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RESILIENCE GUIDE

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HEALTH + SAFETY

ASSET MANAGEMENT

PROF DEVELOPMENT

Resilience Guide

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Disclaimer

This guide has been prepared by representatives of the electricity supply industry to provide guidance on how to apply emergency preparedness principles to improve overall industry resilience in managing major events which may interrupt electricity supply and cause large disruption to normal community activity.

This guide is recommended as good practice by electricity supply industry representatives, but it is not a substitute for legislative or other regulatory requirements. If there is uncertainty on what guidelines or legislative requirements should apply in any particular situation, specialist advice, including legal advice, should be sought.

The Electricity Engineers' Association of New Zealand (Inc.) and the electricity supply industry representatives involved in preparing this guide, accept no liability or responsibility for an error or omission contained in this guide, or any injury, loss, damage (including indirect or consequential loss or damage), or any other claim from any reliance on, or failure to rely on, the contents of this guide.

This guide has been prepared on the basis that the user will be appropriately trained, qualified, authorised, and competent.

Status of Examples and Case Studies

Examples, including sample processes, or case studies in this guide are included to assist in how to apply various aspects of the emergency preparedness principles outlined in this document. The examples or case studies are not a comprehensive statement of matters to be considered, nor steps to be taken, to comply with any statutory obligations pertaining to the subject matter of this guide but they do illustrate how the electricity distribution sector has applied in practice a range of the emergency preparedness principles and plans.

Acknowledgements

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Preface

This Third Edition of the EEA Resilience Guide builds on the previous version published in 2022. It incorporates updated guidance and new material in response to recent natural disasters—including a global pandemic and multiple large-scale weather events, that have significantly impacted *Electricity Distribution Businesses* (EDBs) across New Zealand.

The update has been developed by the Resilience Guide Technical Working Group, operating under the EEA Asset Management Group (AMG), with input from a wide range of industry professionals and organisations.

Prepared by the Electricity Engineers' Association of New Zealand Inc. (EEA), these guidelines are designed to assist EDBs with distributed network assets to assess and strengthen their resilience to major events that may disrupt their ability to supply electricity to customers. Prolonged interruptions to electricity supply can have wide-ranging consequences for communities, affecting everything from industrial and commercial operations to the daily lives of residential customers.

Other essential Lifeline services, such as water supply, sewerage disposal, and telecommunications, are also critically dependent on a reliable electricity supply.

The EEA is the national organisation for engineers and technical managers involved in all aspects of the electricity supply system, including generation, transmission, distribution, as well as technology providers, electricity users, consultants, and contractors. One of the EEA's key roles is to develop and maintain technical, engineering, and safety guidelines for the industry.

While the Resilience Guide is not mandatory, it is informed by, and aligned with, the compliance requirements of the *Civil Defence Emergency Management Act 2002* (CDEM Act). The Act places obligations on Lifeline Utilities to embed emergency preparedness in both strategic planning and operational contingency arrangements.

A new *Emergency Management Bill* is currently being developed to replace the CDEM Act, with enactment expected in 2026. This Bill aims to strengthen New Zealand's emergency management system, including provisions related to critical infrastructure resilience and the roles and responsibilities of Lifeline Utilities[1]. This Guide references the current Act and will be updated once the revised legislation comes into force.

Recent legislative changes have further highlighted the importance of resilience planning. *The Climate Change Response (Zero Carbon) Amendment Act 2019*, which amended the *Climate Change Response" Act 2002*, established the *Climate Change Commission* to provide independent, expert advice to government, and introduced new obligations for reporting entities, including Lifeline Utilities.

Under Section 5ZW of the amended *Climate Change Response Act 2002*, defined reporting organisations—including all Lifeline Utilities—may be required to provide information such as:

- governance arrangements for climate-related risks and opportunities
- the actual and potential effects of these risks and opportunities on business, strategy, and financial planning
- the processes used to identify, assess, and manage climate-related risks
- the metrics and targets used to monitor and manage these risks and opportunities, including relevant timeframes and progress updates.

The identification of climate-related risks should inform risk reduction planning under the CDEM framework, particularly as Lifeline utility assets will be increasingly exposed to climate-driven hazards if global warming trends continue.

To support this, the Guide includes two practical tools:

- the *Resilience Management Maturity Assessment Tool* (RMMAT), which provides a structured way for EDBs to measure their current level of resilience maturity; and
- the *Resilience Planning Roadmap (Section 18)*, which sets out a staged pathway of actions to help businesses strengthen resilience and continuously improve over time.

1 Lifeline Utilities are defined under section 4 and Schedule 1 of the CDEM Act

The content of this guideline will be monitored and periodically updated to ensure it remains relevant and effective.

Suggestions and feedback on this Third Edition of the Guide should be sent to the:

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1. Background

These guidelines have been developed by the Resilience Working Group, which operates under the EEA Asset Management Group (AMG). Effective resilience planning is critical to supporting the industry's ability to manage and mitigate risks arising from:

- major emergency events such as natural disasters, including large earthquakes and extreme weather events. Recent events like Cyclone Gabrielle have demonstrated the devastating impact such occurrences can have on electrical infrastructure, communities, and response capabilities.
- other extreme events such as major supply interruptions caused by equipment failure, terrorism, or cyber-attack.
- pandemics, as seen with COVID-19 (2020–2022), which affected operational staff availability and disrupted supply chains for critical materials.

While this Guide focuses primarily on the impact of major emergency events on network assets, its principles can also be applied more broadly to other business vulnerabilities. These include economic downturns and the increasing integration of customer-owned embedded generation technologies.

Major extreme events can severely disrupt electricity supply, leading to significant economic losses, social disruption, and heightened public safety risks. The impact of Cyclone Gabrielle highlighted the scale of challenges arising from widespread network damage and prolonged equipment outages—causing extended supply interruptions and reinforcing the need for rapid, coordinated restoration efforts.

Recognising the importance of resilience in critical infrastructure, various government agencies have undertaken high-level reviews to assess the resilience maturity of New Zealand's infrastructure operators. These reviews aim to improve preparedness and promote the adoption of best-practice resilience management approaches.

This Resilience Guide outlines key principles of emergency management preparedness and provides practical tools for EDBs and other EEA members. The *Resilience Management Maturity Assessment Tool (RMMAT)* offers a benchmarking framework structured around the 4Rs defined in the *National Civil Defence Emergency Management (CDEM) Plan Order*.

This updated edition also introduces a Resilience Planning Roadmap (Section 18), which provides a staged pathway and a comprehensive checklist of key considerations to support EDBs in developing and enhancing their resilience strategies.

Together, these tools provide a practical pathway for continual improvement in sector resilience, enabling EDBs to strengthen their preparedness and adapt to an evolving risk environment.

2. Purpose and Scope

This Resilience Guide supports resilience planning for electricity transmission and distribution businesses that own and operate network assets. It is also applicable to EDBs that manage natural gas or communications networks. As Lifeline Utilities, these networks face many of the same resilience challenges, and the principles outlined in this Guide are relevant and transferable.

Organisations with electricity generation assets may also adapt the approaches set out here to strengthen resilience planning for generation infrastructure.

The main objectives of this Guide are to assist electricity network owners to:

- improve understanding of the obligations placed on Lifeline Utilities under *the Civil Defence Emergency Management Act 2002* (CDEM Act)
- undertake self-assessment of resilience maturity, capabilities, and preparedness using the *Resilience Management Maturity Assessment Tool* (RMMAT)
- identify gaps in resilience planning systems and processes, and prioritise actions to address them
- conduct systematic risk reduction assessments and develop business cases for investment to mitigate asset or system vulnerabilities
- define and manage critical emergency spares
- plan for the resources, expertise, and mutual aid arrangements needed to respond to and recover from a major event
- provide a reference source to support and enhance resilience planning and continuous improvement, guided by the Resilience Planning Roadmap (Section 18).

This Guide is structured to help electricity network owners embed resilience considerations into their broader asset management and operational strategies. The RMMAT provides a practical benchmarking tool for assessing current resilience maturity, while the Resilience Planning Roadmap sets out a staged pathway to guide continuous improvement over time. Together, they ensure that resilience is approached in a systematic, measurable, and forward-looking way.

3. Glossary and Acronyms

4R's	Approach to hazard management categorised by the four areas of activity known as the 4R's, Reduction, Readiness, Response and Recovery.
AMG	Asset Management Group – an EEA member group that provides governance and oversight for technical working groups, including the Resilience Working Group.
AMMAT	Asset Management Maturity Assessment Tool – a self-assessment tool required under the Electricity Distribution Information Disclosure Determination 2012 (Commerce Commission). Used to assess the maturity of an organisation's asset management practices.
AUFLS	Automatic Under-Frequency Load Shedding – automatic load shedding initiated by Transpower when system frequency falls below a defined level.
CCC	Climate Change Commission – an independent Crown entity established under the Climate Change Response (Zero Carbon) Amendment Act 2019 to provide expert advice to government on climate change mitigation and adaptation.
CDEM	Civil Defence Emergency Management – the application of knowledge, measures, and practices that are necessary or desirable for public safety, or for the protection of property, and are designed to prevent, reduce, or recover from any hazard or emergency. The framework is established under the Civil Defence Emergency Management Act 2002 (CDEM Act).
CDEM Act	Civil Defence Emergency Management Act 2002 – legislation that provides the framework for emergency management in New Zealand and places obligations on Lifeline Utilities to embed preparedness and resilience in their planning and operations.
CIMS	Coordinated Incident Management System – a framework used in New Zealand to support coordination and cooperation among agencies during an emergency event.
Civil Defence	Former name of the Ministry of Civil Defence & Emergency Management (MCDEM). Now replaced by NEMA (National Emergency Management Agency).
ECC	Emergency Coordination Centre – regionally based centre that coordinates response and recovery operations during an emergency.
EDB	Electricity Distribution Business – an entity that owns and operates local electricity distribution networks.
Emergency	Means a situation that:
(Civil Defence Emergency Act, 2002)	*a)* is the result of any happening, whether natural or otherwise, including, without limitation, any explosion, earthquake, eruption, tsunami, land movement, flood, storm, tornado, cyclone, serious fire, leakage or spillage of any dangerous gas

	or substance, technological failure, infestation, plague, epidemic, failure of or disruption to an emergency service or a lifeline utility, or actual or imminent attack or warlike act; and
	b) causes or may cause loss of life or injury or illness or distress or in any way endangers the safety of the public or property in New Zealand or any part of New Zealand; and
	c) cannot be dealt with by emergency services or otherwise requires a significant and co-ordinated response under this Act.
Emergency Management Bill	Draft legislation intended to replace the Civil Defence Emergency Management Act 2002. Enactment is expected in 2026 and is designed to strengthen New Zealand's emergency management system, including provisions for critical infrastructure and Lifeline Utilities.
EOC	Emergency Operations Centre – a local-level facility established to coordinate response and recovery operations during an emergency event.
Extreme event	Also known as a High Impact, Low Probability (HILP) event. Extreme events have a low probability of occurrence (typical return periods of 100 to over 1000 years) but can cause severe disruption to an organisation's ability to maintain normal service. Examples include large earthquakes, volcanic eruptions, and major storms.
GIS	Geographic Information System – a framework for gathering, managing, and analysing geographically referenced data on a map base.
GXP	Grid Exit Point – the point of connection between Transpower's national transmission grid and an Electricity Distribution Business (EDB) network, or in some cases, a major industrial consumer.
HILP	High Impact, Low Probability – see Extreme Event. Refers to events with a low Probability of Failure (PoF) but high Consequences of Failure (CoF).
Lifeline Utility	An organisation or business identified under the CDEM Act that provides essential infrastructure or services to the community, including electricity, water, wastewater, transport, and telecommunications.
MERIT	Measuring the Economics of Resilient Infrastructure Tool – a suite of integrated spatial decision-support systems designed to estimate the economic consequences of disruption events.
NCC	National Coordination Centre – a national-level facility activated during significant emergencies to provide overall coordination and support.

NCMC	National Crisis Management Centre – the central government facility for coordinating crisis management. Provides inter-agency and scalable capability to manage national-level emergencies.
NEMA	National Emergency Management Agency – the government agency responsible for leading and coordinating emergency management in New Zealand. NEMA replaced the Ministry of Civil Defence & Emergency Management (MCDEM).
NIWA	National Institute of Water and Atmospheric Research - is a Crown Research Institute established in 1992. It operates as a stand-alone company with its own Board of Directors and Executive.
NOC	Network Operations Centre – a facility that manages the operational requirements of a distribution network. The NOC oversees power supply restoration following faults or unplanned equipment outages and coordinates safe access for planned maintenance or upgrade works.
RMA	*Resource Management Act 1991* – New Zealand's principal environmental and land-use planning legislation (referenced where relevant to resilience and infrastructure planning).
RMMAT	Resilience Management Maturity Assessment Tool – a self-assessment framework included in this Guide to measure an organisation's resilience maturity. Structured around the 4Rs framework (Reduction, Readiness, Response, Recovery).
Roadmap	Resilience Planning Roadmap – included in Section 18 of this Guide. Provides a staged pathway and checklist to help organisations prioritise and implement resilience improvements over time.
SCE	Sector Coordination Entity – an organisation, group of sector representatives, or individual agreed by the sector to undertake coordination functions in an emergency. In the Electricity Supply Sector this role is currently undertaken by Transpower NZ Ltd.
SCADA	Supervisory Control and Data Acquisition – a control system architecture comprising computers, communications networks, and graphical user interfaces used to monitor and control industrial processes such as electricity networks.
SOROP	System Operator Rolling Outage Plan – a plan developed and implemented by the System Operator for managing rolling outages during periods of electricity supply shortage.
System Operator	The division of Transpower NZ Ltd responsible for the real-time operation of the national power system and aspects of the wholesale electricity market.

TCFD	Task Force on Climate-related Financial Disclosures – an international framework for climate-related financial reporting that has informed New Zealand’s climate disclosure regime.
VoLL	Value of Lost Load – an economic measure of the value placed on electricity that is not supplied to consumers (“unserved energy”) due to planned or unplanned outages of one or more components of the electricity supply chain.

4. Resilience Defined

For the purposes of this Guide, resilience is defined as:

"The ability of assets, networks, systems, organisations, and people to anticipate, prepare for, withstand, adapt to, and recover from disruptive events—ensuring the continued delivery of critical services and functions."

This definition aligns with New Zealand Government policy on resilience, which emphasises reducing risk, adapting to change, and maintaining essential services. It is also consistent with international frameworks, such as those from the *Organisation for Economic Co-operation and Development* (OECD), *United Nations Office for Disaster Risk Reduction* (UNDRR), and the World Bank, which recognise resilience as a dynamic capability that integrates risk management, adaptation, and long-term system transformation.

This Guide focuses on enhancing the resilience of electricity businesses so they can effectively respond to and recover from major emergencies and extreme events, including:

- climate change impacts – more frequent and severe storms, rising temperatures, and sea-level rise
- cybersecurity and digital risks affecting critical infrastructure
- the transition to a low-carbon energy system – including increased electrification and decentralised energy resources
- supply chain disruptions impacting the availability of critical components
- major pandemics reducing operational capability and workforce availability.

Beyond emergency response, resilience must also be embedded into long-term planning and operations to address broader risks, such as:

- future network design and asset specifications, ensuring infrastructure is adaptable and future-proofed
- equipment and support systems, designed to operate under a wide range of uncertainties, including technological shifts and evolving consumer demands.

Resilience in the electricity sector is therefore not only about surviving shocks. It is about adapting, evolving, and building a stronger, more flexible system that supports a secure, reliable, and sustainable energy future for New Zealand.

5. Resilience in New Zealand[2]

5.1 National Disaster Resilience Strategy[3]

The *National Disaster Resilience Strategy (2019–2029)* sets out New Zealand's vision and long-term goals for civil defence emergency management (CDEM). It identifies three key priorities:

– managing risks: understanding and reducing the risks we face

– effective response and recovery: ensuring readiness and capability to respond to, and recover from, emergencies

– enabling, empowering, and supporting community resilience: strengthening communities to adapt and thrive in the face of disruptions

5.2 Civil Defence Emergency Management Framework

CDEM in New Zealand is governed by the *Civil Defence Emergency Management Act 2002* (CDEM Act), which:

– promotes sustainable hazard management that contributes to public safety and wellbeing

– encourages wide participation, including communities, in managing risk

– provides for planning and preparation for emergencies, and for response and recovery

– requires local authorities to coordinate reduction, readiness, response, and recovery activities through regional CDEM groups

– provides the basis for integrating national and local planning and activity through a national strategy and plan

– encourages coordination across a wide range of agencies, recognising that emergencies are multi-agency events affecting all parts of society

These principles are further supported by the National Security System and by guidance issued by the *National Emergency Management Agency* (NEMA).

[2] Note: A government review of New Zealand's emergency management system is currently in progress. The timeframe for completion remains uncertain, but the outcomes may affect how resilience is planned for and delivered across the electricity sector.

[3] *National Disaster Resilience Strategy, G.7D2, April 2019, Ministry of Civil Defence and Emergency Management.*

5.3 Legislation

Under section 60 of the CDEM Act, Lifeline Utilities have specific duties to ensure they are able to function to the fullest possible extent during and after an emergency.

Schedule 1, Part B of the Act defines Lifeline Utilities to include entities that generate or distribute electricity through a network. As a result, electricity generators, Transpower NZ Ltd (as both the transmission owner and System Operator), and all EDBs are classified as Lifeline Utilities.

***Table 1: Summary of Lifeline Utility Duties under the CDEM Act* [4]**

Every lifeline utility must: (a) 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 (b) make available to the Director in writing, on request, its plan for functioning during and after an emergency (c) participate in the development of the national civil defence emergency management strategy and civil defence emergency management plans (d) provide, free of charge, any technical advice to any Civil Defence Emergency Management Group or the Director that may be reasonably required by that Group or the Director and (e) ensure that any information that is disclosed to the lifeline utility is used by the lifeline utility, or disclosed to another person, only for the purposes of this Act.

Some other examples of Lifeline Utilities include:

– transport infrastructure (road, sea, and air)

– community water supply and reticulation systems

– community sewerage and drainage systems

– energy generation and distribution networks, and

– telecommunications network providers.

The *Act* defines an *emergency*[5] as a situation that:

Table 2: Definition of an Emergency under the CDEM Act (Section 4)

(a) is the result of any happening, whether natural or otherwise, including, without limitation, any explosion, earthquake, eruption, tsunami, land movement, flood, storm, tornado, cyclone, serious fire, leakage or spillage of any dangerous gas or substance, technological failure, infestation, plague, epidemic, failure of or disruption to an emergency service or a Lifeline Utility, or actual or imminent attack or warlike act; and (b) causes or may cause loss of life or injury or illness or distress or in any way endangers the safety of the public or property in New Zealand or any part of New Zealand; and (c) cannot be dealt with by emergency services, or otherwise requires a significant and co-ordinated response under this Act.

[4] *National CDEM Plan Order 2015- Sections 57-61*
[5] *Civil Defence Emergency Management Act 2002, Section 4, Interpretation.*

5.4 4 R's

New Zealand's approach to hazard and emergency management is categorised into four areas of activity known as the 4Rs – Reduction, Readiness, Response, and Recovery. These activities are interrelated and together form a continuous improvement cycle (see Figure 1 and Table 3 below). This integrated approach enables Lifeline Utilities to build, assess, and continually enhance resilience before, during, and after major events.

The 4R's as a continuous improvement process.

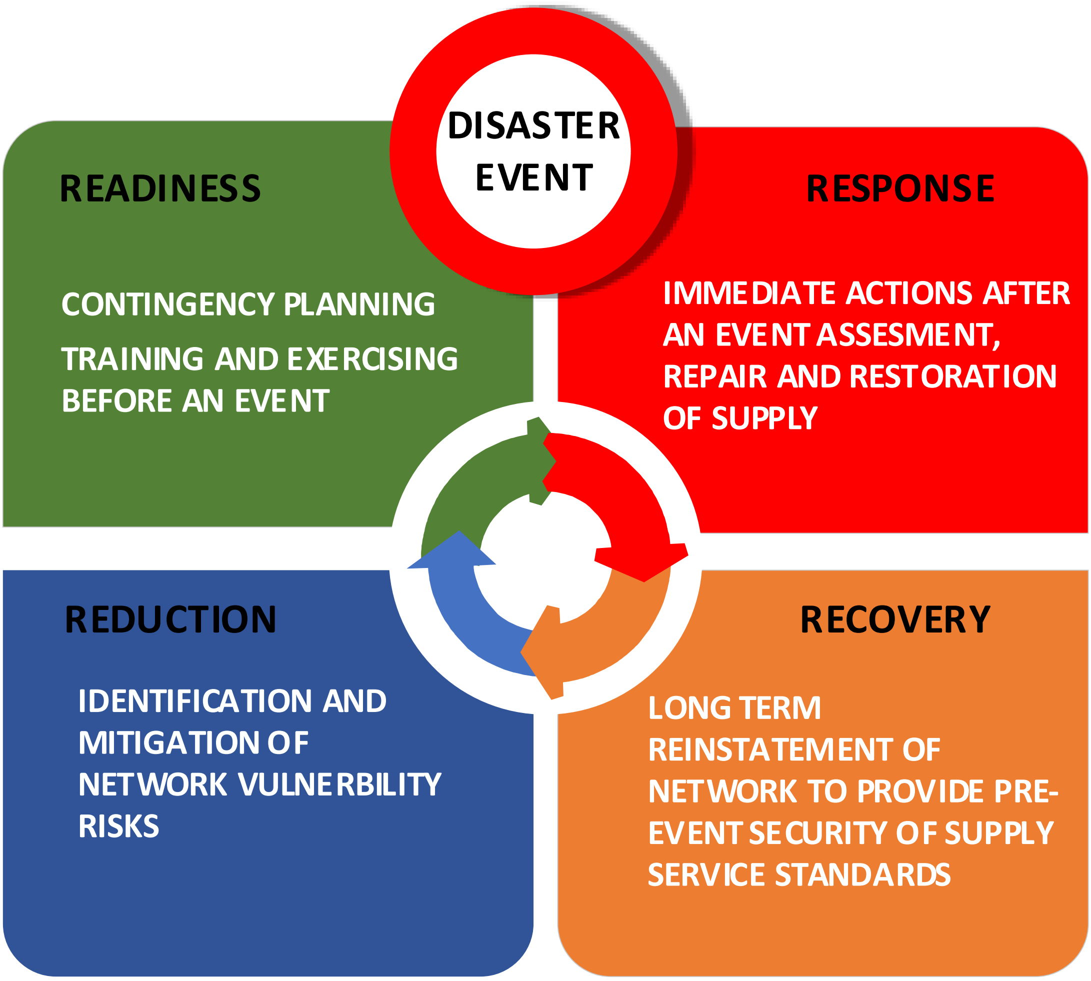


Figure: 1: The 4Rs Framework for Emergency Management in Hazard Planning

Table 3: High Level Definitions of the 4R's

Reduction	**Identify and Mitigate Network Vulnerability Risks** Identifying and analysing long-term risks to human life, property, and infrastructure from hazards; taking steps to eliminate risks where practicable or otherwise reducing their likelihood and impact.
Readiness	**Pre-event Contingency Planning and Training** Developing systems, resources, and capabilities before a major loss event or emergency occurs. This includes self-help and response programmes for the public, and targeted programmes for emergency services, Lifeline Utilities, and other agencies.
Response	**Immediate Actions Following an Event** Actions taken immediately before, during, or directly after an event to save lives, protect property, and restore essential services. In practice, this involves activating readiness plans to enable lifeline utility services to be quickly reinstated.
Recovery	**Long Term Reinstatement of the Network** The coordinated efforts and processes that support the immediate, medium-term, and long-term regeneration of communities following a major event, including the reinstatement and adaptation of electricity network services.

Figure 2 illustrates how the 4Rs align across the timeline before and after a major or extreme event, and how each phase contributes to overall resilience.

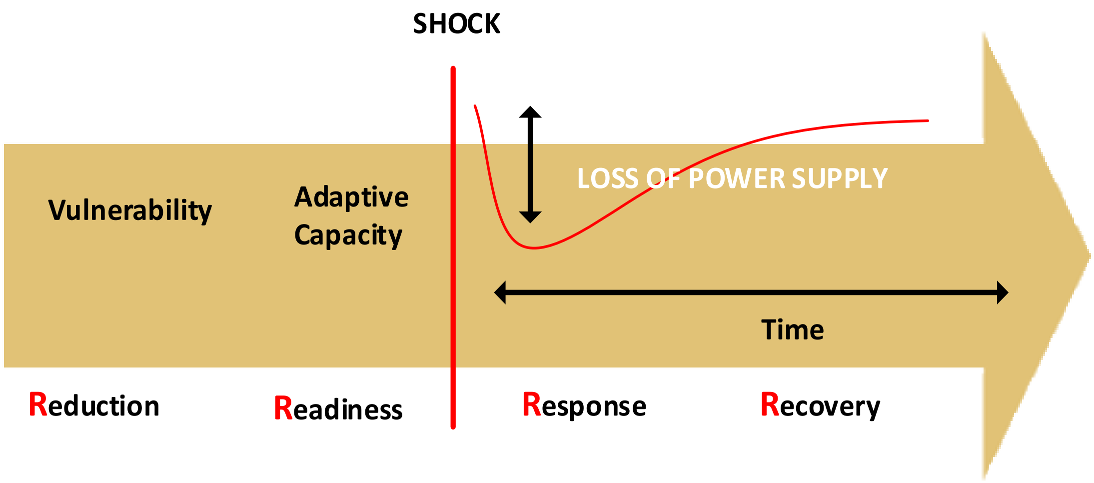


Figure: 2: The Impact of Resilience

A network company that invests across all four areas of the 4Rs is better positioned to restore electricity supply efficiently and meet evolving customer and community needs. Resilience planning ensures that networks can adapt, rather than simply return, to pre-event conditions, particularly where demand patterns or risk profiles have shifted.

Following an extreme event or shock, customer expectations may differ from the pre-event status in terms of service levels and demand. Meeting these needs requires network operators to adapt to new circumstances and embed flexibility in both their planning and operations.

The following sections discuss the requirements of each of the 4Rs in more detail, as they apply specifically to the electricity supply industry.

5.5 Reduction

Purpose of Reduction

Reduction involves identifying, analysing, and prioritising long-term risks, then implementing strategies to eliminate or reduce their likelihood and consequences. This process begins with understanding the exposure and vulnerability of critical assets, both natural and man-made, and taking proactive steps to address these risks.

Effective risk reduction requires a clear understanding of:

- the network's critical assets and their interdependencies
- likely failure modes under different hazard scenarios
- the potential consequences of these failures

For each identified risk, utilities should assess:

- the likelihood of the event occurring
- the potential consequences if it does
- the cost-effectiveness and practicability of mitigation or adaptation measures

This assessment should also consider cascading events, where multiple failures interact.

5.6 Types of Risks

Natural Hazard Risks

- Earthquakes: shaking, liquefaction, lateral ground movement, landslides, tsunami inundation
- Severe Weather: extreme winds, heavy rainfall, snow events, drought with elevated fire risk, landslides / erosion
- Volcanic Eruption: ashfall, lahars, pyroclastic flows
- Space Weather: risks to telecommunications and transmission systems

Man-made and Systemic Risks

– major plant failure (e.g. transformers, busbars, circuit breakers, VTs)

– cyber-attacks on control and protection systems

– fire, explosions, or chemical spills

– transport incidents (vehicle or aircraft crashes)

– structural collapse of network or third-party assets

– sudden major systems failures (communications, SCADA, ancillary equipment) with common-mode impacts

Human Resource and Social Disruptions

– infectious disease pandemics

– toxic substance exposure

– major police emergencies

– civil unrest, demonstrations, or riots

Business-as-Usual Events

– EDBs routinely manage smaller events such as storms or vehicle collisions with poles. While these are considered part of “business as usual,” many of the principles in this Guide remain applicable.

5.7 National Risk Matrix

Figure 3 below shows the National Risk Matrix, developed by the Treasury’s National Infrastructure Unit (2014), which provides an overview of relative risks to New Zealand society.

For each identified vulnerability, the assessment process should:

– clearly define the risk

– evaluate whether it is acceptable if left unmitigated

– determine whether mitigation is economically justifiable.

Utilities are encouraged to identify their top five to ten significant risks and develop targeted resilience plans for these.

When prioritising, businesses should also consider:

– interdependencies with other lifeline utilities (transport, water, wastewater, telecommunications, fuel)

– access to critical resources during emergencies (e.g. fuel, remote communications, road access)

– interdependencies within the electricity sector itself (distribution, transmission, generation, system operation).

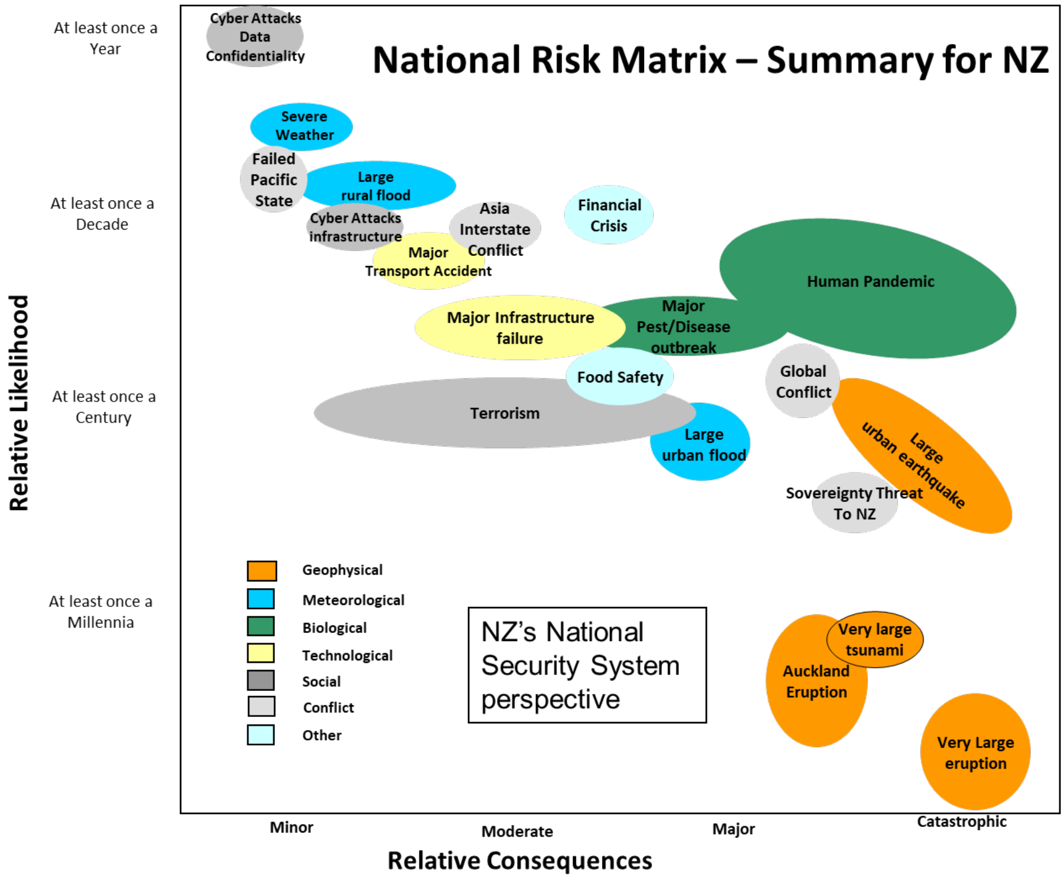


Figure: 3: Overview of the Relative Risks National Risk Matrix

The national vulnerability assessment describes the risks to critical infrastructure including electricity generation, transmission and distribution in part C.[6]

6https://www.civildefence.govt.nz/assets/Uploads/documents/lifelines/NVA-Part-A-Summary-v1.0-Sept-2023.pdf

https://www.civildefence.govt.nz/assets/Uploads/documents/lifelines/NVA-Part-B-Main-report-v1.0-Sept-2023.pdf

https://www.civildefence.govt.nz/assets/Uploads/documents/lifelines/NVA-Part-C-Sectors-and-Hazards-v1.0-Sept-2023.pdfRisk Assessment and Prioritisation

5.8 Lifeline Utility Collaboration

In New Zealand, Lifeline Utility Groups play a central role in assessing the impacts of regional-scale natural disasters. These collaborative forums enable utilities to:

- share knowledge and data
- assess vulnerabilities across sectors (roading, power, communications, water)
- better understand probabilities and potential consequences of major natural events

Such collaboration strengthens cross-sector coordination and supports informed decision-making, (see Section 6 for further detail).

5.9 Risk Mitigation Plans

Risk mitigation, or reduction, plans typically involve practicable capital investment in network assets base or supporting equipment/infrastructure including, plant, spares, and critical systems. These plans should address:

Seismic and Structural Vulnerability

- seismic strengthening of generation and substation assets, including cable bridge crossings
- adequate foundations and anchoring for critical equipment
- clearances from adjacent structures to reduce impact damage
- understanding liquefaction and ground movement impacts on overhead/underground assets
- seismic restraint for critical spares
- testing seismic withstand capacity of ancillary systems (DC supplies, fire protection, water)
- reviewing legacy line designs for resilience against modern storm and snow loads

Network Design Considerations

- ensuring diversity of supply sources for critical loads
- designing GXP interconnections and network architecture with alternate pathways
- adequate line corridors and vegetation/fall-distance management

Emergency Backup Generation

- securing portable or embedded generation capability (including black start and islanded operation)
- ensuring secure emergency fuel supply and storage
- pre-wired connection points at critical sites for diesel generators

Critical Spares and Equipment

- maintaining stocks of critical materials (e.g. cable joint kits)
- arrangements with suppliers/shared stores for rapid replacement
- geographically diverse storage to avoid total loss from single events
- mobile solutions such as portable transformers or HV switchboards

Volcanic Risk Mitigation

- protecting air intakes on generators, vehicles, control rooms, SCADA
- shielding HVAC units and compressors
- protocols for cleaning ash and protecting insulation on outdoor plant

Robust Network Control Facilities

- establishing disaster recovery control centres
- SCADA redundancy with diverse communication links
- alternative backup communications
- fire detection, suppression, and containment systems
- incorporating lessons learned from past incidents

Insurance and Financial Risk Management

- insuring high-value assets (substations, offices)
- considering business interruption or recovery cost coverage where feasible

5.10 Readiness

Definition

Readiness refers to the contingency planning that occurs before a major event or emergency. It includes developing operational systems and capabilities, and training personnel in advance.

While risk reduction often requires significant capital investment, the readiness phase focuses on detailed operational contingency plans, systems, and practices that will be activated during the response phase. These plans outline how risk-reduction investments will be deployed and describe coordination arrangements with emergency agencies.

Five key categories should be considered in readiness planning:

1. Emergency Management Arrangements
2. Network Power Supply Restoration Plans
3. Response Resources
4. Staff Training Requirements
5. Coordination and Communication Requirements

Emergency Management Arrangements

Readiness plans should include comprehensive strategies, such as:

– a company-wide emergency response plan with clearly defined staff roles and incident controller responsibilities

– robust operational control centres and disaster recovery backup facilities with secure SCADA access

– business continuity plans for all critical support functions (e.g. payroll, HR, IT, governance).

Network Power Supply Restoration Plans

Readiness planning for supply restoration should cover:

– documented switching contingency plans for critical asset failures

– system restart plans for regional or island-wide blackouts

– scalable outage management systems

– staff relief and rostering arrangements for operators

– deployment and fuelling of standby generators within LV networks

– access to portable emergency generators for critical loads

– volcanic response strategies, including ash management for plant and equipment

– emergency overhead line build capability and route identification.

All EDBs must also prepare a *Security of Supply Participant Rolling Outage Plan*, aligned with the System Operator's SOROP, to provide predefined load blocks for emergency load shedding. Typical triggers include prolonged hydro shortages, multiple generator failures, or transmission constraints.

Other grid management tools:

– Automatic Under-Frequency Load Shedding (AUFLS): readiness plans should include relay schedules and urgent load locations.

– Special Protection Schemes: automated responses to specific events that support system stability

Response Resources

Plans must ensure adequate resources are available, including:

- mutual aid arrangements with other EDBs, Transpower, and contractors (with manpower management processes)
- contingency plans for high-impact asset failures
- staff welfare arrangements, including fatigue and stress management
- backup accommodation and catering for response teams
- access to critical spares and supply chain continuity plans
- confirmation that key suppliers maintain business continuity arrangements
- aviation services to inspect remote or inaccessible assets
- refuelling logistics for mobile plant, pumps, and emergency generators.

Staff Training Requirements

Exercises are essential to maintain readiness. Two main types are recommended:

1. Civil Defence Exercises – undertaken with Lifeline Utilities to test scenarios and validate processes
2. Organisational Capability Exercises – focused on adaptive capacity, role clarity (including CIMS use), and leadership in emergency management

Exercises should be annual, well-designed, and include asset-specific contingency scenarios for high-impact failures.

Coordination and Communication Requirements

Timely, accurate communication is critical. Readiness plans should set out:

- protocols with emergency agencies (CDEM, Fire and Emergency NZ, Police, ambulance)
- liaison processes with roading authorities (NZTA/Waka Kotahi, local councils) to secure access for crews
- public communication strategies for outage and restoration updates (using social media, websites, public meetings)
- roles and communication pathways for Sector Coordination Entities (SCEs), the National Crisis Management Centre (NCMC), and Lifeline Utility Coordinators (LUCs) as per the Electricity Industry Emergency Contact List.

