on site generators, relying on treated storage reservoirs (typically holding 1-3 days supply) to maintain supply until electricity restored. Reliance on telecommunications for automated control, loss of which could cause reduction in water quality.

1 – Critical for service to function

2 – Critical for service to function with some back up or part function

3 – Not required for service to function

0 – Not applicable

Critical Community Facility Dependence on Lifelines

Most critical community sectors rely on lifeline utilities to be able to function. This section summarises those dependencies.

3.1.3 Civil Defence

CDEM Agencies operate from the following primary sites in an emergency. Emergency Coordination Centre (ECC) or Emergency Operations Centre (EOC)

- Emergency Management Otago (EMO) ECC – Otago Regional Council Head Office, Stafford Street, Dunedin.
- Central Otago EOC - Council Head Office, Alexandra, with Alternate EOC - Otago Regional Rural Fire Authority Depot in Clyde.
- Clutha District EOC - Council Head Office, Balclutha, with Alternate EOC – South Otago High School, Balclutha.
- Dunedin City EOC – Moray Place, Dunedin, with Alternate EOC – Forsyth Barr Stadium.
- Queenstown Lakes District EOC – Council Head Office, Gorge Road, Queenstown, with Alternate EOC – St John Ambulance Base Frankton.
- Waitaki District EOC – Centennial Building, Severn Street, Oamaru, with Alternative EOC - St Kevin's College, Oamaru.

The City and Districts also have ward or community operating centres within communities to help manage local response in an emergency.

The primary ECC/ EOCs are set up to operate under emergency conditions with necessary facilities including backup power generation, telephone, data, radio and satellite communication systems and provision for catering, etc.

Primary sites are the EMO ECC, Dunedin EOC and Queenstown EOC, rated as criticality 2, all other sites are rated as criticality 3.

3.1.4 Welfare and Civil Defence Centres

Information on key welfare sites in Otago have not yet been collated for this report but The Otago CDEM Welfare Manager will be able to provide this information as part of the Group Welfare Plan completion in 2017-2018.

3.1.5 Health

Dunedin Hospital

Dunedin hospital is a 350 bed tertiary Level 6 facility offering a range of health services which includes Emergency Department, Intensive Care, Neo-Natal Intensive Care and Coronary Care Units, eight main operating and two day surgery theatres. It has modern radiology services, including MRI, CT, Ultrasound, Nuclear Medicine and interventional radiology. Dunedin Hospital also operates a regional helicopter retrieval service. It has backup generators to supply essential power with an estimated running time of up to 95hrs. There are a number of water supplies on site that can provide water for up to 20 hours usage. Stored medical gases on site can provide up to 13 days' supply.

Also based in Dunedin is the 91 bed Wakari Hospital which provides non-acute inpatient; rehabilitation and mental health services.

Lakes District Hospital

Based in Frankton, Queenstown this 15 bed level 2 facility provides services which include an Emergency Department, Day surgery, diagnostic services, acute inpatient care (10 beds) and maternity services (5 beds). Backup power generation can provide up to 71 hours supply. Water storage on site will provide a supply for up to 12 hours.

Other Hospitals

Other hospitals in the region are level 2 facilities:

- Clutha Health First, an 18 bed based in Balclutha, has 15 medical inpatient care beds and 3 maternity beds
- Oamaru Hospital has 24 inpatient beds, an Emergency Department, maternity centre and outpatient department.
- Dunstan Hospital is a 24 inpatient bed hospital located in Clyde.
- Maniototo Hospital is a 15 bed hospital in Ranfurly including 7 elderly hospital level care beds, 6 acute inpatient beds and 2 maternity beds.

These hospitals in general have generators providing essential power supply, fuel storage of 12 – 24 hours, water storage for 24 – 48 hours and several days supply of medical gases on site. Health Services are also critically reliant on lifelines. In particular the transport sector; which include roads and helicopter services, communications and fuel. **Figure 3.2** illustrates the location of these facilities

3.1.6 Police

Dunedin Police Station is the main regional facility. It is self-sufficient for 24 hours through stored water (potable and non-potable for firefighting etc.) and on-site generators. IT provide backup communication systems and all repeaters have battery backups.

Smaller police stations in the region do not have backups for lifelines services but would rely on portable power generators, bottled water, etc. **Figure 3.3** illustrates the locations of Police Stations

Stations are located at:

- Oamaru
- Balclutha
- Queenstown
- Alexandra
- Wanaka
- Mosgiel

3.1.7 Ambulance

No further information was provided for this programme but it has been identified that fuel, roading and communications are critical this service. **Figure 3.4** illustrates Ambulance Service locations

3.1.8 Fire

The Fire and Emergency New Zealand (FENZ) has 47 fire stations located throughout Otago in most of the urban centres. Dunedin Central Fire Station houses the Region Headquarters. Located within this building is the Region's Coordination Centre, a facility that allows executive oversight of emergency operations. The Coordination Centre is equipped with a suite of communications technology.

Key functions at the Dunedin Central Fire Station are supplied with an uninterrupted power supply (UPS) and emergency power is supplied by a large diesel powered generator. All other stations have been modified or built to be capable of receiving generator input for emergency power. All fire appliances carry portable generators with a 2 – 2.5 kVA capacity. Limited supplies of drinking water are also carried on each fire appliance.

Radio communication is primarily conducted on the Land Mobile Radio Network (LMRN), a shared network with New Zealand Police. All fire stations have emergency battery back-up for their station based radios. All stations are responded to by one of the 3 Communications Centres located in Christchurch, Wellington and Auckland. Fall back capability is maintained in the Region's Coordinations Centre at Dunedin Central Fire Station.

As with all emergency services, road access is critical for the Fire and Emergency New Zealand. **Figure 3.5** illustrates FENZ locations.

3.1.9 Corrections

Otago Corrections Facility is located in Milburn, South Otago. The prison houses low to medium-high security inmates and has a maximum capacity of 485. Water for the Milburn facility is drawn from the Clutha DC Milton water treatment plant and the prison has an estimated storage capacity of two days. No information was available on dependency on lifelines services.

