Improving Resilience to Natural Disasters

West Coast Lifelines Vulnerability and Interdependency Assessment: Main Report
IMPORTANT NOTES

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Hazard Maps

The hazard maps contained in this report are regional in scope and detail, and should not be considered as a substitute for site-specific investigations and/or geotechnical engineering assessments for any project. Qualified and experienced practitioners should assess the site-specific hazard potential, including the potential for damage, at a more detailed scale.

Cover Photo: South Westland, New Zealand (Photo by David Elms)
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1 INTRODUCTION

This report reviews the vulnerabilities of West Coast infrastructure lifelines to natural disasters and prioritises them as to their importance so that asset managers and communities can work towards improving their resilience.

Some years ago the authors wrote a series of reports for the four West Coast territorial authorities focusing on lifeline performance in an Alpine Fault earthquake and in the immediate response period following it (McCaon et al 2006A, B, C, McCahon et al 2007A, B). The emphasis in that work was on technical capability and its recommendations were mainly technical – install automatic shutoff valves in reservoir pipelines and so forth – though priorities flowed from immediate community needs. Later came a report to Grey District on lessons arising from the Christchurch earthquakes (McCaon et al 2012), which emphasised the dominant importance in the recovery period of non-technical issues such as insurance, money flow, governance, inappropriate and conflicting regulations and other such softer matters. The present report builds on the earlier work, but with some essential differences. First, while the initial reports dealt only with the effects of an Alpine Fault earthquake, the present work takes a broader view and includes the effects of storms and tsunamis as well as other earthquake possibilities. Secondly, the earlier analysis took a risk-based approach, as opposed to a focus on resilience. Risk and resilience are substantially different, particularly in that while risk deals with the likelihood of a specific outcome, resilience assumes that whatever might actually happen is unknown and unpredictable. A third difference is that the emphasis here is on long-term recovery rather than on the immediate response to a disaster.

The West Coast of New Zealand is particularly vulnerable to natural disasters. Not only do its geology and topology mean there is a high risk of earthquake and storm events, but also its communities are held together physically by a far-flung network of fragile connections.

The risk – and it is a high risk – of a major earthquake resulting from rupture of the Alpine Fault is well understood. But there could be other major earthquakes such as the historic earthquakes at Murchison, Inangahua and Arthur’s Pass. It is impossible to predict the extent, locality and nature of an earthquake – even an Alpine Fault event. All that can be said is that a major event will happen, and that because its nature and location are unknown beforehand, it is necessary to expect the unexpected. This is also true of storms. Major storm events are expected because of the interaction between the predominantly westerly winds and the high Southern Alps. But some storms are particularly severe either because of their immediate intensity or because they cover an unusually wide area. Again, what exactly would happen cannot be predicted. A third type of natural event – a tsunami – is rare but could be devastating to coastal areas.
Thus West Coast communities and their related economies will have to deal with severe naturally-occurring disasters whose unpredictability requires a need for resilience. Community resilience depends on a robust and resilient infrastructure. Accordingly, the prime focus in this report is on achieving it.

**Box 1.1**

A word here on resilience – a concept central to this report but not always well understood.

Resilience is the ability of something to recover from an impact – to bounce back. The impact of an earthquake on a bridge might impair its ability to carry traffic. The degree of resilience of the bridge would be a combination of (a) its ability to withstand and minimise damage, and (b) the length of time needed to return the bridge to full capacity. Thus there are two basic strategies for improving resilience: reducing the likely damage and speeding the recovery. The first requires design for robustness, and the second might be helped by reparability and the availability of equipment to speed recovery. A third important strategy is to provide buffering – to buy time, for instance, by having spares and fuel available. Individuals are advised to have emergency supplies of food and water on hand: this is an example of buffering.

Resilience can apply to physical assets, organisations, communities and individuals.

Resilience requires a specific attitude: an awareness that what will happen will be unexpected no matter how prepared one is, and a fleetness of foot, an agility, to change quickly both personally and organisationally to meet a novel and unexpected situation. Flexibility and creativity are central.

One further point: most assets and organisations that are resilient nevertheless have a limit – a tipping point – beyond which recovery will no longer be possible. It is important to ensure the tipping point is not reached if at all possible. Buffering can help here by buying time.

Infrastructure performance is vitally important in a natural disaster emergency. New Zealand’s national emergency management framework divides emergency-related actions into four categories or phases: reduction, readiness, response and recovery, known as the four R’s. The first two, reduction and readiness, take place before an emergency event. Reduction includes actions to eliminate risks or reduce their impact. Readiness activities develop capabilities for dealing with the consequences of an event before it happens. The response phase relates to actions during or immediately after an event such as search and rescue, aiming to save life and property and stabilise the situation. Recovery deals with the regeneration of communities and their
infrastructure and with returning them to a normal and stable functionality. In terms of post-event activities, most thinking has been directed at the response phase because of the immediate urgency of saving lives and also because this is the time when emergency services are most involved. However, a major lesson from the Christchurch earthquakes is the critical importance of dealing well with the recovery phase. Somewhat arbitrarily recovery can be taken to begin a week after the disaster event, though in practice there will be no clear break between response and recovery. The present report focusses primarily on recovery, and for this reason less emphasis is given here to problems that can be dealt with in the first week or so following an event. However, focus on recovery necessarily involves involvement in the other three R’s. Forward planning for recovery needs to be done before the event and thus must take place in the context of reduction and readiness, and there will be actions to be taken in the response phase immediately following the event aimed at facilitating the recovery that will take place at a later stage.

Once infrastructure weaknesses have been identified they need to be addressed. Vulnerable elements must be repaired or made more robust. However, limitations of time, money and resources mean the weaknesses cannot all be dealt with immediately. They need to be prioritised; and so this report not only seeks out vulnerabilities and also prioritises them according to their importance (the word “vulnerability” is used in this report to mean the converse of resilience). Two bridges, for instance, might be equally vulnerable to earthquake damage, but if one leads to a single farm while damage to the other would cut off half the region, clearly the second bridge is more important. The twin ideas of vulnerability and importance underlie most of the report.

Vulnerabilities are determined by considering the West Coast and its infrastructure as a complex system, or even system of systems, and then “probing” it to see what happens. Figure 1.1 shows how this is approached. A system is a number of interacting elements acting together as a whole, and which is defined for some purpose. In this case the purpose is to identify infrastructure vulnerabilities, and so the relevant system represents all the lifelines – road, rail, ports, telecommunications, power so on. The system is then probed by subjecting it, theoretically of course, to three major natural disaster events: an earthquake, a tsunami and a storm. Some elements prove to be too weak – their vulnerability becomes apparent. The importance of each element in the sense of the effect of its failure on the West Coast community is then assessed, and vulnerability/importance pairs are then tabulated and discussed. The resulting tables together with recommendations at different levels of detail become the output of this study.
Importance – that is, the importance of the failure of a piece of infrastructure – will be seen differently by different individuals. Closure of the road over the Karamea Bluff would be seen as vitally important to a Karamea householder, but perhaps less so to someone living in Hokitika. The approach used here is to consider importance in terms of the effect on the West Coast economy as a whole, with the addition of the effect on individual communities. A further simplification is to limit consideration of the economic effects of infrastructure failure to the three most important economic sectors on the Coast: mining, dairying and tourism.

The results of the probing are that most of the system elements show vulnerabilities. A major storm event, for example, might cause serious damage in Franz Josef, so identifying its vulnerability (the converse of its resilience). The importance of the element’s damage is the effect of this on the West Coast as a whole – problems at Franz Josef, for instance, would have a serious impact on tourism. The report breaks the region into 29 elements (discussed in detail in Section 6), each of which is assessed for vulnerability and importance for each of the three probing natural event scenarios.

Note that the probing scenarios are not intended to be predictions of what would actually happen in a disaster. They are simply a theoretical means of testing the resilience of the system and its elements; that is, of the whole system or large parts of it such as the roading network and its overall functionality on the one hand, and of smaller and definable sections on the other, such as, say, Franz Josef township.

**Figure 1.1: Vulnerability and Importance of West Coast Infrastructure System Elements**
The earthquake scenario is based on the AF8 prediction of an event caused by rupture of the Alpine Fault, with the necessary second scenario of the 1968 Inangahua earthquake to enable vulnerability assessments in areas not greatly affected by an AF event.

Insofar as the general level of design required for the seismic design of structures in New Zealand is for a 500-year earthquake, the probing scenarios for storms and tsunamis assume 500-year events. A 500-year storm would involve high winds and heavy rainfall, with both impacting on infrastructure in different ways, not only through primary damage and also by preventing access for restoration and repair.

Tsunamis are fortunately rare but are still a real risk. They are damaging not only because of flooding and direct flow of water but also because of debris impact. A 500-year event would cause serious damage in coastal areas as well as in Westport, Greymouth and Hokitika.

Some vulnerabilities affecting the West Coast are actually outside the administrative boundary of the West Coast Region – for example, the vulnerability of State Highway 73 to slips at the Waimakariri Bluffs – so for this reason discussion of some lifelines has extended beyond the administrative boundaries of the region.

The present report next discusses and elaborates the major elements referred to above, namely:

- Infrastructure and lifelines.
- Community, economy and flow, with the introduction of the idea of a “pipeline”.
- The natural hazard scenario probes: earthquake, storm and tsunami.
- The impact of the scenario probes on West Coast infrastructure.
- Vulnerability and importance pairings.

These sections are followed by recommendations and finally an outline of 12 independent supplements to this report. The supplements contain more detailed discussions of some topics and are published as separate documents in the expectation that because of their specialised focus most readers will not want to read them all.
2 THE WEST COAST AS A SYSTEM: INFRASTRUCTURE AND LIFELINES

One Merriam-Webster dictionary definition of a lifeline is “something regarded as indispensable for the maintaining or protection of life.” In the context of this report, lifelines are the assets and systems that provide foundational services enabling commercial and household functioning. They are owned and operated by lifeline utilities such as the regional and district councils, telecommunications and power companies, the New Zealand Transport Authority (NZTA) and so on. They may be grouped as:

- Transport – roading, rail, ports, airports.
- Telecommunications and broadcasting.
- Energy – electric power and fuel.
- Protection – river and coastal protection works.
- Water and wastewater.

The report focusses on all five and their vulnerabilities, though with less emphasis on the last of the five because this has been covered in earlier work and also because, though important, water and wastewater are local rather than broader network lifelines. The first three groups are complex networks connecting the Coast to the rest of the country.

Also essential for community functioning though not directly addressed in this report are supply chains and services maintaining food supplies, medical services and supplies, building supplies, financial services, insurance, governance, emergency services and education among others. Following a disaster event, the initial priorities will include search and rescue and trying to bring lifelines to at least a temporary functionality to allow communities to survive. Permanent repairs will stretch well into the recovery period starting, as noted above, a week or so after the event. However, there must be a prioritisation. Some lifelines will be needed with more immediate urgency than others as the effectiveness of future activities will depend on them. For instance, greatest urgency will have to be given to roading (for access), to telecommunications (for management, coordination and future planning) and to safety assets such as stopbanks. For instance, although earthquake damage to a dairy farm might take months to repair (recovery phase activities), the farmer would want to know the situation as soon as possible after the event so that he could plan ahead and decide whether or not he would have to dry off his herd. The four phases (reduction, readiness, response and recovery) are not independent, with recovery, the focus of this report, depending on what is done in the other three phases.
Lifelines are not independent of each other, and neither can they be seen as independent of other aspects of a functioning community and economy. Two useful concepts are hotspots and pinchpoints. The New Zealand Lifelines Council defines them thus:

- **Hotspots**: where a number of critical infrastructure assets from different sectors converge in a single area.
- **Pinchpoints**: significant single points of failure for a network or organisation.

Examples of hotspots are the Cobden Bridge at Greymouth which carries a major road but also carries a communication link, sewerage and water supply, and the power poles between the Mikonui River and Bold Head which carry both 11kV power and a fibre optic cable. A pinchpoint example would be the Arahura Bridge, whose failure – there is no alternative route – would cut off the whole of South Westland from the north. A pinchpoint need not be a single point – at the time of writing, road traffic from Blenheim and Nelson to the rest of the South Island must all follow SH 6 between Murchison and Kawatiri. There is no other route possible, so closure anywhere within this link would be serious.

A hotspot could also be a town. For instance major damage in Franz Josef could cut not only the road south but also the fibre optic and power links to Fox Glacier, and a major loss of the town’s accommodation from building damage or failure of the water supply or wastewater systems would destroy a critical link for tourism.

The principal engineering lifelines within the West Coast region are described briefly below. More detailed descriptions are found in Supplements 6 to 12 to this report:

*Supplement 6: Transportation*
*Supplement 7: Telecommunications*
*Supplement 8: Energy – Electricity and Fuel*
*Supplement 9: Regional Flood Infrastructure*
*Supplement 10: Buller District Council*
*Supplement 11: Grey District Council*
*Supplement 12: Westland District Council*

### 2.1 Transport

The primary transportation system on the West Coast is the road network, which extends the length of the region and provides four links to the rest of the South Island. The railway has a line internal to the region between Hokitika and north of Westport, as well as the Midland Line link across the Alps to Canterbury. There are seven airfields, two river-mouth ports and the wharf at Jackson Bay.

#### 2.1.1 Roads

The main road network of 870km is managed by New Zealand Transport Agency (NZTA). It consists of SH 6 which enters the region west of Murchison from Nelson and Marlborough, follows the Buller River to Westport and then the coastline through Greymouth and Hokitika to Haast before crossing the Haast Pass to Wanaka and Otago. Two other routes link to Canterbury: SH 7 over the Lewis Pass to Reefton and then Greymouth, and
SH 73 over Arthur’s Pass to Kumara. Two other state highways link SH 6 and SH 7 in the Buller District and SH 67 links Westport with Mokihinui to the north.