Transpower currently acts as the SCE for the electricity sector through its Civil Defence Operational Emergency Room (Wellington), with access to the National Control Centre (Wellington and Hamilton) and Grid Operating Centres (Auckland and Christchurch). The Transpower Electricity SCE Liaison Officer is the industry's primary Civil Defence contact during national emergencies.

At the regional level, Lifeline Utility Coordinators (LUCs) are the operational contact point for EDBs during emergencies.

Refer to Appendix C for further detail on the SCE role and communication pathways within the Civil Defence structure.

5.11 Response

Definition

Response plans guide the business in managing the immediate aftermath of an extreme event. The primary goals are to save lives, protect property, and support community recovery.

In practice, the Response Phase involves activating some or all components of the organisation's emergency readiness plans. Activation is carried out by designated personnel, as defined in the overarching emergency management response plan.

Considerations During Plan Development (Readiness Phase)

When developing response plans, organisations should define:

- Triggers for activation: clear criteria for when the plan is activated, and the roles authorised to make that decision
- Staff roles and reporting structure: aligned with the Coordinated Incident Management System (CIMS) framework (see Section 7)
- Immediate post-event actions: steps prioritising safety of the public and staff, such as:
    - conducting centralised damage assessments before field deployment
    - initiating short-term restoration of critical loads where safe and practical.

Actions During the Response Phase

Once an event occurs and the response plan is activated, organisations should:

- coordinate response activities: manage a high volume of "no power" reports, track repair progress, and monitor restoration activities
- progressive restoration: restore supply as far as practicable, using temporary measures if required to support critical loads
- safeguard team welfare and capacity: monitor workforce wellbeing, manage fatigue, and deploy reinforcements from other regions if needed
- assess event duration: estimate response timelines and implications for staff availability and resource requirements

- activate mutual aid arrangements: call on pre-arranged support from contractors, other EDBs, or service providers
- implement public communications: provide regular, transparent updates across multiple channels (media, social media, websites) and hold local public meetings if necessary
- interface with national emergency management: follow established processes for coordination with the National Crisis Management Centre (NCMC) and other agencies when a national emergency has been declared

5.12 Recovery

Definition

Recovery refers to the coordinated efforts and processes required to support the immediate, medium-term, and long-term regeneration of communities following a major event. For electricity networks, this involves restoring service to an acceptable pre-event level through rehabilitation, restoration, and rebuilding activities.

Key Considerations for Recovery Planning

- Timeframes: recovery from large-scale events may take one to seven years or more, depending on severity and scale
- Insurance: asset insurance policies (e.g. earthquake and fire) and loss-of-profit coverage should be considered. These can significantly influence both the pace and scope of recovery
- "Build Back Better": recovery should be guided by resilience principles. This does not necessarily mean stronger or more expensive infrastructure. Instead, the goal is to strengthen community resilience, which may involve:
  - modular or simplified designs
  - improved early warning systems
  - selective rebuilding to a lower standard if it enables faster restoration and adaptation
  - long-term planning should aim to reduce vulnerability to future events while improving recovery speed and outcomes
- Shifting Demand: extreme events may alter customer demand patterns, with reductions in some areas and increases in others. Recovery planning should account for these shifts in load
- Cost and Regulatory Impacts: recovery costs may be substantial, requiring additional borrowing or a Customised Price-Path (CPP) application to the Commerce Commission
- Customer and Stakeholder Communication: a robust communication strategy, ideally scoped during the Readiness Phase, is critical.

Communications must:

- provide transparent updates on damage and estimated timeframes (which may span years)
- explain how customer priorities are being considered in repair and rebuild planning.

– Post-Event Planning: while frameworks can be developed in advance, detailed recovery plans must be finalised after an event, once asset damage is assessed and customer demand trends are understood.

– Project Management: the recovery programme should adopt a structured project management approach. Using the Coordinated Incident Management System (CIMS) framework can help ensure clarity, accountability, and coordination across utilities, contractors, and government agencies.

6. Lifeline Groups and Function

Section 60 of the Civil Defence Emergency Management Act 2002 (CDEM Act) sets out specific duties for Lifeline Utilities. These duties require that each Lifeline Utility: is required to:

Table 4: Lifeline Utility Duties: Section 60 CDEM Act

(a) 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:

(b) make available to the Director in writing, on request, its plan for functioning during and after an emergency:

(c) participate in the development of the national Civil Defence emergency management strategy and Civil Defence emergency management plans:

(d) provide, free of charge, any technical advice to any Civil Defence Emergency Management Group or the Director that may be reasonably required by that Group or the Director:

(e) ensure that any information that is disclosed to the lifeline utility is used by the lifeline utility, or disclosed to another person, only for the purposes of this Act.

Clause 59 of the *National Civil Defence Emergency Management Plan Order 2015* (NCDEMPO) outlines the underlying principles that guide Lifeline Utility operations.

These are:

Table 5: Lifeline Utility Principles: Clause 59 NCDEMPO 2015

Clause 59 - Principles

The principles underlying the role of Lifeline Utilities are to:

(a) identify and understand the full range of hazards and risks and implement reduction strategies; and

(b) prioritise the continuity of operations and supply of services in accordance with response priorities set by the Local Controller, Group Controller, or National Controller (even though this may be at a reduced level); and,

(c) plan co-operatively with local authorities, CDEM Groups, emergency services, and other lifeline utilities; and,

(d) establish emergency procedures for communication with government agencies, CDEM Groups, emergency services, and other lifeline utilities; and,

(e) identify examples of best practice, and share and apply them where appropriate; and

(f) facilitate solutions to issues that are sector specific and do not require government assistance and support; and,

(g) develop common and effective approaches to the 4Rs; and,

(h) co-ordinate with other lifeline utilities to promote service restoration following an emergency; and,

(i) provide information on the status of networks to the EOC, ECC, and NCMC as appropriate.

Clause 60 of the NCDEMPO further elaborates on the role of Lifeline Utilities during the Reduction and Readiness phases of emergency management.

Table 6: Role of Lifeline Utilities: Clause 60 NCDEMPO 2015

Clause 60 - Role of Lifeline Utilities During Reduction and Readiness

1. To help fulfil their duties under section 60 of the Act, all lifeline utilities are to:
    a. develop business continuity plans to:
        i. identify critical assets and business processes, assess their vulnerabilities, and undertake appropriate actions to reduce the risks they face; and
        ii. outline response and recovery arrangements, including appropriate contracting arrangements with key suppliers; and
    b. focus on both reduction and readiness, including planning co-operatively with
        i. other lifeline utilities (whether or not in the in the same sector), especially those on which they are dependent; and
        ii. relevant government agencies and
        iii. CDEM Groups; and
    c. regularly test and exercise their response arrangements and participate in the National CDEM Exercise Programme
2. National lifeline utilities are to:
    a. work with the NEMA to prearrange a means of national level sector co-ordination that best suits their sector (this usually entails establishing a single entity that takes responsibility for managing sector readiness, response, and recovery information, which in turn promotes co-ordinated activity); and
    b. participate in testing of sector co-ordination entity arrangements
3. The NEMA is responsible for nominating and training National Lifeline Utility Co-ordinators to perform co-ordination functions during readiness, response, and recovery
4. CDEM Groups are responsible for nominating and training CDEM Group Lifeline Utility Co-ordinators to perform co-ordination functions during readiness, response, and recovery, including establishing relationships and sector planning arrangements during reduction and readiness.

6.1 Role of Lifeline Utility Groups

Overview

Lifeline Groups are established across all regions of New Zealand. It is recommended that all EDBs join and actively engage with their local regional Lifeline Group.

These groups:

- support the exchange of information on risk management and readiness/response arrangements
- work across the 4Rs of emergency management
- provide a confidential technical forum to address interdependency and infrastructure resilience issues
- identify and mitigate regional infrastructure vulnerabilities, particularly at sites where multiple critical services co-locate (e.g. bridges with utility attachments)

A core priority of Lifeline Groups is to identify key regional infrastructure vulnerabilities. This work often results in documentation that includes mitigation recommendations.

When viewed collectively, these recommendations typically provide greater community benefit than if assessed solely from the perspective of individual asset owners.

6.2 Roles and Activities

- Lifeline Groups contribute not only to risk reduction, but also to readiness and response activities. They develop and maintain a range of outputs to support preparedness and coordinated emergency management, including:
- Restoration priorities: agreed priorities for disaster restoration, including access to priority transport routes
- Contingency planning: fuel supply disruption plans; emergency communications protocols; service continuity plans for technological failures
- Scenario assessments: regional volcanic eruption assessments (ashfall contours, mitigation plans); earthquake risk assessments and contingency planning for critical facilities; tsunami risk assessments and evacuation plans; flood risk assessments for vulnerable assets
- Critical asset identification: each EDB and other utilities identify their critical assets, and those dependent on electricity, for inclusion in response plans
- GIS mapping: mapping of critical infrastructure and interdependencies
- Contractor and resource capacity: reviews of regional contractor capability for response and recovery activities

- Rapid impact assessment: agreed processes for post-event infrastructure assessments
- Mitigation support: monitoring and recommendations to support business cases for resilience investments, redundancy, and hazard management

6.3 Regional Structure

There are currently 17 regional Lifeline Utility Groups in New Zealand (refer to Appendix D).

Further information on Lifeline Groups including contact details and activities are available from the New Zealand Lifelines Council Appendix G.

7. Coordinated Incident Management System

The *Coordinated Incident Management System* (CIMS) was first developed in New Zealand in 1998 to provide emergency management agencies with a consistent framework for coordination and cooperation in response to major events. It was modelled on similar systems used in North America and Australia.

Now in its third edition, CIMS describes how New Zealand agencies coordinate, command, and control incident responses at any scale. It outlines:

- how response structures can be configured
- the relationships between various CIMS functions
- the linkages between different levels of response

It is the primary reference document for incident management in New Zealand

7.1 Definition of an Incident

Within the CIMS framework, an incident is defined as any occurrence that requires a response from one or more agencies. While most incidents are emergencies, CIMS can also be applied to manage non-emergency events such as large public gatherings. Incidents vary in scale and complexity and may be managed at one or multiple levels.

7.2 Purpose of CIMS

The purpose of CIMS is to support effective, coordinated incident management by:

- establishing common structures, functions, and terminology for incident management within a flexible, modular, and scalable framework adaptable to any incident
- enabling agencies to develop processes, procedures, and training aligned with the CIMS framework

CIMS sets out the fundamental elements of response: structures, functions, processes, and terminology. While each agency adapts it to their own roles, resources, and legislative obligations, application begins in the Readiness Phase and is fully deployed during the Response Phase.

7.3 Application of CIMS

- Mandated users: agencies such as NEMA and Fire and Emergency New Zealand are required to use CIMS
- Civil Defence Emergency Management (CDEM): CIMS is applied at multiple levels of CDEM group operations
- Lifeline Utilities: increasingly, utilities such as EDBs are adopting CIMS to align response plans, training, and coordination processes

The EEA recommends that all EDBs incorporate CIMS principles and practices into their emergency management response plans.

Appendix F provides a Powerco NZ Ltd case study of CIMS implementation in managing emergency events.

7.4 CIMS Functions

All CIMS functions should be considered during incident response, regardless of scale. In small incidents, a single person may cover multiple roles, while large-scale responses may require dedicated teams. Organisations may adapt the structure to suit their needs and the objectives of each event. Figure 4 illustrates the CIMS functions for response management. Table 7 summarises their roles.

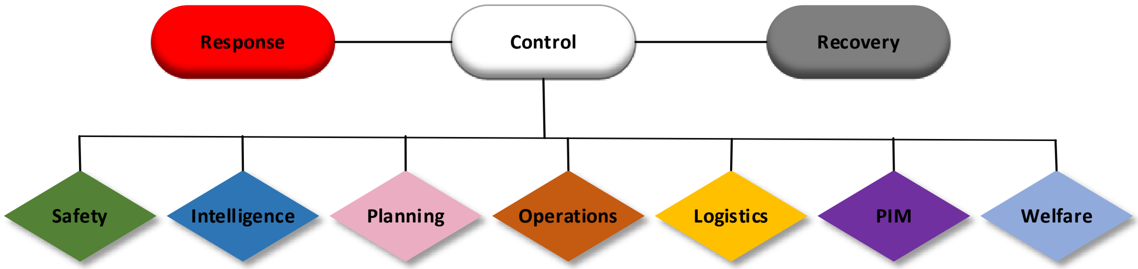


Figure: 4: CIMS Functions

FUNCTION	COLOUR	RESPONSIBILITIES
Control	White	Coordinates and controls the response
	Red	Controller's support
Safety	Green	Adviser on measures to minimise risk to response personnel
Intelligence	Dark Blue	Collects and analyses information and produces intelligence related to context, impacts, consequences, and forecasts.
Planning	Pink	Plans for response activities and resource needs.
Operations	Orange	Tasks, coordinates, and tracks execution of the Action Plan
Logistics	Yellow	Provides personnel, equipment, supplies, facilities, and services to support response activities
Public Information Management	Purple	Develops and delivers messages to the public and liaises with the impacted community. Develops messaging for governance when Strategic Communications is not activated.
Welfare	Light Blue	Ensures planned, coordinated, and effective delivery of welfare services to affected individuals, families / whānau and communities, including animals.
Recovery	Grey	Starts the recovery management process during the initial response phase and ensures the recovery process is integrated with the response

Table 7: CIM Functions

8. Extreme Event Analysis

8.1 Overview

Extreme event analysis is a key component of the Reduction Phase of emergency preparedness (see Section 5.5). It supports electricity network businesses in assessing and managing risks associated with rare but severe events.

Risk assessment and reduction, where economically justified, form a core part of asset management for transmission and distribution networks. A wide range of potential events, each with different probabilities and consequences, should be evaluated and summarised using a risk matrix format. This provides a comprehensive profile of network vulnerabilities.

8.2 High Impact, Low Probability Events

High Impact, Low Probability (HILP) events are a distinct class of risk, generally with return periods from 1-in-100 to 1-in-1000 years or more. Despite their rarity, the consequences can be catastrophic, warranting careful consideration in network planning.

Examples of HILP events include:

– major asset failure or cascading failures: causing system instability, long-duration outages, and potential widespread blackouts

– severe earthquakes: damaging assets and leading to extended restoration timeframes

– severe weather events: cyclones, extreme winds, high rainfall, snowstorms

– volcanic eruptions: especially in the north island, with widespread ashfall

8.3 Risk Assessment Process

To carry out a complete HILP risk reduction assessment, asset owners should:

1. Identify vulnerabilities: determine which assets are exposed to plausible HILP events
2. Assess consequences: estimate potential damage and interruption impacts
3. Evaluate mitigation options: identify measures to reduce risk or speed recovery
4. Undertake economic analysis: compare costs and benefits to prioritise investment

Even modest expenditure may deliver meaningful risk reduction outcomes. HILP analysis also supports better understanding of relative exposure and strengthens engineering judgement in resilience planning.

This process allows network owners to target investment where it delivers the most value, recognising that even modest expenditure may lead to useful risk reduction outcomes. HILP analysis also enhances understanding of relative risk exposure and supports sound engineering judgement when making investment and resilience decisions.

A recommended approach to carry out a *HILP* event risk reduction investment analysis involves the steps outlined below.

Table 8: Risk Reduction Analysis

STEP	ACTION
1	Carry out event risk analysis by obtaining return period / probability of occurrence data from regional Lifelines group reports and, plant reliability performance data. Assess the vulnerability of, and possible damage to, various asset classes to the event types, and assess the likely consequences of this damage. Refer to "Return Period Calculation", below.
2	Estimate the supply interruption in magnitude and duration related to the damage consequences for key assets classes, considering operational power supply restoration strategies such as network switching and typical repair times.
3	Using the event supply interruption duration analysis, establish the risk cost, i.e., benefit, based on the unserved energy multiplied by the Value of Lost Load (*VoLL*). Identify the costs associated with a range of possible risk mitigation options. Rank the options in terms of relative benefit / cost ratios. Note that *VoLL* represents the economic value, in dollars per MWh, that a consumer places on the electricity it needs but does not receive due to power interruption. *VoLL* can vary significantly depending on: – time of year and time of day – equipment accessibility – equipment redundancy – back feed capacity – outage duration, and / or – customer type. The Electricity Industry Participation Code 2010 value of $25,000/MWh can be utilised as a benchmark for *EDB's* that can be amended if studies have been undertaken for a particular load type e.g., that may have a higher *VoLL*, in a location. In the case of a major *HILP* event, power supply may not be able to be restored within a relatively short time frame. A *VoLL* figure that represents the economic damage to the region impacted by an *extreme event* over an extended period may be more relevant.

Return Period Calculation

The term “return period” is an estimate of event likelihood or recurrence interval.

$$P = \frac{1}{T} = \frac{m}{n}$$

Where *P* = probability of an event occurring in a given year

T = return period

n = sample in years

M = number of recorded events (over *n* years)

e.g., for a 1-in-1000-year Earthquake, T=1000

There is a probability

$$= \frac{1}{1000} \times \frac{100}{1}\%$$

= 0.1% chance of occurrence in any given year

Figure: 5: Return Period Calculation

8.4 Key Considerations

- Data reliability: estimates depend on historical knowledge, geology, and sampling period; short samples or incomplete records may understate probabilities
- Organisational memory: past events or near misses may be forgotten, leading to underestimated risks
- Cumulative impacts: more frequent but less severe events (e.g. floods) should also be considered for their long-term cumulative effects
- Cognitive bias: rare events tend to be discounted; extreme events should remain classified at least as moderate risks despite low likelihood

8.5 Beyond Benefit – Cost Ratios

Cost benefit analysis as described in Table 8: Risk Reduction Analysis may not always yield a ratio >1, but resilience investment can still provide significant value through:

- reduced reputational damage
- minimised community hardship, especially in remote/vulnerable areas
- alignment with regulatory expectations
- reduced interdependency risks with other lifeline services

Resilience should therefore be embedded in broader investment decision-making, alongside asset renewals and capacity upgrades, to ensure long-term service continuity and community trust.

9. Other Economic Impact Assessment Tools

9.1 Overview

This section outlines emerging developments in economic assessment tools that enable more sophisticated cost–benefit analysis (CBA) for risk mitigation initiatives aimed at improving infrastructure resilience.

Globally, this is an evolving field, with new tools and frameworks under development to better capture the societal and economic consequences of infrastructure failure. The following provides an overview of current New Zealand practice and highlights international trends.

9.2 Cost Benefit – Current New Zealand Practice

In New Zealand, resilience-related CBA typically relies on the Value of Lost Load (VoLL) to estimate the benefit of reducing outage duration. While this provides a useful starting point, more complex methodologies are emerging.

Standard Approach

– identify resilience threats and pinpoint critical or vulnerable assets

– vulnerable assets are often those below new design standards; a simple metric such as return period (RP) can be used to flag risks

– once vulnerabilities are identified, risk reduction or preparedness options can be assessed by:

  - evaluating a range of mitigation options, including those led by other organisations or communities
  - estimating both the costs and effectiveness of proposed solutions
  - applying an options assessment framework to determine whether quantified analysis is justified based on investment scale and complexity

Quantified Benefit Approach

This involves calculating a benefit–cost ratio (BCR) for each mitigation option at each site, considering:

– reduction in likelihood achieved by mitigation

– solution lifetime and cost

– estimated cost of failure

– uncertainty, addressed through conservative estimates and refined in later phases

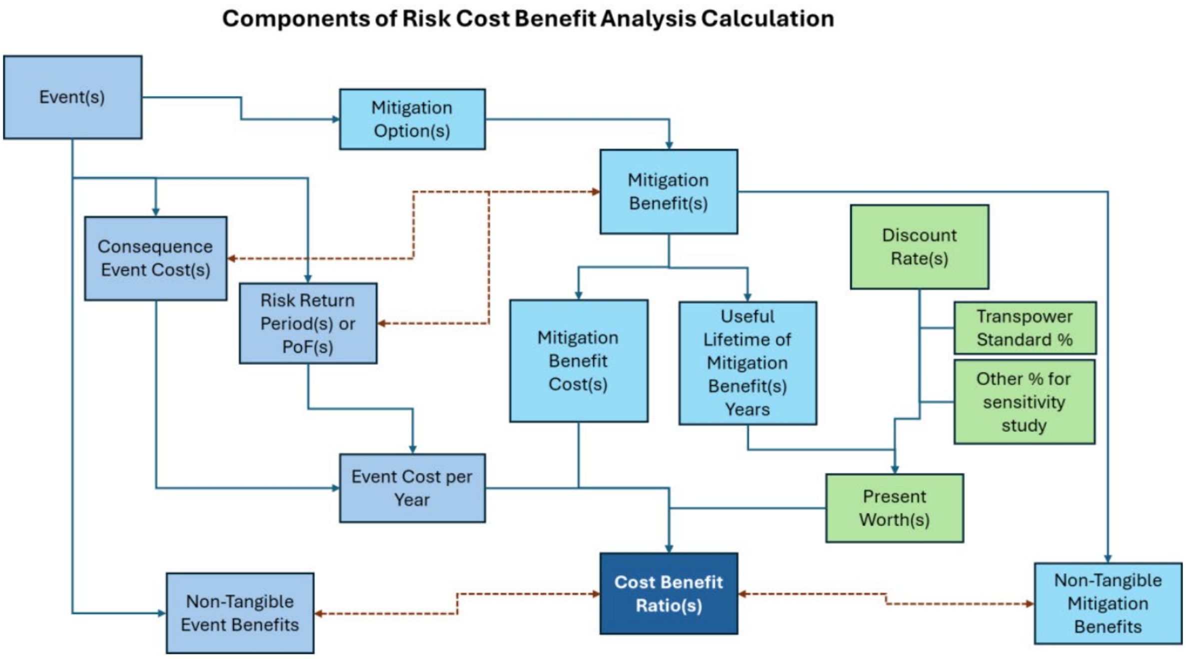


Figure: 6 Components of Risk Cost Benefit Analysis Calculations

9.3 Components of Risk Cost-Benefit Analysis

Key cost-of-failure components include:

– service performance losses (where service can be monetised for societal impact)

– direct financial costs (repair/replacement, operational expenses)

– other societal and reputational costs

For electricity services, service performance costs depend on:

– unserved energy volumes

– outage duration and restoration timeframes

– VoLL (Value of Lost Load)

Accounting for uncertainty:

– estimates must reflect future load growth and changing risk profiles (e.g. climate-driven weather extremes).

– for short outages (≤8 hours), VoLL of $25,000/MWh (per EIPC guidance) is typically applied.

– for longer outages, full VoLL becomes less credible. A reduced VoLL of ~20% is often applied beyond 8 hours, with ranges tested in sensitivity analysis.

Benefit–Cost Ratio (BCR):

– the standard BCR equation is widely used in relevant literature, see Figure 7 below

Cost Benefit (technically B/C ratio):

$$\frac{B}{C} = \frac{(Probability \times Event\ Cost \times Present\ Worth)}{Mitigation\ Cost}$$

Where: $Present\ Worth = \frac{(1+rate)^{Yrs}-1}{rate(1+rate)^{Yrs}}$ technically this is the "*Present Worth Factor*"

$Probability\ x\ Event\ Cost$ = annual value of risk reduction

$rate = Discount\ rate$

Yrs = the number of years that the mitigation is effective

Figure: 7 Cost Benefit Ratio Equation

9.4 Programme - Level Considerations

Beyond individual mitigations, it is good practice to assess the cost–benefit performance of an entire programme, enabling balanced investment across initiatives.

Factors influencing investment decisions include:

– implications of severe low-probability events

– ability of the organisation to recover within acceptable timeframes

– reputational risk if service restoration targets are not met

– compounding hazards at specific locations

Sound decision-making requires integrating quantitative CBA with qualitative judgement, due diligence, and established risk management frameworks.

Typical outputs can include view across a program by cost benefit, program investment and risk as shown below. This can be tested with different cost estimates and discount rates.

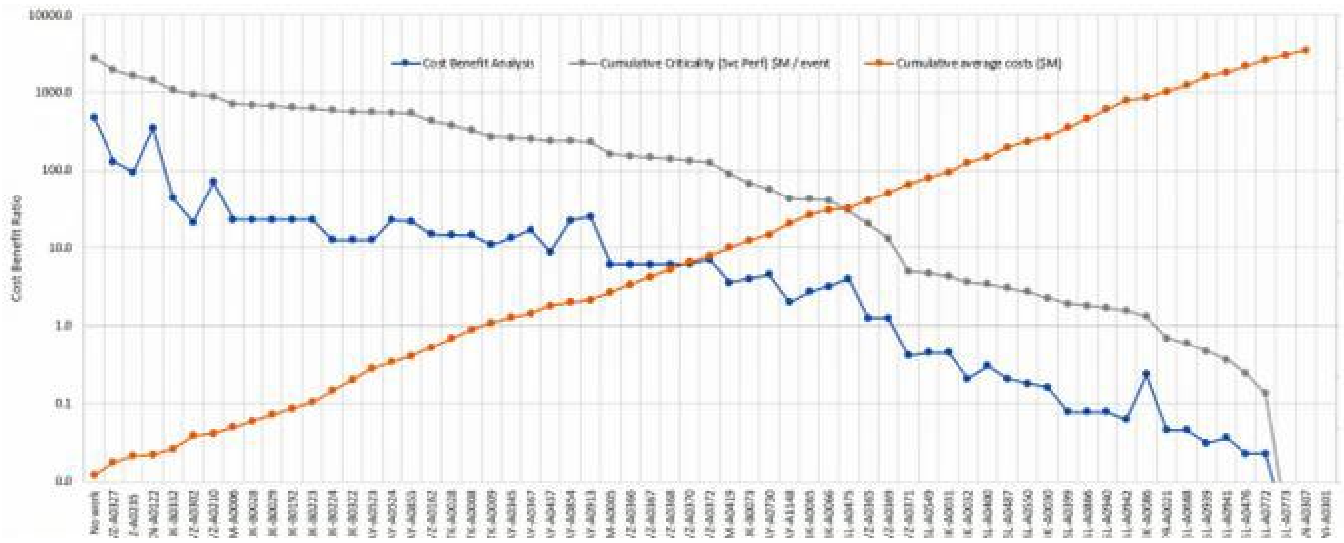


Figure: 8 Typical Programme-Level Outputs

9.5 Advanced Tool – MERIT

For large-scale or complex resilience investments, broader tools are needed to capture system-wide socio-economic impacts.

The Measuring the Economics of Resilient Infrastructure Tool (MERIT), developed through a New Zealand Government research programme, provides:

- high-resolution, spatially integrated economic assessments
- dynamic modelling of outage impacts over time (not just point-in-time values)
- spatial and temporal analysis of recovery trajectories
- modelling of business response and recovery behaviors
- quantification of local, regional, and national GDP losses
- assessment of socio-economic implications of different investment options.

Data requirements:

- MERIT requires detailed spatial modelling of electricity demand (current and future) across distribution feeders and transmission networks, combined with restoration staging scenarios.
- Applications in New Zealand:

MERIT has been successfully used to:

- analyse the economics of an Alpine Fault rupture on the West Coast
- evaluate the impact of a major electricity supply failure in Auckland
- support the Wellington Lifelines business case for resilience investment
- assess resilience options for the Central North Island transmission upgrade.

More information: is available at the MERIT website: [1] https://www.merit.org.nz/merit/

9.6 The Australian Perspective

New South Wales (NSW) Treasury Policy and Guidelines: TPG23-08 and the Disaster Cost–Benefit Framework

The Disaster Cost–Benefit Framework (the Framework), issued as a Treasury Policy and Guidelines paper, sets out how to undertake disaster resilience cost–benefit analysis (CBA). It aligns with the NSW Government Guide to Cost–Benefit Analysis (TPG23-08), which applies to all NSW Government initiatives.

The Framework aims to strengthen the robustness and consistency of resilience CBAs, ensuring better-targeted investment and decision-making. It provides guiding principles, methods, data sources, and standard parameters to support appraisal. While mandatory for some initiatives, the guidance is scalable and should be applied as relevant, depending on the size, significance, and nature of the proposal.

Some relevant extracts from the NSW guide are presented below.

Key considerations when applying CBA to disaster resilience include:

– uncertainty and complexity of climate change impacts Climate change increases the frequency and severity of extreme events, but projections remain uncertain. CBAs must account for wide confidence intervals and use sensitivity testing to avoid under - or over - valuing resilience measures

– expectations of society about government disaster response: Communities increasingly expect rapid restoration of services and proactive investment in resilience. CBAs should reflect the social and political context in which decision-makers operate, not just financial outcomes

– stage of decision-making: The level of detail required in a CBA varies depending on whether the analysis is being used for early prioritisation of options, business-case development, or final investment approval

– timing and focus of the decision: Whether the initiative relates to prevention, preparedness, response, or recovery will influence both the costs and the types of benefits that should be captured. For example, prevention investments often have high upfront costs but long-term system-wide benefits

– stakeholder impacts and views: Disaster resilience initiatives affect a broad range of stakeholders, from consumers to local councils and infrastructure operators. Their perspectives, including willingness to pay and tolerance for service risk, should be integrated into CBA assumptions

– initiative scale and significance: Larger and more complex initiatives may justify more detailed CBAs with advanced modelling, whereas smaller initiatives may rely on simplified approaches

– available resources, data, and capability: The robustness of any CBA is limited by the quality of data, analytical tools, and expertise available. Where information gaps exist, conservative assumptions, qualitative analysis, or scenario testing may be necessary

9.7 The Australian Regulator View

The Australian Energy Regulator (AER) has issued guidance to help networks and consumer groups understand how resilience investments are assessed under the National Electricity Rules (NER). This includes the introduction of a Value of Network Resilience (VNR), alongside the established Value of Customer Reliability (VCR).

Network resilience is defined as:

- a performance characteristic of a network: the ability to continue to provide adequate services and to recover those services when subjected to disruptive events
- the AER highlights the close relationship between resilience and reliability. Improved reliability is typically a service-level outcome of a more resilient network, though other outcomes, such as safety and security, are also relevant
- key expectations for resilience expenditure proposals:
  - a demonstrated causal link between proposed expenditure and the expected increase in extreme weather or other disruptive events
  - expenditure justified as necessary to maintain service levels, based on the option delivering the greatest net benefit of those considered
  - evidence that consumers have been fully informed of resilience expenditure options and support the preferred approach (including willingness-to-pay assessments)
- the guidance also addresses the distinction between network resilience and community resilience:
  - a resilient electricity network contributes to community resilience, but many entities (government, infrastructure operators, social agencies) have broader roles in supporting communities during disasters
  - some initiatives, such as portable back-up generation for community hubs, blur the line between network services and community services. The AER notes that the scope of network service responsibilities under the National Electricity Law (NEL) will influence how such investments are classified

Importantly, the AER emphasises that climate change increases uncertainty around event frequency and severity, making optimal risk allocation essential, between ex ante funding (via revenue proposals) and ex post mechanisms (cost pass-throughs).

9.8 United States of America Perspective

The National Renewable Energy Laboratory (NREL) is a U.S. Department of Energy (DOE) national laboratory operated by the Alliance for Sustainable Energy, LLC under the Office of Energy Efficiency and Renewable Energy.

Key insights are drawn from the NREL technical report "Measuring and Valuing Resilience: A Literature Review for the Power Sector" (NREL/TP-5R00-87053, August 2023).

Key Findings

– Resilience vs. Reliability: resilience and reliability are related but distinct. Reliability generally refers to the ability of systems to withstand and quickly recover from routine, short-term events, while resilience extends this focus to low-probability, high-consequence disruptions. Resilience is therefore considered the broader, higher-level concept.

– Resilience metrics: resilience measurement is still in its early stages, and there is no universal approach. Metrics can be grouped into:

  - Attribute-based metrics: describe system characteristics that enable resilience (e.g., robustness, redundancy, resourcefulness)
  - Performance-based metrics: quantify the effects of resilience investments on system outcomes (e.g., magnitude and duration of unserved energy)
  - Consequence-focused metrics: a subset of performance-based measures, focusing specifically on community or economic impacts of disruptions

– Assessment methodologies: a variety of methods exist to evaluate resilience enhancement strategies, including:

  - N + M redundancy (ensuring sufficient independent components plus spares)
  - network-based methods
  - layer of Protection Analysis (LOPA)
  - probabilistic Risk Assessment (PRA)

– Valuing resilience - Monetisation methods for resilience include:

  - Value of Lost Load (VoLL): widely used in New Zealand and internationally
  - Customer Damage Functions (CDFs): an extension of VoLL that estimates costs by customer class and outage duration
  - Cost–Benefit Analysis (CBA): traditional economic evaluation of investments
  - Social impact metrics: capturing broader consequences such as fatalities, hospitalisations, and community economic stability

Observations

The U.S. literature recognises resilience as a multi-dimensional and evolving concept. While reliability remains a core measure, resilience integrates both technical system performance and broader socio-economic impacts. Metrics are moving beyond purely economic indicators to capture community outcomes, suggesting parallels with approaches such as MERIT in New Zealand.

10. Critical Spares and Equipment Management

Critical spares are essential plant and equipment items required to restore power supply following major or extreme events. Ensuring that these spares are readily available is vital to enable timely repair and restoration of damaged network assets.

10.1 Categories of Spares

Spares can be grouped into three categories, as shown in Table 9 below.

Table 9: Types of Critical Spares

CATEGORY	DESCRIPTION	Examples
Critical	Specialised unit or component items with long procurement lead times or that are no longer manufactured.	Tap changer components, bushings, CTs, VTs, power transformer protection relays, DC battery chargers, station batteries.
Emergency	Standard equipment items required to restore supply quickly. A minimum stock level is desirable to support emergency response.	Transformers, cable sections, switchgear, poles, cross-arms, conductor drums, temporary towers.
Network / Operational	Consumables used in business-as-usual activities, but which may also be needed in emergencies. Stock can be managed with minimum levels.	Cable jointing/termination kits, insulators, line hardware.

Minimum stock holdings should reflect emergency response requirements, the criticality of the asset, and supplier ramp-up capability.

10.2 Developing a Critical Spares Strategy

A comprehensive spares strategy should account for both high-impact low-probability (HILP) events and more frequent, lower-impact disruptions. Its primary goal is to ensure sufficient spares are available to meet restoration timeframes and customer service expectations.

Key elements include:

– Asset specific requirements: legacy assets may require unique components that are obsolete or difficult to procure. Original specialised parts should be securely catalogued and stored

– Storage and documentation: spares selection, location, seismic securing, issue, and reordering procedures should be formally documented

– Procurement lead times: understand and plan for long replacement times for bespoke or imported equipment (e.g., power transformer bushings with >12-month lead times)

– Lessons from past disasters: events such as the 1998 Auckland CBD outage and the 2010–2012 Christchurch earthquakes demonstrated the need for:
  - sufficient spare stock to rebuild up to 10 km of overhead line (66–110 kV rating)
  - ample underground cable joint kits and LV link boxes to replace damaged sections in liquefied soil zones

10.3 Readiness and Inventory Planning

Critical spares planning should align with Readiness contingency plans Section 5 Inventories should include:

– consumables and fast-access parts

– specialised spares for key assets

– emergency overhead line construction kits

– large volumes of joint kits, particularly in earthquake-prone urban areas

Consumables may deteriorate over time; therefore, rotation programs or supplier agreements should be established to maintain stock quality and enable rapid resupply.

10.4 Legacy Asset Considerations

Older fluid-filled cable technologies present unique risks:

– highly specialised jointing/termination kits are required

– skilled personnel are scarce, e.g., repairs to a 66 kV fluid-filled cable may require international experts and take up to four weeks

These risks are best managed through targeted asset replacement programmes alongside spares planning.

10.5 Industry Coordination and Mutual Aid

In a widespread disaster, individual company spares may be insufficient. Sector-wide strategies should be considered, such as:

– establishing an industry-wide inventory of critical consumables

– documenting holdings and storage locations

– formalising mutual aid agreements to enable sharing of spares between EDBs

10.6 Key Steps for Managing Critical Spares

Table 10 below outlines a structured approach to developing and maintaining a critical spares programme.

Table 10: Critical Spares Steps

STEP	DESCRIPTION
1	Conduct a damage assessment analysis (based on network vulnerabilities) to estimate the spares required for various event scenarios.
2	Catalogue current spares holdings and add items identified in Step 1, including consumables and specialised components and their location.
3	Identify strategic storage locations, considering restricted access risks and the need for seismic restraint.
4	Implement or extend an inventory management system with minimum critical spares partitions reserved for emergencies. Outsourcing to service providers may be appropriate. For some businesses this may be a contractor / service provider outsourced function.
5	Determine supplier stock levels and delivery lead times, factoring in potential simultaneous demand from multiple networks asset owners.
6	Consider pooling arrangements with other EDBs to share critical items under mutual aid agreements.
7	Establish an annual audit and review cycle to validate spares holdings, usage, and adequacy.

11. Resilience Management Maturity Assessment Tool

The *Resilience Management Maturity Assessment Tool* (RMMAT) is a self-assessment framework based on similar principles to the Commerce Commission's *Asset Management Maturity Assessment Tool (*AMMAT*)*.

