Franz Josef Natural Hazards Options Assessment and Cost Benefit Analysis

Appendices

Appendix A: Study scope

West Coast Regional Council (WCRC) engaged Tonkin + Taylor (T+T) and EY to undertake an analysis of options to mitigate the natural hazard risks facing Franz Josef township. The scope of work included:

- Understanding the natural hazard risks as identified in the literature and through engagement with stakeholders
- Identifying options to manage these risks to protect the value at stake in the township and the wider Franz Josef area
- Undertaking a multi-criteria assessment (MCA) of the options identified to identify three packages of options which best fulfil the investment criteria for testing in the cost benefit analysis (CBA)
- Evaluating the three preferred packages using CBA and CBAx

The work is intended to provide the Franz Josef community, as well as wider stakeholder groups, with an evidence base to enable important discussions to be had and decisions to be made about risk, tolerance and the future prosperity of Franz Josef.

Figure 15-1 provides an overview of our approach to assess the costs and benefits of a preferred programme to provide resilience to the natural hazards that are a reality for the township. Additional detail for each task follows.

Figure 15-1: Study approach

Tasks	Key Steps	Outcomes
Study inception	• Review and agree project timeframes and outcomes • Agree engagement process with Franz Josef Working Group • Agree frequency of updates to WCRC	Study Plan Risk Register
Task 1. The case for change	• Review and synthesise existing knowledge about community expectations, aspirations and risk tolerance • Review hazard assessment information and create simple picture of potential hazard consequences	Case for change documented
Task 2: Investment objectives	• Develop long list of investment objectives based on the information gathered in Task 1, and refine based on input from the expert team • Translate to evaluation criteria for use in the options assessment (Task 4) • Test and agree investment objectives and critical success factors as assessment criteria with the FJWG (and wider external stakeholders as possible)	Agreed investment objectives and critical success factors
Task 3: Options identification	• Develop long list of options leveraging internal specialist expertise to ensure options are practical, effective and feasible • Test and refine with FJWG • Map against vulnerabilities and determine beneficiaries	List of agreed options to be assessed including efficacy and potential value
Task 4: Hazard risk analysis	• Develop scenarios for earthquake and flood events • Develop baseline consequences (including environmental, social, cultural and economic impacts) • Undertake geospatial mapping to support visualisation of consequence	Baseline assessment of the value at stake for the ‘do nothing’ scenario
Task 5: Options assessment	• Develop MCA based on agreed evaluation criteria • Initial filter of options to develop potential intervention programmes • Refine programmes and demonstrate impacts geospatially • Cost benefit analysis and CBAx	Cost and benefits of preferred programmes documented
Reporting & next steps	• Summary report of the preferred way forward in a format suitable for ongoing consultation	Final report summarising the results

1 Task descriptions

Task 1: Document and confirm the need to invest and the case for change

To document the case for change we drew on local knowledge and experiences as well as extracted public information which describes and characterises the community's expectations and aspirations for protection and growth. Documents included:

- Tai Poutini West Coast Growth Study and Action Plan
- Relevant provisions of current regional and district plans
- Relevant information from the (now withdrawn) Plan Change 7 process (section 32 & 42 reports, submissions, evidence and decisions)
- Masterplanning process to-date

We also extracted information from the GNS Natural Hazards Assessment report and available flood reports. This was combined with photographs and other information from our experience with other natural hazard events (including Christchurch and Kaikoura earthquakes and flood events in similar catchments) to produce a simple and clear picture of what the consequences of potential future hazard events may look like.

Task 2: Agree investment objectives (including critical success factors and evaluation criteria)

Drawing on the information reviewed to document the case for change, our core team developed a strawman of investment objectives and critical success factors to evaluate potential options.

We then facilitated a workshop with the FJWG at which we presented and tested:

- The case for change
- Proposed investment objectives
- Proposed critical success factors

Task 3: Options Identification

Using the list of options in the Request for Proposal document as a starting point, our core team and specialist expert team undertook a collaborative process to identify a long list of potential options to mitigate hazard risks and enable growth. The focus of that work was on developing practical and pragmatic options, based on the team's extensive hands-on experience. It is crucial to note that we see options identification as a broad exercise where all potential options (engineering, people, process, technology, finance, etc.) should be considered.

Potential options were also generated is three sessions in Franz Josef:

- Franz Josef Working Group
- Waiho River Working Group
- Community members who attended a townhall-style community meeting

Task 4: Analyse hazard risk

The 2016 GNS Natural Hazard Assessment was the starting point for our analysis of hazard risks. It identifies the following key natural hazard scenarios presenting risk to Franz Josef township:

- Ground (faulting) rupture
- Earthquake shaking (including potential co-seismic large rock landslide)

- Inundation by water and flood debris

The consequences (to people, property, local and regional economy, environmental and socio-cultural values) of these scenarios were identified. Costs were quantified and estimated as appropriate using indicative damage and cost relationships for physical assets, life and injury and qualitative descriptions where appropriate.

The thrust of our approach was to simplify the hazard assessment to concentrate only on the effects from natural hazards that materially affect Franz Josef township and the wider Franz Josef area. An Alpine Fault rupture and a flood scenario both have the potential to significantly impact Franz Josef, and both are possible in the next 50 years. This assessment formed the 'do nothing' assessment, and is the base case which packages of options are tested against in the CBA in Task 5.

Task 5: Options assessment

The options assessment comprised two components: multi-criteria assessment, and cost benefit analysis (including CBA and CBAx).

Multi-criteria assessment

MCA is an excellent tool through which to measure and prioritise options against objectives that may, or may not, be able to be monetised, such as many of the critical success factors developed for Franz Josef and agreed with the FJWG in Task 2 which can be summarised as:

- ***Effectiveness***: How effective will the solution be in achieving the investment objectives?
- ***Value:*** What are the costs and benefits?
- ***Implementation:*** Does the community endorse and support the implementation of the option and does the option have interdependencies or barriers to implementation (e.g. legislative / regulatory, technical, political)?

The MCA took a wide view of value, and included the potential broader environmental, social, cultural and wider economic costs and benefits of each option, as well as the cost of implementation. In developing the MCA we leveraged our recently completed research for NZTA (published in April 2017) which resulted in the development of an MCA-based approach to evaluate resilience options.

Options were then filtered and grouped into packages of options. Each package includes the most appropriate mix of options which provide resilience in the context of the hazards faced and meet the investment criteria. Packages include consideration of interdependencies (enablers and dependencies) between options, as well as practical approaches to staging.

Cost benefit analysis

Following the creation of distinct packages of work, we then used an economic CBA to assess the short-listed packages of options.

CBA is an options assessment and decision-making tool that assesses the value of a project or competing projects on a consistent basis. It is not 'more important' than other analytical techniques, but does provide another lens by quantifying all costs and benefits in monetary terms, where possible and discounting them to a common point in time to determine the net benefits of each project. In this sense it is often the 'visible' end point of wider process.

A range of costs and benefits (some able to be derived financially, and some not) are identified in the CBA, including costs and benefits locally, regionally, and nationally.

CBAx

We subsequently applied the detailed CBA to Treasury's CBAx model. This provides a national perspective for central Government decision-making.

Task 6: Reporting and Next Steps

Following the completion of the above five tasks, this report was produced to form the evidence base to progress through the various decision-making processes, as well as interact with affected stakeholders.

Timeframes

The study was undertaken between February and July 2017. Due to the short timeframe of this engagement and the significance of the pathway to the preferred option proposed, we suggest that consultation with key local and central government stakeholders, and the Franz Josef Working Group, continue beyond completion of the analysis.

Assumptions

Key assumptions include:

- That the FJWG is empowered to represent the Franz Josef community
- That other relevant perspectives (such as government agencies, and neighbouring councils) would be able to be accessed if needed and that the FJWG will provide the primary conduit to this
- That all secretariat duties for Working Group meetings are provided by the FJWG
- That all information to be included in the assessment is provided in a timely manner (to the extent possible)

Appendix B: Figure notes

Figure No.	Title	Notes
2-2	Wider Franz Josef Area	1,2,3,4,5,6
2-5	Infrastructure Network	1,4,5,7,8
2-10	Earthquake Scenario	1,4,5,9,10
2-11	Earthquake Scenario	1,3,4,8,9,11
2-17	Flood Depths 100 year ARI with 0 m bed aggradation	1,3,4,5,12
2-18	Flood Depths 100 year ARI with 0 m bed aggradation	1,4,5,8,12
2-19	Flood Depths 100 year ARI with 6 m bed aggradation	1,3,4,5,13
2-20	Flood Depths 100 year ARI with 6 m bed aggradation	1,4,5,8,13
8-1	Avoid nature's most significant challenges - Waiho River Area	1,4,8,9,14
8-2	Avoid nature's most significant challenges - Lake Mapourika Area	1,4,9,14
8-4	Live with nature's challenges - Phase 1a	1,4,8,9,14,15
8-5	Live with nature's challenges - Phase 1b	1,4,8,9,14,15
8-6	Live with nature's challenges - Phase 2 & Long-term	1,4,8,9,14,15
8-7	Defend against nature's challenges - Phase 1	1,4,8,9,14,15
8-8	Defend against nature's challenges - Phase 2	1,4,8,9,14,15
15-7	Wider Franz Josef Area	1,2,3,4,5,6
15-19	Earthquake Scenario	1,4,5,9,10
15-20	Earthquake Scenario	1,3,4,8,9,11
15-27	Flood Depths 100 year ARI with 0 m bed aggradation	1,3,4,5,12
15-28	Flood Depths 100 year ARI with 0 m bed aggradation	1,4,5,8,12
15-29	Flood Depths 100 year ARI with 6 m bed aggradation	1,3,4,5,13
15-30	Flood Depths 100 year ARI with 6 m bed aggradation	1,4,5,8,13

Notes No.	Note
1	LINZ aerial: Contains data sourced from Land Information New Zealand and Landcare Research under CC-BY 3.0 NZ, http://creativecommons.org/licenses/by/3.0/nz/
2	Property boundaries: Sourced from Westland District Council for use on the Franz Josef Project.
3	Airstrip: Contains data sourced from Land Information New Zealand and Landcare Research under CC-BY 3.0 NZ, http://creativecommons.org/licenses/by/3.0/nz/
4	State Highway 6: base data sourced from New Zealand Transport Agency and Landcare Research under CC-BY 3.0 NZ, http://creativecommons.org/licenses/by/3.0/nz/
5	Local roads: Base data sourced from Land Information New Zealand and Landcare Research under CC-BY 3.0 NZ, http://creativecommons.org/licenses/by/3.0/nz/
6	Accommodation: Based on Franz Josef tourism map and accommodation stats for April 2017 provided by WDC and Franz Josef working group.
7	3-water assets: Sourced from Westland District Council for use on the Franz Josef Project.
8	Stopbank location provided by WCRC.
9	Alpine Fault alignment: Base data sourced from Westland District Council. Modified to align with GNS 2016 report.
10	Peak ground acceleration isoseismal contours based on July 2016 report by GNS Science, "Natural Hazard Assessment for the Township of Franz Josef, Westland District"
11	Potential landslide and rock avalanche inundation: based on July 2016 report by GNS Science (after Davies, 2015).
12	100 year ARI floodplain estimate for 0 m bed aggradation - Based on model sourced from Land, River, Sea (2016) through West Coast Regional Council for use on the Franz Josef Project and rerun by Tonkin + Taylor.
13	100 year ARI floodplain for 6 m bed aggradation - Based on model sourced from Land, River, Sea (2016) through West Coast Regional Council for use on the Franz Josef Project and rerun by Tonkin + Taylor.
14	Waiho River 100 year ARI floodplain extent for option - Floodplain estimated based on results of 2D hydraulic modelling and expert opinion on likely changes in extent as a result of the option. Original model sourced from Land, River, Sea (2016) and modified for purposes of this project by Tonkin + Taylor.
15	Waiho River future unmitigated 100 year ARI floodplain - estimated based on results of 2D hydraulic modelling to 2050 which assumes 6m of bed aggradation in the Waiho River only. Gaps in the floodplain removed to represent future uncertainty in terrain. Bed aggradation added to baseline model sourced from Land, River, Sea (2017), and rerun by Tonkin + Taylor.

Appendix C: Calculating Franz Josef GDP

We have derived this bespoke 'Franz Josef GDP' value by averaging the following approaches:

Employment approach

a) West Coast Regional GDP / West Coast Regional Employment by sector, provides an estimate of the GDP contribution of each job, by sector, across the West Coast[31]

b) Multiplying the number of jobs across each sector in Franz Josef by the proxy identified in a) above, provides a sense of the GDP contribution of Franz Josef[32]

Per capita approach

i. West Coast Regional GDP / West Coast population, provides an estimate of the GDP per capita, across the West Coast[33]

ii. Multiplying the number of people in Franz Josef by the proxy identified in i) above, provides a different sense of the GDP contribution of Franz Josef[34]

Using an average of these two findings, we have assumed a GDP figure of $23 m (2016) to provide a sense of order and magnitude of the Franz Josef contribution to the national economy.

[31] GDP data is taken from Stats NZ Regional GDP estimates (2013). Employment data is taken from Industry level statistics from Census 2013.

[32] Franz Josef Employment figures are taken from Industry level statistics from Census 2013.

[33] GDP data is taken from Stats NZ Regional GDP estimates (2013). Employment data is taken from Industry level statistics from Census 2013.

[34] Franz Josef Employment figures are taken from Industry level statistics from Census 2013.

Appendix D: MCA technical annex

The purpose of the options assessment framework (MCA) is to support moving from a long-list of potential options, to a short-list, based on agreed investment objectives and critical success factors. The short-list is then used as the initial basis for developing packages of options for further evaluation in the CBA.

1 Resilience decisioning principles

The MCA framework developed for this study is based on the investment objectives and critical success factors developed in conjunction with the FJWG, as well as the principles for understanding and valuing resilience established in NZTA research report 614[35] including:

- ***Understanding the service or function that an option protects***: This means making sure that functions of assets are protected, not just the assets themselves. For example, in considering creating resilience around potable water supply, stores of bottled water or individual purification systems are just as effective (in the short-term) as building a more robust reticulated supply. Both should be evaluated in the context of their efficacy to the challenges we're trying to create resilience to.
- ***Placing communities at the heart of decision-making:*** In the MCA for Franz Josef this is directly manifest though the relatively high weighting given to the community acceptability of each option. However, more broadly, options should be considered in the context of the consequences of a service or function being unavailable, and how the consequences of that unavailability change over time for different communities of interest. For example, power being unavailable for a few hours has limited consequences, but if the outage extends to 24 hours consequences increase and tolerance to the outage may be reached. It may also be that consequences for the hospitality sector (as a particular community of interest) become significant more quickly (as potential customers are turned away) than the consequences within individual households. Communities of interest do not necessarily need to be locally situated (such as residents or business owners / operators), but can include other groups impacted indirectly by a disruption. For Franz Josef, communities of interest may also include tourist operators, councils, government departments and iwi living outside the area. Understanding consequence in this way also help to begin to understand willingness to pay and the answer to the questions *who are we creating resilience for* and *how resilient do we want to be?* In all cases, including in Franz Josef, we can also include accepting living with risk (i.e. agreeing we are resilient enough) as an answer to the latter question.
- ***Taking a wide view of challenges:*** It is important to understand the wide spectrum of stresses and shocks to which our communities are vulnerable (which includes systemic or organisational challenges as well as natural hazards risks), and how these may change overtime to help answer the question *what are we being resilient to?* Within the MCA framework we consider the *resilience dividend* of options (i.e. where an option creates resilience to challenges in addition to earthquake and flooding risk) as well as how the efficacy of options change overtime in terms of flood risk (which will increase over time due to bed aggradation).
- ***Taking a wide view of value:*** Our approach recognises that there are other types of value in addition to traditional economic or financial value. These include environmental, social and

[35] Money, C, R Reinen-Hamill, M Cornish, N Bittle and R Makan (2017) *Establishing the Value of Resilience*. NZ Transport Agency research report 614. 64pp. https://www.nzta.govt.nz/resources/research/reports/614/https://www.nzta.govt.nz/resources/research/reports/614/.

cultural values. Environmental capital can be thought of as ecosystems and their constituent parts, including people and communities; and all natural and physical resources. In Franz Josef it is the inherent environmental value in the region (the glaciers in particular) that create a significant proportion of the economic capital. Social capital encompasses social cohesion and access to social net networks, as well as to services, including critical services, essential services, non-essential services and recreational facilities. Cultural capital is generated by the value attributed to physical natural and built environment landmarks or assets, and may be tangible or intangible. Cultural value extends from what is valued today, to sites or artefacts which are part of New Zealand's history. In Franz Josef examples of cultural assets include the church as well as wāhi tapu sites or other taonga.

- ***Considering all pathways to resilience:*** Resilience can be achieved thorough a number of pathways, including though increased robustness and redundancy, recovery actions and governance and leadership initiatives. Robustness includes physically strengthening assets, but can also include creating robust organisations that will be able to act even after an event has occurred. Redundancy means finding other ways to deliver the same service (such as in the potable water example earlier). Including recovery in our thinking means that we explicitly consider options which support the provision of services after a disruption and plan for that in advance. Governance and leadership includes the way that our leaders and institutions plan for resilience and create a culture that is able to resist, absorb and thrive in the context of change. The MCA framework records what type of measure each option is so that we can consider if the overall package of options is balanced across these pathways.

2 MCA scoring and weighting

The total MCA score for each option is out of 1, based on the performance of each option across the critical success factors (Table 4-1). In general, the higher the MCA score, the more potential an option has to meet the critical success factors, and should therefore be considered as part of a potential package of options.

The 'score' for each option is effectively a summation of all of the aspects by which we are assessing them – these aspects are based explicitly on the investment objectives and the critical success factors.

There are some cases where a critical success factor is characterised appropriately by one aspect only as in the case of contribution to investment certainty (see Section 2.2), and there are others where a number of different aspects are used to determine performance, as in the characterisation of efficacy to challenges (Section 2.3).

In accordance with standard MCA practice, aspects are generally 'scored' on a seven-point scale as per Table 15-1.

Table 15-1: Standard approach to MCA scoring

3	Significant Positive contribution to critical success factor
2	Moderate Positive contribution to critical success factor
1	Minor Positive contribution to critical success factor
0	Neutral contribution to critical success factor
-1	Minor Negative contribution to critical success factor
-2	Moderate Negative contribution to critical success factor
-3	Significant Negative contribution to critical success factor

There are occasions where only part of this scale is used, most notably when the scale is 'uni-directional' (positive or negative).

In recognition of the importance of clarity in understanding how this initial filter has been used, the application of the scoring framework, including tailoring it to the specific aspects that make up the critical success factors, is detailed in the following sections.

2.1 Option characterisation | Not scored

In addition to recording the option name and details at a high level, the information collected in this section of the framework is primarily used to understand the function or service each option seeks to create resilience for and how that resilience is created. The fields in this section (summarised in Table 15-2) do not contribute to the overall MCA score, but are useful for packaging and understanding how, where and for whom resilience is being created.

Table 15-2: Option characterisation

Aspect	Detail	Assessment
Resilience measure	The resilience pathway an option leverages.	- Robustness - Redundancy - Recovery - Governance
Approach to risk	The approach to risk an option takes.	- Avoid - Manage - Transfer - Accept
Function / service	Characterisation of the primary service or function that the option addresses, noting that options may provide more than one service.	- Reduction of life / injury risk - Protection of built environment capital - Enable community self-sufficiency <7 days - Enable effective rescue / response / sustenance - Enables recovery (return to BAU)
Sector	The sector that the option creates resilience in.	- Potable water - Waste water - Water distribution network - Electricity - Fuel - Roads - Aerodrome - Helipad - Building stock - Communications
Location	The physical location of the option. This becomes useful when considering how the criticality of particular areas change as a result of implementing option.	Categorised as: - Area-wide - Township - North of Franz Josef - South of Franz Josef - South of Waiho River (Southside or west of the township) - Aerodrome - Waiho River - Callery River - Lake Mapourika - Stony Creek - Lake Wombat - Outside the Franz Josef area
Spatial extent	The spatial spread of the effectiveness of the option.	- Single property / business - Multiple properties / businesses - Whole of community

2.2 Investment certainty | 5%

The contribution of each option to investment certainty is categorised within the framework on a seven-point scale:

- ***Significant positive (3)***: Option creates certainty for current investors (including maintaining current tourist flows); potentially results in additional investment; and results in resident population growth.
- ***Moderate positive (2)***: Option creates certainty for current investors (including maintaining current tourist flows) and potentially results in additional investment.

- ***Minor positive (1)***: Option creates certainty for current investors (including maintaining current tourist flows).
- ***Neutral (0)***: Option is neutral or has no impact on flows or resident population.
- ***Minor negative (-1)***: Option creates uncertainty for current investors (including potentially impacting current tourist flows).
- ***Moderate negative (-2)***: Option creates uncertainty for current investors (including potentially impacting current tourist flows) and potential new investors are deterred.
- ***Significant negative (-3)***: Option creates uncertainty for current investors (including potentially impacting current tourist flows); potential new investors are deterred; and there is the potential for a reduction in the resident population.

Options were assessed to generally be neutral, or to contribute positively to investment certainty. To demonstrate the investment certainty assessment process, Table 15-3 shows two examples that scored positively and negatively. Because relocation to Lake Mapourika includes a transition pathway to the new area for current residents and businesses, which increases the cost, it would also likely result in a positive impact on investment certainty. In contrast, in isolation, a diversified development strategy would likely have a negative impact on investment certainty in the township, as current and potential investors would be torn between the 'new' and 'old' development areas.

Table 15-3: Example of investment certainty characterisation in the MCA and how this investment criterion informed options development

Option	Option Summary	Investment Certainty
Relocate to Lake Mapourika	Planned and facilitated relocation of the township	2
Diversified development strategy	Establishment of other development areas to encourage growth in areas with a reduced risk profile to natural hazards. Potential areas include between Stony Creek and Lake Mapourika, and adjacent to Lake Wombat.	-3

2.3 Efficacy in the context of challenges | 35%

Collectively these are the highest weighted aspects, which is in accordance with the stated purpose of this assessment and the primary investment objective.

Efficacy of options is considered across four scenarios with a collective weighting of 35% to represent current, and likely-worst-case scenarios:

- ***Alpine fault rupture (10%)***: How effective is the option at avoiding, managing or transferring the impacts of shaking and the impact of uplift / lateral spread around the active, known fault lines?
- ***Large rock landslide (7.5%):*** How effective is the option at avoiding, managing or transferring the impact of a large rock landslide?
- ***Flood – present day (7.5%):*** How effective is the option at avoiding, managing or transferring the impacts of a 1-in-100-year flood event with current levels of bed aggradation?
- ***Flood ~30 years (10%)***: How effective is the option at avoiding, managing or transferring the impacts of a 1-in-100-year flood event with 6m of bed aggradation, which is the point at which the town would effectively become the river bed. With current rates of aggregation this occurs at ~30 years.

While the efficacy of options to manage the risks associated with an Alpine Fault rupture remain constant over time (assuming business-as-usual), options to manage flooding risks may become less effective over time due to bed aggradation. Accordingly, we have developed measures of efficacy at two ends of the temporal spectrum for this analysis in avoiding, managing or transferring flooding risks, and a premium (though higher weighting) is included for effectiveness against flooding in the longer-term. Effectiveness in the context of Alpine Fault rupture is also weighted more highly based on the likelihood of an Alpine Fault rupture event occurring.

The efficacy of options in the context of the types of value they protect, and when they are effective across the stages from response to recovery are also included for each of the four scenarios using five separate aspects (Table 15-4). These are each evaluated on the seven-point scale (Table 15-1) for each of the four natural hazards scenarios (i.e. 20 separate assessments for each option).

Table 15-4: Characterisation of effectiveness of options to natural hazards challenges

Aspect	Detail
Protects life and /or reduces chance of injury	How effective the option is in changing the potential for injury or loss of life as a result of Alpine Fault rupture and flooding. This includes consideration of the broader Franz Josef area, as well as the township, and residents as well as visitors.
Protects built environment capital	How effective the option is in protecting building stocks and infrastructure during an event. The scope of this assessment is restricted to the wider Franz Josef area defined as the study area (Figure 2-2).
Improves community self-sufficiency (<7 days)	How effective the option is in creating pathways for the Franz Josef community to be self-sufficient given the likely damage to building stocks and infrastructure over the initial response period (~7-days).
Enables effective external rescue/response (1-2 days)	How effective the option is in supporting external rescue or recovery effort in accessing and operating in Franz Josef over the initial response period (~1-2-days).
Enables restoration of BAU	How effective the option is in creating pathways for the Franz Josef community to recover to business-as-usual, or a version of business-as-usual.

Options to 'manage' risks were generally mutually exclusive i.e., options that create resilience to the effects of Alpine Fault rupture do not generally create resilience to flood risks, with the exception of options to 'avoid' risks by moving away from the fault line, range-front and Waiho River. 'Avoid' options are also the only options that change the risk associated with an earthquake-triggered large rock landslide.

Options also generally do not create resilience across all five aspects of effectiveness considered, although there is a connection between reducing life risk, protecting built environment capital, enabling effective response and the subsequent return to business-as-usual (or a version of business-as-usual). This fits with the idea that *recovery starts on day one* and therefore options which support aspects of response and recovery score well.

Efficacy to challenges also includes an additional, non-weighted, aspect which allows the potential for a *resilience dividend* to be recorded. A *resilience dividend* is created when an option has the potential to create resilience to another challenge in addition to an Alpine Fault rupture and / or flooding. In this assessment, the resilience dividend was most commonly around providing resilience to the consequence of climate change, including more extreme weather events and the potential for glacial retreat. This is recorded so that if a decision is to be made between progressing two options, which are equal across the weighted aspects, this additional positive contribution can be taken into account in the decision-making. Understanding the 'resilience dividend' is also helpful when thinking about next steps and the ability to seek support from wider stakeholder groups for certain investments over others. It is not weighted as this study is specifically and purposefully constrained to earthquake and flooding hazards.

2.4 Community acceptability | 15%

Community acceptability is measured on a four-point scale which contributes 15% to the overall score for each option:

- ***Not acceptable (0)***: Option is not considered acceptable by the majority of the Franz Josef community
- ***Isolated levels of support (1):*** Pockets of support for the option exist across the community i.e. 1-2 different stakeholder groups support the option
- ***Split levels of support (2):*** ~50% of the community is likely to support the implementation of the option
- ***Wider/full levels of support (3):*** The majority of the community are likely to support the implementation of the option

The determination of likely acceptability for each option for the purposes of this MCA was based on:

- Engagement with the FJWG as a proxy for the community, noting that while the FJWG did not review and score every single option, the sentiment expressed by the group for the various options was included in the scoring.
- One-on-one engagement with individual community members and FJWG members.
- Records regarding the development and implementation of various options previously.

Generally only smaller, no-regrets options, such as the finalisation of the Community Resilience Plan, could be considered to have wide support. Generally options for flood mitigation in particular were considered to have isolated or split levels of support, predominantly due to the fact that these options have clear beneficiaries and those who may incur a cost.

A planned relocation to Lake Wombat and developing an alternative (and competing) development area in an alternate location were the only options to be considered not acceptable.

2.5 Implementation | 15%

Ease of implementation is split into three aspects with a cumulative weighting of 15% (Table 15-5).

Table 15-5: Characterisation of ease of implementation

Aspect	Detail	Assessment
Legislative / regulatory (5%)	How the implementation of the option would be viewed from a legislative and regulatory perspective.	0: National level change or regional level change with national implications OR measure has been attempted previously and failed 1: Regional or district level change which would require significant debate 2: Regional or district level change which would require limited debate 3: Business-as-usual
Technical (5%)	This aspect considers the methodology for option implementation and availability of materials, people and equipment to deliver. Excludes the cost of implementation as this is captured in whole-of-life cost.	0: Has never been attempted OR has been attempted previously with limited success 1: Approach has not been attempted in New Zealand, or there is limited capacity to deliver in New Zealand 2: Approach is well developed in New Zealand, but availability of people or equipment to deliver on the West Coast is limited 3: Business-as-usual
Political (5%)	Considers the political appetite to implement an option from a local, regional and national perspective.	7-point scale from significant support to significant opposition

Technical and legislative / regulatory aspects did not utilise the negative component of the seven-point scale as these are barriers, but not reasons to 'red-line' an option. Overall, there was a spectrum of ideas from BAU through to challenging from a technical and legislative / regulatory perspective.