Figure 3.2 Health Facilities

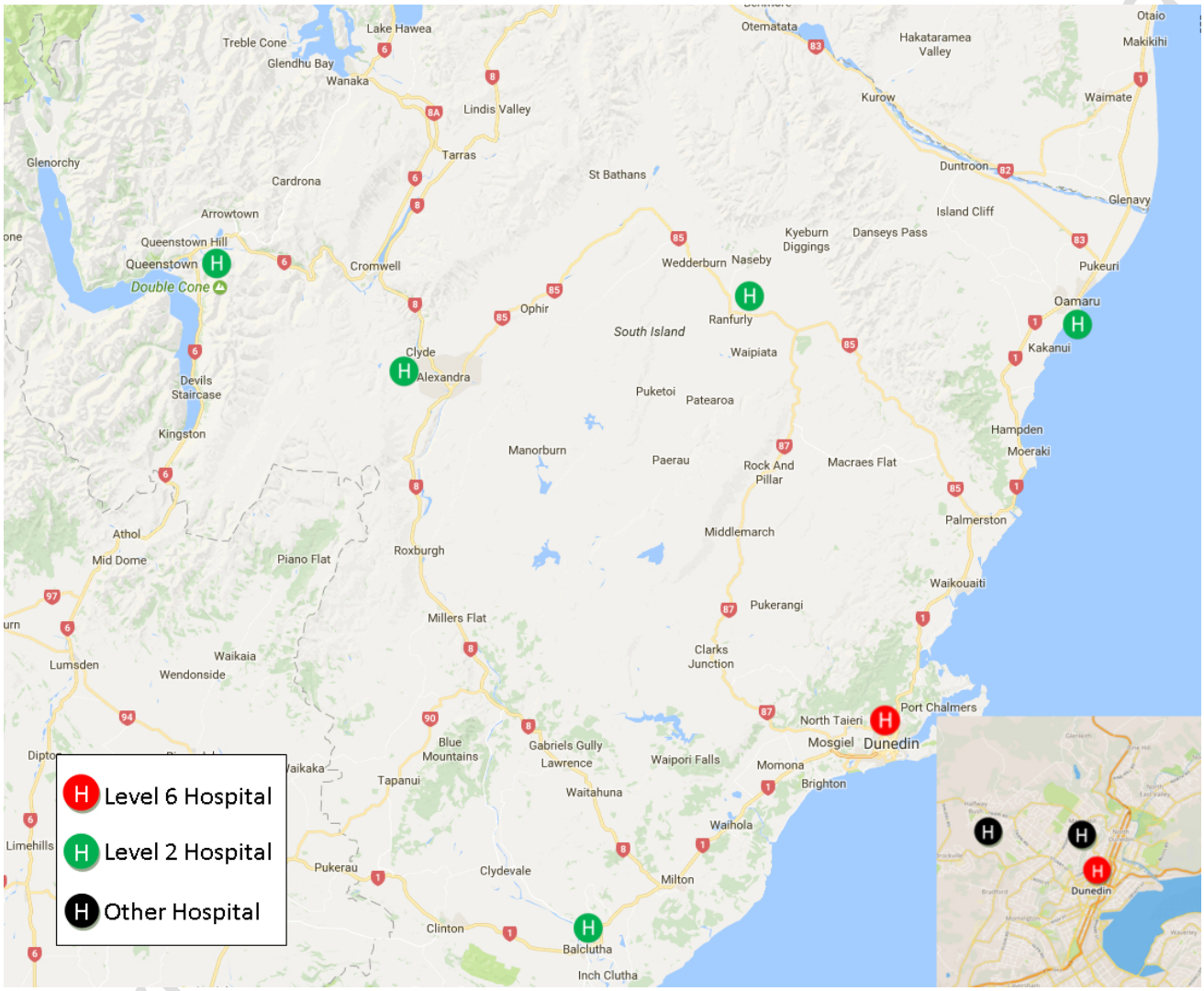


Figure 3.3 Police Stations in Otago

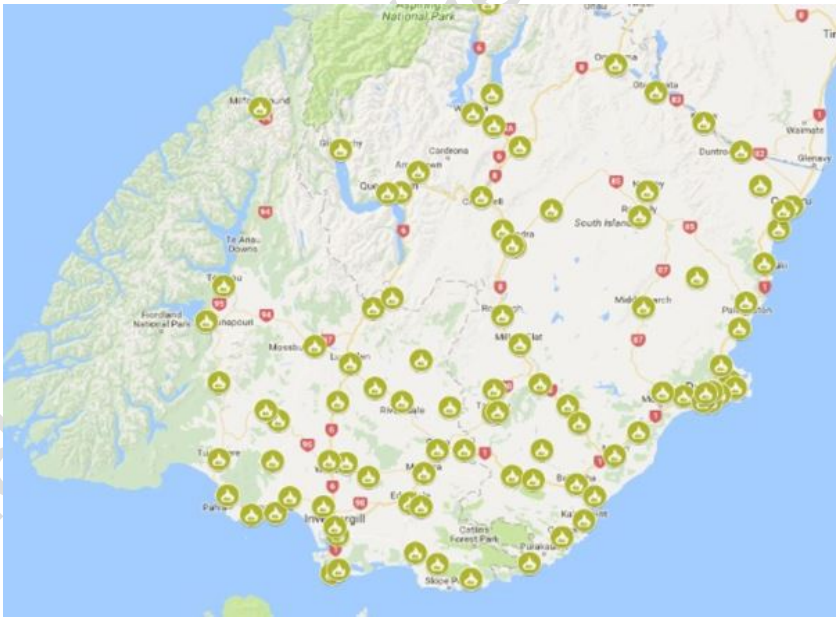


Figure 3.4 Fire Response Stations

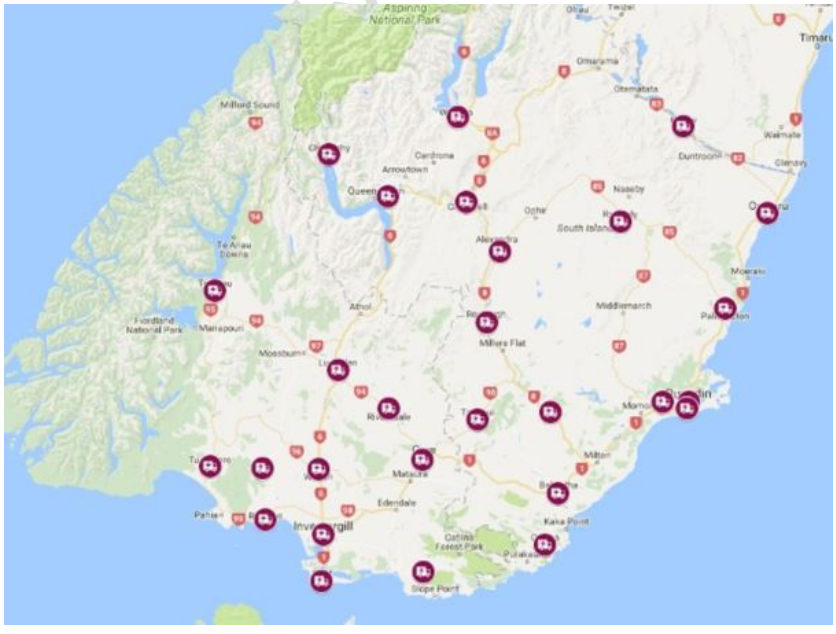


Figure 3.5 Ambulance Stations

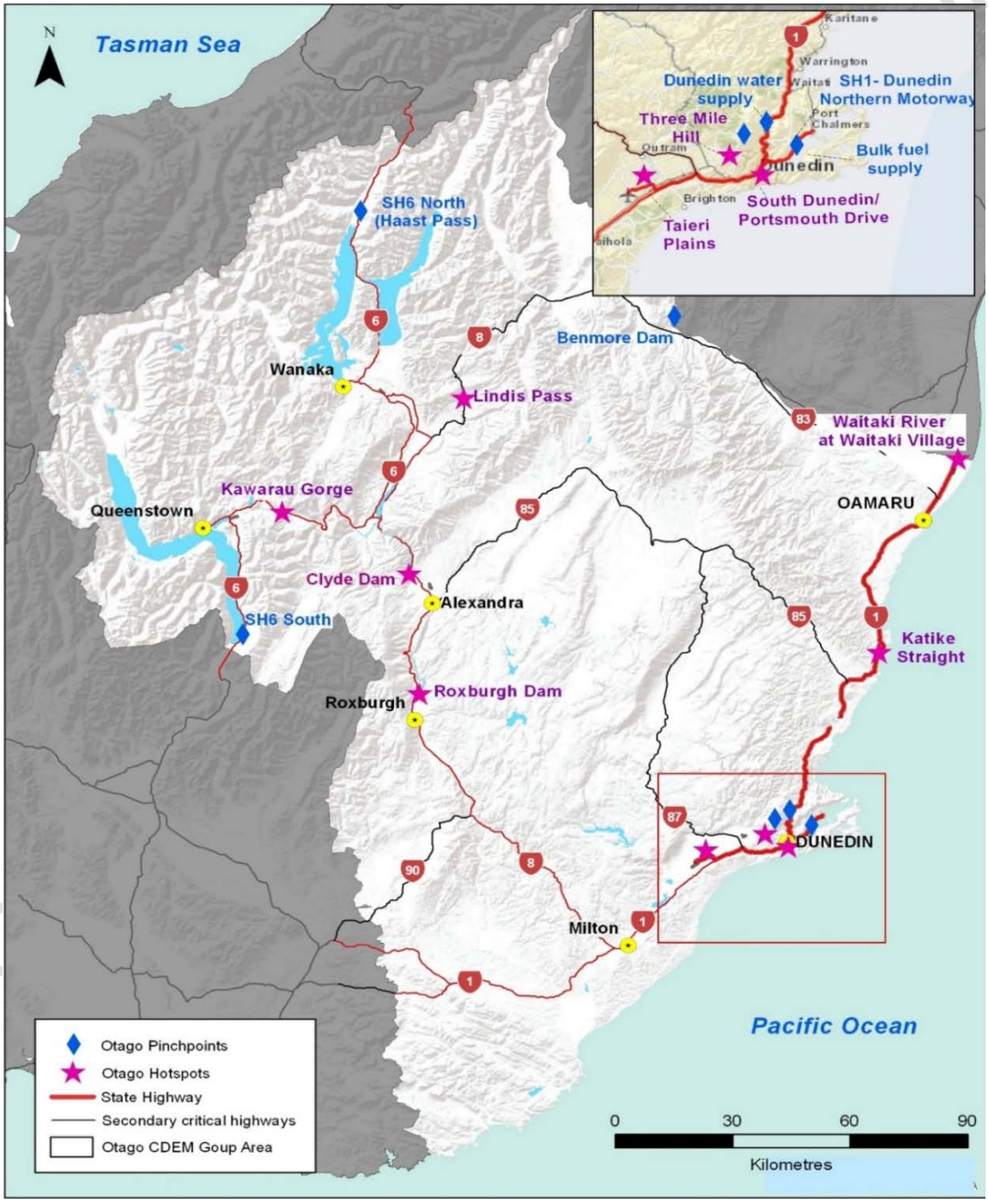
4. Infrastructure 'Hotspots' and 'Pinchpoints'

Hotspots

Figure 4.1 illustrates the location of the hotspots in the Otago Region where a number of critical lifelines infrastructure assets converge and are in a hazardous area (i.e. where they overlap with hazard zones mapped by ORC). The hotspot area may be a specific site (e.g.: the Waitaki Bridge), a line or route (e.g.: the Kawarau Gorge) or a larger area impacted by a single hazard (e.g.: South Dunedin, Taieri Plain). **Fuel supply is completely reliant on Roads and Air.**

Figure 4.1 Otago Region's Infrastructure Hotspots: *Hotspots are defined as areas where there are:*

- *A number of critical infrastructure assets from different sectors converge in a single area.*
- *Significant single points of failure for a network or organisation (also called 'pinchpoints').*



Hot Spot Roads:

SH1	Waitaki River Bridge
SH1	Katiki Coast
SH1	Kilmog/Northern Motorway
SH86	Dunedin Airport
SH88	Dunedin to Port Chalmers
SH6	Haast Pass to Hawea
SH6	Kawarau Gorge
SH6	Frankton to Kingston
SH6a	Frankton to Queenstown
SH8	Lindis Pass
SH8	Cromwell Gorge/Clyde Dam
SH8	Cromwell to Milton (Manuka Gorge)

All Central Otago Roads are critical infrastrucutre as Cromwell can be a staging point if Queenstown affected.

4.1.1 South Dunedin/Portsmouth Drive

The low lying South Dunedin and harbourside area is at risk of flooding (either due to runoff from the surrounding hills or groundwater ponding from an elevated water table in South Dunedin), storm surge, tsunami and liquefaction and contains a number of critical utilities, including:

- The South Dunedin sub-station GXP which services 17000 customers.
- The Tahuna wastewater treatment plant and the Musselburgh pumping station which pumps Dunedin's wastewater to the treatment plant.
- The main telecommunications exchange.
- Subsidence concerns during liquefaction in South Dunedin Sub Station

Future mitigation plans:

- Delta is evaluating a project to link the Halfway Bush and South Dunedin substations to provide back-feed options if the South Dunedin substation is not operating.
- A Dunedin City Council project is underway to assess the potential impacts of sea level rise around this area and exacerbating impacts on other hazards (storm surge, flooding).

4.1.2 Kawarau Gorge

The Kawarau Gorge has numerous locations prone to alluvial fan activity, rock fall and landslides, many of which interact with the areas of appreciable seismic risk.

The electricity transmission lines to Queenstown run along or near the Gorge as does SH6 and the main fibre cable owned by Chorus.

SH6 through the Kawarau Gorge is the main road route from Cromwell to Queenstown with alternative State Highway routes adding around 4 hours to the journey.

Without Transpower's transmission lines operating, the local generation in Queenstown would be redundant as there is no blackstart capability.

Future mitigation plans:

- Transpower is developing contingency plans that would enable quick replacement of structures and lines, but restoration is still likely to be some days to weeks if there is major road and transmission damage due to the hazards described above.

4.1.3 Roxburgh Dam

With Transpower's Roxburgh substation/switchyard and three major electricity transmission lines through the area, this is a key electricity hub for the South Island. Loss of the switchyard would cause significant disruption to electricity supply in the South Island, though the criticality of the transmission lines depends on the time of year (demand is high in winter and the Aurora transmission lines through the area do provide some diversity).

SH8 passing by the Dam is also part of the key roading route from Dunedin to Cromwell (the alternative route of SH 85 adds at least another 30 minutes to the journey)

The main risks to the area are landslides, with ongoing monitoring of those located on the slopes above Lake Dunstan.

4.1.4 Waitaki Bridge

The Waitaki Bridge area is at risk from flooding from the Waitaki River, tsunami and liquefaction during an earthquake. SH1, Transpower overhead transmission lines, the Chorus fibre cable and the main South Railway line all pass over the river in close proximity.

The alternate route to SH1 via Kurow adds 1.5 hours to the journey

4.1.5 Haast Pass

The Haast Pass is a key inter-regional link to the southern portion of the West Coast and becomes increasingly mountainous and remote around the divide. The area is prone to tree fall due to strong winds, snow, ice and heavy rain. There are significant areas of rockfall hazard around the shores of Lake Wanaka and the upper reaches of the pass. Heavy rainfall can result in several creeks and streams crossing the highway, depositing a significant amount of material.

4.1.6 Lindis Pass

Significant assets crossing the Lindis Pass include one of two Chorus fibre cables supplying Otago, SH8 and Transpower transmission lines. The area is most vulnerable to snow due to its altitude but parts of the road can be affected by flooding and alluvial fan activity during times of heavy rainfall. A number of landslides are mapped over the Pass and strong seismic shaking may trigger them.

The State Highways linking to the north of the Lindis Pass (SH8) and to the south of Queenstown (SH6) are vulnerable to landslides while en route to the West Coast the Haast Pass (SH6) can be ~~a~~ difficult to access in certain conditions

4.1.7 Taieri Plain

Assets on the Taieri Plains include SH1 and SH86, Kiwirail's main trunk railway line, Dunedin International Airport, critical Transpower transmission lines and Berwick Switchyard and transmission lines connecting Trustpower's Mahinerangi power generation assets to the grid.