Under the Electricity Distribution Information Disclosure Determination 2012, EDBs are already required to self-assess and disclose the maturity of their asset management capabilities through AMMAT. While AMMAT contains some questions on emergency preparedness, it does not provide a comprehensive measure of resilience maturity. The RMMAT addresses this gap.

11.1 Purpose of the RMMAT

The RMMAT provides organisations with a structured method for assessing their resilience management capability and maturity. It is designed to:

– provide a consistent industry approach to assessing resilience maturity
– identify areas of low maturity for targeted improvement
– enable organisations to monitor and track progress over time
– maintain a focus on continuous improvement
– highlight and share best practice across the industry
– support justification of resilience initiatives to senior management, boards, and regulators

Annual use of the RMMAT is recommended to embed resilience as an ongoing focus rather than a one-off exercise.

11.2 Updates in this Edition

This Guide updates the RMMAT with additional questions reflecting lessons from recent extreme weather events and the growing need to plan for climate change impacts. These additions ensure the tool remains aligned with evolving resilience challenges and best practice adaptation planning.

Refer to Appendix E for the full set of updated RMMAT questions.

11.3 Using the RMMAT

The tool is intended to be used flexibly:

– Scope: organisations may conduct a full self-assessment or focus on priority areas
– Application Levels: it can be applied at the business unit, network, or enterprise-wide level
– Integration: results can inform resilience planning, investment decisions, and external reporting to boards, regulators, or shareholders

Completion is voluntary but strongly encouraged, as it provides a valuable external measure of resilience maturity and demonstrates commitment to continuous improvement.

11.4 Structure of the RMMAT

The RMMAT (Excel-based) includes:

– a user guide on how to complete the assessment

– 71 specific questions grouped into 19 functions, aligned with the 4Rs framework: Reduction, Readiness, Response, and Recovery - Figure: 9: RMMAT Question Structure

– a five-level maturity scoring system Table 11: RMMAT Scoring System

– space for recording evidence supporting scores, ensuring transparency and tracking of progress

– a summary tab with scoring tables - Table 11: RMMAT Scoring System and a radar plot Figure: 10: RMMAT Sample Summary Radar Plot for visualising results.

An Excel *RMMAT* spreadsheet is provided with this guide for organisations to use as a template.

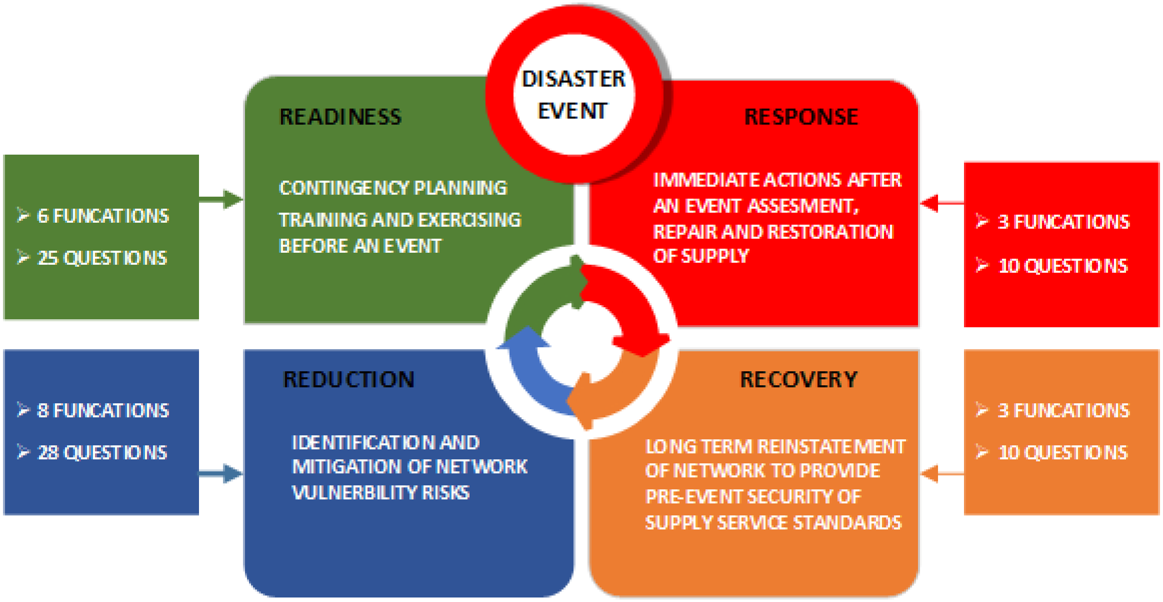


Figure: 9: RMMAT Question Structure

The *RMMAT* questions are grouped under key resilience functions and linked to the 4R's framework; Reduction, Readiness, Response, and Recovery.

SCORE	DESCRIPTION
0 Not Aware	No recognition of the requirement; no evidence of commitment.
1 Aware	Requirement identified; evidence of intent to progress exists.
2 Developing	Systematic and consistent approaches are being progressed with credible, resourced plans.
3 Competent	Requirements are systematically and consistently achieved, with only minor inconsistencies.
4 Excellent	Practices consistently exceed requirements, align with leading international practice, and demonstrate a mature continuous improvement culture.

Table 11: RMMAT Scoring System

ASPECT	FUNCTION	AVERAGE FUNCTION SCORE
REDUCTION	Network Risk Alignment	2.7
	Risk Identification & Assessment	2.0
	Risk Documentation	2.0
	Mitigation of Risks	2.2
	Lifelines Engagement	2.3
	Design Standards	1.0
	Network Spares	1.0
	Contingency Planning	3.0
READINESS	Business Continuity Management	2.1
	Contingency Switching Plans	2.0
	Contingency Planning	1.6
	Communication Plan	2.7
	Contracting Resourcing	1.8
	Lifelines Liaison	2.0
RESPONSE	Response Systems & Processes	2.2
	Generation Capability	2.3
	Response Reviews	2.0
RECOVERY	Recovery Strategy & Plans	1.4
	Recovery Costs	3.0

ASPECT	AVERAGE PHASE SCORE
REDUCTION	2.0
READINESS	2.0
RESPONSE	2.2
RECOVERY	2.2
TOTAL	2.04

Table 12 RMMAT Sample Summary Scoring Tables

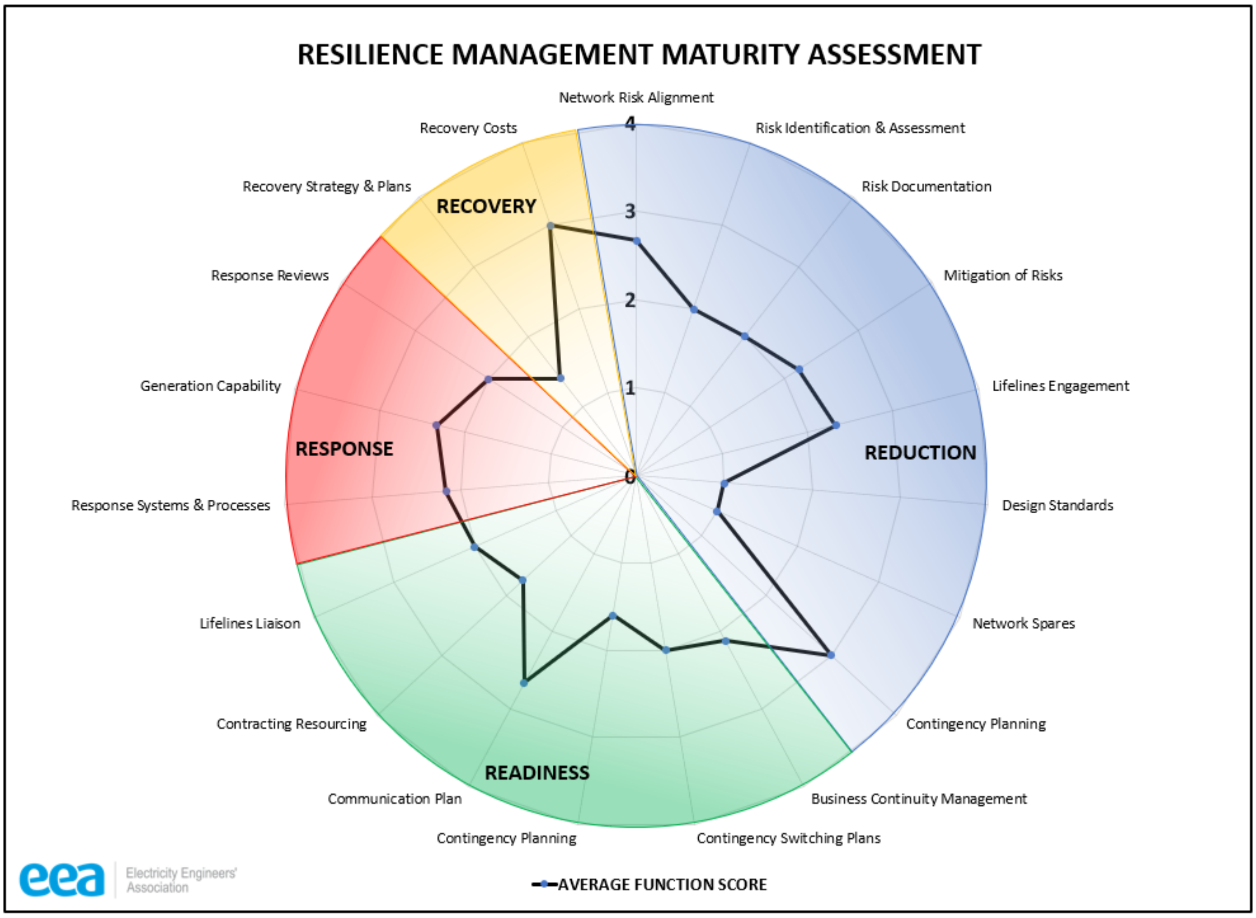


Figure: 10: RMMAT Sample Summary Radar Plot

11.5 Assessment Approach

Organisations should consider their level of maturity based on the five-stage scale outlined above.

After completing the RMMAT, organisations should:

– review areas of lower maturity and prioritise improvement

– celebrate areas of strength and communicate progress

– update resilience strategies, asset management plans, and investment priorities accordingly

– reassess periodically to measure improvement and track maturity growth

11.6 Focus on Practical Validation and Continuous Improvement

The RMMAT promotes a practical, evidence-based approach to resilience maturity. Recommended validation activities include:

- desktop reviews and internal audits
- incident debriefings and lessons learned exercises
- experience sharing through lifeline groups
- regular updates to emergency contacts, plans, competencies, and staff training
- exercises and drills using backup systems and facilities to test real-world capability

These activities ensure that the RMMAT is not just a reporting tool but a driver of continuous improvement in resilience practices.

The detailed RMMAT questions, including the new climate resilience and extreme weather-related additions, are provided in Appendix E.

12. Climate Change Risk

Climate change adaptation is an increasingly critical element of resilience planning. Given the uncertainty in future climate impacts, a least regrets approach is recommended, prioritising actions that deliver resilience benefits under a wide range of possible futures.

Electricity networks are increasingly leveraging geospatial data overlays within *Geographic Information Systems* (GIS) to enhance climate resilience. By integrating multiple data sources, these overlays enable asset owners to identify vulnerabilities, prioritise mitigation measures, and improve emergency preparedness and response.

12.1 Key Applications of Geospatial Data for Climate Adaptation

Flood and Storm Surge Mapping

– historical floodplain data, real-time rainfall forecasts, and sea-level rise projections can be overlaid to identify substations, distribution lines, and other critical assets at risk

> **Example:** National Institute of Water and Atmospheric Research (NIWA), *Coastal Hazards and Climate Change Tool* provide regional sea-level rise scenarios, enabling utilities to plan reinforcement and adaptation strategies for at-risk infrastructure.

Wildfire Risk Analysis

– vegetation cover, wind patterns, and historical wildfire data can be combined to support proactive vegetation management, maintenance, and, where necessary, asset relocation

> **Example:** New Zealand: Future fire risk in New Zealand - *Forest fire danger (1990s, 2040, 2090) - Datasets - Whitiwhiti Ora: Land Use Opportunities*

> **Example:** Australia: The *Bushfire Risk Management Tool* integrates satellite data and AI to model fire spread near energy infrastructure.

Landslide and Erosion Risk Assessment

– GIS overlays of slope stability, rainfall intensity, and seismic activity can help prevent failures in hilly or earthquake-prone regions

> **Example:** Land Information New Zealand (LINZ) *Topo50 maps* provide detailed elevation and terrain data for assessing slope risk - *linz.govt.nz/products-services/maps*

> **Example***:* NZ Transport Agency Waka Kotahi (NZTA) mapping highlights landslip risks along critical state highway corridors - *State Highway Resilience*

Temperature Stress and Heatwave Planning

– urban heat island maps, climate projections, and network load models can be integrated to anticipate thermal stress on overhead lines, transformers, and cables, while also informing dynamic demand forecasting

> **Example**: NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) Land Surface Temperature Data has been used internationally to track heat stress on transmission and distribution assets - *modis.gsfc.nasa.gov*

Implementation and Integration

Electricity utilities should aim to:

– integrate national datasets (e.g., NIWA, LINZ, Scion) with real-time monitoring tools

– use AI-driven predictive analytics to model future risks and adaptation needs

– employ robust GIS platforms such as ArcGIS, QGIS, and Google Earth Engine to layer and analyse climate risk factors at scale

Further Resources, utilities can explore:

– NIWA Climate Change Projections for NZ: *https://niwa.co.nz/climate*

– LINZ Data Service: *https://data.linz.govt.nz/*

– NZ Wildfire Threat Model: *https://www.scionresearch.com/fire*

12.2 Link to the RMMAT

Climate change adaptation and geospatial risk assessment directly align with the Resilience Management Maturity Assessment Tool (RMMAT) framework:

Reduction:	Identifying long-term climate-driven risks (e.g., flooding, wildfire, landslides, heat stress) and embedding adaptation measures into network design and asset management.
Readiness:	Using GIS overlays, national datasets, and predictive models to develop contingency plans and train staff for climate-related emergencies.
Response:	Leveraging monitoring systems and data feeds (e.g., NIWA, GeoNet, Scion) to inform immediate operational decisions during climate-driven events.
Recovery:	Rebuilding or relocating vulnerable assets using climate-resilient design principles and incorporating adaptation into long-term planning.

By linking climate risk management to the RMMAT, EDBs can benchmark their maturity, demonstrate progress in addressing climate adaptation, and ensure that resilience measures remain integrated with asset management and strategic planning.

12.3 Climate Change Risk Checklist

EDBs should consider the following actions to embed climate adaptation and resilience into planning and operations:

Climate Risk Assessment

– conduct vulnerability assessments for key assets against climate-related hazards (flooding, wildfire, sea-level rise, landslides, heat stress)

– incorporate both short-term risks and long-term projections (2040, 2090 scenarios)

– apply a “least regrets” approach to manage uncertainty

Geospatial Data Integration

– use GIS overlays to map hazards such as floodplains, wildfire zones, and erosion-prone areas

– integrate national datasets (NIWA, LINZ, NZ Wildfire Threat Model, NZTA hazard maps)

– apply real-time monitoring and AI-driven analytics for predictive risk modelling

Design and Asset Management

– update design standards to account for future climate projections

– prioritise resilience upgrades for assets in high-risk areas (e.g., substations in floodplains, lines in fire-prone zones)

– incorporate modular and flexible designs to enable rapid adaptation

Operational Readiness

– embed climate hazard scenarios into readiness and response plans

– test restoration strategies under extreme weather and climate stress conditions

– ensure maintenance programs account for increased asset exposure (e.g., vegetation management in fire zones)

Stakeholder and Community Engagement

– collaborate with local councils, Civil Defence, and regional Lifeline Groups on climate adaptation planning

– share hazard mapping and climate risk data with communities to support preparedness

– engage with Iwi / Māori and local stakeholders on long-term resilience planning

Governance and Reporting

- link climate resilience planning to organisational risk registers and asset management strategies
- align with disclosure requirements (e.g., climate-related financial disclosures)
- track progress using the RMMAT (Section 11) to measure maturity in climate adaptation planning

13. Support for Community Hubs

Community hubs play a critical role in providing essential services, shelter, and support during and after extreme weather events or major network disruptions. As climate-related risks increase, EDBs must consider how best to support these hubs to strengthen overall community resilience.

Collaboration between EDBs, local authorities, iwi, marae, and civil defence groups is essential for identifying key hubs—such as emergency shelters, marae, schools, and civil defence centres—and prioritising them in resilience planning. This includes:

- assessing backup power options such as distributed energy resources (DERs), battery storage, and microgrid capabilities
- designing grid connections to maximise reliability and prioritising hubs for restoration in emergency response plans

Examples of Resilient Community Hubs

Marae Resilience Projects (New Zealand): Several marae across Aotearoa have been equipped with solar PV and battery storage to provide backup power during emergencies. For example, Te Puea Memorial Marae in Auckland supports vulnerable communities during extreme weather events

Waikato Community Resilience Initiatives (NZ): Waikato Civil Defence, in partnership with councils and EDBs, has enhanced power resilience at designated emergency hubs, integrating renewable generation and ensuring hubs are prioritised for restoration

Hume Region Community Power Hubs (Australia): In Victoria, a network of hubs equipped with solar-plus-storage systems supports essential services in bushfire-prone areas, maintaining energy supply during extended outages

13.1 Strategies for Network Support

- Resilient Network Design: prioritise connections to designated hubs in investment and maintenance planning to reduce outage risk.
- Local Energy Solutions: support installation of on-site renewables and battery storage for backup supply.
- Demand Flexibility: enable hubs to participate in demand response programmes to optimise use of limited supply during outages.
- Microgrids and Islanding Capability: equip hubs with controls that allow safe operation independent of the grid.
- Stakeholder Collaboration: partner with emergency services, local government, iwi, and community groups to co-design resilience strategies that reflect local needs and cultural priorities.

13.2 Practical Checklist for EDBs

When assessing how to support community hubs, EDBs should:

- identify and map key community hubs (e.g., marae, schools, civil defence centres)
- confirm critical load requirements and restoration priorities with local authorities and emergency services
- assess existing connection resilience and vulnerability to hazards (flood, storm, fire, seismic)
- explore backup power solutions (DERs, batteries, mobile generation)
- consider microgrid and islanding options where feasible
- establish restoration priority protocols in outage management systems
- engage stakeholders regularly to update and test hub resilience plans

13.3 Link to the RMMAT

Supporting community hubs aligns directly with several dimensions of the Resilience Management Maturity Assessment Tool (RMMAT), including:

Reduction:	Proactively reducing community vulnerability through targeted investment in resilient hub connections.
Readiness:	Planning for emergency power supply, hub prioritisation, and coordination with stakeholders.
Response:	Ensuring protocols for rapid restoration of hubs and communication with communities.
Recovery:	Embedding “build back better” principles into hub-related infrastructure upgrades.

By mapping hub-support activities to the RMMAT, EDBs can benchmark their maturity, identify gaps, and track progress in integrating community resilience into network planning and operations.

Summary

Proactive planning, strong stakeholder engagement, and integration with national and regional emergency management frameworks are essential to strengthening the role of community hubs in resilience. By supporting these hubs, the electricity sector can contribute directly to safer, more adaptive communities—helping them withstand, respond to, and recover from disruptive events more effectively.

14. Cyber Security

As the electricity sector becomes increasingly digitalised, cyber security is now a core component of resilience. The convergence of operational technology (OT) and information technology (IT) systems creates new vulnerabilities that, if exploited, can threaten both the reliability and security of electricity supply.

The integration of advanced distribution management systems, smart meters, distributed energy resources (DERs), and cloud-based services expands the potential attack surface. Robust cyber resilience planning is therefore essential to safeguard both critical infrastructure and community trust.

14.1 Key Cyber Security Considerations for Resilience

Threat Landscape Awareness

Electricity networks face a fast-evolving cyber threat environment, including ransomware, supply chain attacks, and state-sponsored intrusions. A proactive, intelligence-led approach is essential, drawing on resources such as:

– CERT NZ: New Zealand's national cyber security advisory body (cert.govt.nz)

– NCSC**:** National Cyber Security Centre, providing critical infrastructure guidance and threat intelligence (ncsc.govt.nz)

Network Segmentation and Access Controls

Strong separation between IT and OT environments reduces the risk of operational disruption. Segmentation, multi-factor authentication, and least-privilege access should be standard practice. Adoption of *Zero Trust Architecture (ZTA) (NIST SP 800-207)* is recommended as a modern best practice.

Incident Response and Recovery

Every EDB should maintain a well-defined and tested cyber incident response plan. Regular exercises and simulations ensure the organisation can rapidly detect, contain, and recover from cyber-attacks. Relevant frameworks include:

– National Metrology Institute for the United States (NIST) *Cybersecurity Framework (CSF)* – widely applied internationally

– Australian Energy Sector *Cyber Security Framework (AESCSF)* – sector-specific guidance for energy networks

Supply Chain Security

Third-party vendors, cloud services, and smart grid devices may introduce cyber risk. Applying *Cyber Supply Chain Risk Management* (C-SCRM) practices *(NIST SP 800-161)* helps ensure that suppliers meet robust security expectations.

Regulatory Compliance and Standards Alignment

Aligning with international frameworks builds consistent sector-wide resilience:

– ISO 27001: Information Security Management

– IEC 62443: Industrial Cybersecurity for Energy and Critical Infrastructure

Workforce and Culture

Human error remains the most common cause of cyber incidents. Regular staff training, awareness campaigns, and cultivating a strong security culture are vital. The NCSC's Critical Infrastructure Cyber Resilience Framework provides sector-specific guidance for embedding these practices.

14.2 Link to the RMMAT

Cyber security maturity is embedded across several dimensions of the Resilience Management Maturity Assessment Tool (RMMAT). In particular cyber practices strengthen:

Reduction:	Identifying and mitigating cyber risks before they materialise.
Readiness:	Embedding cyber incident response plans, exercises, and supply chain safeguards.
Response:	Ensuring rapid detection, containment, and communication during a cyber incident.
Recovery:	Incorporating "build back stronger" approaches for digital infrastructure, systems, and processes post-event.

By mapping cyber security activities to the RMMAT, EDBs can benchmark their maturity, identify gaps, and demonstrate progress to boards, regulators, and stakeholders. This integration ensures cyber resilience is not treated as an isolated IT function but as a core element of enterprise-wide resilience planning.

14.3 Cyber Security Resilience Checklist

EDBs should consider the following actions to strengthen cyber resilience:

– Threat Awareness and Intelligence

- regularly review advisories from CERT NZ and NCSC
- participate in sector-wide cyber threat information sharing forums
- maintain up-to-date awareness of evolving threats, including ransomware, supply chain risks, and state-sponsored activity

– Network Segmentation and Access Controls

- implement strict separation between IT and OT networks
- adopt Zero Trust Architecture (ZTA) principles for all systems and users
- enforce multi-factor authentication (MFA) and least-privilege access

- Incident Response and Recovery
    - maintain and test an incident response plan covering detection, containment, and recovery
    - run regular cyber exercises and simulations with critical staff
    - ensure data backup and recovery systems are isolated and protected from compromise
- Supply Chain Security
    - require vendors and service providers to comply with recognised cyber security standards (e.g., ISO 27001, IEC 62443)
    - apply Cyber Supply Chain Risk Management (C-SCRM) practices to assess third-party risks
    - review contracts to include cyber resilience obligations and breach reporting requirements

- **Compliance and Standards Alignment**
    - align organisational policies with frameworks such as the NIST Cybersecurity Framework, ISO 27001, and IEC 62443
    - benchmark against the Australian Energy Sector Cyber Security Framework (AESCSF) for sector-specific guidance
    - review regulatory obligations for critical infrastructure cyber resilience
- **People and Culture**
    - deliver ongoing training and awareness programs tailored for IT, OT, and field staff
    - promote a security-first culture where employees report suspicious activity without hesitation
    - maintain current emergency contact lists and ensure critical roles have cover for absences

Summary

By integrating cyber security into resilience planning and aligning with recognised frameworks, electricity sector participants can:

- strengthen operational continuity
- reduce the risk of catastrophic cyber disruptions, and
- support New Zealand’s transition to a more secure, reliable, and sustainable energy system

15. Impact of Volcanic Activity

New Zealand's active volcanic landscape presents unique risks to electricity networks, ranging from ashfall and seismic activity to lahar-induced damage. Impacts can vary from localised disruption to widespread outages, depending on the scale and location of an eruption.

15.1 Key Risks to Electricity Infrastructure

Ashfall

– conductive volcanic ash can cause insulator flashovers, tripping lines and damaging equipment. Heavy ash accumulation may also overload substations, transformers, and transmission lines

Seismic Activity and Ground Deformation

– volcanic events are often accompanied by earthquakes and ground movement, damaging poles, substations, and underground cables

Lahars and Pyroclastic Flows

– volcanic mudflows and high-energy pyroclastic flows can destroy infrastructure in valleys and river systems close to active volcanoes

Air Quality and Cooling Systems

– fine ash can clog filters in thermal generation plants and disrupt cooling systems for generators, leading to efficiency losses and potential shutdowns

15.2 Resilience Strategies for Electricity Networks

Preventative Maintenance and Design

– use hydrophobic (ash-resistant) insulators, increase creepage distances, and reinforce critical structures in high-risk zones

Monitoring and Early Warning Systems

– integrate real-time volcanic activity data from GNS Science and GeoNet into operational planning and system control centres

Emergency Response Planning

– maintain and regularly exercise volcanic response plans, including ash cleanup, equipment inspections, and safety checks before re-energisation

Redundancy and Islanding Capability

– improve network flexibility through segmentation, microgrids, and distributed energy resources (DERs) to reduce the extent of service loss

Stakeholder Collaboration

– Coordinate with Civil Defence, local councils, and other lifeline utilities to ensure an integrated response

15.3 Case Studies and Further Reading

1986 Mount Ngauruhoe Eruption

– Ashfall disrupted local power lines and required extensive substation cleaning

1995–1996 Ruapehu Eruptions

– Heavy ashfall affected transmission lines and hydro intakes in the Central North Island. Sector coordination between Transpower and lines companies was critical to maintaining stability

GeoNet Volcanic Monitoring

– Provides real-time seismic and volcanic activity updates, enabling improved readiness

Lifelines and Volcanic Hazards Report (GNS Science)

– Outlines infrastructure vulnerabilities and resilience options for volcanic risk

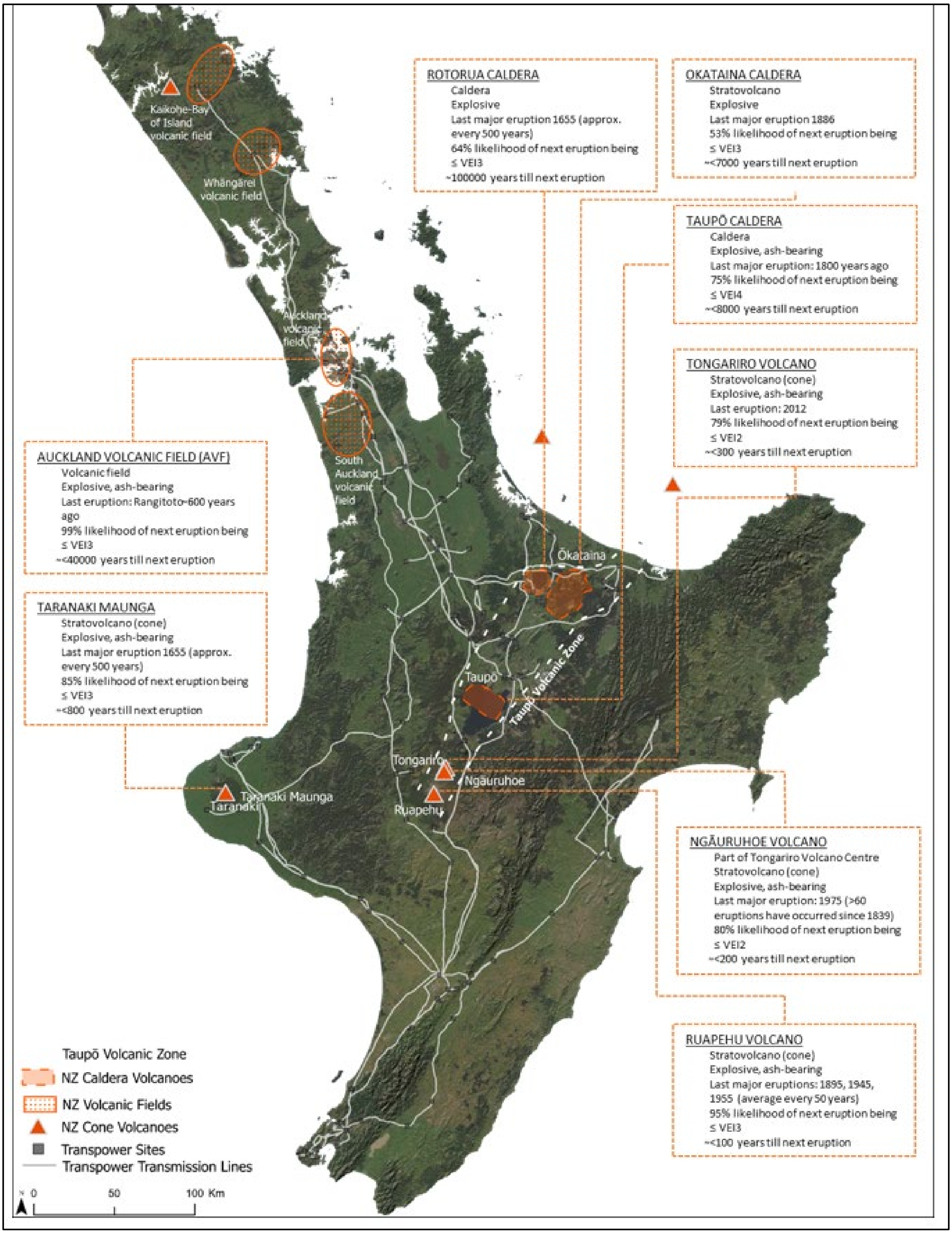


Figure: 11: Volcanic hazard identification for high-energy surface flow hazards from active volcanoes in Te Ika ā Māui | North Island

Credit: Transpower

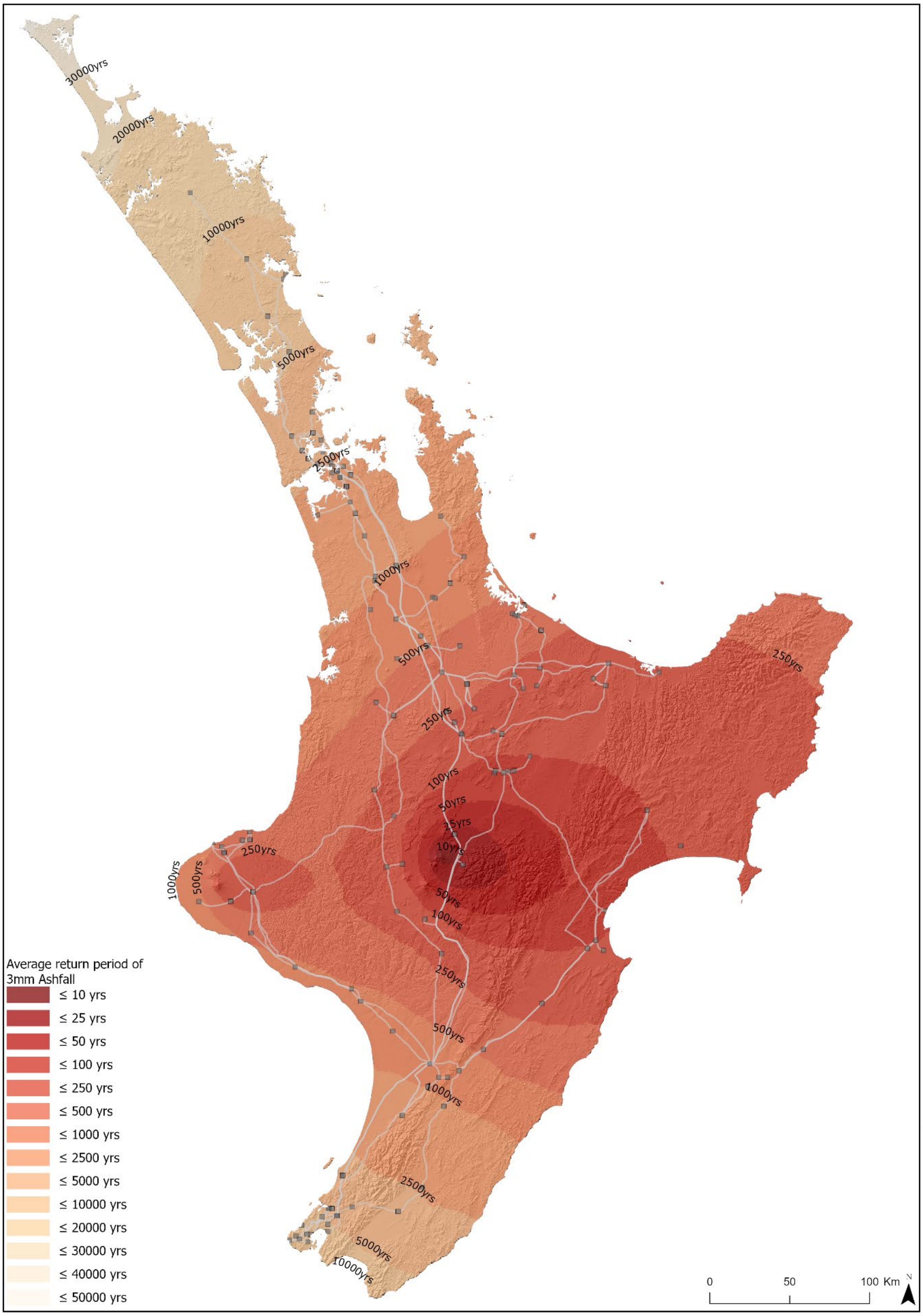


Figure: 12 Volcanic Hazard and Risk Assessment of the Aotearoa NZ Transmission Network

Credit: Transpower

15.4 Hazard Mapping and Probability Assessment

The probability of exceeding 3 mm of volcanic ashfall from New Zealand volcanoes in any given year highlights areas most at risk. Due to low eruption probabilities, the Auckland Volcanic Field (AVF) and Taupō volcano make a relatively small contribution to exceedance probability. Higher risk zones downwind of Mount Taranaki / Taranaki Maunga and the Taupō Volcanic Zone (TVZ) reflect prevailing westerly winds.

The probabilistic ashfall model was developed by Dr Christina Magill (GNS Science), using data from Bebbington et al. (2018), with probability layers overlain against Transpower's high-voltage transmission network for context.

15.5 Link to the RMMAT

Volcanic risk management aligns with multiple elements of the Resilience Management Maturity Assessment Tool (RMMAT):

Reduction:	Designing and maintaining infrastructure to withstand ashfall, seismic activity, and lahars.
Readiness:	Integrating GeoNet and GNS early warning data, training staff, and testing volcanic hazard response plans.
Response:	Rapid mobilisation for ash cleanup, damage assessment, and temporary restoration of critical loads.
Recovery:	Applying "build back better" principles when replacing damaged assets, considering future hazard exposure and community needs.

Mapping volcanic resilience strategies to the RMMAT enables EDBs to benchmark their maturity, track improvements, and ensure volcanic hazards are systematically addressed as part of wider resilience planning.

15.6 Volcanic Activity Resilience Checklist

EDBs should consider the following actions to strengthen resilience against volcanic hazards:

Monitoring and Early Warning

– subscribe to GNS Science and GeoNet volcanic alerts and integrate into operational planning

– establish protocols for rapid escalation when volcanic activity is detected

Design and Preventative Measures

– install hydrophobic (ash-resistant) insulators and increase creepage distances in high-risk zones

– reinforce substations, poles, and lines against ash loading, seismic activity, and ground deformation

– protect cooling and ventilation systems against ash ingress

Emergency Response Readiness

– develop volcanic hazard-specific response plans, including ash cleanup procedures

– pre-position essential equipment and consumables (e.g., spare insulators, joint kits, PPE for ash handling)

– train field crews in working safely under ashfall and poor air quality conditions

Redundancy and Flexibility

– enhance grid flexibility through microgrids, islanding, and distributed energy resources (DERs)

– identify critical assets and customers requiring priority restoration under volcanic hazard scenarios

Collaboration and Coordination

– participate in regional Lifeline Group volcanic hazard planning

– coordinate with Civil Defence, local authorities, and other lifeline utilities for joint response and recovery

Learning and Continuous Improvement

– incorporate lessons from historical eruptions (e.g., Ruapehu 1995–96, Ngauruhoe 1986)

– update volcanic hazard plans as new scientific data, mapping, and scenario assessments become available

16. Pandemic Management

Pandemics present unique challenges to electricity network resilience and business continuity. While each outbreak may differ in scale and impact, the COVID-19 pandemic demonstrated the importance of preparedness, adaptability, and strong sector coordination.

Key learnings

Remote Operations

– office-based and control room staff transitioned effectively to remote work or into isolated team structures, ensuring continuity of network monitoring and control.