Many options were considered to likely have split levels of support across the local and national political spectrums, and this reinforces the need to undertake fulsome community and stakeholder consultation in the pursuance of a preferred package of work. .

A range of other aspects pertinent to implementation are also captured, but not scored (Table 15-6). These are used for packaging options to make the best use of interdependencies and consider how options should be staged within a package.

Table 15-6: Characterisation of other aspects of implementation

Aspect	Detail	Assessment
Enables other options	Records another type of resilience dividend – the degree to which an option facilitates or enables the implementation of another option or options.	0: Does not enable other options 1: Supports the implementation of one other option 2: Supports the implementation of two other options 3: Supports the implementation of three or more other options
Reliance on other options	Records whether an option relies on another option to be realised. This indicates whether there are interdependencies to take into consideration.	0: Does not rely other options 1: Relies on the implementation of one other option 2: Relies on the implementation of two other options 3: Relies on the implementation of three or more other options
Time to implementation	Records the likely timeframes for implementation.	- Short-term: Less-than 1-year - Mid-term: 1-10 years - Long-term: more-than 10-years
Lead Organisation(s)	Records the organisation(s) who would lead the implementation of the option. Note that leadership does not necessarily correlate to paying for the option from existing budgets.	
Partner Organisation(s)	Records the organisation(s) who would support or partner with the lead organisation to implement an option.	
Stakeholders	Records the key stakeholders identified who would need to be consulted or engaged in the implementation of an option.	

The seven-point scale reflecting interdependencies is split into two aspects:

- Enabling other options
- Reliance on other options

This is because it is possible that an option is both an enabler and has reliance, which would result in a neutral score and the information on those interdependencies effectively not recorded in the assessment.

2.6 Value for money | 20%

The 20% attributed to value for money is split between whole-of-life-cost (WOLC) of implementation (10%) and the economic value created, protected or eroded (10%).

WOLC is based on preliminary estimates from the FJWG, WCRC, WDC and our subject matter experts. The scoring is on a purposefully and necessarily course five-point scale (Table 15-7). A more detailed assessment of costs and benefits is undertaken for those options that progress to cost benefit analysis.

Table 15-7: Characterisation of whole-of-life cost

Score	WOLC
5	<$1m
4	$1m-$10m
3	$10m – $50m
2	$50m - $200m
1	>$200m

This means that lower-cost options are viewed more favourably than high-cost options. An upper limit of $200 million was selected as this is the approximate current value of the capital in the township. Thresholds were developed from this point, balancing the desire for granularity, with the need to be able to use the scale effectively at this point of the assessment to estimate whole-of-life cost.

For the purposes of the MCA, a cost element is important to consider because it aligns with the critical success factors. However, it is important to stress that the cost benefit analysis phase will be where the costs and benefits of each package of options is more fully assessed.

The flipside of WOLC is the characterisation of the broader economic value protected or eroded. This is estimated on a net basis (recognising that some options simultaneously protect and erode value, such as the release of the Waiho River to the north or south). Broader economic value is estimated on a nine-point scale to allow consideration of the disparate nature of the value of stocks and flows (Table 15-8).

Table 15-8: Characterisation of wider economic benefits

Score	Wider economic benefits
-4	Significant tourist and capital value eroded
-3	Significant tourist OR capital value OR moderate tourist and capital value eroded
-2	Moderate tourist OR capital value OR minor tourist and capital value eroded
-1	Minor tourist OR capital value eroded
0	Neutral
1	Minor tourist OR capital value protected / enhanced
2	Moderate tourist OR capital value OR minor tourist and capital value protected / enhanced
3	Significant tourist OR capital value OR moderate tourist and capital value protected / enhanced
4	Significant tourist and capital value protected / enhanced

2.7 Wider costs and benefits | 10%

The wider costs (5%) and benefits (5%) that are likely as a result of the implementation of the option are characterised on a four-point scale for environmental, social and cultural values (i.e. six separate assessments for each option) (Table 15-9 and Table 15-10).

Table 15-9: Characterisation of wider costs

Score		Wider environmental, social and cultural costs	
3	Neutral	No change to environmental / social / cultural value in the study area as a result of implementation of the option.	
2	Low	Minor reduction in environmental / social / cultural value in the study area as a result of implementation of the option.	Impacts are characterised by one or more of the following: - In a specific area - Temporary - Can be effectively avoided or mitigated - May not require specific mitigation strategy - Recovery likely in ~1-year - Of concern to one set of stakeholders
1	Medium	Moderate reduction in environmental / social / cultural value in the study area as a result of implementation of the option.	Impacts are characterised by one or more of the following: - In a specific area - Temporary - Require significant effort to avoid or mitigate - Recovery likely in >1-year - Of concern to more than one stakeholder group
0	High	Significant reduction in environmental / social / cultural value in the study area as a result of implementation of the option.	Impacts are characterised by one or more of the following: - Across the wider Franz Josef area - Impacts an area of significance e.g. wāhi tapu, taonga, UNESCO designation - Permanent - Not possible to avoid - Require significant effort to mitigate - Of concern to the majority of the community - Of concern to stakeholders outside of the Franz Josef area

Table 15-10:Characterisation of wider benefits

Score		Wider environmental, social and cultural benefits	
0	Neutral	No change to environmental / social / cultural value in the study area as a result of implementation of the option.	
1	Low	Minor improvement in environmental / social / cultural value in the study area as a result of implementation of the option.	Impacts are characterised by one or more of the following: - In a specific area - Temporary (during implementation only or <1-year) - Benefits one set of stakeholders
2	Medium	Moderate improvement in environmental / social / cultural value in the study area as a result of implementation of the option.	Impacts are characterised by one or more of the following: - In a specific area - Temporary (beyond implementation) - Benefits more than one stakeholder group
3	High	Significant improvement in environmental / social / cultural value in the study area as a result of implementation of the option.	Impacts are characterised by one or more of the following: - Across the wider Franz Josef area - Enhances or protects an area of significance e.g. wāhi tapu, taonga, UNESCO designation - Permanent (or more than 50-years) - Benefits the majority of the community - Benefits stakeholders outside of the Franz Josef area

The seven-point scale reflecting non-financial costs and benefits is effectively split into two:

- Wider environmental, social and cultural costs
- Wider environmental, social and cultural benefits

This is because it is possible that an option generates both positive and negative non-financial outcomes over whole-of-life, which would result in a neutral score and the information on those different costs and benefits effectively not recorded in the assessment.

For example, when considering the outcomes of moving the centre of gravity of the township to the north (north-east of the current location of the health centre), there is a positive resilience outcome, but there is also the potential for both positive and negative social and cultural impacts as existing places and spaces are disrupted and new spaces are established. These trade-offs can and should be recorded (Table 15-11).

Table 15-11:Example of wider costs and benefits characterisation in the MCA

Option	Wider Costs			Wider Benefits		
	Environmental	Social	Cultural	Environmental	Social	Cultural
Move centre of gravity north	L	L	L	None	L	L

When undertaking the assessment of wider costs and benefits, we have attempted to avoid double counting wherever possible. For example, when thinking about the development of a Community Resilience Plan, implementation would result in reduced life-risk, increased self-sufficiency and a faster return to business-as-usual. These benefits are recorded in the *efficacy to challenges* section of the framework. There are also potential additional social and cultural benefits created though the development of the plan, as a result of increased community understanding and cohesion. These benefits are captured in the *wider benefits* section of the framework. The social benefit of reduced life risk is not included again in the wider benefits.

Appendix E: Long list of options

Committed or Future Initiative	Resilience Measure	Approach to Risk	Function / Service	Sector	Option Name	Brief Option Detail
Future	Recovery	Accept	Enables recovery (return to BAU)	Communications	Education	Programme to help community co-develop and implement resilience strategies (identified in resilience plan).
Future	Governance	Avoid	Reduction of Life/injury risk	Building stock	Stopbank damage warning system	Fibre optic break warning system. Install a buried fibre optic which if broken sets of a warning and then allows identification along the alignment.
Future	Governance	Avoid	Reduction of Life/injury risk	Building stock	Landslide warning system	Landslide dam. Parametric warning system or flow monitoring system.
Future	Governance	Avoid	Reduction of Life/injury risk	Building stock	Flood warning system	Water level warning system or forecasting warning system.
Future	Governance	Avoid	Reduction of Life/injury risk	Building stock	Isolated rockfall break-up	Evaluate rocks / sections of the hillside at risk of falling in an earthquake.
Future	Robustness	Avoid	Protection of built environment capital	Building stock	Relocate from the fault zone	Relocate key assets (including the service station, fire and police stations, and accommodation) from the high risk active known fault zone at the south end of town to the north. Consider using above ground storage tanks instead of USTs to isolate the tanks from ground deformation and liquefaction effects. Includes cost of closure of existing facility.
Future	Robustness	Avoid	Protection of built environment capital	Roads	SH6 Tunnel	New road alignment including a tunnel under the Waiho to remove flooding risk.
Future	Redundancy	Avoid	Protection of built environment capital	Helipad	New Helipad	Development of a new helipad operation area.
Future	Robustness	Avoid	Protection of built environment capital	Roads	State highway 6 new road alignment south	Realign SH6 to the south so it is out of the main flow path over the south (left) stop bank.
Future	Governance	Avoid	Reduction of Life/injury risk	Building stock	Relocate to Lake Mapourika	Planned and facilitated relocation of the township.
Future	Governance	Avoid	Reduction of Life/injury risk	Building stock	Relocate to Lake Wombat	Planned and facilitated relocation of the township.
Future	Governance	Avoid	Reduction of Life/injury risk	Building stock	Relocate to Franz Alpine Resort / Stony Creek	Planned and facilitated relocation of the township.

Committed or Future Initiative	Resilience Measure	Approach to Risk	Function / Service	Sector	Option Name	Brief Option Detail
Future	Robustness	Avoid	Protection of built environment capital	Building stock	Divert Waiho River flow through tunnel to the south	Divert ~20% of the flow out to the South before it reaches the Waiho Bridge. Diverted through a tunnel (alignment beneath approximate location of Lake Wombat).
Future	Governance	Avoid	Reduction of Life/injury risk	Building stock	Diversified development strategy	Establishment of other development areas to encourage growth in areas with a reduced risk profile to natural hazards. Potential areas include between Stony Creek and Lake Mapourika, and adjacent to Lake Wombat.
Future	Governance	Avoid	Reduction of Life/injury risk	Building stock	Exit strategy	Government initiated exit from the community.
Committed	Governance	Manage	Enables recovery (return to BAU)	Communications	Community resilience plan	Completion of community resilience plan to understand current resources (e.g. fuel and machinery); lay the foundations for additional initiatives (some of which are included in this assessment) and establish evacuation and recovery strategies. This should include an agreed approach to supporting tourists (and being clear what can be expected in terms of decision-making re: evacuation).
Future	Robustness	Manage	Protection of built environment capital	Roads	Raise Waiho Bridge - long term	Increase the height of the existing Bailey bridge by a further 2m due to bed aggradation.
Committed	Robustness	Manage	Protection of built environment capital	Roads	Raise Waiho Bridge - short term	Increase the height of the existing bailey bridge by 2m.
Future	Governance	Manage	Protection of built environment capital	Building stock	Collaboration with NZTA	Agree process for working more closely with NZTA, Ngai Tahu and Scenic Hotel Group to coordinate resilience activities.
Committed	Robustness	Manage	Protection of built environment capital	Waste water	New waste water treatment plant	Build a new centralised Wastewater Treatment Plant waste water treatment plant. The location of the plant may be at the existing location with stopbanks or a new location. It may take the form of oxidation pond or a compact high rate plant. The Opus Franz Josef waste water treatment plant Technical Memorandum #7 Comparative Options Report details six potential sites for the oxidation ponds and two for the compact high rate plant.
Future	Governance	Manage	Protection of built environment capital	Building stock	Waiho River Management Plan	Cross sector Waiho River management plan.
Future	Redundancy	Manage	Enable community sufficiency <7-days	Fuel	Stores of fuel, food, water & medicine	Provisions stored at 3 locations (minimum) for ~7-days for ~500 pax.
Future	Robustness	Manage	Enable effective rescue/response/sustenance	Aerodrome	Aerodrome resilience	Raise the Aerodrome infrastructure to reduce vulnerability to flood (inundation and impact) and earthquake (ground deformation).

Committed or Future Initiative	Resilience Measure	Approach to Risk	Function / Service	Sector	Option Name	Brief Option Detail
Future	Robustness	Manage	Protection of built environment capital	Building stock	Additional stopbank (55 km)	Additional stopbank adjacent to 55km corner to protect the township and train the Waiho River to the South.
Future	Governance	Manage	Reduction of Life/injury risk	Building stock	District Plan amendments - EQ	New developments to have mandatory resilience measures including single story, lightweight materials, reinforcing (where appropriate), suitable foundations.
Future	Redundancy	Manage	Enable community sufficiency <7-days	Electricity	3 x back-up generators	Back up diesel generators with dedicated fuel tanks protecting critical services (health centre, school, Aerodrome).
Future	Redundancy	Manage	Enable community sufficiency <7-days	Waste water	Off-grid public toilets	Pre-dug / pre-existing off-grid toilets for public use during an emergency.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Bed load deflection bunds	Large boulders can deflect the Waiho River into the stopbanks causing a breach. Use bed load training bunds to deflect large boulders in preferable direction. Bunds would be designed to be overtopped.
Future	Robustness	Manage	Protection of built environment capital	Water distribution network	Stormwater solutions	Review where stormwater pipes get blocked or can't outflow during heavy rain events and consider redesign.
Future	Redundancy	Manage	Enable community sufficiency <7-days	Communications	Satellite phones at 3 x locations	Provide 3 x 3 (minimum) satellite phones at 3 x locations (minimum) for emergency communication.
Future	Robustness	Manage	Protection of built environment capital	Roads	Raise roads to prevent flooding	Locally raise state highway alignment to provide local protection from flooding. This may be with or without stopbanks depending on the area. Use the material from the Waiho River bed gravel extraction to raise the areas above the flood plain flow level protecting infrastructure.
Future	Redundancy	Manage	Enable effective rescue/response/sustenance	Aerodrome	Float plane access	Development of float plane docking station to allow access in the event that the Aerodrome and helipads are unavailable.
Future	Governance	Manage	Enables recovery (return to BAU)	Building stock	Pre organised Lidar mapping	Satellite imagery to support response and recovery decisions.
Future	Redundancy	Manage	Protection of built environment capital	Roads	Bailey Bridge storage SH6	Store bailey bridges along the route between Franz Josef and Hokitika at logical locations to use in the event of bridge collapse to re-open the road. Place at bridges that are most like to have a collapsed section i.e. multispan in areas of lateral spread.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Gravel management plan in the Callery River	Regular inspection of the Callery River and removal of any dams that may have formed to avoid a dam break flood which would impact the Waiho.

Committed or Future Initiative	Resilience Measure	Approach to Risk	Function / Service	Sector	Option Name	Brief Option Detail
Future	Robustness	Manage	Enable effective rescue/response/sustenance	Aerodrome	Extend existing runway	Invest in an extended runway that can accommodate planes up to the size of the New Zealand DF Hercules. This would provide both a commercial flight option to Franz Josef and a runway for emergency response activities in the event of a disaster.
Future	Robustness	Manage	Enable community sufficiency <7-days	Potable water	Decentralised water supply	Stimulation for the uptake of rainwater collection systems and water tanks. In an Alpine Fault event which puts the centralised water supply out of action there will be some capacity till the tourists are evacuated and going forward residents will be self-sufficient.
Future	Robustness	Manage	Protection of built environment capital	Roads	SH6 bridge resilience	Package to assess and improve the seismic and flooding exposure of the SH6 bridges from Hokitika to Franz Josef.
Future	Robustness	Manage	Protection of built environment capital	Water distribution network	Strengthen 3-waters network	Remove AC and PVC pipes and replace with ductile pipe types like MDPE. This could be through a renewals programme or an upgrade programme.
Future	Redundancy	Manage	Enable community sufficiency <7-days	Waste water	Decentralised waste water strategy	Residential dwellings to have individual or shared septic tanks or composting toilets. Commercial activities to remain on centralised town network. In an Alpine Fault event which puts the centralised wastewater system out of action there will be capacity till the tourists are evacuated and the going forward residents will be self-sufficient.
Future	Robustness	Manage	Protection of built environment capital	Roads	SH6 landslide resilience	Package to assess and improve the landslide exposure of SH6 from Hokitika to Franz Josef.
Future	Robustness	Manage	Reduction of Life/injury risk	Building stock	Modular buildings	An extended version of implementing planning controls to encourage resilient buildings -- new buildings to be modular and moveable. Modular buildings provide for an adaptable township which can evolve with the ever changing natural hazards. They can be raised to evolve with increasing flood floor levels, moved to avoid hazards as they eventuate and are also resilient to earthquake shaking with the appropriate foundations.
Future	Robustness	Manage	Enables recovery (return to BAU)	Electricity	Power distribution resilience	Improve power distribution route resilience by realigning distribution poles away from slope inundation, or stabilise slope in location of poles, and water paths from the sub-station to the township.
Future	Redundancy	Manage	Enable community sufficiency <7-days	Electricity	Decentralised power supply	Incentivise the uptake of alternative power generation options with limited horizontal infrastructure for distribution. Options include micro hydro, wind and solar combined with battery technology.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Upstream bed load deflection area	Create an area upstream where large boulders are deflected, caught and removed. Potential area near the FJ glacier carpark.

Committed or Future Initiative	Resilience Measure	Approach to Risk	Function / Service	Sector	Option Name	Brief Option Detail
Future	Robustness	Manage	Enables recovery (return to BAU)	Communications	Telecommunication repeater towers	Set the telecommunication towers up as repeater towers to build redundancy from network outages.
Future	Governance	Manage	Protection of built environment capital	Building stock	District Plan amendments - Flood	Policy to raise development areas to provide local protection from flooding. This may be with or without stopbanks depending on the area. Use the material from the Waiho River bed gravel extraction to raise the areas above the flood plain flow level protecting infrastructure.
Future	Governance	Manage	Reduction of Life/injury risk	Building stock	Small to moderate landslide stabilisation	Evaluation of slope and installation of surficial rock anchors in the most vulnerable location(s).
Future	Governance	Manage	Reduction of Life/injury risk	Building stock	Full slope stabilisation	Large scale slope stabilisation measures including drainage, high tensile rock anchors and monitoring programme.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Engineered/planned failure of the true left stopbank under flood conditions	Passive - Fuse plug. Active - actively demolish in a large flood event.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Raise the height of the existing stopbanks	Raise the height of the existing stopbanks.
Future	Governance	Manage	Reduction of Life/injury risk	Building stock	Resilience rating system	Establish a resilience star rating scheme to promote accommodation options which are a lower risk to tourists including engineering and non-engineering measures. Incentivise lower risk, resilient developments.
Future	Governance	Manage	Reduction of Life/injury risk	Building stock	Retrospective District Plan amendments - EQ	Strengthening of existing buildings to shaking damage by improving ties between the structure and the foundations. This is to prevent the structure from moving off its foundations.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Long term management programme for engineered stopbanks (without gravel extraction)	Put in place a long term management programme for engineered stopbanks to be designed, constructed, monitored, maintained and reviewed. They would be designed to a dam like standard, for the specific conditions in the Waiho River. They would be constructed in the same location as the existing stopbanks.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Long term management programme for engineered stopbanks (with gravel extraction)	Put in place a long term management programme for engineered stopbanks to be design, constructed, monitored, maintained and reviewed. They would be designed to a dam like standard, for the specific conditions in the Waiho River. They would be constructed in the same location as the existing stopbanks. Includes the option of gravel extraction.

Committed or Future Initiative	Resilience Measure	Approach to Risk	Function / Service	Sector	Option Name	Brief Option Detail
Future	Robustness	Manage	Protection of built environment capital	Building stock	Long term management programme for engineered stopbanks (with gravel extraction and conveyer)	Put in place a long term management programme for engineered stopbanks to be design, constructed, monitored, maintained and reviewed. They would be designed to a dam like standard, for the specific conditions in the Waiho River. They would be constructed in the same location as the existing stopbanks. Includes the option of gravel extraction and conveyor belt system as a potential lower cost option to transfer the Waiho River bed aggregate to the fill area. This also has the benefit limiting truck movements to the earthworks area lessening the effects i.e. not using the roads.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Engineered spillway on left (south) stopbank	Create a engineered spillway on the left (south) stopbank which may require bridging of SH6 over the spillway.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Move centre of gravity north	Move the centre of gravity of development to the north (e.g. new town square). Assume this is predominantly retail and entertainment.
Future	Robustness	Manage	Enable effective rescue/response/sustenance	Helipad	Helicopter storage	Minimise post EQ damage through improved storage practice.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Allow Waiho River to follow natural course to the south below Franz Josef	Remove the stopbank between Waiho Bridge and Canavans Knob to allow the Waiho River and the bed aggradation to spread out to the south, lowering the flow height on the true right (north) stopbank.
Future	Robustness	Manage	Reduction of Life/injury risk	Building stock	Rockfall protection	Add bunds or fencing to protect the township against rockfall.
Future	Redundancy	Manage	Enables recovery (return to BAU)	Electricity	Power distribution duplication	Duplicate the power transmission line from ~Whataroa into Franz Josef.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Train the path of the Waiho River with stopbanks to flow to the south of Canavans Knob	Change to main course of the Waiho River to the south of Canavans Knob so the Waiho River would not flow to the north past Canavans Know. If breach were to occur then secondary flow path would be down its old course.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Allow the Waiho River to follow natural course to the north below Franz Josef	Remove the protection on the true right stopbank to allow the Waiho River and the bed aggradation to spread out to the north, lowering the flow height on the true left (south) stopbank.
Future	Robustness	Manage	Protection of built environment capital	Building stock	Remove part of the terminal moraine	Remove part of the terminal moraine to reduce the deposition of river bed material upstream, with the potential to reduce aggradation adjacent to Franz Josef.

Committed or Future Initiative	Resilience Measure	Approach to Risk	Function / Service	Sector	Option Name	Brief Option Detail
Future	Governance	Transfer	Enables recovery (return to BAU)	Building stock	Traditional insurance (and reinsurance)	Individual homeowners and business owners approach their individual insurance companies seeking adjustments to premiums, or increases in coverage, on the back of improved risk management resulting from this study.
Future	Governance	Transfer	Enables recovery (return to BAU)	Building stock	Collective Bargaining	Individual homeowners and business could aggregate together and leverage their greater buying power to reduce premiums when approaching insurers. To support this, the Council could act as a trusted intermediary to co-ordinate this interaction (via a broker).
Future	Governance	Transfer	Enables recovery (return to BAU)	Building stock	Collective Bargaining - Reinsurance	Acting as this trusted intermediary, there is further opportunity for the council to either approach reinsurers directly (depending on the potential risk/premium). The insurance costs could then be allocated across households/businesses/etc.
Future	Governance	Transfer	Enables recovery (return to BAU)	Building stock	Catastrophe Bonds	A primary party could aggregate the collective insurance risk into a 'catastrophe bond'. In this case a third party (or third parties) would purchase the bond and the primary party would pay an agreed coupon rate for the life of the bond. If a predetermined event occurred the bond value would be retained and the coupon payments would end. If the event did not occur, the primary party would return the bond value.

Appendix F: Summary of major options

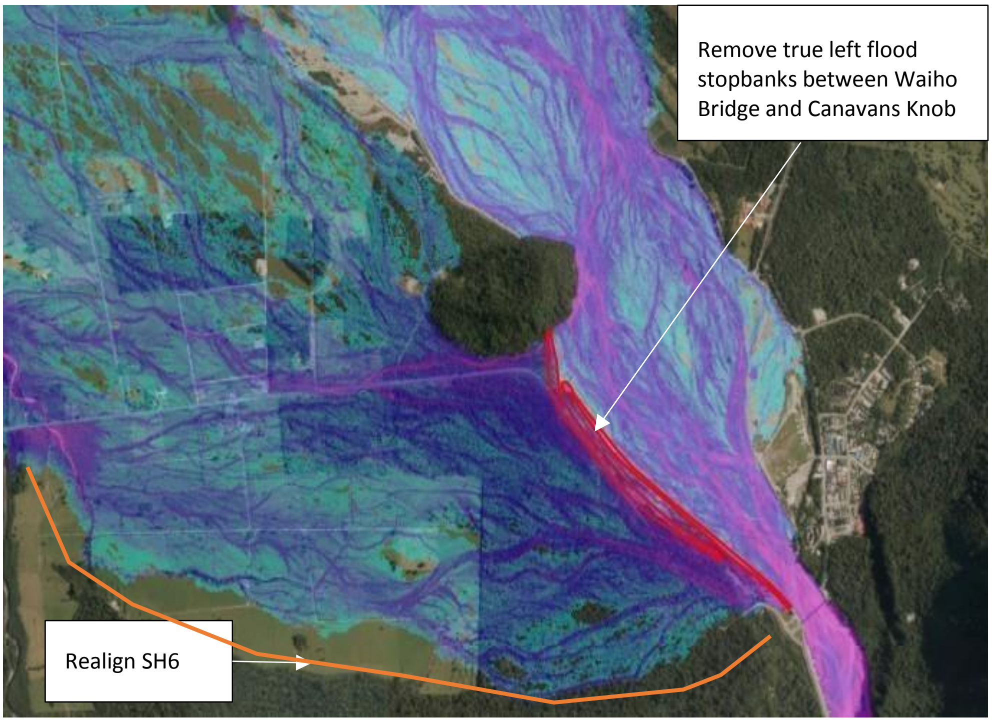
After an initial filter of options it was recognised that a significant intervention is required in order to alter the risk profile of the township and the wider Franz Josef area.

The following represents the initial longlist of major options which were considered as key components of potential packages and were assessed through the MCA process:

- Allow Waiho River to follow natural course to the south below Franz Josef
- Allow Waiho River to follow natural course to the north below Franz Josef
- Long term management programme for engineered stopbanks.
- Move the centre of gravity of the township to the north
- Relocate to Franz Alpine Resort / Stony Creek
- Relocate to Lake Mapourika
- Relocate to Lake Wombat

1 Allow Waiho River to follow natural course to the south below Franz Josef

Description of option
The Waiho River is allowed to flow to the south (true left) between the Waiho Bridge and Canavans Knob. This includes the complete removal of the true left flood protection stopbanks and the realignment of SH6 south through DoC estate and farmland in a more direct route to Dohertys Creek Bridge. Supporting options or variations: - The alignment of the road could be raised on a fill embankment of 1 to 2 m height where it is likely to be exposed to flood - There is the option of undertaking some gravel management in the river in the medium- to long-term, and in perpetuity - There is the option of building an engineered stopbank at the crest of the town Suggested alternative route for SH6 shown below.



Efficacy in the context of natural challenges
There is no change in the challenge faced from earthquake and large rock landslide. Because there is a 2 to 3m height difference between the current river bed level and level of the land south of the true left bank, the river channel would, at some stage, divert to the south and deposit aggregate on the land. The bed aggradation rate in the current river bed is likely to reduce, and a reduction in the level of gravel in the area of the Waiho Bridge may occur for a period of years, while the beds find equilibrium again. Once bed aggradation resumes, the rates are likely to be less per year than current rates because of the increased deposition area to the south. The efficacy of this option, to the challenge of flood is good.