Many of these assets rely on the Taieri flood protection and drainage schemes for flood protection, however larger 'super-design' events are still possible and could potentially inundate large amounts of the Taieri Plains. The basin is bound by active faults to the north and south and consists of fine silts and sands that are potentially susceptible to liquefaction.

West Taieri is especially low-lying and may be affected by tsunami and storm surge events that restrict the passage of water down the Taieri River during high flows. Alluvial fans and landslides have been mapped on the margins of the Taieri Plains, although most assets are sufficiently set-back from slopes to be directly affected.

Future mitigation plans:

- ORC have an on-going programme of work to ensure there is backup generation available at pump stations across the Taieri.

4.1.8 Katiki Strait

Assets passing through this area include SH1, Transpower overhead transmission lines supplying areas from Waitaki to Oamaru and Chorus's trunk telecommunications cable.
This area is most susceptible to coastal hazards including coastal erosion, storm surge and tsunami and will be increasingly affected by such hazards under predicted future sea level rise.

4.1.9 Three Mile Hill – Dunedin

Three Mile Hill is a critical road route into Dunedin from the south, as well as having Transpower transmission lines and a switchyard supplying a significant portion of Dunedin's electricity. Three Mile Hill is most susceptible to closure due to snowfall and ice.

4.1.10 Clyde

Clyde is a significant electricity hub as well as having SH8 passing through the area. The Clyde switchyard feeds power into the National Grid for the supply of electricity North or South as well as supplying the local distribution network from Alexandra to Raes Junction and out towards the Maniototo. There is some local generation (Pioneer) which can supply a small area. Clyde PowerStation has the ability to Black Start in case of a total South Island national grid blackout.

Pinchpoints

Pinchpoints are significant areas for single sectors, in comparison to hotspots where multiple sectors' assets converge.

4.1.11 Bulk Fuel Supply – Port of Otago

The Port of Otago is the primary export port for the region and all of the region's fuel comes in via the Port. Therefore the oil and gas wharves, oil and gas terminals and oil pipelines provide a single point of supply into the region. However, ports in other regions provide alternative routes of supply (Lyttleton oil and gas, Timaru oil, Bluff), mitigating the potential regional impact of a closure of Port Otago.

4.1.12 Dunedin Water Supply

At present, the city is highly reliant on the pipelines that bring water from the Deep Creek/Deep Stream sources. The pipeline is vulnerable to a number of hazards – passing through both landslide and liquefaction prone soils. However network upgrades are underway to provide diversity and mitigate the risk of failure of those pipelines.

4.1.13 Regional Telecommunications

The two fibre cable telecommunications routes that connect Otago and Southland with the rest of the world cross major river systems that stretch from the Southern Alps to the coast; the Waitaki River on Otago's north coast and the Clutha/Mat-Au River to the west. The extent of service disruption will depend on the level of diversity around the location of where the cable fails.

4.1.14 State Highway 8

SH 8 is a key regional transport route and the main route from Christchurch to Queenstown. It is highly vulnerable at several points to slips and flooding and the alternate route is via SH1/SH85 which adds approximately 1 hour to the journey.

4.1.15 Benmore

Benmore is a key electricity hub for the South Island, as discussed in more detail in Section 2.2.2. It is potentially vulnerable to direct seismic damage to dam/equipment and overtopping due to tsunami caused by upstream landslip.

4.1.16 Dunedin's Northern Motorway

Dunedin's Northern Motorway is a critical transport route and is vulnerable to landslides and snow/ice. There is alternate access via the Mount Cargill route, but these may be unsuitable for larger vehicles. Kilmog Hill, north of Waitati on SH1 is also vulnerable to landslides and snow/ice. The alternate route via Coast Road (along the coast) is suitable for light vehicles, but also has a number of mapped, active landslides present

5. Infrastructure – Hazard Risk Assessment

Figure 5.1 illustrates the extent to which various asset types are vulnerable when the assets intersect with hazard areas (e.g. tsunami inundation areas). It does not represent the probability or extent to which these assets intersect with hazards in the Otago region – that is discussed in the remainder of **Section 5.** *This is only intended as a quick and broad guide to the risk assessment as impacts will differ according to the scale of the event.*

Figure 5.1 Potential for asset damage by various hazards

1	*Unlikely to cause damage post event*
2	*Possible damage, short term repair (days)*
3	*Possible damage, long term repair (weeks/months)*
4	*Complete failure - full reconstruction required.*

	Flooding	Landslip	Winds	Equake	Tsunami	Snow
Electricity						
Electricity transmission lines - overhead	1	3	2	2	1	2
Electricity distribution lines - overhead	2	2	3	3	3	3
Electricity Substations / Switchyards	3	3	1	2	3	1
Underground electricity cables	2	3	1	3	2	1
Fuel						
Storage Tanks	2	1	1	3	2	1
Pipelines	1	1	1	3	2	1
Transport						
Roads	2	4	1	3	2	1
Bridges	4	4	1	4	3	1
Wharves	1	1	1	3	3	1
Airport	3	1	1	4	2	2
Rail lines	3	4	1	3	3	2
Water Supply						
Pipelines	2	4	1	3	1	2
Pump stations	3	4	1	3	3	2
Water treatment plant	3	1	1	3	4	2
Wastewater						
Pipelines	2	4	1	3	1	1
Pump stations	3	4	1	3	3	1
Water treatment plant	3	1	1	3	4	1
Gas						
Pipelines	1	2	1	2	1	1
Storage Tanks	2	1	1	3	2	1
Telecommunications						
Transmission tower	2	3	3	3	3	3
Cell sites	2	2	2	2	2	2
Roadside cabinets	2	2	2	2	2	1
Exchanges	2	2	3	3	2	3
Fibre cable	2	2	1	2	2	1

Hazard Impacts on Lifelines Infrastructure Assets

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).

The Otago CDEM Risk Register was completed in early 2017 and included non-natural hazard risks and some of the regional businesses that contribute to a prosperous region i.e. Agriculture, Fruit Growers, Viticulture, Academia. The Risk Register supports this programme as a linked but separate document

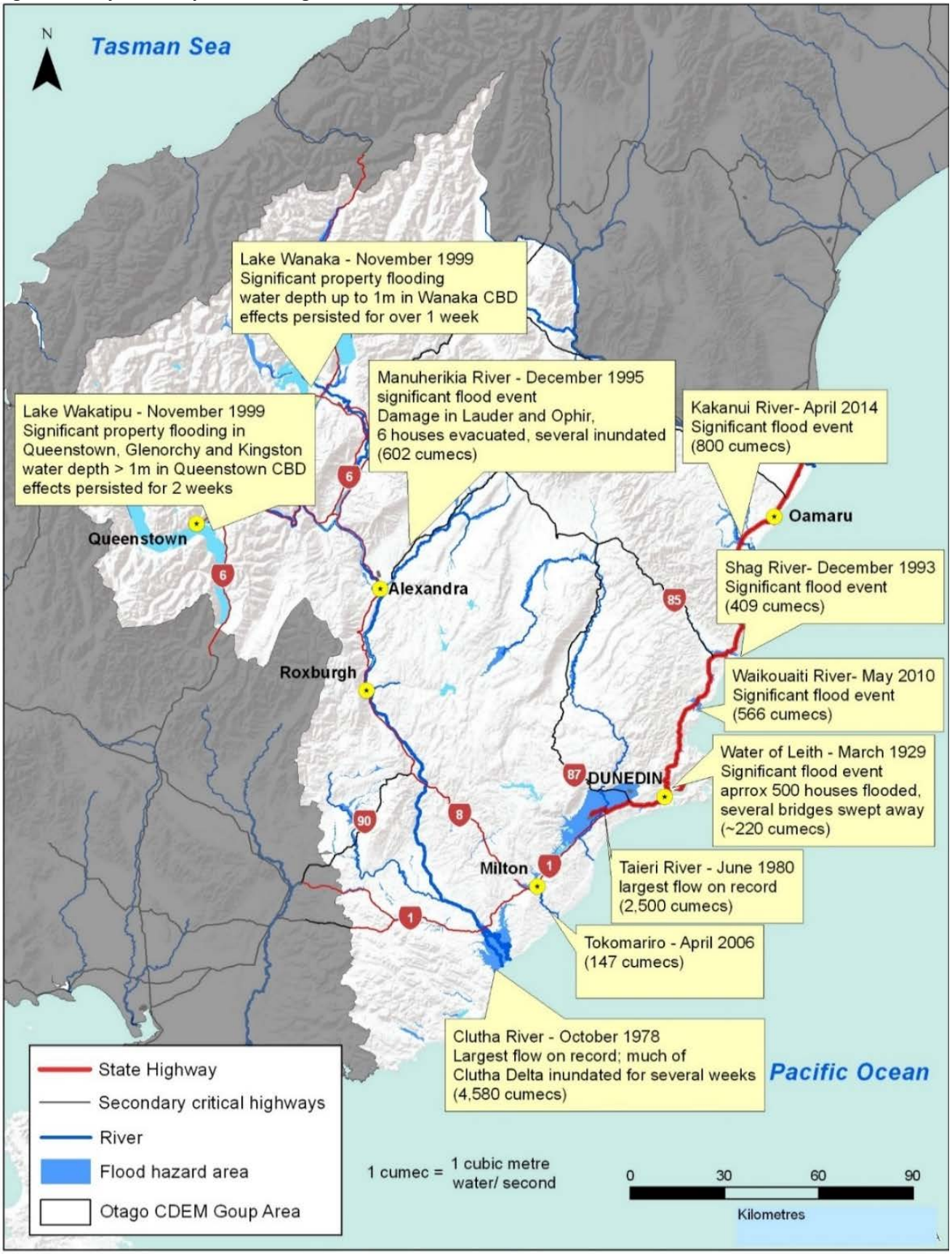
As this section predominantly focusses on the natural hazards assessed for this programme, this has been drawn from information held by the ORC. Each hazard has been described separately but it is important to note that many have common triggers (such as heavy rainfall or seismic shaking) and that they interact, e.g. a landslide or debris flow from an alluvial fan may block a channel, exacerbating the effects of river flooding. The assessment considers the impacts of hazards primarily on the region's most critical assets.

Storm /Flood

5.1.1 An Overview of the Hazard

The term flooding describes spilling of water from a stream, river or lake onto the surrounding land, or surface runoff associated with heavy rainfall events. Both shallow, high-velocity and deeper, slow-moving floodwaters can cause significant damage to buildings, roads and infrastructure in Otago. Sediment and debris often become entrained in floodwaters and can exacerbate the effects of flooding by blocking flow paths and further damaging bridges, roads and structures. ***Figure 5.12*** shows some of the major river systems in the Otago region and significant historical flooding events.

Figure 5.2 Major River Systems in Otago



The flooding of November 1999 is an example of a large flood event originating in the headwaters of Otago. Lakes Wakatipu and Wanaka inundated the low-lying parts of lakeside communities for over two weeks.

Consideration must be given to the fact that the Clutha River spans over three districts within the Otago Regional and the Waitaki River is shared between South Canterbury and Otago regions.

The flood hazard areas mapped by the ORC and used in this study show land which is at risk of inundation due to flood events in rivers and lakes and does not include flooding due to overloading of the urban storm water network, or inundation associated with coastal processes such as storm surge or tsunami (these are discussed separately in **Section 0**). Although not mapped in detail, surface runoff during heavy rainfall events can present a serious hazard, especially when it is concentrated into natural drainage features (swales, or overland flow paths).