Field Workforce Challenges

– public health restrictions, safety concerns, and logistical barriers (e.g., access to closed public facilities) created challenges for field crews. Clear communication, PPE availability, and prioritisation of critical works were essential to maintain safe operations.

Maintenance Triage

– EDBs were required to rapidly distinguish between essential and deferrable works. Coordination across the sector, for example, CEO Zoom calls in the South Island, helped ensure consistent approaches to prioritisation.

Operational Continuity

– despite lockdown constraints, EDBs maintained reliability and responded to emergencies. In one case, crews restored storm damage supply during strict alert level restrictions, demonstrating adaptability under pressure.

Financial Resilience

– stability provided through regulatory revenue settings helped the sector manage short-term financial disruptions.

Sector Coordination

– information-sharing across EDBs, regulators, and government agencies reduced uncertainty and enabled faster decision-making

16.1 Good Practice Example

Northpower Pandemic Management Plan

Northpower developed proactive protocols covering:

– Essential services exemptions for critical works

– Workforce protection measures (including rostering and separation of teams)

– Community lockdown navigation (e.g., safe travel arrangements), and

– Deployment strategies to maintain both operational resilience and public confidence

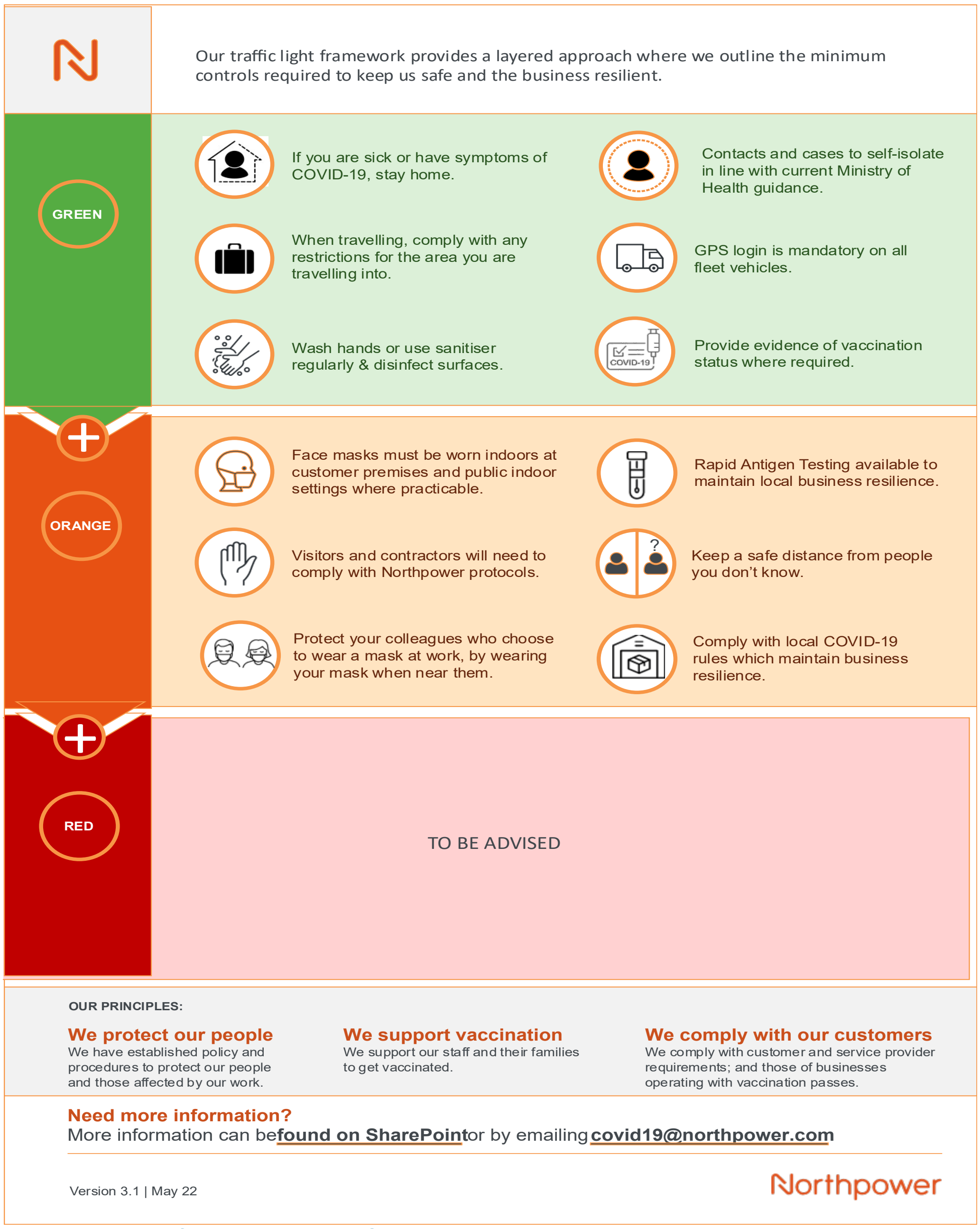


Figure: 13 Extract from Northpower's Covid pandemic management policies

16.2 Link to the RMMAT

Pandemic management aligns with several aspects of the Resilience Management Maturity Assessment Tool (RMMAT):

Reduction:	Identifying potential workforce, supply chain, and operational vulnerabilities to health emergencies.
Readiness:	Developing pandemic response plans, stockpiling PPE, and training staff in safe work practices.
Response:	Rapidly activating contingency measures (e.g., remote operations, workforce rostering, essential works prioritisation).
Recovery:	Embedding lessons learned from COVID-19 into updated business continuity and resilience frameworks, improving adaptability for future events.

By integrating pandemic management into the RMMAT framework, EDBs can benchmark their preparedness, track improvements, and ensure that health-related disruptions are considered alongside physical and cyber risks in resilience planning.

16.3 Pandemic Resilience Checklist

EDBs should ensure their pandemic preparedness and response plans include the following core actions:

Governance and Planning

– maintain an up-to-date pandemic response and business continuity plan

– establish clear decision-making protocols for activating pandemic measures

Workforce Protection

– stockpile PPE and hygiene supplies.

– develop workforce rostering, separation, and redundancy plans (e.g., split teams)

– provide training in safe work practices under public health restrictions

Remote and Isolated Operations

– enable secure remote working for office and control centre staff

– ensure contingency measures for critical operations if staff isolation is required

Field Operations

– define “essential works” and triage maintenance activities

– pre-plan logistics for field staff (food, fuel, access to sanitary facilities)

Sector and Stakeholder Coordination

- participate in industry-wide coordination forums and share lessons learned
- maintain clear communication channels with regulators, government, and communities

Financial and Supply Chain Resilience

- assess impacts on revenue stability and financial reserves
- secure critical supply chains, including spares and consumables

Recovery and Continuous Improvement

- capture lessons learned and integrate into resilience planning
- reassess plans regularly through exercises or desktop simulations

17. Fire Risk Management

Fire risk management is critical to maintaining the resilience of New Zealand's electricity networks. Both wildfires and equipment-related fires can damage infrastructure, disrupt supply, and endanger public safety. With climate change increasing the frequency and intensity of extreme weather events, proactive fire mitigation strategies are essential.

Key Considerations

Vegetation Management

- regular clearance of vegetation around power lines, substations, and poles to reduce ignition risk from conductor contact

Fire-Resistant Infrastructure

- use of fire-retardant materials in poles, transformers, and substations to enhance resilience

Asset Design and Protection

- engineering equipment to minimise arc faults and applying automatic reclosing strategies to prevent repeated ignition attempts in high fire-risk conditions

Monitoring and Early Detection

- deployment of technologies such as thermal cameras, LiDAR, and AI-driven monitoring systems to identify overheating or ignition points before escalation

Emergency Response Planning

- coordination with Fire and Emergency New Zealand (FENZ) and local authorities to enable rapid response, effective firefighting, and timely system restoration

17.1 Case Studies and Best Practices

California – Public Safety Power Shutoff (PSPS) Program

– Utilities such as PG&E de-energise lines during extreme fire weather. This reduces ignition risk but requires careful balancing to minimise disruption to communities.

Australia's Bushfire Management Strategies

– The Australian Energy Regulator (AER) requires network operators to implement risk-based vegetation management and asset hardening.

– Victorian networks (e.g., AusNet, Powercor) apply Resonant Earthing Fault Current Limiters (REFCLs) to restrict earth fault currents and reduce ignition energy. *(See REFCL Functional Performance Report, Energy Safe Victoria)*

New Zealand's Wildfire Risk Modelling

– Collaboration between the forestry and energy sectors has improved risk mapping, allowing networks to better target resilience investments in fire-prone areas.

17.2 Link to RMMAT

Fire risk management practices should be assessed regularly using the Resilience Management Maturity Assessment Tool (RMMAT) (Section 11).

Reduction:	Implementing risk-based vegetation management, adopting fire-resistant materials, and integrating fire-weather and ignition-risk data into network planning and asset design.
Readiness:	Developing and testing fire response plans, maintaining coordination with Fire and Emergency New Zealand (FENZ), and training staff on preventive maintenance, field safety, and emergency communication procedures.
Response:	Using real-time monitoring and detection systems (e.g., thermal imaging, LiDAR, and weather analytics) to identify ignition risks early and deploy field crews safely under high-risk conditions.
Recovery:	Restoring damaged infrastructure efficiently, assessing post-event performance, and embedding lessons learned into future design and maintenance practices.

By integrating fire risk management into the RMMAT framework, EDBs can benchmark their current maturity, identify areas for improvement, and track progress in strengthening wildfire resilience across their networks and operations.

17.3 Fire Risk Management Checklist

Vegetation Management

– Regularly inspect vegetation clearance zones around lines, poles, and substations.

– Implement risk-based trimming schedules in fire-prone areas.

– Coordinate with forestry and local landowners to manage encroachment risks.

Fire-Resistant Infrastructure

– Use fire-retardant poles, transformers, and substation components where feasible.

– Assess high-risk areas for targeted asset hardening upgrades.

Asset Design and Protection

– Review and apply design standards to minimise arc fault ignition.

– Implement adaptive reclosing strategies (e.g., disabling auto-reclose in high-risk conditions).

– Consider application of *Resonant Earthing Fault Current Limiters* (REFCLs) in rural high-risk zones.

Monitoring and Detection

– Deploy thermal cameras, LiDAR, and/or AI tools to detect overheating and ignition risks.

– Integrate wildfire risk mapping into network operations and planning.

– Establish real-time communication links with fire monitoring agencies (e.g., FENZ, NIWA).

Emergency Response Planning

– Maintain protocols for coordination with Fire and Emergency New Zealand (FENZ).

– Pre-identify critical assets requiring priority response in wildfire scenarios.

– Stock emergency firefighting kits and mobile suppression resources for field crews.

– Train staff in wildfire safety and emergency shutdown procedures.

Industry and Community Collaboration

– Participate in regional Lifeline and wildfire resilience forums.

– Share fire risk models with local authorities and emergency services.

– Engage with communities to explain Public Safety Power Shutoff (PSPS) or other emergency measures if adopted.

17.4 Further resources

Fire and Emergency New Zealand (FENZ) Wildfire Management: *www.fireandemergency.nz*

Australian Energy Regulator’s Bushfire Risk Strategies: *www.aer.gov.au*

Pacific Gas and Electric (PG&E) Wildfire Safety Plan: *www.pge.com*

18. Resilience Planning Practices

EEA members are increasingly embedding resilience improvement initiatives within their Asset Management Plans (AMPs). These initiatives often begin with network hardening measures to address the impacts of climate change, requiring updates to network design parameters, materials, and asset siting to maintain robust performance under more extreme conditions.

However, resilience improvement must extend beyond physical hardening. It should also encompass business functions, workforce capability, operational readiness, and recovery planning, ensuring that EDBs are prepared for a wide range of risks.

This section provides a checklist of resilience improvement topics that can be assembled into a tailored roadmap. The topics reflect current practices across New Zealand EDBs and align with international best practice and emerging industry trends.

18.1 Resilience improvements by network hardening

The following areas should be addressed:

Vegetation Management

- deploy LiDAR or satellite imaging to assess tree clearances from power lines
- scope and prioritise management of high-risk vegetation sections
- collaborate with local councils to improve management of council-owned trees near network assets

Hardening the Network

- replace bare overhead conductors with aerial bundled conductor (ABC) or covered conductor in high-risk areas
- convert radial networks to meshed configurations where economically viable
- introduce composite crossarms for improved durability
- reassess legacy line designs against modern wind and snow-loading standards

Fire Risk Mitigation

- use FENZ and NIWA data to identify high fire-risk areas
- remotely disable automatic reclosing on lines in fire-prone areas during extreme fire days
- introduce sparkless fuse technology
- consider installing *Ground Fault Neutraliser* (resonant earthing) technology in very high-risk areas

Seismic and Tsunami Resilience

- Undertake seismic strengthening of substations and other critical network assets
- Assess liquefaction-prone soil zones and evaluate asset impacts
- Evaluate tsunami exposure for coastal assets and design mitigation measures

Managing Sudden Asset Failures

- Implement dynamic cable rating adjustments based on soil moisture and NIWA data, with SCADA integration
- Review overhead line thermal ratings for rising ambient temperatures
- Conduct enhanced condition inspections of key assets
- Ensure power transformers are operated within rated capacity and supported by adequate spares

Asset Vulnerability and Climate Change

- Identify exposure to sea-level rise, floods, landslips, and storm surges
- Integrate climate projections into siting and civil works design

Advanced Resilience Solutions

- Deploy microgrids to support communities during prolonged outages
- Partner with global firms to apply predictive weather and outage modelling tools
- Invest in *Distributed Energy Resource Management Systems* (DERMS) to optimise distributed generation and demand response
- Assess volcanic risk, including ashfall impacts, and implement mitigation strategies
- Provide backup power (diesel, solar-plus-storage, wind, or satellite comms) for community hubs

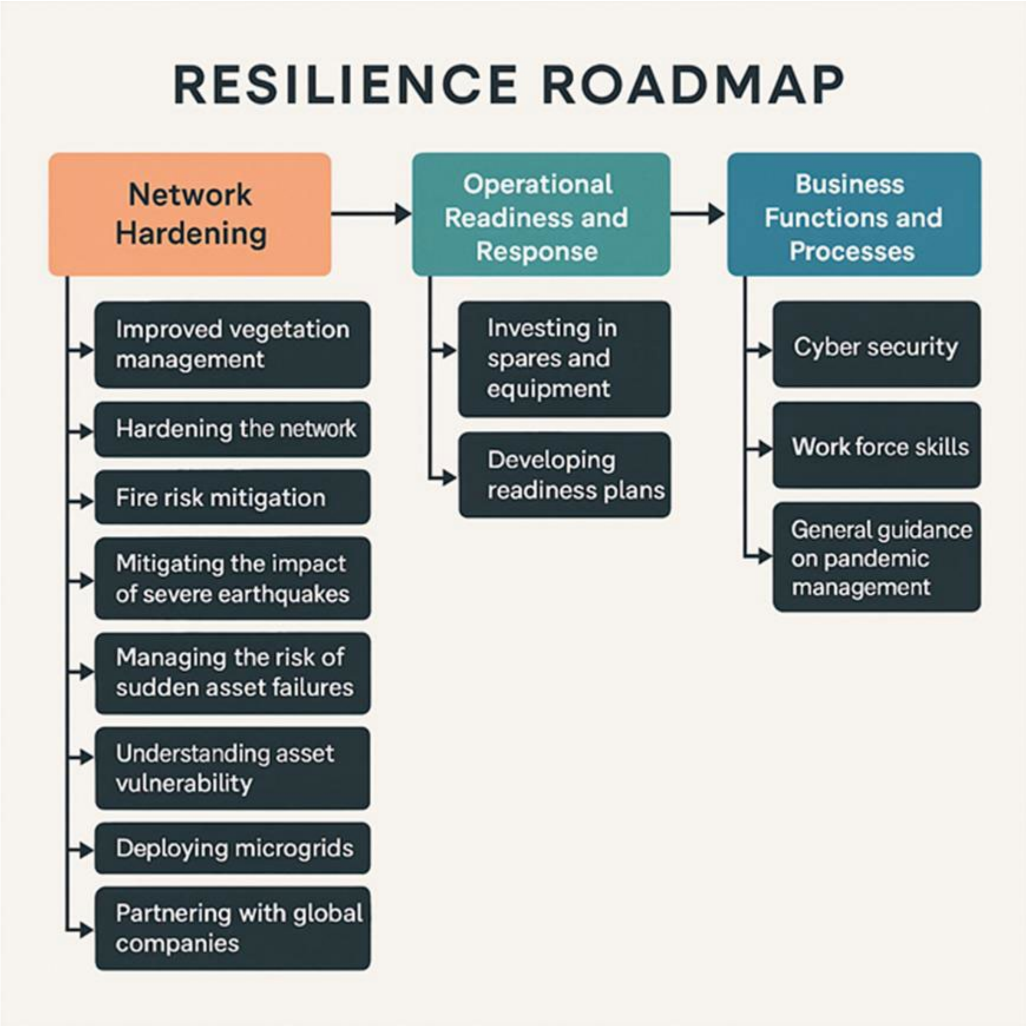


Figure: 14 Resilience Planning Roadmap Overview

18.2 Resilience improvements through operational readiness and response

Critical Spares and Equipment

- Maintain inventories of transformers, switchgear, protection equipment, and consumables
- Participate in mutual aid and spare sharing arrangements across the sector
- Ensure sufficient mobile generators, modular substations, and deployable comms systems are available for rapid restoration

Readiness and Emergency Planning

– regularly review and test emergency response and business continuity plans, aligned with Civil Defence and emergency services

– conduct scenario-based exercises (extreme weather, cyberattack, earthquake, volcanic activity)

– train staff in decision-making under pressure, supported by clear escalation and communications protocols

18.3 Resilience through Business Functions and Processes

Cyber Security

– strengthen cyber defences across IT and OT systems (see Section 14)

– incorporate security by design into digital transformation programs

Workforce Capability and Supply Chains

– monitor workforce demographics, training needs, and capability gaps

– diversify supply chains to reduce exposure to global disruptions

Pandemic Preparedness

– maintain business continuity plans for infectious disease events

– establish isolated facilities for essential operations

– invest in secure digital collaboration platforms to support remote operations

18.4 Conclusion

Building resilience requires a systems-based approach that integrates physical hardening, operational readiness, business processes, and community collaboration. The checklist in this section provides a structured foundation for EDBs to design a Resilience Improvement Roadmap, tailored to their risk profile and strategic objectives.

19. Labour Force Skills and Common Competency Framework

19.1 Building a Resilient Workforce

A skilled and adaptable workforce is critical for maintaining the resilience of New Zealand's electricity sector. The increasing complexity of networks, driven by decarbonisation, decentralisation, electrification, and climate-related challenges, requires workers with advanced technical expertise, strong safety culture, and the ability to respond effectively under pressure.

Workforce resilience is not only about skills. It also requires capacity (enough trained people to meet demand) and capability (the right mix of expertise). Both are essential for maintaining safe operations during business-as-usual conditions and scaling up response during extreme events.

19.2 Competency Frameworks for Workforce Development

A Common Competency Framework (CCF) standardises qualifications, training, and skill sets across the sector. This ensures consistent safety and technical practices, reduces duplication, and supports mutual recognition of skills across organisations. Importantly, it enables more agile workforce deployment during emergencies by breaking down barriers to mobility.

Key Elements of a Common Competency Framework:

- Core Safety and Technical Training: standardised switching, safety protocols, and emergency response procedures
- Specialised Resilience Skills: training for storm restoration, fault response, and critical event management
- Cross-Industry Recognition: alignment between EDBs, transmission operators, and contractors to ensure workforce mobility
- Upskilling Pathways: structured development for emerging areas such as cyber resilience, digital grid technologies, and DER (Distributed Energy Resource) integration

19.3 Examples of Industry - Led Initiatives

- EsiTrain and Connexis (New Zealand): industry-recognised training for line mechanics, cable jointers, and electricians, providing a consistent national baseline
- EEA Common Competency Framework and associated guidelines: https://eea.co.nz/what-we-do/capability-development/common-competency-framework/
- ENA Common Competency Framework (Australia): a structured framework that harmonises training across utilities, improving cross-border workforce deployment during major events
- EEA Workforce Development Initiatives (NZ): technical guidelines and programmes that promote best practice in workforce capability and training

19.4 Future Workforce Considerations

With the transition to a low-carbon and more distributed energy system, the workforce will need to evolve rapidly. Key focus areas include:

Digital Skills Investment

– training in automation, SCADA, AI-based monitoring, and data-driven decision-making.

Workforce Mobility

– sector-wide agreements to enable rapid deployment of workers across regions during extreme events.

Diversity and Inclusion

– expanding recruitment to attract Māori, Pasifika, and underrepresented groups, building cultural as well as technical resilience.

19.5 Conclusion

A coordinated approach to workforce competency will ensure that New Zealand's electricity sector has the right skills in the right place at the right time. Embedding a Common Competency Framework across the industry strengthens everyday operations and emergency response, ultimately delivering a more resilient and secure electricity supply for consumers.

19.6 Further Reading and Resources

Connexis NZ: Energy Industry Training

EsiTrain: Electricity Supply Industry Training

Energy Networks Australia's (ENA): Common Competency Framework (Australia)

Appendix A - CIMS Structure

Background

The *Coordinated Incident Management System* (CIMS) was first developed in New Zealand in 1998 to provide a consistent framework for emergency management agencies to coordinate and cooperate effectively during incident response. It draws on similar systems used in North America and Australia.

The third edition of CIMS (2019) replaces earlier versions and describes how agencies and organisations in New Zealand use the framework to manage:

- incident responses of any scale
- the respective functions within the response structure
- levels of response and their relationships, and
- how a response can be structured at each level.

CIMS is the primary reference document for incident management in New Zealand. An "incident" is defined as any event requiring a response from one or more agencies or organisations. Incidents can range from small-scale to complex, multi-agency emergencies under the *Civil Defence Emergency Management Act* (CDEM Act).

The framework is overseen by a steering group representing 18 stakeholder organisations and endorsed by the Officials' Committee for Domestic and External Security Coordination. CIMS is reviewed every five years, or more frequently if required.

Purpose: A Common and Modular Framework

The purpose of CIMS is to ensure that personnel can respond effectively to incidents through coordination across functions and organisations, both vertically and horizontally, by:

- establishing common structures, functions, and terminology within a flexible, modular, and scalable framework tailored to specific circumstances, and
- providing organisations with a reference model they can use to align their own processes and procedures, supporting both internal responses and multi-agency interoperability while respecting each organisation's unique responsibilities, resources, and legislative authority.

Mandates

Emergency management arrangements in New Zealand are coordinated under the CDEM Act 2002 and the *National Civil Defence Emergency Management Plan Order 2015*, alongside other relevant legislation.

These legislative frameworks provide response personnel with access to special emergency powers, such as entry, direction, exclusion, or removal. Most powers under the CDEM Act require a declared state of emergency before they can be exercised, though other statutes enable the use of emergency powers by appointed officials. In most incidents, however, management occurs without invoking these powers.

When to Use CIMS

The National CDEM Plan Order 2015 expects emergency services to use CIMS to:

- coordinate their operations, and
- ensure those in key national, regional (CDEM Group), and local roles are trained and practiced in its use

CIMS applies to all hazards and risks and provides effective management across a wide range of incidents, including:

- natural hazards (earthquakes, floods, storms, volcanic activity)
- biosecurity incursions
- environmental damage
- fire incidents
- food safety issues
- hazardous substance incidents
- mass maritime arrivals
- marine mammal strandings
- missing person/search and rescue operations
- pandemics and communicable disease outbreaks
- public disorder and terrorism
- public health and medical emergencies
- transportation accidents
- technological failures, and
- business continuity disruptions

It may also be used for planned events (e.g., parades, celebrations, concerts, official visits) where coordinated incident management is required.

Audience

CIMS is intended for:

- agency and organisational planners and SOP developers
- trainers and capability development personnel
- readiness, response, and recovery personnel, and
- Chief Executives and managers responsible for governance and oversight

CIMS in the Context of the 4Rs of Emergency Management

The overarching goal of emergency management in New Zealand is to protect people and property from natural and man-made hazards.

While the 4Rs framework covers Reduction, Readiness, Response, and Recovery, CIMS primarily focuses on the Response Phase, but its principles also apply to readiness and recovery activities.

An example of how CIMS can be applied within an Electricity Distribution Business (EDB) context is provided in Appendix F.

Appendix B - Civil Defence Emergency Management Structure

Purpose and Functions

The Civil Defence Emergency Management Act 2002 (CDEM Act) establishes the duties, functions, and powers of central government, local government, emergency services, Lifeline Utilities, and the public.

One of the Act's key purposes is to encourage coordination across emergency sectors, primarily delivered through 16 regional CDEM Groups. Each Group comprises local authorities working in partnership with emergency services, guided by the National Emergency Management Agency (NEMA).

NEMA and the Groups are responsible for:

- identifying and understanding hazards and risks, and
- preparing and maintaining CDEM Group Plans, consistent with the 4Rs (Reduction, Readiness, Response, Recovery).

CDEM Group Plans

Under the CDEM Act, each Group must prepare and approve a CDEM Plan, which must:

- identify participating local authorities
- set out hazards and risks to be managed
- define the CDEM arrangements required to manage those hazards
- state objectives and their alignment with the National CDEM Strategy
- apportion liability for financial and other resources between local authorities
- specify arrangements for declaring states of emergency, and
- outline cooperation and coordination mechanisms with other Groups

CDEM Plans must be consulted on publicly and reviewed at least every five years.

Emergency Declarations and Powers

The CDEM Act allows:

- local emergency declarations by a delegated Group member or a mayor, and
- national emergency declarations by the Minister of Civil Defence

Declarations last seven days but may be extended or terminated earlier.

Emergency powers under the Act enable controllers and CDEM Groups to:

- restrict access to roads/public places
- remove or secure dangerous structures/materials
- provide rescue, first aid, food, and shelter

- conserve essential supplies and regulate traffic
- manage disposal of deceased persons or animals
- requisition equipment, vehicles, or premises
- order evacuations, and
- direct or advise the public

Local Emergency Declarations

Each CDEM Group must appoint at least one member with authority to declare a local emergency. Mayors also hold this authority within their districts.

When declared, the Group Controller coordinates the response. Local controllers may be appointed, but they act under the direction of the Group Controller.

National Emergency Declarations

For nationally significant events, the Minister of Civil Defence may declare a state of national *emergency.* Once declared, the National Controller (Director of Civil Defence Emergency Management or delegate) assumes responsibility for coordinating the overall national response.

National Crisis Management Centre

The NCMC, located beneath the Beehive in Wellington, facilitates central government crisis management. It is designed for maximum self-sufficiency in the event of a major local disaster and includes:

- seismic resilience (MMX earthquake design standard),
- independent emergency water and power supply,
- standalone IT and telecommunications systems (with satellite/microwave backup),
- air conditioning and filtration systems,
- secure operational areas, offices, and conference facilities,
- catering for up to 100 people,
- basic food supplies,
- and accommodation, ablution, and medical facilities.

The NCMC is maintained in a continuous state of readiness by NEMA.

Activation

When activated for a CDEM emergency, the NCMC is staffed by NEMA personnel and officers from relevant support agencies. Its functions include:

- monitoring and assessing emergencies,
- collecting, analysing, and disseminating information,

- coordinating national support to local CDEM responses,
- facilitating central government decision-making, and
- directing the national response during a declared national emergency.

Transpower's Sector Coordinator (liaison officer) may be activated to represent the electricity sector in the NCMC. NEMA also runs fortnightly training sessions to maintain readiness of NCMC staff.

Appendix C - Electricity Sector Coordinating Entities Process

Introduction

This section outlines the sector coordination processes to be followed during emergencies that affect the electricity sector at a national level.

The objectives are to ensure:

- effective management of emergencies impacting national electricity transmission and regional distribution,
- mitigation of threats to national electricity infrastructure, and
- timely communication to government on the developing situation.

Communication

In a national emergency, communication between the electricity sector and the National Crisis Management Centre (NCMC) will occur as follows:

- direct telephone contact from NCMC to the designated Transpower contact person, and
- deployment of Transpower Liaison Officer(s) to the NCMC as required.

Note: Transpower will provide Situational Reports (SITREPs) to the NCMC, based on real-time monitoring of the electricity grid and SITREPs received from affected generation or distribution businesses.

Communication to the Electricity Sector

Transpower will communicate with the electricity sector and direct customers through its established communication arrangements and procedures.

Note:

- Transpower will disseminate relevant national CDEM information or priorities to the electricity sector.
- Local and regional CDEM priorities will be communicated through the appropriate CDEM Group Emergency Coordination Centre (ECC) to regional electricity points-of-contact.

Activation

Activation of the electricity SCE occurs when Transpower is requested to act as the SCE by either:

- the NCMC Lifeline Utility Coordinator, or
- the NEMA Duty Officer

When to Activate

Transpower should be requested to act as the SCE when:

- the National Controller considers it necessary
- the NCMC Lifeline Utility Coordinator considers it necessary, and/or
- an emergency is likely to, or has already, caused a major impact on national electricity infrastructure

How to Activate

The electricity SCE is activated by contacting designated Transpower personnel, in the order specified in the current Electricity Industry Emergency Contact List (EIECL). Details of this list can be obtained from EIECL@transpower.co.nz (which is confidential to electricity industry participants).

Duties

Once activated, the duty Transpower Electricity SCE Liaison Officer will:

- act as the primary contact for the electricity industry, including generation, transmission, distribution, and retail
- maintain regular SITREPs to NCMC on industry status, and
- arrange and manage a roster for the ongoing SCE Liaison Officer role

Location

Transpower operates the SCE from its Civil Defence Operational Emergency Response (OER) Room on Level 5 of its Wellington offices. These offices have direct access to the:

- National Control Centre (also located in Wellington)
- Hamilton National Control Centre, and
- National Grid Operating Centres in Auckland and Christchurch

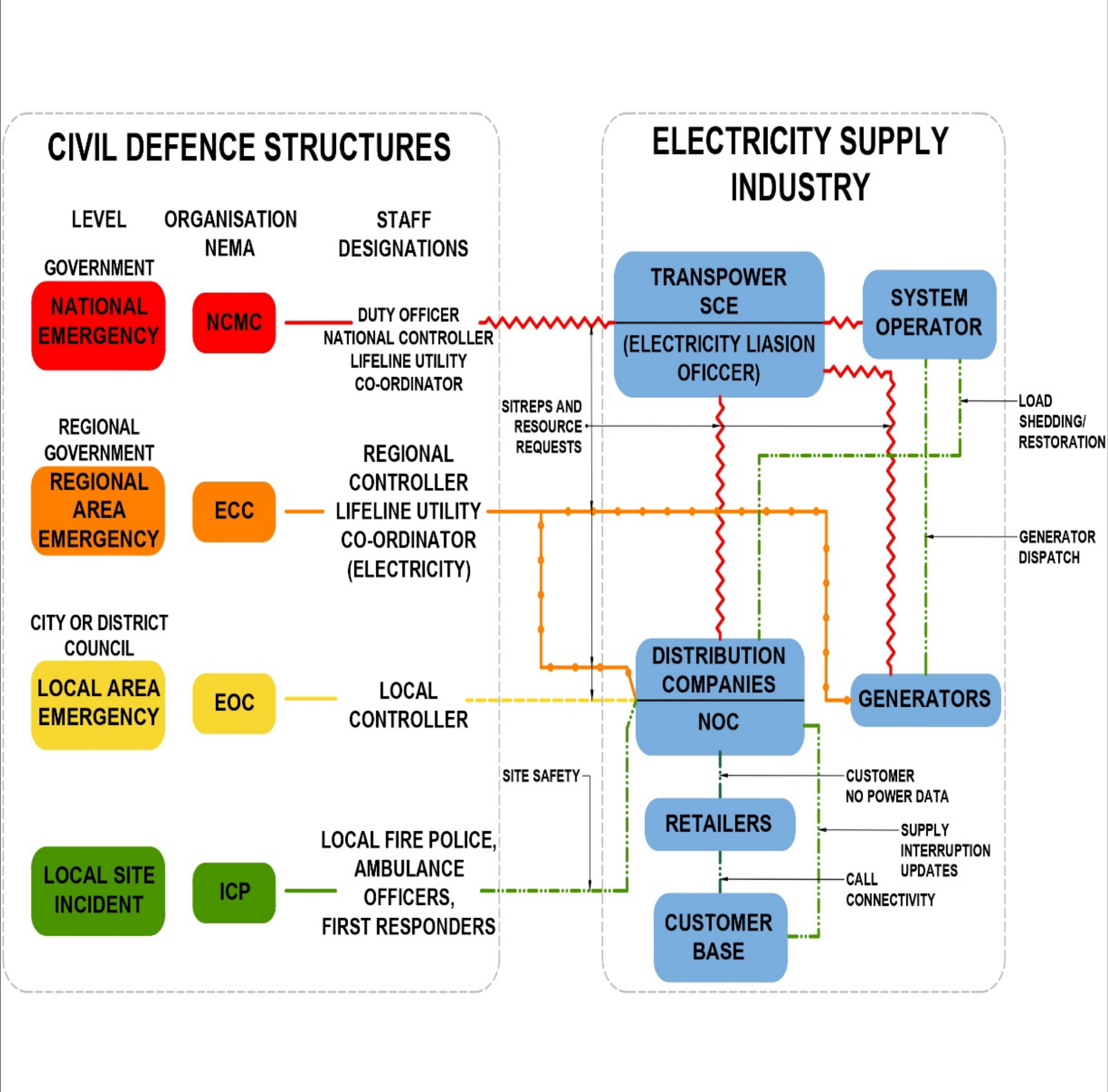
These centres monitor and control the national electricity grid 24/7 as business-as-usual. If required, the duty Electricity SCE Liaison Officer may operate directly from the NCMC.

Once activated, contact will be maintained through:

- the duty Transpower Electricity SCE Liaison Officer, or
- the Transpower Senior Principal Engineer

Electricity Supply Industry Interaction with Civil Defence

The diagram below illustrates the levels of communication between electricity industry participants and Civil Defence structures, based on the type of emergency declared (national, regional, or local).



ABBREVIATION:

NEMA	NATIONAL EMERGENCY MANAGEMENT SYSTEM
NOC	NETWORK OPERATIONS CENTRE
NCMC	NATIONAL CRISIS MANAGEMENT CENTRE
ECC	EMERGENCY CO-ORDINATION CENTRE
EOC	EMERGENCY OPERATIONS CENTRE
ICP	INCIDENT CONTROL POINT
SCE	SECTOR COORDINATING ENTITY
LUC	LIFELINE UTILITY CO-ORDINATOR

COLOUR CODE - COMMUNICATION FLOWS:

- NATIONAL EMERGENCY INCIDENT
- REGIONAL EMERGENCY INCIDENT
- LOCAL EMERGENCY INCIDENT
- BUSINESS AS USUAL

INFORMATION FLOW TYPES:

- SITREPS - SITUATIONAL REPORTS
- RESOURCE REQUESTS
- GENERATION DISPATCH
- LOAD SHEDDING
- OPERATIONAL SWITCHING
- SITE SAFETY

Figure: 15 ESI Emergency Management Communications Interface with Civil Defence

Appendix D - Regional Lifeline Utility Groups

The current Regional Lifelines Groups are as follows:

REGION	LIFELINES GROUP
Northland	Northland Lifelines Group
Auckland	Auckland Lifelines Group
Waikato	Waikato Lifeline Utilities Group
Bay of Plenty	Bay of Plenty Lifelines Group
Gisborne	Tairawhiti CDEM Group
Hawkes Bay	Hawkes Bay CDEM Group Lifelines
Taranaki	Taranaki Lifelines Group
Manawatu-Wanganui	Manawatu-Wanganui Lifelines Advisory Group
Wellington	Wellington Lifelines Group
Wellington (Wairarapa)	Wairarapa Engineering Lifelines Association
Nelson-Tasman	Nelson-Tasman Lifelines Project
Marlborough	Marlborough Engineering Lifelines Group
West Coast	West Coast Engineering Lifelines Group
Canterbury	Canterbury Engineering Lifelines Group
Otago	Otago CDEM Group
Southland	Southland Regional Lifelines Steering Group
Chatham Islands	Chatham Islands CDEM Group

Table 13: Current Regional Lifelines Groups

Appendix E RMMAT Questions

The following set of updated questions are from the accompanying *RMMAT* and have been developed to enable an *EDB* or organisation to self-assess its overall resilience maturity level and degree of preparedness to respond, manage and recover to and from an *extreme event*.

Further detailed information on the RMMAT is provided in Section 11.