Efficacy of supporting options: - Gravel management of the river has the potential to further improve the efficacy of this option, particularly in the longer-term and in perpetuity - Building an engineered stopbank at the crest of the town (on the true right bank) would provide further protection of the township
Contribution to investment certainty
This option provides investment certainty as it helps provide confidence that the risk of flooding from the Waiho River has been reduced. However, ongoing concerns about the risk from earthquake (and rock landslide) remain as well as residual risk behind stopbanks.
Major potential stakeholder impacts
- Township residents: Improved protection against flood risk - NZTA: Approximately 4-5km of new highway is required - Residents and businesses south of the Waiho: Significantly increased risk of flooding in the medium-term and may need to relocate. Potential for compensation for loss of value of land and business - DoC: Some conservation land will be reclaimed by the River - Township, Council and NZTA: Potential for ongoing cost of gravel management in perpetuity
Economic benefits
This option protects the local economy, as the majority of the existing tourist infrastructure remains in-situ. Some economic benefits that are derived from the south side of the Waiho would need to be replicated elsewhere within the region (for example the Aerodrome).
Cost of implementation
Elements: - SH 6 realignment (approximately 4km) - ~2,800m of existing flood protection to be removed - Compensation package / relocation for land impacted by flooding (between the Waiho River and Dochertys Creek) - Additional option elements o Gravel management o Engineered town stopbank

Estimated cost of implementation for MCA	$10-$50m

Environmental costs / benefits
- Some Crown / conservation land will be subject to increased flooding / inundation frequency - Short term impacts on stream ecology as the Waiho River takes time to find its new low flow channel - Potential impacts on Dochertys Creek from increased flows / influx of Waiho waters - Potential effects on coastal edge (Waiho Beach/dune features) - Potential effects on wetlands downstream – with 4m raised bed the Waiho Beach Swamp and Waiho Kahikatea Forest could be impacted

- Potential impacts on Te Wahipounamu – UNESCO World Heritage Area
Social or cultural costs / benefits
- No identified heritage sites or taonga (following review of District Plan and Archsite) but potential that there would be some archaeological features in the footprint of the Waiho River due to extent of river flows
Interdependencies
- Protection of the southern Waiho Bridge abutment
Barriers
- Overcoming loss of value to the south with increased flooding frequency - Impact on SH6 - Consenting requirements for diversion of water/ impacts on schedule 2 wetland - Impact on access to the Aerodrome

2 Allow Waiho River to follow natural course to the north below Franz Josef

Description of option

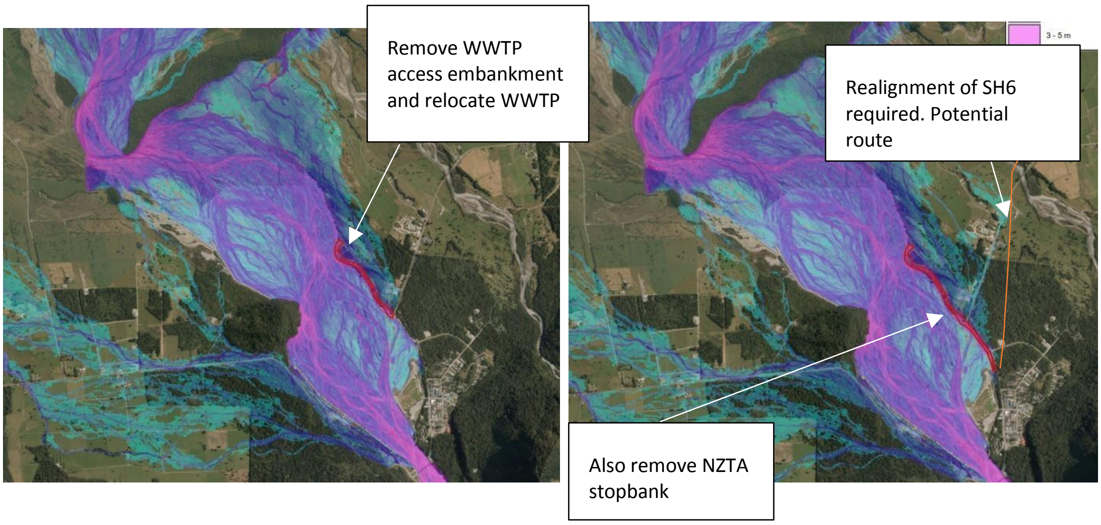
The Waiho River is allowed to flow to the north (true right) by removing the true right flood protection stopbanks downstream of the township. The waste water treatment plant will need to be moved to a location away from the new river bed.

This option has two key potential variants regarding the removal of flood protection:

- Remove the waste water treatment plant access embankment only, leaving SH6 protected
- Remove the waste water treatment plant access embankment and the NZTA stopbank protecting SH6. If the NZTA stopbank was removed, SH6 would have to be realigned with land purchase likely required

Supporting options or variations:

- There is also the option to include gravel management and / or an engineered stopbank to further protect the township
- This could also be coupled with a release to the south



Efficacy in the context of natural challenges

There is no change in the challenge faced from earthquake and rock landslide (including with supporting options).

The efficacy of this option to the challenge of flooding in the medium-long term is limited, as there will likely be little reduction in bed aggradation. The Waiho River would be constrained from above the Waiho Bridge to the helicopter operation area, which is the main confined area causing bed aggradation.

Efficacy of supporting options:

- There is the option for gravel management of the Waiho River and/or to build an engineered stopbank to further protect the township. In this situation the gravel management or the township stopbank would be providing the majority of the benefit, rather than the release of the Waiho River.

- Release to the north likely provides its greatest efficacy when it is combined with release to the south, gravel management and a township stopbank, by providing the maximum opportunity to reduce bed aggradation (i.e. the combination of many parts making up the best solution). This would need to be weighed up against the value of the land to the north which would be inundated.

Contribution to investment certainty

This option provides investment certainty in the short term, but this is limited due to the short-term nature of the reduced flooding risk. Ongoing risk from earthquake and rock landslide are not addressed by this option.

Potential stakeholder impacts

- Township residents: Improved protection against flood risk in short-term
- Property owners in release areas to the north: Would need to relocate. Likely impacts Scenic Circle Group, Top 10 Holiday Park, Westpower Substation, Franz Josef School, kindergarten and wastewater treatment plant
- NZTA: Realignment of ~2km of SH6
- Township, Council and NZTA: Cost of ongoing gravel management in perpetuity
- Flooding to the south of the Waiho River still occurs

Economic benefits

This option protects some township and tourism infrastructure by protecting the town where the majority of tourism infrastructure is located.

Cost of implementation

Elements:

- Relocation of the waste water treatment plant
- Removal of embankments
- Purchase of land north of river
- Relocation of privately owned buildings
- Relocation of the substation
- Relocation of the School and Kindergarten
- Additional option elements: Realignment of 2km of SH6

Estimated cost of implementation for MCA	$10-50m

Environmental costs / benefits

- Some Crown / conservation land will be subject to increased flooding / inundation frequency
- Potential ecological and erosion impacts on lower reaches of Tatare Stream from flooding
- Potential ecological impacts on Lake Pratt and associated wetland from flooding

Social or cultural costs / benefits

- Key local services, including Franz Josef Glacier School and Kindergarten, will need to be relocated outside of the flood zone or protected
- Key infrastructure like the waste water treatment plant will need to be relocated

Interdependencies
Release to the north likely provides its greatest efficacy when it is combined with release to the south, gravel management and a township stopbank by providing the maximum opportunity to reduce bed aggradation (i.e. the combination of many parts making up the best solution).
Barriers
- Large number of social services / key infrastructure would be affected by this option, which could change acceptability of the option

3 Long term management programme for engineered stopbanks

Description of option
A long term management plan for engineered stopbanks to be designed, constructed, monitored, maintained and reviewed. Supporting options or variations: - It is likely that this option would require ongoing gravel management of the river in order to limit the height of the bed, and therefore the rate that the engineered stopbanks would need to be built
Efficacy in the context of natural challenges
There is no change in the challenge faced from earthquake and large rock landslide (including with supporting options). Stopbanks would be designed for the specific conditions in the Waiho River. They would be constructed generally in the same location as the existing stopbanks. Without gravel management of the river bed the height of the stopbank beside the township would need to be up to 6m high by year 50 (assuming current levels of bed aggradation). The Waiho River Bridge would need to be constantly lifted 2m at a time, approximately every 10 years (five lifts over the study period). As raising the bridge and stopbanks would need to continue in perpetuity, the longer-term feasibility is limited without gravel management. Supporting options or variations: - This option could be combined with gravel management of the Waiho River bed to make this option more effective in the longer-term - It would be beneficial to move the wastewater treatment plant and slightly realign SH6 (to enable removal of selected stopbanks) to reduce the river bed confinement, therefore minimising the rate of bed aggradation There will be some residual risk, as the consequence of failure of stopbanks at the ~6m height is potentially significant. Gravel management reduces this risk.
Contribution to investment certainty
Engineered stopbanks without gravel management provides little investment certainty as the value of the township will still be at risk. With gravel management this option provides some investment certainty over the study period, but may still be limited by the ongoing risk from earthquake and large rock landslide and requirements for gravel management in perpetuity.
Potential stakeholder impacts
This option benefits landowners on both sides of the Waiho River, who will continue to be able to utilise their properties. Impacts associated with the option, excluding gravel management:

- Environment: Unsightly visual impact. The stopbanks would reduce the natural value of the area due to their size and dominance - NZTA: Regularly raising the Waiho Bridge (if no regular and ongoing gravel extraction) - Tourists: This option would negatively impact on the tourist experience due to impacts on the aesthetic and landscape values of the area Impacts associated with the option, including gravel management: - Environment: Impacts associated with ongoing gravel management, including the presence of machinery in the river bed on a regular basis and the impacts of gravel disposal - Residents in the township and south of Waiho River: Improved protection against flood risk - NZTA: Protection against flood risk, but likely increased maintenance required on roads given number of trucks carrying gravel expected - Township, Council and NZTA: Ongoing cost of gravel management, in perpetuity - Tourists: This option would negatively impact on the tourist experience due to impacts on the aesthetic (up to seven diggers in the river 43 weeks a year, and significantly increased numbers of truck movements)
Economic benefits
This option protects the existing value of the township, as tourism infrastructure remains in its' current location. However, this may be put in jeopardy in the long-term due to the change in amenity value associated with the size and scale of the stopbanks and / or ongoing gravel management.
Cost of implementation
Elements: - Engineered town stopbanks Additional option elements: - Gravel management - Relocation of waste water treatment plant - Relocation of Scenic Circle Group assets

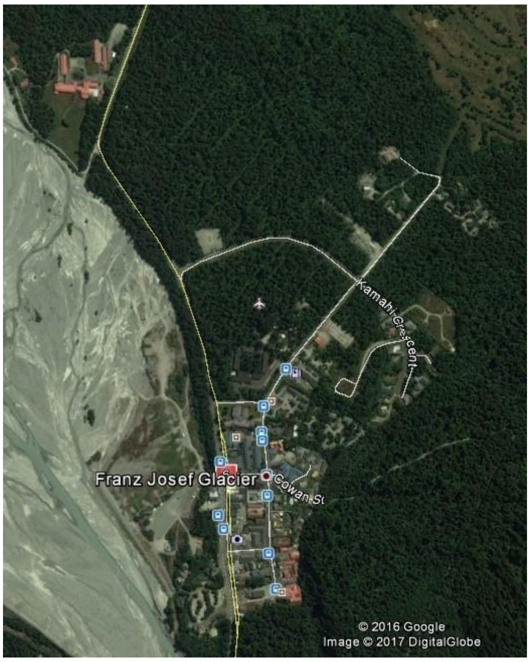
Estimated cost of implementation for MCA	$50-200m >$200m (including options)

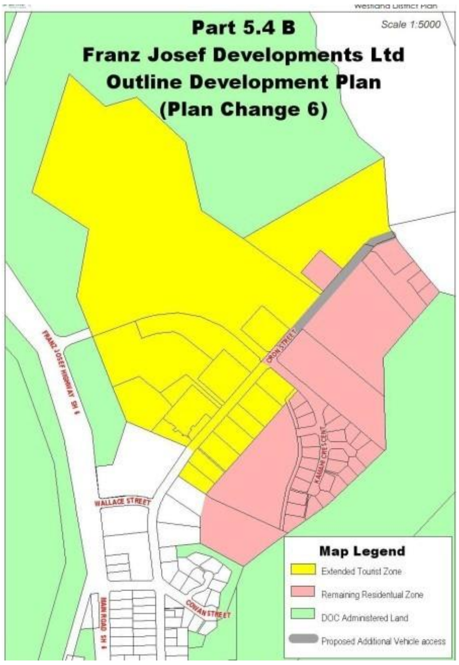
Environmental costs / benefits
- Ongoing effects on the ecological values of the river from ongoing gravel management
Social or cultural costs / benefits
- No identified heritage sites or taonga (following review of District Plan and Archsite) - Change in amenity value due to stopbanks and / or ongoing gravel management
Interdependencies
- Gravel management reduces the residual risk associated with this option
Barriers

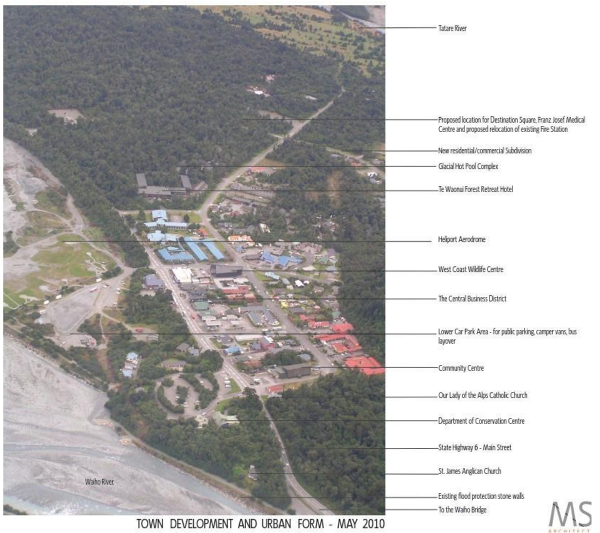
- Change in amenity value may make the option unacceptable in the longer-term - Suitable location for the deposition of gravel material in perpetuity

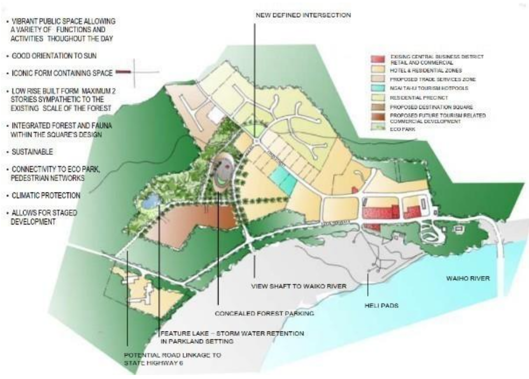
4 Move centre of gravity of township to the north

Description of option
Move the centre of gravity of Franz Josef township to the north within the area identified in the Outline Development Plan (Plan Change 6) in the District Plan. The yellow zone identified below provides for an extended tourist zone and the pink zone provides for an extended residential zone. Franz Josef Development Ltd presented to the public in late 2007 on some conceptual ideas for a destination square for Franz Josef to the north of New Road. Some of these concepts could be carried forward into a new Franz Josef town centre.









Supporting options or variations:

- This option could be incentivised to encourage movement to the growth area

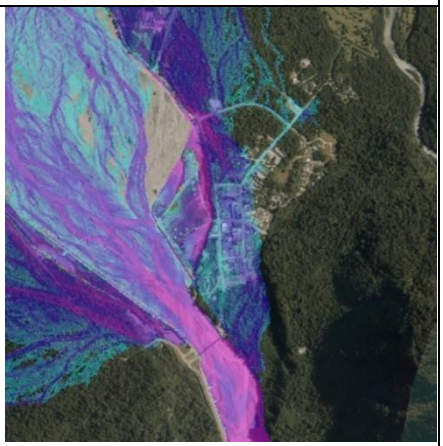
- This option could be used to lower the risks associated with key assets being located in the active known fault zone. This would require the development of an appropriate way to support this transition
- This option is most effective when considered in conjunction with other flood mitigation options

Efficacy in the context of natural challenges

The efficacy of this option to mitigating the challenge of Alpine Fault rupture is good, as the fault is unlikely to pass beneath the north end of town (however more detailed investigation should be undertaken).

The efficacy of this option to mitigating the challenge of rock landslide is poor as the north end of the town is still exposed to inundation from a rock landslide.

The efficacy of this option in mitigating the challenge of flooding is limited, as part of the area is likely to be flooded if bed aggradation continues without intervention (see opposite).



Contribution to investment certainty

Moving the centre of gravity provides some investment certainty for the future, as it could be formalised in the District Plan and via Masterplanning.

Certainty is created by moving away from the Alpine Fault, but could be limited by the ongoing risk from rock landslide. There is still some exposure to flooding with bed aggradation if implemented in isolation.

Potential stakeholder impacts

- Some township residents stand to benefit from this option, particularly landowners in the area proposed for development and those who wish to move outside of the fault zone

Economic benefits

- Protects current tourism activities by providing for certainty around the fault rupture zone

Cost of implementation

Elements:

- Masterplanning
- Construction of local roads and 3-waters network extension in new location
- Construction of new private building stock in new location
- Any potential incentives to encourage or facilitate relocation

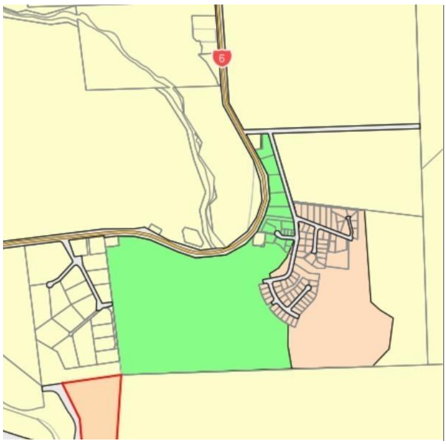
Estimated cost of implementation for MCA	$10-50m

Environmental costs / benefits

- Impacts on native vegetation as a consequence of clearance and construction activities
- Impact on waterways as a consequence of tree clearance and construction
- Positive opportunities to enhance adjacent conservation areas through mitigation

Social or cultural costs / benefits
- No historic or heritage protection sites identified in the WDP - No sites of archaeological significance identified on Archsite - Potential positive benefits if the community is involved in the design of a new and improved town centre which could provide for an improved tourist experience
Interdependencies
- Requires the implementation of flood management option(s) - Incentivisation to encourage transition - Support for the transition of assets in the active known fault zone to the north to further reduce overall risk profile of the township
Enablers
- There are already provisions for development in this area in the District Plan

5 Relocate to Franz Alpine Resort / Stony Creek

Description of option
Option for Stony Creek to be developed as the main town centre. Stony Creek is a partially bush clad site, located approximately 8 km along SH6 to the north-west of the current main town centre. Stony Creek itself runs through the site and eventually discharges into the Tatare Stream, which flows into the Waiho River. Key services (i.e. wastewater treatment plant and water supply) would be required. The area would require flood protection (although at a lesser scale than adjacent to the Waiho River). Development at Stony Creek is already provided for in the District Plan – the plan has specific objectives and rules which allow for development to occur with particular restrictions. There is an Outline Development Plan for the site which identifies a tourist zone and a residential zone, there are particular restrictions relating to the development that can occur in each zone. The area currently provided in the Outline Development Plan may need to be extended to provide a suitably sized area for the development of a town.   This option would require the development of a managed transition plan to ensure that investment is not split between the existing township and the new development area and some additional Masterplanning
Efficacy in the context of natural challenges
The efficacy of this option to mitigating the challenge from earthquake is poor, with little improvement from potential rock landslide from the Alpine Range front, although there is the potential that development can avoid the Alpine Fault rupture zone in this area (more detailed investigation is likely required). The efficacy of this option to mitigating the challenge of flood is good, moving development out of the Waiho flooding area. There remains some flood risk from the Stony Creek which would need to be mitigated with flood protection works.
Contribution to investment certainty

This option provides some investment certainty, but this is limited by the continued risk from earthquake and rock landslide. As noted in the option description, Masterplanning and a transition plan is required so that investment certainty isn't negatively impacted.
Potential stakeholder impact
- Township residents and businesses: Disruption from relocation activities; living with reduced risk; masterplanned town with new and more sustainable infrastructure and building stock - Farming and agriculture businesses that do not relocate to the new area: significantly increased risk of flooding in the medium-term - Tourists: Minimal disruption from construction and relocation activities (as outside of town area and building on existing infrastructure) - Landowners at Stony Creek: Benefit from land sales for development of the town in this location - Council/Central Government/NZTA: Development of new town and associated infrastructure
Economic benefits
Potential for increased economic benefits as town and services could be designed to better support tourism activities, and to encourage residents to relocate to, and remain, in the town.
Cost of implementation
Elements: - Masterplanning and potential amendment to District Plan - Construction of local roads and 3-waters network extension in new location - Upgrade of power and telecommunication infrastructure in new location - Relocation of heliport and Aerodrome - Construction of new private building stock in new location - Construction of new community facilities in new location - Planned decommissioning of the existing township

Estimated cost of implementation for MCA	>$200m

Environmental costs / benefits
- Native vegetation clearance will be required - The natural values of the site (i.e. Stony Creek and native vegetation) are considered to be high and in need of protection. A sensitive approach to any development is required, as outlined in the District Plan - Potential impacts on Stony Creek from intensified development - Construction impacts including sediment discharge, earthworks, construction vehicles, noise - Potential for landscape and visual effects
Social or cultural costs / benefits
- No heritage protection sites or historic sites identified in the WDP - No archaeological sites identified on Archsite - Impacts on social values of Franz Josef by displacing/ moving the community

Interdependencies
- Flood protection at Stony Creek may be required to address any flood hazard risk - Support for the transition to the new area required
Barriers
- Some members of the community have indicated that community support for this option would be mixed

6 Relocate to Lake Mapourika

Description of option
Establishment of a new town development around Potters Creek / Lake Mapourika to the north of SH6. This would require new infrastructure (waste water treatment plant, water, roading) and likely some flood protection from Potters Creek (and potentially Stony Creek). The town is best located to the north of Potters Creek away from the most likely potential rock landslip inundation area. There is the potential that the development could be masterplanned to extend along the lake front to capitalise on the views the location affords.  This option would require the development of a managed transition plan in order to ensure that investment is not split between the existing township and the new development area.
Efficacy in the context of natural challenges
The efficacy of this option in mitigating the challenge from Alpine Fault rupture and rock landslide is good, providing a permanent risk avoidance solution. The new township centre would be located well away from the known fault alignment and out of the likely rock landslide inundation extent. There would still be strong shaking in this location. However, structures built with this in mind could be designed to be resilient. The efficacy of this option in mitigating the challenge from flooding of the Waiho River is good. It moves the township away from the fast aggrading Waiho River into a more manageable area, providing a permanent mitigation from the Waiho flooding hazard. There will need to be flood protection works to manage the residual flooding risk from Potters Creek and Stony Creek.
Contribution to investment certainty
This option promotes investment certainty as it mitigates against fault rupture, rock landslide, and flooding. A formal masterplanning process can significantly increase investment certainty. As noted in the option description, a transition plan is required. This option also contributes to a diversified tourism offering, with a strong focus on the lake front, which may provide greater investment certainty in the longer term.
Potential stakeholder impacts
- Township residents and businesses: Disruption from relocation activities; living with reduced risk from fault rupture, rock landslide, and flooding; masterplanned town with new and more sustainable infrastructure and building stock - Farming and agriculture businesses that do not relocate to the new town: Significantly increased risk of flooding in the medium-term

- Tourists: Minimal disruption from construction and relocation activities (as outside of town area) - Landowners whose land is to be developed/subdivided: benefit from land sales for development of the town in this location - Council/Central Government/NZTA: Development of new town and associated infrastructure - DoC: Potential for encroachment on conservation estate (depending on the Masterplan and constraints of any land-swap policies and decisions)	
Economic benefits	
Potential for increased economic benefits as town and services could be designed to better support tourism activities, and to encourage residents to relocate to, and remain, in the town.	
Cost of implementation	
Elements: - Construction of local roads and three waters network extension in new location - Upgrade of power and telecommunication infrastructure in new location - Relocation of heliport and Aerodrome - Construction of new private building stock in new location - Construction of new community facilities in new location - Planned decommissioning of the existing township	
Estimated cost of implementation for MCA	>$200m
Environmental costs / benefits	
- The land is largely farming land, so ecological impact from land clearance would be minimal. Should the design extend around the lake-front, there could be acquisition of, and impact on, the Conservation Estate (which may be constrained by DoC land-swap policy changes). - Construction impacts including sediment discharge, earthworks, construction vehicles, noise - Impacts on Potters Stream from implementing flood protection works - Visual and landscape effects of developing a new town in a largely natural environment	
Social or cultural costs / benefits	
- No heritage protection sites or historic sites identified in the WDP - No archaeological sites identified on Archsite - No identified Taonga sites - Impacts on social values of Franz Josef by displacing/ moving the community	
Interdependencies	
- Flood protection at Potters Creek may be required to address any flood hazard risk - Support for the transition to the new area required	
Barriers	
- Land is currently zoned rural. A District Plan change would be required to provide for residential and tourism development in this area - Development risk would need to be taken by a party able to bear this risk	

7 Relocate to Lake Wombat

Description of option
Growth strategy to establish a new township at Lake Wombat. The site is located on DoC conservation estate to the south of the existing township, to the east of Lake Wombat and to the west of the Waiho River. The potential development site lies in native bush with no current infrastructure or facilities present. Any development here would require a waste water treatment plant, water supply and other key services. This option would require the development of a managed transition plan in order to ensure that investment is not split between the existing township and the new development area.
Efficacy in the context of natural challenges
The efficacy of this option in mitigating the challenge from Alpine Fault rupture, rock landslide and flooding is good. The new township centre would be located well away from the known Fault alignment and out of the likely rock landslide inundation extent. There would still be strong shaking in this location. However, structures built with this in mind could be designed to be resilient. The efficacy of this option in mitigating the challenge from flooding of the Waiho River is good. It moves the township away from the fast aggrading Waiho River and into an area with negligible potential flooding risk.
Contribution to investment certainty
New development here could proceed with certainty around natural hazard risk. As noted in the option description, a transition plan is required so that investment certainty is not negatively impacted. Changes to land-swap policy by DoC (likely following recent Supreme Court decision) could significantly decrease investment certainty for this option.
Potential stakeholder impacts
- Township residents and businesses: Disruption from relocation activities; living with reduced risk from fault rupture, rock landslide, and flooding; masterplanned town with new and more sustainable infrastructure and building stock - Farming and agriculture businesses that do not relocate to the new town: Significantly increased risk of flooding in the medium-term - Tourists: Minimal disruption from construction and relocation activities (as outside of town area) - Council/Central Government/NZTA: Development of new town and associated infrastructure - DoC: Encroachment into the Conservation Estate
Economic benefits
Potential for increased economic benefits through town and service design that better supports tourism and encourages residents to locate and remain in the town. There could also be the potential to diversify tourism offerings around a remote ‘eco-village’.
Cost of implementation

Elements: - Construction of local roads and three waters network extension in new location - Upgrade of power and telecommunication infrastructure in new location - Relocation of heliport and Aerodrome - Construction of new private building stock in new location - Construction of new community facilities in new location - Planned decommissioning of the existing township	
Estimated cost of implementation for MCA	>$200m
Environmental costs / benefits	
- Clearance of native vegetation required for new township as well as all access roads - Construction impacts including sediment discharge, earthworks, construction vehicles, noise - Landscape, visual and aesthetic effects of developing an area with high natural values	
Social or cultural costs / benefits	
- No heritage protection sites or historic sites identified in the WDP - No archaeological sites identified on Archsite - Impacts on social values of Franz Josef by displacing/ moving the community	
Interdependencies	
- Support for the transition to the new area required - Development risk would need to be taken by a party able to bear this risk	
Barriers	
- Land is managed by DoC and publically owned. Permission from DoC is required in addition to the council for activities on this land. The recent Supreme Court decision on land swaps may significantly impact on this option. - No existing planning provisions for the development of this land - No existing infrastructure of other development to build upon - Anecdotally, it was reported that there is limited support for this option in the Franz Josef community	

Appendix G: No-regrets resilience options

As discussed in Section 0, there are a number of low-cost, options, which are comparatively easy to implement, which scored well in the MCA including:

- Development and implementation of a Community Resilience Plan
- Education on resilience and emergency response
- Establishment of community resilience hubs
- Collaboration with NZTA and an integrated Waiho River management plan

There are a number of additional no-regrets actions that could be considered for implementation in the short term (Table 15-12). The primary function of these options can be summarised as (Figure 15-2):

- Additional community resilience measures to support self-sufficiency
- Resilience as part of asset management business-as-usual
- Additional business continuity cover

The majority of these options 'manage' risk, as opposed to avoid or transfer risk. They also predominantly create self-sufficiency in the context of post-event response and seek to protect built environment capital.