The three district councils maintain a total of 1,890km of local roads. The bulk of these are effectively no-exit access roads off the state highway network, but the Stillwater to Jacksons road provides an alternative route to part of SH 73 and the road on the west bank of the Grey River is an alternative to part of SH 7. Other important district roads include the Karamea Highway, providing the only access to that area, and the Haast–Jackson Bay Road at the south end of the region.

The road system is characterised by its length, low traffic volumes, frequently mountainous or hilly terrain with high rainfall and the many rivers and streams that cross the main routes. The central part of the region has some redundancy within the system and some of the roads also traverse less hazardous terrain, but south of Hokitika and north of Westport, the system has both no redundancy and generally higher hazard exposure.

Roads are a, if not the, key lifeline for the West Coast Region. The whole economy is dependent on them, and they provide the necessary access to other utilities.

### 2.1.2 Rail

The railways on the West Coast are owned and operated by KiwiRail. There are two ways of viewing the railway network in the region. Historically, the system developed from local lines linking coal mines to the ports at Greymouth and Westport, and this first perspective is of one internal line from Ngakawau (north of Westport) to Hokitika, with an external link through Otira to Canterbury. However, in recent years, the railway has lost its local use and is now almost solely used for export from the region. The second perspective is by predominant traffic, which is coal transportation from Ngakawau, through Stillwater and Otira to Canterbury and the Port of Lyttleton, with a secondary line from Stillwater to Hokitika mainly serving the dairy factory. The only passenger service on the railway is the TranzAlpine, which is essentially a daily tourist operation from Christchurch to Greymouth and return.

Like the roads, much of the railway follows river valleys within a mountainous terrain and has many bridges and tunnels. It is therefore very much exposed to natural hazards. Damage and outage of the railway has a direct impact on coal mining and to a significant degree the dairy factory, and it thus has an indirect impact on the economy and community; but otherwise it is not a critical infrastructure for recovery of the region.

### 2.1.3 Airports

There are seven airfields listed with the Civil Aviation Authority (Karamea, Westport, Greymouth, Hokitika, Franz Josef, Fox Glacier, and Haast) as well as about 20 other private grassed airstrips. Regular passenger services are from Westport to Wellington and Hokitika to Christchurch. The other airfields are used for private operators, charter flights and local tourist operations. Most of the airports are expected to be made operable within a relatively short time following a major disaster, at least to light planes, and are expected to be a
valuable asset after a major disaster in assisting recovery when some of the road links might be blocked for extended lengths of time.

2.1.4 Ports

Historically the river-mouth ports of Greymouth and Westport were key parts of the region’s transport system, but now the only regular use is by fishing boats. Some wharf capacity is maintained at both harbours but the infrastructure is aging. Neither facility is likely to be able to be used reliably to any great extent after a major disaster. A third port structure is the wharf at Jackson Bay. It is an 80 year old timber structure of limited use, but may be of great value after a disaster if the roads into the Haast area are blocked for an extended time.

2.2 Energy

2.2.1 Electricity

The electrical power system network in the West Coast consists of:

- Supply into the region from the national grid operated by Transpower, with the main transmission line coming from the north through Murchison to Westport (2 lines) and Dobson (near Greymouth, 2 lines) with a secondary connection over Arthur’s Pass to Hokitika and Greymouth.
- The Westpower distribution network, covering most of the region between Inangahua and Paringa.
- The Buller Electricity Ltd (BEL) distribution network serving the coastal area of Buller District from Fox River to Karamea.
- Network Tasman which supplies Springs Junction and the Maruia Valley from Murchison.
- Eleven hydro-electric power stations with capacities of between 0.5 and 7.4MW for a total of 32MW.
- A privately owned and operated hydro-electric power station at Okuru supplying the small Haast–Jackson Bay distribution line, which is isolated from the rest of the network.

Transpower has commitments toward a reliable supply of power, as do the local distribution companies. The local generation also provides additional resilience to the network. Some outage must be expected in a major disaster, but in general, electricity should be able to be restored relatively quickly, depending on the scale and location of the worst damage.

2.2.2 Fuel

Fuel is an essential energy source for transportation and industry, as well as for generators during the periods when electrical supply is lost. There is no bulk fuel storage on the West Coast, which is typically supplied on a regular basis from Nelson or Canterbury.
2.3 Communications

Communication lifelines include telecommunications, radio and satellite.

- The telecommunication network provides land line telephone service to all households on the West Coast. All the fixed line network (fibre-optic and copper cables), telephone exchange buildings and cabinets along with some VHF radio are owned and operated by Chorus.
- The microwave tower network of five sites is owned and operated by Kordia.
- Cell phone service is between Karamea and Fox Glacier although coverage can be patchy between centres. There is no cell phone coverage between Fox Glacier and Makarora. Cell phone towers are owned and operated by Spark, 2 Degrees and Vodafone.
- Satellite phone coverage is available, with Iridium being the main service provider.
- Very High Frequency (VHF) radio has a wide coverage over the West Coast through a number of operators using several hundred radio repeater sites.
- CDEM is in the process of installing a “Controllers Net” radio network, which will allow radio coverage of West Coast through a single robust system.

Fibre-optic cables are increasingly important for communication. The two links between Greymouth and the rest of the country are, to Nelson via Reefton, Springs Junction and Murchison, and to Christchurch via Moana and Arthur’s Pass. A regional cable runs from Greymouth up the coast to Westport and Karamea, and a second from Greymouth to Hokitika and Fox Glacier. The telephone exchanges at Greymouth, Westport and Hokitika are understood to be being phased out and all local traffic, both land line and cell phone, will be dependent on the cable links to outside the region.

Communication is a vital lifeline. Without good communication recovery would be greatly slowed. Loss of links can impact on many activities in society with most retail and bank transactions now reliant on data and internet connections to outside the region.

2.4 Flood Control

There are a large number of water control assets on the West Coast. Most are managed by the West Coast Regional Council, but some are managed by the district councils. Others are related to waterway management at bridge crossings and are managed by KiwiRail or the New Zealand Transport Agency. Some of these have ancillary functions in providing protection to downstream areas, although this is not their prime purpose. Most of the assets are for flood control but WCRC also manages three drainage schemes and two coastal protection assets.

Most of the flood control structures are stopbanks or groynes which protect largely rural land. The flood capacity is unknown, but it is likely that their capacities would be for no more than 50 to 100 year return period floods, and thus very large flood events could result in them being overtopped. The most significant flood control structures are the Greymouth floodwall and the stopbank at Inchbonnie, the latter reducing the potential for the Taramakau River to avulse into Lake Brunner and the Grey River.
2.5 Water Supply

There are ten water supplies managed by Buller District Council, six by Grey District Council and ten by Westland District Council. The more important ones are Westport (5,600 population), Reefton, (1,200), Greymouth (7,500) and Hokitika – Kaniere (3,700), as well as Franz Josef which might need to serve a population of over 1,500 in the tourist season. The smaller schemes might serve populations as small as thirty.

Water supplies include surface water from rivers (11 in number), one lake and 12 bores. Treatment varies from UV to filters plus chlorination. Most schemes have at least some storage. Distribution is by pipe networks. The older systems still retain many rigid-jointed brittle pipes, but these are being progressively replaced with flexible PVC and ductile materials. The more recent schemes are mostly in plastic pipe.

Water supply is an essential lifeline, primarily for the general population, but also for industry, including the dairy factory at Hokitika. Many of the stream intakes are vulnerable to flood damage and require vehicle access for restoration. Fifteen of the 26 schemes are reliant on electricity to power pumps.

2.6 Sewerage

There are 12 sewerage schemes in the region managed by the District Councils – three in Buller, five in Grey and four in Westland – and also some smaller privately run ones. There is a total of about 300km of sewerage pipework in the region. The larger schemes are in the main centres and these tend to be older with a high proportion of rigid brittle pipes, although these are progressively being replaced with modern flexible pipes as required. The larger schemes have pump stations – five in Hokitika, including one which pumps all the sewage out to the oxidation ponds, 19 at Westport, and 36 in the Greymouth area. The smaller schemes only treat sewage by oxidation ponds, but Greymouth and Westport both have treatment plants prior to discharge to the Grey and Buller Rivers.

Failure of the sewage systems does not stop things working (as might a failure of the water supply) but it does create significant health issues. As well as damage to the pipes and pump station from a natural disaster, the schemes are reliant on electricity to operate the pumping stations and treatment plant pumps.

2.7 Stormwater

The district councils manage a number of stormwater systems. There are about 21km of open drains within nine systems in Buller, as well as five piped systems. In Grey District about 10km of open channel and 121km of pipe are spread across nine stormwater systems, whereas Westland has nine piped systems and six smaller open channel systems. Hokitika has 38km of stormwater pipe. Much of the pipe is concrete or earthenware. There are four stormwater pump stations in Greymouth.

Damage to stormwater systems is not usually critical, but local flooding as a result of system failure can cause additional damage to property and exacerbate difficulties and stress levels faced by a community after a natural disaster.
3 THE WEST COAST AS A SYSTEM: COMMUNITY, ECONOMY, FLOW AND PIPELINES

Assessing the relative importance of different vulnerabilities requires an understanding of the West Coast communities and its economy.

The region as a whole is long and narrow, stretching from Kahurangi Point in the north 400km to Jackson Bay and the Cascade River in the south (Figures 3.1). It is separated from the rest of the South Island by high mountains with only four crossings. Administratively it is broken into three districts: Buller District in the north, Westland District in the south and Grey District between them. The region is relatively sparsely populated with an overall population of about 32,500, the populations of Buller, Grey and Westland Districts being 10,500, 13,500 and 8,500 respectively. The district administrative centres are Westport, Greymouth and Hokitika, and they are the region’s three largest towns, with populations of about 4,000, 10,000 and 3,000 respectively.

![Figure 3.1: West Coast Region](image)
The spread-out nature of the Coast means that transportation and communication links are particularly important – and transportation includes roading, rail, air transport and fuel and also power distribution.

In 2016 the overall GDP of the Coast was $1,636 million in 2010 prices, with 16,615 filled jobs (Infometrics 2017). The three biggest economic sectors are mining, dairying and tourism, and these three can be taken to stand for the whole. GDP and employment for 2016 in the three sectors is as follows:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Regional GDP ($M)</th>
<th>Employment</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining</td>
<td>207.2</td>
<td>685</td>
<td>4.1%</td>
</tr>
<tr>
<td>Dairy farming and manufacturing</td>
<td>234.5</td>
<td>1,528</td>
<td>9.2%</td>
</tr>
<tr>
<td>Tourism</td>
<td>111.0</td>
<td>2,627</td>
<td>15.8%</td>
</tr>
</tbody>
</table>

Roughly speaking, the three sectors together contribute about a third of both the region’s GDP and its employment, but whereas the biggest contribution to GDP comes from dairying, tourism is the largest employer.

Figure 3.2 shows the total estimated tourist spending in the region in 2016 is about $488M, a figure more than four times greater than the $111M tourism contribution to GDP. The difference has to do with the way in which GDP is calculated, and with how much of the tourists’ spending remains in the region. The chart below shows how the expenditure is distributed. Most goes towards transportation and accommodation. Clearly, the longer a tourist stays in the region, the greater the contribution to the economy from food, drink and accommodation.

**Figure 3.2: Breakdown of West Coast Tourist Spending, 2016**
The relative importance of different lifeline segments depends on the effect of their failure on the regional economy, and more specifically on the effect of lifeline asset failure on the three main economic sectors of mining, dairying and tourism. This is done by introducing the concept of a virtual pipeline.

Each of the three economic sectors can be thought of in terms of flow. Slowing or stopping the flow harms the sector. For mining, the flow is a flow of coal (not gold, because its high value-to-volume ratio means that although it is important for the economy, it is less vulnerable to infrastructure failure). The main flow of coal is from the Stockton Mine to the Port of Lyttelton by train. The volume of coal is such that there is no viable alternative means of transport at present. The flow pattern in the dairy industry is more complex. Milk has to be collected from farms throughout the Coast and brought to Hokitika for processing, and there are often alternative routes should a road be closed. The processed product—roughly a thousand tonnes a week—is then shipped from Hokitika to Canterbury by rail. Tourism is also a flow, with tourists travelling from Canterbury down to the glaciers, possibly taking in Punakaiki on the way, and then on south through the Haast Pass to Wanaka and Queenstown.

The “virtual pipeline” comprises all those things needed for maintaining the flow. Take tourism for example. Obviously, tourists need roads to travel on. Almost all also need accommodation as the West Coast loop is too far to traverse in a single day. They also need food and drink, electric power, telecommunication links, toilet facilities, tourist attractions and shops. All these are part of the pipeline, and problems in any one aspect would impinge on the flow. For instance, even if all the roads were passable, the flow would have to stop if there were no accommodation, and it would be seriously affected if there were no tourist attractions—glacier tours and the like—available.

The report therefore considers where and how the mining, dairy and tourism pipelines would be affected by major earthquake, storm or tsunami events being used to probe the system.
4 NATURAL HAZARDS

Although an Alpine Fault earthquake remains by far the most damaging hazard for the region as a whole, the brief for this study requires a full range of natural hazards to be considered. The hazards themselves are not the focus of this study – rather it is the potential damage to lifeline infrastructure and the consequential impact on the community and the economy.

4.1 Hazard, Environment & Infrastructure

There are three contributors to infrastructure damage at any particular location: the natural hazard event itself, the particular environment, and the nature of the infrastructure element.