The source documents for mapped flood hazard areas vary across the region, and use observations from past events, flood modelling, geomorphic characteristics (e.g. identification of the flood plain using geology and topography) and a number of other investigations.

5.1.2 Electricity

Distribution lines are unlikely to suffer damage from floodwaters. Individual power poles may be affected by bank erosion and impact of debris during flood events, although these effects are likely to be localised. The biggest potential for damage is at substations or switchyards where control rooms are inundated with the potential for days to weeks for full restoration of services for larger substations. Critical sites in flood risk areas include:

- South Dunedin substation (loss of supply to South Dunedin)
- Clyde (loss of supply to Alexandra) and surrounding areas.
- Mosgiel Zone substations (has been threatened in the past but the risk was mitigated using temporary barriers).
- Aurora's underground substations in the Dunedin CBD, though systems are in place to manage this.
- Oamaru-Transpower lines, Lower Waitaki.

All large dams are operated to minimise the risk of floodwaters overtopping dams and are designed to withstand the probable maximum flood (PMF). Damage to the switchyard and power house are possible if overtopping does occur.

5.1.3 Fuel and Gas

The fuel and gas terminals in Dunedin are in a flood prone area and would be exposed to slow-moving floodwaters if the Water of Leith were to overtop its banks during a large super-design event, as was the case in 1923. However it is expected that water on the fuel terminal sites would be ponding rather than fast flowing and therefore unlikely to cause damage or wash away the tanks. If the tanks are empty, the main risk would be the possibility of the tanks lifting off their bases.

The assets considered most at risk are the pipelines from the fuel wharf to the fuel terminal tanks, which cross the Water of Leith on a Kiwirail bridge.

5.1.4 Water Supply

Water supplies sourced from rivers are likely to have water intakes disrupted during floods on those rivers. However the local authorities that own these supplies note that supply can be quickly restored once flood water recede and major damage to assets is unlikely.

Some water treatment plants are also in flood prone areas, including Balclutha and the Mosgiel and Taieri bores (Dunedin). These are typically bunded to protect against an estimated 1:100 year event. Larger flood events have the potential to inundate the treatment plant areas and may cause service disruption and damage to plant.

5.1.5 Wastewater

Wastewater pump stations are often in low lying or coastal areas as they typically receive gravity fed wastewater and pump this to treatment plants. The impact of flooding of pump stations is that flood waters will be contaminated with wastewater, however whether asset damage occurs depends on the pump station design. All areas have some pump stations in flood prone areas, the larger pump stations likely to be impacted include:

- Musselburgh pump station (Dunedin)
- Mosgiel Wastewater treatment plant and transfer station (Dunedin)

There are also a number of treatment plants in flood prone areas – again, by their nature, these sites are often close to waterways. However other than temporary disruption to treatment capacity and contamination of flood waters, major damage from flood waters is not expected and, if there is some minor damage, service can expect to be restored within a few days.

5.1.6 Telecommunications and Broadcasting

Buried cables are at risk where they surface to cross waterways. Failures occur typically at bridge abutments and from river channel scouring.

There are also a number of key nodes that are vulnerable to flood events, including Oamaru (Oamaru Creek flooding), Alexandra (Manuherekia River flooding) and Balclutha (Clutha River flooding).

The main exchange in South Dunedin is also in a flood prone area, and this site hosts a number of smaller sites supplying outside the South Dunedin area as well.

5.1.7 Transport – Roads

Almost all State Highways have sections of road within flood risk areas (**Figure 5.2**).

Historic events have shown that the most vulnerable roads include:

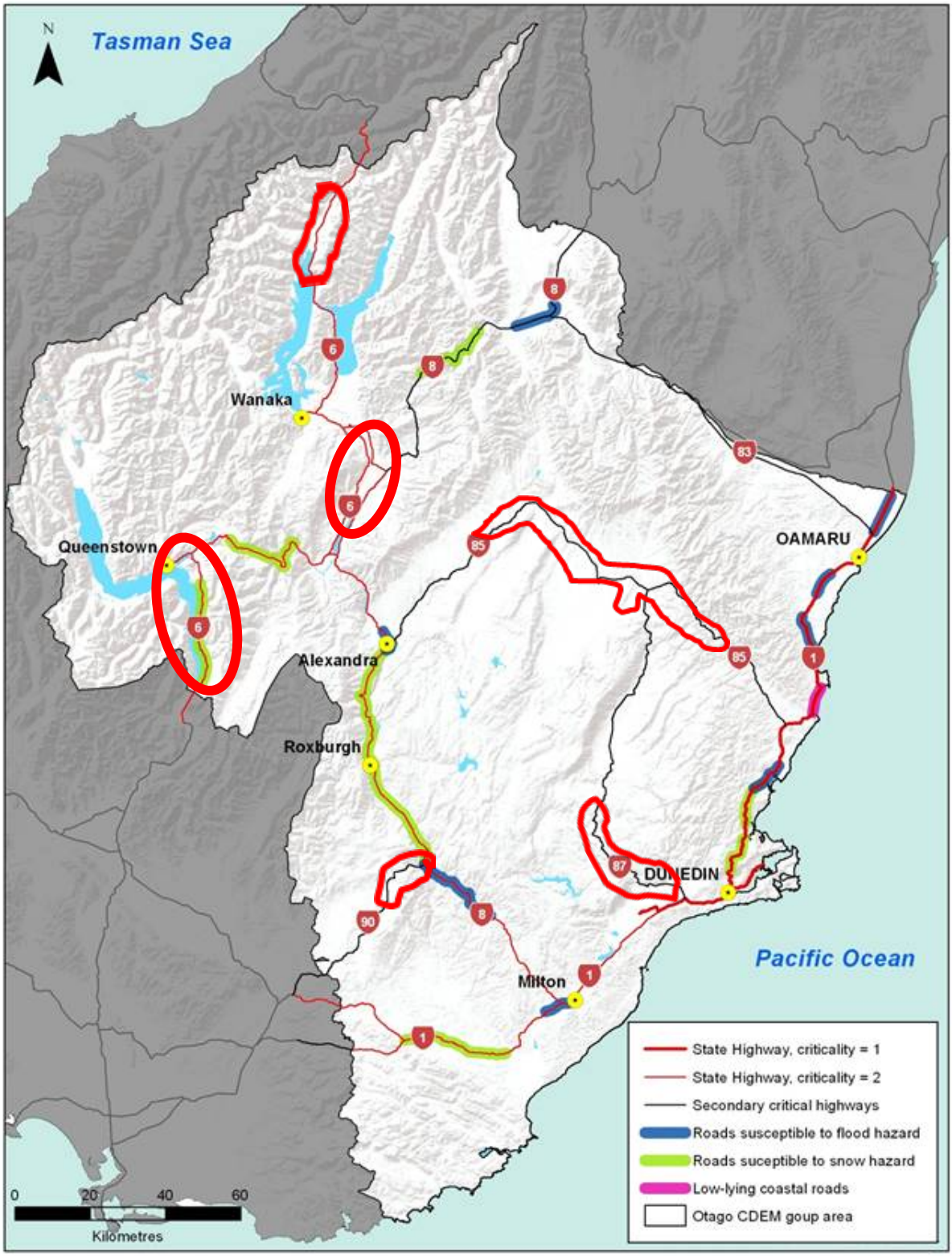
- five sections of SH1 - Hilderthorpe area, North of Maheno, north of Hampden, south of Waikouaiti & south of Milton.
- three sections of SH8 – Lawrence to Raes Junction, Alexandra and Omarama Stream

Flooding would typically result in localised impacts only with minimal damage expected after flood waters have receded. Worst impacted areas are typically where the road crosses a waterway so bridges tend to be more vulnerable. Storm events often cause landslides, as discussed in **Section 0.**

5.1.8 Transport – Other

A flood in the 1980s closed the Dunedin Airport for 6 weeks. However flood protection works have improved since then and all operational facilities are located on the second floor. The Taieri flood protection scheme and the associated West Taieri drainage scheme are designed to provide protection against a flood with a 1:100 year return period (approximately 2,500 cumecs at Outram). Larger super-design events beyond this can potentially affect large parts of the Taieri Plains. The ORC is currently implementing plans to install backup generation at all pump stations on the Taieri.

Figure 5.2 State Highways Vulnerability to Snow and Flood Hazards



SH6 (Haast Pass) and large parts of SH85/SH87/SH90 are prone to snow hazard but are predominantly secondary critical highways. The road to Glenorcy, Crown Range Road are special purpose roads (high tourist use) so a type of highway in effect. The Cromwell to Alexandra road is critical as Alexandra could serve as a backup airport to Queenstown

Storm / High Winds

5.1.9 An Overview of the Hazard

Strong winds can occur under a number of different atmospheric conditions, including strong north-west winds lasting from 6-10 hours generated from a deep trough advancing across the Tasman Sea squeezing against an intense blocking anticyclone to the east of the South Island. Another high wind scenario is short (less than one hour) but extreme southerly wind gusts associated with a rapid progression of cold air up the eastern coast of the South Island. Average annual wind speed maps identify areas more likely to experience high winds, such as higher altitude and coastal areas. Wind speeds may be significantly larger than average values during a storm or period of high winds.

5.1.10 Electricity

Transpower's transmission towers, poles and lines are designed to 200km/hr winds, and can typically withstand even higher. It is more common for damage to occur to conductors, but this is generally not widespread and, if there is access, a fix can usually occur within 24 hours.

The local networks are typically designed to AS/NZS 7000, designed for around 900-1200Pa or 160km/hr. There is expected to be widespread impacts in a significant wind event, with events in the last few years illustrating days to weeks restoration time can be expected (typically the lines servicing individual properties in isolated areas are the last to be restored). Inadequate tree regulations are widely considered by the industry to be a major issue in that respect, in that landowners are required to maintain tree drip lines away from the lines but the trees may still provide a fall hazard. However lines companies do actively manage this through pole and vegetation management practices.

5.1.11 Telecommunications

Chorus operates a number of elevated radio sites. These do suffer damage due to high winds but typically damage does not affect services. Repairs can be made once conditions allow. The major effect on Chorus' services will result from loss of power.

5.1.12 Roads

Roading assets are not likely to be damaged by high winds (other than perhaps large signs, street lights and signal poles) however they may be blocked by falling trees and other debris and some vehicles may be unable to operate safety (motorcycles, large sided vehicles).

5.1.13 Other Infrastructure Impacts

High winds are unlikely to directly damage assets in the fuel, water, gas and transport sector. Any impacts will arise from knock on impacts of failure of other lifelines sectors described above.

Some facilities may be temporarily unable to operate safely (e.g.: port and airport) which in turn may impact on other sectors such as gas and fuel.

Tsunami / Storm Surge

5.1.14 An overview of the hazard

Tsunami

A tsunami is a natural phenomenon consisting of a series of waves generated when a large volume of water in the sea, or in a lake, is rapidly displaced (Power, 2013). Low-lying land near the coast and lakeside communities are most vulnerable to the effects of tsunami, although harbours, offshore islands and headlands do afford a degree of protection.

- 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.
- 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.