Figure 15-2: Summary of the primary function of no-regrets options: no-regrets options create resilience by improving community self-sufficiency and protecting built environment capital

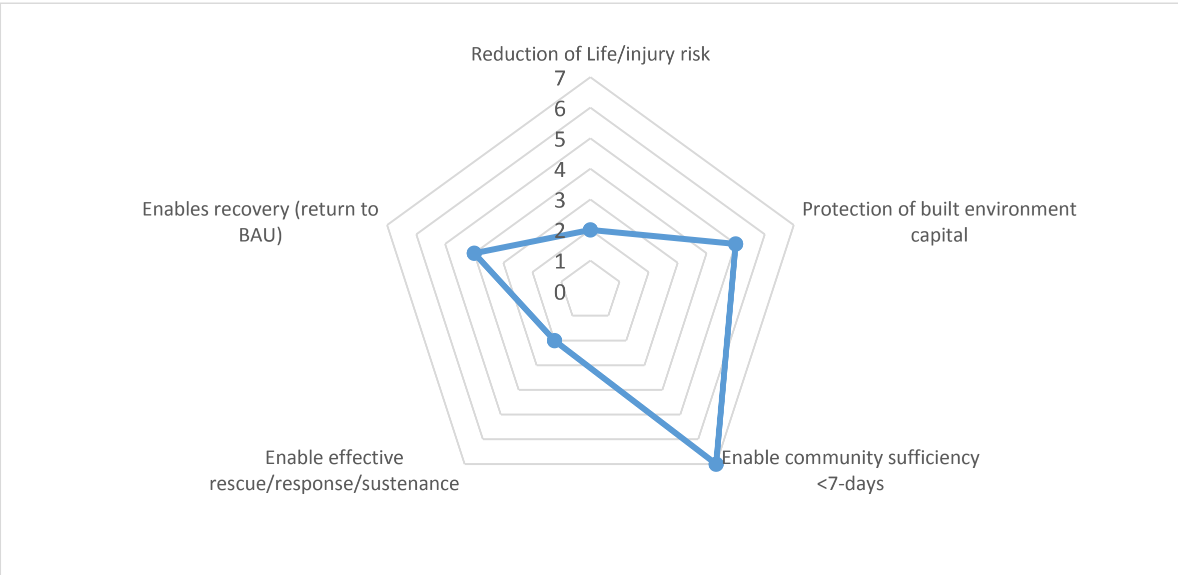
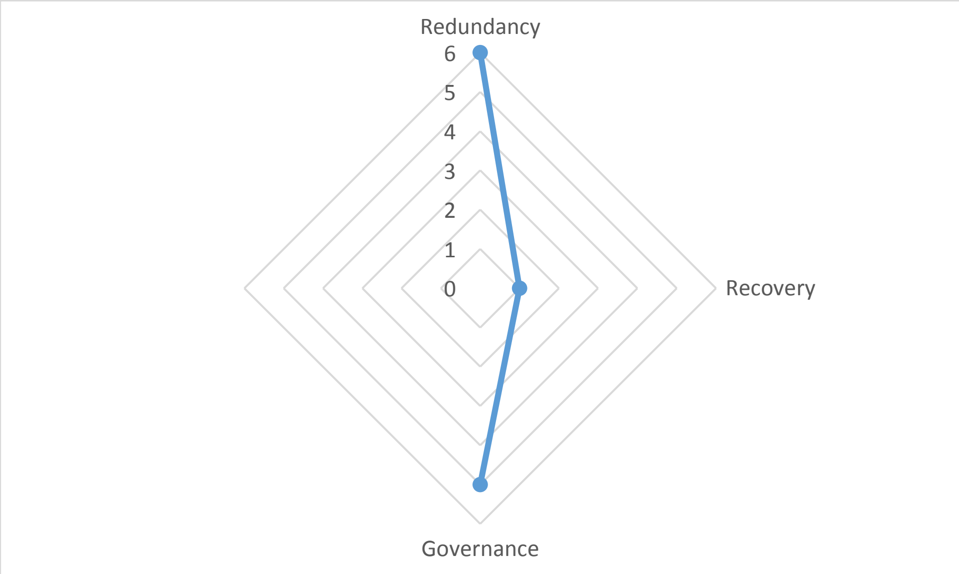


Table 15-12: No-regrets resilience options

Committed or Future Initiative	Resilience Pathway	Approach to Risk	Service / function	Sector	Option	Total MCA
Committed	Governance	Manage	Enables recovery (return to BAU)	Communications	Community resilience plan	0.60
Future	Recovery	Accept	Enables recovery (return to BAU)	Communications	Education	0.59
Future	Governance	Manage	Protection of built environment capital	Building stock	Collaboration with NZTA	0.57
Future	Governance	Manage	Protection of built environment capital	Building stock	Waiho River Management Plan	0.56
Future	Redundancy	Manage	Enable community sufficiency <7-days	Fuel	Stores of fuel, food, water & medicine	0.54
Future	Robustness	Manage	Enable effective rescue/response/sustenance	Aerodrome	Aerodrome resilience	0.54
Future	Governance	Transfer	Enables recovery (return to BAU)	Building stock	Traditional insurance (and reinsurance)	0.53
Future	Governance	Manage	Reduction of Life/injury risk	Building stock	District Plan reinforces earthquake resilient building stock	0.52
Future	Redundancy	Manage	Enable community sufficiency <7-days	Electricity	3 x back-up generators	0.52
Future	Redundancy	Manage	Enable community sufficiency <7-days	Wastewater	Off-grid public toilets	0.52
Future	Robustness	Manage	Protection of built environment capital	Water distribution network	Stormwater design solutions	0.51
Future	Redundancy	Manage	Enable community sufficiency <7-days	Communications	Satellite phones at 3 x locations	0.51
Future	Robustness	Manage	Enable community sufficiency <7-days	Potable water	Decentralised water supply	0.48
Future	Robustness	Manage	Protection of built environment capital	Water distribution network	Strengthen 3-waters network	0.46
Future	Redundancy	Manage	Enable community sufficiency <7-days	Wastewwater	Decentralised waste water strategy	0.45
Future	Robustness	Manage	Reduction of Life/injury risk	Building stock	Modular buildings	0.43
Future	Robustness	Manage	Enables recovery (return to BAU)	Electricity	Power distribution resilience	0.43
Future	Redundancy	Manage	Enable community sufficiency <7-days	Electricity	Decentralised power supply	0.43
Future	Robustness	Manage	Enables recovery (return to BAU)	Communications	Telecommunication repeater towers	0.42
Future	Governance	Manage	Protection of built environment capital	Building stock	District Plan reinforces flood resilient building stock	0.41
Future	Robustness	Manage	Enable effective rescue/response/sustenance	Helipad	Helicopter storage	0.37

Figure 15-3 shows the pathway used to create resilience, with the majority of the options creating resilience through increased robustness.

Figure 15-3: Summary of primary resilience pathway of no-regrets options: no-regrets options create resilience via increased robustness



The additional no-regrets options which could be considered for implementation in the short-term are summarised in the following sections.

1 Additional community resilience measures to support self-sufficiency

There are a range of additional initiatives which come at higher cost than the stores of food, water, fuel and medicine, which could be implemented though the community resilience / CDEM plans. These include:

- **Back-up generators** with dedicated fuel tanks protecting critical services (e.g. health centre, school (as a CDEM facility), Aerodrome)
- **Satellite phones** at community resilience hubs: A minimum of three phones at each of the three locations to support emergency communication
- **Off-grid public toilets**: Pre-dug / pre-existing off-grid toilets for public use during an emergency
- **Helicopter storage**: Minimise post-earthquake damage to ensure helicopters can be used as a response resource by changing storage practices. This may require larger hangar spaces to allow increased space per helicopter as well as tie-down protocols.

2 Resilience as part of asset management BAU

There are actions that could be taken to create robustness in infrastructure networks as part of the asset management cycle:

- **Stormwater management**: Review where stormwater pipes get blocked or can't outflow during heavy rain events, and consider possibilities to amend the design to reduce the likelihood of secondary flooding during storm events.
- **Strengthen 3-waters network**: Review the 3-waters network in the context of criticality, fragility and vulnerability. Consider developing a programme to remove AC and PVC pipes at

key locations, and replace with ductile pipe types like MDPE. This could be initiated through either a renewals or an upgrade programme.

- **Power distribution resilience**: Review the power distribution network in the context of vulnerability to earthquake induced landslide and flood paths, particularly the poles situated near the Waiho River (Figure 15-4). Consider improving power distribution resilience by realigning poles away from slopes, or potentially stabilising slopes, and the Waiho River from the sub-station to the township.
- **Telecommunications resilience**: Review the communications network (poles and wires) in the context of vulnerability to earthquake-induced landslide and flood paths. Consider relocating poles away from the most significant threats.
- **Telecommunication repeater towers**: Consider setting the telecommunication towers up as repeater towers to build redundancy from network outages. This would likely need to be considered as part of a wider West Coast approach to telecommunication resilience.

Figure 15-4: Power distribution network adjacent to the Waiho River

The current building stock in Franz Josef is generally resilient to earthquake – lightweight and single storey – which could be entrenched though the District Plan to ensure that future buildings have these resilience characteristics:

- **District Plan reinforces resilient building stock:** New developments to have mandatory resilience measures including single storey, lightweight materials, reinforcing (where appropriate) and suitable foundations. This could also include policy to raise development areas to provide local protection from flooding.

There is also the potential that business-as-usual could be supported to move towards even more resilient building stock, which would also provide redundancy for horizontal infrastructure:

- **Modular buildings**: To encourage resilient buildings; new buildings would be modular and moveable. Modular buildings could help create an adaptable township, as buildings can be raised to respond to increasing flood floor levels, moved to avoid hazards as they eventuate and are resilient to earthquake shaking with the appropriate foundations.

- **Decentralised power supply**: Incentivise the uptake of alternative power generation options with limited horizontal infrastructure for distribution. Solar panels are likely to provide the best performance for Franz Josef, particularly when combined with battery storage technology, although need to be balanced against prevailing weather patterns.
- **Decentralised wastewater strategy**: Incentivise or require residential dwellings to have individual or shared septic tanks or composting toilets. Commercial activities would likely be best placed remaining on the centralised town network. If the centralised wastewater system is disrupted, this would provide some capacity (in conjunction with public facilities) until tourists are evacuated, and post-evaluation residents could be self-sufficient.
- **Decentralised potable water supply:** Incentivise or require the installation of rainwater collection systems and water tanks. If the centralised water supply is disrupted, this would provide some capacity until tourists are evacuated, and post-evaluation residents could be self-sufficient.
- **Aerodrome resilience:** Resilience of the Aerodrome could be improved by raising and strengthening the runway to reduce vulnerability to flood (inundation and impact) and earthquake (ground deformation). There is also the potential to extend the length of the Aerodrome to allow NZDF Hercules aircraft to land to provide emergency support. These principles could be employed at the existing Aerodrome and in any new Aerodrome location.

3 Risk transfer

Risk transfer through the provision of Insurance (including self-insurance) is a tool for managing the financial risk that low frequency natural disasters in particular present. New Zealand (and Franz Josef) is characterised by:

- High levels of residential cover penetration (due predominantly to the EQC scheme) noting that there is the potential for increasing levels of under-insurance due to changes in the standard terms of individual cover
- Comparatively high levels of commercial insurance penetration (due predominantly to financial institution lending terms), but many do not have insurance that extends to appropriate levels of business continuity cover. SMEs are particularly vulnerable due to limited drawdown facility
- Infrastructure tends to be self-insured which may lead to under-insurance

New Zealand has looked to transfer its natural disaster risk for residential property, at least its financial risk from natural disasters since 1945, when earthquake cover was added to war damage cover and the Crown-owned natural disaster insurance scheme (NDIS) was established. Other perils (tsunami, volcanic eruption) were added in 1949. Landslip was added in 1970 and land cover was added to building cover in 1984. That (EQC) scheme is still the most effective way to manage the financial risk that natural disasters pose to individuals who own residential property.

In 1993 commercial and industrial buildings were dropped from the scheme and the liability of EQC for damage to residential buildings was capped at $100,000 (excl. GST). This is likely to increase to $200,000 under a proposed revision. Insurance cover for commercial property, including business continuity insurance, is readily available in Franz Josef through private insurers.

A key lesson from Christchurch was the financial resilience that insurance provided to home owners and businesses. For home owners, the multi-peril, distributed, flat rate insurance scheme that EQC and the private insurers have operated for the past 50 years has ensured that natural disaster insurance is widely available and affordable throughout New Zealand. At the time of the Canterbury Earthquake Sequence (CES), affordable natural disaster insurance had translated to high levels (95%) of risk transfer, which ensured financial resilience for most residential property owners. This high rate of residential insurance cover has allowed most residential communities to be financially resilient to natural disaster damage.

Up until the early 1990s, Government had not only taken responsibility for natural disaster damage to commercial and domestic buildings (and, since 1984, residential land), but Government had also taken responsibility for all costs associated with the restoration of water and sewage and other essential services (infrastructure) that Local Authorities found difficult to insure.

In 1991, the Government introduced a Disaster Recovery Plan which placed specific responsibilities on local authorities in order for them to be eligible to share the restoration costs of infrastructure. Beyond a threshold, central Government would pay only 60% of the restoration costs with the local authorities responsible for the remaining 40%, effectively transferring the risk from the tax payer to the ratepayer. To qualify for the 60% subsidy local authorities would have to demonstrate:

1. Proper maintenance
2. The provision of reserve funds
3. Effective insurance and/or participation in a mutual assistance scheme with other local authorities

A month before the EQC Act came into effect in August 1993, the Local Authority Protection Programme (LAPP) Disaster Fund commenced operations (July 1993). The insurer, New Zealand Local Government Insurance Corporation Limited, trading as Civic Insurance, is owned by local Government. Like the multi-peril distributed risk model of EQC, a major advantage of the LAPP scheme was that the costs and risks could be spread throughout New Zealand and that the funds were locked in. The LAPP Fund was designed for catastrophe protection only, covering serious disruptive loss or damage which may or may not involve the declaration of a Civil Defence Emergency. Perils included (but were not necessarily limited to) earthquake, storms, floods, cyclones, tornadoes, volcanic eruption and other disasters of a catastrophic nature such as a gas explosion.

It is noteworthy that less than half of the public assets (based on their carrying value) evaluated by the Auditor General in 2013 had insurance cover[36]. Self-insurance, either through the ability to borrow or having sufficient funds available, is relatively common, but the most common reason for having no insurance was the public entity believing the cost of insurance exceeded the insurance risk. The Canterbury earthquakes have depleted the LAPP Fund, and the future of LAPP is uncertain. Local Government New Zealand and The Treasury are currently scoping the creation of a Local Government Risk Agency to address the variable risk management skill level across local authorities.

A key lesson from Christchurch is that there is no point in having domestic services that are resilient if the Council or agency receiving or delivering service infrastructure is not at least as resilient. The situation is similar for schools and businesses. Community resilience requires schools and businesses to be functional as soon as homes are functional.

Therefore, a resilient Franz Josef will be a community (public and private) that is insured to a high degree (including self-insured) against natural disasters. Four specific options were tested in the MCA as potential ways to further transfer natural hazards risk in Franz Josef:

- **Traditional insurance (and reinsurance)**: Individual homeowners and business owners approach their individual insurance companies seeking adjustments to premiums, or increases in coverage, on the back of improved risk management.

[36] Office of the Auditor General, 2013. Insuring public assets, Discussion Paper June 2013

- **Collective bargaining:** Individual homeowners and businesses could band together and leverage their greater buying power to reduce premiums when approaching insurers. To support this, local government could act as a trusted intermediary to coordinate this interaction (via a broker).
- **Collective bargaining – reinsurance:** In acting as this trusted intermediary, there is further opportunity for local government to approach reinsurers directly (depending on the potential risk/premium). The insurance costs could then be allocated across households, businesses, etc.
- **Catastrophe bonds:** A primary party could aggregate the collective insurance risk into a 'catastrophe bond'. In this case a third party (or parties) would purchase the bond and the primary party would pay an agreed coupon rate for the life of the bond. If a predetermined event occurred the bond value would be retained and the coupon payments would end. If the event did not occur, the primary party would return the bond value.

UN Principles of Sustainable Insurance

There are many options around insurance, and the four overarching Principles for Sustainable Insurance[1] provide a useful framework to consider how insurance products can assist in achieving resilience objectives including:

- Embedding environmental, social and governance issues in decision-making
- Working together to raise awareness of environmental, social and governance issues, reduce risk and develop solutions
- Working together with governments, regulators and other key stakeholders to promote widespread action across society on environmental, social and governance issues
- Demonstrating accountability and transparency in regularly disclosing publicly our progress in implementing these Principles

Traditional insurance (and reinsurance) and collective bargaining performed particularly well in the MCA based on their accessibility, and the value that they are able to protect (Table 15-13).

Table 15-13: Risk transfer options

Committed or Future Initiative	Resilience Pathway	Approach to Risk	Service / function	Sector	Option	Total MCA
Future	Governance	Transfer	Enables recovery (return to BAU)	Building stock	Traditional insurance (and reinsurance)	0.53
Future	Governance	Transfer	Enables recovery (return to BAU)	Building stock	Collective Bargaining	0.52
Future	Governance	Transfer	Enables recovery (return to BAU)	Building stock	Collective Bargaining - Reinsurance	0.46
Future	Governance	Transfer	Enables recovery (return to BAU)	Building stock	Catastrophe Bonds	0.30

Based on the recovery from the CES, and the insurance landscape in New Zealand post-CES, we see that there would be particular value in businesses reviewing their business continuity cover and considering extending cover from months to years, to more fully cover the period of disruption that is likely to be the result of a significant natural hazard event.

Working with the Insurance Industry

ICNZ have published a handbook on natural hazard protection[1]. Franz Josef could partner with ICNZ to educate communities around the availability, and costs and benefits, of domestic and commercial insurance as part of Franz Josef community risk management. Knowing the level of insurance cover in Franz Josef would be helpful for recovery planning if this information is made available before a natural disaster occurs. ICNZ may be able to assist Franz Josef with this initiative.

1. ICNZ, 2014. Protection New Zealand against Natural Hazards.

4 Summary

Overall, these options could support community response and self-sufficiency post-event through:

- Development and implementation of community resilience and CDEM plans
- Development of community resilience hubs
- Decentralisation of utilities (3-waters and power)
- Entrenchment of the development of resilient building stock

In addition, there are a number of activities to be led by local government and other asset owners to improve the robustness of infrastructure including:

- Three waters network
- Power distribution network
- Communications network
- Aerodrome resilience

These activities should be tested and developed in collaboration with all asset owners so that there is an integrated approach to Waiho River and asset management.

Finally, we also recommend that insurance cover is reviewed, and that in particular, business owners consider the coverage provided by their business continuity insurance to allow return to business-as-usual.

Appendix H: Base case technical annex

1 Introduction

The base case describes the 'do nothing' option for Franz Josef, capturing the expected losses or 'value at risk' associated with earthquake and flood events in the absence of interventions to avoid or mitigate the effects. The base case serves several purposes:

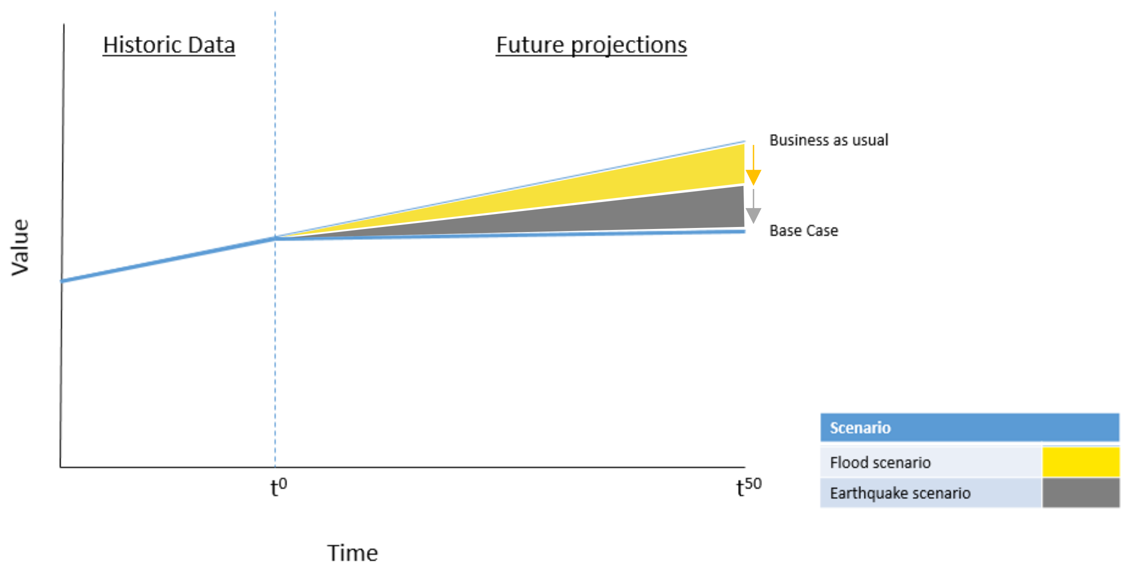
- To transparently outline key study assumptions about future investments, projected stocks and flows, size and magnitude of the impacts of each scenario and emergency response expectations.
- To act as a reference point for a number of decisions made across during multi-criteria analysis (MCA), which will narrow the long list of options and enable the packaging of options.
- To use as a baseline in the development of the cost benefit analysis (CBA) and eventual translation into Treasury's CBAx tool. The CBA will use the base case as a consistent baseline to assess the short-listed packages of options and arrive at a preferred package of options.

Owing to the unique nature of this study, the base case has been developed in a series of layers, each individually assessed, comprising:

- A business-as-usual (BAU) scenario (see Section 2 of this appendix)
- Losses expected from earthquakes e.g. rupture of the Alpine Fault (see Section 3 of this appendix)
- Losses expected from flooding of the Waiho River (see Section 4 of this appendix)

Figure 15-5 shows how the base case is arrived at, starting from an assessment of the business-as-usual scenario over time and then 'removing' the potential for flood and earthquake losses.

Figure 15-5: Styled example of the development of the base case



This appendix describes the scale and magnitude of the value at risk from each scenario. It does not characterise the time-adjusted effects of any of the scenarios, i.e. it does not factor in inflation in asset prices through the PPI or the CPI, nor does it account for changing probability and risk profile of the scenarios. Dynamic and intertemporal analysis including discount rates, average annualised losses from flooding events, and probability-weighted losses from earthquake events will be formally captured in the Cost-Benefit Analysis chapter of this report.

The Cost Benefit Analysis is used to support decision making by providing a way to calculate the potential benefits (or avoided costs) from an investment. In the case of Franz Josef, the CBA aims to determine the value of life, property, and economic activity protected by making investments to reduce the impacts of a flooding or earthquake event. The purpose of the base case in this analysis is to understand what happens if nothing is done. In this sense we calculate the damage of a flood or earthquake and apportion it by the probability of an event occurring.[37]

2 Business-as-usual

2.1 Introduction

The business-as-usual scenario is the first layer of our base case assessment and consists of a range of assumptions about key dimensions of value that exist within Franz Josef (as well as the enabling decisions that support this value) in lieu of any natural disaster event. In other words, in the eventuality that there is no natural disaster event in Franz Josef, what is a reasonable estimate of the expected growth pattern for a range of variables that define, or help support, the 'value at stake' over a selected time horizon?

The geographic area considered in the assessment is shown on Figure 15-8.

The business-as-usual scenario is not a prediction of future growth patterns. Rather it is a plausible and credible baseline that serves to provide an integration point for the two natural hazard scenarios, and serves as a general anchor for the options assessment.

An example of an *enabling decision* dimension would be our assumptions about the Planning environment (such as that development will continue incrementally in areas with permissive development controls).

Examples of *value* dimensions include:

- Tourism (number of visitors and expenditure)
- Investment in major infrastructure (such as the wastewater treatment plant)

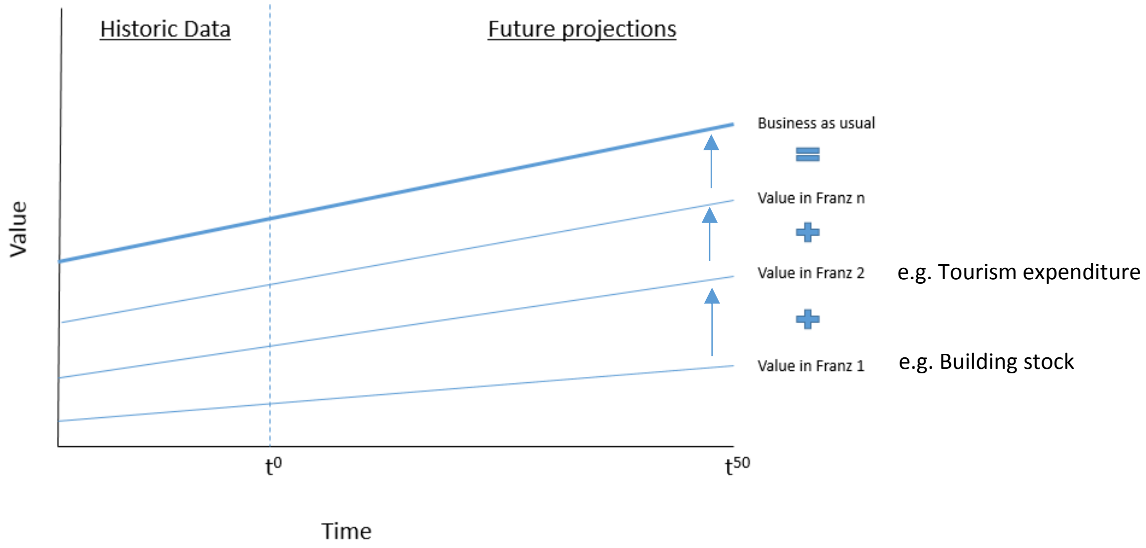
A stylised example of how these 'values' are stacked to develop a total 'value at stake' is provided in Figure 15-6. In this instance, 'Value in Franz Josef 1' might be the capital value of the building stock, and 'Value in Franz Josef 2' might be the value of tourism expenditure.[38]

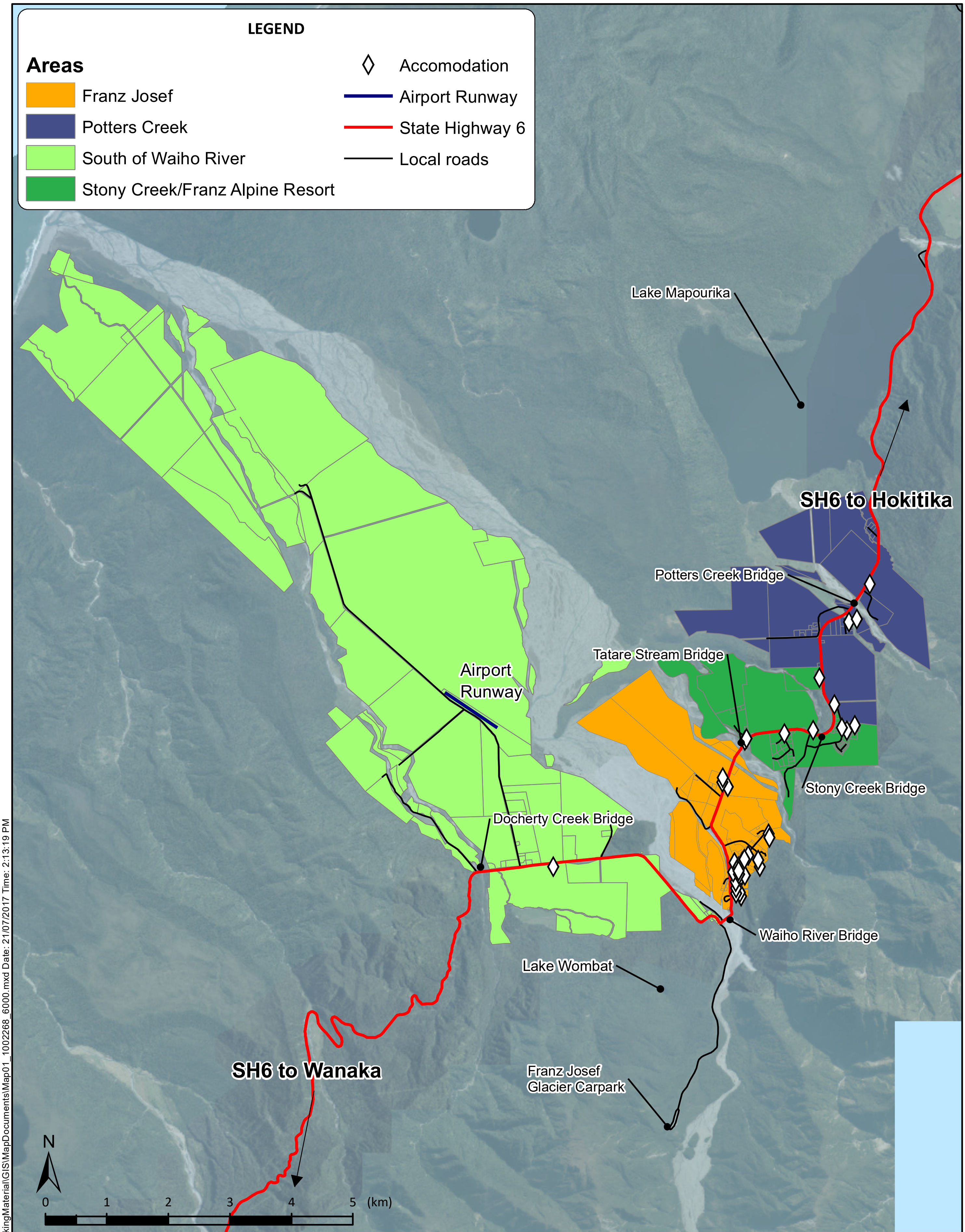
Once we have a picture of the forecast value at stake for Franz Josef, we can then begin to overlay natural disaster events to understand the 'value at risk' for each natural disaster scenario and, ultimately, the risk-adjusted base case.