Reduction – Identification and Mitigation of Network Vulnerability Risks

Question Number	Function	Question
1.1.1	Network Risk Alignment	Are risk management processes, used to establish network risk categories and matrices, aligned to ISO 31000-2009 or other relevant and widely recognised standard?
1.1.2	Network Risk Alignment	Are network risk categories and risk (likelihood / consequence) matrices aligned to the company's corporate risk framework?
1.1.3	Network Risk Alignment	Have identified network vulnerabilities and risks, with the most significant residual risks, been reported and escalated in alignment with the company's risk policy and appetite?
1.2.1	Risk Identification and Assessment	Have significant and credible network asset and asset system failure related vulnerabilities and risks (likelihood and consequences) been systematically identified, assessed, prioritised, and documented?
1.2.2	Risk Identification and Assessment	Is there a clear awareness and understanding within the organisation of the key, credible natural hazards the network is exposed and susceptible to, and the likelihood of these events occurring, according to the latest available scientific information?
1.2.3	Risk Identification and Assessment	Have network asset and asset system related vulnerabilities and risks (likelihood and consequences), resulting from all credible and significant, extreme (high impact low probability) natural hazard events that the network is exposed and susceptible to, been systematically identified, assessed, prioritised, and documented?
1.2.4	Risk Identification and Assessment	Does the company have an asset criticality framework that can be applied to aid in quantifying vulnerability and consequence metrics, from a network resilience perspective?
1.2.5	Risk Identification and Assessment	Are network vulnerability and risk identification processes monitored and periodically reviewed, audited, and updated to ensure their effectiveness, fitness for purpose and to incorporate the latest hazard and network information?
1.3.1	Risk Documentation	Are network vulnerability and risk policies, processes and outputs detailed in key, controlled, company documentation and summarised in the disclosed Regulatory Asset Management Plan (RAMP)?

Question Number	Function	Question
1.4.1	Mitigation of Risks	Does the company have a formal process whereby mitigations to the most significant network vulnerability / resilience related risks are considered, identified, costed and where appropriate and justified, implemented?
1.4.2	Mitigation of Risks	Are critical risk control measures for all identified, significant inherent network risks, regularly reviewed and audited as part of a risk assurance programme?
1.4.3	Mitigation of Risks	Does the company have a risk-based process that facilitates the evaluation of resilience driven projects alongside tradition renewal and system growth / security of supply projects?
1.4.4	Mitigation of Risks	Where it is decided that mitigations for significant network risks are not viable, is the rationale for the decision documented and communicated to key stakeholders?
1.4.5	Mitigation of Risks	Has network security back-up architecture and the diversity of alternative supply options been evaluated and analysed, including any constraints in relation to transferring load between adjoining Transpower GXP's?
1.4.6	Resilience Improvement Plan- network hardening	Does the Company have a formal resilience Improvement Investment Plan which addresses the likely impacts of Climate Change causing extreme weather events or other identified natural catastrophic events and prioritises mitigation initiatives related to network hardening e.g., for wind speed, landslips flooding impacts and fire risks and enhanced vegetation control
1.4.7	Non network resilience improvements	Does the Resilience Improvement Plan also address non network resilience improvement topics such as Cyber security, work force skills, and pandemic management.
1.4.8	Resilience improvement evaluated by a cost/benefit Analysis	Are mitigation investments evaluated by using a form of cost/benefit analysis to determine priorities for investment.
1.4.9	Resilience improvement Investment plan	Does the current AMP contain a resilience investment expenditure plan based on a prioritised list of projects.
1.5.1	Lifelines Engagement	Is the company an active and engaged participant of the local CDEM & Lifelines Groups?
1.5.2	Lifelines Engagement	Are interdependencies with other key regional and national Lifeline utilities clearly understood by the organisation, including other electricity supply system participants such as Transpower and generation companies?

Question Number	Function	Question
1.5.3	Lifelines Engagement	Is there a documented understanding within the organisation of key infrastructure and connections of other Lifeline utilities including, hospitals, emergency service connections, designated evacuation centres, ports (sea and air), critical telecommunication sites and three water pumping infrastructure etc, and are they clearly identified in the company's systems including the Distribution Management System?
1.5.4	Support for Community Hubs	Does the Company provide practical support to designated emergency “Community Hubs” such as by supplying back up power supply systems e.g. solar plus batteries and or diesel generator sets Community Hubs are designated emergency Centres agreed with Civil Defence emergency management -such as Marias and school or community Halls etc
1.6.1	Design Standards	Do network design standards and processes incorporate resilience considerations and are they aligned to relevant industry related standards?
1.7.1	Network Spares	Does the company have a critical / emergency / network operational spares strategy and policy that considers the vulnerability and risk to the network posed by credible extreme events?
1.7.2	Network Spares	Based on the outputs of network vulnerability studies and projected asset damage for creditable scenarios, have critical, emergency, and operational spares requirements across all asset fleets been assessed based on organisational requirements, including restoration of service objectives and is there periodic reviews of these requirements?
1.7.3	Network Spares	Based on the assessment above, are appropriate volumes of spares held or alternatively, are there robust and plausible plans in place to secure required items if an extreme event was to occur?
1.7.4	Network Spares	Has the resilience of, and accessibility to, network spare storage locations been considered in relation to extreme events?
1.7.5	Network Spares	Is there ongoing management of network spares including documentation, seismic securing and strapping arrangements, stock rotation and issuing and re-ordering of items?
1.7.6	Network Spares	Based on the network vulnerability / risk analysis, does the company carry sufficient stock of line hardware (i.e., poles, conductor, insulators etc.) to construct any required emergency overhead sub-transmission lines, and have provisional plans for this eventuality been developed?
1.7.7	Spares inventory	Has consideration been given to developing a national or regional spares inventory list which could be accessed if necessary

Question Number	Function	Question
1.8.1	Contingency Planning	Does the organisation have a designated, resilient, fit for purpose Disaster Recovery (DR) or Alternative Operation Centre (AOC) facility, where network operations can continue to be managed, if the normal Network Operations Centre (NOC) is damaged, out of action or unavailable for any reason?
1.8.2	Contingency Planning	Does the organisation have an alternative, resilient, fit for purpose facility to enable critical network support functions, business continuity and emergency response activities to be undertaken, if existing buildings are damaged, out of action or unavailable for any reason?
1.8.3	Contingency Planning	Is there sufficient redundancy of existing data and SCADA servers and communication links to critical sites to enable NOC and critical business activities to continue if an extreme event was to occur?
1.8.4	Contingency Planning	Does the company have documented, communication contingency and implementation plans in place, that would allow notification and communication with key staff, that is independent of the public landline / cell phone / internet networks and is this system periodically tested?

Table 14: RMMAT Reduction Questions

Readiness – Pre-Event Contingency Planning and Training

Question Number	Function	Question
2.1.1	Business Continuity Management	Does the company have an overarching, organisation-wide, business continuity strategy / policy that describes how the organisation approaches Business Continuity Management, including governance, structures, and plans?
2.1.2	Business Continuity Management	Are there up to-date, documented and published, company-wide, scalable disaster emergency response and business continuity plans (BCP), that encompass all critical company business areas, and all employees and clearly define roles and responsibilities?
2.1.3	Business Continuity Management	Are these plans aligned to the Coordinated Incident Management System (CIMS), and are all relevant staff familiar with the requirements of their designated role/s, have received the necessary training, and are competent to effectively contribute to any response?
2.1.4	Business Continuity Management	Does the organisation have specific and comprehensive response plans, including required equipment, vehicles, clothing, tools, technology etc, for the range of potential and credible extreme events that the network is susceptible to. For example, if the network has exposure to volcanic activity, is there a specific plan that deals with this eventuality?
2.1.5	Business Continuity Management	Are plans periodically (at least every 24 months), realistically exercised via extreme event scenario simulations including local, regional, or national CDEM exercises, a real event, or through more regular desktop exercises?
2.1.6	Business Continuity Management	As a result of these exercises, are any identified learnings and improvement opportunities captured, and appropriate actions implemented to enable continuous improvement of relevant plans?
2.1.7	Business Continuity Management	Has a business impact analysis been undertaken that includes the identification of critical business systems, applications, functions, processes, and services as well as agreed recovery timeframes with relevant business owners?
2.1.8	Business Continuity Management	Have supplier and out-sourced service provider dependencies been identified, including ensuring contractual responsibilities are in place, clearly understood and validation received that their business continuity provisions are acceptable to support the company's critical services?
2.2.1	Contingency Switching Plans	Are there pre-prepared and documented switching plans for managing a partial or full GXP outage?
2.2.2	Contingency Switching Plans	Are there pre-prepared and documented switching plans for managing a major or multiple, zone substation outages?

Question Number	Function	Question
2.2.3	Contingency Switching Plans	Are there pre-prepared, documented, and prioritised, restoration plans that consider critical feeder loads and customers and can be utilised following a major system outage such as the loss of Transpower supply to a single or multiple GXP's?
2.2.4	Contingency Switching Plans	Where embedded generation or an alternative supply is available either via Transpower or a third-party generator, is there a pre-prepared, documented, and approved contingency switching plan that can be used to establish an islanded or alternative network to partially or fully restore supply?
2.3.1	Contingency Planning	Are there contingency plans in place to manage risks to highly critical asset / asset systems post an extreme event, where it has been determined mitigation costs are not viable or plans are yet to be implemented?
2.3.2	Contingency Planning	Are there contracts in place for the engagement of structural engineers that can assess the integrity of buildings and other critical infrastructure following an extreme event?
2.3.3	Contingency Planning	Does the company have contingency plans in place to cover for critical staff such as NOC Controllers / Operators should for any reason their availability be constrained or the workload after an extreme event requires additional resourcing?
2.3.4	Contingency Planning	Are emergency diesel generators available (company-owned or accessed via priority third party hire agreements) which can be immediately deployed to supply critical loads following an extreme event?
2.3.5	Contingency Planning	Does the company have its own fuel plan, that following an extreme event would allow the refuelling of response vehicles, critical generation sites such as DR / AOC buildings and emergency generators?
2.4.1	Communication Plan	Does the company have a comprehensive, documented emergency communication plan, which clearly defines roles and responsibilities, and that details how effective communication with its customers, shareholders, directors, and other important stakeholders, including the media, will be managed?
2.4.2	Communication Plan	Is the plan reviewed periodically reviewed to ensure it is up to-date and reflects the latest contact information and includes the utilisation of the most effective technology platforms and mediums?
2.4.3	Communication Plan	Have multiple, effective methods of communicating power outages and restoration progress directly with customers, other key stakeholders and the media been identified, developed, and implemented?

Question Number	Function	Question
2.5.1	Contracting Resourcing	Are there formal, mutual aid, contractor agreements in place that would provide additional field resources to manage workloads following an extreme event?
2.5.2	Contracting Resourcing	Are there pre-prepared external contractor safety induction plans available to allow the efficient deployment of additional external contracting resources?
2.5.3	Contracting Resourcing	Has the company considered how additional resourcing bought in from outside the region would be accommodated and are there any contracts in place to guarantee these arrangements?
2.5.4	Contracting Resourcing	Is there a staff welfare policy in place which covers such matters as fatigue, stress, and provisions for feeding staff working extended hours whilst dealing with the response to an extreme event?
2.5.5	Contract resourcing and common skills framework	Has the Company engaged in any common work force skills training programme which enables easier integration of outside contractor/ field resources to assist with repair response
2.6.1	Lifelines Liaison	Are documented protocols and arrangements in place for liaison with Civil Defence, local Lifeline Utilities and other emergency service organisations including clearly defined roles, responsibilities, contact information, rosters and required competencies for key personnel?

Table 15: RMMAT Readiness Questions

Response – Immediate Actions Following an Event

Question Number	Function	Question
3.1.1	Response Systems and Processes	Does the Company have systems and processes to manage the immediate, and large-scale loss of power supply following an extreme event?
3.1.2	Response Systems and Processes	Do these processes include a robust, documented methodology to assess network damage to ensure restoration activities are appropriately controlled to ensure the health and safety of the public, staff, and contractors?
3.1.3	Response Systems and Processes	Does the company have scalable outage management systems and processes that would be able to manage the large volume of outages that would be generated by an extreme event?
3.1.4	Response Systems and Processes	Is there an ability for distribution management systems and processes to manage the status of the low voltage network and any connected generators operating in islanded or parallel mode?
3.1.5	Response Systems and Processes	Does the company have scalable works management systems and processes that would be able to generate (both from the office and field), prioritise, issue and track, the potentially large volume of defects and subsequent repair work that would be generated by an extreme event?
3.1.6	Response Systems and Processes	Does the company have clear identified thresholds that would enact the customer / stakeholder communication response plan?
3.2.1	Generation Capability	Are emergency generator supply contracts in place and able to be readily activated to meet any required increased demand for a large scale, emergency response?
3.2.2	Generation Capability	Does the company have a documented process that would be referenced for the deployment of a large number of emergency diesel generators with suitable leads to enable efficient installation and restoration of the power supply to critical loads or supply long repair time damaged residential networks at low voltage?
3.2.3	Generation Capability	Are available network standby generators maintained in good working order and regularly tested, and are they capable of running in parallel, if required?
3.3.1	Response Reviews	Is there a mechanism and process (including review templates) in place to enable reviews to be undertaken following a major or extreme event? Does the organisation have documented thresholds established that would initiate these reviews and are reviews undertaken, including the identification of learnings and implementation of corresponding actions?

Table 16: RMMAT Response Questions

Recovery – Long Term Reinstatement of the Network

Question Number	Function	Question
4.1.1	Recovery Strategy and Plans	Does the organisation have a documented recovery strategy that defines and outlines, the high-level principles and processes the company will adopt and implement to manage a recovery following an extreme event?
4.1.2	Recovery Strategy and Plans	Does the organisation have a recovery plan in place that covers off key requirements to restore the network to its former level of service capability, e.g., security levels, reliability and safety and realistic restoration targets?
4.1.3	Recovery Strategy and Plans	Has the company assessed potential future network architecture options that could be considered following an extreme event, with the objective of improving resilience?
4.1.4	Recovery Strategy and Plans	Does the organisation have a recovery communication plan that outlines the processes and methodologies that would be followed to provide effective and timely updates to key stakeholders on recovery progress over a prolonged period?
4.1.5	Recovery Strategy and Plans	Does the organisation understand the processes and stakeholder consultation / engagement required to restore its network following an extreme event including the management of potential regulatory compliance issues?
4.2.1	Recovery Costs	Does the organisation have sufficient network insurance cover in place, in alignment with its risk appetite, to limit its exposure to an extreme event and are these provisions periodically risk reviewed?
4.2.2	Recovery Costs	Has the company balance sheet got sufficient headroom / capacity to draw down on reserves and or borrowings to offset long term recovery cost implications following an extreme event?
4.2.3	Recovery Costs	Is there an understanding within the organisation of the process required to lodge a Customised Price Path (CCP) with the Commerce Commission to increase the allowable revenue to service extraordinary costs over a longer period?

Table 17: RMMAT Recovery Questions

Appendix F Case Studies

Case Study 1: Wellington Electricity Earthquake Readiness Programme

(Updated July 2024)

Introduction

Following the 2016 Kaikoura Earthquake, GNS Science issued updated information about Wellington being at elevated risk of a large earthquake. In response, the Commerce Commission was instructed in September 2017 through a Government Policy Statement[7] to consider options that would allow Wellington Electricity (WE*) to invest in additional earthquake readiness expenditure.

WE* prepared and submitted a Customised Price Path (CPP) application, with support from stakeholders, which was approved by the Commission on 28 March 2018.[8] This resulted in $32m of expenditure from 2018 to 2021 to improve WELL's earthquake readiness.

This has set an example of good industry practice in developing a business case for seeking the approval of resilience expenditure by the Regulator.

WE*'s CPP was a unique "streamlined" CPP that assumed that WE*'s business-as-usual operations would continue as set by DPP2, with the readiness expenditure sitting on top of that, and subject to a quality path that measured delivery of the initiatives. The 2023 amendments to the Input Methodologies defined a Resilience Capex reopener event, meaning that future projects of this type may be able to be funded using the simpler process of reopening the Default Price Path, rather than requiring a CPP. Despite this, the process for developing the business case for additional funding would be similar regardless of the funding mechanism used.

Background

The 2016 Kaikoura earthquake highlighted the risk of earthquake that is present in much of New Zealand, with additional urgency due to the risk that the aftershocks could trigger a major earthquake in Wellington.

Wellington Electricity began developing a CPP application to deliver a three-year programme of short-term initiatives aimed at improving its ability to respond following a major earthquake.

[7] https://gazette.govt.nz/notice/id/2017-go4910
[8] https://comcom.govt.nz/regulated-industries/electricity-lines/projects/wellington-electricitys-20182021-cpp

Previous studies by Wellington Lifelines had identified that in a major earthquake scenario, access into and within the Wellington region would be severely limited for an extended period. In developing the options that would be most beneficial for readiness improvement, it was first necessary to estimate the potential damage to the network. From these damage estimates, outage and restoration times were estimated based on the Lifelines studies, with options being compared based on the reduction in projected outage durations.

Kaikoura Earthquake

Two minutes after midnight on 14 November 2016, multiple fault lines ruptured from Culverden to Kaikoura resulting in a magnitude 7.8 earthquake causing widespread damage throughout the Upper South and Lower North Islands and resulting in two fatalities.

In the Wellington region, several buildings were damaged beyond repair and many others had to be evacuated while seismic assessments and repairs were completed. This included WE*'s head office, which was assessed as being unsafe for occupation and subsequently demolished. This required WE* to relocate to its disaster recovery site for a period of three months while replacement office accommodation was procured.

This earthquake caused significant disruption to the WE*'s distribution network, with approximately 28,000 customers losing supply. The majority of outages occurred on the overhead network, most of which were able to be restored within 18 hours. Changes made to power transformer protection schemes following the Seddon earthquakes in 2013 prevented any zone substation outages. Sustained outages were limited to underground cable damage due to liquefaction at CentrePort.

It was apparent that this quick restoration following the earthquake would not have been possible had an earthquake within the region caused more widespread damage while also limiting transport between areas within the region.

WE* experienced a period of significantly decreased underground cable reliability across its network in the 18 months following the earthquake as damaged cables progressed to failure, however this was not evident in the immediate aftermath of the event.

Wellington Earthquake Risk

The Wellington Region contains numerous known fault lines with the potential to cause a severe shaking event. The three most well-studied of these are the Wellington, Ohariu, and Wairarapa faults.

The Wellington Fault runs from Long Gully, through Thorndon, then roughly follows State Highway 1 around Wellington Harbour and then up the Hutt Valley to Kaitoke along State Highway 2. This is the most active of the three faults and would likely cause the most damage in the Wellington City and Hutt Valley areas in the event of a rupture. The Wellington fault last ruptured between 300 and 500 years ago and has historically caused a major earthquake in the region every 500-1000 years.

A rupture of any of the main fault lines within the region is expected to cause a Magnitude 7+ earthquake leading to a level of damage similar to, or exceeding that of, the February 2011 Christchurch earthquake. There is also potential risk from unknown faults, as shown by the 2010 Christchurch earthquake which occurred on a previously unknown fault near Darfield approximately 40km west of Christchurch.

For the purpose of WE*'s analysis, it was necessary to consider an earthquake from any fault line within the region. Figure 1 shows the locations of the major faults within the Wellington region.

How often do earthquakes occur along the fault?

The last time the Wellington Fault ruptured through the Wellington region, causing a major earthquake, was around 300 - 500 years ago. Geoscientists estimate the Wellington Fault will cause a major earthquake every 500-1000 years. However other faults around the Wellington region are also active and capable of generating major earthquakes, for example the Ohariu Fault, and the Wairarapa Fault which last ruptured in 1855 causing a great earthquake that severely affected Wellington. The frequency of large earthquakes affecting the Wellington Region is therefore much higher, with an average return time of about 150 years for a very strong or extreme ground shaking quake.

How do we know which fault is most likely to rupture next in Wellington?

Figure: 16 Map of fault lines in the Wellington Region (GNS Science)

For the purpose of benefit calculation, a return period of 300 years was used, as it falls within the ranges estimated by GNS while not being so short that benefit calculations would be skewed too high. Sensitivity analysis was also carried out with return periods of 150 and 400 years.

A 2013 Wellington Lifelines report based on modelling work by Opus9 concluded that in the event of a major earthquake, the Greater Wellington region would be split into seven 'islands', five of which are within WE*'s network area. There would be no land transport access between these islands, and roads into the region could be closed to the public for up to four months.

It is currently expected that road transport between the 'islands' will not be possible for at least one week after the event with roads progressively opening over the following weeks. Hutt Valley is likely be the worst affected with WREMO estimating that road damage will prevent access into the area by emergency services for three months.10

[9] Opus. 2013. Restoring Wellington's transport links after a major earthquake

[10] WREMO. 2019. Wellington Lifelines Project. Pages 149-150

Damage Modelling Methodology

To enable improvement options to be developed and assessed, it was necessary to model the damage that was expected to be sustained by the network in its current state, and the restoration times that would result. Options could then be assessed based on how they improve this baseline restoration timeframe. Due to the short timeframe of the CPP, options that required asset replacement were not considered.

The response of the Orion network to the Christchurch earthquakes has been extensively studied, and this formed the basis for the estimation of damage to network assets in the event of a severe earthquake in Wellington.

Most of the damage to electrical distribution equipment in the Christchurch earthquake was cable damage due to liquefaction, with oil pressurised cables being particularly vulnerable. Analysis of the damage rates indicated that modern XLPE insulated cables perform slightly better in an earthquake, however there was not enough of this cable in areas of high liquefaction to get an accurate estimate of what the failure rate per kilometre would be for different types of cable. For this reason, cable type was not considered when estimating the damage rates throughout the network, with the ground type expected to have much more effect on whether a cable will sustain damage than the construction of the cable itself.

Based on studies of the damage sustained in the Christchurch earthquake 11,12 and confirmed by discussions with people who had been involved in the restoration, it was estimated that there would be a failure rate of approximately three faults per kilometre of cable installed in areas of high liquefaction potential.

There are additional risks present in the Wellington region as a result of the hilly terrain, which increases the possibility of network assets being damaged by slope failure, and the location of the Wellington and Ohariu faults, both of which run through built up areas. The rupture of either the Ohariu or Wellington fault would cause significant direct damage to network assets close to the rupture. Assets on steep and potentially unstable hillsides are at risk of damage should the earthquake cause a slip.

Damage estimation was carried out by breaking the network up by both area and asset class and then assessing the exposure to the different hazards present in an earthquake. The earthquake hazards are as follows:

- ground shaking
- liquefaction
- fault line movement
- slope failure

[11] Massie and Watson. 2011. Impact of the Christchurch earthquakes on the electrical power system infrastructure
[12] Eidinger and Kempler. 2013. Performance of Buried High Voltage Power Cables due to Earthquake Loads

Maps of these hazards were overlaid with WE* network assets to construct a matrix of risks. During this exercise it was noted that the ground shaking and liquefaction risk maps were very similar and for this reason these risks were considered together.

WE*'s network was divided into three islands (as a simplification of the five islands identified in the 2013 Opus report) based on the major transport links likely to be affected in an earthquake. For damage estimation, each of WE*'s 33 distribution zones were assessed individually. These zones were made up of 27 zone substations, two switching stations at Petone and Titahi Bay, and three Transpower GXPs that supply directly into WE*'s 11kV network at Haywards, Melling, and Kaiwharawhara.

Network assets were classified as Sub-transmission, Zone Substation, or Distribution, with each of these being assessed to provide an estimate of the load lost as a result of their exposure to different levels of hazard. These categories largely mirrored the makeup of the network with the exception of the two major distribution sites being classified as zone substations for the purpose of this analysis, with the high capacity 11kV circuits supplying these substations being classified as sub-transmission circuits.

It was not practical to assess distribution-level assets individually, instead these were assessed based on the exposure of the zone substation areas to each hazard. Each zone was given a high, medium, or low risk score for each of the asset and hazard types, resulting in a risk matrix which shows where in the network the most severe damage was expected.

- Low risk indicates that minimal damage is expected from a particular hazard.
- Medium risk indicates that some damage is expected but supply is expected to remain on, though with potentially reduced capacity.
- High risk indicates an expectation of total loss of supply to that site.

As fault line movement and slope failure are more limited in the area affected, the most widespread damage is expected to be due to liquefaction. As the scenario being used for this exercise was an earthquake on the Wellington fault line, only the Wellington fault was considered for damage due to fault line movement, although the initiatives that were considered as part of analysis would have benefits in the event of a rupture on any of the other fault lines within the region.

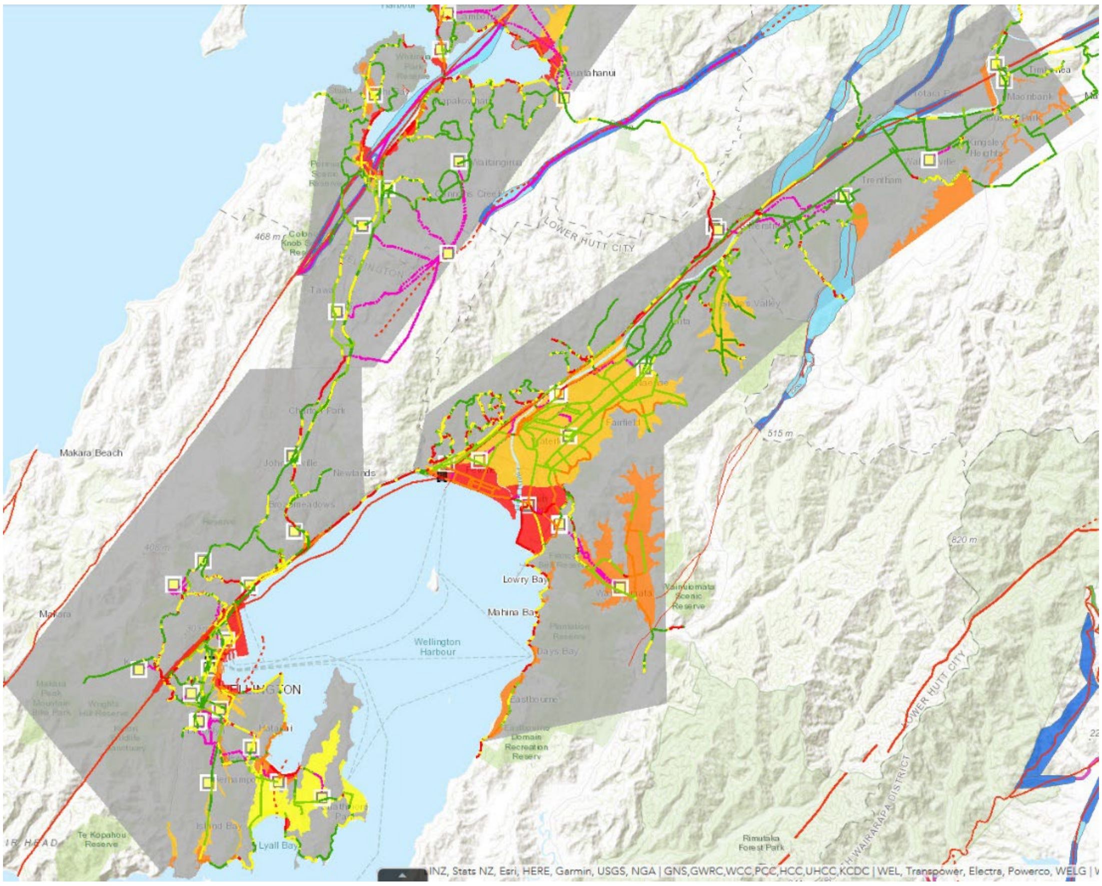


Figure: 17 GIS - Regional Hazard Map showing areas of liquefaction and expected road damage

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Figure 17 shows the regional liquefaction and fault line hazards, with road and electricity (in pink) networks overlaid. The figure also shows the location of key Wellington Electricity substations. Table 18 below is the damage matrix showing the risk for each hazard type by area, which formed the basis of outage estimation and the benefits of each initiative.

Table 18 Risk for each hazard type by area name

Wellington Electricity Risk Areas		Sub-transmission			Zone Substations			11kV Distribution		
Area	WE* Zones	GS/L	FLM	SF	GS/L	FLM	SF	GS/L	FLM	SF
Northeastern	Brown Owl	L	H	L	L	L	L	L	M	L
	Maidstone	L	H	L	L	L	L	L	M	L
	Trentham	L	M	H	L	L	L	L	L	L
	Haywards (Transpower)	N/A	N/A	N/A	N/A	N/A	N/A	L	H	H
	Naenae	L	L	L	M	L	L	L	L	L
	Melling (Transpower)	N/A	N/A	N/A	N/A	N/A	N/A	L	M	L
	Waterloo	L	L	L	L	L	L	L	L	L
	Petone	H	L	L	H	L	L	H	L	L
	Seaview	M	L	L	H	L	L	H	L	L
	Gracefield	L	L	L	H	L	L	H	L	L
	Korokoro	H	H	L	H	H	L	H	H	L
	Wainuiomata	L	L	H	M	L	L	L	L	L
Northwestern	Plimmerton	L	L	L	H	L	L	H	L	M
	Mana	L	L	H	H	L	L	H	L	H
	Waitangirua	L	L	L	L	L	L	L	L	L
	Titahi Bay	H	L	L	L	L	L	M	L	L
	Porirua	L	L	L	M	L	L	L	L	L
	Kenepuru	L	L	L	L	L	L	L	L	L
	Tawa	L	L	L	L	L	L	L	L	M
	Johnsonville	L	L	M	L	L	L	L	L	M
	Ngauranga	L	L	M	L	L	L	L	L	M
Southern	Waikowhai Street	L	L	M	L	L	L	L	L	M
	Kaiwharawhara	N/A	N/A	N/A	N/A	N/A	N/A	H	H	M
	Karori	L	L	M	L	L	L	L	L	L
	Moore Street	M	H	M	H	L	L	H	M	L
	The Terrace	L	L	L	M	M	L	M	M	L
	University	L	L	L	L	L	L	L	M	M
	Frederick Street	L	L	L	M	L	L	M	L	L
	Nairn Street	L	L	L	L	L	M	L	L	M
	Palm Grove	L	L	M	L	L	L	L	L	L
	Hataitai	L	L	L	L	L	L	M	L	L
	Evans Bay	H	L	L	H	L	L	H	L	L
	8 Ira Street	H	L	L	M	L	L	H	L	L
GS/L = Ground Shaking/Liquefaction FLM = Fault Line Movement SF = Slope Failure										

Sub-transmission

For sub-transmission assets, liquefaction risks were high wherever a significant amount of oil- or gas-filled cable supplying that zone substation runs through land that has a high liquefaction risk. Moore Street and Seaview were given a Medium risk rating due to having a relatively short section of solid insulated cable going through liquefiable land.

Fault line movement has allocated a high risk where cables cross the fault and a medium risk when overhead lines cross the fault. This is due to the comparative ease with which damage to overhead lines can be identified and repaired.

Slope failure risk was directly related to the risk of failure along the circuit route. Circuits were given a high risk where they cross a slope identified as having a high risk of failure or where there is a high risk of slope failure along a cable route which will make any necessary repairs significantly more difficult.

There is no sub-transmission component for the three Transpower GXPs that supply directly into the 11kV network.

Zone Substations

Zone substation risks were assessed at each site, with liquefaction again being of the most concern. Only Korokoro substation is close enough to the fault line to be identified as being at a high risk of damage due to fault movement. It is possible that Nairn Street substation could experience damage due to slope failure.

Transpower confirmed that it did not anticipate significant damage to its assets and was confident that its sites would remain in a serviceable condition after an earthquake, although minor repairs may be required. This is consistent with the experience from the Christchurch earthquakes of 2010-2011 where, although there was some damage to equipment, supply was able to be restored following inspection.

11kV Distribution

Distribution risks were assessed differently as it was not practical to assess the likelihood of a failure of each individual cable, nor was it possible to get a precise estimate of the size of outages due to the level of uncertainty about which pieces of equipment would be damaged. For this reason, loss of supply is expected for areas at high and medium risk.

The total load lost was reduced based on the level of damage to the surrounding areas, as less damaged zones will be likely to be able to provide an alternate supply to some customers in the more severely affected areas.

Outage Estimation

Rather than attempting to model the combined effects of each hazard when estimating the damage to the distribution network, only the highest risk at a sub-transmission or zone substation was considered when assessing the probable loss of 33kV supply at a zone substation.

A zone with a high risk at the 11kV distribution level is expected to lose supply to 50% of its load before accounting for backfeeds. A zone with a medium risk at 11kV is expected to lose 20% of its load. This value is then reduced based on the number of connections to adjacent zones with medium or low risk of damage. As the outages are of an extended duration and could happen at any time of year, the average loading was used as a starting point for calculating the load lost. Table 18 shows the estimated load loss for each zone.

Table 19: Estimation of load loss for each zone

Zones	2016/17 Peak MVA	2016/17 Average MVA	Worst 33kV Damage	11kV Damage	Backfeed Multiplier	Load Lost at 33kV (MW)	Load Lost at 11kV (MW)	Total Load Lost (MW)
Frederick Street	27.51	15.75	M	M	50%	-	3.57	3.57
Palm Grove	26.17	13.06	L	L	25%	-	-	-
University	19.00	10.31	L	M	50%	-	0.98	0.98
Hataitai	17.39	7.86	L	M	100%	-	1.49	1.49
The Terrace	27.50	14.47	M	M	60%	-	5.96	5.96
Evans Bay	12.94	7.90	H	H	50%	3.75	1.88	3.75
8 Ira Street	15.97	9.67	H	H	100%	9.18	4.59	9.18
Nairn Street	26.33	11.55	M	L	33%	-	-	-
Korokoro	18.40	10.60	H	H	50%	5.03	2.52	5.03
Gracefield	11.48	5.39	H	H	67%	3.42	1.71	3.42
Wainuiomata	17.00	7.48	H	M	100%	7.11	1.42	7.11
Seaview	14.30	8.00	H	H	67%	5.07	2.53	5.07
Trentham	13.85	6.97	H	L	100%	6.62	-	6.62
Waterloo	15.59	8.37	L	L	67%	-	-	-
Naenae	14.68	7.02	M	M	33%	-	0.44	0.44
Mana	20.37	7.87	H	H	100%	7.47	3.74	7.47
Waitangirua	14.00	6.10	L	L	50%	-	-	-
Porirua	20.84	11.56	M	M	33%	3.50	0.73	3.50
Kenepuru	11.11	5.59	L	L	50%	-	-	-
Tawa	15.09	7.27	L	L	0%	-	-	-
Ngauranga	10.00	4.82	L	L	0%	-	-	-
Johnsonville	21.12	9.52	L	L	0%	-	-	-
Maidstone	14.10	7.94	H	M	50%	3.77	0.75	3.77
Brown Owl	15.11	6.93	H	M	100%	6.59	1.32	6.59
Moore Street	20.00	10.45	H	H	100%	9.92	4.96	9.92
Karori	16.31	7.04	M	L	100%	-	-	-
Waikowhai	15.50	6.13	M	M	100%	-	1.16	1.16
Kaiwharawhara	31.56	17.26	X	H	67%	-	5.47	5.47
Melling	25.96	13.02	X	M	50%	-	1.24	1.24
Haywards	18.21	7.83	X	H	33%	-	1.23	1.23

Worked Example - 8 Ira Street

8 Ira Street zone substation is expected to sustain significant liquefaction damage to sub-transmission cables and the distribution network in the area supplied from this zone substation. The only other substation that interconnects with 8 Ira Street is Evans Bay, which is also at a high risk of damage, meaning that loss of supply at 8 Ira Street will not be able to be picked up from other parts of the network.

The loss of sub-transmission to this site will lead to a total loss of supply until the 33kV supply can be restored, giving a 33kV load loss of:

- Load Lost (MW) = Average MVA x Power Factor

For the purpose of this exercise a power factor of 0.95 was assumed:

- Load Lost (MW) = 9.67 x 0.95 = 9.18 MW

The expected 11kV load lost is calculated as follows:

- Load Lost (MW) = Average MVA x 11kV Damage Multiplier x Backfeed Multiplier x Power Factor

In this case the risk of 11kV damage is high which gives an estimated 50% of load lost and there are no adjacent zones that are expected to be able to supply some of this load so the backfeed multiplier is 1:

- Load Lost (MW) = 9.67 x 50% x 100% x 0.95 = 4.59 MW

As the load lost due to 33kV damage is higher, only this is used in the benefit calculation, to avoid double counting the impact of both the 33kV and 11kV being damaged.

Worked Example - Haywards

Haywards substation is a major point of interconnection for Transpower in the Wellington region, so it is not supplied through the WE* sub-transmission network. Sub-transmission and zone substation damage was not considered for Transpower sites. Most of the 11kV supply out of Haywards crosses the Wellington fault, so a high level of damage is expected giving an estimated loss of load of 50%. Haywards ties into Melling, Naenae, and Trentham zones at 11kV. Of these, only Trentham has a high risk of damage. As two of three interconnected zones are not expected to sustain a high level of damage the backfeed multiplier used was 33%, due to 1/3 of the potential backfeeds being unavailable. This gives a lost load of:

- Load Lost (MW) = 7.83 x 50% x 33% x 0.95 = 1.23MW

This approach was used for most sites and zones in the network, but there were some situations where it was not applicable. Two substations in Central Wellington, The Terrace and Frederick Street, have a small number of feeders that are almost entirely in a high-risk area, while the majority of the rest of the zone is expected to sustain relatively little damage. These sites were treated as having a high risk with the total load being reduced to the load on those feeders.

Titahi Bay zone substation is supplied at 11kV via Porirua zone substation through two oil-filled cables that run along the edge of Porirua Harbour. As all alternate supplies into the Titahi Bay zone also run through areas of high liquefaction risk, it is anticipated that the full 3.5 MW supplied by this substation will be lost.

Restoration Timeframes

Outage durations were based on the work required to carry out the necessary repairs given the level of staffing, equipment, and spares held at the time of the analysis. The repair strategy differs for each level of the network.