Local tsunami sources such as landslides into lakes or embayments or the displacement of the sea floor due to earthquakes on nearby faults may arrive at the shoreline within minutes and have the potential to cause significant destruction and loss of life. Local tsunami sources in Otago include a landslide into any of the major lakes in the region, cliff collapse or landslide along the coastal cliffs or rupture of nearby faults including the Alpine Fault, Akatore Fault or the Puysegur and Hikurangi Subduction Zones (ORC, 2012).

Tsunami modelling of selected communities along the Otago coastline indicates that a tsunami on the Puysegur Subduction Zone (local source) would take approximately 1 hour 45 minutes to reach the southern part of the coast and produce wave heights of up to 2.75m above msl for a 1:600 year event (NIWA, 2007). Wave heights of up to 6 m are also possible along the Otago coastline, however the modeling used to derive these figures is far coarser than that used by NIWA (2007).

A number of faults capable of producing tsunami are located in subduction zones at the edges of the Pacific Ocean (Powell, 2013). The exposure and orientation of Otago's coastline make it most vulnerable to tsunami originating from the coast of South America (Powell, 2013) with expected travel time of over around 15 hours for a 1:500 yr event (NIWA, 2007).

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.

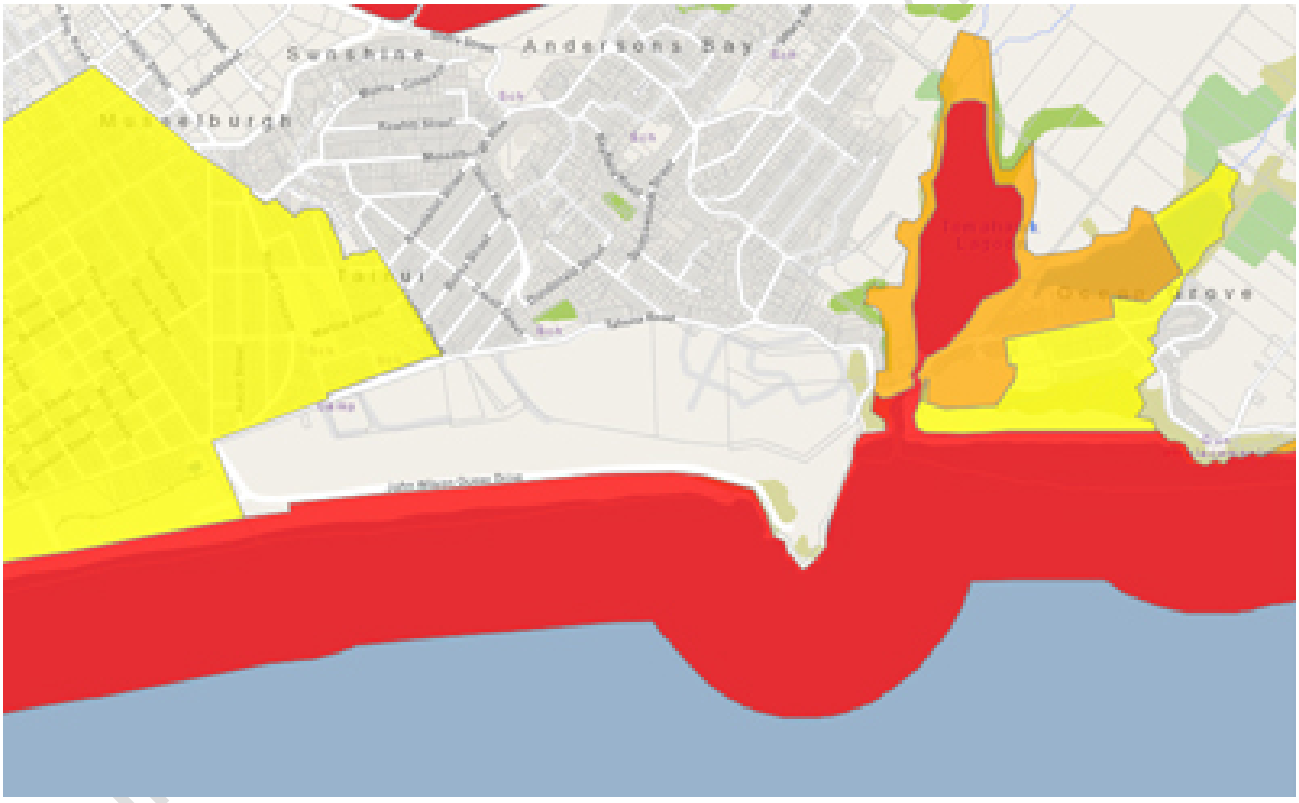
In 2013 GNS Science reviewed New Zealand's tsunami hazard. The national scale of the modeling means that tsunami hazard was reported as wave height at the coast, not inundation depths and extents as with the earlier, more detailed modeling completed by NIWA.

2017 Update – Tsunami Evacuation Zones

Emergency Management Otago have just completed their GIS Coastal Otago Evacuation Zone Mapping available on their website. This is not inundation mapping, but a credible guide for people living within high risk areas to use in their emergency household planning and to know what to do on receipt of a Tsunami threat.

- Red Zone indicates the whole of the coastline ' beach and marine threat'
- Orange indicates land close to sea level at risk from waves of 1 to 3 metres above high tide levels
- Yellow are areas that would be affected from a wave 3 metres above high tide levels

Emergency Management Otago – Tsunami Evacuation Zone Maps



Storm Surge

The term storm surge describes a state of elevated sea level due to a combination of tides, wind-stress, atmospheric pressure and waves and as the name suggests, are associated with storms (NIWA, 2007).

Detailed modeling of selected communities along the Otago coastline by NIWA (2008) considered a range of storm surge return periods between 20 and 500 years. This modeling suggests that for storm surge events with return periods as low as 20 years the sea may reach a level of up to 2.37m above msl on the Otago coastline (NIWA, 2008). Storm surge can inundate land, often for prolonged periods resulting in damage to buildings, roads and submerged infrastructure. Storm surge waters may also entrain debris which can cause additional damage.

Hazard information used in this Study

The storm surge and both the NIWA and GNS Science tsunami studies were used in conjunction with LiDAR data collected in 2004 to establish hazard areas along the entire coastline. For each part of the coastline the 1:100 year storm surge elevation, wave height of the Puysegur Trench tsunami scenario and the wave height of the most likely tsunami source determined by the GNS Science were selected from the nearest modeled community or coastal section and projected over the surrounding area using the LiDAR data. Therefore, the landward extent of the storm surge/tsunami hazard zones varies slightly along the coastline.

5.1.15 Infrastructure Impacts

One area where there are a number of critical assets in coastal / low lying area is South Dunedin, with assets potentially in inundation zones including electricity substations.

Road and Rail

State Highway 1 passes through low lying coastal areas in a number of places, notably around Waitati and north of Palmerston (Katiki Straight and the Karitane Straight). Brighton Road, a key arterial road in Dunedin, also runs along the coast.

The Kiwi Rail network runs alongside much of the road network being adjacent to the coastline along the majority of the eastern coast of Otago.

Impacts are likely to be similar to that with flooding due to scouring and deposition of debris, though damage post event may be higher considering the force of the waves on above ground structures.

Port Otago/Fuel/Gas at Dunedin Harbourside

Otago's Port, fuel and gas terminals are also in low lying coastal areas on the harborside of Dunedin. However detailed modeling nationally has not been completed in many areas making the likely extent of inundation unknown. Current estimations by ORC are that tsunami waves entering the harbour at the Ravensbourne to Wharfside end of Dunedin are unlikely to damage fuel and gas terminal sites. (Petroleum and gas terminals may suffer damage to their pipe networks and tank farms in tsunami depths of 2m or greater).

While local fuel supply assets (wharf, pipelines and terminals) are considered unlikely to be damaged by a tsunami, a tsunami impacting the Marsden Refinery (south of Whangarei) has the potential to cause fuel disruptions in Otago as this supplies 75% of New Zealand's fuel and the time to source alternatives is estimated at weeks.

The fuel and gas terminals at Dunedin may become very important in the South Island following a tsunami impacting New Zealand's south-eastern coast line as it is less vulnerable to tsunami than many other ports and there are no oil wharves on the west coast of the south island.

Wastewater and Potable Water

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. This is particularly of significance in relation to the Tahuna Wastewater Treatment Facility in South Dunedin.

Telecommunications

Telecommunications networks will most likely be disrupted locally due to damage to buildings and electrical equipment at exchanges and failure of cellular sites particularly the South Islands East Coast Fibre route

Energy Networks/Power

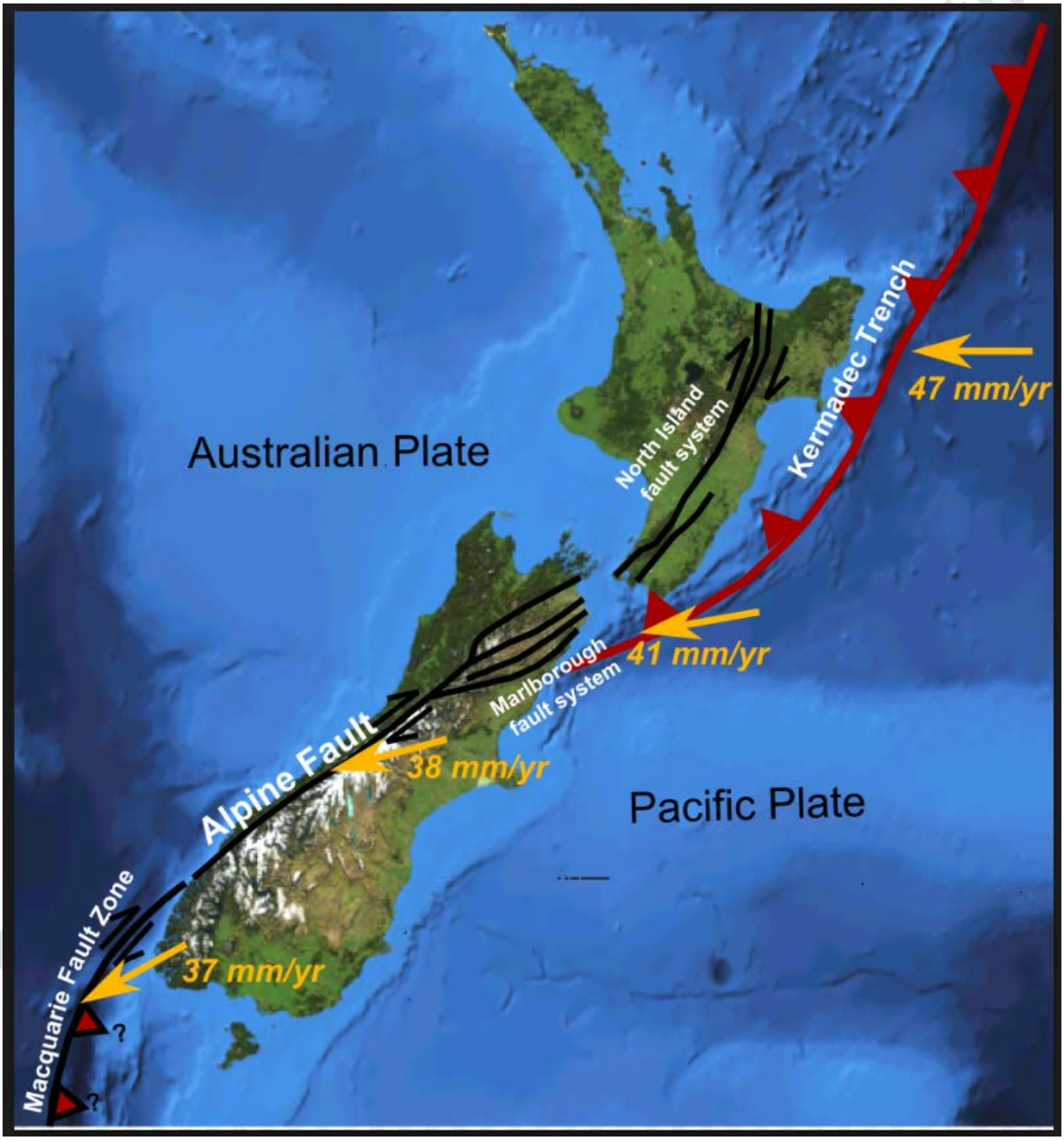
Energy networks, particularly electricity, will be impacted due to shorting of buried cables if they become exposed to the water and have pre-existing casing damage. Also, overhead lines are susceptible to failure by toppling of poles, which can be damaged by debris strikes.