[37] For example, if you toss a $1 coin twice but win only if it falls 'heads side' up, then after two flips you could expect to have $1. That means the value of a single flip is 50c.

[38] These two value dimensions will have different annualised 'values' but have been shown below for simplicity.

Figure 15-6: Stylised example of the development of the business-as-usual projection





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Tonkin+Taylor
105 Carlton Gore Rd, Newmarket, Auckland
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APPROVED	NWR	Jul.17

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1002268

WEST COAST REGIONAL COUNCIL
FRANZ JOSEF NATURAL HAZARDS OPTIONS ASSESSMENT
Wider Franz Josef Area

FIGURE No. 15.7

Rev. 0

2.1.1 Projection over time

A decision on the time horizon for the analysis is subjective. Different dimensions of value will inherently have different timescales that lend themselves to analytical effort. We have selected a time horizon of 50 years to align with the Treasury CBAx model process.

Preparing a credible baseline over a 50-year horizon inherently includes the need to address uncertainties as well as a time dimension.

We have documented all assumptions made in our business-as-usual forecast in Section 5 of this appendix so uncertainties can be compared to the business-as-usual assessed here. As a general principle, the business-as-usual scenario only includes investments that have been explicitly budgeted for, or publically announced, and uses official government projections, where relevant.

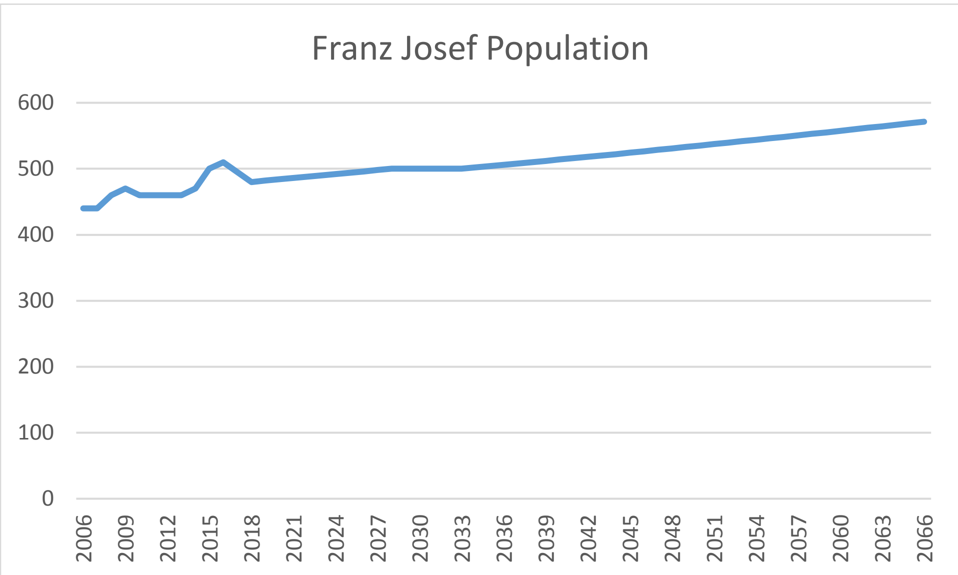
To reflect the general time dimensions at play, we have provided a visual representation of all input assumptions wherever possible. This includes long term trends, and where appropriate, more frequent cyclical fluctuations. Detailed analysis, incorporating how value (at stake and at risk) changes over time, is then provided in the cost-benefit analysis chapter.

2.2 Township population

As shown in Figure 15-9 the resident population of Franz Josef has been estimated to grow by 61 over the next 50 years, to 571 people.

This figure has been extrapolated from Statistics New Zealand area unit projections and does not include any assumptions around the catalysing effect that investments in tourist infrastructure, or investments to mitigate the natural disaster risk(s) facing the township, may have. Nor does this estimate include assumptions about the occurrence of any natural disaster event over the forecast period.

Figure 15-9: Population growth profile to Year 50 (2066)



2.3 Stocks

As shown in Table 15-14, total building stocks within Franz Josef are assumed to increase by 368 over the forecast period. This represents a capital value uplift of $138m as shown in Table 15-14 and Table 15-15. We have assumed that this growth is proportional to the current density of development in the existing township and surrounds (including Stony Creek) and is also impacted by our assumption about the future planning environment.

Building growth numbers are based on the general assumption that residential buildings and 'other buildings' will increase in line with forecast population growth, while commercial buildings will increase in line with forecast tourist growth. Land values for property in the region have been held constant, while capital values have increased at a rate commensurate to current average property improvement values for both commercial and residential property as shown in Table 15-15.

How this growth profile extends over the 50-year period is shown in Figure 15-10.

Table 15-14: Summary of growth in building stock to Year 50 (2068) – Building numbers

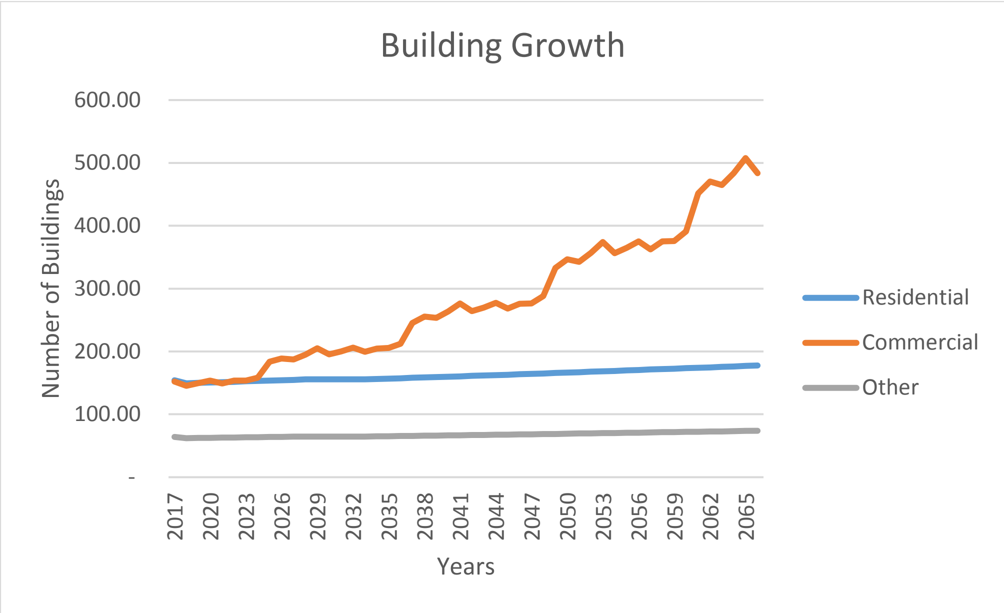
Area	**Current**			**Year 50 (2068)**		
	Number of buildings			**Number of buildings**		
	Residential	Commercial	Other	Residential	Commercial	Other
Franz Josef and Stony Creek	~152	~154	~64	~175	~490	~73
	Total = ~370			Total = ~738		

Table 15-15: Summary of growth in building stock to Year 50 (2068) - Capital value[39]

Area	**Current**		**Year 50 (2068)**	
	Land value (NZD)	**Improvement value (NZD)**	**Land value (NZD)**	**Improvement value (NZD)**
Franz Josef and Stony Creek	$57m	$84m	$57m	$222m
South of Waiho River	$23m	$6.5m	$23m	$6.5m
Potters Creek	$10m	$6.6m	$10m	$6.6m
Subtotal	**$90m**	**$97m**	**$90m**	**$235m**
Total	**$187m**		**$325m**	

[39] Land values have been assumed to remain constant over the forecast period. Improvement values have been assumed to increase in line with current per-property improvement values for Stony Creek and Franz Josef township.

Figure 15-10: Building stock growth profile to Year 50 (2066) (estimate of building numbers in the Franz Josef township and Stony Creek areas only)



2.4 Flows

2.4.1 Tourism

Alongside capital values of properties in Franz Josef, tourism flows are the most significant monetisable value at stake in Franz Josef over the 50-year period.

Based on modelling, the number of tourists visiting Franz Josef annually are projected to grow to 883,000 by Year 50. This translates to 1.85m visitor nights and $411m in annual expenditure per annum. This estimate has been developed through consultation with MBIE.

The following steps have been taken in the determining this forecast:

- A general rate of growth was applied based on historic year-on-year growth rates over the last 10 years
- A 'cyclical element' was then overlaid, whereby the range of rates between the two historic peaks, 2003 and 2016, were applied in sequence over the 50-year period

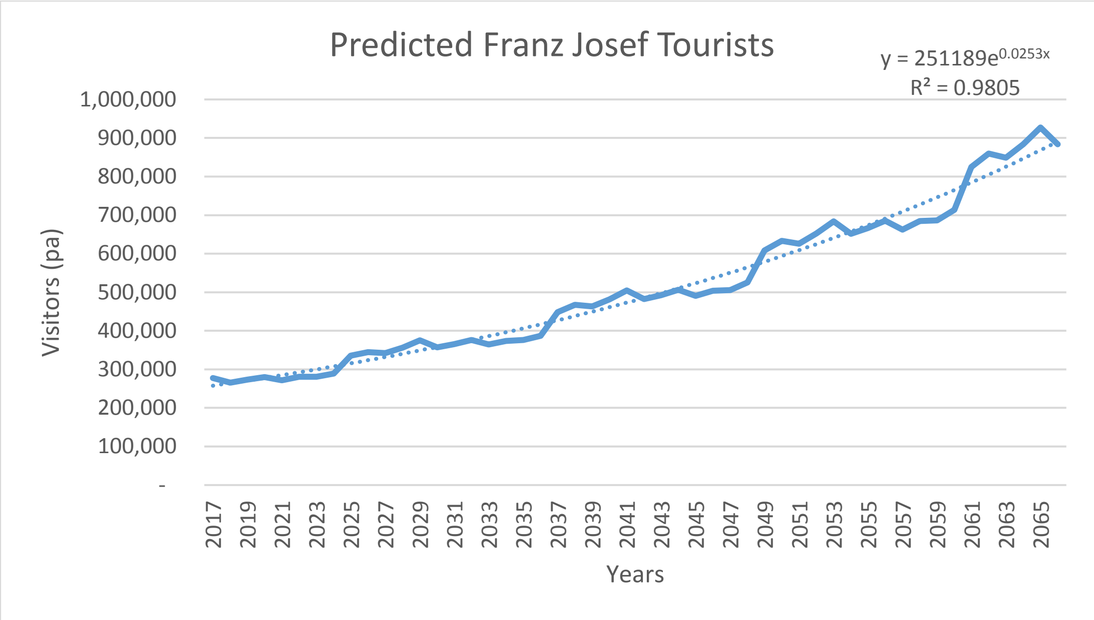
The uncertainty associated with potential glacier retreat (see Section 6 of this appendix) was originally included, but then removed given the scale of the uncertainty. Accommodation capacity was also modelled, but was found to be immaterial given the 65% utilisation rate.[40,41]

The effects of this modelling are demonstrated in Figure 15-11.

40 A line of best fit will then be applied to the forecasting when used in CBAx modelling.

41 This represents an annualised occupancy rate. We appreciate that there are peaks and troughs, but for the purposes of analytical simplicity and long term modelling have not assumed this to be a major constraint.

Figure 15-11: Tourism projections to Year 50 (2066)

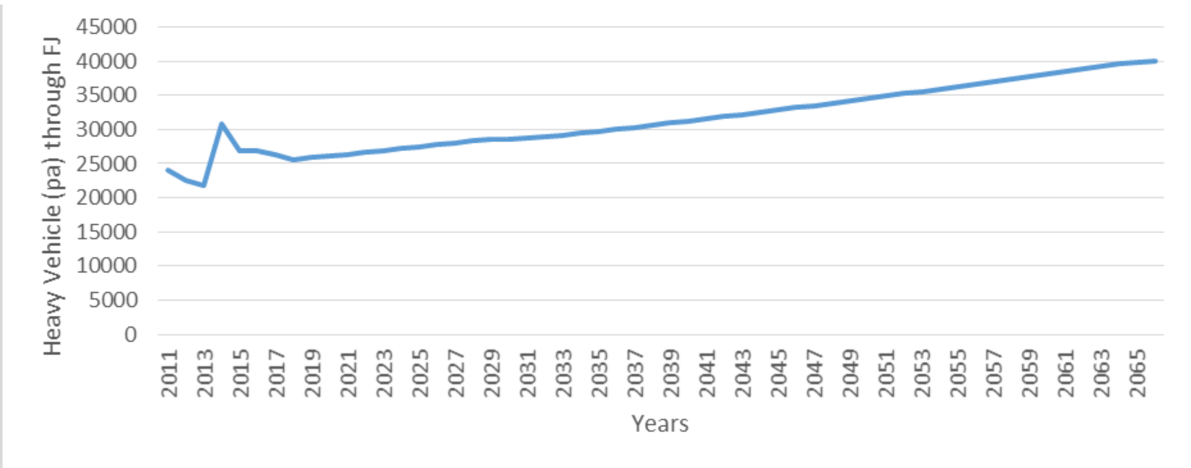


2.4.2 Freight

As noted in the Strategic Case, key inputs for business are predominantly imported into Franz Josef. It is assumed that there is no (or very limited) trans-regional freight that passes through Franz Josef. The export freight task that is generated on the West Coast by and large travels to major sea ports (Lyttelton or Port Chalmers) via Arthurs Pass and SH1.[42]

We do note however that there are currently 68 'heavy vehicles' per day that pass through Franz Josef, and this number is forecast to increase to 110 per day by Year 50 (2068). This represents an annual increase in heavy vehicles from 24,000 to 40,000 per annum as shown in Figure 15-12.

Figure 15-12: Projected number of heavy vehicles per annum passing through Franz Josef to Year 50 (2066)



A summary of the stocks and flows for business-as-usual is provided in Figure 15-16.

[42] Freight Task data taken from Ministry of Transport (2012) Freight Demand Study. Identification of fastest routes taken from google maps. This hypothesis has been tested and supported through numerous forums.

Table 15-16: Summary of business-as-usual stocks and flows

Aspect	Current – BAU value		Year 50 – BAU value	
	Count	Value[>] NZD	Count	Value[>] NZD
Population	510 residents 1,593[#] visitor nights on average over the year	8.8bn VoSL	571 residents 5,070[#] visitor nights on average over the year	23.7bn VoSL
Stocks				
Residential building stock	471 buildings*	$32m^	836 buildings*	$35m^
Commercial building stock		$60m^		$195m^
Other building stock		$4.3m^		$5m^
Land value		$90m^		$90m^
Total property stock		$187m^		$325m^
Potable water treatment	1 treatment facility	$2.3m	1 treatment facility	$2.3m
Wastewater treatment plant	1 treatment facility	$3m	1 treatment facility	$3m
Three waters network	Pipes, manhole, pumpstations	$4.4m	Pipes, manhole, pumpstations	$4.4m
Flood protection	8.4 km stopbanks	$8.5m	8.4 km stopbanks	$8.5m
Power distribution network	33kv Transmission Line FJ zone substation Distribution network Distribution substation	~$1m	33kv Transmission Line FJ zone substation Distribution network Distribution substation	~$1m
Communications network	Cell towers Copper network	~$1m	Cell towers Copper network	~$1m
Road network	44 km roads 5 bridges'	$80m	44 km roads 5 bridges'	$80m
Aerodrome	1 Aerodrome	$2m	1 Aerodrome	$2m
Flows				
Tourism	278,000 tourists/yr 581,000 visitor nights/yr	$122m/yr	883,000 tourists/yr 1.85m visitor nights/yr	$411m/yr
Freight	68 trucks per day	N/A	110 trucks per day	N/A

* Building count for the Franz Josef and Stony Creek area has been manually assessed based on GIS data. The building count for the wider study area has been extrapolated based on this count and land use assumptions. There is naturally subjectivity in what counts as a 'building'.

^ Capital values include all properties in the wider, defined, Franz Josef area for this assessment. Property valuations are informed by WDC data. Valuation Properties valuations have been divided uniformly on a per metre basis to inform building valuations where more than one building is modelled on a property.

' Bridges on SH6 in the assessment area.

[#] This number represents the number of visitor nights in Franz Josef in a year divided by 365 days.

VoSL = Value of statistical life applied is $4.21 million /person

[>] Value presented are based on current values, not inflated by the consumer price index or producer price index projections. No depreciation of assets has been applied and the infrastructure is assumed to be able to provide for the growth in population and tourist numbers over 50 years.

2.5 Current controls

There is also a range of controls that are assumed to continue to be operative and effective to Year 50 (2068) under the business-as-usual scenario. A brief description of these controls is provided below, with details provided in Section 5 of this appendix (together with associated assumptions included in the analysis).

It is important to remember that in the business-as-usual scenario, all of these controls are assumed to be effective (because a natural hazard scenario is explicitly excluded). However, these assumptions will become material when we consider the two natural hazard scenarios in later chapters.

2.5.1 Planning

A continuation of the currently operative version of Westland District Plan is assumed. In particular Natural Hazard provisions (in section 4.14 of the plan) remain, which includes the method that WDC will work with WCRC and other agencies to develop and implement a comprehensive package of measures to avoid, remedy or mitigate adverse effects from natural hazards.

2.5.2 Stopbanks

For the base case the following is assumed:

- ***Maintenance of stop banks at current height***: Stopbanks will not be increased above their current height. The level of service, relative to flood average recurrence interval, will therefore decrease and this represents a base case of no investment in stopbanks.
  This position has been taken because there is no official commitment to a forward stopbank raising programme in any public documents.
- ***Periodic dredging programme does not exist***: GNS (2016) reports bed aggradation of 0.16 to 0.2m per year. West Coast Regional Council has confirmed there is no formal programme currently in place to dredge the Waiho River to mitigate bed aggradation at this time.

The option of further raising the height of the current stopbanks, combined with improved construction and/or dredging of the river, to maintain a level of service is considered as an investment option.

2.5.3 Waiho Bridge

The Waiho Bailey bridge is assumed to continue to provide access over the river during the assessment period. In 2017/2018 it will reportedly be raised by 2m.[43] We have assumed that it remains at this level (2m above current) for the 50-year period of the base case. At this height it will be close to the level of the crest of town terrace. For the base case it will, therefore, be exposed to an increasing risk of flood damage with time. In reality the bridge would likely require further intervention over the 50-year period, which is considered as an investment option.

2.5.4 Waste water treatment

- ***Maintain current level of service through investment***: We have assumed that the waste water treatment plant upgrade proceeds, as it is reaching its operational limit. It is assumed that this continues in a staged manner, with an interim option of a pond upgrade put in place in 2018, and a new pond or tank based sequential batch reactors (SBR) constructed in 2020. This

[43] This investment had been released on GETS, but had not yet been confirmed at the time of writing.

option, and the level of investment it represents, is the mid-point estimate of the options available to continue the current required level of service[44].

- ***The existing site of the oxidation ponds remains:*** The location of the wastewater treatment infrastructure is assumed to be in the current location of the oxidation ponds. This location is at risk of damage from flood on a regular basis. For the base case we have assumed that it is impacted, on average, every 10 years to an extent similar to the damage which occurred in the 2016 floods. The repair cost has been taken on average to be 70% of the value of the asset, which has been taken to be approximately $3 million.

3 Earthquake losses

3.1 Scenario

We have considered a rupture of the Fiordland to Kaniere segment of the Alpine Fault, with a magnitude of 8.1. This is likely to cause very strong shaking and rupture of the ground surface in Franz Josef. The expected alignment of the surface rupture has been indicated to pass through the township of Franz Josef and is shown on Figure 15-19 and Figure 15-20. This alignment was identified by GNS in their 2016 report. Along each trace of the fault is a 130m to 190m wide area, which we have applied as the area of potential ground deformation for the assessment of loss. GNS (2016) indicate that the ground deformation across the surface rupture area may total 2m vertical and 8m horizontal relative movement. The area shown **does not represent a fault avoidance zone** and the area of ground deformation in an actual Alpine Fault is likely to vary from that applied here.

Figure 15-13: Fault rupture across road and rail in the 14 November 2016 Kaikoura EQ (T+T)

Figure 15-19 shows the spread of shaking as contours of maximum (peak) ground accelerations that may be felt. 0.75g is 75% of the force of gravity. Within the 0.75g contour the accelerations may be higher closer to the fault. We have considered up to 1.25g. In the Christchurch and Kaikoura earthquakes, near fault shaking reached 1g to 2g; however, this was in isolated locations and not likely over the full fault length.

The areas of surface rupture will cause more extensive damage to property and infrastructure. Significant, yet lesser damage is likely in the rest of Franz Josef, which would experience shaking, without fault rupture.

The annual probability of an Alpine Fault rupture occurring materially increases each decade until a rupture event occurs. Considering this time-varying characteristic, GNS (2016) has summarised the probability of rupture as 27% probability in the next 50 years. Comparing this to an event that has the same annual probability of exceedance each year, over 50 years, a 150-year average recurrence interval (ARI) event has the same probability.

[44] Based on scoping document provided to the Franz Josef Working Group regarding options for the waste water treatment plant in April 2017.

Figure 15-14: Landslides on to SH1 in the 14 November 2016 Kaikoura Earthquake

The risk of landslides from the terrace and range-front slopes impacting the township has also been considered. For landslides that do not turn into large rock landslides, the impact area is likely to be limited to those buildings immediately at the base of the terrace slope. A large landslide scenario is discussed in the Section 3.3 of this appendix.

Section 3.2 of this appendix summarises the loss from an Alpine Fault rupture scenario.

More frequent, less severe earthquake shaking events are also possible. These is estimated at a less detailed level than for the Alpine Fault rupture to determine an annual average loss for the 50-year assessment period.

Details of the assessment of average annual losses for earthquake provided in Appendix I with the CBA.

3.2 Consequences of Alpine Fault rupture

The consequences (to people, property, local and regional economy, environmental and socio—cultural values) of this Alpine Fault rupture scenario have been identified, and costs quantified and estimated as appropriate using indicative damage and cost relationships for physical assets, life and injury and qualitative descriptions where appropriate.

As discussed above, this excludes the catastrophic scenario of an earthquake-triggered large landslide, which could impact the main township area.

A dam break post an earthquake event has also not been considered.

3.2.1 Stocks

The low height, and light-weight construction, free of unreinforced masonry, chimneys and parapets, makes the building stock of Franz Josef generally resilient to collapse in strong earthquake shaking and helps to protect life. For similar building types and construction, this was demonstrated in the Christchurch and Kaikoura earthquakes. It is always possible that some buildings in Franz Josef have severe structural weakness which may make those specific buildings vulnerable to collapse. This requires specific assessment to determine.

Figure 15-15: Shaking damage in Waiau in the 14 November 2016 Kaikoura Earthquake

While collapse of buildings in Franz Josef is less likely, damage to the cladding and the structure affecting the amenity of buildings is likely. This may include a loss of watertightness, utilities and function of elements such as doors. This damage may require rebuilding.

Our desktop assessment indicates that, on average, 99% of residential dwellings would not be expected to collapse. Over 80% would be expected to have moderate structural damage, which may include significant cracking of the walls around doors and windows and smaller cracking on the panels, with any masonry having fallen off the dwelling exterior.

Residential properties with moderate damage are expected, on average, to be able to be used after three months, with dwellings that are extensively or completely damaged taking one to two years to rebuild and for residents to move back in.

For commercial accommodation properties, 80% are estimated to experience extensive or complete building damage. Return-to-operation times are, on average, three months for moderately damaged buildings, with accommodation buildings extensively or completely damaged taking one to two years to return to operation.[45]

For other commercial business properties, 50% are estimated to experience damage which is extensive or completely damaged. Those with only slight or moderate damage could reopen in one month. Those with extensive damage may take one to two years to repair or rebuild. However, Franz Josef businesses may resume operating, on average, in three to six months, likely by using alternative buildings or other means. The experience in Christchurch and Kaikoura is that small to medium size (SME) businesses are generally resilient and good at finding ways to return to operation.

The buildings in the area of ground deformation due to rupture of the fault are all likely to have the most extensive damage. Some may collapse. There are approximately 40 properties which intersect, at least in part, the area which may incur ground deformation. They include the Police station, petrol station, fire station, community hall, Catholic Church, the Department of Conservation workshop and fire depot, along with a number of accommodation and residential buildings. The total direct capital building loss for those properties considered to be in the fault rupture ground deformation area is $11 million, with a total building value of $14 million, which represents an 80% loss based on building values. The estimated land value of these properties is $6.4 - $8 million. Buildings not in the fault rupture area on average, could incur a 35% loss against the building value. However, the range will include buildings with minor to complete loss. It is possible that the losses could be less than this in the area of fault rupture considered, if the deformation is not as extensive or severe.

The Franz Josef water supply source is surface water from a nearby creek and a backup bore close to the Waiho River (*Water NZ*, 2012). Treatment of the water supply is a combination of sand filtration, cartridge filtration and chlorination (*Water NZ*, 2012). The damaged proportion of the three waters network is likely to be greater in the Alpine Fault Rupture Zone. It is likely that the water supply would be completely damaged and cut off from the pipe network, due to deformation of the ground across the area of fault surface rupture. The network itself could have significant damage and may be blocked and any water flowing could be subject to severe leaking and be potentially contaminated by mixing with wastewater leaking into the ground.

Flood protection stopbanks would be subject to shaking damage, requiring repair. Where the stopbanks or bank protection works cross the area of fault surface rupture, they are likely to be severely damaged and require near full repair.

Figure 15-16: Example of a bridge approach which has settled and impeded access temporarily

[45] This assessment does not consider issues such as access to labour, insurance payout timeliness or damage to wider parts of the country, which may slow the recovery time even further.

The Waiho River bridge crosses the Alpine Fault and it is possible that it would be subject to ground deformation that could cause it to collapse. The road bridges north and south of the town will also be subject to significant damage. Some may collapse; however; it is also possible that they all remain standing, but are heavily damaged. In severe shaking, it is common for the fill embankments approaching bridges to settle and displace. The bridge could possibly still be passed by light vehicles, if the area between the bridge deck and approach is filled. We have considered a loss ratio of approximately 80% for the bridges. For the road surfaces we have considered a 15% loss ratio for areas requiring repair or reconstruction.

Figure 15-17: Example of fault rupture from Wenchuan Earthquake, China in May 2008, with lateral and vertical offset across road and river (Yu et al., 2010)

We have applied a 50% loss ratio to the aerodrome for damage to the runway and buildings.