4.1.1 Natural Hazard Event

- Any one specific natural hazard event will have a unique set of characteristics such as areal extent, distribution of intensity (e.g. ground shaking for an earthquake, wind speed for a wind storm, accumulated depth of rainfall), duration etc.
- There is great uncertainty in the prediction of these characteristics and hence of the “profile” of a hazard event itself.
- The same location can have two different sets of damage consequences from two superficially-similar natural hazard events. This was graphically illustrated by the September 2010 and February 2011 earthquakes, both of which affected Christchurch, but with quite different characteristics and consequences.
- In effect an infinite number of natural hazard events can occur.
- Impacts of a natural hazard can be mapped either for a specific event (such as intensity of shaking for a particular earthquake) or in a probabilistic manner (such as shaking intensity expected at a particular annual probability). The first map better approximates reality in that specific events are what actually occur, but because of the huge number of different possible events, it is limited by its very specific nature. A specific event map is useful for probing a system to see how it might respond and find its weaknesses, but it cannot probe the whole system at once (especially if it is the size of the West Coast Region). The second map is useful in showing what areas have greater hazard probability and is appropriate for planning actions to improve infrastructure at a particular point, such as a water treatment plant or a specific section of road. A probabilistic map probes the whole system at once in a uniform manner, but cannot show how the system will respond to a real event. Neither map gives a complete picture of a hazard event in the real world.

4.1.2 Environment

- The same natural hazard event occurring in two different locations will have two different sets of damage consequences, as the locations will have different characteristics in terms of topography,
geology, with different strengths of rocks and soils, run-off characteristics, with respect to rainfall, hills, funnelling, focusing strong winds, etc.

- These locational characteristics can be assessed and mapped, but on a regional basis much of the area will have little information on all but surface topography and generic geology, and hence there will be large uncertainties.
- The locational characteristics both modify the natural hazard (local wind effects, topographic amplification of earthquake shaking) and affect the exposure of infrastructure.

4.1.3 **Infrastructure**

- The infrastructure is essentially man-made with manufactured materials. There are uncertainties as to the strengths of these materials, how particular structures will respond to loadings, etc., but the susceptibility of the infrastructure to a hazard can generally be assessed to a greater accuracy than either the hazard or the environmental factors can be.
- Infrastructure susceptibility will be different for different natural hazards. For instance buried cables are largely immune to strong winds (although heave from a tree root ball blown over in a wind is possible) but are likely to be broken in a landslide or through earthquake-induced ground movement.

These three aspects of natural event, environment and infrastructure interweave to result in a particular and unique combination of damage in any one natural disaster.

4.2 **Consequences**

Damage to infrastructure results in loss of service and this has consequences for the community. It is important to note that similar degrees of damage to infrastructure can have very different consequences to and impacts on communities, depending on where the natural hazard event occurs. Consider an earthquake. In 1969 it took ten weeks to reopen the road through the Upper Buller Gorge from damage resulting from the Inangahua earthquake. While this was a significant disruption to the roading network, there was alternative access between Inangahua and Murchison. If similar damage had occurred to the Karamea Road from a similar earthquake but with an epicentre between Mokihinui and Karamea, then the consequences would have been more severe as this road is the only access to Karamea other than by small aircraft. As a third example, earthquake damage confined to SH 6 across Mt Hercules, for instance, would leave all the West Coast south of Whataroa still accessible, but only via the Haast Pass. If the road outage were for a short time there would be inconvenience but little profound impact. However, an outage of several weeks would have a far greater impact. Thus redundancy and reparability are also key aspects in estimating consequences.

4.3 **Disaster Scenarios for Probing the System**

Given uncertainties in the hazard, the lack of knowledge pertaining to the environment and a necessary overview level of the infrastructure, it is not possible to predict in more than a general way what would actually happen in a natural hazard event. The types of damage that are likely to occur can be outlined and the more vulnerable places and structures where damage is more likely can be identified, but it is not possible to be specific about what would actually happen.
There is thus a great deal of unpredictability and uncertainty, which is where the concept of resilience becomes so important. As accurate prediction is impossible, it is important to prepare for the unexpected. Indeed, to try to give predictions that are too precise is actually counterproductive. Ultimately, prediction is not the issue, but rather, vulnerability and what could be done about it. The approach taken is therefore to use extreme natural-hazard scenarios as probes to test the system and identify system vulnerabilities. The objective is to arrive at ways in which the West Coast Region as a whole could be made more resilient to natural disasters.

It is useful to bear in mind the distinction between areal (or system) and local resilience. An example is the 2011 Christchurch earthquake. Many buildings in the CBD were built to code requirements for a probabilistic earthquake loading level. In themselves they performed adequately, but the impact on the overall system was unforeseen with a large proportion (in excess of 80%) of all CBD buildings being demolished post-earthquake (the system in this context includes such things as insurance, investment priorities and the social and economic activities of the CBD). Yet while the local resilience of individual buildings could be seen as having been low – they had to be demolished – the resilience of the Christchurch region as a whole was surprisingly high as many activities from the CBD were able to be relocated to other locations. Thus structural resilience was low while community resilience was far higher.

Although the brief was to consider all natural hazards, this study focusses on only three: earthquake, extreme storm (including wind) and tsunami. Many other natural hazards pertinent to the West Coast such as snow, fire, coastal erosion or localised landslides are generally of short duration and have little impact on lifeline function beyond the first week after the event, so they are not considered. Where they do impact for longer, the effects on the lifeline systems will not be greatly different from those of the three selected hazards, and resilience against earthquake, storm and tsunami will also provide resilience against other hazards. A very different hazard would be a coronal mass emission (CME), in which an unusually large release of plasma and magnetic field from the sun’s corona hits the earth. This too is not considered because of its esoteric nature and because although it would cause serious damage to electronics, power distribution and communications it would not directly affect most other lifelines.

The three chosen scenarios are summarised below.

### 4.4 Earthquake scenario

The earthquake scenario used for probing the infrastructure is a hybrid made up of two possible events: one (out of many) possible ruptures of the Alpine Fault, and, to cover the northern region, the 1968 Inangahua earthquake, for which actual records are used. The earthquakes and associated lifeline damage are described more comprehensively in Supplement 2: Earthquake Scenario.

#### 4.4.1 Earthquake 1: Rupture of the Alpine Fault

The M8.2 rupture scenario on the Alpine Fault as adopted for the Project AF8 is used as the first of the probing earthquakes. This possible earthquake has the rupture starting in Fiordland and progressing about 400km north to end close to Lake Kaniere, thus remaining in Westland District. Although this is just one of many scenarios
possible with the Alpine Fault, it appears to be the most likely and retains consistency with the AF8 work. There is an estimated 30% to 50% probability of an earthquake of this nature in the next 50 years. The 2006 Lifelines study (McCahon et al 2006A, B, C) assumed a different rupture length and location and reference should be made to that report for an outline of the effects of a different set of assumptions for the source earthquake on the spatial extent of damage and consequences to the lifeline systems.

Direct effects of such an earthquake would include ground rupture destroying buildings, road and pipelines on or crossing the fault, and shaking damage to buildings, bridges and infrastructure over a wide area. Secondary effects would include liquefaction in susceptible sandy areas and particularly in coastal estuaries and lagoons, and landslides, particularly close to the fault line and in the mountains, some of which would be likely to create dams across rivers. Seiches could be produced on lakes.

Indirect and longer-term impacts would result from the large volumes of landslide material entering rivers, particularly those with catchments in the Southern Alps. The increased sediment load would result in high river water turbidity, river aggradation and channel avulsion with implications for drinking water quality, river control, stopbanks and bridging for many years after the earthquake.

The types of damage that would be possible include:

**Roads**
The most intense damage would be in the rupture zone close to the Alpine Fault between Haast and Lake Kaniere, but with damage throughout the region. Roads would be effectively blocked and most bridges damaged in the rupture zone. All road links out of the region could be cut, and significant landslide or bridge damage would effectively divide the region into a series of isolated areas.

**Railway**
The railway would be extensively damaged between Cass and Jacksons, with other damage throughout the region, but predominantly south of Ikamatua.

**Airports**
The airports at Hokitika and Westport would suffer little damage other than building contents damage, but the Greymouth aerodrome could be damaged by liquefaction under part of the runway.

**Harbours**
Greymouth harbour wharves could be deformed and damaged by liquefaction and failure of the banks behind them, as could the structures in Westport harbour. The Jackson Bay wharf could be badly racked and unsafe.

**River and flood works**
Large landslide dams would be likely throughout the region and particularly in the steep mountain valleys immediately east of the Alpine Fault rupture. Significant dams in several rivers would present a dam break hazard.

The Greymouth floodwall would be damaged by liquefaction under some short lengths, in conjunction with dislodgement of rock on the steep batter. Longer lengths of the floodwall around the lagoons
would be damaged by liquefaction-induced lateral spreading and fissuring. Liquefaction under some short lengths would damage the Hokitika River stopbank adjacent to the CBD. Other stopbanks throughout Westland District would be damaged with slumping of the batters, and the stopbank on the south bank of the Waiho River would be destroyed on the fault trace by the rupture.

The fault rupture would cut through the Inchbonnie stopbank with major relative displacement between the sheared ends.

**Sewerage**

Brittle pipes in the urban areas would be likely to be damaged. The oxidation ponds at Moana, Runanga, Blackball, Hokitika, Franz Josef, Fox Glacier and Haast would all be damaged. Liquefaction in sands under portions of the three main towns would cause some gross pipe displacement. Pump stations in Greymouth and Hokitika would be likely to be damaged by liquefaction. The sewer system at Franz Josef would be significantly damaged and all pipes crossing the fault would be destroyed.

**Water supply**

Water supply to all the major towns would be disrupted. All pumps would stop, and breaks in the gravity systems would mean that supply from the intakes would be lost. There would be widespread damage to the reticulation in Hokitika and to a lesser degree in Greymouth, and some liquefaction damage would occur at the north end of Westport. Damage to the smaller schemes would also be likely to occur and except for some small supplies in coastal Buller, all public water supplies would fail.

The Hokitika reservoirs would empty and the system lose pressure because of breaks in the reticulation. Similar draining of reservoirs would occur at virtually all the smaller schemes south of Reefton. There would be turbidity issues at the Greymouth intake wells but earthquake valves at most of the Greymouth reservoirs should limit loss from the system, except the Omoto reservoir, which would be likely to be damaged. Some parts of the Greymouth reticulation would be isolated due to leakage from pipe damage. Greymouth, Hokitika and Reefton as well as parts of Westport would all have some days without water.

**Power Supply**

Power supply would be lost throughout the whole region. All links into the region would lose supply, all the local generation would be shut down by the earthquake, and there would be significant shaking damage at substations. The Transpower line through Arthur’s Pass would be cut by loss of poles and landslides. There would be extensive damage to the Electronet system with poles down and other breakages. The line between Franz Josef and Fox Glacier would be destroyed for a large part of its length.

The power stations at Dillmanstown and the Arnold should escape significant damage, but the Amethyst Scheme would be badly damaged in this scenario with rock fall over the intake. The Turnbull station at Okuru would suffer a penstock failure and subsequent damage from released water, and the distribution system between Haast and Jackson Bay would be damaged.
Telecommunications

The fibre-optic cables over Arthur’s Pass and to Nelson would be cut due to bridge abutment settlement and road dropout. At present the existing analogue system exchanges allow calls to be made on land lines within each exchange area, but when these exchanges are phased out over the next few years, there would be a complete loss of service (land line and cell phone) within the whole of the West Coast. Several cell towers would be damaged.

4.4.2 Earthquake 2: Inangahua and Buller

The Buller area has been subject to two large earthquakes: the 1929 Murchison event and the M7.2 Inangahua earthquake 1968. The latter is chosen as the probing scenario. It has the advantage of being an actual event with records of damage and thus reduces the amount of speculation and uncertainty as to the effects. The damage is described as follows:

Roads

There was widespread damage to roads, from landslides, slumping and fissuring and spreading of embankments. Subsidence of bridge abutment fills was particularly large in the Inangahua area, but extended as far south as Reefton and west to Westport, with one (fatal) instance near Runanga (about 85km from the epicentre).

The main road between Reefton and Inangahua was closed for three weeks after the earthquake, due to bridge damage and a large slip, but access was restored after three days by using the alternative Brown Creek Road. The Lower Buller Gorge Road was damaged by landslides and by rock falls at Whitecliffs. It was reopened 3 weeks after the quake, with a low level road to by-pass the rock falls. The Upper Buller road was extensively damaged with several sections completely carried away by landslides. It was reopened 10 weeks after the earthquake.

Structural damage to bridges was substantial within about 7km of Inangahua, but minor to none beyond this distance. Generally the bridges could be used after comparatively minor repairs, but temporary repairs were needed to the Landing Bridge to allow traffic after 3 weeks closure.

If the same earthquake occurred today, subsidence to new bridge abutments should be less because bridges built in the last 30 years have settlement slabs. Bridge replacements and road re-alignments since 1968 should see SH 69 reopened within 2 – 3 days and SH 6 through the lower Buller Gorge cleared within a few days. Similar damage to 1968 could be expected through the Upper Buller gorge.

Because of the current safety environment, we consider that no improvement on re-opening time for the Upper Buller Gorge should be expected, and it could even take considerably longer than the ten weeks in 1968.

Railway

The Inangahua earthquake resulted in spreading of railway embankments and pronounced vertical and horizontal distortion to the track. A number of slips blocked the line in the Buller Gorge, including one
1,900m$^3$ rock fall and collapse of a river bank below the line which needed 2,300m$^3$ of fill to rebuild the line. The railway was reopened with severe speed restrictions about 3 weeks after the earthquake.

**Rivers**

A major effect was a rock fall avalanche, which blocked the Buller River upstream of Lyell, forming a lake about 8km long in the Upper Buller Gorge. The dam was overtopped within a short time without any significant flood. Similar events could be expected in any large earthquake in the area, but next time the dam break might not be so fortuitous and there could be downstream flooding.

**Telecommunications**

Telecommunications were all wire-based in 1968. Subscribing telephones that lost connection ranged from 8% in Hokitika to 40% in Westport, and in the area of stronger shaking the lines were cut by fallen trees, slips and spreading of embankments which displaced poles. About 2.5km of underground cabling was badly damaged by ground subsidence and cracks and was replaced with aerial cable on existing poles.