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.

Earthquake

Major Fault/plates in New Zealand



5.1.16 An Overview of the Hazard

For this programme, seismic hazard is defined as the hazard associated with ground shaking during earthquakes, fault surface rupture and the liquefaction and lateral spread of soils due to ground shaking:

- Surface rupture involves land movement either side of a fault, generally confined to a relatively narrow corridor along the fault trace. This 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.
- While the intensity of ground shaking decreases with increasing distance from the source, the complex interaction of seismic waves means that certain topography and soil types are more susceptible to strong ground shaking. The combination of ground shaking and earth movement can produce secondary effects including rockfall / landsliding, tsunami, ground settlement and liquefaction. While ground shaking will almost always be felt during large earthquakes, the occurrences of liquefaction, lateral spread and surface rupture are largely dependent on the size and style of earthquake. Strong shaking can cause damage to structures – the extent of damage can be mitigated through modern seismic design.
- Liquefaction and Lateral Spread occurs when saturated fine grained sediments (such as sand and silt) are subjected to high intensity shaking and lose their ability to stay cohesive, causing deformation, settlement, and sometimes lateral spread towards rivers or lakes. Areas with fine-grained and unconsolidated sediments, soils, and high groundwater tables are susceptible to liquefaction and settlement. Error! Reference source not found. illustrates locations of critical assets in vulnerable areas to 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.

A large number of active faults lie within Otago and many more further afield are capable of affecting the region (in New Zealand a fault is generally considered active if it has ruptured in the last 120,000 years (MfE, 2003). The full information relating to the AF8 SAFER Project is available as a **separate document**.
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 dropped by up to 2m) and more recently in Kaikoura

Areas susceptible to liquefaction in Otago include alluvium-filled river basins such as the Taieri, the margins of lakes such as Wakatipu and Wanaka and the embayments of coastal Otago. Variability in the nature and extent of fine grained materials susceptible to liquefaction means that more detailed site-specific investigations are usually needed to properly characterise liquefaction hazard at any one site.

Hazard Information Used in this Study

Active fault traces for the region were sourced from GNS in 2012 and were drawn from the national active faults database, also maintained by GNS. Land deemed to be potentially susceptible to liquefaction (based on the factors described above) was identified in a regional level seismic hazard assessment completed by Opus in 2005. Liquefaction susceptibility was further refined for the Dunedin District by GNS science in 2014.

Ground shaking was not used as the duration and intensity of shaking is highly dependent on the magnitude of the earthquake, the distance between any site and the earthquake epicentre and the underlying soil conditions.

Section of South Island Active Fault Database – GNS Science

5.1.17 Electricity

Generation

In general, all the region's larger infrastructure assets (dams, substations, transmission towers) are structurally designed to withstand ground shaking and large scale hydropower dams and substations/ switchyards are subject to regular seismic surveys to identify potential risks and mitigations.

For example, the Contact Energy Clyde Dam is built on a secondary fault (the major active fault in the area is the Dunstan Fault) but a slip joint within the dam is designed to allow ground movement without serious damage to the dam. The joint can accommodate up to 2 metres of movement – 10 times the amount of any movement considered possible on this fault.

Clyde Dam Slip Joint

Hawea Dam

Earth Dams such as Hawea are considered more vulnerable to ground shaking, but are considered highly unlikely to suffer significant damage resulting in dam breaks - in the unlikely event, dam break procedures are in place for all dams.

There are processes in place to deal with the specific risk of silt behind Roxburgh Dam liquefying.

The February 2011 Christchurch earthquake demonstrated Transpower's network resilience with restoration of supply occurring within 4 hours[3].

Local Distribution Networks

Most of the local network is overhead and not too susceptible to seismic loads – engineering design checks are regularly undertaken for line structures that support heavy equipment. An earthquake is most likely to break underground cables and damage older substations (possibly designed to lower standards) in soils prone to liquefaction.

Restoration times are longer for underground cables as the breaks are less easy to find. With pockets of liquefaction across most areas of the region, the impacts of a major earthquake on local networks are likely to be similar to that experienced in Christchurch, with most supplies restored within a week and the remainder within 1-2 months except in the most badly damaged areas. Aurora's relatively urban network is around 30% underground with OtagoNet and Waitaki having only 1.2% and 5% of their cables underground respectively.

[3] they have since changed their protocols to ensure that staff and contractors do not put themselves at risk with rapid response to large earthquake events.

Aurora has identified the Neville Street Zone substation as being subject to liquefaction risk, and this site is programmed for re-location in 2014/15 with earthquake mitigation measures in place.

5.1.18 Fuel and Gas

The tanks in the Lyttleton Terminal suffered only minor damage in the February 2011 Christchurch event, indicating that the (similarly designed) fuel and gas terminals in Dunedin may also withstand liquefaction and shaking. However it is very difficult to predict exact impacts as much depends on the type of soils and construction methods used in the reclamation. The tanks are more likely to be at risk from lateral spreading (i.e. the ground slipping towards the coast) and if sufficient ground displacement were to occur, tank damage from this scenario is possible.

5.1.19 Telecommunications

Copper cables in liquefaction-prone soils are considered to be at highest risk of damage. Equipment in buildings continued to process and handle traffic following the Christchurch earthquake despite some building damage and localized deformation of equipment cabinets. Access constraints hindered network reconfiguration to some extent.

Chorus has an ongoing process for reviewing buildings for seismic resistance and none in the Otago region are considered at risk of major damage from an earthquake.

5.1.20 Water Supply and Wastewater

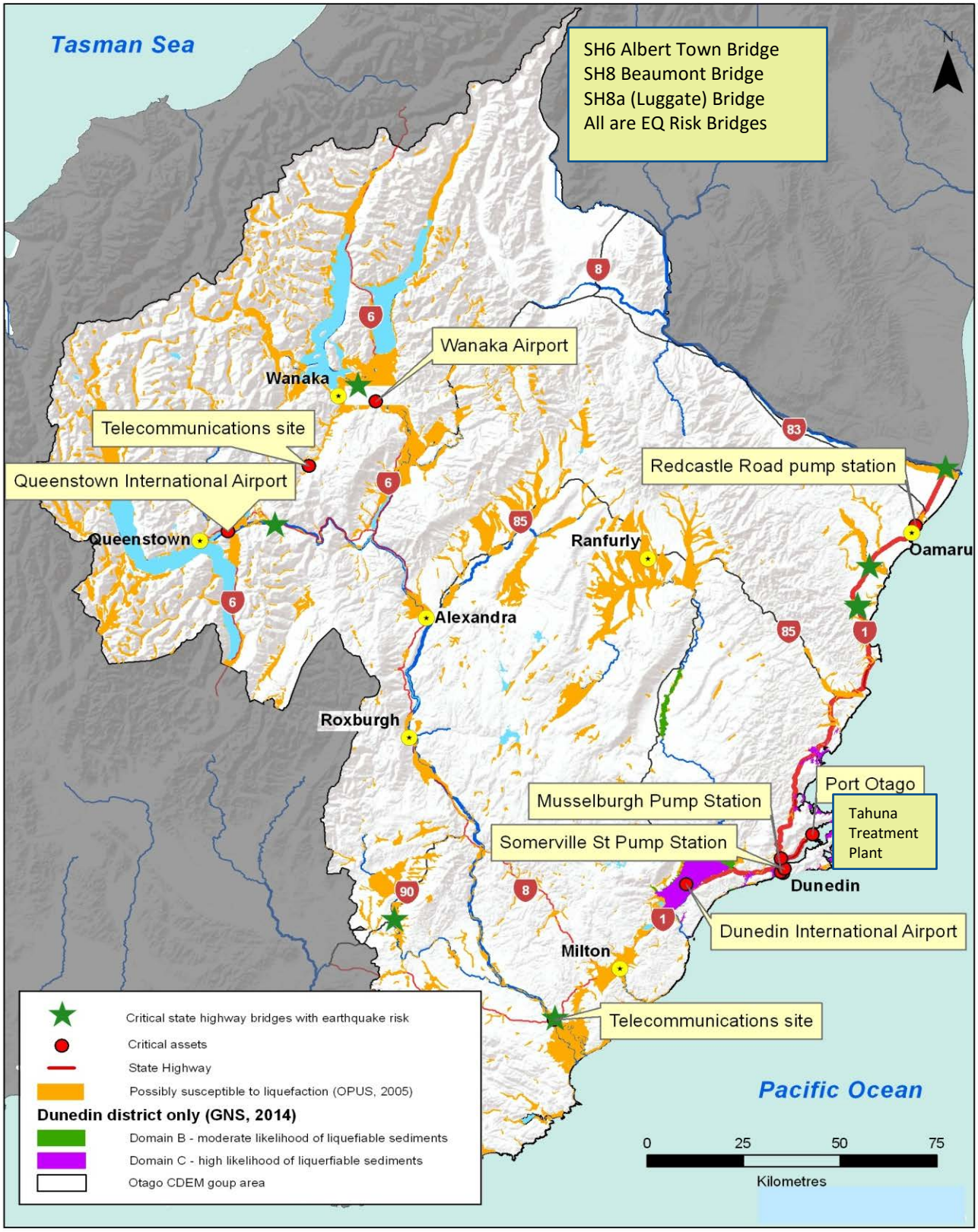
In a major earthquake, widespread damage can be expected to local reticulation networks, particularly in liquefaction prone areas, as was observed in the February 2011 Canterbury earthquake. Service restoration times are likely to be weeks to months and full recovery to take years. Modern, major assets providing bulk supply services such as treatment plants, storage reservoirs and larger pump stations have generally been designed to withstand seismic events and have controls to shut off supply following an earthquake, however there are still a number of older critical assets that are at risk in liquefaction prone soils, including:

- Musselburgh wastewater pump station (servicing most of central Dunedin)
- Tahuna Wastewater Treatment Plant
- Somerville Street water pump station (servicing the peninsula, Dunedin).
- Tainui and Portobello Stormwater pump stations (servicing South Dunedin) Dunedin City Council has undergone a seismic strengthening programme on major water storage tanks but this does not yet cover all the City's water storage facilities.