3.2.2 Township

Our assessment indicates that loss of life as a result of an Alpine Fault rupture will be low (between 0 and 1 people). This is due to the low number of buildings across the township, and general building type (predominantly low-rise and lightweight roofs). This inherently resilient building stock may be significantly damaged by shaking or directly by fault rupture (Figure 15-18), and not collapse.

Figure 15-18: Dwelling impact directly by fault rupture, Kaikoura, November 2016 (stuff.co.nz after GNS)

These positives must be placed in the context of the potential that there could be buildings in the township which have unidentified severe structural weaknesses, which would lead to collapse and subsequently loss of life or serious injury of occupants. Collapses due to severe structural failure, particularly in commercial buildings, could see loss of life increase to 10s of people, depending on the number of buildings impacted and the number of occupants at the time of the event.

Small to moderate landslides and rockfalls triggered by the rupture could also result in serious injury or loss of life, depending on the number of people outside at the time of the event. Again, we anticipate numbers impacted could be in the order of 1 to 10s of people.

3.2.3 Disruption to the transport network

Franz Josef is connected to Hokitika via SH6 to the north and to Wanaka via SH6 to the south. From Hokitika there are multiple routes to the east coast of varying lengths.

Robinson et al. (2015) conducted analysis on infrastructure restoration strategy, with time, on the West Coast as a result of an Alpine Fault shaking event (magnitude 8) with landsliding and bridge outages, for 0, 3, 14, 30 and 90 days. It has been assumed that roads reopen (likely from alternatives to Arthurs Pass) from the 90-day situation. At 730 days it has been assumed that Arthurs Pass (or functional alternative) and the access from the south is reopened. The road access post-event will likely vary from this assumption.

The disruption of road access to Franz Josef post an Alpine Fault event is assumed to be for this assessment:

- Day 0: No access to any vehicle north or south.
- Day 3: Access from the north for emergency vehicles from the east coast. No access via Arthurs Pass or from the south.
- Day 14: Access from the north for emergency vehicles and vehicles < 3.5 tonne from the east coast. No access for vehicles > 3.5 tonnes. Improved travel times for emergency vehicles. No access via Arthurs Pass or from the south.
- Day 30: Improved travel time from the north for emergency vehicles and public vehicles < 3.5 tonnes. Access for vehicles > 3.5 tonnes to reach Hokitika, but not to the east coast. No access via Arthurs Pass or from the south.
- Day 90 to 729: Improved travel time from the north for all vehicles. No access via Arthurs Pass or from the south.
- Day 730: Return to full access from the north and south. Arthurs Pass opens.

In Table 15-17 we have presented the assumed travel times to or from Franz Josef post an Alpine Fault rupture event, for this assessment only.

Table 15-17:Travel times in minutes, to or from Franz Josef pre- and post-earthquake[46]

Travel time in minutes from Franz Josef														
Time interval	Vehicle	Christchurch	Dunedin	Greymouth	Haast	Hokitika	Invercargill	Milford Sound	Mt Cook	Nelson	Picton	Queenstown	Reefton	Westport
Pre-earthquake	All vehicles	375	439	125	101	92	429	495	332	335	373	272	181	198
T = 0	Emergency													
	Small (< 3.5 tonne)													
	Large (3.5-6 tonne)													
T = 3	Emergency	761	954	193		144	1179		920	427	465	1023	273	282
	Small (< 3.5 tonne)													
	Large (3.5-6 tonne)													
T= 14	Emergency	723	916	164		120	1141	1216	882	389	427	985	235	245
	Small (< 3.5 tonne)	723	916	164		120	1141		882	389	427	985	235	245
	Large (3.5-6 tonne)													
T = 30	Emergency	592	785	160		118	1010	1085	751	385	423	854	231	241
	Small (< 3.5 tonne)	592	785	160		118	1010	1085	751	385	423	854	231	241
	Large (3.5-6 tonne)					118								
T = 90	All vehicles	590	783	159		118	1008	1083	749	383	421	852	229	240
T = 180	All vehicles	590	783	159		118	1008	1083	749	383	421	852	229	240
T = 365	All vehicles	590	783	159		118	1008	1083	749	383	421	852	229	240
T = 730	All vehicles	375	439	125	101	92	429	495	332	335	373	272	181	198

46 Robinson, T. R., Wilson, T. M., Buxton, R., Cousins, W. J., & Christophersen, A. M. (2015) An Alpine Fault earthquake scenario to aid in the development of the Economics of Resilient Infrastructure's MERIT model.

3.2.4 Flows

Economic flows resulting from an earthquake scenario can be expected to be disrupted at a local, regional and national level. While there would be a wide-range of factors that would influence disruptions to economic flows, we have sought to describe the most material relationships that would underpin these expectations and have sought to use contemporary examples (Canterbury and Kaikoura earthquakes) as broad indicators of potential responses

In broad terms, we have considered an earthquake to be a national level event, which cascades impacts down to a local level. While we have reported individual figures across local, regional and national levels, we do not consider these to be additive as, inherently, we would expect there to be some overlap between these three perspectives (with the precise level of addition being outside of the scope of this study). However this analysis does serve to show the relative importance of an earthquake event at a local, regional and national level.

3.2.4.1 Tourism Flows | National

Understanding the impacts on tourism at a national level presents challenges because of the high levels of uncertainty about the extent to which a localised earthquake event will impact on the entire economy.

Nevertheless, we assume that there would be a national 'lost tourist' measure from the glaciers not being 'open for business', i.e., some tourists would not come to New Zealand because they would be unable to access the glaciers via the West Coast. The Canterbury Earthquake Sequence made international news media and we would expect the same in an Alpine Fault event. We assume that subsequent displacement of tourists around New Zealand is not a matter for national consideration.

We have undertaken a scan of relevant earthquake events over the past 50 years to assess whether there are any comparable events to model national-level tourist impacts. Of these, Kaikoura would be the most appropriate, but the lack of observable data is a limitation. We have therefore looked to the impacts following the Canterbury Earthquake Sequence as a basis for several assumptions.

In looking at the impacts of the Canterbury Earthquake Sequence, we can see that there was a roughly 250,000 decrease in international visitor numbers between 2010 and 2012 (Table 15-18). At national level, total tourist numbers virtually stalled after showing a roughly 80,000 - 100,000 tourist increase annually over the same period. Therefore, we can simply assume that the 'impact' of the Canterbury earthquakes was roughly a 100,000-person reduction in tourists at national level.

We have pro-rated this change to Franz Josef numbers and consider this an upper bound. This is in recognition of the fact that Franz Josef is one of the most visited tourist attractions in New Zealand, and that tourist numbers to Franz Josef are roughly one third of the numbers that visited Christchurch in 2016.

In recognition of the fact that Canterbury is a very different tourist market to Franz Josef (including but not limited to the presence of an international airport, being a major urban node, and being a base for wider tourist activity), we have then applied a 50% discount to form a lower bound.

Applying these assumptions, we an estimate that there would be a reduction in New Zealand tourist numbers for one year following an earthquake event of between 40,000 and 20,000 (average of 30,000). This represents approximately 1.3% of total national visitors in 2011.

Using an average stay of 17 days per tourist[47], this represents a reduction in potential visitor nights of 730,000. Multiplying this amount by an average daily spend of $171 per night[48] spend gives us a

[47] Statistics NZ International Visitor Survey
[48] ibid

gross national level loss figure of $125m, which transforms into an AAL of $836,000 after considering a 1 in 150 year earthquake.

Table 15-18:Tourism impacts from the Canterbury Earthquake Sequence

	2009	2010	2011	2012	2013	2016
Total Int visitors NZ	2,153,383	2,237,682	2,315,838	2,287,809	2,421,446	3,127,114
Total Int visitors Christchurch	749,842	783,894	573,191	535,534	664,583	1,000,764
Franz Josef visitors	293,324	300,184	252,270	236,215	261,109	358,352

3.2.4.2 Tourism Flows | West Coast Region

Understanding the impacts on tourism across the West Coast presents similar challenges to understanding the impact on Franz Josef, because of the levels of uncertainty about the extent to which the earthquake event will impact on the West Coast. Nevertheless, we assume there will be a range of responses to an earthquake:

- Some tourists will not make the trip to New Zealand at all, which will obviously affect the West Coast tourist numbers
- Some tourists who would have gone to Franz Josef will go to other regions in New Zealand
- Some tourists who would have gone to Franz Josef will stay within the West Coast region, but go elsewhere within the West Coast

We have assumed that the 1.3% tourists who would not come to New Zealand as a result of an Earthquake event (as described in 3.2.4.1 above) will not spend time on the West Coast. This reduces total West Coast tourist numbers from 566,000 (in 2017) to 525,000.

Of the 525,000 tourists assumed to visit the West Coast, we assume that an average of 15% and 85% (50%) of these would forego their West Coast experience entirely and go to another region of New Zealand. These upper and lower bounds have been informed through anecdotal comments from stakeholders interviewed through this process. These bounds also reflect the fact that despite traditional visitor numbers likely decreasing significantly, that there would likely be an uplift in workers who are participating in the recovery and response efforts (and these would be recorded as visitors). In other words, visitors with ‘bum bags’ would decrease, while visitors with ‘tool bags’ would increase.

In summary, we assume that 262,000 tourists would not spend money on the West Coast over the same period, resulting in a loss of expenditure of $122m, which equates to $813,000 AAL.

Across total lost tourist numbers, we assume that total expenditure per day is $222.[49] We have also assumed that the average stay per tourist foregone for ‘lost national tourists’ and for ‘displaced regional tourists’ is 2.1 days.[50]

[49] MBIE International Visitor Survey https://mbienz.shinyapps.io/tourism_dashboard_prod/https://mbienz.shinyapps.io/tourism_dashboard_prod/https://mbienz.shinyapps.io/tourism_dashboard_prod/https://mbienz.shinyapps.io/tourism_dashboard_prod/ It is assumed that International Visitors are visiting ‘places’

[50] 2.1 days are assumed be the amount of time that tourists on MBIE Data.

3.2.4.3 Tourism Flows | Franz Josef

In a town dominated by the tourism sector, we assume there is a strong a relationship between tourist spend and commercial investment, such that the growth in tourism expenditure drives an increase in commercial investment and vice versa. We have assumed that this relationship remains proportional in real terms over time.

Key determinants of traditional tourist flows following an earthquake will therefore be affected by:

- Access to Franz Josef, and the ability of commercial premises to sell to customers
- The rate and nature of the commercial recovery, including commercial rebuild and return to operability
- The additional 'visitor' expenditure from those parties tasked with rebuilding and recovering the township

Disruption to the transport network would likely have a material impact on the flow of goods, services and tourism to and from Franz Josef. Based on the timeframes discussed in Section 3.2.3, we have assumed a time of 30 days for tourists to be able to arrive from the North, which is the more common route. Similarly, goods and services will take 30 days to arrive in meaningful quantities.

Access to larger capital items required for recovery will be dependent on the ability of larger trucks to enter Franz Josef, which is assumed to occur from day 90 (and would likely occur through an alternate route from the far north of the south island, rather than over Arthurs Pass as is traditional. We therefore assume that commercial building recovery begins after 90 days.

General tourist numbers, and expenditure in the Franz Josef region, are then assumed to recover in line with the expected recovery times for commercial building stock recovery. A return to some level of normality could easily take up to three years. We have used 2016 tourist numbers as our recovery profile for this scenario.

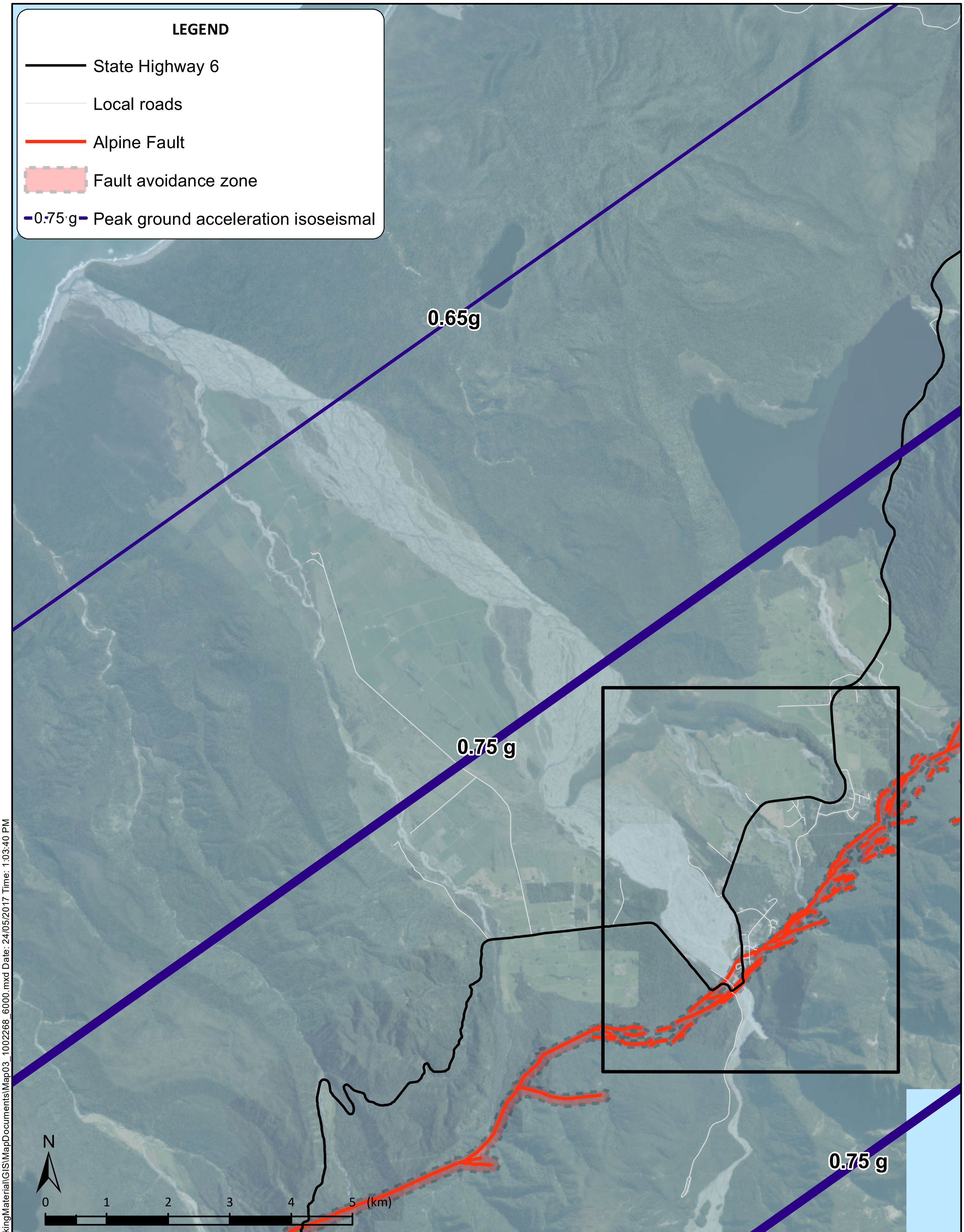
The disruption curves for building repair time and return-to-amenity for residential buildings and operability for commercial buildings is based on the tables provided in the Hazus multi-hazard loss estimation methodology for earthquakes[51].

We assume that commercial recovery brings in additional visitor expenditure, but that this will be meaningfully brought in during the commercial rebuild and will inherently be captured within tourist numbers.

In the broadest terms, we have assessed this impact as an annual average loss of tourism expenditure of $2m[52] for an earthquake event. This is presented in Table 15-19.

51 FEMA. (2015). Multi-hazard Loss Estimation Methodology Earthquake Model: Hazus-MH 2.1: Technical Manual. National Institute of Building Sciences and Federal Emergency Management Agency (NIBS and FEMA).

52 Calculated using tourism revenue for all of Franz Josef, converting to Tourism dollars per commercial building meter square and considering total disruption days for the loss tourism revenue



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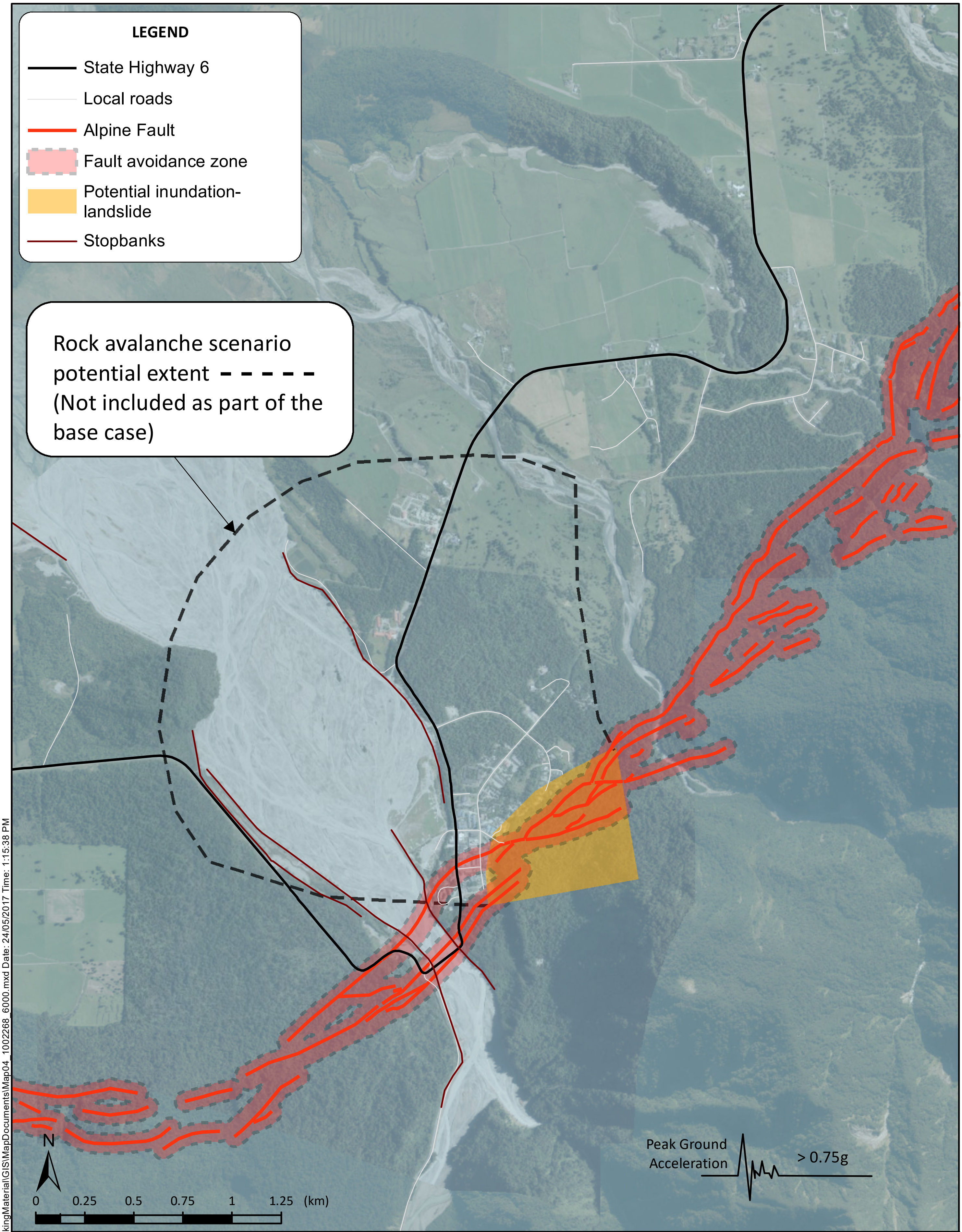

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1002268

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FRANZ JOSEF NATURAL HAZARDS OPTIONS ASSESSMENT
Earthquake Scenario

FIGURE No. 15.20

Rev. 0

Table 15-19: Summary of losses attributable to an Alpine Fault rupture based on current business-as-usual. Losses are presented as AALs with respect to 2016 stock and flow levels

Aspect	Current BAU Value		Earthquake AAL[>] NZD
	Count	Value[>] NZD	
Life Loss	510 residents 1,593[#] visitor nights on average over the year	$8.8bn VoSL	$46,000 VoSL
Stocks			
Building Stock	471 buildings*	$97m^	$560,000
Land Value		$90m^	$0m
Total property stock		$187m^	$560,000
Potable water treatment	1 treatment facility	$2.3m	$18,000
Wastewater treatment plant	1 treatment facility	$3m	$24,000
Three waters network	Pipes, manhole, pumpstations	$4.4m	$3000
Flood protection	8.4 km stopbanks	$8.5m	$37,000
Power distribution network	33kv Transmission Line FJ zone substation Distribution network Distribution substation	~$1m	$3,700
Communications network	Cell towers Copper network	~$1m	$3,700
Road network	44 km roads 5 bridges’	$80m	$272,000
Aerodrome	1 Aerodrome	$2m	$12,000
Flows			
Tourism	278,000 tourists/yr 581,000 visitor nights/yr	$122m/yr	Local: $2m Regional: $814,000 National: $836,000
Freight	68 trucks per day	N/A	N/A– freight impacts are assumed to be inherently captured through tourist expenditure

* Building count for the Franz Josef and Stony Creek area has been manually assessed based on GIS data. The building count for the wider study area has been extrapolated based on this count and land use assumptions. There is naturally subjectivity in what counts as a ‘building’.

^ Capital values include all properties in the wider, defined, Franz Josef area for this assessment. Property valuations are informed by WDC data. Valuation Properties valuations have been divided uniformly on a per metre basis to inform building valuations where more than one building is modelled on a property.

‘ Bridges on SH6 in the assessment area.

[#] This number represents the number of visitor nights in Franz Josef in a year divided by 365 days.

VoSL = Value of statistical life applied is $4.2 million /person

> Value presented are based on current values, not inflated by the consumer price index or producer price index projections.

3.3 Earthquake-triggered large landslide

The criteria for earthquake-triggered large landslide are:

1) Long sackungen (cracking) at top of slope
2) Notable amounts of throw (movement) on the sackungen
3) Tectonically damaged rock
4) Presence of slope bulging or over steepened slopes below the sackungen
5) Asymmetry in the sackungen distribution (*GNS 2016 after Barth 2013*)

GNS (2016) has indicated "the range-front hillslope immediately to the east of Franz Josef meets most of these criteria and hence has the potential to fail in a catastrophic large rock landslide (*Barth, 2013; Davies, 2015*)."

An example of large rock landslide debris, which likely occurred as a result of an Alpine Fault rupture, can be seen just north of Hari Hari, approaching the Wanganui River crossing (*Chevalier et al.,* 2009). The shaded area in Figure 15-21 indicates the area from where the material came down and where it now rests. This is only part of the avalanche debris. The arrow indicates where the rest of the material would have been. However, this has been eroded away by the Wanganui River over time.

Figure 15-21: Historic example of large rock avalanche landslide debris, which likely occurred as a result of an Alpine Fault rupture, which can be seen just north Hari Hari, approaching the Wanganui River bridge.

The reality is the likelihood of a large rock avalanche occurring in the next Alpine Fault rupture is unknown and uncertain. A large rock avalanche has a lower probability of occurring than a rupture of Alpine Fault itself. However, there is no good evidence to indicate an appropriate estimate of the likelihood of it occurring in the next Alpine Fault rupture, as no study has considered the progressive development of failure mechanisms with each Alpine Fault rupture event. If the town is to remain in its current location the risk, all stakeholders need to accept and acknowledge the uncertainty. For indicative purposes, we have made an assessment of the potential loss, which is summarised in Table 15-20.

To define the area of impact we have followed the GNS (2016) scenario description; "In the event of catastrophic failure, the potential for long runout and large surficial area of the debris could result in a considerable portion, if not the entire town, being overrun." The area impacted is shown in Figure 15-20 and is based on previous general extents indicated by Davies (2015).

In this scenario the loss of life and loss of capital is very high and could result in the Franz Josef township being abandoned. It would be expected that there would also be significant impacts on tourist flows. The precise nature of these has not been quantitatively assessed, but would be expected to be similar to the fault rupture scenario, multiplied over an indefinite period of time.

As the likelihood of a large landslide is uncertain, and there is no practical mitigation strategy other than relocation of all of the existing assets, it is not proposed to be included in the cost benefit analysis. Inclusion of this scenario may change the estimate of loss for earthquake significantly, given the potentially large loss of life. This would depend on the likelihood assumed.

It is possible, however, that the options chosen at the end of this process may reduce the loss from a large rock landslide and this has been considered in the MCA.

Table 15-20: Summary of losses attributable to a large landslide triggered by an Alpine Fault rupture based on current business-as-usual

Aspect	Current BAU Value		Event Losses (AF + rock landslide)	
	Number	Value> NZD	Damage	Loss*> NZD
Life Loss	510 residents 1,593# visitor nights on average over the year	$8.8bn VoSL	700 – 1200" lives lost	3 – 5 bn VoSL
Stocks				
Building Stock	471 buildings*	$97m^	80-95%	$80-93m
Land Value		$90m^	50%^	$45m
Total property stock		$187m^		$125 - 138m^
Potable water treatment	1 treatment facility	$2.3m	100%	$2.3m
Wastewater treatment plant	1 treatment facility	$3m	100%	$3.0m
Three waters network	Pipes, manhole, pumpstations	$4.4m	80%	$3.5m
Flood protection	8.4 km stopbanks	$8.5m	70%	$6m
Power distribution network	33kv Transmission Line FJ zone substation Distribution network Distribution substation	~$1m	100%	$1m
Communications network	Cell towers Copper network	~$1m	Cell towers destroyed. Assumed 80 loss ratio%	$0.8 m
Road network	44 km roads 5 bridges'	$80m	30-50%	23-38m
Aerodrome	1 Aerodrome	$2m	50%	$1m
Flows				
Tourism	278,000 tourists/yr 581,000 visitor nights/yr	$122m/yr	Significant loss and displacement of tourism expenditure at a local, national and regional level can be envisioned over a long period of time	Difficult to quantify how large the loss will be
Freight	68 trucks per day	N/A	No freight	N/A

* Building count for the Franz Josef and Stony Creek area has been manually assessed based on GIS data. The building count for the wider study area has been extrapolated based on this count and land use assumptions. There is naturally subjectivity in what counts as a 'building'.

^ Capital values include all properties in the wider, defined, Franz Josef area for this assessment. Property valuations are informed by WDC data. Valuation Properties valuations have been divided uniformly on a per metre basis to inform building valuations where more than one building is modelled on a property.

' Bridges on SH6 in the assessment area.

This number represents the number of visitor nights in Franz Josef in a year divided by 365 days.

VoSL = Value of statistical life applied is $4.2 million /person

*Alpine rock fall scenario loss values are single event estimates not AALs.

> Value presented are based on current values, not inflated by the consumer price index or producer price index projections.

4 Flood losses

4.1 Scenarios

The significant flood hazard to the town of Franz Josef from the Waiho River is widely documented and reported (*GNS, 2016; Land River Sea, 2014; McSaveney and Davies, 1998*).

The March 2016 and December 2010 storm events provide evidence of the risk posed by flooding. In particular, the March 2016 event severely impacted the Scenic Circle Group complex, to the north of the main town centre. This occurred when an access road embankment to the wastewater treatment pond, which was holding back the flood waters, was breached.

Figure 15-22: Waiho River from true right bank looking upstream at Bailey Bridge (low flow)

Uncontrolled, the flood hazard will increase over time due to river bed aggradation, which has the effect of reducing the capacity of the river channel before overtopping of banks occurs. *Optimix* (2002) and *Land River Sea* (2014) indicate that long term bed aggradation is in the order of 0.16m to 0.2m per year at the State Highway 6 Waiho bridge. For the base case (and for the options) we have used 0.2m per year bed aggradation.

However, it is also noted by GNS (2016) and in a WCRC report on the December 2010 storm event, that there can be significant increases in bed level as a result of individual flood events. WCRC estimated the following bed level increases as a result of the December 2010 event:

Figure 15-23: Flood water in the March 2016 event impacting the Scenic Circle Group staff accommodation (stuff.co.nz)

1. One to two metres of bed aggradation in the Waiho River
2. Five to six metres of bed aggradation in the Callery River, which is a tributary to the Waiho and located a short distance upstream from Franz Josef township.

Furthermore, GNS (2016) identified that a single 100 year ARI flood event could raise the bed of the Waiho River by 4m. For the base case, rapid bed aggradation as a result of a major flood or earthquake event, has not been included.