The Inangahua exchange building was threatened by a large slip resulting in it being relocated after 2.5 weeks. The Reefton exchange building was demolished with a replacement exchange installed in a temporary building in Christchurch and transported to site. Greymouth and Reefton were re-connected by the end of day one, Inangahua to Westport after 3 weeks, and a temporary repair on the Upper Buller line was in place about 2 months in advance of the road re-opening. The technical advances in telecommunications since 1968 will have alleviated many of the vulnerabilities, but damage to cables from ground damage and movement of equipment through inadequate fixing remain relevant.

**Power**

Damage was not significant other than at the Inangahua substation, where equipment was disconnected and bypassed allowing the restoration of supply after only 3 hours. However, landslides threatened several transmission towers. Re-routing the lines will have mitigated the 1968 problem, but the lines across the steep topography must remain somewhat vulnerable.

**Water and Sewer**

There is little information reported. There appears to have been less damage in Westport in 1968 than in 1929, although shaking intensities were similar (MM VIII). The direction and duration of strong shaking may have had some influence. Some pipe damage in Westport was obviously the result of liquefaction. Much of the pipework remains constructed of rigid and old material and failure is expected of all three water services.

### 4.5 Extreme Storm

The storm scenario assumes a very large storm event that brings very heavy rain and high winds over the entire region with the maximum rainfalls occurring over a 20 – 30 hour period as the weather system moves up the South Island: see *Supplement 3: Storm Scenario* for further details.

Precipitation and runoff have not been modelled in detail as this would have been a significant exercise. Rather, a very large rainfall is assumed over the whole coast. Although this may be questionable as a realistic scenario
it is appropriate for this lifelines study. The damage scenario as described in Supplement 3: Storm Scenario is based on reported flooding and landslips on the West Coast over the last 100 years, but whereas these have tended to occur only in small areas, the scenario collates the worst records for each locality which have occurred over the last 100 years and assumes that they occur at the same time in a single storm. In addition, there has been some extrapolation of the damage. The study has used existing flood modelling for Karamea and Westport and the 1988 flood record for Greymouth as representative of the flooding at these areas in a 500-year event.

The storm scenario would result in extensive flooding throughout the region. Stopbank systems, where they exist, would fail or be overtopped, while all the main urban areas would be flooded to varying degrees. While floodwaters would precipitate a civil defence emergency, they would recede relatively quickly, and it would be the residual damage that would be the real impact on lifelines. The type of damage expected includes:

- Bridge and bridge abutment damage from scour and bank erosion; some bridge failures.
- Loss of pipe or cable services across damaged bridges.
- Landslides of various sizes throughout the affected area, burying or undermining transport routes and other infrastructure.
- A few landslides large enough to block rivers and form landslide dams with subsequent risk of failure and dam break flood subsequent to the main event.
- Debris flows with deposition of fluvial transported sediment from steep catchments on to flatter land, thus obstructing and burying transport routes, bridges and other infrastructure.
- Flooding of electrical cabinets with resultant damage; as part of electrical distribution, telecommunications, sewerage systems (pump stations etc.) water supply (pump stations) and fuel supply.
- Flooding of buildings containing electrical systems (such as telephone exchanges, or generators) or records pertaining to infrastructure.
- Scour and erosion of ground in areas of fast flowing flood water, which might damage power and telephone poles, roads, railway, buried services, embankments, pipe outlets etc.
- Scour and erosion of river control structures such as stopbanks, groynes etc.
- Damage to parts of hydroelectric generation facilities, including scour and erosion of spillways, pipelines and embankments, landslides on to pipeline, penstocks or headworks.

For an extreme and large area storm as envisaged in this scenario, damage would be extensive and widespread. Recovery would be more than just clearing off more and larger slips than normal from the roads. For structures on waterways, such as bridges, culverts, dams or other water intakes and flood protection works and stopbanks, the size of flood would be at or above the nominal design levels, and thus some damage must be expected to at least some of these structures.

Wind damage could be widespread and significant, damaging buildings, cutting power lines and resulting in major access difficulties. However, most wind damage would probably be repaired within a week or so and thus would not impact on the recovery period which is somewhat arbitrarily taken to commence one week after the event. The exception would be possible severe damage to the three suspension bridges on SH 6 which could
take longer to repair. A video of the behaviour of the Karangarua suspension bridge in Cyclone Ita gives an idea of what could happen (Jarrett 2014).

4.6 Tsunami

For tsunami a 1 in 500 year event is assumed to occur uniformly along the entire coast. Although in reality it is highly improbable that the whole coast would be impacted to the same degree, the assumption is appropriate for determining local vulnerabilities. See Supplement 4: Tsunami Scenario for more details.

The scenario is based on a very simplified approach to get some estimate of the threat posed by tsunami. Some simple modelling has been done for the coastal urban areas where LiDAR elevation data was available, but elsewhere it has simply been assumed that the beach ridge extends the full length of coast with height of 6m (except at river mouths). This would confine tsunami inundation to the open beach for tsunami of 100 – 300 year return period, but flooding would occur at estuary and river mouths.

The main areas exposed to tsunami are:

- Karamea, with inundation of the western end of the township, the airstrip, the coastal road, electrical substation and several bridges.
- Grainty to Mokihinui: most of 18km of SH 67, several bridges, electrical substation and transmission lines, telephone lines, railway and coal loading facility at Ngakawau.
- Westport, which could be flooded for 3km in from the beach, as well as from the Buller and Orowaiti Rivers, but only the northern extremity of the urban area is affected, as far inland as the high school. Damage to wharf structures and boats and scour could affect storm water outfalls into the river.
- Carters Beach, with all of the settlement and the airport inundated.
- Cape Foulwind – Rapahoe, which has several lengths of SH 6 at low levels close to the shore, with several bridges and power lines.
- Rapahoe, which could have about 40% of the township inundated as well as the SH 6 bridge.
- Cobden and Greymouth to Camerons, which are expected to have inundation up to 1km in from the shore, with damage to SH 6, railway, harbour works, the sewer across the estuary, the waste water treatment plant at Karoro, some telecommunication sites and bridges. The airport could be flooded, and the floodwall could be expected to be damaged around the lagoon.
- Kumara Junction to Hokitika, where much of the 18km of road and railway is likely to be inundated.
- Hokitika, which is particularly vulnerable with all the CBD and the town west of SH 6 potentially flooded by up to 4m from both the beach and the river. Extensive building damage would compound inundation and both service stations and the telephone exchange could be affected. Oxidation ponds could be flooded and stopbanks overtopped probably as far inland as the diary factory. The Hokitika Bridge abutments are at risk together with services on it.
- Hokitika to Ruatapu, which could have sections of SH 6 flooded, and where power lines might be affected by scour at poles which would also impact on the fibre-optic cable. The power line and cable are exposed along much of the way between Ruatapu and Bold Head.
• Okarito, which would probably be severely affected with the loss of power and telephone lines and damage to roads.

• Bruce Bay, where about 1km of SH 6 on the beachline is vulnerable to scour and possibly complete destruction, with a further 4km within the inundation zone. The power line is similarly exposed.

• The Haast area, where sections of SH 6 totalling 6km would be inundated, as would large parts of the road between Haast and Jackson Bay. Power lines would be lost and some bridges are also vulnerable. The wharf at Jackson Bay would be destroyed.

The immediate coastal areas would probably be devastated in the tsunami as modelled, and in particular the built up areas of Granite, Ngakawau and Hector, Carters Beach, Punakaiki, parts of Rapahoe, Cobden and Greymouth to South Beach, the seaward part of Hokitika, Okarito, Bruce Bay and the Haast coast settlements would all be likely to be severely damaged. Debris generated from lightweight timber houses would compound the damage from water flows and flooding. As it is only a narrow coastal strip that would be directly impacted, most of the region would remain operational, but reinstatement of road links north of Westport and between Greymouth and Hokitika would be necessary to connect otherwise isolated parts of the region.

5 IMPACT OF PROBING SCENARIOS

The next step is to examine the effects of the earthquake, storm and tsunami scenarios on the three key economic sectors of dairy, mining and tourism. The effects arise from the infrastructure damage outlined in the previous section. The aim is to identify the importance to be associated with each of the different lifeline vulnerabilities. The results are summarized in the tables of vulnerability/importance pairs given in Section 6 below.

It becomes clear that the roading network is the key lifeline for dairy and tourism partly because of its general importance but also because repair would take longer than for other lifelines. Roading is therefore treated in more detail after first considering the impacts of the probing scenarios on the three economic sectors.

5.1 Dairy Industry

There are several components to the dairy system on the West Coast:

• Farms, milk production and transport of milk to Hokitika,

• The Westland Milk Products factory at Hokitika, and

• Transport of milk products from the factory out of the region.

While the industry clearly uses all utilities and communication is central to all operations, some lifelines are more specifically critical than others:

• Farms are reliant on power supply and road transport.

• The factory is reliant on power supply, water supply and transport.
• Export is mainly by rail.

It is assumed that the Westland Milk Products factory would only be damaged by an earthquake and not by storm or tsunami.

### 5.1.1 Earthquake Impact on the Dairy Sector

Although the impact of an actual earthquake would be very dependent on the size and location of the event, the focus here is not on what would actually happen so much as on the effects of any earthquake-related lifeline damage throughout the region on the dairy economy.

A major earthquake would seriously disrupt flow in the virtual pipeline of the dairy industry. There would be:

- Damage to key roads in both the north and south of the region and across the Alps.
- Damage to access roads into the farming areas.
- Damage to the railway.
- Damage to rotary milking sheds and other farm buildings.
- Great disruption to the communities.
- Probable damage to the dairy factory.
- Damage to power and telecommunications throughout the region impacting on farms and factory and also water supply to the factory.

The dairy factory would probably be closed for a minimum of two weeks and perhaps several months, depending on the damage sustained. Initially there would be problems in getting engineers to the site for damage assessment, and then carrying out whatever immediate repairs were needed to safely secure the structures and allow even rudimentary operation to resume.

Some farms would continue milking even without the factory operating or roads open, but many others would be likely to be severely disrupted and many herds would be dried off because of the damage and uncertainty as to when services might be restored. Communication between factory and farm would be a major problem. Decisions would have to be made by farmers stressed by the earthquake and on-going aftershocks, with partial or insufficient information about the state of roads and factory. Farms without generators would probably be forced to dry off their herds as it would be likely that network power would be out for a considerable time, particularly in remoter areas and to the south. Even some farms with generators would have to dry off their herds if they ran out of fuel with no replenishment available in the near future. Depending on how long the Hokitika factory was closed, milk from the West Coast Region might have to be transported by road to factories in Canterbury, and it could be several weeks before the first of the alpine passes would be repaired sufficiently for regular tanker traffic. Even with roads re-opened, severe ongoing disruption could be expected with both a reduced level of service with speed restrictions and delays at repair sites and from ongoing stability issues at landslide sites, SH 1 south of Kaikoura was closed 72 out of 150 days in the first five months following its’ re-opening after the 2016 earthquake. Thus ongoing problems with milk supply to the factory must be expected from those parts of the region most affected by landslide and road damage.
5.1.2 Storm Impact on the Dairy Sector

A 500-year widespread storm would have a major impact on the dairy industry. Widespread flooding would damage paddocks and fences throughout the affected area. Many stopbanks would be overtopped, and milking sheds and houses flooded. There would be a long term drop in farm milk production. Wind damage would knock out power lines and communication cables both directly and through tree fall, and wind debris would hinder access for repair and restoration. Power would be restored to most farms within a few days but some outlying farms would have to rely on generators for up to two weeks – fuel might become a problem. Roads and bridges would also be damaged and only 30% of the milk production could be transported to the factory by the end of one week, increasing to 70% by the end of week two and 90% by the end of month one. Farmers south of Harihari and north of Granity could decide to dry off their herds because of damage to road access.

The dairy factory would be impacted by short term local flooding and turbidity issues with the water supply, as well as staff being affected by flooding to their homes. However, it could resume production within a week as soon as the local situation had stabilized and milk could be delivered again, and provided the Hokitika water supply was able to supply sufficient and clean enough water. Significant damage to the Lake Kaniere supply could mean insufficient water to the factory for operation, as the alternative gallery intake has lower quality water than the lake, which would reduce the capacity of the treatment plant. It could be a few weeks for the water supply to the factory to be fully restored.

Export of milk products would be interrupted for two weeks until the railway re-opened.

5.1.3 Tsunami Impact on the Dairy Sector

A large tsunami, as outlined in Supplement 4, would have devastating effects on some coastal communities, but would leave the dairy industry largely intact, although a few farms directly on the coastline would suffer loss of cows and significant damage to pasture. The major impact would be on transport and power. Farms and roads south of Hokitika would be unaffected, and the factory would be unaffected except for the social dislocation from the damage to Hokitika CBD and to some employees’ houses. Milk supply from the north would be disrupted by damage to the Greymouth – Hokitika road. It could be 1 to 2 weeks before this road would be operable for milk tanker traffic, but farmers would continue to milk their herds, as it would be clear that the link would be restored in a relatively short time. Farmers in the Mokihinui – Karamea area would have longer to wait, as the Granity – Mokihinui and Little Wanganui – Karamea roads could take 2 to 3 weeks to reopen. A few farms on the coast road could be forced to dry off their herds as it would be clear that the coast road could take many weeks to reopen. Milk from north of Westport would have to be transported through Reefton, adding some additional time and distance. Export of milk products would be delayed by 1 to 2 weeks until the railway reopened.

Overall, the tsunami would have a low impact on the dairy industry.
5.1.4 Summary of Key Infrastructure for the Dairy Industry

The main infrastructure for the dairy industry is the road network, but only in the sense that roads take longer to repair than power and telecommunications, the other two main networks. Rail is also important. The daily milk production at the farms cannot be stored for more than a short time and there has to be good road transport to Hokitika. In addition, the roads are needed to provide supplies to the farms, including fuel, and access to power lines to restore power supply. Telecommunications are essential in keeping all parties in touch and up-to-date with the network problems and developments. Farmers’ decisions on how to manage their herds, for instance, would be predicated on their prediction of the future and how long it would be before road access were restored. If they had little information about possible recovery times, were surrounded by very visible damage and with no available outside perspective and only a few days’ supply of fuel for the generator, they might decide to dry off their herds.