Tahuna Wastewater Treatment Plant

Figure 5.3 Critical Assets in Areas Potentially Susceptible to Liquefaction

Note the map only lists single sites in liquefaction prone areas, not lines or roads.



5.1.21 Roads

Road pavement failures can occur, more so in liquefaction prone areas, but roads can also be impacted indirectly where underground utilities need to be replaced or the traffic demand changes (such as the movement of South Island State Highway (SH) traffic from SH1 to SH's 63/6/65/7).

All significant state highway bridges meet seismic strengthening standards. The following are those listed within 'Critical State Highways' risk tables for earthquakes:

- SH1 - Waitaki bridge (to be strengthened 2017), Waiareka Creek bridge, Kakanui bridge, Waianakarua North River bridge, Waianakarua South River bridge, Pleasant Valley bridges (two) & Balclutha bridge.
- SH6 - Victoria Bridge (Kawarau Gorge) & Albert Town bridge
- SH90 – Pomahaka bridge.
- SH 8 – Alexandra bridge, Beaumont bridge & Luggate bridge (SH8A)

Dunedin City Council is currently carrying out an assessment of all bridges and significant retaining structures.

5.1.22 Airports

Dunedin Airport is located in soils considered at risk of liquefaction, though the runway and terminal design takes this into consideration and damage due to earthquake is considered very low probability.

Alluvial Fans

5.1.23 An Overview of the Hazard

An alluvial fan is an accumulation of river or stream (alluvial) sediments which form a sloping landform, shaped like an open fan or a segment of a cone. They typically occur near the boundary between hill slopes and valleys where well incised streams spread out and deposit entrained material. Many are only active during times of heavy rainfall. The episodic nature of alluvial fan activity means that large volumes of sediment and debris can be deposited across the fan in a relatively short period of time.

The size, activity level and hazard associated with alluvial fans in Otago are highly variable. Steep mountains and high precipitation in the west of Otago mean that erosion rates and fan-building activity are also high. Further inland in the ranges and basins of Central Otago a more humid to semi-arid climate means rates of erosion and fan building are lower than in northwest Otago, though there are historical examples of intense rainstorm events causing fan flooding and extensive sedimentation (see example below).

Subdued topography, a humid climate and variable geology mean both 'floodwater dominated' and 'debris style' alluvial fans have formed on the margins of hills and valleys in coastal Otago. Although many of the fans consist of fine grained silt and clay, small to moderate landslides in the catchments of these fans are still capable of initiating rapid and damaging debris flows.

5.1.24 Impacts on Infrastructure Assets

A number of critical sites intersect with the alluvial fan hazards mapped by ORC, although the level of hazard associated with alluvial fans in the Dunedin District is highly variable. These include:

- 5 Aurora Substations (Cranston St, Quarry Rd, Crawford St, Great King St and North Road, Dunedin.
- A number of pump station and bore sites, including Roxburgh Pump Station, Somerville St Pump Station, Bayview Road Wastewater Pump Station, Marine Parade Wastewater Pump Station, Glenorchy Water Bores and Redcastle Road Raw Water pump station.

Snow Storms

5.1.25 An Overview of the Hazard

Snowstorms can represent a severe hazard for people in Otago, particularly when deep snow accumulates in densely-populated coastal areas which are not regularly affected by snow. Snow may fall to sea level for one to three days and form into drifts. When such an event is followed by an advancing anticyclone, clear skies and cold temperatures may mean that the snow persists for several days, with resulting in frosts and widespread ice.
ORC does not currently hold a snow hazard map covering the entire Otago region. In general, high altitude areas, especially in western and central Otago are most susceptible to large snowfall events.

5.1.26 Electricity

Snow and ice can break overhead electricity lines (rarely), typically impacting on the older distribution lines in local networks – though usually the biggest issue is trees and branches falling across the line. While the extent of failure in past events has not been huge, the issue is the ability to gain road access to repair lines. Following the Canterbury snow event in 2005, electricity lines companies took a month to restore supplies to all customers.

In general, Transpower's transmission system is more resilient than the more extensive and fragile distribution system.

In past events, Aurora's Omakau zone substation and Ettrick / Roxburgh substations have been affected.

5.1.27 Transport – Roads

Snow disrupts the passage of traffic but does not damage the road structure. The following critical state highways are most susceptible to snow:

- SH1 – Kilmog, Northern Motorway and Balclutha to Clinton area.
- SH6 – Kawarau Gorge & Remarkable Range section.
- SH8 – Manuka Gorge, Raes Junction to Alexandra & Lindis Pass/Lindis Valley area.

5.1.28 Other

Snow is unlikely to directly impact or damage assets in the fuel, gas, telecommunications, water and wastewater areas, however restricted road access may cause longer service response times. Snow could potentially disrupt operations at ports and airports during the event, but is unlikely to cause damage once the event is over. Snow and ice buildup on antenna plant at high altitude sites can affect radio services.

Landslides

5.1.29 Hazard Overview

The term "landslide" describes a variety of processes that result in the downward and outward movement of slope-forming materials including rock, soil, artificial fill, or a combination of these. Landslides can vary in size from a single boulder in a rock fall to tens of millions of cubic metres of material in a debris avalanche.

Many landslides were mapped by identifying landforms in aerial photography and as a result there is uncertainty in the age, type and activity level of many of the landslides. Not all of the landslides identified in the ORC database represent a current and credible hazard. Landslides are particularly numerous on the steep slopes of the Southern Alps in the west of Otago and the coastal hills that border much of the eastern coastline. Landslides in Otago generally fall into two broad categories; shallow, surficial slides typically in the mantle of soils that overlay slopes and more deep-seated slides in the underlying bedrock. Although landslides can occur at any time without any obvious trigger, heavy or prolonged rainfall, seismic shaking and site excavation are the most common causes of instability.

One of the most notable examples of a large, damaging landslide in the Otago region is the 1979 East Abbotsford landslide, located in the south-western suburb of Abbotsford, Dunedin. The large, 'first time' slide occurred in moderately steep (7°) weak clay layers and destroyed 69 houses at an estimated cost of $10–13 million (Hancox, 2009). Unfavourable geology, sand excavation at the slide toe and a leaking water main all contributed to the initiation of movement.

View across the chasm of the Abbotsford landslide, 1979. Photo supplied by GNS science (IC McKellar)

Landslide information held by the ORC is derived from a number of sources including geological maps, technical reports and unpublished reports such as university thesis. This information was compiled for the ORC in 2006 by the Institute for International Development (IID). A subset of this data, for the Dunedin District, was further refined by GNS Science in 2012 and again in early 2014. Landslides are represented as either mapped areas or point data. In 2017 Matthew Hughes (University of Canterbury) produced potential 'hotspot' mapping for Landslides in Otago as a result of an AF8 scale event to support the work being undertaken for the AF8 SAFER Project.

5.1.30 Impacts on Infrastructure Assets

Major landslides are typically highly damaging to all assets in the direct area and may be one isolated event or a series of landslides triggered by another disaster such as a cyclone or earthquake.

Landslides in a lake can cause an inland tsunami. All larger dams in the region have undergone studies of the risk associated with potential wave surges arising from upstream landslides, and all dams are considered able to withstand the impacts without major damage.

There is a risk of landslides causing partial / complete blockage of the Roxburgh Gorge resulting in a large, high velocity flood wave travelling downstream either as an immediate consequence of the landslide or following a delayed 'dam-break' scenario sometime after the initial impoundment of the river water.

Roxburgh Gorge

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 focused on natural hazards and the information available on this hazard for this report is limited.

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. Emergency Response Principles and Priorities

Key Response Agencies

This section aims to establish a common understanding amongst all key response agencies of regional priorities following a major disaster. This in turn will enable:

- key agencies to prioritise their own response to support other critical agencies service restoration.
- resources that are being coordinated by lead agencies to support those regional priorities.

While the priorities will vary according to the specific nature of the disaster, resource priority should be given to the following services to ensure the community disruption is minimised (Guide to the National CDEM Plan, 2009):

- critical health services (hospitals, ambulance, public health)
- emergency management (Police, Fire, EOCs, welfare centres)
- lifelines infrastructure
- vulnerable sectors (e.g.: immobile or vulnerable groups of people such as rest homes or prisons)
- isolated communities
- key areas (e.g.: CBDs)
- commercial producers
- residential zones.

The top three priority sectors are further discussed below.

Emergency / Health Services

Particularly immediately after an event (or prior to, if there is warning), Police, Fire, St Johns and Hospital services are obviously key to rescue operations and focussing on the protection of life and property. Armed Services resources may be brought into support in major emergencies.

CDEM Agencies

Depending on the scale of the event, local, regional and national CDEM operations may be activated to support and coordinate the response to the emergency across all agencies and the wider community.

Welfare Agencies

While CDEM Groups have the legislated responsibility for Welfare (National CDEM Plan 2015) the sub functions of welfare are still the responsibilities of the relevant welfare agencies who have an important role in supporting people that require assistance such as well as supporting the longer-term recovery.

Lifelines Organisations

The ability for lifelines organisations to function following an emergency is critical to the ability of the community to recover from it. Medium to long term failures can trigger evacuation of people from the area (either by choice or by direction) and prolong the community's recovery.

- As highlighted in **Figure 3.1,** electricity is critical for most other lifelines organisations to be able to function. Electricity restoration is a commonly reported indicator of the extent to which the community's 'business as usual' has been restored.
- Transport is important for moving response resources (such as support personnel) into the area, evacuating people from hazardous areas and enabling lifelines (and other organisations) to access sites to restore services.
- Communications is critical for coordinating and deploying resources.
- Water and wastewater services are fundamental for maintaining public health. While temporary alternatives such as bottled water and portaloos can provide temporary response, in a large scale event they can take time to source and deploy.

- Fuel (petrol/diesel) is required to fuel vehicles, aircraft etc and, if there are power failures, generators. Fuel needs to be available at service stations and by tanker deliveries to key sites. There are logistical issues in the Otago Region such as a number of remote areas with significant distances between fuel stations and areas such as Queenstown that may be cut off in a major event. Work needs to be done to better understand service station capacity and locations, availability of other stocks that could potentially be used (such as on large farms) and regional processes to ensure fuel is available to key response agencies. **A regional fuel contingency plan is included as a future action in Section 7 and Appendix 7 - Regional Fuel Planning Template)**

Chevron's Fuel Terminal

Critical Response and Recovery Resources

The resources that are generally critical for the above agencies during a major response (as well as for other agencies and the wider community) are summarised below.

Demand for any of these resources is likely to exceed immediate supply in a major disaster. There are a number of improvement actions noted in **Section 7** that are aimed at ensuring these resources are efficiently used and processes are in place to prioritise supply to key response agencies.

1. **Helicopters:** are important both for rescue operations and impact assessments. There are currently limited plans for coordination of impact assessments and individual organisations would be looking to source and deploy helicopters. There is potential benefit from a reconnaissance plan that would see helicopters deployed along pre-determined critical sites and routes recording visual images for all key response agencies. This may include an agreement that some sectors have specialist personnel on the helicopter.