Sub-transmission: Where fluid-filled cables are damaged, these will not be practical to repair given the complicated nature of these joints and the long lead time for joint kits. The quickest method of restoring supply would be to construct temporary overhead lines to replace the entire length of the circuits that have been damaged. XLPE cables are simpler to repair, and joint kits are more readily available so where there is damage to an XLPE cable this will be repaired.

Zone Substation: At the time of analysis, WE* had one spare power transformer and no complete spare primary class switchboards. Spares held would be able to cater for the loss of individual breakers within a switchboard, but not the failure of an entire board or the substation building. The restoration method would be to repair any failed buildings and utilise the system spare transformer in the event of a transformer failure. If there is more than one transformer failure, it will be necessary to obtain another spare unit from outside the region or to temporarily relocate one from another substation.

Distribution: The majority of damage to the distribution network is expected to be cable damage due to liquefaction. The restoration progress will therefore be constrained by the speed of locating and repairing cable faults. Following the Christchurch earthquake of February 2011, the limiting factor in the repair of cable faults was technician and fault location equipment resources. Restoration was assisted by a joint supplier setting up a temporary warehouse in the area so that supplies could be shipped directly to Christchurch and kits assembled there. At the time of the analysis, WE* did not carry significant quantities of spare cable accessories for 11kV cable repairs, as under normal circumstances these are readily available from suppliers and can generally be sourced within 24 hours.

For each site/zone where a loss of supply is expected, a repair time for that site was estimated. The estimation of outage durations assumed that cable fault location equipment was available and that machinery and fuel required for installation of equipment was available. It was also assumed that a spare transformer and switchboard would be able to be sourced from outside the region. Most transformers at risk of sustaining damage could be replaced with a similar transformer from another site in the same area. The 11kV damage is expected to be widespread and be repaired over many months.

On top of these repair times, the timeframe for transport corridors into the area to become available was discussed with Wellington Lifelines, including the likelihood of access being available by sea or air. These transport corridor delays were added to the repair timeframe to produce a total restoration time for each high risk 33kV circuit or zone substation.

Table 20 Outage Durations (Weeks)

Impact	Weeks		
	Repair	Transport	Total
Brown Owl 33kV Line	3	12	15
Maidstone 33kV Line	3	12	15
Trentham 33kV Line	3	1	4
Petone 33kV Line	2	13	15
Korokoro 33kV Line	4	12	16
Wainuiomata 33kV Line	2	0	2
Mana 33kV Line	4	1	5
Titahi Bay 33kV Line	4	1	5
Evans Bay 33kV Line	8	2	10
Ira Street 33kV Line	12	2	14
Moore Street 33kV Line	2	2	4
Petone Sub	4	12	16
Seaview Sub	8	0	8
Korokoro Sub	4	12	16
Mana Sub	8	1	9
Evans Bay Sub	12	2	14
Gracefield Sub	0	0	0
Plimmerton Sub	0	0	0
Moore Street Sub	0	0	0
Ira Street Sub	12	2	14

It is apparent that transport of parts into the region is often expected to take longer than the repair itself. This is particularly true where there is extensive work or major plant required to restore service. Actions that reduce these transport times or allow repairs to commence ,without relying on transport corridors, will result in a significant reduction in the outage durations.

Benefit Estimation

While much of the equipment required for the repair of the network is readily available within the country, very little was held within the Wellington region. Although this is not an issue in normal operating conditions, in the case of a major earthquake it would mean that transport from warehouses in other areas into the Wellington Region would delay restoration.

The initiatives that were proposed by WE* in its CPP application were intended to reduce reliance on transport into the region and between network areas as far as possible, enabling repairs to be commenced without reliance on roads reopening.

WE* valued the impact of outages based on the Value of Lost Load (VOLL) as established in the Electricity Industry Participation Code (EIPC). VOLL is estimated based on the impact of relatively short outages, with VOLL charts showing the cost of an outage reducing over time as, generally, the majority of an outage's financial impact is lost production at industrial sites. The costs of extended outages, lasting from weeks to months, is not well researched but it is likely that social costs will increase over time, offsetting the reduction in industrial cost, especially as power outages will delay other service restorations. Accordingly, WE* used the $20,000 per MWh VOLL figure published in the EIPC, adjusted for inflation, as a constant figure in the calculation of outage costs, giving a value of $28,278 per MWh. Sensitivity analysis was carried out using alternative VOLL figures of $15,000 per MWh and $45,000 per MWh.

Improvement options were grouped into Sub-transmission damage, Zone Substation damage and 11kV cable damage, with cost benefit analysis completed for each option. Figure 6 shows an example of options that were considered for improving Sub-transmission resilience.

Table 21 Example Improvement Options

OPTION	
1	No additional action
2	Carry overhead line components for vulnerable routes
2a	Carry 33kV fluid-filled cable spares including transition jointing kits
3	Replace all fluid-filled cables with XLPE
4	Carry 33kV XLPE cable spares including jointing kits

Benefits were calculated by estimating the potential reduction in outage length, multiplied by the amount of load that benefits from the earlier restoration and the VOLL, then divided by the earthquake return period to obtain an annualised value of the avoided risk for each option.

In all cases Option 1 was to take no action to improve response times, to establish a base case for comparison of other options.

Options were assessed for their individual viability and deemed worthwhile if the cost to implement was less than the total benefit over a 20-year NPV. There was some overlap in the benefit of some options that had to be accounted for in the final business case to ensure that benefits were not being double counted. Each proposed option needed to provide a net benefit alone as well as the overall programme being beneficial once any overlap between options was removed.

Final Readiness Programme

Following the cost benefit analysis, the recommended programme for the CPP as approved by the Commerce Commission comprised five workstreams:

1. Seismic strengthening of 91 substations to 67% of New Building Standard (NBS) at Importance Level 4, to increase the likelihood of these substations being able to continue operating after a major earthquake.
2. Procurement of 20km of overhead line equipment for building temporary overhead lines to bypass damaged fluid-filled 33kV circuits, including design of potential line routes.
3. Procurement of two mobile 10MVA 33/11kV substations and one containerised 11kV switch room.
4. Procurement of spare underground cable, cable joints, cable fault location equipment, distribution transformers, and distribution switchgear as emergency spares.
5. Construction of three backup data centres with attached network control rooms, one per “island”, to allow the network to be operated in a decentralised manner with communications links broken between islands.

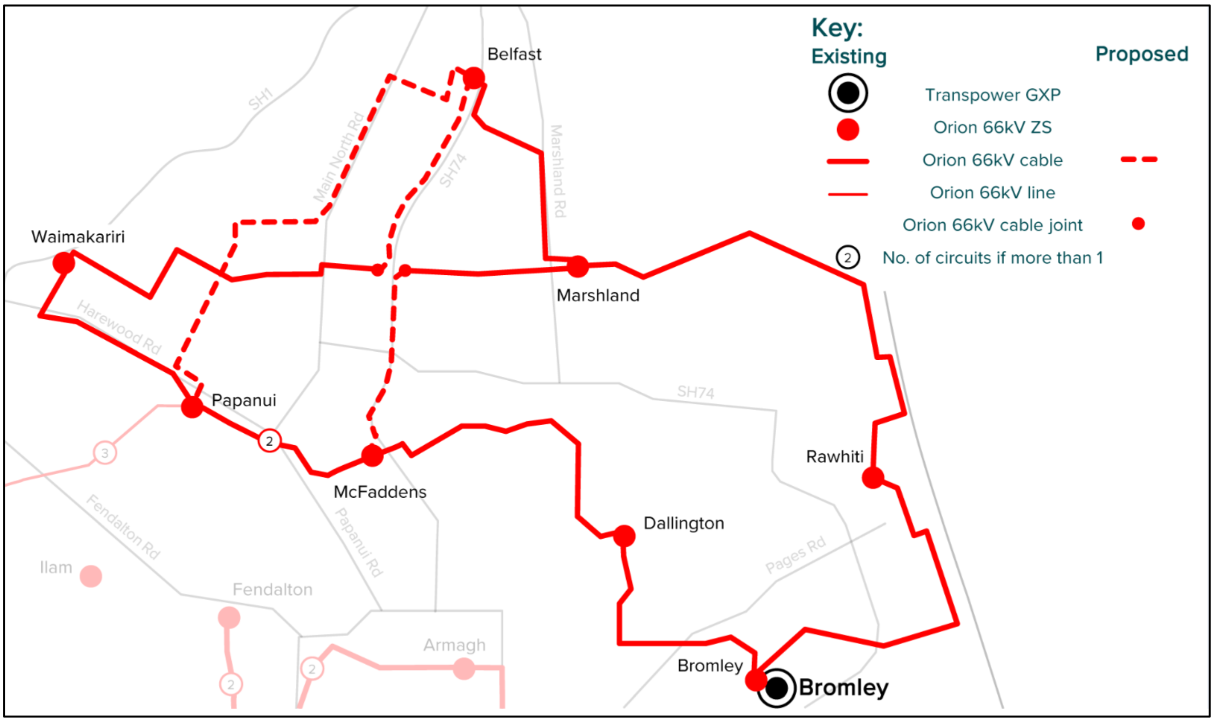
The exact location and nature of future earthquake damage cannot be predicted, so the purpose of these workstreams was to provide WE* with a cost-effective set of tools that would enable a flexible response to a major earthquake and create an appropriate level of self-sufficiency for critical materials that allows restoration to commence prior to the transport corridors opening.

Case Study 2: Orion Earthquake Recovery Lessons Update

Fourteen years on, Orion has completed the replacement of the 66kV cabling in the North and East. The temporary overhead 66kV lines have also been removed. As growth in the North continues, lessons learned from the earthquake are being used to plan cable routes that support both resilience and security of supply.

One of the key lessons learned during the cable replacement was related to bridges. Christchurch has numerous natural waterways, and historically, the preference was to attach cables to road or pedestrian bridges to cross them. However, Orion's cables suffered significant damage where they left the bridge due to shear forces between the seismically reinforced abutment and the seismically susceptible riverbank. This not only damaged the cables but also the bridges. Repairs to the bridges can take several years and might require complete demolition or changes to the roads leading up to them – all impacting cable routes and restoration / continuation of supply.

As a result, Orion now opts for direct drilling and ducting of cables under rivers or carefully considers the lead up to a cables entry onto a bridge. A common practice is to install large loops on either side of the bridge, allowing for any future damage to be cut out and the cables rejoined by shortening the loop.



Earthquake Recovery Lessons

This case study is intended to illustrate the scale and impact of an actual major event on an *EDB* network and operational facilities and describes the likely issues and actions required to carry out a full recovery phase after a major event.

Earthquake Sequence

On Saturday 4th September 2010 at about 5:40 am, a shallow depth magnitude 7.1 earthquake occurred on a previously unknown fault, now referred to as the Greendale Fault, about 40km from Christchurch City.

Although the earthquake was centred in a predominately rural area to the west of Christchurch, the shaking, and the incidence of severe liquefaction in areas of vulnerable soil type led to widespread damage throughout Christchurch and the surrounding area. *Civil Defence* emergencies were declared for Christchurch City, Selwyn District and Waimakariri District.

This earthquake later named the “Darfield Earthquake” affected much of Christchurch’s infrastructure including the electricity supply system. Orion immediately lost about 60% of supply to the city.

Supply restoration was rapid, requiring the resetting of tripped zone substation transformers (due largely to tap changer gas protection tripping) but also repairs to some damaged equipment. Thousands of aftershocks were experienced over the next four to five months, some as big as R5, with many centred much closer to urban areas of Christchurch.

On Tuesday 22nd February 2011 at 12:51 pm, a magnitude 6.3 earthquake ruptured a fault almost directly beneath Christchurch. This generated extreme ground shaking intensities with maximum intensities reaching MMIX and very high vertical accelerations up 2.2 G and horizontal acceleration of up to 1.7 G at Heathcote Valley and levels of 1 to 1.88 G in other areas of the city.

Considerable damage was inflicted on buildings and infrastructure resulting in building collapses and extensive liquefaction, particularly in the Eastern suburbs.

A national *Civil Defence emergency* was declared. 185 lives were lost, and many thousands of people were injured. The CBD was evacuated and locked down requiring *Civil Defence*-issued passes to gain access. Orion’s headquarters was located in this access-controlled zone which made things more difficult.

The earthquake sequence continued with a number of major aftershocks over the next 12 months, several being greater than R5.

The impact of the February earthquake is considered to be seven to ten times greater than the initial September quake when assessed in terms of power supply restoration times, direct repair costs and customer minutes lost.

Damage to the Orion network coincided closely to the areas where liquefaction was present and also where shaking effects were high, e.g., around areas of the Port Hills where cliff collapses and rock falls occurred.

Network Damage

During the response phase, which lasted approximately six months, Orion asset staff assessed the residual damage to network assets and began to formulate the necessary plans to reinstate the level of security back to at least pre-earthquake levels.

The legacy 66kV oil filled cable sub-transmission network was greatly impacted with 50% of it being damaged beyond economic repair due to multiple damage along each circuit route.

Approximately 10% of Orion's underground 11kV distribution network was damaged with many circuits suffering multiple fractures particularly in areas of liquefiable soils.

The condition of MV cables was assessed once the immediate repairs to faulty circuits was completed, by carrying out partial discharge testing in areas where there was evidence of ground movements.

Within the CBD, many building distribution substation sites were damaged and, along with the buildings, had to be bypassed and abandoned.

Brighton zone substation (40 MVA capacity) and an associated 66kV switching station nearby were extensively damaged by liquefaction and were written off. A replacement zone substation was constructed in a tight timeframe at the Rawhiti Domain on soils which demonstrated much less liquefaction effects.

Damage to network substation and switching centre buildings was minimised due to an extensive seismic strengthening programme carried out as a risk reduction strategy over a 15-year period prior to the earthquake events.

Orion's material damage insurance cover was limited to only substation and office buildings as, since 1992, extensive cover for other network assets such as lines and cable networks had become economically uninsurable on the global scene.

A significant shortfall in available finances was anticipated based on a significant repair bill to carry out a full recovery programme following completion of the initial response phase repairs. This led to Orion lodging a CPP application with the Commerce Commission to enable line charges to be increased to raise sufficient finance.

During this period Orion's line charge revenue was reduced due to the closure of the CBD and the red zone housing losses which caused the loss of customer connections through building demolitions and the population relocating their housing and businesses. This loss of revenue is estimated at $50M over the first four years after the earthquakes.

The 'Recovery Phase' costs to fully restore the network to its pre-earthquake security level were estimated at an extra $155M of CapEx above what was originally planned over a possible ten-year period.

In the meantime, there were many other costs to be met such as ongoing repair costs, new housing relocations from the red zone, and paying for uninsurable losses on various parts of the damaged network.

The five-year CPP did not commence until 1st April 2014, leaving Orion to finance all post-quake costs for a considerable period. The approved CPP did not cover all the items requested by Orion.

In replacing the written-off oil-filled 66kV cables, Orion moved to solid insulation (XLPE) cables and decided not to use the previous radial transformer feeder configuration with both substation circuits laid alongside each other. This older architecture turned out to very vulnerable to common mode failure.

The long-term impact on staff and their families of this major event led to a period of relatively high staff turnover which also had to be managed, whilst carry out an ambitious recovery phase.

The main lessons learned were:

- a big event like an earthquake creates huge, extraordinary repair and recovery costs coupled with a potential drop in revenue
- under existing regulatory rules, lodging a CPP application with the Commerce Commission is likely to be necessary for the affected EDB to be able to fund these additional costs. It may take several years to get a CPP prepared and approved and may not lead to all requested work being funded
- material loss damage claims involving building demolitions and rebuilds can take several years to work through. Most of the damaged network assets were effectively self-insured
- the recovery plan should assess whether the replacement network should stay as like for like or be built in a more resilient manner the older weak mix concrete thermal backfill 66kV cable design proved to be too rigid and replacement 66kV cable backfill designs introduce more freedom for the cable to move about during earthquake waves
- as a result, the Orion 66kV network in the eastern suburbs has been rebuilt using better and diverse routes, improved modern cables with the improved cable trench design. A northern 66kV cable ring system has been created by this process to provide interconnection diversity
- improvements have been made to the supply arrangements to key lifelines entities such as the as Christchurch Airport and Port of Lyttleton
- in this type of event there are likely to be relocations of customer loads requiring reinstated capacity but in a different location to the pre-event network, and
- where a built-up CBD is involved, which has sustained considerable damage, there are multiple work streams occurring, involving; working with demolition and rebuild work programmes
- liaison with relevant local body and central authorities requires sufficient resources to be deployed (the size of which should not be underestimated) to focus on safety and network rearrangements including the provision of completely new substations in new buildings and a high disconnection / connection rate
- cable networks in these areas are very likely going to have to be re-configured
- in some cases, opportunities arise to eliminate older legacy network assets rather than replace

- the impact on field resources having to carry out years of repair and recovery work can take a toll and it is important to look after these people some of whom were dealing with their own recovery issues
- it was important to communicate progress to stakeholders (customers, shareholders) as the recovery plan unfolded
- the location of an EDB headquarters and related contractor depots need to be considered to avoid suspect close neighbouring buildings or potentially suspect access areas. This resulted in a move to a resilient (IL4) and fit for purpose main office which includes the 24/7 network control centre
- Connetics, Orion's key network services provider, was also moved into a new resilient and fit for purpose base. Other site related improvements in resilience have been made, e.g.
- critical network component spares have been moved to diverse sites that are less susceptible to natural disaster risks
- a new disaster recovery site has been established if use of the normal administration office and control room is not possible after a major event and
- business priorities following a big event, can be quite different from business-as-usual resource deployment and part of being resilient is the ability to adapt to these new circumstances.

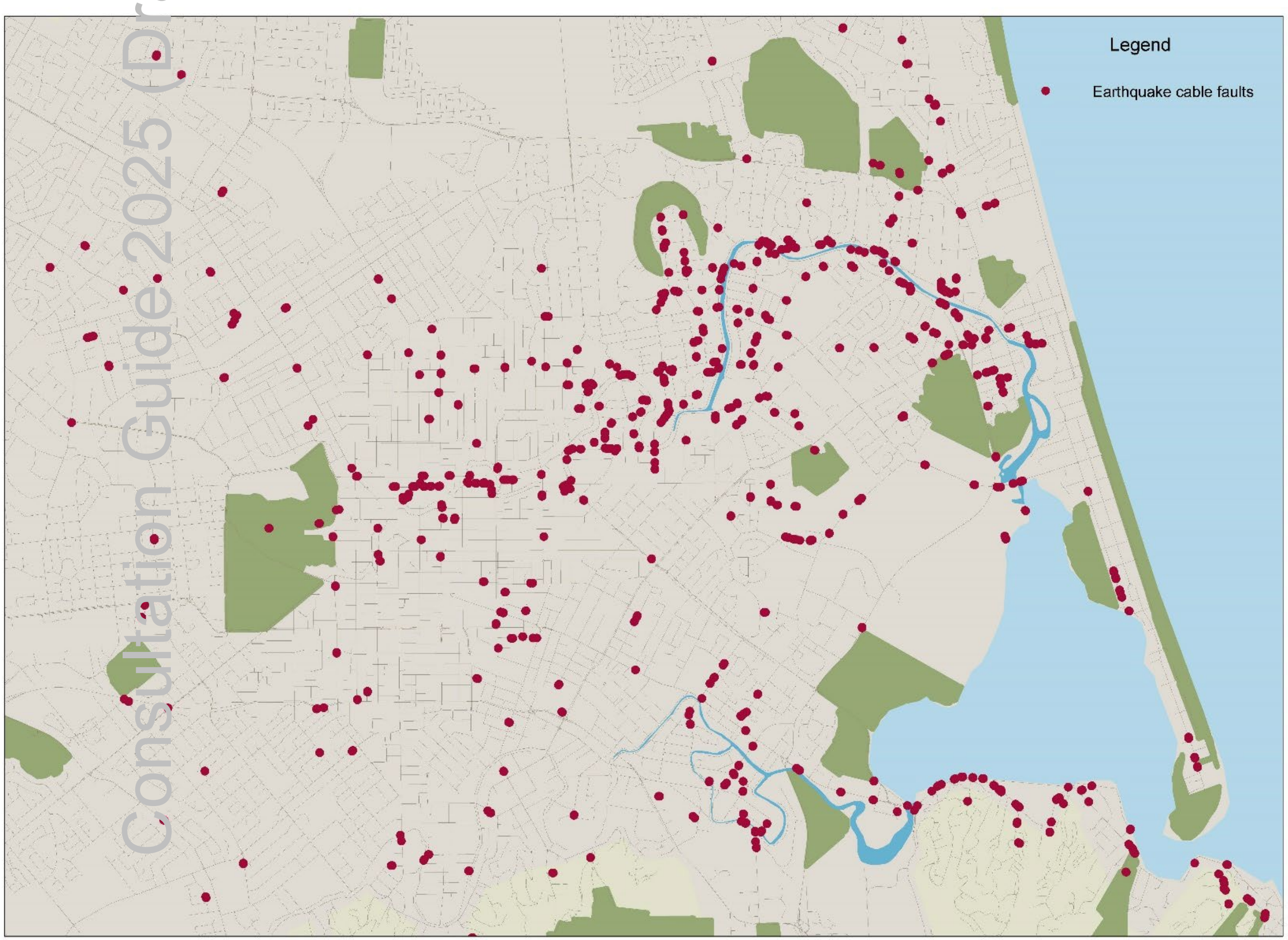


Figure: 18 High Voltage Cable Damage Locations

Figure: 19: Urban Damage

Figure: 20: 66kV Oil Filled Cable Damage – Armagh Street

Figure: 21: 66kV Cable Damage

Figure: 22: Low Voltage Line Damage

Figure: 23: Liquefaction Impact on Major Substation

Figure: 24: Liquefaction Inside Major Substation

Figure: 25: Substation Damage Comparison

Figure: 26: Substation Damage from Bolder - Wakefield Avenue

Figure: 27: Substation Rock Fall Damage

Figure: 28: Orion Office Demolition

Figure: 29: Second Floor Office Damage

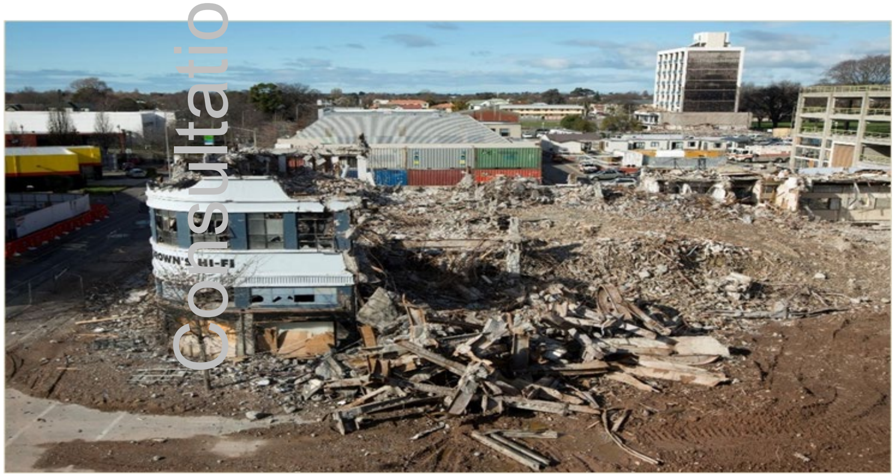


Figure: 30: Orion Office Demolition

Figure: 31: Orion's New Office

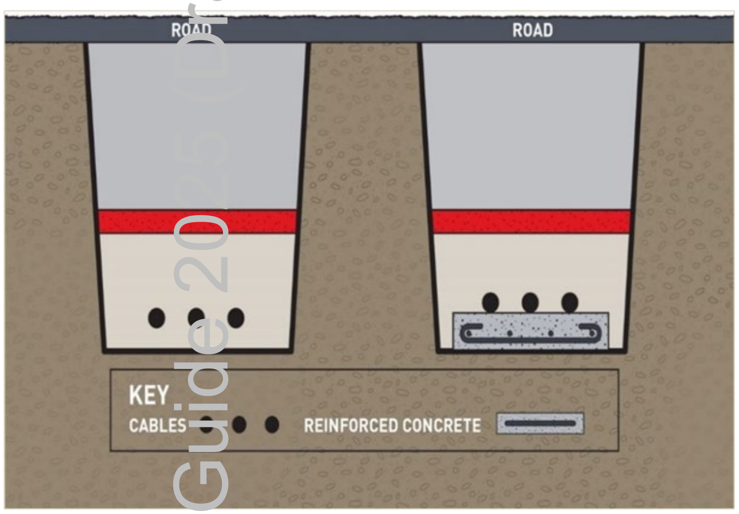


Figure: 32: 66kV Replacement Trench Design: Liquefiable Soil

Figure: 33: Substation Strengthening - Steel Framing

Figure: 34: Replacement Zone Substation

Figure: 35: Emergency 66kV Overhead Line

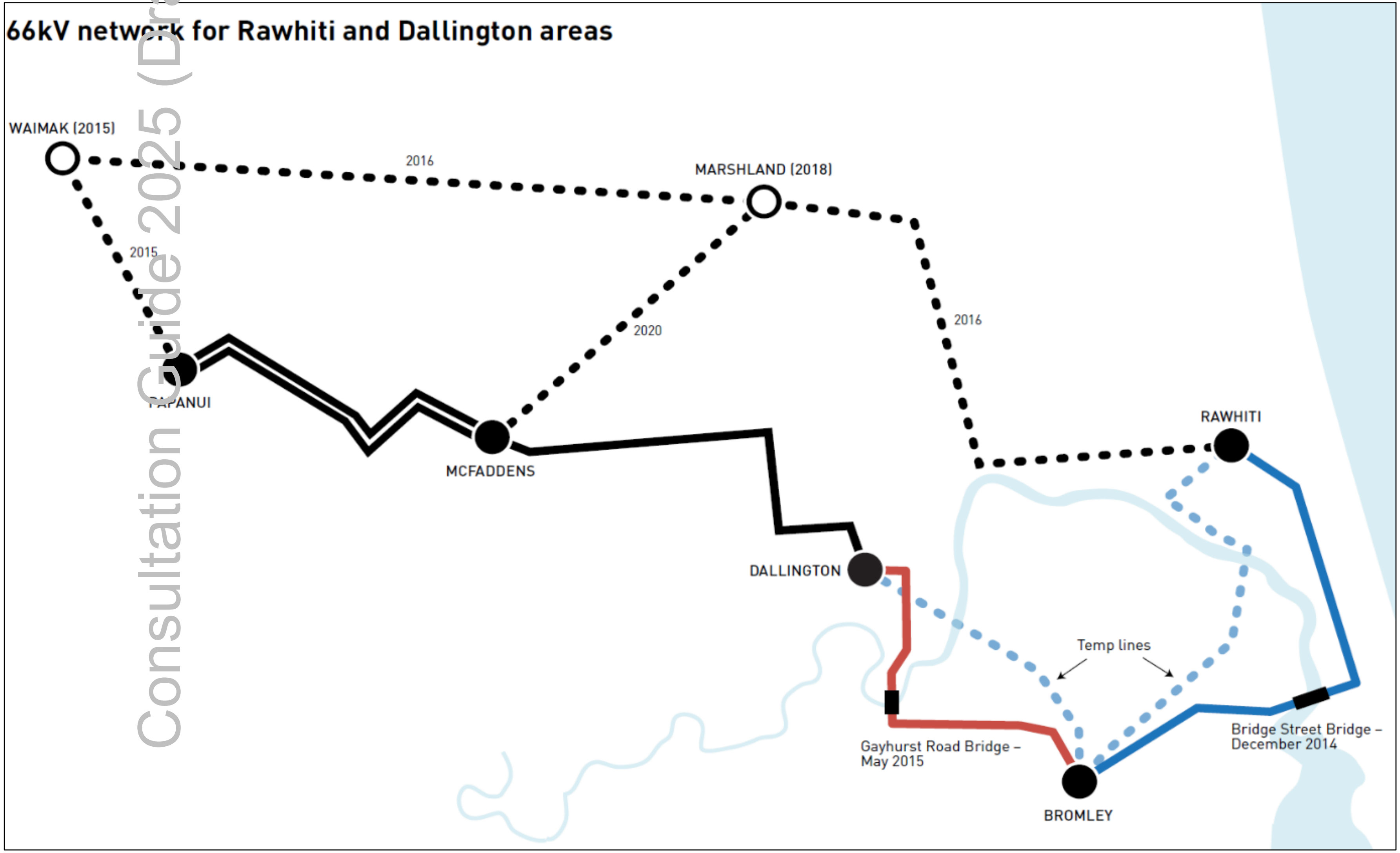


Figure: 36: Designing Resilience into Recovery Plan

Case Study 3: Powerco CIMS Implementation

Powerco has adopted the Coordinated Incident Management System (*CIMS*) framework to handle a range of incidents from relatively small to major events impacting their extensive network. The following figures illustrate how this standard has been rolled out to meet Powerco's operational requirements.

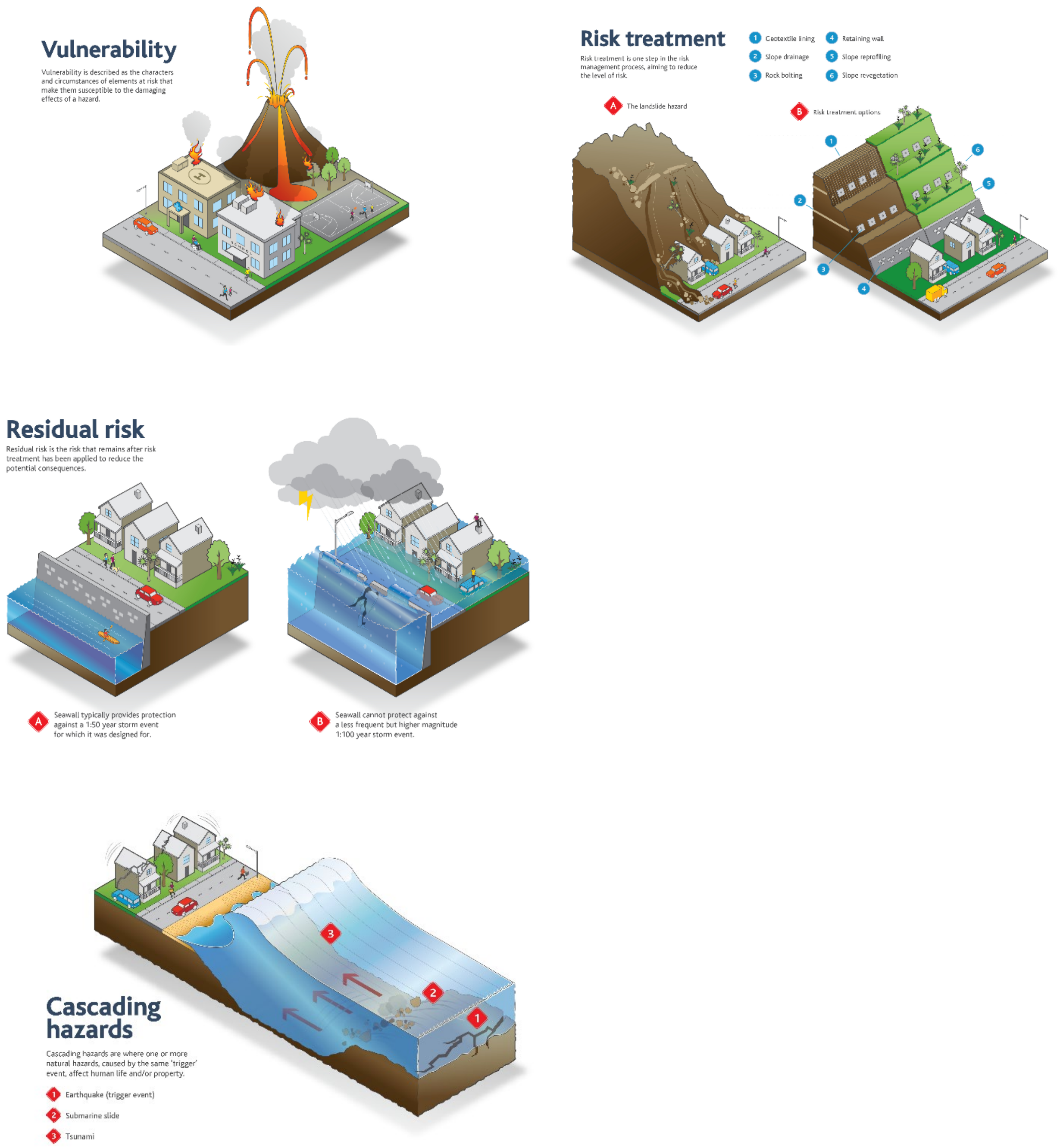


Figure: 37: Risk View

Response Level	Description
National	Includes national organisations' Coordination Centres and headquarters, and national level sector coordinating entities and clusters. Coordinated from National Coordination Centres (NCC).
Regional	Includes Civil Defence Emergency Management (CDEM) Groups, District Health Boards (DHBs), inter-regional DHB coordination, police districts, fire regions and regional organisation offices. Coordinated from Emergency Coordination Centres (ECC).
Local	Includes local authorities, DHBs and organisation offices at the local (district/city) level. Coordinated from Emergency Operations Centres (EOC).
Incident	The first level of official response. It includes first responders. Coordinated from Incident Control Points (ICP).
Community	The public, including individuals, families/whānau, community groups and businesses that participate in the response.