Earthquake impact would vary from a relatively minor drop in production to catastrophic failure, depending on the size and location of the earthquake. The key vulnerabilities are the main transport links to and from the factory, but significant damage to the Hokitika water supply could also prevent operation.

An extreme storm would impact farms directly, but major lifeline vulnerabilities are bridge damage and landslides blocking road access as well as power loss. Many of the flood protection and drainage works in the region protect dairying areas, and failure of these could have long term effects from damage to pasture, fences and other farm infrastructure. Damage to power lines might place some farms in stress if they had no generators or insufficient fuel. The factory would not be able to operate if the water supply from Lake Kanierere were interrupted for any length of time.

Tsunami would have only a limited impact on dairying beyond those coastal farms directly impacted by inundation and damage to coastal road links. The major vulnerability is to the road and rail between Hokitika and Greymouth. While in the 500-year tsunami scenario these transport links would be restored relatively quickly, some unexpected loss of a bridge or bridges could result in a much longer outage with severe consequences in blocking milk transport to the factory and stopping export.

5.2 Mining

The mining industry on the West Coast is mainly made up of coal and gold. Gold mining produces a high-value low-volume product. Provided daily living requirements are met and fuel supply is sufficient, gold mining could continue without outside service support. It is therefore not particularly reliant on lifelines. Coal mining is the opposite: a low-value high-volume product. Without regular transport of the coal from the mines, coal storage becomes full or is limited because of the risk of spontaneous combustion, costs increase with necessary double handling and the mines have to shut down. The coal industry is dependent on the rail link to Canterbury. The volumes transported are not possible on the roads, either physically with the number of trucks and drivers needed on the current road system, or economically due to higher costs. The following discussion is confined to coal mining.
5.2.1 Earthquake Impact on Mining

A large earthquake would cause significant damage to the largest mines, which are in the Buller District, and also to the railway. It took three weeks for the railway to reopen between Westport and Reefton after the 1968 Inangahua earthquake. A similar sized earthquake would also have devastating impacts on the railway and an outage of several months is conceivable.

Multiple large landslides and fault rupture of the Otira rail link would be anticipated, followed by an extended period of frequent debris flows and river aggradation with heavy rain mobilizing landslide debris. A study in 2011 (McCahon et al 2011) suggested a median outage time of 5 weeks (in a range of 1 to 10 weeks), but with initial capacity at only 70% of that pre-earthquake and 95% after one year. This was based on many assumptions, and with resourcing issues and increased emphasis on workplace safety, a current assessment is that it would be considerably longer. A large earthquake could also trigger a large rock avalanche that could partially fill one of the alpine valleys. It is estimated that the time to reinstate the railway over such a feature would be about one year.

Power supply might take some time to reinstate but this would be far less time than the railway and is thus not critical.

5.2.2 Storm Impact on Mining

An extreme storm would have some impact on the mines directly with some damage to mine roads, working faces, etc. The aerial ropeway at Stockton might be vulnerable to extreme wind. There could also be power line damage. However the main impact would be on the rail link to Canterbury. A major 500-year storm event would bring multiple landslides on to the railway, cause some dropouts below the line and possibly lead to the loss of some bridges. The railway would be closed for several weeks as a result. Some of the railway through the Lower Buller Gorge is remote from road access. If a bridge were lost in this length, a measure of replacement time is the six weeks taken to replace two piers on the bridge damaged by fire in 2017 on a similarly remote location at Broken River to the east of the Alps. Power supply might take some time to reinstate but this would probably be much faster than the railway and thus would not be critical.

5.2.3 Tsunami Impact on Mining

The coal mines would not be directly impacted at all, but the railway and the Stockton Mine loading bins at Ngakawau would be inundated. About 4km of track could be severely damaged with ballast washed out, track dislodged, and the route covered by debris and a few small slips. The loading bins would be structurally intact but ancillary facilities could all be greatly damaged. The power supply could be destroyed with 3km of line lost and the substation inundated. Rail access might take 2 – 3 weeks to restore, and a similar time period could also be needed to make the loading bins operable and restore the power supply (which operates the aerial bucket-way from the mine). The remainder of the railway on the coal route would be undamaged by tsunami.
5.2.4 Summary of Key Infrastructure for the Mining Industry

The main vulnerability for the mining industry is the railway. A break at any point would sever the transport link and if the outage were for more than a few days, production would stop. There are multiple pinchpoints on the railway including bridges susceptible to floods and scour, embankments susceptible to slumping, and cuttings and steep hillside susceptible to landslide or rock fall. Railway bridges are designed for large transient loads from trains and so are usually not susceptible to earthquake-related structural damage, although some smaller bridges on the Kaikoura coast suffered considerable damage in the 2016 earthquake (Davies, A.J. et al, 2017). Tunnels are not particularly vulnerable to earthquake damage.

5.3 Tourism

Tourism relies on the flow of people through the region – through the virtual pipeline. Although tourists are encouraged to linger for more than a quick drive through, they remain transitory. The transport system is therefore essential: without roads for tourists to travel into, within and out of the West Coast Region, tourism stops. There is also a preference by many tourists for round trips rather than lengthy journeys on no-exit roads requiring a return on the same road (visitor numbers to Kaikoura dropped after the 2016 earthquake when the through route was cut). Tourists need accommodation, and so they also need the pipeline supporting services of power, accommodation, communication, water supply and sewerage systems. They also require the noteworthy landscapes, attractions and experiences which entice people to visit in the first place.

5.3.1 Earthquake Impact on Tourism

A major Alpine Fault earthquake would cause devastating damage to South Westland, and more particularly to SH 6. It would entirely block the tourist flow pipeline. The road would not reopen for many months and an entirely plausible possibility would be for it not to be reopened for several years due to cost, priorities for Government expenditure and the ongoing aggradation and debris flows that would be expected. Damage to the landscape would be such that it would no longer be the attraction it had been previously, and the reasons for tourists to travel there would be greatly diminished, at least for several years. World-wide news about an earthquake of this magnitude and stories relating to the stranding and evacuation of tourists from places like Franz Josef would have an adverse effect on tourist numbers for some years, not just for the West Coast but for the whole of New Zealand. The southern tourist circuit linking the West Coast with Queenstown, Mount Cook and other attractions of the east side of the Alps would not be easily replaced. A northern circuit across Lewis Pass (and later Arthur’s Pass when re-opened), to Greymouth, Punakaiki and on through the Buller Gorges to Nelson could attract some custom, but overall tourist numbers would fall dramatically.

Franz Josef could conceivably remain a tourist destination, once the road from Hokitika was reinstated, but it would be the end of a long no-exit road. However, the Alpine Fault earthquake would cause great damage to the township with loss of water supply and sewerage as well as most accommodation. The Waiho River would behave unpredictably with a high probability of aggradation and avulsion, and the township could be effectively abandoned. The earthquake would also damage other infrastructure and buildings, but the impacts on the road network would be the predominant vulnerability.
5.3.2  **Storm Impact on Tourism**

A large widespread storm would clearly have an immediate short term effect in stopping travel for perhaps several days due to flooding, slips and washouts as well as windfall debris blocking roads. Longer term impacts would again depend on the location and scale of the storm damage. Major landslides, debris flows or bridge damage in South Westland would cut the southern tourist circuit for what could be several weeks. Further north, the greater redundancy in the road network would mean that tourist flows would be diverted rather than stopped. Damage to the Midland Railway would mean that the TranzAlpine train (both a tourist attraction and means of travel) would probably be cancelled up to a few weeks. Repair to roads after a very large event would take time and delays would result for many weeks. This could well deter many tourists for some time.

Flooding would damage accommodation, as the Waiho stopbank failure in 2016 demonstrated at Franz Josef. Major flooding in Hokitika or a floodwall failure in Greymouth would have similar effects on accommodation there. Even if accommodation were not damaged, impacts on water supply would also inhibit the ability to host visitors. Many water supplies might be operating again within a week or so, but some smaller schemes dependent on surface water sources would be out of action for prolonged periods depending on changes to stream channels and ongoing turbidity problems.

A large storm would adversely affect telecommunications. A bridge approach washout could sever a fibre-optic cable; and microwave and cell phone towers would be affected by high winds. Without communication, the complex web of parties within the tourism pipeline (individuals, tour group leaders, accommodation operators, attraction operators, bus companies, rental care firms) would have great difficulty in adapting to the changing circumstances, re-routing, re-booking and generally adopting to the changed situation.

5.3.3  **Tsunami Impact on Tourism**

The 500-year tsunami outlined in *Supplement 4: Tsunami* would have devastating effects on some coastal communities. This would impact seriously on tourism, even though most of the tourist attractions were left intact. The vulnerable pinchpoints are:

- SH 6 at Bruce Bay and near Haast, thus closing the southern tourist circuit.
- The through road links (SH 6) in Hokitika.
- The coastal highway between Greymouth and Westport and north of Westport.
- The coastal road north to Karamea.
- The towns of Hokitika and Greymouth, where a large proportion of travellers’ accommodation (hotels, motels, campgrounds) in these centres would be lost.

The roads around Hokitika would reopen within a few days, but damage at Bruce Bay would require the reconstruction of the road along the beach or on a new route back from the shore in a remote area away from supporting facilities. In either case SH 6 would be closed for a period of several weeks to several months. Some tourists might choose to drive to and return from Franz Josef from the north but SH 6 closure would have a pronounced impact on tourism for much of the West Coast Region. The closure of the roads through Punakaiki and north to Karamea would have a significant effect on the local areas in terms of loss of access and
the consequential temporary loss of attraction, but would have a lesser impact than a South Westland circuit closure.

Hokitika and Greymouth would both take a considerable time to recover from a large tsunami. The loss of tourist accommodation would be compounded by the demands for temporary accommodation for those displaced from damaged or destroyed homes and for engineers, assessors and other people from outside the region called in to assist the recovery.

Other services would not be expected to be affected by tsunami outside the immediate inundation zones. Tsunami damage on the coastal road to Westport would include loss of large sections of the fibre-optic cable. This would compound the difficulties for Westport tourist operators.

5.3.4 Summary of Key Infrastructure for the Tourism Industry

As for the dairy industry, the road network is clearly the key infrastructure for tourism. Other services are unlikely to be as critical except for telecommunications, which have an obvious essential role in the immediate response phase but are also essential for recovery and the ongoing operation of tourism.

The key vulnerabilities for earthquake impact are the main transport links, especially through South Westland.

The effect of an extreme storm on tourism would again primarily involve the road system as it is central to tourism, although loss of accommodation and other services such as water supply could have a local impact.

A tsunami in the Buller District or on the Punakaiki coast would have a major local affect but would not be particularly significant for the overall region as the southern circuit would be unaffected. A tsunami that destroyed the section of SH 6 at Bruce Bay would have a short to medium term impact in that it would close the southern tourist circuit. A third susceptible area is Hokitika to Greymouth and here again the effect would be more on the local economy with the loss of accommodation and the diversion of tourists past the area. Other services important to tourism would be little affected outside the immediate inundation zones.
5.4 Road Network

Looking beyond immediate issues of economic and social recovery, one of the first things required after a major event would be road connection both within the West Coast and between the Coast and the rest of New Zealand. A strategic recommendation is thus to establish a robust central spine of roads either immediately useable after an event or easily and quickly reparable. The red roads in Figure 5.1 represent such a spine. The diagram is based on an analysis of roading vulnerability and importance – see Supplement 6: Transportation for details. The spine runs northwards from Ross to Greymouth and then up the Grey Valley to Reefton where it divides, with one arm going to Inangahua then down the Lower Buller Gorge to Westport while the other crosses to Springs Junction before turning north and following the Maruia River to the Buller and up to Murchison and Kawatiri. This road system connects main centres of population (Greymouth, Westport, Hokitika and Reefton) while working towards possible connections to Nelson, Blenheim and Canterbury. The roads marked in red are key and should be made as robust as possible. Next in priority are those shown in yellow, extending the spine south to Franz Josef and north to Karamea. Priority for restoring those other roads shown in blue would be determined by the nature of the event and where restoration would be easiest: down through the Haast Pass, through Arthur’s Pass or over the Lewis Pass as seemed most appropriate at the time.

The proposed priority ranking looks at the overall network and is biased towards serving the greater concentrations of population. It has not placed emphasis on the many smaller population areas, often on dead-end roads. There is a tension between the local need and the network perspective that is not easily solved.

Figure 5.1: West Coast Road Network Prioritisation
5.5 Summary

The road network is the key lifeline for both the dairy and tourism industries on the West Coast. For dairying, the most important link is between Hokitika and Greymouth for transport of milk to the Hokitika factory, while product export relies on the rail link to Lyttleton. Outages on other roads, while locally significant or even catastrophic, do not have the same impact on the industry as a whole. For tourism, the key route is SH 6 south of Hokitika as this forms part of the main southern circuit tourist route. Both tourism and dairying, which are characterized by having many individual parties within the industries, are highly reliant on communications for normal operation and, for dairying in particular, during the recovery period. Power supply to both factory and farms is also important for dairying, and the Hokitika factory is vulnerable to any prolonged outage of the water supply from Lake Kaniere. Tourism needs accommodation and hence water supply and sewerage systems need to be functioning for this industry to operate.

Mining is a little different in that its key lifeline is the railway to Lyttelton. This is likely to be critical in terms of recovery times, with other services such as power likely to be reinstated more rapidly. Road access is important to facilitate the railway recovery, and in places where both road and rail share the same corridor, reinstatement is likely to be a joint exercise.