We have estimated the loss in the study area for flooding up to a 100-year average recurrence interval (ARI) flood event for the base case assuming, as outlined in Section 2.5.2 and 2.5.3:

- Maintenance of stop banks at current height
- Periodic dredging programme does not exist
- Waiho Bridge height will be 2m higher than the current (May 2017) height and will not be raised further

4.1.1 Waiho River bed aggradation

For the base case, each year the flood hazard increases due to bed aggradation. Figure 15-28 shows the extent of flooding possible for current river bed levels (0m bed aggradation). This is basis for the Year 1 potential 100-year ARI flood loss scenario.

With an aggradation rate of 0.2m per year, without mitigation, in 20 years the bed will have aggraded 4m and the flood level will be above the level of the crest of the stopbanks in the town area, putting the township at risk of flooding.

At 30 years, the bed level will potentially be 6m above its current level and similar to the crest of the town stopbanks. This represents the point at which part of the town potentially becomes the river bed. The potential extent of flooding is shown on Figure 15-30. The extent of flooding extends into the town and covers a greater area over the true left bank, to the south of the Waiho River. At some point, part of the town will be untenable to occupy. We have assumed this to be year 31, at which point the value of the land and property impacted is fully eroded. This includes the loss of the current alignment of SH6.

Figure 15-24: Flood waters in crossing from the Waiho River to the Tatare Stream in the 27-28 December 2010 Weather event (WCRC, 2010)

Over years 21 to 30 we have assumed the ARI of flooding is reduced by 10 years, every year, as a simple way to include the change in likelihood of flooding.

We have directly assessed the loss for 100-year flooding for 0m (Figure 15-28), 4m, 5m, 6m (Figure 15-30) and 6m with the town becoming part of the river bed. For more frequent flooding we have made a high level portfolio level estimate in order to calculate and average annualised loss (AAL) for each year, up to Year 50 (2068).

We have not included the increase in rainfall with climate change as reported by NIWA (2010). This may also exacerbate the flood risk of the township.

There are significant uncertainties in the hydraulic modelling undertaken for Franz Josef. The model used was developed by *Land River Sea* (2016) for West Coast Regional Council. We have used this model to understand the possible impacted areas for different bed aggradation scenarios. Only simple adaptions to the model were made and we have not undertaken a full verification process. These results, shown in Figure 15-27, Figure 15-28, Figure 15-29 and Figure 15-30, may have anomalies. They are only intended to be generally indicative for the loss estimation for this base case and should not be relied upon for any other purpose without more detailed assessment. The effect of these uncertainties also increases over time, as different scenarios play out differently from that assumed in this assessment.

The remainder of this chapter details the flood loss estimate.

In reading the remainder of this chapter, it is important to remember that this chapter discusses two ends of the spectrum (essentially 1-in-100 year flood event in year 0; and 1-in-100 year flood event in a 6m bed aggradation scenario). The presentation of these two ends of the spectrum is designed to give a general sense of scale and magnitude of flooding impacts. Detailed modelling around average annualised loss occur in support of the cost-benefit analysis and have been carried for specific levels of bed aggradation.

4.2 Consequences of 100 ARI flood event

4.2.1 Stocks

At Year 1 with 0m bed aggradation, the impacted areas are the wastewater treatment plant waste water treatment plant oxidation ponds, property between the Waiho River and Tatare Stream, and State Highway 6 and property to the south of the Waiho River (Figure 15-27 and Figure 15-28). While the figures show that the area of the Scenic Circle Group worker accommodation is not impacted, we have assumed that a breach, like that of March 2016, could occur and have included these assets in the loss range in Table 15-21. The potential total direct capital loss estimate is $4.3 million.

At Year 20, the town could be impacted by flooding from the Waiho River in a 100-year ARI event.

Figure 15-25: Flooding of the Waiho River in March 2016 impacting the wastewater treatment ponds (Opus, 2016)

The area which would be impacted on the true left bank to the south of the Waiho River increases and the Waiho River Bailey bridge would incur some damage. The potential total direct capital loss estimate increases to $8 million.

The situation at Year 25 is similar to Year 20, with increased damage in the same areas. The potential total direct capital loss increases to $17 million, with $9 million to buildings.

At Year 30 (2048) the potential total direct capital loss from a 100-year ARI event reaches $25 million and in Year 31 the property and infrastructure in the potential 100-year ARI flood extent is written off and the loss number reaches $110 million. This area includes the majority of Franz Josef township, including the Catholic Church, fire and police stations, community hall, Department of Conservation workshop and fire depot and main commercial area.

4.2.2 Township

It is unlikely that flooding would cause loss of life (unless stopbanks were built to protect the township and they breached). However, there is always a possibility that up to a few people get caught in the flood waters and life is lost.

The population of the township is estimated to be displaced from its current location in approximately Year 30 or 31 without a flood protection programme (to be considered in the investment options assessment).

Figure 15-26: Main street of Franz Josef that would likely flood with continued Waiho River bed aggradation.

4.2.3 Flows

In a storm event causing flooding, it is possible that the road network to and from Franz Josef would be closed. Disruption to the transport network would have a material impact on flow of goods, services and tourism to and from Franz Josef.

There would also be flooding impacts on individual commercial businesses depending on the scale and magnitude of the flooding event and the geographic location of the commercial business.

4.2.3.1 Tourism | Franz Josef impacts

Modelling the impacts of tourism impacts from a flooding event is inherently difficult given the scale and nature of any flood event, as well as the behavioural response of tourists in and around the Franz Josef area. However, as a general methodology, the loss of tourism expenditure in the township of Franz Josef from flooding has been estimated to be a function of:

- Total daily expenditure[53]
- The timeframe for which transport links are inaccessible

[53] It is assumed that daily expenditure is $222 per day.

- Time premium added depending on assumptions about whether Franz Josef is 'open for business'
- Any adjustments for reduced tourist numbers on the West Coast or at a national level
- The proportion of commercial buildings within Franz Josef that are materially affected by the flooding event

It is worth reiterating that cost benefit modelling demonstrates the annual average loss of the flooding scenario(s) between year 0 (current bed level) and year 30 (6m bed aggradation) that will account for the increased likelihood of disruption, the increased value at risk, and ultimately the increased expected impacts. The following descriptions and assumptions present two ends of the spectrum AALs in year 0 and in year 30.

<u>Current bed level</u>

The AAL for this scenario is estimated to be $341,000. Specifically, this is based on the following assumptions:

- Road access from the north and south would be unavailable for one day. On day two, access from the south would open. Access from the north would be closed until day 14. Tourists would then take an additional five days to realise that the town is 'open for business', as was a similar experience following the Diana Falls road outage. Collectively, this is a total impact of 19 days for a 1-in-100 year flood; for a 1 in 20 year flood in our AAL calculations a 3-day unavailability is assumed.
- It is assumed that commercial businesses would only be materially affected by a flood event if building disruption days are longer than the road recovery time.

<u>6m bed aggradation</u>

It is assumed that the annual average loss of tourist revenue under this scenario is $1.26m per annum. Specifically, this is based on the following assumptions:

- Once the bed aggradation reaches 6m at Year 30 the town have to be relocated. This relocation occurs at an undefined site near Franz Josef township.[54]
- At years 31 and 32, total local tourism losses are equal to all predicted tourism revenue in each year. This is conservative as the town would likely take longer than two years to relocate, resulting in smaller benefits for each option.
- After year 30, annual average losses are expected to drop back down to the 0m bed aggradation period, representing that the town is moved away from the Waiho River but still in the nearby area where small flooding could occur.
- The relocation costs of this scenario have not been included.

The disruption curves for return-to-amenity for residential dwelling and operability for commercial activity is based on Reese and Ramsay (2010).

[54] It is important to note that this is a purely hypothetical scenario, and one that is technically inconsistent with assumptions made around capital stocks. The reason why tourism impacts have been modelled beyond 30 years (and a hypothetical relocation occurs) is because tourism has impacts at a regional and national level (whereas capital stocks are primarily a local issue) and so must be represented over 50 years. Because these effects are described in the base case, they will have equal effects across all three option packages.

4.2.3.2 Tourism | Regional impacts

Current bed level and 6m bed aggradation level

It is assumed that the annual average loss of regional tourist expenditure to be $395,000. Specifically this is based on:

- An assumption that 15% of West Coast tourists forgo their West Coast experience entirely, and visit another region of New Zealand. This value is based on anecdotal comments from stakeholders interviewed through this process, resulting in an annual average loss of expenditure of $395,000 pa. This assumption is supported by the view that despite there being significant flooding in and around Franz Josef township, that access to the Glacier from the south is still fairly operable. Moreover, access to helipads to the north is still operable. I.e. visitors can still 'get near enough' to the glacier, even if they cannot spend money in Franz Josef township.
- It is assumed that those visitors who leave the region do not spend the average the number of nights, 2.1 and daily expenditure of $222 per day.[55]

4.2.3.3 Tourism | National impacts

It is assumed that there would be a negligible impact on tourism expenditure at a national level.

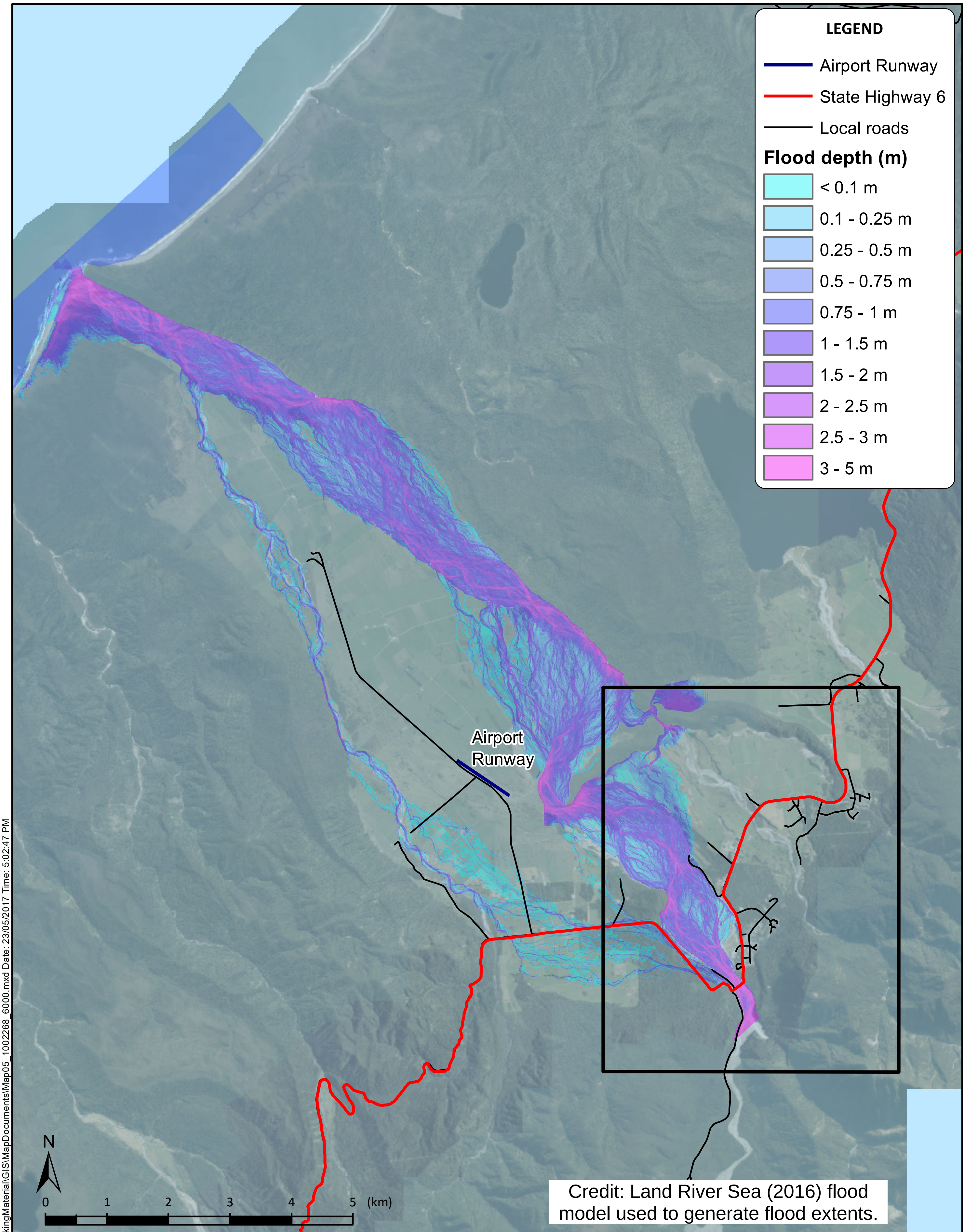
Current bed level

It is assumed that there are no national level impacts from a flooding event at current bed levels. A flooding event is unlikely to draw the same level of international media attention as, say, an earthquake event. All lost Franz Josef visitor expenditure would be displaced within different regions of New Zealand.

6m bed aggradation

It is assumed that loss in tourists from of a significant flood event in a 6m bed aggradation scenario would be negligible, for similar reasons to the current bed level scenario. There may in reality be natural constraints across other tourist destinations to accommodate the influx of tourists (to, for example, Fox township) but this is considered to be outside of the scope of this assessment.

[55] MBIE International Visitor Survey https://mbienz.shinyapps.io/tourism_dashboard_prod/ It is assumed that International Visitors are visiting 'places' and therefore spend $177 per day. Two days are assumed be the amount of time that tourists on average spend in Franz Josef (1.4 nights on average).



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WEST COAST REGIONAL COUNCIL
FRANZ JOSEF NATURAL HAZARDS OPTIONS ASSESSMENT
Flood Depths 100 year ARI flood
with 0 m bed aggradation

FIGURE No. 15.27
Rev. 0

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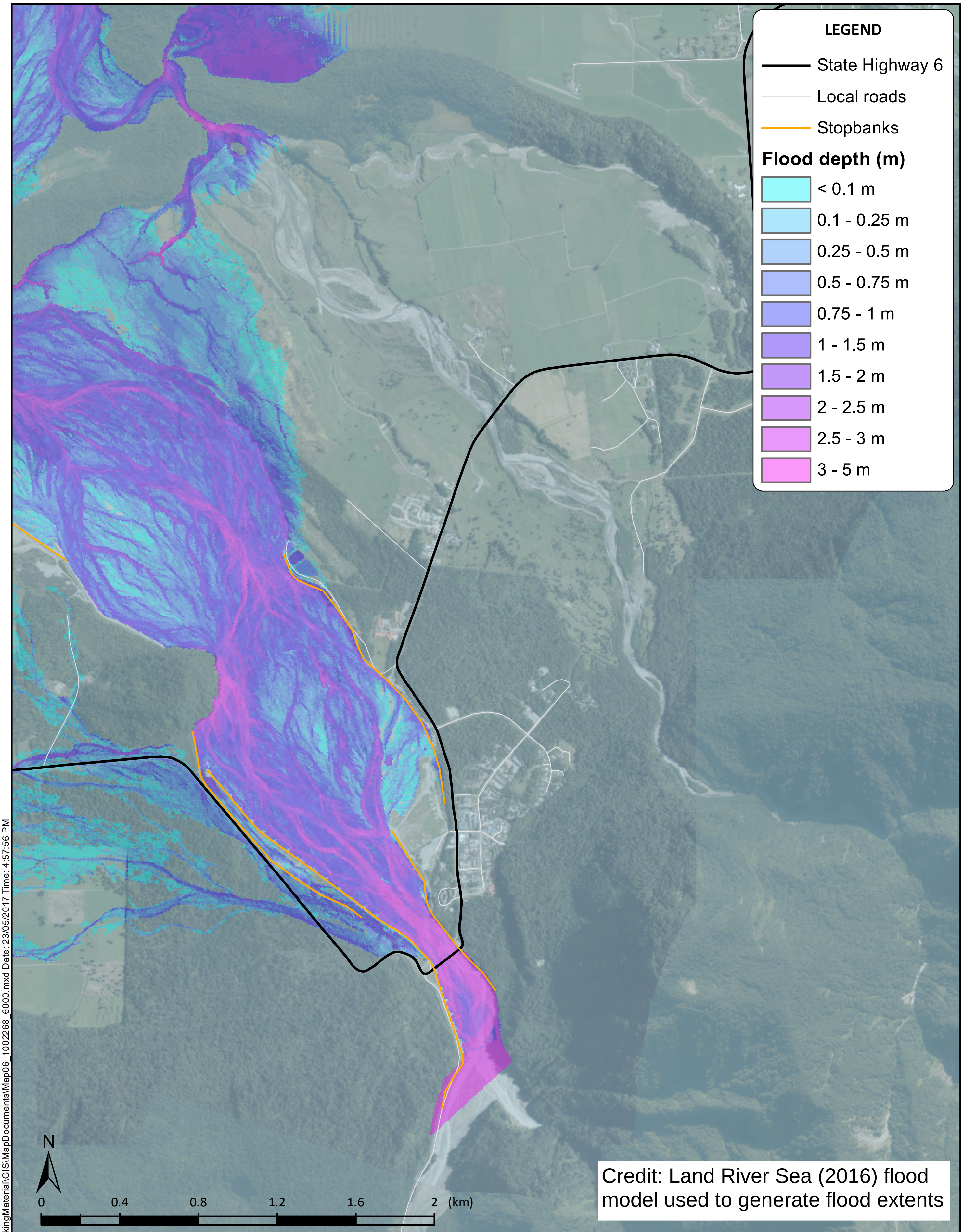

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FRANZ JOSEF NATURAL HAZARDS OPTIONS ASSESSMENT

Flood Depths 100 year ARI flood
with 0 m bed aggradation

FIGURE No. 15.28

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Table 15-21: Summary of AAL attributable to flooding in Year 0 with 0m bed aggradation based on current business-as-usual

Aspect	Current BAU Value		Flooding AAL>
	Count	Value> NZD	NZD
Life Loss	510 residents 1,593# visitor nights on average over the year	$8.8bn VoSL	$84,000 VoSL
Stocks			
Building Stock	471 buildings*	$97m^	$94,000
Land Value		$90m^	$0m
Total property stock		$187m^	$94,000
Potable water treatment	1 treatment facility	$2.3m	$0
Wastewater treatment plant	1 treatment facility	$3m	$383,000
Three waters network	Pipes, manhole, pumpstations	$4.4m	$0
Flood protection	8.4 km stopbanks	$8.5m	$7,000
Power distribution network	33kv Transmission Line FJ zone substation Distribution network Distribution substation	~$1m	Negligible
Communications network	Cell towers Copper network	~$1m	Negligible
Road network	44 km roads 5 bridges'	$80m	$28,000
Aerodrome	1 Aerodrome	$2m	$0
Flows			
Tourism	278,000 tourists/yr 581,000 visitor nights/yr	$122m/yr	Local: $341,000 Regional: $395,000 National: Negligible
Freight	68 trucks per day	N/A	N/A– freight impacts are assumed to be inherently captured through tourist expenditure

* Building count for the Franz Josef and Stony Creek area has been manually assessed based on GIS data. The building count for the wider study area has been extrapolated based on this count and land use assumptions. There is naturally subjectivity in what counts as a 'building'.

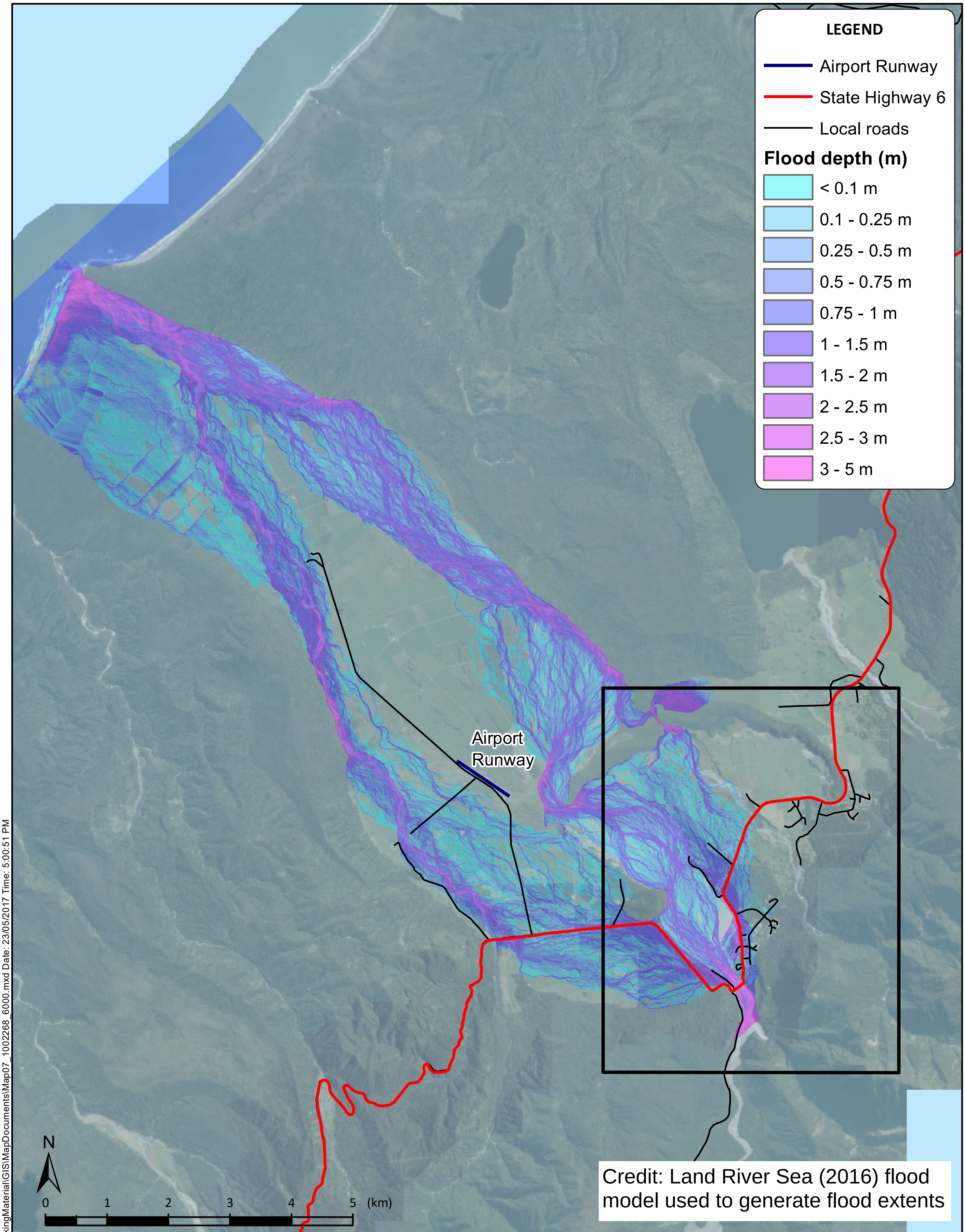
^ Capital values include all properties in the wider, defined, Franz Josef area for this assessment. Property valuations are informed by WDC data. Valuation Properties valuations have been divided uniformly on a per metre basis to inform building valuations where more than one building is modelled on a property.

' Bridges on SH6 in the assessment area.

This number represents the number of visitor nights in Franz Josef in a year divided by 365 days.

VoSL = Value of statistical life applied is $4.21 million /person

> Value presented are based on current values, not inflated by the consumer price index or producer price index projections



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Flood Depths 100 year ARI flood
with 6 m bed aggradation

FIGURE No. 15.29
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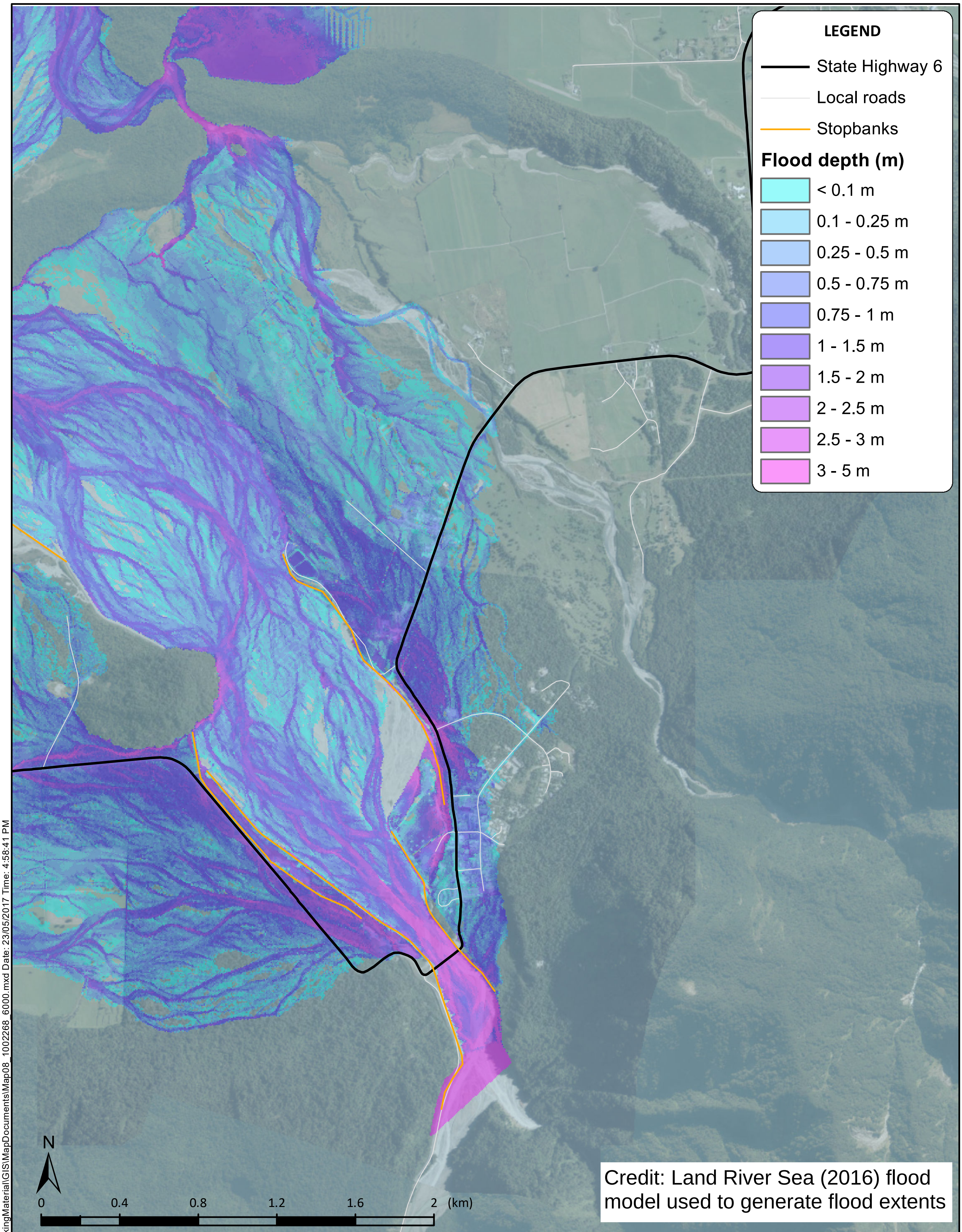

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WEST COAST REGIONAL COUNCIL
FRANZ JOSEF NATURAL HAZARDS OPTIONS ASSESSMENT
Flood Depths 100 year ARI flood
with 6 m bed aggradation

FIGURE No. 15.30

Rev. 0

Table 15-22: Summary of annual average losses (AAL) attributable to flooding in Year 30 with 6m bed aggradation based on current business-as-usual

Aspect	Current BAU Value		Flooding AAL>
	Count	Value> NZD	NZD
Life Loss	510 residents 1,593# visitor nights on average over the year	$8.8bn VoSL	$137,000 VoSL
Stocks			
Building Stock	471 buildings*	$97m^	$2m
Land Value		$90m^	$0m
Total property stock		$187m^	$2m
Potable water treatment	1 treatment facility	$2.3m	$0
Wastewater treatment plant	1 treatment facility	$3m	$41,000
Three waters network	Pipes, manhole, pumpstations	$4.4m	$0
Flood protection	8.4 km stopbanks	$8.5m	$13,000
Power distribution network	33kv Transmission Line FJ zone substation Distribution network Distribution substation	~$1m	$38,000
Communications network	Cell towers Copper network	~$1m	$43,500
Road network	44 km roads 5 bridges'	$80m	$558,000
Aerodrome	1 Aerodrome	$2m	$0
Flows			
Tourism	278,000 tourists/yr 581,000 visitor nights/yr	$122m/yr	Local: $2.3m Regional: $717,000 National: Negligible
Freight	68 trucks per day	N/A	N/A– freight impacts are assumed to be inherently captured through tourist expenditure

* Building count for the Franz Josef and Stony Creek area has been manually assessed based on GIS data. The building count for the wider study area has been extrapolated based on this count and land use assumptions. There is naturally subjectivity in what counts as a 'building'.