Figure: 38: CIMS Response Level Descriptions

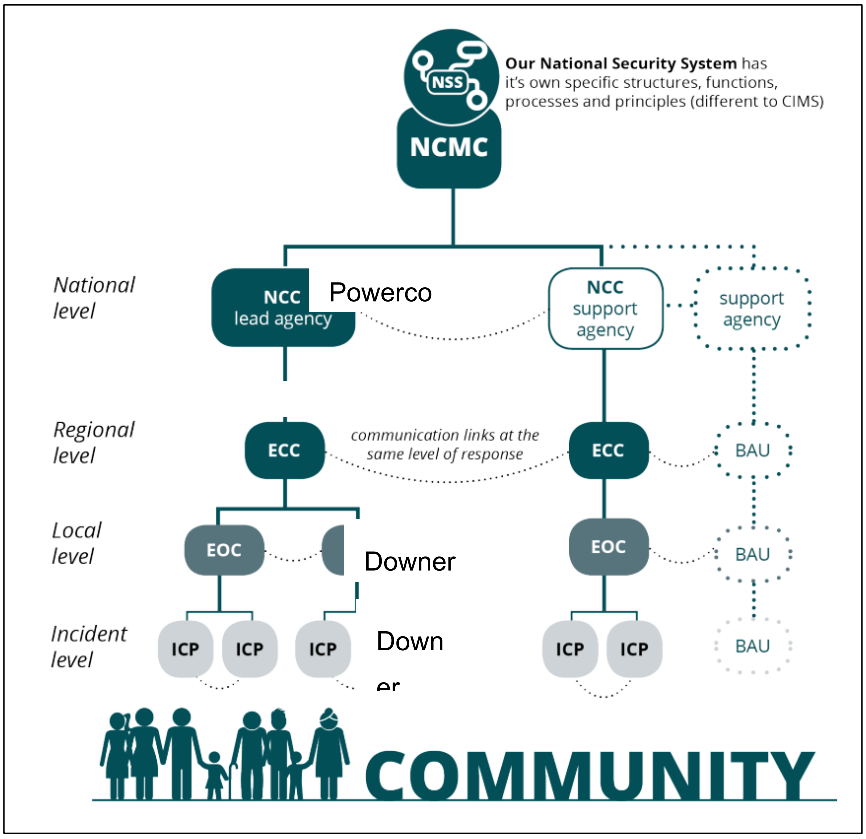


Figure: 39: CIMS National, Regional and Local Structures

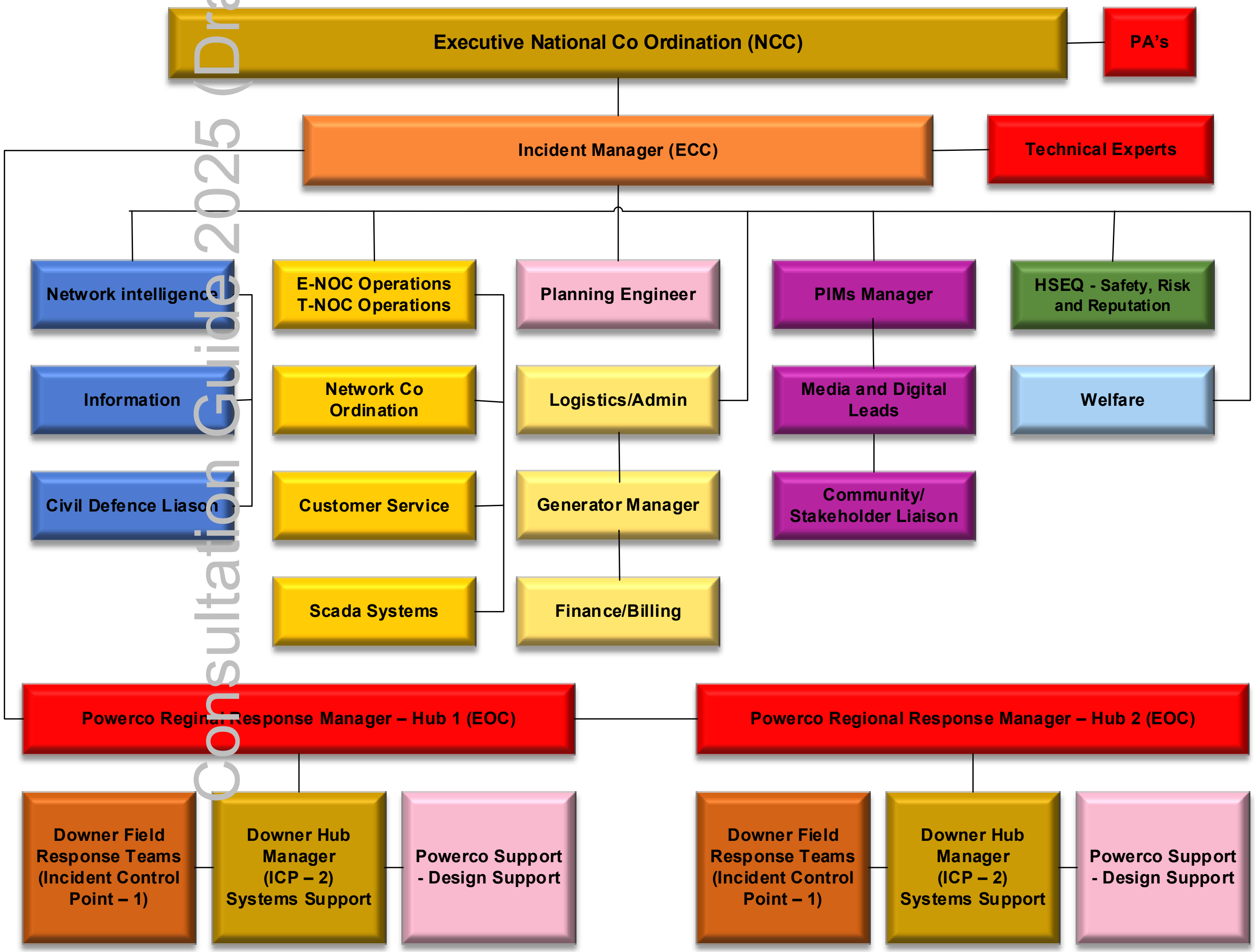
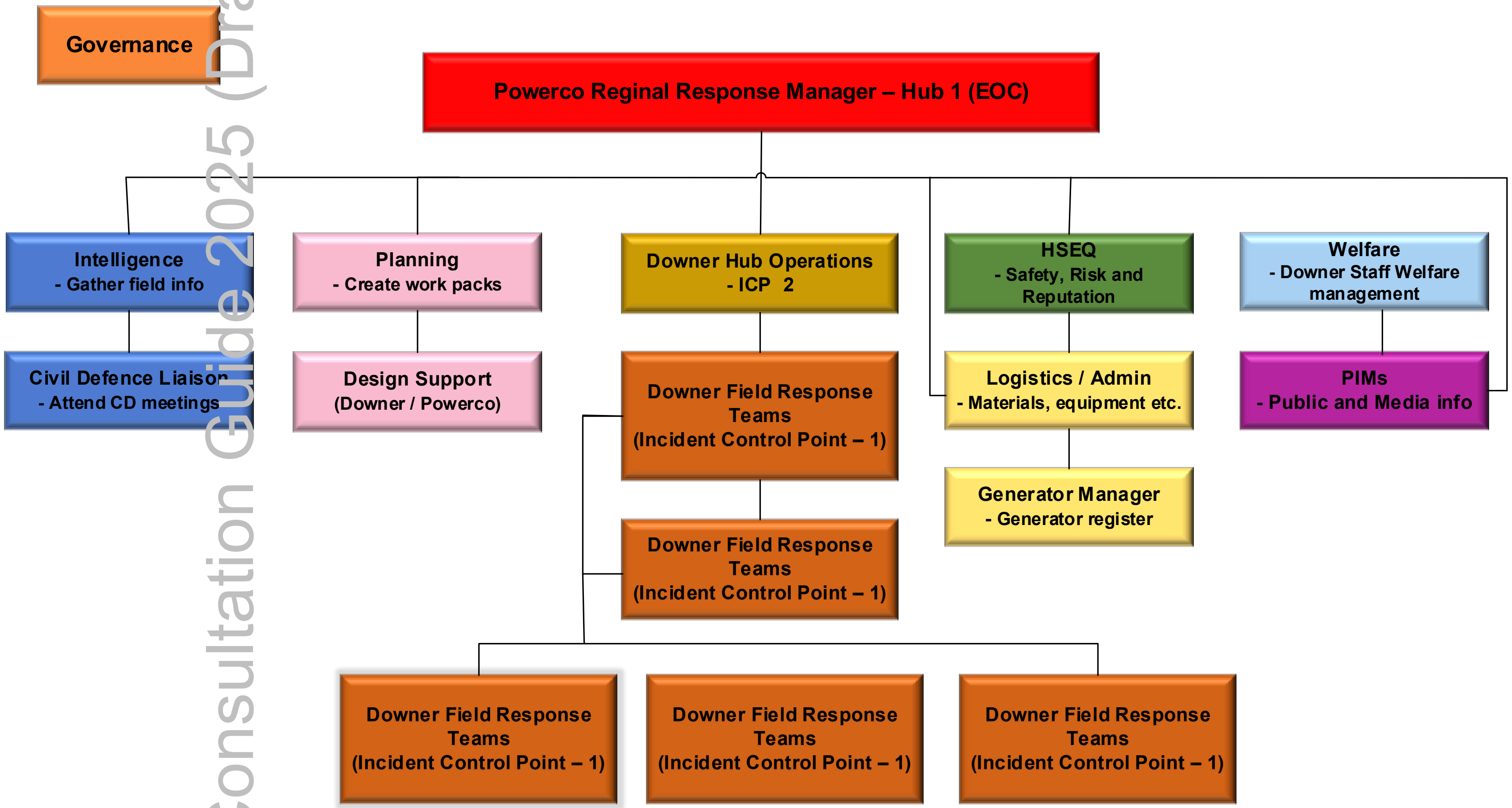


Figure: 40: CIMS Major Events Management Structure



Note: Response Manager assumes ‘Control or Command’ function.

Figure: 41: Major Event Hub Incident Planning Functions

Case Study 4: Powerco CIMS Training Initiative

Powerco EDB implementation of CIMS (Co-ordinated Incident Management System) Training / Role Play Scenario Training November 2019.

Background

Following an external report on the Taihape Snowstorm event in July 2017 it was realised that while *CIMS* concepts were being followed by *NOC*, *CIMS* processes were not understood by the wider business with low levels of engagement. It was highlighted that 'Response, Planning & Organising' of major events was a significant factor to improve major event performance resulting in a 10-point 'Action Plan on a page'.

CIMS L2 Training

Over the next 18 months / 2 years Powerco has been working on this Action Plan, engaging external training providers 'Devereaux-Blum, delivering 18 *CIMS* Level 2 training courses to frontline team leads & managerial staff (Including IS engineers Re: Cyber-attack risk) for both Powerco and Contractors in this internationally recognised system used by Civil Defence, Police, Fire & Emergency services to ensure common language during major events. By mid-November 2019 216 staff have received training to Level 2 standard across the Electricity and Gas businesses.

Response Kits

To support this training initiative, Powerco has developed dedicated *CIMS* 'Response' kits, ready with relevant documents, plans and systems to ensure consistency of product. It has deployed 21 kits. Also, five Emergency RT Radio Grab boxes are deployed at Powerco and Contractor strategic locations.

Storm Room

NOC has set up a dedicated *CIMS* Storm room at Junction St with permanent display of *CIMS* functions & lanyards etc., which can be made ready at a moment's notice.

Scenario Training

Bedding in *CIMS* Level 2 training, we have conducted several hub scenario role play exercises with both Downer and Powerco staff reinforcing the message of "working together" during major events. Scenario Role Play training has been undertaken at Paeroa, Wairarapa Hubs and recently with *NOC* practicing new SAP storm role concepts. Next will be Downer New Plymouth, Tauranga, Wanganui, and Manawatu Hubs. Role play scenario training will be an ongoing action to hone existing processes and implement improvement opportunities.

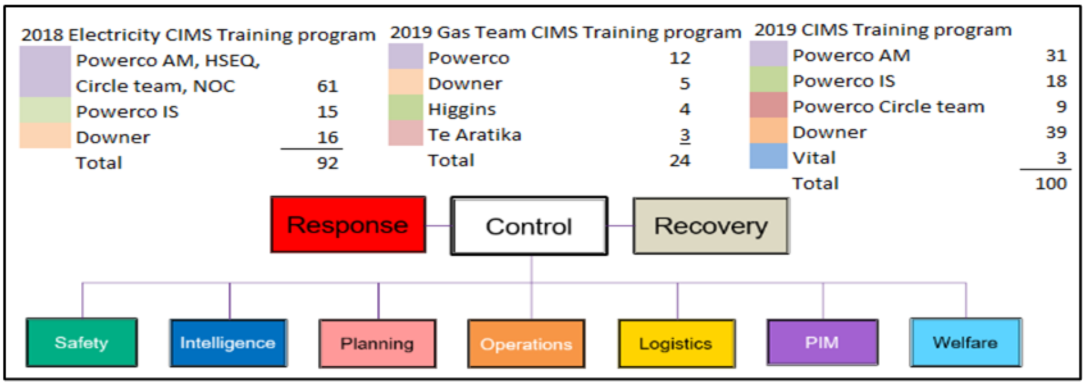


Figure: 42: Completed CIMS Training Program

Powerco's Response Plan Based on *CIMS* Principles

Response Level		Event Classification		Event Name:
		1 Minor		Response Plan on a Page Incident Objectives & Strategies.
R 2	Stable	2 Moderate		
		3 Major		
N = National. R = Regional. L =Local. I=Incident.		4 Severe		
		Date:		
		Time:		

4.0	Incident Objectives - Create a Response Plan to transition from 'Reactive to Proactive' activities in the shortest possible time frame, keeping customers Safe & informed.
4.01	Ensure Public Safety is maintained including Contractors & Powerco personnel.
4.02	Protection of plant and equipment & Compliance with legislative requirements.
4.03	Create a Response Team - Incident / Response manager assumes CIMS 'Control / Command ' positions & holds a series of storm Hub management planning meetings recording - Safety / Intelligence / Planning/ Operations / Logistics / PIMs, Welfare & Recovery functions to follow event Life cycle Phases of 1/ Triage, 2/ Discovery, 3/ Planning, 4/ Restoration of HV, 5/ Restoration of LV & 6/ Recovery.
4.04	Ensure Security of supply and maximising the reliability of supply to Powerco customers.
4.05	Operating the network efficiently to NOM Operating standards.

Generic Strategy Plan of actions to meet incident objectives			Priorities
	Restoration priority will in general follow:		
4.10	Phase 1 - Triage / Public Safety (Emergency / Hazard faults, including lines down). (Re-Active)	4.10	During Triage Phase 1 (Ground zero, Event is still occurring) 1. Isolate 2. Make Safe 3. Minimise (Record scope of damage (SAP / OMS) & report to Hub) Minimum 25% resources allocated to Emergency / Hazard faults
	Minimum of 25% resources allocated to 'Emergency' faults		
4.12	Lines down in urban areas		
4.13	Lines down in public thoroughfares (road reserves)		
4.14	Lines down on private property		
4.15	Environmental considerations - Oil spills etc.	4.15	Report any oil spill immediately to Powerco & mitigate.
4.20	Phase 2 - Discovery - Prioritise Intelligence gathering.	4.20	Line patrols to Photograph / report back extent of damage to Storm Planner / Response manager / NOC to record in Scada, SAP, OMS etc, issue info to Response manager. Quick wins limited to fuse replacements only.
4.21	Collect info from Retailers / Public, Faults OMS data, Prioritise & arrange Field patrols / Heli patrols, to scope & report extent of damage.		
4.30	Phase 3 - Planning - Creation of Work Packs. (Pro-Active)	4.30	From gathered intelligence create work packs, establish Estimated Time of Restoration (ETR) & inform Restoration / Incident manager.
4.31	Design / Planners create work packs & issue to Operations		

4.40	Phase 4 - Restoration -Prioritise Restoration of HV Supply	4.40	Operations follow the general hierarchy of restoration - Proactive stage, complete Work Packs, accurately record what we do at all stages. This allows understand of the scope of work completed - Consideration of HV Generation if access & sites are suitable - During the event Incident manager may request priorities to be changed. This will be communicated with the situation reports
4.41	Sub transmission feeders causing loss of supply		
4.42	Zone Substation issues causing loss of supply		
4.43	Feeders supplying central business districts		
4.44	Feeders with major strategic business impacts		
4.45	Feeders supplying large numbers of domestic customers		
4.46	Feeders supplying dairy farms		
4.50	Phase 5 - Restoration - Prioritise LV Fault Restoration	4.50	Note: LV fault volumes are of concern - Focus on Lines Down, Hazards, Public Safety, medically dependant / elderly consumers etc. - Focus on oldest faults received as a priority - Ensure sufficient resources are available for volume of LV faults. - Strategy for PAC contractors follow or precede HV rebuild works to ensure Private LV network is repaired ready for HV back bone restoration. Ensure PAC directly bills consumers for this work.
4.51	Priority LV Faults		
4.52	Aged LV Faults		
4.53	LV Faults (Powerco)		
4.54	LV Faults (Private)		
4.55	LV Generators	4.55	As a general rule, where outages are greater than 48 hours & the expectation of supply will be off for a further 24 hours, LV generation will be supplied on request, on the basis of Welfare or hardship issues.
Note	Restoration priority considers special focus on hospitals, community water pumping stations, sewage stations, supermarkets, fuel supply, rest homes, farmers, and negative publicity etc.		
4.60	Phase 6 - Recovery. - Create a Recovery Team	4.60	Create a recovery team & formulate a plan, restoring network to normal configurations ASAP. Focus on Defects, Abnormal switching & Storm patrols etc.
Copied to:			
Release:			
Date and time issued:			
Operational Period Covered:			
Reviewed by:			
Approved by:			

Figure: 43: CIMS Based Response Plan

Case Study 5: Transpower's Cost / Benefit justification of a Readiness Investment in a Portable Control Room

TRANSPOWER

The proposed portable control room concept involves a readily transportable and deployable example of the critical functions of a standard control room. This would reduce restoration timeframes following an event that catastrophically impacts an existing control room.

It is estimated that initial restoration times could be reduced by at least 5 days compared to rebuilding a control room from scratch. Recent experience following the Cyclone Gabrielle event supports this assumption.

The expectation is that prior to the delivery of the portable control room, protection from the remote end and a smaller 'protection in a box' portable solution would enable the initial response of any event. Protection from remote ends does not cater for backfeed protection and thus sets limitations on paralleling circuits during the recovery phase. The portable control room will serve as a longer-term solution, allowing full utilisation of the primary plant until a permanent solution is built.

The deployment of the portable control room would avoid further intermediary solutions, avoiding effort and resources for switching over from one stage to the next.

Sites identified for portable emergency assets

The table below details which sites are **included** as benefitting from portable solutions. Further details on which sites benefit from which solution can be seen in the workbook.

	FLOOD	FIRE	SEISMIC EVENT
Portable control room	69 sites that meet the following conditions: – Has been estimated to have a risk of flooding below our resilience criteria – And is not proposed for risk reduction work within RCP4	**All 187 sites**	**All 187 sites**

Assumptions

- One in three significant events will result in the need for deploying the control room.
- ODJB's are in recoverable condition to connect into.
- Cabling costs from the control room to the ODJB's will be covered by the efforts to recover the site, since this is quite site dependent i.e. costs not included in the estimate.
- The inundated site has sufficient space to place the portable control room.

- Resourcing and capability for deployment readiness in an emergency would be maintained through regular deployment exercises involving Transpower and key service providers, with at least one exercise per five years
- There is connectivity and protocol dependency on the availability of communications to National SCADA (via Starlink or fibre).
- We can transport our solutions to site within the timeframes allocated.
- Deployment plans will need to be developed for some sites prior to any deployment

Cost estimates

Cost estimates were developed. These will be refined and validated during detailed capital investigations as part of normal asset planning and delivery processes.

A summary of the capital and operational costs anticipated for RCP4 is as follows:

Portable solutions	Capital costs	Operational costs for deployment exercise
Portable control room	6,946,373	200,000

Cost benefit

A cost benefit analysis has been carried out. The basic cost benefit formula used is shown below:

CBA=PoF x Loss ($)/hour x outage reduction (hrs) x present worth of the annual cost avoidance x VOLL factor

Cost of the solution

Loss/hour is the expected service cost due to site failure ($/hour)

Outage reduction is an assumed period of savings due to deployment of the portable solution

Present worth of annual cost avoidance =

$$\frac{(1 + \text{Discount rate})^{\text{lifespan of solution}} - 1}{\text{Discount rate} \times (1 + \text{Discount rate})^{\text{lifespan of solution}}}$$

VOLL factor is an assumed factor for longer duration outages

Calculation parameters	Portable control room
Discount rate	0.07
Lifespan of solution	20
Present worth of the annual cost avoidance	10.594
Reduction in outage duration (hours) by using portable	24
VOLL factor to use for longer duration outages	0.2
Probability of using this solution for flooding	Site Flood PoF/3
Probability of using this solution for a fire event	0.000410004
Probability of using this solution for a seismic event	0.002105263
Load recovery from using portable solution	Site load - Load recovery from protection
Exclusions for flood analysis	All sites hardened within RCP4

Reduction in outage duration (hours) by using the portable control room - the cost benefit analysis uses conservative numbers to ensure that the investment is justified in the minimum case (1 day reduction for all portable control rooms)

VOLL factor:

VoLL may initially reduce over time and is estimated as 20% of the peak VOLL for all portable solutions.

Probability of using a portable solution:

It is anticipated that not every event would require a portable solution and thus the flood PoF is divided by a factor to ensure conservative results.

- For every third flood, either protection in a box, portable control room or a portable switchboard would be required.
- The probabilities of fire and seismic events are quite low already and the decision was made to assume that a portable solution would be required for every event.

Load recovery:

- Protection in a box is assumed to recover the load of 4 feeders at any supply site and thus the proportion of load covered by 4 feeders. Sites with no feeders or zero flood PoF gain no benefit from the protection in a box solution.
- Portable control room is assumed to recover the site load, beyond the load recovered from the protection in a box.

Exclusions:

Where there are hardening jobs in the plan to mitigate flooding, we assumed that sites would gain no benefit from portable solutions. This is a conservative assumption since the flood mitigation work will not make the site flood proof, but this assumption will ensure that there are no overlaps between the cost benefit analysis of hardening sites and portable solutions.

Results

Based on the assumptions above, the following CBA results were obtained

	Flood	Fire	Seismic	Combined CBA
Portable control room	1.43	1.0	5.17	7.6

A cost benefit analysis value of more than 1 implies that the investment is justifiable. A cost benefit ratio of less than one reflects that the project's cost outweighs the benefits, but the reputational cost of loss of supply during an emergency has not been added to the assessment. A higher cost benefit ratio would be obtained if it were included in the analysis.

Case Study 6: Transpower's Risk Reduction justification for Volcanic Ash Impacts

TRANSPOWER

Aim

To estimate the risk cost benefit ratio for the replacement of standard insulators with desert discs insulators on 60 structures of BPE-WKM-A, BPE-WKM-B, BPE-WRK-A and RPO-DEV-A lines.

Background

The Volcanic Ash Transmission Line Risk Mitigation workstream identified 358 structures within the 25 years return period zone on 4 lines (namely: BPE-WKM-A, BPE-WKM-B, BPE-WRK-A and RPO-DEV-A) and recommended insulator replacement with desert discs insulators on 65 structures (strain towers).

Assumptions

The following assumptions were made in the cost benefit analysis:

- The assumptions from the System Planning CNI Ruapehu Eruption Outage Study report are applicable.
- The "voltage stability" scenarios were used for total event cost in the model as they were worse than the thermal limit constraints.
- In an environment with mild corrosion, the typical lifespan of a glass insulator is expected to be 40 years.
- A 10-day outage is anticipated. Volcanic research indicates that an eruption alone may last up to 10 days before a response could be initiated. Based on the 1995 eruption of Mount Ruapehu, response and insulator washing took seven days to complete. Hence, for the cost benefit analysis we have estimated a total of 10 days for the eruption plus response and restoration.
- The value of lost load (VoLL) is $25,000/MWh is used for the first 8 hours (0.3 days) and $5,000/MWh (20% of VOLL) for the remainder of 9.7 days. This calculation assumes that customer load would be managed in a more cost-effective manner given the long duration.
- The installation of the desert disc insulators will *not* eliminate the risk of ash fall flashovers; it will reduce it by half from a 25-year to a 50-year return period.
- Direct costs for response are excluded from the analysis.

Analysis Method

The steps taken in this analysis were as follows:

1. Outage study (*by System Planning*) to estimate the financial impact of four Central North Island (CNI) 220 kV circuits tripping in response to a Mt Ruapehu volcanic eruption event. The circuits are Bunnythorpe–Tokaanu–1, Bunnythorpe–Tokaanu–2, Rangipo–Tangiwai–1 and Rangipo–Wairakei–1. Three levels of impact were defined and calculated.
2. Calculate the present worth of the annual cost avoidance, using 40 years useful lifetime of the mitigation and three possible discount rates.
3. Calculate the cost benefit of a full elimination based on the current risk state (probability based on 25 years return period).
4. Calculate the cost benefit based on a 50% risk-reduction scenario to result in 50 years return period probability, the difference being the amount of reduction anticipated.
5. Incorporate sensitivity analysis in steps 3 and 4 above using: three levels of impact; three discount rates; and 10 days vs 5 days event duration.
6. Calculate averages of the three impact states and the associated cost benefit ratios.

Extracts from the analysis spreadsheet are shown below:

Present Worth = ((1+rate)Yrs-1)/(rate*(1+rate)Yrs)

Present Worth			
Present Worth of the annual cost avoidance	13.33	17.16	19.79
Discount rate	0.07	0.05	0.04
Number of years considered in the analysis for useful lifetime of mitigation options (average)	40		

Cost benefit = (Probability x Event Cost x Present Worth) / Mitigation Cost

			Risk				Cost Benefit Analysis				
			Return Pd. (RP)	ALE (25 yrs RP)	ALE (Reduce to 50 yrs RP)		Total Event Cost	Mitigation Cost	Cost Benefit (7% rate)	Cost Benefit (5% rate)	Cost Benefit (4% rate)
Current risk state											
High Impact (10 days)			25	46,272,000	23,136,000		1,156,800,000	1,400,000	440.63	567.13	654.18
Med Impact (10 days)			25	7,500,800	3,750,400		187,520,000	1,400,000	71.43	91.93	106.04
Low Impact (10 days)			25	358,400	179,200		8,960,000	1,400,000	3.41	4.39	5.07
Average Impact (10 d)			25	18,043,733	9,021,867		451,093,333	1,400,000	171.82	221.15	255.10
High Impact (5 days)			25	23,136,000	11,568,000		578,400,000	1,400,000	220.32	283.57	327.09
Med Impact (5 days)			25	3,750,400	1,875,200		93,760,000	1,400,000	35.71	45.97	53.02
Low Impact (5 days)			25	179,200	89,600		4,480,000	1,400,000	1.71	2.20	2.53
Risk reduced state											
High Impact (10 days)			50		23,136,000		1,156,800,000	1,400,000	220.32	283.57	327.09
Med Impact (10 days)			50		3,750,400		187,520,000	1,400,000	35.71	45.97	53.02
Low Impact (10 days)			50		179,200		8,960,000	1,400,000	1.71	2.20	2.53
Average Impact (10 d)			50		9,021,867		451,093,333	1,400,000	85.91	110.58	127.55
High Impact (5 days)			50		11,568,000		578,400,000	1,400,000	110.16	141.78	163.54
Med Impact (5 days)			50		1,875,200		93,760,000	1,400,000	17.86	22.98	26.51
Low Impact (5 days)			50		89,600		4,480,000	1,400,000	0.85	1.10	1.27
Difference (reduction)					ALE (reduction)				CB (reduction)		
High Impact (10 days)					23,136,000		1,156,800,000	1,400,000	220.32	283.57	327.09
Med Impact (10 days)					3,750,400		187,520,000	1,400,000	35.71	45.97	53.02
Low Impact (10 days)					179,200		8,960,000	1,400,000	1.71	2.20	2.53
Average Impact (10 d)					9,021,867		451,093,333	1,400,000	85.91	110.58	127.55
High Impact (5 days)					11,568,000		578,400,000	1,400,000	110.16	141.78	163.54
Med Impact (5 days)					1,875,200		93,760,000	1,400,000	17.86	22.98	26.51
Low Impact (5 days)					89,600		4,480,000	1,400,000	0.85	1.10	1.27

Conclusion

The cost benefit analysis produces a positive ratio in all impact scenarios. At the lowest impact, the cost benefit is **1.71**, while medium impact results in a ratio of **35.71**.

Although all three impact scenarios are considered equally likely, the high impact result is significant, being approximately 6 times higher than the medium impact event. The outage calculation is very sensitive to high impact events of this type due to the long duration (10 days) and the amount of load unserved in the affected area, being a significant area of demand.

The average impact produces a cost benefit of **85.91**.

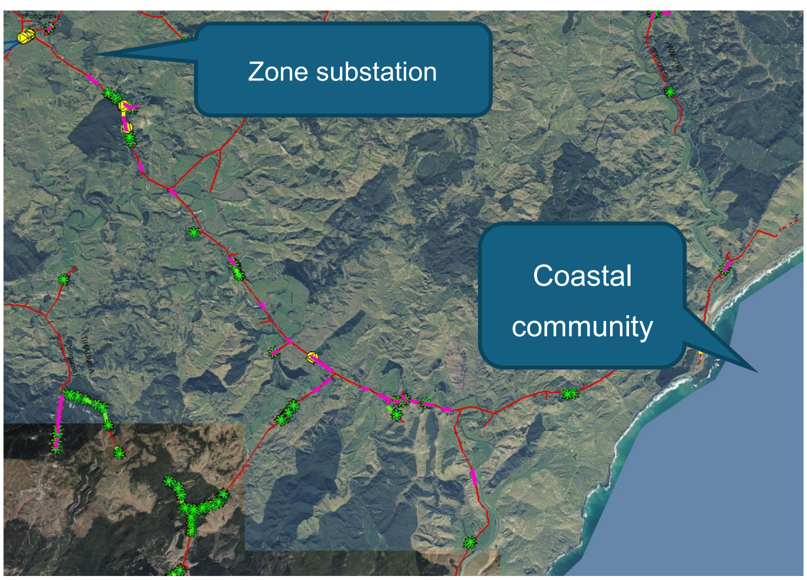
Case Study 7: Powerco Resilience Economic Model to justify improvements in resilience to a remote rural community Example

Below is a case study for provision of Value of Lost Load type approach that can be used to support justification for investment in to improving energy resilience for remote communities based on natural hazard event return periods.

Identify the issue/need

Some rural communities can experience long duration outages during severe weather events and earthquakes, given the remoteness from the main population centres and disrupted transport links increasing the time taken to survey and repair damaged network. In some cases, the restoration efforts can exceed days or even weeks, with loss of power and communications greatly hindering emergency response efforts, as has been experienced in recent Cyclone Dovie and Cyclone Gabrielle. Due to climate change, the severity and frequency of these events is expected to increase, and industry reviews have noted the critical responsibility of energy networks to support these communities.[13][14]

An example designated Civil Defence Emergency Centre for this coastal community experiences on average (17 interruptions per year since 2016-2023, 40,000 lost minutes), whose spur line traverses a large number of forestry areas, river crossings and slip-prone areas that risk damaging network infrastructure.



[13] Electricity Distribution Network Resilience Review – May 2022 – Victoria State Government

[14] Report to Electricity Networks Aotearoa – Electricity Distribution Sector Cyclone Gabrielle Review - 13 July 2023

This example shows a 25km 11kV spur line that passes through forestry (green), slip prone land (yellow) and a large number (10) river crossings (pink) to supply a coastal community

Potential mitigations

5. Network hardening to survive 1-in-100y rainfall event

For example – rebuilding 5x river crossings, relocating line sections out of slip prone areas, vegetation clear felling

Item	Units	Unit cost	Total
11kV river-crossing strengthening (complex)	5.00	$20 0k	$1,000k
Slope stabilisation/planting	3.00	$15 0k	$450k
Vegetation clear felling (tree removal)	200	$10 0	$20k
Total			**$1,470k**

6. Alternate network supply route

For example – Completing an 11kV link to an alternative feeder, providing increased level of supply redundancy

Item	Units	Unit cost	Total
Establish 11kV feeder tie (remote access)	5.00	$200k	$1,000k
Line capacity upgrades to allow back feeding	10.00	$40k	$400k
Total			**$1,400k**

7. Full Off-grid supply

For example – re-supply load to permanent homes via a number of remote area power supplies, allowing disestablishment of lines

Item	Units	Unit cost	Total
Per ICP Off grid supply (solar/battery/genset)	20.00	$200k	$4,000
Line removal	10.00	$10k	$100k
Total			**$4,100k**

8. Establish Community Hub

For example – install standalone community hub generation

Item	Units	Unit cost	Total
Hub off grid supply (solar/battery/genset)	1.00	$400k	$400k
Total			**$400k**

9. Do nothing

Note: Costs above are greatly simplified only ballpark/indicative capex costs and excludes ongoing OPEX costs or variance in other benefits of the individual solutions (for comparison purposes only).

Assess the VoLL benefits of the options

10. Baseline variables

Return period (P)

This is the estimated likelihood of event to occur and is broken into two categories:

– major/extreme events (P_M)

– minor events (P_m)

Magnitude (Mag)

This is the total amount of energy not served via the event and is broken into two categories:

– Magnitudes of major/extreme events (Mag_M)

– Magnitudes of minor events (Mag_m)

Value of lost load (VOLL)

This assigned monetary value of the non-supply electricity and can be broken into two factors:

- VOLL for major/extreme events (VOLL_M)
- VOLL for minor events (VOLL_m)

11. Common Values

Common values can be used if no real data is available. resulting in a "Ball Park figure" but will most likely not be an exact answer.

2.1 Return period

A common value for P_M is 0.04 (1 in 25 year)

A common value for P_m is 1 (once per year)

2.2 Magnitude

For magnitude we can use ADMD values, breaking it down into basic customer types, example of Energy Not Served (ENS) calculation:

- Res ADMD of 2kVA, therefore a consist 2kVA over magnitude (2kWh), ENS_R is (2kWH multiply by # residential properties)
- Com ADMD of 12kVA therefore a consist 12kVA over magnitude (12kWh), ENS_C is (12kWH multiply by # commercial properties)
- Ind ADMD of 25kVA therefore a consist 25kVA over magnitude (25 kWh), ENS_I is (25 kWH multiply by # industrial properties)

With kWH, it would then be multiplying outage period (OP):

- Major/extreme events 48-hour is a common value (OP_M)
- Minor events 2 to 6 hours (depending on distance from substation) is a common value (OP_m).

2.3 VOLL

The standard of $20,000 per MWh ($20 per kWh)

Equations

Mag_M = ENS *OP_M, (ENS_R*OP_M +ENS_C*OP_M)

Mag_m = ENS *OP_m, (ENS_R*OP_m +ENS_C*OP_m)

Val_M = Mag_M*VOLL_M

Val_m = Mag_m*VOLL_m

Per year value (PY_Val) = P_M*Mag_M + P_m*Mag_m

4. Additional factors

Additional factors are listed below, which can be included to increase the level of accuracy if appropriate.

- 48-hour period increase for area with one road in and out (ORIO) (only for OP_M) In example below
- Community hubs should be potentially classed higher usage in Major events versus minor events in example below
  - Major events = Commercial load
  - Minor events = Residential load
- Increase of VOLL_M by 1.5 of standard value, for critical infrastructure (water and communication)
- Increase of VOLL_M 1.15 of standard value, for communities that lack emergency and medical infrastructure
- These multipliers above are consistent with the AER approach seen in section 7 below

5. Example

The example is for an excluded area (max substation distance) of 60 residential properties with the additional factors of a community hub, and ORIO)

ENS_R = 60*2 = 120 (without community hub), 61*2 = 122 (with community hub)

ENS_C = 1*12 = 12 (community hub)

OP_M = 48 (common value) + 48 (For ORIO) = 92

OP_m = 6 (max distance from substation)

Mag_M = (120*92+12*92) = 12,144

Mag_m = (122*6) = 732

Val_M = 12,144 * 20 (due to using kWh) = $242,880

Val_m = 732*20 = $14,640

PY_Val = 0.04*242880+ 1*14,640 = 9715.2+14,640 = $24355.2

Therefore, a project scoped to be 30 years should be around:

30*$24,355.2 = $730656

Represents the economic value of lost load for the community over a 30-year period. It serves as the counterpart to the investment cost required to enhance reliability and resilience, whether through network hardening or non-network alternatives. NPV can also be incorporated to determine the annualized value over the specified period.

Determine the Benefit/ Cost ratio of the options—recommend adoption of the preferred option

Note: For the purposes of this case study, all options are considered to have the same VoLL benefit, noting that the community hub option is not a true/full replacement for the lost load, and other network solutions are not expected to completely remove risk of faults during 1-in-100y storm event

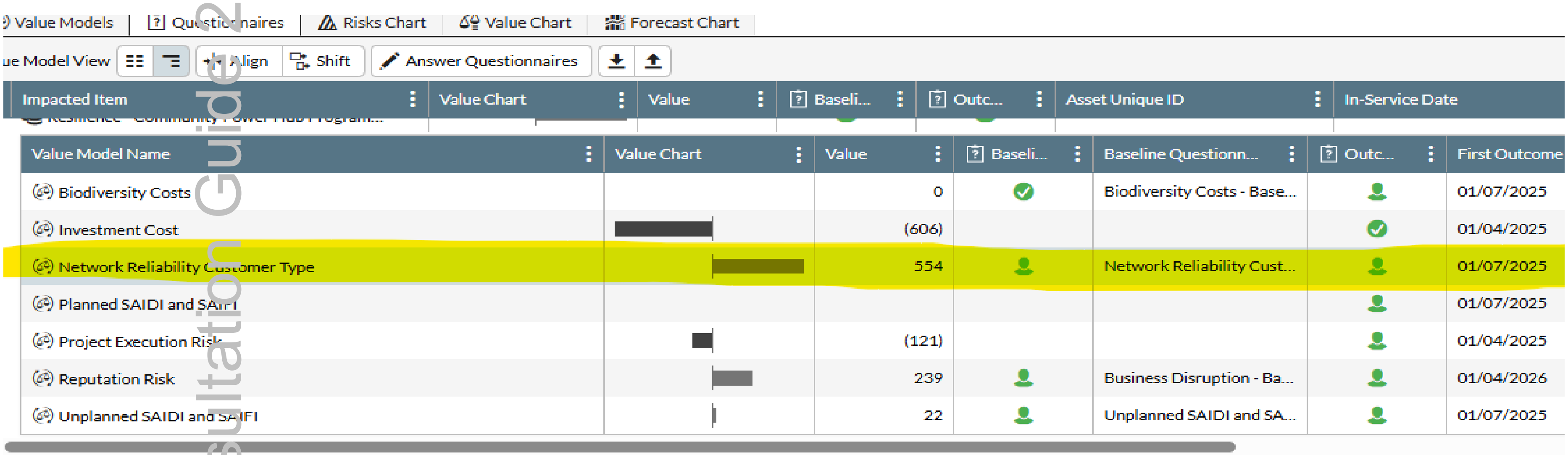
Option	Capex cost ($)	Benefit (VoLL)	Preferred option
Network Hardening	1,470k	730k	
Alternate Network supply route	1,400k	730k	
Off-grid supply	4,100k	730k	
Community Hub	400k	440k	Preferred option for this scenario
Do-nothing	0	0	

*For this case, the community hub option assumed to provide 60% for a “full” network solution, but this would need to be investigated per community and their valuing of resilience

Comparison to other models

Copperleaf

Our existing economic model returns a value of $554,000 for a resilience hub (non-network resilience solution. With the real-world example, similar matching the example of 60 residential properties example above.



Value Model Name	Value Chart	Value	Baseli...	Baseline Questionn...	Outc...	First Outcome
Biodiversity Costs		0		Biodiversity Costs - Base...		01/07/2025
Investment Cost		(606)				01/04/2025
Network Reliability Customer Type		554		Network Reliability Cust...		01/07/2025
Planned SAIDI and SAIFI						01/07/2025
Project Execution Risk		(121)				01/04/2025
Reputation Risk		239		Business Disruption - Ba...		01/04/2026
Unplanned SAIDI and SAIFI		22		Unplanned SAIDI and SA...		01/07/2025

Appendix

AER VOLL multipliers

4.1.1 VCR multiple

We proposed to apply a tiered multiple approach with different tiers for residential and business customers. While this approach would initially require the use of the 2023 VCR, we expected network businesses to use the updated 2024 VCR when they are published in December 2024.