It is clear that how the overall system is affected depends very much on the scale and location of the damage from a natural hazard disaster. It is easier to plan for tsunami because of the limited areas and small extent of lifeline infrastructure directly affected. Both large storm and earthquake cover a very wide range of possible scenarios and therefore it is much harder to conceive concrete mitigation plans for them beyond the ongoing incremental improvement of infrastructure and routine maintenance and condition monitoring. An attempt to identify priority sections of the road network has been made, with the intent of providing a spine of roads which are both less likely to be damaged in a major disaster and which are likely to be more easily repaired if they are damaged.

6 VULNERABILITY, IMPORTANCE AND PRIORITIES

The final step in the analysis is to bring together the vulnerability and importance of different elements of the West Coast infrastructure – both lifelines and urban centres. The complexity of the region has been simplified by breaking it down into the 29 elements shown in Figure 6.1. Some are areas or corridors, while others are specific points or facilities such as an airport. Items 11, 20 and 27 are outside the formal regional boundary but are included because of their relevance to the West Coast’s response and recovery.

Each element has been assessed as to its vulnerability and importance. The assessment is shown in Tables 6.3 to 6.5 which deal with vulnerability to earthquake, storm and tsunami respectively together with corresponding importance. They should be read in conjunction with the map in Figure 6.1. Where there is no vulnerability – Stillwater is not vulnerable to tsunami, for instance – the element does not appear in the table, otherwise vulnerability and importance are graded using three colours whose meanings are given in Tables 6.1 and 6.2.
Figure 6.1: Vulnerable Locations on or Related to the West Coast Region
The vulnerability/importance tables are presented principally as guides for asset managers so that they can see the whole picture, as it were, note vulnerable points which might need detailed assessment and prioritise action, guided by importance. Note, though, that importance of any element is assessed not only according to its effects on the economic sectors of mining, tourism and dairy, but also on its importance to the local community. Thus Table 6.2. lists “community” in parallel with the economy: both contribute to importance assessment.

### Table 6.1: Vulnerability Grading for Tables 6.3 – 6.5

<table>
<thead>
<tr>
<th>Vulnerability</th>
<th>Recovery Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Somewhat vulnerable</td>
<td>1 – 2 weeks</td>
</tr>
<tr>
<td>Vulnerable</td>
<td>2 – 4 weeks</td>
</tr>
<tr>
<td>Very vulnerable</td>
<td>More than 1 month</td>
</tr>
</tbody>
</table>

In a 500 year event the lifeline will be out of action into the recovery period for:

### Table 6.2: Importance Grading for Tables 6.3 – 6.5

<table>
<thead>
<tr>
<th>Importance</th>
<th>Mining</th>
<th>Dairy</th>
<th>Tourism</th>
<th>Community</th>
</tr>
</thead>
<tbody>
<tr>
<td>Important</td>
<td>Less than 4 weeks</td>
<td>Less than 4 weeks</td>
<td>Less than 2 weeks</td>
<td>Important</td>
</tr>
<tr>
<td>More important</td>
<td>4 to 8 weeks</td>
<td>4 to 8 weeks</td>
<td>2 to 8 weeks</td>
<td>More important</td>
</tr>
<tr>
<td>Very important</td>
<td>More than 8 weeks</td>
<td>More than 8 weeks</td>
<td>More than 8 weeks</td>
<td>Very important</td>
</tr>
</tbody>
</table>
## Table 6.3: Lifeline Asset Vulnerability and Importance – Earthquake

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Lifeline Assets</th>
<th>Vulnerability</th>
<th>Importance</th>
<th>Comment</th>
</tr>
</thead>
</table>
| 1   | Karamea     | • Airport  
• Stopbanks  
• Roads | Liquefaction damage | Air travel would be the only transport route to the area if the road is not available. | Some damage to all lifelines expected from shaking, liquefaction and ground movement. |
| 2   | Karamea – Little Wanganui | • Road  
• Power  
• Fibre | Liquefaction damage. | Lifelines important for the dairy farms to allow communications, production and regular export of milk from the area | Farmers have generators but fuel supply might be a limiting factor. |
| 3   | Karamea Bluffs & Mokihinui | • Road  
• Power  
• Fibre | Multiple slips and debris-flow damage due to earthquake | The only land link to the Karamea area | There is no alternative route available for all three assets. Failure of any for an extended time would have a severe impact on the community on the Karamea area. |
| 4   | Hector - Waimangaroa | • Road  
• Power  
• Fibre | Slips and structural damage | Loss of lifelines impacts on coal and dairy production and export. | Limited alternative power options particularly for the Stockton mine and in the Karamea area if the road (for fuel transport and milk export) is also affected. Loss of lifelines would isolate communities of Hector and Granty. |
| 5   | Westport Port | | Earthquake shaking damage | Used by fishing boats. No impact on mining, dairy and tourism | The port is only used by fishing boats. Vulnerable to lateral spreading of steep batter slopes and to liquefaction. |
| 6   | Westport Airport | | Earthquake shaking damage | Limited to no impact on mining, dairy and tourism | Impacts on the Buller District and may impact on Grey District also as it is the only airport on the Coast with regular direct flights to Wellington. |
| 7 | Westport (hotspot) | • Road inc SH 67  
• Rail  
• Power  
• Fibre  
• Water Supply  
• Sewerage | Earthquake shaking damage | Significant impact on mining as rail passes through Westport and many employees live in Westport. Dairy and tourism also affected but to a much lesser extent | Significant damage to Westport would impact directly on the mining and to a lesser extent the dairy and tourism sectors. The District Council’s building as well as BEL’s main office and main substation are in Westport and the fibre optic cable passes through Westport. |
| 8 | Buller River Bridge (hotspot) | • Road  
• Power  
• Fibre  
• Water  
• Sewage | Earthquake shaking damage | Would impact on a small part of West coast dairy and tourism. Major impact on the Westport community | Relatively high importance as it carries five lifelines and is the only road access to Westport and communities to the north. It is the only road access for communities, milk export from the area and mining supplies such as fuel. Temporary bridge could probably be reinstated in 4 to 8 weeks depending on availability. |
| 9 | Lower Buller Gorge | • Road  
• Rail | Landslide and debris flow damage due to earthquake | Main power supply for Buller district. Only route for exporting coal from Stockton. | Rail likely to be damaged for longest period and is the only route for coal export. Coastal SH 6 offers an alternative route for road traffic. |
| 10 | Upper Buller Gorge | • Road  
• Power | Landslide and debris flow damage due to earthquake | Loss of main Transpower supply to West Coast region would impact mining, dairy and tourism | Alternative road route. However main route for bringing most of Transpower to West Coast region. The Transpower 66kV line over Arthur’s Pass together with local generation might be able to meet much of the demand but depends on extent of shaking. |
| 11 | SH 6 Owen River - Kawatiri | • Road  
• Fibre  
• Landslide and debris flows  
• Bridge shaking damage | Loss of this SH route and the fibre would impact West Coast dairy and tourism. | Important road and fibre optic cable lifelines for the South Island. |
| 12 | Rapahoe – Charleston | Road • Power • Fibre | Landslide and debris flows | Complete disruption of tourism at Punakaiki | Route for the only fibre link to Westport and the north |
| 13 | Cobden Bridge (hotspot) | Road • Fibre • Water • Sewage | Earthquake shaking damage | Alternative road routes for dairy and tourism. Tourism north of the bridge affected by loss of telecommunications. South of the bridge tourism affected by loss of water. | Bridge failure would be a serious blow to the communities to the north of the bridge as they rely on Greymouth for many services. High community impact. Importance higher than for storm and tsunami because less likelihood of alternative route via Taylorville being available after a massive earthquake. |
| 14 | Greymouth airport | Shaking damage and liquefaction | Limited to no impact on mining, dairy and tourism. | Impact on the West Coast Region as the airport is a key resource for transporting patients between Greymouth and Christchurch hospitals. |
| 15 | Greymouth Port | Shaking damage | Used by fishing boats and fish processing. No impact on mining, dairy and tourism | The port is only used by the fishing industry. |
| 16 | Greymouth (hotspot) | Road incl SH 6&7 • Rail • Power • Fibre x2 • Water Supply • Sewerage • Floodwall/stopbanks | Shaking damage | Minimal impact on mining. However some impact on tourism and dairy as Greymouth is a central urban centre on the coast. Major community impact. | Significant damage to Greymouth may not impact directly on the mining, dairy and tourism sectors. However, the Regional and District Council offices as well as a number of engineering and other support services are located in Greymouth and all telecommunications are directed through the Greymouth exchange. Secondary effects on lifeline recovery management |
| 17 | Stillwater (Dobson to Arnold River) (hotspot) | • SH 7  
• GDC Road  
• Rail to north and south West Coast  
• Transpower x2  
• Westpower  
• Fibre x2 | Shaking damage to infrastructure and bridges, landslips in Brunner Gorge | The combination of disrupted lifelines will affect mining, dairy and tourism economies. | Closure of SH 7 and the Arnold Valley Road would significantly disrupt dairy and, to a lesser extent, tourism traffic.  
Loss of the railway would impact on coal dairy exports.  
Damage to the Transpower and Westpower networks would impact on power supply to the region, as would damage to the two fibre cables to the Coast. |
| 18 | Taramakau Bridge | • SH 6  
• Fibre | Shaking damage. | Does not affect mining. Loss of bridge and fibre would impact on tourism and dairy. Moderately severe community impact. | There are alternative routes around the Taramakau Bridge. However they can be substantially longer for those travelling between Grey and Westland districts e.g. between Hokitika and Greymouth.  
Loss of telecommunications would have a substantial impact until the fibre optic cable could be repaired.  
Bridge likely to be repaired at least temporarily within 4 weeks. |
| 19 | Stillwater to Jacksons | • Road  
• Rail  
• Fibre  
• Stopbank | Shaking damage, ground rupture and slips.  
Damage to bridges over Arnold and Crooked Rivers and possibly Taramakau River. | Potentially severe impact on mining, dairy and tourism as well as on community. | Major alternative road route bypassing Kumara. Road rail and fibre all pass along AF rupture zone.  
Severe possible consequence of Alpine Fault movement cutting through and displacing Inchbonnie stopbank. This could be dealt with simply by widening the stopbank. |
| 20 | Jacksons to Springfield (hotspot) | SH 73 | Midland Railway | Transpower | Westpower to Orla | Fibre | Landslide and debris flow damage to infrastructure and via dams | Ongoing material washed down streams | Bridge damage | Potentially severe impact on mining, dairy and tourism | Areas that are particularly vulnerable are the Otira Gorge (SH 73), the northern entrance to the Otira tunnel (rail), the Waimakariri Bluffs (SH 73) and Staircase (rail). Rail and road could potentially be disrupted for more than 6 months. When existing Bealey Bridge is replaced consider rerouting SH 73 along line of railway to avoid Waimak Bluffs/Paddys Bend. |
| 21 | Arahura Bridge | SH 6 | Rail | Fibre | Shaking damage | Severe impact on dairy and tourism | Loss of this new bridge would cut off Westland from the north – no alternative route other than Haast. |
| 22 | Hokitika Airport | Road incl SH 6 | Rail | Power | Fibre | Water Supply | Sewerage | Earthquake shaking damage. | Limited to no impact on mining, dairy and tourism. Community impact. | Significant impact on the West Coast community as it is the only airport providing routine flights to Christchurch. Runway damage unlikely and repair reasonably rapid. |
| 23 | Hokitika | Road incl SH 6 | Rail | Power | Fibre | Water Supply | Sewerage | Shaking damage | Significant impact on dairy and tourism as the WMP factory is located in Hokitika and most tourists pass through Hokitika. Major community impact. | Significant damage to Hokitika would impact directly on the Council building and on WMP as many of their employees live in Hokitika. Hokitika is an important town on the tourist route through the West Coast. Secondary impact on lifeline utilities if Council management capability compromised by damage. |
| 24 | Westland Milk Products factory | Power | Water supply | Telecomms | Earthquake shaking damage. | Severe impact on dairy industry | Earthquake is likely to cause structural damage to the factory buildings and damage the integrity of the factory processing equipment. Major importance to regional economy. Structural and equipment integrity would have to be checked after earthquake event. |
### Ross to Fox Glacier (hotspot)
- Road incl. SH 6
- Power
- Fibre

- Shaking damage
- Landslides
- Bridge damage
- Ground rupture

Great impact on tourism and to a much lesser extent dairy. Little or no impact on mining.

Earthquake, such as a large Alpine Fault earthquake in the Ross to Fox area would seriously damage all three lifelines. Catastrophic effect on tourist pipeline. Road crosses AF rupture zone a number of times and several bridges are close to the fault.

### Franz Josef and Fox Glacier townships (hotspot)
- Road incl. SH 6
- Power
- Fibre
- Water supply
- Sewerage
- Stopbanks

- Shaking damage
- Landslides
- Bridge damage
- Ground rupture

Great impact on tourism

Major loss of accommodation – tourism pipeline would be shut for many months.

### Fox to Haast
- Road incl. SH 6

- Shaking damage
- Landslides
- Bridge damage
- Ground rupture

Great impact on tourism and the small number of dairy farms in the area.

Earthquake, such as a large Alpine Fault earthquake in the Fox to Haast area would seriously damage all three lifelines. Road route crosses expected AF rupture zone a number of times from Fox to Haast, and several bridges are close to the fault.