A helicopter reconnaissance plan is included as a future action in **Section 7.**

2. **People:** Operating a 24/7 response can stretch staff and contracting resources considerably. A range of formal arrangements (contracts, mutual aid agreements with other organisations) are in place in some sectors. There is also a less formal understanding that support will be available from others where needed – and this was evidenced in many ways following the Canterbury and Christchurch earthquakes 2010/11 and later in the Kaikoura Earthquake in 2016. There are many issues that need to be dealt with such as use of different equipment, standards, safety procedures, etc. Sector mutual aid agreements would be useful in all sectors (though practical only in non-competitive sectors) including protocols for managing resources from other organisations.

3. **Spares**: Again, the scale of an event has the potential for the immediate need to exceed the initial response phase, though there is some anecdotal evidence from Christchurch that in fact the need for large quantities of spares in the first few days is limited by the availability of crews to effect repairs. The electricity sector identified the need to better understand the collective need for and availability of spares (such as electricity poles) and consideration of the benefit of moving to a more standardized approach to equipment, parts, etc.

4. **Other critical resources** – in no order of priority – mentioned include:

a) Communications equipment – RT.
b) Social media
c) Generators
d) Food and water
e) Vehicles
f) Contractors
g) Specialist equipment
h) Plant – diggers etc.
i) Portable heating
j) Mobile catering
k) Portaloos and showers (ablutions)
l) Accommodation
m) Bottled water / tanker water
n) Temporary traffic signs, cones and barriers

The development of a regional plan for management of portable generator resources was identified as a high priority and is included in **Section 7**.

Response and Restoration Processes

6.1.1 Lifelines Response Prioritisation Arrangements

Electricity Sector

Electricity Sector priorities are covered in Participant Outage Plans. Where a major shortage requires planned, rolling outages, customers on higher priority feeders are less likely to be cut off.

Under these arrangements, residential consumers are typically on the lowest priority feeders. However in an emergency, priorities may change and the sector would expect to take direction from CDEM agencies as to whether their normal prioritisation protocols need to be modified.

Telco Sector

Prioritisation is based on the criticality of the node and trunk.

Water Sector

Prioritisation is typically asset based – trunk supplies restored first (from treatment plants to reservoirs), then would consider prioritisation of supply to critical customers.

Road Sector

The One Network Road Classification is used to prioritise restoration / response. Other factors to be considered would be availability of alternate routes and traffic volumes (triage phase).

6.1.2 Response and Restoration Principles

To support a coordinated and effective regional response, lifelines agencies will, unless otherwise directed by the lead agency:

- Give priority to restoring services to key response agencies that rely on their service (**Section 0**), where practical.
- Be able to quickly mobilise and prioritise restoration of services in the absence of direction from the lead agency.
- Implement plans and arrangements that are aligned with local, regional and national CDEM processes.
- Operate in accordance with national, regional and local response arrangements such as fuel contingency plans, sector coordination plans, where they are in place.

7. Future Actions

Improvement Programmes

7.1.1 Regional CDEM / Lifelines Sector Projects

At the final project workshop in July 2014, the projects detailed in
Table *7.1* were agreed as a high priority for Otago's lifelines sector. These projects could either be led by the lifelines sector or CDEM sector but, regardless, will need significant input from both. As, these projects have already been completed by at least one region in New Zealand, some by several, and it is intended that these can be used to inform the Otago programmes.

At the November 2016 Lifelines workshop a regional fuel plan was identified as the highest priority for our Lifelines.

Following the January 2017 Combined Lifelines and Project AF8 workshop in addition to the fuel plan importance was placed on an air reconnaissance plan and was identified as the key priority for the newly established Lifelines committee commencing in February 2017. It was decided that due to the intrinsic risk from an Alpine Fault Earthquake and the shared Lifelines in both Regions that Otago would complete an Otago Southland Air Operations and Reconnaissance Plan and Southland would complete an Otago Southland Fuel Plan. Emergency Management Otago have contracted Peter Amyes from Fire and Emergency New Zealand with his significant Air Operations experience within both the Defence Force and as a Private Pilot to undertake the Air Operations and Reconnaissance Plan. Workshops have already been held with some key partners in the aviation environment and emergency services to contribute to this. This piece of work will be completed early 2018.

Future projects for 2018, once funding and recruitment of a suitable Lifelines Project manager are established include a generator plan, VHF Radio and Satellite phone directory and an all of Lifelines GIS Situation Awareness Data set.

7.1.2 Lifelines Organisations Mitigation Projects

Over time infrastructure networks are improving in resilience as organisations install more resilient assets as renewals are required. All organisations also have asset inspection and safety programmes targeted at critical assets. Seismic screening programmes are in place for dams, bridges and other critical structures. As well as these ongoing programmes, several specific mitigation projects were identified in the Otago Region.

Table 7.1 Regional CDEM / Lifelines Sector Projects

Project	Description and scope
Regional Fuel Contingency Plan	This plan would outline how fuel would be managed in a significant shortage to ensure critical lifelines and community organisations can be supplied. It will support the National CDEM Fuel Plan and identify, at a regional level, bulk fuel stocks (type and location), fuel stations, organisations to be prioritised with fuel supply and their likely fuel demand requirements, plans to extract fuel in power outages, and communication processes to implement the plan. **SOUTHLAND TO COMPLETE THIS 2018**
Regional Air Operations and Reconnaissance Plan	This plan aims to optimise the use of limited helicopter resources for rapid damage impact assessment. It would include the types of helicopter resources likely to be available (including drones), how/who will decide on allocation of helicopter resources, how information would be captured (e.g.: video versus on board experts) and disseminated, and route maps taking in critical infrastructure sites and routes. Consideration will be given to multi-purpose trips (e.g.: reconnaissance and supplies). Recommendations will also be made such as the need for Mutual Aid agreements with agencies owning helicopters (media, police, etc.). **EMERGENCY MANAGEMENT OTAGO UNDERTAKING THIS FOR COMPLETION EARLY 2018**
GIS Situational Awareness Data Mapping	This plan intends to provide real time situational awareness of all critical infrastructure and risks within the region during an event. **This will be completed by Eagle Technology in conjunction with Emergency Management Otago and Lifelines in 2018**
Regional Emergency Generator Management Plan	This plan would outline how electricity generator stocks would be managed in a significant electricity outage. It would include an assessment of electricity generators (numbers and capacity) likely to be available such as from hire depots, Defence Forces, etc., critical infrastructure sites likely to need them and their plug in capability. **This will be started on the recruitment of a dedicated and funded Project Manager for Otago Lifelines**
Lifelines – CDEM Sector Communication Protocols	These protocols would outline how lifeline utilities coordinate with the CDEM sector, and each other, in an emergency. It would look at local, group and national CDEM communication lines with lifeline utilities and the type of information to be exchanged. **This will be completed in conjunction with other Lifelines and CDEM Groups across New Zealand in 2018 by the existing Lifelines Committee and Emergency Management Otago's Planning and Development Manager**
Lifelines – CDEM Sector Communication Systems	This project would look at alternative communication methods (such as radio channels, satellite phones) to be used when normal communication channels (telephone/fax/email) fail. It would assess the current use of these other communication methods by lifelines and CDEM and make recommendations to ensure alternate channels are available. **This will be started on the recruitment of a dedicated and funded Project Manager for Otago Lifelines or a shared resource between Otago and Southland.**

Table 7.2 Future Lifelines Organisations Mitigation Programmes

Organisation	Future Mitigation Programmes and Projects Identified (10 years)
Electricity	
Aurora/Delta	Upgrades to SCADA to improve communications links to key sites. Relocation of Neville Street Zone Substation outside of liquefaction risk area.
Contact Energy	5 Yearly critical safety review programme and undertake actions arising. Upgrades to SCADA to improve communications links to key sites.
Meridian Energy	5 yearly critical safety review programme and undertake actions arising.
Network Waitaki	Linking isolated GXPs to provide loop redundancy.
Transpower	Preparation of a Kawarau Gorge contingency plan. Feasibility study on linking Halfway Bush / South Dunedin substations to provide loop redundancy.
Fuel / Gas	
Caltex	Independent fire protection tank and upgrades.
Liquigas	SCADA upgrades and installation of temporary power connection systems for generator compatibility.
Telecommunications / Broadcasting	
Kordia	2 yearly tower inspection programme plus ongoing analysis, using latest NIWA data, to ensure all structures are able to withstand the worst predicted severe weather events.
Local Authorities (Water/Transport/Flood Protection)	
All	Development and measurement of resilience indicators (ONRC).
Central Otago District Council	Submitting case for backup generation at key water/wastewater sites. Developing plans for management of isolated communities.
Dunedin City Council	Develop and implement mitigation programme arising from recent climate change studies. Water Supply upgrades to provide redundancy for Deep Creek Pipelines – connects two supply zones (2014), repair Ross Creek Dam (2015), new pump / pipe from Ross Creek Dam to Mt Grand WTP (2016)
Queenstown Lakes District Council	Assessment of rock fall susceptible areas (roads).
Otago Regional Council	Installation of backup generators on pumps in the Taieri Plains flood protection system.
Waitaki District Council	Reviewing options to alleviate flooding at key pinchpoints.
Transport	
Dunedin Airport	Reviewing case for backup generation for infrastructure such as wastewater treatment plant.
New Zealand Transport Agency	Reviewing capacity of detour routes and develop upgrade programme.

Recommendations

It was recommended that:

1. Lifelines organisations representatives present the findings and recommendations from this programme to their Executive Teams and seek endorsement for ongoing participation and reviewing of the information in the regional Lifelines Group.

2. The Otago CDEM Lifelines Steering Committee Group Utilities will lead this programme with support from their territorial local authority peers providing a supporting role. This should include consideration of appropriate ways to progress the projects identified in **Section 0.**

3. Lifelines organisations review their response and recovery arrangements for alignment with the principles outlined in **Section 6.1.2**

4. All Otago Lifelines Utilities look towards a future funding model for the Coordination of Lifelines both during and event and to manage projects to build resilience and manage risk.

References

Barrell, D.J.A.; Glassey, P.J.; Cox, S.C. and Smith Lyttle, B. 2014 'Assessment of liquefaction hazards in the Dunedin City district', *GNS Science Consultancy Report* 2014/068. 66p.

Hancox, T. 2008 'The 1979 Abbotsford Landslide, Dunedin, New Zealand: a retrospective look at its nature and causes', *Landslides*, 5, pp. 177-188.

NIWA, 2007 'Otago Regional Council storm Surge Modelling Study', *NIWA client report* no CHC2008- 047.

NIWA, 2008 'Otago region hazards management investigation: tsunami modelling study', *NIWA client report* no CHC2007 – 030.

Opus, 2005 'Seismic Risk in the Otago Region' Opus client report no SPT: 2004/23

Otago Regional Council, 2012 'Community vulnerability to elevated sea level and coastal events in Otago'.

Power, W.L. (compiler), 2013 'Review of Tsunami Hazard in New Zealand (2013 Update)', *GNS Science Consultancy Report* 2013/131, 222 p.

UK Met Office, 2014 'Storm Surge', URL: http://www.metoffice.gov.uk/learning/learn-about-the-weather/weather-phenomena/storm-surge, accessed on 3/6/2014.

USGS, 2012 'Earthquake hazard program glossary; active fault definition', http://earthquake.usgs.gov/hazards/qfaults/glossary.php, accessed on 28/05/2014.

GNS Science

M Hughes – University of Canterbury 2017

National Lifelines Vulnerability Assessment Sept 2017

AF8 SAFER Project 2017

Otago Risk Reduction Register 2017