For residential customers, the proposed tiers were:

[29] Energy Queensland, *Submission on VNR 2024 draft decision* [letter], August 2024, p. 2; Jemena, *Submission on VNR 2024 draft decision* [letter], August 2024, p. 1; Power and Water, *Submission on VNR 2024 draft decision* [letter], August 2024, p. 3; ENGIE, *Submission on VNR 2024 draft decision* [letter], August 2024, p. 1.

[30] Ibid.

[31] CPU, *Submission on the VNR 2024 draft decision* [letter], August 2024, p. 1-2; AusNet, *Submission on the VNR 2024 draft decision* [letter], August 2024, pp. 1-2.

[32] Erne Energy cited the work of Electricity North-West Limited in the UK, which demonstrated that Electricity North-West residential customers placed a lower value on electricity as outages became more prolonged.

[33] Erne Energy, *Submission on VNR 2024 draft decision* [letter], August 2024, p. 1.

[34] Ibid., pp. 5-6.

[35] JEC, *Submission on the VNR 2024 draft decision* [letter], August 2024, pp. 1-2.

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Value of Network Resilience 2024 Final Decision

- the standard VCR (as built up by the network business from the segmented residential VCR) for the first 12 hours of a prolonged outage
- a multiple of 2x the standard VCR (the VCR used for the first 12 hours) for the period of 12-24 hours
- a multiple of 1.5x the standard VCR (the VCR used for the first 12 hours) for the duration of the outage that extends beyond 24 hours, until the upper bound is reached.

For a residential customer, we noted this approach would result in the upper bound being reached in 7 days (based on average Victorian residential customer annual consumption and the Victorian residential VCR for outages up to 12 hours).

For business customers, the proposed tiers were:

- the standard VCR (as built up by the network business from the segmented business VCR) for the first 12 hours of a prolonged outage
- a multiple of 1.5x the standard VCR (the VCR used for the first 12 hours) for the period of 12-24 hours
- a multiple of 1.0x the standard VCR (the VCR used for the first 12 hours) for the period of 24-72 hours (1-3 days)
- a multiple of 0.5x the standard VCR (the VCR used for the first 12 hours) for the duration of the outage that extends beyond 72 hours (over 3 days).

Stakeholder views on the draft VCR multiple approach

Stakeholders expressed a range of views on the draft VCR multiples and tiers in their submissions on our draft decision, including:

- JEC did not support the VCR multiple as it considered it would result in the AER approving expenditure that would effectively set network reliability at a level higher than customers were willing to pay for. JEC also recommended using the standard VCR in tandem with the draft upper bound approach.[36]
- Energy Queensland supported the proposed VNR multiples and tier increments on the basis that the initial VNR were short-term values to be replaced with a well-considered, longer-term approach.[37]
- ENGIE supported our draft approach to adjust the rate of cost increases as the length of the outage extended but suggested it might be reasonable to extend the period that the highest multiple applied from 12-24 hours to 12-48 hours.[38]

[36] Ibid., p. 2.

[37] Energy Queensland, *Submission on VNR 2024 draft decision* [letter], August 2024, p. 3.

[38] ENGIE, *Submission on VNR 2024 draft decision* [letter], August 2024, p. 2.

- While AusNet acknowledged the use of a VCR multiple as acceptable given the time constraints for the review, it thought the draft VNR looked low relative to its own values and suggested the VCR multiple be adjusted to align with its adjusted direct cost data.[39]

Three stakeholders also commented specifically on the draft business customer VCR multiples and tiers:

- Energy Queensland supported the draft VNR multiples and tier increments for business customers.[40]
- Ausgrid was concerned about the 0.5x multiplier and asked the AER to either reconsider this approach or consider, more broadly, how the customer types were grouped when determining the final multipliers.[41]
- AusNet considered the draft decision to apply a 0.5 multiplier implied the value attached to prolonged outages was less than current business VCRs. It considered the multiplier should be set at minimum of 1, across all time periods.[42]

Case Study 8: Impact of Cyclone Gabrielle on various Networks

Case A: Northpower's Cyclone Gabrielle Experience

From the Northpower perspective weather events requiring Operations going into storm mode occur every 2-3 years and impact can vary depending on the strength and scale of the weather. Cyclone Gabrielle is our most recent major weather event and the worst since cyclone Bola in 1988, and the impact was similar so was the wind speed and duration. Communication technology has moved on. Internet and cell phones are how we communicate and receive information, and these are very dependent on electricity. Gabrielle for Northpower was mainly a high wind event, however we had a very wet summer leading up to Gabrielle.

Impact summary

- Fall zone trees were the main issue. These do a lot more damage to the OH network, than small size vegetation wind- blown debris and take a lot more resources to fix. Interestingly, this is also an issue for other emergency services such as fall zone trees also blocking road access.
- While landslips were not a major issue during this event, we did have a cascaded failure of more than 30 poles on a 33 kV line across flat terrain due to waterlogged soil.
- The storm was predicted, and it arrived as expected.

Learnings

- Manage fall zone trees not just vegetation covered by the tree regs. This was already known but the weak tree Regulations have not been helpful in managing this risk effectively.
- Consider cascaded pole failure in existing and new line designs particularly critical lines where there is only N security.
- Ground stability is an issue not just for landslips but also for waterlogged ground.
- Reconsider stock levels consumables and overhead line fittings and conductors that is no longer used e.g. copper conductor, particularly if you are some distance from your suppliers. During the response we were making daily trips to Auckland and as far away as Hamilton. This was made more difficult by the condition of the roads.
- Watch out for copper theft particularly if the line has been brought down.
- Assess early on if the restoration is going to take time and communicate this to customers, Lifelines and CDEM as well as looking at bringing in more resources. You need to pace yourself for weather events like Gabrielle.

- We brought in line crews from a Wellington depot and Operators from Orion. This was the first time using Operators from another EDB and it worked very well with the advantage of using the same ADMS and standard industry operating practices. However, we also need to consider common field worker competencies more generally across the work force.
- Staff welfare- look after your staff, they are the ones that will get you through this. Our HSQE team, with support from others, did exceptionally well in this area.
- Use of Internal staff not directly involved in the response in a support role, - this proved invaluable during Gabrielle.
- Close relationships with the other Lifelines and Regional & District CDEM group. In Northland we are fortunate to have these close relationships, also a secondment to CDEM proved very useful to both.
- Storms have their Health & Safety risks for staff and the public, without going into detail but ‘situation awareness’ is very important. We found in a few cases farmers are very practical people and like to help, like finding they have propped at pole up and in other cases neatly coiled up the conductor ready the fault staff other it was initially isolated before the fault staff was called away on a more urgent task.
- Have a strategy for storms. Northpower’s has been to identify the fault, isolate and make safe and restore supply to those not in the faulted area. In identifying the fault, you also get intel on the resources needed to fix the fault, so you send the right crew with the equipment and material needed.
- The employment of remotely controlled switches means you can restore sections of lines without deploying staff. This means you get more customers on and narrow down the area to find the fault.
- The productivity is greater working in the daylight hours but still need some staff available during the night to isolate for safety.
- Be aware of Lifeline / CDEM critical sites.
- Medically dependent customers are an issue for several reasons; information comes via the Retailer and is not always accurate and in most cases usually impossible (particularly for those in rural areas) to restore supply in the expected time frame given the storm can be still raging and the level of damage. There is also a degree of dependency on electricity depending on the medical condition and that is not documented and it too coarse to state ‘yes’ or ‘no’ for medical dependency.
- A good outage management system is important. Our old system we have had for many years got us by, but we have now introduced a new system, yet to be tested in a real storm event.

Weather Bombs

From experience these are a little different

- Less predictable and subject to warnings at short notice and with less accuracy.
- They usually affect a smaller area, but for the area affected, the damage is more intense and generally passes relatively quickly.
- Because the overall scale of the damage is less you generally have a focus and deploy your resources on the affected area

For lightning events you may need to consider the stock levels of pole mounted transformers. We have lost up to 30 transformers in one event and there is some evidence that the newer transformers are more prone to failure due to lightning.

Case B: Unison's Cyclone Gabrielle Experience

This information has been extracted from the Unison RESPONSE AGGREGATED DEBRIEF; REPORT Date: 25 October 2023

Note this is very detailed in terms of lessons learned and improvement recommendations

Background

Cyclone Gabrielle hit the Hawke's Bay region on the night of 13 February 2023, continuing through 14 February 2023.

Between 12 and 14 February, Cyclone Gabrielle resulted in parts of New Zealand incurring 300-400 mm of rainfall, wind gusts of 130-140km/h and waves as high as 11 metres along some of its coasts. Cyclone impacts were extreme and far reaching, the size and force of the cyclone presented Northland and Wellington with gale force winds simultaneously

Ten regional states of emergency were declared due to Cyclone Gabrielle: Northland, Auckland, Coromandel, Bay of Plenty, Gisborne, Opotiki, Waikato, Hauraki, Whakatane, and Hawke's Bay. Total costs resulting from the impacts of Cyclone Gabrielle were reported to be between $9 and $14.5 billion

The resulting impact of the storm saw extensive damage to the Hawke's Bay region with severe flooding to over 16% of Hastings District (including 1,600 homes), three of the four regional access routes (road) were blocked or damaged, eight of 10 key bridges damaged or destroyed and over five million cubic metres silt was left

Public displacement was significant seeing multiple emergency evacuation centres being established across the region with national support from New Zealand Defence Force "NZDF", National Emergency Management Agency "NEMA" and other agencies from the declaration of a national state of emergency on 14 February 2023.

Multiple lifeline utilities for the region were impacted including electricity distribution. The effect on Unison's Network saw approximately 500 poles damaged, three substations severely flooded and its two key fibre links between Napier and Hastings damaged due to bridge losses. With two of Transpower's substations flooded (Redclyffe and Whirinaki) and ten of their towers damaged, the culminative effect resulted in a peak of 75,000 Unison customers without power and 3,135 SAIDI minutes.

Unison has adopted the Coordinated Incident Management System ("CIMS") (national best practice for emergency management) as outlined in its Incident Management Response Plan - FC9007.

In accordance with the procedures in this plan, Unison continually monitors weather that has the potential to affect its network regions. With respect to Cyclone Gabrielle, Unison commenced with the initial procedural notification and assessment following weather and news reports on 8 February 2023, and by 10 February 2023 was on standby.

Unison stood up an initial Incident Management Team ("IMT") to discuss its potential response, preparedness messaging, and liaison with local Civil Defence Emergency Management Teams (in its regions).

The team met again on the 13th. February 2023 and moved to active response as the cyclone hit its regions, scaling up as the event progressed.

Unison moved into recovery phase on 24 April 2023

The cyclone caused disruption to Unison's fibre network in Hawke's Bay, and to its electricity network in Taupo, Rotorua and Hawke's Bay regions, as well as to Centralines' electricity network. The disruption in Hawke's Bay was widespread and resulted in peak disruption of 75,000 Unison ICPs (total connection base approximately 118,000).

Unison's IMT established three clear mission objectives throughout the response phase:

- Keep our people and communities safe,
- Maintain supply to critical infrastructure where possible, and
- Manage the impact for customers.

These mission objectives were applied to all decision making and actions undertaken during the four phases of Unisons response to Cyclone Gabrielle: Restoration of Hastings, Restoration of Napier, Rural Restoration, and the Transition to Recovery.

Many lessons were learnt, and a review of the Union emergency response operation has led to a wide range of improvement recommendations i.e.,

Key Findings

The key findings within this report have been summarised by the response function noted in Unison's controlled document FC9007 Incident Management Response Plan, that aligns to CIMS, national best practice for emergency response: i.e.,

- • Control (including specialist advice)
- • Safety (including People)
- • Intelligence (including Lifelines)
- • Operations (including Fibre)
- • IT (including Comms)
- • Logistics (including Finance)
- • Planning

- • Public Information Management (Including Stakeholder and Customer Engagement

Recommendations

Recommendation 1:

Organise training:

(a) CIMS training (for wide pool of staff for cover for long duration events).
(b) Training on internal procedures including IMRP & BCPs and all roles/functions that could be undertaken.
(c) Consider people who could conduct public interview/media during response and provide training.

Recommendation 2:

Review internal incident response documentation:

(a) Note response/BAU prioritisation for all staff.
(b) Document and process for transition to recovery (and alleviating pressure post response into BAU).
(c) Additional function specific guidance and templates (collation, analysis, and dissemination process).
(d) Ensure all incident contacts are recorded in BU BCPs and update regularly therein.
(e) Review SITREP template to cover more extensive requirements and other dissemination templates (e.g., INTREPs).
(f) Clarify chain of command for comms and info requests during incidents.
(g) Consider draft legal templates for emergencies that contain key protections.
(h) Consider process for recording and storing planning and operations docs during/for response.
(i) Consider and if required detail the value of face-to-face regular communication with key community groups (such as rural groups) and fronting community meetings in impacted areas in documentation.

Recommendation 3:

Consider IR functions:

(a) Consider separating Logistics Manager and Communication/IT functions within the formal structure.
(b) Review critical role contingencies for redundancy and note in BCPs (including for NOC)
(c) Review outputs of Stakeholder Liaison Role, including understanding systems required during response

Recommendation 4:

Review capture of contact and emergency contact details to ensure one source of truth. Review feasibility of integrating routine contact information validation updates through OneEnergy. Add note to individual business unit BCPs to explain that most up to date contact details for staff are in OneEnergy and to contact HR.

Recommendation 5

Elevate issue of movements during emergencies for essential workers to NEMA for a process to be established and circulated to all groups.

Recommendation 6

Consider accommodation arrangements for critical staff during events, including potential for onsite sleeping locations for personnel isolated or shift based

Recommendation 7

Review contractor induction processes considering incidents of scale to ensure they remain effective.

Recommendation 8

Review PPE spares to ensure operational effectiveness during events of various scale as appropriate.

Recommendation 9

Review the current fatigue management process to determine feasibility of integration for third parties

Recommendation 10

Review process for dealing with aggressive customers and training for all customer facing roles. Capture integration of third-party security staff (including approved providers) in process.

Recommendation 11

Review the need to hold water and food for response teams during an event.

Recommendation 12

Review Safety Alert information release procedures to ensure procedure for release is recorded, and various dissemination methods (for example: dissemination at in-person toolbox meetings) are used where usual communication methods are not available.

Recommendation 13

Consider use of information sharing platforms for use during events, to share with relevant agencies including HBCDEM, BOPCDEM, WAICDEM and other emergency services in Unison's operational areas.

Recommendation 14

Undertake analysis of Unison's geospatial asset management tool with a view to running appropriate solution for both BAU and event response. More specifically, review Unisons current GE Smallworld software version. Review current access and data state of regional CDEM units ArcGIS platforms. Consider licencing during BAU and incident response (should subscriptions be available to scale during response if required)

Recommendation 15

Review damage assessment process:

(a) Standardise asset damage information collection into routine works using the OneEnergy Field platform. Include appropriate training to end users including line managers, and those trained in IMT Intelligence and Operations roles. Where formalised asset management information collection is required during an event, the GIS function (unless directed otherwise by the Controller during an event) are to assume responsibility. Asset information collection is to be co-ordinated in accordance with an agreed intelligence collection plan and resourcing approved by the Controller. – IMG,

(b) Review aerial based damage assessment process to ensure consistency during emergency response. Unison to review feasibility of inspection training to a broader staff audience to support the capability demand during a significant event.

(c) c. Review damage assessment procedure to ensure it is capable of scaling appropriately. Damage assessment information for the purposes of collating through the appropriate systems is to be managed under standard business practises of the Asset Management Team

(d) . d. Review damage assessment process and prioritisation during incident response period to better enable planning requirements throughout the business

Recommendation 16

Review current reporting against geospatial mapping from the response period with a view to integrating reporting on its public website.

Recommendation 17

Investigate an alternative solution to MS Teams that can integrate with core systems: ADMS, OneEnergy and GIS

Recommendation 18

Determine responsibility for customer level livening.

(a) Consider formal position on Customer Level Livening for future events.

(b) Consider if same needs to be communicated, and to whom (CDEM / NEMA / Customers)

(c) Review requirement for data management process for customer disconnections, review current customer disconnection process to ensure fit for purpose and scalable to meet incidents of varied scale.

Recommendation 19

Review requirement for a formal procedure, including inspection maps, checklists, and documentation to ensure all assets have been inspected to the required standard before re-livening

Recommendation 20

Review which corporate system (ADMS or OE), if any, who should hold the customer connection status (service fuses etc). Unison does not have exclusive control of service fuses as electricians and OS1010 agents can operate these assets. Ownership of service fuses varies between installation configurations and should also be fully documented and clearly defined.

Recommendation 21

Review feasibility for UCSL to incorporate the creation of switching plans as part of BAU process (for simple outages) to build competency and capability, mitigating NOC constraints and enhancing workforce dynamics

Recommendation 22

Formalise procurement arrangements with Emergency Management for provision of generation (or other significant activities outside the scope of Lifeline responsibilities

Recommendation 23

Influence/lead regional lifelines planning to ensure greater understanding of critical sites, infrastructure interdependencies to support better prioritisation and coordination of response.

Recommendation 24

Review battery and generation at substation sites in relation to communication resilience.

Recommendation 25

(a) Handling of large quantities of remote events that cause system responsiveness issues [new version of ADMS may filter these events out and this functionality should be tested].

(b) Capability to provide granular records, including ETAs where required for individual customer reconnections [in scope for upgrade currently underway].

(c) Handles customer calls from Gentrack [in scope for upgrade] to ensure reporting is appropriately notified and responded.

Recommendation 26

Review OneEnergy Field application and use by field crews during BAU and incident response, with a view to introducing a OneEnergy training programme for crews

Recommendation 27

Consider OneEnergy Field in terms of damages assessment/defects:

(d) Determine standard damage assessment fields within OneEnergy to enable swift integration for information requirements during incidents.

(e) Define alternative Emergency response defect process for events where OneEnergy is not functional.

Recommendation 28

IMG to review functionality of alternative communication system to ensure functionality during periods of use

Recommendation 29

Review procedure for deployment of stock within region and determine if merit to stores at additional depot/s for redundancy.

Recommendation 30

Determine the use of Faraday in future, and ensure it has all elements it requires for intended use, and that documentation reflects any limitations.

Recommendation 31

Review SOH levels for common and critical stock, taking into account stock needs during recent events.

Recommendation 32

Review field crew fleet to ensure appropriate balance of capabilities are achieved.

Recommendation 33

Ensure an emergency response business process is established and formalised in regard to work orders.

Recommendation 34

Establish/maintain key relationships through key stakeholder management, including with regional PIM teams, and rural groups (e.g., Rural Advisory Group)

Recommendation 35

Determine business owners for customer data sets, data management responsibilities and how it is represented for future operational requirements.

Recommendation 36

Review the need to explain its emergency responsibilities to its customer base (once defined) as expectations towards customer support and activities during the cyclone response may differ to future operational scopes.

Case C: Powerco's Resilience Improvement plan

As a result of the impact of Cyclone Gabrielle on Powerco's extensive network, a comprehensive resilience improvement plan has been published in the 2024 AMP.

This plan is reproduced here as an example of good industry practice.

Resilience – Case for change

Climate change is increasingly impacting our ability to reliably supply our customers

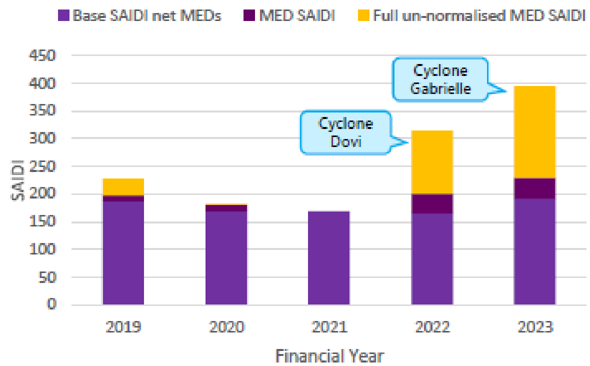
Major event days (MEDs) – primarily by storms – are currently normalised out of our network managed SAIDI/SAIFI targets, but we are observing an upward trend in storm severity and impacts on the network. Cyclone Gabrielle in Feb 2023 had significant impacts on our communities in the Coromandel and Tararua networks, in particular, approaching a year's worth of outage time across just a few days.

Weather events of 2022 and 2023 have resulted in increased government focus on the need for critical infrastructure resilience. With decarbonisation making more of the NZ economy reliant on electricity, our ability to recover from shock events will have even more importance.

Long-term trends of the projected climate scenarios (IPCC/NIWA) to the end of the century show worsening climate conditions that will place additional pressure on the network to perform:

Extreme precipitation
- +**5-15%** across our footprint
- +**20-25%** in some of our coastal networks and Coromandel

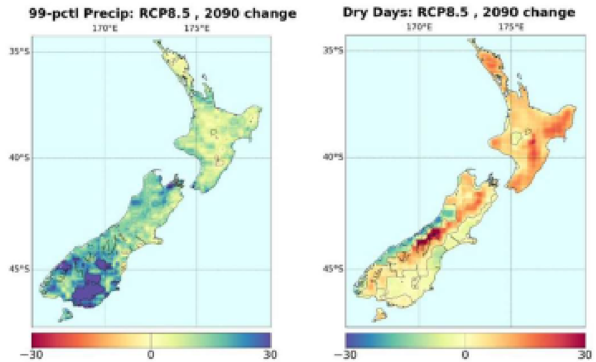
Dry days
- +**5% - 20%** across our footprint
- +**25%** in our Wairarapa networks



SAIDI FY19 – FY23, is showing an increase in storm activity and impact on the network

Inundation and ground movement associated with heavy rainfall severely impacted our supply, and ability to access network, during heavy rainfall events

Bushfires are already a risk to people and property, particularly in dryer areas like the Wairarapa and central plateau



Projected % change in heavy precipitation (cause of slips and flooding) and dry days

POWERCO

Given the long install life of most network assets, the majority of assets installed now will need to be sufficient for the conditions in 2050 (27 years from now), or longer life assets to 2090 (67 years - substation buildings, concrete poles)

Resilience – Climate Scenarios

All future scenarios show an increase in severe weather events, though the amount varies

Powerco has undertaken a climate scenarios exercise in 2023, aligned to TCFD requirements, to guide our resilience approach

Scenario	Policy ambition	RCP	Severe weather	Policy change
Scenario 1: Global Alignment The globe and New Zealand pursue aggressive emissions reductions, and this succeeds in limiting global temperature increases to 1.5°C (above pre-industrial temperatures), with global net zero emissions being achieved by 2050. The transition occurs in a coordinated manner across government and the energy sector, with clearly signalled policy changes.	1.5˚C policy ambition	RCP 2.6 (0.9-2.3˚C by end of century)	Lower increase in severe weather events	Policy change is clearly signalled and smooth
Scenario 2: Global Delay The globe and New Zealand are delayed in their transition, resulting in a steady increase in temperature between 2020-2030. The New Zealand energy sector direction is unclear, and decisions are protracted. Realisation occurs in 2030 that action is urgently needed, however this results in abrupt and poorly coordinated policy and market changes.	2˚C policy ambition	RCP 4.5 (1.7-3.2˚C by end of century)	Moderate increase in severe weather events	Policy change is delayed and chaotic
Scenario 3: Hothouse Global emissions continue to grow unabated largely due to a failure (reversal) of key emissions reduction policies both in New Zealand and in key developed, high-emitting countries. This leads to warming levels that reach 2°C by 2050, and continue to increase steeply thereafter, reaching 4°C by the end of the century. Climate 'chaos' enters mainstream discourse, across all sectors and communities.	No ambition	RCP 8.5 (3.2-5.4˚C by end of century)	Extreme increase in severe weather events	No new policies, possible reversal
Scenario 4: New Zealand Greenhaven New Zealand and most of the developed world continue to pursue net zero targets by 2050. However, the rest of the developing world does not follow suit, leading to a rise in global temperatures between 2-3˚C by the end of the century. New Zealand is viewed as a 'Greenhaven' by many in the world and attracts investment and immigration as a result.	1.5˚C policy ambition	RCP 4.5 (1.7-3.2˚C by end of century)	Moderate increase in severe weather events	Policy change is indicated and smooth for New Zealand

8

Resilience - Approach

We have taken a data-driven approach to understanding climate change vulnerability, and prudent investment

Understanding vulnerability

We have been working with updated natural hazard geospatial data to better model current and future worsening climate hazards (linked to Powerco scenarios), at a more detailed level than previously. This has included datasets for:

- Coastal inundation from sea level rise, storm surge
- Inland inundation such as flood risk near rivers
- Land subsidence / slips
- Overhead line design strength related to wind speed

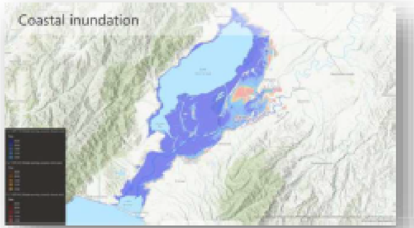
A vulnerability assessment was carried out (expected damage of different asset fleets to different hazards) to identify potentially affected assets. Two main approaches were used:

- Site-by-site desktop assessment for higher criticality assets (e.g., subtransmission river crossings, zone substation flood risk) using drawings, aerial photography & LiDAR
- Sampling for higher volume assets – such as distribution transformers affected by flooding or lines affected by slips – to account for uncertainties in the data analysis and expected criticality prioritisation

The phasing of forecast work has then been spread out over 10 – 20 years depending on the high-level assessment of expected event return periods. The data available continues to evolve, such as central government sponsored data capture for slips from GNS and volcanic hazards. As information becomes available, we plan to keep our vulnerability maps up to date with current modelling.

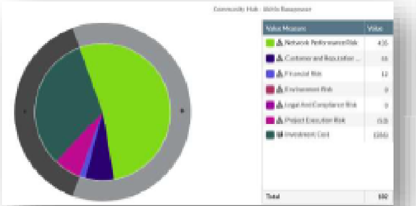
Valuing resilience

We have started investigations into how we can augment our current CNAIM based asset risk models to quantify long-term resilience risks. We have started with critical network, civil defence and lifelines priorities. Continuing our customer consultation to better understand preferences for resilience investment will be a key aspect in the ongoing development of our resilience strategy.



Hazard
(e.g., Coastal Inundation, Inland Inundation)

Vulnerability
Assets expected to be damaged by impact by hazard



Risk prioritised Investment
Vulnerable assets are tested for whether proactive investment passes the cost/benefit test (work underway – initial forecasts developed)

Case D: Transpower's Proactive Resilience Programme for 2025-2030

TRANSPOWER

For vulnerable sites or lines that are decades away from upgrades or replacements, proactive investment can be considered. We developed a proactive resilience programme as part of our funding proposal for 2025-2030.

Broad areas of proactive funding include:

- increasing portable and mobile solutions for substation assets, together with deployment exercises to reduce emergency response times (readiness)
- addressing flood risks at substations (reduction)
- addressing flood risks for HVAC and HVDC transmission lines that cross braided rivers (reduction)
- strengthening HVDC towers against wind (reduction)
- mitigating land stability risks for towers and poles (reduction)
- running emergency exercises for tower restoration (readiness)
- investing in anti-pollution insulators on towers that are vulnerable to volcanic ash (reduction)
- seismic strengthening of buildings

Readiness planning - Edgecumbe

A post event review of Cyclone Gabrielle found that Transpower was well prepared and that a pre-defined contingency plan was deployed effectively despite challenges with operational communication.

Both the Grid Resilience Strategy and the post event review identified the need to strengthen readiness planning. We recognise undertaking collaborative readiness planning allows for a holistic view of both the impacts for major hazard events and the potential options.

After sharing risk information about the Edgecumbe substation with Local Government and with the local electricity distribution business, Horizon Networks, it was agreed to collaborate through a readiness planning workshop.

During the workshop Bay of Plenty regional council took us through the $50 million of floodway improvements that were prompted by the floods in 2004 and 2017. They provided an overview of the geomorphology of the region, making future stop bank failures credible due to the permeable volcanic ash layers and that stop banks were originally constructed using silt. We discussed how climate change will increase the frequency and severity of flooding, even with upstream buffering in dams.

Being prepared is key.

Whakatāne District Council had strong information on where they would prioritise electricity Supply restoration in such an event, what emergency generation they would use and how they would communicate and co-ordinate a response.

As the local electricity distribution business, Horizon Networks had key information on the future of generation and demand for the region, and potential options to back feed within their network. Further work will be done with Horizon on what options could be employed within their network and from the transmission grid perspective, and this will inform a high-level site readiness plan.

Further work is progressing to understanding back feed capability and to develop a readiness plan to reduce the time to recover in a future flood event.

Risk reduction investment – Wairau Road

Our Grid Resilience Strategy outlines how we identify, prioritise, and manage physical risks from major hazards. Since 2018, we have been working to develop a national picture of the exposure, vulnerability, and criticality of our grid assets to a wide range of resilience threats (including climate-related hazards). We deliver more resilient infrastructure when we build new assets and replace old assets using up-to-date information and modern design standards.

Wairau Road substation, Auckland

To ensure the security of electricity on Auckland's North Shore, we built a new substation at Wairau Road in 2012 with local lines company Vector. We knew there was potential for flooding at the site, which informed our design.

Accounting for water levels expected in a 1 in 450-year storm, all equipment was designed to prevent water ingress and was elevated above the design flood level.

During Auckland's flooding events in February 2023, Wairau Road operated exactly as planned. While water entered the substation (flotsam marked the levels at 1.7 m), key equipment remained dry, and the lights remained on for the approximately 41,000 households and businesses the substation serves.

Risk reduction investment – Wairau Road

Our Grid Resilience Strategy outlines how we identify, prioritise, and manage physical risks from major hazards. Since 2018, we have been working to develop a national picture of the exposure, vulnerability, and criticality of our grid assets to a wide range of resilience threats (including climate-related hazards). We deliver more resilient infrastructure when we build new assets and replace old assets using up-to-date information and modern design standards.

Case E: Vector's Resilience Planning Approach

Example of Good Industry Practice – Vector 2024 AMP

The following initiatives are extracted from Vector's 2024 Asset Management Plan and provide an example of current good industry practice in developing a resilience improvement roadmap.

Robustness (Reduction)

- Risk-based vegetation management, supported by LiDAR inspections and collaboration with local councils.
- Network hardening by upgrading to aerial bundled conductors (ABC) or covered conductors, using composite crossarms, and meshing networks where appropriate.
- Fire risk mitigation through real-time monitoring, disabling automatic reclosing devices in high-risk conditions, and deploying sparkless fuse technologies.
- Dynamic asset rating adjustments based on NIWA soil moisture monitoring.
- Relocation or strengthening of assets vulnerable to sea level rise, flooding, or storm surge.
- Deployment of microgrids to enhance community-level supply resilience.
- Advanced weather and outage modelling, developed through international partnerships.
- Investment in Distributed Energy Resource Management Systems (DERMS) to improve network flexibility and resilience under stress conditions.

Resourcefulness (Readiness)

- Comprehensive business continuity planning and testing, including pandemic resilience measures.
- Isolated control centre facilities to ensure continuity of operations under pandemic or major disruption scenarios.
- Incorporation of international lessons from major resilience events.
- Maintenance of emergency response plans and field force readiness.
- Investment in customer communications, including digital platforms and advanced outage management systems.
- Collaboration with Civil Defence and other emergency management agencies to align readiness and response planning.

Recovery (and Response)

(Note: several of these activities also support immediate response)

- Effective management of fulltime and contingent workforce resources during extended recovery periods.
- Stock and spares management to ensure availability of critical equipment.
- Deployment of temporary generation to restore supply while permanent repairs are underway.
- Trialling of vehicle-to-home (V2H) technology to provide household-level resilience.
- Use of robust tracking and reporting systems to monitor restoration progress.
- Sustained customer communications during and after events.
- Conducting post-event reviews and embedding lessons learned into future plans.

Key Insight

Building resilience requires a comprehensive, systems-based approach that strengthens:

- physical infrastructure,
- organisational capability,
- operational readiness, and
- community collaboration.

This example illustrates how a structured roadmap can help EDBs tailor their resilience strategies to evolving risk profiles and strategic objectives.

Appendix G Additional Information

TITLE	YEAR	AUTHOR	LINK
AELP- 2 Section2: Auckland Lifelines	Dec 2017	Auckland Lifelines group	http://www.alg.org.nz/document-library/critical-infrastructure-reports/
Advice for Power Transmission and Distribution System Operators	May 2013	GNS	https://www.gns.cri.nz/Home/Learning/Science-Topics/Volcanoes/Eruption-What-to-do/Ash-Impact-Posters/Advice-for-power-transmission-and-distribution-system-operators
Asset Management Plan, (Section 3, Managing Risks)	2019	Orion NZ Limited	https://www.oriongroup.co.nz/assets/Company/Corporate-publications/Orion-AMP-FINAL-2019.pdf
AS/NZS 5050:2010 Business Continuity Managing Disruption-Related Risk	2010	Australian/ New Zealand Standards Joint Technical Committee OB-007	https://Shop.standards.govt.nz
CDEM Capability Assessment Tool	Aug 2014	National Emergency Management Agency	https://www.civildefence.govt.nz/cdem-sector/monitoring-and-evaluation/cdem-capability-assessment-tool-
Civil Defence	2020	National Emergency Management Agency	https://www.civildefence.govt.nz/
Coordinated Incident Management System (CIMS). 3rd Ed (ISBN 978-0-478-43525-2)	Aug 2019	New Zealand Government	https://www.civildefence.govt.nz/assets/Uploads/CIMS-3rd-edition-FINAL-Aug-2019.pdf

TITLE	YEAR	AUTHOR	LINK
Critical Infrastructure Reports	1999-2018	Auckland Lifelines Group	*http://www.alg.org.nz/document-library/critical-infrastructure-reports/*
Framework to Implement Lifelines Projects	June 2018	Auckland Lifelines Group	*http://www.alg.org.nz/document-library/other-documents/?key=2018*
Guideline for Emergency Preparedness	May 2019	Stay Live; Electrical Industry Health & Safety Group	*https://www.staylive.nz/Site/staylive/Working-Groups/current-working-groups/emergency-response.aspx*
Leadership training. Response and recovery leadership capability development	2020	Matatū Mataora Aotearoa - Response & Recovery Aotearoa New Zealand	*https://rranz.org.nz*
Lifeline Groups	Mar 2020	National Emergency Management Agency	*https://www.civildefence.govt.nz/cdem-sector/lifeline-utilities/lifelines-groups/*
Multiple infrastructure failures and restoration estimates from an Alpine Fault Earthquake: capturing modelling information for MERIT	2015/04	Robinson, T.R.; Buxton, R.; Wilson, T.M.; Cousins, W.J.; Christophersen,	*https://www.naturalhazards.org.nz/NHRP/Hazard-themes/Societal-Resilience/EoRI/EoRI-Outputs-Publications/EoRI-Research-Reports*
Northland Civil Defence Emergency Management Plan	2016	Northland Civil Defence Emergency Management Group	*https://www.nrc.govt.nz/media/10685/northlandcivildefenceemergencymanagementplan20162021.pdf*
National Civil Defence Emergency Management Plan Order 2015		New Zealand Government	*http://www.legislation.govt.nz/regulation/public/2015/0140/latest/DLM6485804.html*
National Lifelines Council Website	2015	New Zealand Government	*https://www.nzlifelines.org.nz*

TITLE	YEAR	AUTHOR	LINK
New Zealand Lifelines Infrastructure Vulnerability Assessment: Stage 1	Sep 2017	New Zealand Lifelines Council	*https://www.civildefence.govt.nz/assets/Uploads/lifelines/National-Vulnerability-Assessment-Stage-1-September-2017.pdf*
Pandemic Business Continuity Checklist: Tools for board, CEOs & Executives of NDIS Services:	April 2020	DSC (Disability services consulting)	*https://teamdsc.com.au/resources/pandemic-business-continuity-checklist*
Pandemic Planning Guide:	March 2006	Local Authority Pandemic planning working party; ISBN 0-478-25469-5	*https://www.civildefence.govt.nz/cdem-sector/the-4rs/readiness-and-response/nz-influenza-pandemic-action-plan-information-for-cdem-groups/*
Recovery Plan for Electric Distribution Networks Under Major Impact	Nov 2018	Nirmal-Kumar C. Nair	*https://www.researchgate.net/publication/334428327_Recovery_Plan_for_Electric_Distribution_Networks_under_Major_Impacts*
RMA, Emergency Management & Infrastructure Resilience	Oct 2014	The Treasury	*https://www.rmla.org.nz/wp-content/uploads/2016/09/rmla_141009_wgtn.pdf*
Research & Publications	Multiple	Natural Hazards Research Platform	*https://www.naturalhazards.org.nz/NHRP/Publications/Research-Publications*
Transmission planning and unexpected events: An economic framework	July 2014	Dr Simon Todd, Dr Graeme Ancell, Transpower New Zealand Ltd	*https://ieeexplore.ieee.org/document/6960578*
ISO22301:2019 **Security and resilience -Business Continuity Management Systems-Requirements**	2019	International Organization for Standardization	*https:// www.iso.org*

TITLE	YEAR	AUTHOR	LINK
Wellington Lifelines Project **Protecting Wellington's Economy through accelerated infrastructure Investment Programme Business case**	Oct 2019	Wellington Lifelines	*https://wremo.nz/assets/Uploads/191111-Wellington-Lifelines-PBC-MAIN-20191009.pdf*

Table 22: Additional Information