### Haast Aerodrome
- Shaking damage

Small impact on tourism flights

### Haast to Jackson Bay
- Road
- Power
- Wharf

- Shaking damage to bridges and wharf, landslides close to Bay

No impact on mining, dairy or tourism

Great damage to the wider area by an Alpine Fault earthquake would mean that the Haast Aerodrome and Jackson Bay wharf would become vital transport links for many weeks/months until roads are repaired.
### Table 6.4: Lifeline Asset Vulnerability and Importance – Storm

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Lifeline Assets</th>
<th>Vulnerability</th>
<th>Importance</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Karamea</td>
<td>• Stopbank</td>
<td>Flood inundation damage</td>
<td>The bridge and possibly the stopbanks are important lifeline assets for the dairy industry in the Karamea area, as well as for the community.</td>
<td>Includes the Karamea township, stopbanks and bridge. Flood debris can be cleared relatively quickly to provide road access though property damage will take longer.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Bridge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Karamea – Little Wanganui</td>
<td>• Road</td>
<td>Flood damage</td>
<td>Lifelines important for the dairy farms to allow communications, production and regular export of milk from the area</td>
<td>In a major storm, not only could flooding be widespread but also wind damage could affect power and telecommunications lines and road access. However, unless there were major problems on the Karamea Highway, access and power could probably be restored within a week. Farmers have generators but fuel supply might be a limiting factor.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Power</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fibre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Karamea Bluffs &amp; Mokihinui</td>
<td>• Road</td>
<td>Multiple slips and debris from major storm including wind</td>
<td>Apart from air, the only access to the Karamea area affecting the dairying economy and the community</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Power</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fibre</td>
<td>Possible flood damage at Mokihinui.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Hector - Waimangaroa</td>
<td>• Road</td>
<td>Exposed to storm surge and wind damage. Should be repairable within a week. Rail probably not affected.</td>
<td>Loss of lifelines impacts on coal and dairy production and export.</td>
<td>Limited alternative power options particularly for the Stockton mine and in the Karamea area if the road (for fuel transport and milk export) is also affected. Loss of lifelines would affect communities of Hector and Gravity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Power</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fibre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Westport Port</td>
<td>Flood inundation damage</td>
<td>Used by fishing boats. No impact on mining, dairy and tourism</td>
<td>The port is only used by fishing boats.</td>
<td></td>
</tr>
<tr>
<td>#</td>
<td>Location</td>
<td>Lifelines at Risk</td>
<td>Impacts</td>
<td>Details</td>
<td></td>
</tr>
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</tr>
<tr>
<td>6</td>
<td>Westport Airport</td>
<td>Flood inundation damage from storm surge.</td>
<td>Limited to no impact on mining, dairy and tourism</td>
<td>Impacts on the Buller District and may impact on Grey District also as it is the only airport on the Coast with regular direct flights to Wellington.</td>
<td></td>
</tr>
</tbody>
</table>
| 7 | Westport (Hotspot) | • Road incl. SH 67  
• Rail  
• Power  
• Fibre  
• Water Supply  
• Sewerage | Flood inundation damage | Significant impact on mining as rail passes through Westport and many employees live in Westport. Dairy and tourism also affected but to a lesser extent. Major effect on community. | Significant damage to Westport would impact directly on the mining and to a lesser extent the dairy and tourism sectors. BEL’s main office and main substation as well as the District Council building are in Westport and the fibre optic cable passes through Westport. Secondary effects on lifeline assets could occur through management capability being compromised. The Buller District Council building would be impacted. |
| 8 | Buller River Bridge (Hotspot) | • Road  
• Power  
• Fibre  
• Water  
• Sewage | Flood damage possible | Would impact on a part of West coast dairy and tourism, but major effect on Westport community. | High importance as it carries five lifelines and is the only road access to Westport and communities to the north. It is the only road access for communities, for milk export from the area and for mining supplies such as fuel. Temporary bridge could probably be reinstated in 4 to 8 weeks depending on availability. |
| 9 | Lower Buller Gorge | • Road  
• Rail | Landslide and debris damage due to major storm. Rail is vulnerable to slips. | Only rail route for exporting coal from Stockton. | Rail blockage should be reparable within a week. SH 6 offers an alternative route for road traffic. Any damage to Transpower would probably be repaired within a week apart from possible major wind damage. |
| 10 | Upper Buller Gorge | • Road  
• Power | Landslide and debris damage due to major storm. | Loss of main Transpower supply to West Coast region would impact mining, dairy and tourism but less likely than road closure. | Alternative road route available. Main route for bringing in most of Transpower to West Coast region, although less vulnerable to slips than the road. Vulnerability of power lines to wind needs to be looked at. |
<table>
<thead>
<tr>
<th>Page</th>
<th>Location</th>
<th>Impact</th>
<th>Recovery</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>SH 6 Owen River - Kawatiri</td>
<td>Bridge and road damage due to storm scour, flooding or debris flows near Kawatiri.</td>
<td>Loss of this SH route and the fibre would impact seriously on West Coast dairy and tourism.</td>
<td>Important road and fibre-optic cable lifelines for the South Island.</td>
</tr>
<tr>
<td>12</td>
<td>Rapahoe – Charleston</td>
<td>Storm damage. Only fibre route to Westport and the north. Power less an issue here.</td>
<td>Disruption of tourism at Punakaiki and communication to the north.</td>
<td>Coastal erosion and storm surge could take out sections of road and lead to breaks in fibre cable.</td>
</tr>
<tr>
<td>13</td>
<td>Cobden Bridge (Hotspot)</td>
<td>Flood/scour damage (unlikely)</td>
<td>Mining not affected. Alternative road routes for dairy and tourism. Tourism north of the bridge affected by loss of telecommunications. South of the bridge tourism affected by loss of water. However likely to both be fixed quickly. Bridge outage major blow to communities N of the river.</td>
<td>Though the bridge is unlikely to be damaged, nevertheless its loss would be a major blow to communities north of the bridge which rely on Greymouth for many services. There is an alternative route through Stillwater however.</td>
</tr>
<tr>
<td>14</td>
<td>Greymouth airport</td>
<td>Flood inundation damage</td>
<td>Limited to no impact on mining, dairy and tourism</td>
<td>Impact on the West Coast Region as the airport is a key resource for transporting patients between Greymouth and Christchurch hospitals. Low vulnerability to storm surge however.</td>
</tr>
<tr>
<td>15</td>
<td>Greymouth Port</td>
<td>Flood inundation damage</td>
<td>Used by fishing boats and fish processing. No impact on mining, dairy and tourism</td>
<td>The port is only used by the fishing industry.</td>
</tr>
</tbody>
</table>
| 16 | Greymouth (Hotspot) | • Road incl SH 6&7  
• Rail  
• Power  
• Fibre x2  
• Water Supply  
• Sewerage | Flood inundation damage | Minimal impact on mining. However some impact on tourism and dairy as Greymouth is a central urban centre on the coast. Major impact on community. | Significant damage to Greymouth might not impact directly on mining, dairy or tourism. However, the Regional and District Council offices as well as a number of engineering and other support services are located in Greymouth, all telecommunications are directed through the Greymouth exchange and there could be secondary effects on lifelines through impact on management capability. The size of the urban community means that a flood overtopping the floodwalls – which would happen in a 500-year precipitation event – would have a serious effect. |

| 17 | Stillwater (Dobson to Arnold River) (Hotspot) | • SH 7  
• GDC Road  
• Rail to north and south West Coast  
• Transpower x2  
• Westpower  
• Fibre x2 | Storm damage including flood inundation and slips through Brunner Gorge | The combination of disrupted lifelines would affect the mining, dairy and tourism economies. | Vulnerability not extreme, but closure of SH 7 and the Arnold Valley Road would significantly disrupt dairy and, to a lesser extent, tourism traffic so high importance level. Loss of the railway would impact on coal (flooding, scour near Arnold) and dairy exports (slips in Brunner Gorge). Damage to the Transpower and Westpower networks less likely but would impact on the power supply to the region. |

| 19 | Stillwater to Jacksons | • Road  
• Rail  
• Fibre  
• Stopbank | • Landslide and debris flow damage  
• Bridge damage | Potentially severe impact on mining, dairy and tourism. | Flood damage and slips would probably be cleared within a week but bridge damage might take longer to repair. |
<table>
<thead>
<tr>
<th></th>
<th>Jacksons to Springfield (Hotspot)</th>
<th>Arahura Bridge (Hotspot and pinchpoint)</th>
<th>Hokitika (Hotspot)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>20</strong></td>
<td>SH 73</td>
<td>Deck damage to infrastructure</td>
<td>Road incl. SH 6</td>
</tr>
<tr>
<td></td>
<td>Midland Railway</td>
<td>Bridge damage.</td>
<td>Rail</td>
</tr>
<tr>
<td></td>
<td>Transpower</td>
<td>Storm damage including scour and flooding</td>
<td>Power</td>
</tr>
<tr>
<td></td>
<td>Westpower to Otira</td>
<td></td>
<td>Fibre</td>
</tr>
<tr>
<td></td>
<td>Fibre</td>
<td>Flood damage (unlikely)</td>
<td>Fibre</td>
</tr>
<tr>
<td><strong>21</strong></td>
<td>SH 6</td>
<td></td>
<td>Road incl. SH 6</td>
</tr>
<tr>
<td></td>
<td>Rail</td>
<td></td>
<td>Rail</td>
</tr>
<tr>
<td></td>
<td>Fibre</td>
<td></td>
<td>Power</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fibre</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water Supply</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sewerage</td>
</tr>
<tr>
<td><strong>23</strong></td>
<td></td>
<td></td>
<td>Road incl. SH 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rail</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Power</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Fibre</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water Supply</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sewerage</td>
</tr>
</tbody>
</table>

The Otira Gorge area is particularly vulnerable to slips and debris flows which could occur in unexpected locations. The railway has historically been affected by washouts. Some streams can carry large debris loads (Kellys Creek and Rough Creek for example), and bridges are vulnerable to aggradation and scour. Most storm-related problems would be cleared up within a week though. Although the Arahura Bridge is not particularly vulnerable to storm-related damage, it is highly important as failure here would cut the tourist pipeline and most of the dairy pipeline. Significant impact on dairy and tourism as the WMP factory is located in Hokitika and most tourist pass through Hokitika. Significant damage to Hokitika would impact directly on the Council building and hence its ability to manage, and on WMP as many employees live in Hokitika. Hokitika is an important town on the tourist route through the West Coast. A 500-year flood would cause major damage to the community, especially impacting the CBD. As with Greymouth and Westport, major flooding would have a secondary effect on lifelines by compromising emergency management capability. Westland District Council offices are vulnerable.
| 25 | Ross to Fox Glacier (Hotspot) | Roads incl. SH 6 • Power • Fibre • Water • Sewage | Flooding, slips, bridge scour. Wind-related problems such as power pole fracture, access problems, structural or bridge failure. | Greatest impact on tourism and to a much lesser extent dairy. | Major impact on the tourist pipeline, with severe threats to roading, power and communication. Tree-fall from a severe windstorm could lead to serious access problems when repairing faults in power lines and communication cables. |
| 26 | Franz Josef and Fox Glacier townships (Hotspot and pinchpoint) | Roads incl. SH 6 • Power • Fibre • Water supply • Sewerage | Storm and flood damage | Great impact on tourism | Major impact on the tourist pipeline, with severe threats to roading, power, accommodation and communication as well as local sewage and water services. |
| 27 | Fox to Hawea | Roads incl. SH 6 | Storm damage, flooding, debris flows, slips. Wind damage | Greatest impact on tourism and the small number of dairy farms in the area. | Major impact on the tourist pipeline. The route contains a number of specific storm-related vulnerabilities such as at the Gates of Haast, and debris-flow problems on SH 6 at the top end of Lake Wanaka. |
| 28 | Haast Aerodrome | | Flood inundation damage | Small impact on tourism flights |
| 29 | Haast to Jackson Bay | Roads • Power | Flood inundation and storm surge damage, particularly at Okuru Estuary and Neils beach Slips near Jackson Bay Wind damage | | Local hydro station exposed to flood damage and distribution lines to wind damage. Impacts could be severe for the local community even though minimal for the region as a whole. |
## Table 6.5: Lifeline Asset Vulnerability and Importance – Tsunami

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Lifeline assets</th>
<th>Vulnerability</th>
<th>Importance</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Karamea</td>
<td>• Airport • Stopbank</td>
<td>Inundation damage to town and moderate impact on some lifeline assets from major tsunami.</td>
<td>Town, airport and roading are vulnerable to tsunami. Dairying and community are both affected</td>
<td>No obvious resilience improvement. The stopbank geometry might amplify effect on town: check effect of changed geometry at mouth (lagoon). Typical damage would include impact from surge-carried debris.</td>
</tr>
<tr>
<td>2</td>
<td>Karamea – Little Wanganui</td>
<td>• Road • Power • Fibre</td>
<td>Inundation damage along low-lying coast including loss of substation and generator.</td>
<td></td>
<td>Power loss would mean farms N of Little Wanganui would have to rely on generators. Fuel availability would be an issue.</td>
</tr>
<tr>
<td>4</td>
<td>Hector to Waimangaroa (hotspot)</td>
<td>• Road • Rail • Power • Fibre</td>
<td>Major inundation damage would have severe effect on all structures and lifeline assets including loss of Ngakawau substation.</td>
<td>Loss of lifelines would impact on coal and dairy production and export.</td>
<td>Major impact on communities of Hector and Gravity – tsunami would seriously damage or destroy homes and other structures in the area. Limited alternative power options particularly for the Stockton mine and in the Karamea area as fuel supply cut off due to road damage. Road closure would also stop milk export. All lifelines seriously damaged. Protection generally infeasible.</td>
</tr>
<tr>
<td>5</td>
<td>Westport Port</td>
<td></td>
<td>Inundation damage</td>
<td>Used by fishing boats. No impact on mining, dairy and tourism</td>
<td>The port is only used by fishing boats.</td>
</tr>
<tr>
<td>6</td>
<td>Westport Airport</td>
<td></td>
<td>Inundation damage</td>
<td>Limited to no impact on mining, dairy and tourism</td>
<td>Impacts on the Buller District and may impact on Grey District also as it is the only airport on the Coast with direct flights to Wellington.</td>
</tr>
<tr>
<td>7</td>
<td>Westport and Carter’s Beach (hotspot)</td>
<td>• Road incl. SH 67 • Power • Water Supply • Sewage</td>
<td>Inundation of northern part of the town</td>
<td></td>
<td>Significant impact on Westport community but minor impact on lifeline assets. Services affected are peripheral networks of power, water supply, sewerage and communication cables.</td>
</tr>
<tr>
<td>Page</td>
<td>Location</td>
<td>Lifelines</td>
<td>Impact</td>
<td>Significance</td>
<td></td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>8</td>
<td>Buller River Bridge (hotspot)</td>
<td>Road, Power, Fibre, Water, Sewage</td>
<td>Scour and impact damage (unlikely)</td>
<td>Would impact on a small part of West Coast dairy and tourism, but major impact on Westport community.</td>
<td>Relatively high importance as it carries five lifelines and is the only road access to Westport and communities to the north. It is the only road access for communities and milk export from the area and main supply route for commodities for mining (e.g. fuel). Temporary bridge could probably be reinstated in 4 to 8 weeks depending on availability e.g. Bailey bridges are stored in Canterbury.</td>
</tr>
<tr>
<td>12</td>
<td>Rapahoe – Charleston (hotspot)</td>
<td>Road, Power, Fibre</td>
<td>Inundation and scour damage, including loss of sections of road and fibre cable</td>
<td>Major disruption of tourism at Punakaiki</td>
<td>Community between Charleston and Rapahoe directly affected. Loss of fibre would severely impact on telecommunication from Charleston northward to Karamea.</td>
</tr>
<tr>
<td>13</td>
<td>Cobden Bridge (hotspot)</td>
<td>Road, Fibre, Water, Sewage</td>
<td>Scour damage (unlikely)</td>
<td>Mining not affected (no mining at Spring Creek at the moment). Alternative road routes for dairy and tourism. Tourism north of the bridge affected by loss of telecommunications. South of the bridge tourism affected by loss of water, though both are likely to be fixed quickly.</td>
<td>The Greymouth community south of the bridge would be severely affected loss of water. North of the river sewage would have to be directed to treated outfall at Nelson Quay. Communities north of the bridge relying on the fibre optic cable would have no telecommunications. Neither would they have easy access to medical services or food and other supplies. Hence serious effect on a large community.</td>
</tr>
<tr>
<td>14</td>
<td>Greymouth airport</td>
<td></td>
<td>Inundation damage</td>
<td>Limited to no impact on mining, dairy and tourism, but significant community impact.</td>
<td>Impact on the West Coast Region as the airport is a key resource for transporting patients between Greymouth and Christchurch hospitals.</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>Inundation, scour and impact damage</td>
<td>Used by fishing boats and fish processing. No impact on mining, dairy and tourism</td>
<td>The port is only used by the fishing industry.</td>
<td>Significant damage to Greymouth may not impact directly on the mining, dairy and tourism sectors. However the Regional and District Council offices as well as a number of engineering and other support services are located in Greymouth and all telecommunications are directed through the Greymouth exchange. Impacts all Grey District. Secondary impairment of lifelines could occur due to impact on management capability.</td>
</tr>
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</tr>
<tr>
<td>15</td>
<td>Greymouth Port</td>
<td>Inundation damage</td>
<td>Major community impact on largest urban area on the Coast. Some impact on tourism and dairy. Minimal impact on mining.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(hotspot)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>16</td>
<td>Greymouth</td>
<td>Road incl. SH 6&amp;7</td>
<td>Inundation damage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bridge (hotspot)</td>
<td>Rail</td>
<td></td>
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<td></td>
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<td>Power</td>
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<td>Fibre x2</td>
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<td>Water Supply</td>
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<td></td>
<td></td>
<td>Sewerage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Arahura Bridge</td>
<td>SH 6</td>
<td>Inundation and scour damage</td>
<td>Severe impact on dairy and tourism</td>
<td>The bridge is a critical link between Westland and the north, with no alternative route round it.</td>
</tr>
<tr>
<td></td>
<td>(hotspot)</td>
<td>Rail</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Power</td>
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<tr>
<td></td>
<td></td>
<td>Fibre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Hokitika</td>
<td>Road incl. SH 6</td>
<td>Inundation damage</td>
<td>Significant impact on dairy and tourism as the WMP factory is located in Hokitika and most tourist pass through Hokitika. Major centre of population, and serious damage to CBD.</td>
<td>Significant damage to Hokitika and particularly the CBD. WDC offices and telephone exchange likely to be seriously affected. Would impact directly on WMP as many of their employees live in Hokitika. Hokitika is an important town on the tourist route through the West Coast.</td>
</tr>
<tr>
<td></td>
<td>(hotspot)</td>
<td>Rail</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power</td>
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<td></td>
<td></td>
<td>Fibre</td>
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<td></td>
<td></td>
<td>Water Supply</td>
<td></td>
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<td></td>
<td></td>
<td>Sewerage</td>
<td></td>
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<tr>
<td>25</td>
<td>Ross to Fox</td>
<td>Power</td>
<td>Inundation damage</td>
<td>Greatest impact on tourism and to a much lesser extent dairy. Little or no impact on mining.</td>
<td>Tsunami damage likely to be minor and soon repaired. The most vulnerable assets would be the power lines and fibre cables on common poles between the Mikonui River and Bold Head.</td>
</tr>
<tr>
<td></td>
<td>Glacier</td>
<td>Fibre</td>
<td></td>
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<td>Section</td>
<td>Impact</td>
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</tr>
<tr>
<td>Fox Glacier to Hawea</td>
<td><strong>Road</strong></td>
<td><strong>Inundation damage</strong></td>
<td>Great impact on tourism and the small number of dairy farms in the area.</td>
<td>Tsunami damage severe in a small number of localities, especially Bruce Bay and between Ship Creek and the Haast River.</td>
<td></td>
</tr>
<tr>
<td>Haast to Jackson Bay</td>
<td><strong>Road</strong></td>
<td><strong>Inundation damage</strong></td>
<td>No impact on mining, dairy or tourism but significant impact on local community.</td>
<td>Major tsunami would be likely to destroy the wharf and several sections of road, and damage several bridges, power lines, the diesel generator and substation.</td>
<td></td>
</tr>
</tbody>
</table>
7 RECOMMENDATIONS

Recommendations are made in three levels. Those in the first set are general with broad application, such as the recommendation about a central roading spine given Section 5 above.

At the second level the recommendations are more specific. They are derived from the step-by-step survey of vulnerability and importance across the region, and briefly beyond it where infrastructure failure would directly affect the Coast, as presented in Tables 6.3 to 6.5 above. The second-level recommendations relate to those West Coast elements where both vulnerability and importance are judged to be very high.

At the third level the recommendations are local and detailed. They are not given here but are confined to the report’s supplements, particularly Supplements 10 to 12 which deal with the infrastructure assets of the three West Coast districts, and Supplements 6 to 9 which address other lifelines. Section 8 below lists and describes all Supplements.

Level 1 recommendations are as follows:

1. When considering resilience, three points should be remembered. The first is to expect the unexpected. The second is that quick, flexible and creative response is required – a need to be fleet of foot. The third is to use and enhance buffering wherever possible, to buy time. All three are helped by practice.

2. Consider what can be done to improve the resilience (robustness and reparability) of a central spine of roading, as identified in Figure 5.1 above.

3. Consider how power from local electricity generation (including diesel) can best be made available and distributed following a disaster which has taken out grid power.

4. Review the adequacy and availability of fuel supplies for recovery, in particular for road repairs and emergency generators.

5. Immediately following a disaster ensure the speedy availability of communication and information to help future planning through the recovery period.

6. Emphasise restoration of the economy, including the three virtual pipelines: essential flows of mining, dairy and tourism.

7. Consider improving fibre-optic redundancy by installing a cable from Inangahua to Westport.

8. Check infrastructure resilience to flooding in Westport, Greymouth and Hokitika.

9. In the light of the Christchurch experience, review the importance of non-technical issues such as insurance, money flow, governance, inappropriate and conflicting regulations in the recovery period.
Level 2 recommendations are given in Table 7.1 below.

<table>
<thead>
<tr>
<th>No</th>
<th>Description</th>
<th>Lifeline assets</th>
<th>Comments</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Karamea Bluffs and Mokihinui</td>
<td>Road, power, fibre</td>
<td>Only surface link to Karamea area. Major earthquake would give long outage due to ongoing slips and also debris flow down streams.</td>
<td>Review hardening possibilities in detail, including rerouting, benching, providing passage for stream debris.</td>
</tr>
<tr>
<td>2</td>
<td>Westport</td>
<td>Road, rail, power, fibre, water supply, sewage, asset management</td>
<td>Level of destruction from a 500-year storm-related flood would have significant impact on mining, community (local and regional) and to a lesser extent tourism and dairy.</td>
<td>Work to improve flood protection. bearing in mind that though it might deal with most flooding, there would always be the possibility that a 500-year storm might overwhelm the defences. Review infrastructure resilience including management capability.</td>
</tr>
<tr>
<td>3</td>
<td>Greymouth</td>
<td>Road, rail, power, fibre, water supply, sewage, asset management</td>
<td>Flood due to 500-year storm would have severe impact on local and regional community and on a number of engineering and support services including hospital. Local infrastructure would suffer and so might telecommunications. Asset management capability could be compromised.</td>
<td>Review infrastructure resilience including management capability on the assumption that someday the floodwalls would be overtopped.</td>
</tr>
<tr>
<td>4</td>
<td>Stillwater to Jacksons</td>
<td>Road, rail, fibre, stopbank</td>
<td>Earthquake damage: shaking, ground rupture, slips, bridges; potentially severe impact on mining, dairy, tourism. Stopbank shearing at Inchbonnie could result in diversion of Taramakau through L. Brunner</td>
<td>Resources available for speedy restoration. Consider doubling width of Inchbonnie stopbank to avoid complete shear rupture.</td>
</tr>
<tr>
<td>5</td>
<td>Jacksons to Springfield</td>
<td>Road, rail, fibre, power</td>
<td>Widespread earthquake damage, potentially severe impact on mining, dairy and tourism.</td>
<td>Ensure resources available for speedy restoration. Consider rerouting vulnerable (and awkward) section of SH 73 at Paddys Bend/Waimakariri Bluffs to follow rail route.</td>
</tr>
<tr>
<td>6</td>
<td>Westland Milk Products factory</td>
<td>Earthquake shaking damage</td>
<td>Severe impact on West Coast dairy industry</td>
<td>Earthquake is likely to cause structural damage to the factory buildings and to damage the integrity of the processing and storage facilities. Suggest careful checking of all.</td>
</tr>
<tr>
<td>7</td>
<td>Ross to Fox Glacier</td>
<td>Road, power, fibre</td>
<td>Earthquake and storm damage would have great impact on tourism and some impact on dairy. Earthquake would give shaking damage, ground rupture, landslides and bridge damage. Major storm would produce flooding, slips, bridge scour and wind-related damage. Restoration would suffer from access problems.</td>
<td>Resources available for speedy restoration, including availability of temporary bridging and fuel. Capability required for rapid damage assessment.</td>
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<tr>
<td>8</td>
<td>Franz Josef and Fox Glacier townships</td>
<td>Road, power, fibre, water supply, sewerage, accommodation</td>
<td>Franz Josef particularly is very vulnerable to earthquake and storm (flood) damage. The two townships are critical points for West Coast tourism.</td>
<td>Every effort should be made to decrease the vulnerability of Franz Josef in particular and to ensure resources are in place to repair damage and restore functionality as quickly as possible.</td>
</tr>
<tr>
<td>9</td>
<td>Fox Glacier to Hawea</td>
<td>Road</td>
<td>A major earthquake in this region would produce major damage to infrastructure through shaking ground rupture, landslides and bridge damage. The area is vulnerable to storm damage through flooding, slips and debris flows as well as to wind damage. The road is a critical link for tourism.</td>
<td>Resources available for speedy restoration, including availability of temporary bridging and fuel. Capability required for rapid damage assessment. Consider possible means of decreasing road vulnerability at Knights Point.</td>
</tr>
</tbody>
</table>
8 THE REPORT SUPPLEMENTS

The report as a whole deals with West Coast lifeline vulnerabilities and how the Coast might respond to a major natural disaster. It is split into the report itself, covering the broad issues, and a series of supplements which go into more detail. The twelve supplements are stand-alone documents in their own right, designed to be read independently according to the reader’s particular interests.

The supplements are summarised as follows:

<table>
<thead>
<tr>
<th>Supplement No.</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>A short piece on the nature of resilience and on strategies for improving it. For many people, a focus on resilience requires a shift in stance, a change of attitude with an emphasis (the report explains) on black swans. It is background information, and recommended reading for all ages.</td>
</tr>
<tr>
<td>2</td>
<td>Outline of the earthquake disaster vulnerability-probing scenario.</td>
</tr>
<tr>
<td>3</td>
<td>Outline of the storm disaster vulnerability-probing scenario and reasoning behind choice of 500-year storm. Wind and precipitation are both included.</td>
</tr>
<tr>
<td>4</td>
<td>Outline of the tsunami disaster vulnerability-probing scenario.</td>
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<tr>
<td>5</td>
<td>A general discussion on landslides, slips and debris flows, clarifying the distinction between them.</td>
</tr>
<tr>
<td>6</td>
<td>A discussion of transportation: road, rail, air and sea together with the relevant infrastructure.</td>
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<tr>
<td>7</td>
<td>This supplement deals with telecommunications – landlines, cell phones and radio communications of different sorts, focusing again on infrastructure as well as functionality.</td>
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<tr>
<td>8</td>
<td>Energy on the West Coast: electric power and its distribution as well as fuel issues.</td>
</tr>
<tr>
<td>9</td>
<td>A consideration of regional flood protection infrastructure.</td>
</tr>
<tr>
<td>10</td>
<td>Review of Buller District Council lifeline assets.</td>
</tr>
<tr>
<td>11</td>
<td>Review of Grey District Council lifeline assets.</td>
</tr>
<tr>
<td>12</td>
<td>Review of Westland District Council lifeline assets.</td>
</tr>
</tbody>
</table>
REFERENCES