^ Capital values include all properties in the wider, defined, Franz Josef area for this assessment. Property valuations are informed by WDC data. Valuation Properties valuations have been divided uniformly on a per metre basis to inform building valuations where more than one building is modelled on a property.

' Bridges on SH6 in the assessment area.

This number represents the number of visitor nights in Franz Josef in a year divided by 365 days.

VoSL = Value of statistical life applied is $4.21 million /person

> Value presented are based on current values, not inflated by the consumer price index or producer price index projections

Table 15-23: Loss from relocation of the town in Year 31 due to flooding with 6m bed aggradation based on current business-as-usual

Aspect	Current BAU Value		Event Losses (Flood + 6m Bed Agg)	
	Number	Value> NZD	Damage	Loss*> NZD
Life Loss	510 residents 1,593# visitor nights on average over the year	$8.8bn VoSL	0-3	$12m
Stocks				
Building Stock	471 buildings*	$97m^	70%	$67m
Land Value		$90m^	50%	$45m
Total property stock		$187m^		$113m^
Potable water treatment	1 treatment facility	$2.3m	0%	$0
Wastewater treatment plant	1 treatment facility	$3m	100%	$3.0m
Three waters network	Pipes, manhole, pumpstations	$4.4m	100%	$4.4m
Flood protection	8.4 km stopbanks	$8.5m	50%	$4.3m
Power distribution network	33kv Transmission Line FJ zone substation Distribution network Distribution substation	~$1m	FJ substation needs relocation including part of transmission and distribution network. 70% loss assumed	$0.7m
Communications network	Cell towers Copper network	~$1m	Cell towers have to be moved. Assumed 50% loss	$0.5 m
Road network	44 km roads 5 bridges'	$80m	30-50%	23-38m
Aerodrome	1 Aerodrome	$2m	50%	$1m
Flows				
Tourism	278,000 tourists/yr 581,000 visitor nights/yr	$122m/yr		Local: $235m Regional:$0.7m National:$0m
Freight	68 trucks per day	N/A	N/A	N/A– freight impacts are assumed to be inherently captured through tourist expenditure

* Building count for the Franz Josef and Stony Creek area has been manually assessed based on GIS data. The building count for the wider study area has been extrapolated based on this count and land use assumptions. There is naturally subjectivity in what counts as a 'building'.

^ Capital values include all properties in the wider, defined, Franz Josef area for this assessment. Property valuations are informed by WDC data. Valuation Properties valuations have been divided uniformly on a per metre basis to inform building valuations where more than one building is modelled on a property.

' Bridges on SH6 in the assessment area.

This number represents the number of visitor nights in Franz Josef in a year divided by 365 days.

VoSL = Value of statistical life applied is $4.21 million /person

> Value presented are based on current values, not inflated by the consumer price index or producer price index projections

5 Business-as-usual: Assumptions and limitations

Detailed assumptions for each scenario is provided below:

Dimensions	Assumptions	Methodology and *supporting data* (if relevant)	Level of investment forecasted (50 years)
Planning	No change will be made to the currently operative version of Westland District Plan.	WDC has withdrawn Plan Change 7 Fault Rupture Avoidance Zone Natural hazard provisions (4.14) include the method that WDC will work with WCRC and other agencies to develop and implement a comprehensive package of measures to avoid, remedy or mitigate adverse effects from natural hazards.	N/A
	Incremental new residential development is likely to occur to the north/east of Cron St or (to a lesser extent) at Stony Creek.	These areas are within the residential zone in the Tourist Settlement Policy Area in the District Plan. Residential dwellings are permitted activities to a density of 1 per 300m^2 (and limited other development controls) –in the residential zone northeast of Cron St. No resource consent is required if meeting development controls. Elsewhere, residential dwellings are permitted activities to a density of 1 per 800m^2 with an extensive range of other development controls and design requirements. No resource consent is required if meeting development controls. While there are no natural hazard rules constraining residential development within the development control envelopes, Policy 4.14 is that development and subdivision should avoid areas of known natural hazard risk unless the risk….can be adequately mitigated.	N/A
	Commercial development to meet tourist demand will occur incrementally and be focused in the area north west of Cron St.	This area is within in the tourist zone in the Tourist Settlement Policy Area in the District Plan. Any commercial or residential activity is permitted (subject to limited development controls) and does not require resource consent. A tourist zone and core commercial area are also in place at Stony Creek. These are subject to more extensive development controls established in the Franz Alpine Development Plan.	N/A
	Development of new dwellings on the lower Waiho, south of Waiho River will be constrained.	This area is in the Waiho River Flood Hazard Policy Unit. New dwellings are restricted discretionary activities for which resource consent is required. Consents will not be granted if suitable methods to avoid, remedy or mitigate adverse effects of flooding on the dwelling, occupants, adjoining land and buildings are not available.	N/A
Stop Bank	Maintenance of stop banks at current height.	Stopbanks will not be increased overtime above their current height. The level of service, relative to flood average recurrence interval, will decrease. This represents a base case of no investment in stopbanks. The option of stopbanks combined with dredging, to maintain a level of service, will be considered as an investment option.	N/A

Dimensions	Assumptions	Methodology and *supporting data* (if relevant)	Level of investment forecasted (50 years)
	Periodic dredging programme does not exist – annual aggradation of river bed of 0.2m/yr	GNS (2016) reports bed aggradation of 0.16 to 0.2m per year. For the base case (and for the options) we have used 0.2m per year. There is no formal programme currently in place to dredge the Waiho River.	N/A
	Current approach to governance of stop bank management remains	No formal proposal on the table to put in place an integrated stop bank management governance regime.	N/A
Roads	NZTA Continues to maintain SH6 (within the confines of Franz Josef) to current levels of service	There is no proactive maintenance programme, and so historic costs are used as a basis for estimates + ongoing cost of maintaining the bailey bridge. - 192k p.a. of maintenance costs. Flood protection works (stop bank raising, river control works, clean-up following flood events) $1.992M over the last 10 years. - 270k p.a. of maintenance costs for the Bailey bridge. $250k per year for Bailey Bridge hireage costs (paid to NZTA internally to cover various costs associated with hireage and management of Bailey components)+ $20k (approx.) per year on average for ongoing bridge maintenance works costs.	Est. $462k p.a.
	SH6 Waiho River Bailey Bridge will be raised by 2m – completed in 2018.	https://www.gets.govt.nz/NZTAHNO/ExternalTenderDetails.htm?id=18561584 https://www.gets.govt.nz/NZTAHNO/ExternalTenderDetails.htm?id=18561584 http://www.stuff.co.nz/the-press/news/west-coast/82098565/16-million-to-lift-franz-josef-bridge-over-waiho-river http://www.stuff.co.nz/the-press/news/west-coast/82098565/16-million-to-lift-franz-josef-bridge-over-waiho-river	$1.6m in 2017
	Raising of the bridge does not occur again.	https://www.nzta.govt.nz/media-releases/key-westland-bridge-about-to-get-a-lift/https://www.nzta.govt.nz/media-releases/key-westland-bridge-about-to-get-a-lift/	N/A
Aerodrome	No expansion to the Aerodrome	Assumption	N/A
Waste Water	Maintain current level of service through investment	An upgrade to the existing infrastructure occurs, as limits are being reached. This is done in a stage approach with an interim option of a pond upgrade put in place in 2018 and a new pond or tank based 'SBR' constructed in 2020. Investment represents the mid-point estimate of the options provided to establish the current require level of service. Forthcoming decisions about the oxidation ponds and future investments in Wastewater Treatment Plants have been ignored for this assessment.	Interim pond upgrade $545,000 in 2018 New 'SBR' $2,400,000 + GST in 2020 Total value assumed to be ~$3m

<table>
<tr><th>Dimensions</th><th>Assumptions</th><th>Methodology and supporting data (if relevant)</th><th>Level of investment forecasted (50 years)</th></tr>
<tr><td rowspan="2"></td><td>The existing site of the oxidation ponds remains</td><td>The location of the wastewater treatment infrastructure is assumed to be in the current location of the oxidation ponds.</td><td>N/A</td></tr>
<tr><td>Flooding damage every 10 years</td><td>The position of the waste water treatment plant puts it at risk from flooding damage, as which occurred in 2016. GNS (2016) after Land River Sea Ltd. (2014) reports for the true right bank, “downstream of the limits of the main flood protection stopbanks the 10 year flood could be expected to overtop the Town terrace and flow across it”. For the base case we have assumed that the waste water treatment plant is impacted on average once every 10 years.</td><td>Cost to repair new ‘SBR’ every 10 years due to flooding assumed to be 70% of the total value of the asset $2.4 million dollars</td></tr>
<tr><td rowspan="5">Capital Stock</td><td>Current value of land and buildings is based on RV.</td><td><table>
<tr><th>Area</th><th>Sum of capital_va</th><th>Sum of land_value</th><th>Sum of Improvemen</th></tr>
<tr><td>Franz Josef Township to Tatare Stream</td><td>$112,768,500</td><td>$43,274,500</td><td>$69,494,000</td></tr>
<tr><td>Potters Creek/Lake Mapourika Area</td><td>$16,872,000</td><td>$10,065,000</td><td>$6,807,000</td></tr>
<tr><td>Plains south of Waiho</td><td>$29,502,000</td><td>$22,934,000</td><td>$6,568,000</td></tr>
<tr><td>Stony Creek</td><td>$29,404,500</td><td>$14,253,000</td><td>$15,151,500</td></tr>
<tr><td>Grand Total</td><td>$188,547,000</td><td>$90,526,500</td><td>$98,020,500</td></tr>
</table></td><td>N/A</td></tr>
<tr><td>154 commercial buildings projected to grow over 50 years</td><td>Commercial building growth (number of units) is based on forecast tourist growth.</td><td>490 buildings</td></tr>
<tr><td>152 residential buildings projected to grow over 50 years</td><td>Residential building growth (number of units) is based on forecast population growth.</td><td>175 buildings</td></tr>
<tr><td>64 ‘other’ buildings projected to grow over 50 years</td><td>Growth in other buildings (number of units) is based on forecast population growth.</td><td>73 buildings</td></tr>
<tr><td>DoC land, Ngai Tahu land, Stony Creek and major developments do not come to fruition.</td><td>Assumption based on lack of formal proposals.</td><td>N/A</td></tr>
<tr><td>WDC and WCRC Rates Value</td><td>Total rating values will increase in line with building growth.

Current rateable values are noted to the right.</td><td>Refer to table below</td><td>N/A</td></tr>
</table>

Area	Sum of WDCRates_Total_Rates_for_This_Year	Sum of WCRC General_Rate_Westland	Sum of WCRC Franz_Josef_Special Rating Area for Stopbank	Sum of WCRC Lower_Waiho_2011_ Special Rating Area for Stopbank	Sum of WCRC Regional_Emergency_ Management__Westland
Franz Josef Township to Tatare Stream	$757,393	$34,600	$111,118		$4,321
Potters Creek/Lake Mapourika Area	$55,222	$5,526			$690
Plains south of Waiho	$81,483	$9,176		$101,688	$1,146
Stony Creek	$196,292	$9,580			$1,196
Grand Total	**$1,090,391**	**$58,883**	**$111,118**	**$101,688**	**$7,353**

Dimensions	Assumptions	Methodology and *supporting data* (if relevant)	Level of investment forecasted (50 years)
Population [56]	Resident population of 576 by 2068	*Statistics New Zealand. Area unit projections* state that 520 residents will live in Franz Josef by 2043. Extrapolating this growth rate out to 50 years gives us the population projection.	N/A
GDP[57]	GDP is forecast to grow to $29m p.a in 2068.	There is no official measure of GDP at an Area Unit level. Therefore we have had to estimate current GDP and create assumptions around forecasts. We have taken the average of two approaches: - **Employment approach**: A GDP per employee figure at a West Coast level is derived, and then applied to the current projected number of employees in Franz Josef. - **Population approach**: A GDP per capital figure is derived at a West Coast level, and then applied to the current projected number of employees in Franz Josef.	N/A
Tourism[58]	Tourists are projected to grow to 883,000 in 2068. There will be considerable cyclical movement of numbers over this period.	To forecast the tourism figures, the following steps have been taken, and discussed with MBIE: - The range of rates between the two historical peaks, 2003 and 2016, and applied it in the same sequence to all years between 2017 and 2066. This enabled us to capture the seasonal fluctuations shown historically instead of steady exponential growth. Accommodation capacity was modelled, but is not considered material for the purposes of modelling given the 65% utilisation rate and the rate of growth in commercial buildings.	N/A
Tourist expenditure	An increase in tourist expenditure to $410m p.a in 2066 (from $122m).	$222 per visitor night is assumed based on a derived figure from Stats NZ and information received from MBIE. These value of tourist expenditure fluctuates year on year because of the forecast tourist cycles, and so this final dollar figure should not be considered a linear end point.	N/A

[56] Population projection is provided graphically in Appendix A.
[57] GDP projection is provided graphically in Appendix A
[58] Tourism Projection I provided graphically in Appendix A

Dimensions	Assumptions	Methodology and *supporting data* (if relevant)	Level of investment forecasted (50 years)
Freight[59]	The current freight profile is 68 trucks that pass through Franz a day carrying a range of goods.	There is currently no inter-regional freight that passes through Franz Josef – everything that passes through Franz Josef is for consumption on the West Coast. Deloitte Freight Demand study (2014) shows that freight between Dunedin and Greymouth is unlikely to go through Franz Josef as there are shorter routes available.	N/A
	We assume that freight volumes increase to 110 heavy vehicles per day in line with GDP growth.	GDP assumptions used to forecast this growth.	N/A
Governmen t Investment	No new investments in educational facilities will be made.	No new investment is assumed.	N/A
	No new investments in health facilities will be made	No new investment is assumed.	N/A
	Current levels of service for both education and health remain.	No new investment is assumed.	N/A
Other Investments	No additional investments forecast for Franz Josef	Proposed investments have been mentioned in passing, but we have not seen anything that is 'announcement ready'. Hence we have assumed no further investment.	N/A
Time horizon	Full 50 years assumed	50 years is assumed to align with Treasury CBAx model. In some instances, values have not been carried on beyond 30 years, however. For instance, the threat from the Waiho River is significant. Analysis of previous modelling demonstrates that the bed of the Waiho River could potentially be at the height of the town Franz Josef after thirty years. While this has been considered in the discussion of risks, and the case for change, this has not been formally modelled in the base case because this would skew the results by a magnitude far beyond reasonable.	N/A

6 Franz Josef Glacier detail

Recent scientific literature concerning Franz Josef Glacier suggests a continuing trend of sizeable retreat and loss of volume,[60] which would also increase safety risks on and around the glacier.[61]

Continuing a 125-year trend of glacial retreat and loss of volume

Franz Josef Glacier has shown a significant pattern of overall retreat for nearly 125 years, which corresponds with the overall pattern of glaciers retreating in New Zealand.[62] Since 1893, Franz Josef Glacier has retreated more than 3 km and lost about 3 to 4 km^2 in volume.[63]

Despite Franz Josef Glacier being one of many West Coast glaciers to experience some advancement during New Zealand's glacier advance phase – which lasted from about 1983 through 2008[64] and saw the glacier's length increase by 1.4 km[65] – the glacier has since resumed retreating and has already lost 1.5km in length since the advancement phase ended.[66] Anticipated global temperature increases through at least 2050[67] suggest Franz Josef Glacier will continue along its 125-year trend of significant retreat.

Franz Josef Glacier's 25-year advance phase was unusual for a time when most of the world's glaciers were retreating and losing volume as global temperatures increased.[68] But Franz Josef's advancement period is characteristic of New Zealand's glaciers, which are among the world's most sensitive to fluctuating temperatures, precipitation and regional climate variability.[69] New Zealand's regional climate variability caused at least 58 glaciers to advance, particularly along the West Coast of the South Island, at some point between 1983 and 2008.[70] Contributors to New Zealand's regional climate variability include the El Nino Southern Oscillation (ENSO) phases and south-westerly airflow anomalies.[71] Together, those factors have caused almost decadal advancement periods at Franz Josef Glacier since the 1940s.[72]

When temperature changes affect Franz Josef Glacier, those changes happen relatively quickly.[73] It is particularly sensitive to temperature and precipitation fluctuations when compared with other New Zealand glaciers[74], which are themselves more sensitive relative to the rest of the world's, because of their generally smaller and steeper topography.[75] The most recent estimate of Franz

60 Mackintosh, A. M., Anderson, B. M., Lorrey, A. M., Renwick, J. A., Frei, P. & Dean, S. M. (2017) Regional cooling caused recent New Zealand glacier advances in a period of global warming. *Nature Communications.*https://www.nature.com/articles/ncomms14202https://www.nature.com/articles/ncomms14202 https://www.nature.com/articles/ncomms14202https://www.nature.com/articles/ncomms14202

61 Purdie, H., Gomez, C. & Espiner, S. (2015). Glacier recession and the changing rockfall hazard: Implications for glacier tourism. *New Zealand Geographer.*

62 (Mackintosh et al. 2017, WGMS 2017, Purdie, H., Anderson, B., Chinn, T., Owens, I., Mackintosh, A. & Lawson, W. (2014) Franz Josef and Fox Glaciers, New Zealand: Historic length records. *Global and Planetary Change*, 121, pp.41-52.)

63 (Purdie et al. 2015, Purdie et al. 2014).

64 (Mackintosh et al. 2017)

65 (Mackintosh et al. 2017)

66 (Mackintosh et al. 2017, Purdie et al. 2014, NIWA 2017, WGMS 2012, WGMS 2017).

67 *NZ and international climate policy is intended to cap warming at 2 degrees C since post-industrial temperature levels.*

68 (Mackintosh et al. 2017)

69 (Anderson, B., Lawson, W. & Owens, I. (2008). Response of Franz Josef *Glacier Ka Roimata o Hine Hukatere* to climate change. *Global and Planetary Change,* 63, pp. 23-30. Anderson, et al. 2008; Salinger, J., Chinn, T., Willsman, A. & Fitzharris, B. (2008). Glacier response to climate change. *Water & Atmosphere*, 16/3.

70 Salinger et al. 2008)

71 (Purdie et al. 2014)

72 (Purdie et al. 2014)

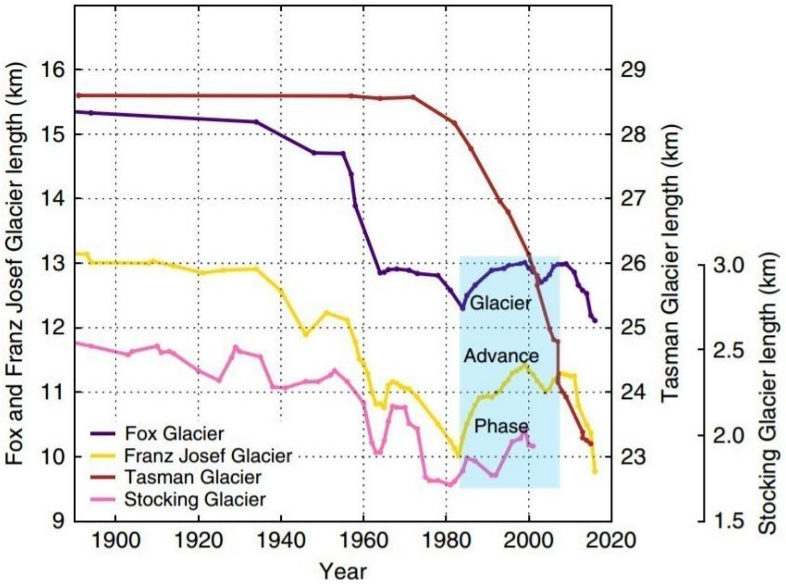
73 (Salinger et al. 2008, Purdie et al. 2014)

74 (Salinger et al. 2008, Purdie et al. 2014)

75 (Salinger et al. 2008)

Josef Glacier's response time to climatic events is three years.[76] In contrast, longer and lower-gradient glaciers such as Tasman Glacier have slower response times of up to 100 years. As a result, the Tasman Glacier does not experience the rapid advance and retreat cycles of Franz Josef Glacier and similar glaciers, such as Fox Glacier.[77]

Figure 15-31: From: Historic length changes for four glaciers in New Zealand (Mackintosh et al. 2017)
https://www.nature.com/articles/ncomms14202



Given the overall trend of retreat by Franz Josef Glacier,[78] and of glaciers in New Zealand[79] and worldwide,[80] Franz Josef Glacier's 25-year advancement phase should not be interpreted as an indication that a similar 1.4 km advancement is likely in the next several decades. Since 2008, Franz Josef Glacier has retreated by 1.5 km.[81] A continuing overall trend of retreat and volume loss by Franz Josef Glacier would be consistent with the global trend of glacial activity since the 1980s; a pattern of glaciers significantly retreating and thinning.[82] That pattern correlates to the past three decades having consecutively warmer average global temperatures.[83]

Climate scenario research conducted in 2008 on Franz Josef Glacier has modelled several different outcomes, which vary depending on how much warming will occur this century.[84] The research's minimum warming scenario shows the glacier retreating a further 3.9 km and losing 26% of its volume.[85] The maximum warming scenario modelled in this research predicted a 6.4 km retreat and

76 (Mackintosh et al. 2017, Salinger et al. 2008, Purdie et al. 2014)
77 (Salinger et al. 2008, Purdie et al. 2014)
78 (Purdie et al. 2014, Purdie et al. 2015, Mackintosh et al. 2017, Salinger et al. 2008, Anderson et al 2008)
79 (Mackintosh et al. 2017, Salinger et al. 2008)
80 (WGMS 2012, WGMS 2017)
81 (Mackintosh et al. 2017)
82 (WGMS 2012, WGMS 2017)
83 (IPCC, 2015)
84 (Anderson, Lawson & Owens, 2008)
85 (Anderson, Lawson & Owens, 2008)

a 58% loss in volume.[86] That research has not been revised to account for Franz Josef Glacier's 1.5 km of retreat since 2008.

Safety risks related to retreat and melting

Franz Josef Glacier's continuing retreat would exacerbate safety risks to tourists and other visitors to the glacier.[87] Glacial erosion and freeze-thaw – in which freezing and thawing water breaks apart rocks – can each destabilise the glacier's adjacent hillsides, increasing the risk to visitors from rocks and other debris.[88] Further, melting at Franz Josef Glacier has already caused a cavity to form underneath the glacier, which has caved in the surface in some places.[89] Thus, Franz Josef Glacier's value as an iconic tourist attraction is threatened both by the glacier's overall pattern of retreat and the physical risks to safety that are likely to accompany glacial retreat.

[86] (Anderson & Lawson, 2008)
[87] (Purdie, Gomez & Espiner, 2015)
[88] (Purdie, Gomez & Espiner, 2015)
[89] (Purdie, Gomez & Espiner, 2015)

Appendix I: Cost benefit analysis technical annex

1 Methodology adopted for the CBA

The economic analysis technique used to assess suitability of short-listed options is Cost Benefit Analysis (CBA). CBA is a decision making tool that aims to assess the value of project options on a consistent basis. This is done by quantifying all costs and benefits in monetary terms, where possible, and discounting them to a common point in time to determine the benefit to cost ratio of each option.

This CBA is not a detailed financial assessment of the viability of each package of options. It does however provide an indicative assessment of which general course of action is most likely to represent good value for money in the pursuit of the investment objectives.

When interpreting the CBA results for each package of options, it is important to note the resulting NPVs and BCRs are suitable for comparison relative to the short list options and should not be considered as an absolute value to be assessed outside of this context.

A two-stage CBA process has been adopted given the inherent characteristics of this study.

- A bespoke CBA model ('base model') has been built as the primary model for the purposes of this study. This model captures all of the relevant costs and benefits of interventions across a range of different parties (for instance we have included the expected effect of potential interventions at a local, regional and national level).
- The base model has then been used to produce inputs for the CBAx. CBAx naturally concerns itself with costs and benefits at the national level – and therefore is not strictly applicable for the level of decision making associated with this study.

A separate chapter of this annex explains the relevant features of CBAx *vis-a-vis* the base model. Unless otherwise stated, all remaining discussion applies to the construction and population of the base model.

2 Limitations

Crucially, this analysis does not take into account a range of important considerations. It would broadly be expected that any future business case process would look to develop these inputs further:

- *Ability to pay*: The CBA has identified the package of options that have the highest BCR ratios. However, the CBA, and indeed this study, has not sought to build consensus behind any decision. It is expected that further rounds of consultation and detailed feedback would be pursued as next steps.
- *Financial cost*: While a CBA investigates the various costs of options, it does not investigate the true financial cost of investment. For example, cost of capital and interest rate considerations are not made. It would be expected that any future business case would investigate the true financial cost of investing in any options.
- A discount rate of 6% is mandated for CBAx, as described through the Better Business Case process, and so has been carried through into the base model.
- *Insurance costs*: Insurance costs have explicitly not been considered as part of this analysis. It is unclear of the precise levels of coverage for each and every property and business within Franz Josef township and it is not possible to understand the precise insurance pay-outs that could be expected following any natural hazard event. Accordingly, insurance responses and

dynamic adjustments to premiums following any intervention have been ignored for the purposes of this assessment.

- *'Building back better'*: Following most natural disaster events, there is normally a desire to build back better. That being, a location is often restored to a state that is even better than prior to a natural disaster event, because decisions may not experience community or planning inertia and the presence of insurance funds can facilitate co-investment opportunities. Any concept of 'building back better' has been ignored as part of this analysis due to the speculative nature of any assumptions.
- *Book value vs replacement value*: Damage values of private properties are based on Council Valuations (CVs) as this is the best estimate we have at this stage to determine the value lost due to a hazardous event. Rebuild (replacement) values have been used in the estimate of damage value to infrastructure and the new town at Lake Mapourika.
- *Operation & Maintenance Costs*: Operational expenditure is generally not included in calculations for practical reasons. This fact has a balancing effect as our base case's operating and maintenance costs are expected to be similar for each option therefore they have not been included in the analysis
- *Consideration of individual circumstances*: To the extent possible, a wider town view of costs and benefits has been taken. In some instances there will be individual impacts on properties and businesses, but modelling these has been constrained only to the times that it is necessary.
- *No formal indexation*: Specific indexation of any of the cost or benefit inputs (i.e. to consumer price index, producer price index, or land value inflation indexes) for any package of options has not been undertaken. This is considered appropriate because of the stage of analysis – the study is looking at what the preferred pathway forward is, not the specific costs and benefits of each option as could be expected to accrue over time. However, this level of detail would be expected for future business cases, specifically in financial cases.

Key inputs such as tourism, population and building growth (but not capital value growth) have been used as 'anchors' for the base case, however.

An important point to remember is that while there may be some divergences between cost items (i.e. different cost estimates for stopbanks) as well as between what is modelled and what might be developed following detailed investigation (i.e. compensation could be CV at the top end or might be less than land value at the bottom end), it is believed that all costs to be of broadly the right scale. It is also noted that while these divergences may exist, that cost estimates have been applied consistently as this supports the notion of comparative testing.

In short, while limitations inherently exist in the modelling, they have been applied consistently, and where this isn't the case, there are justifiable reasons for doing so that have been transparently explained.

3 Assumptions and sources of information

Inputs have been drawn from desktop research (including official data sources, previous research, contemporary desktop research and professional judgements) and insights provided by the representatives from FJWG, local stakeholders, and other relevant stakeholders (such as central government officials, local government officials and business representatives).

The Study team has identified a wide range of potential costs and benefits associated with each package of options. Each of the potential costs and benefits were further identified as either monetary or non-monetary and whether or not they could be appropriately quantified based on the information available for this study.

A full description of the base case and how it is applicable to this analysis is provided in Appendix H. Moreover, a full bibliography of desktop research is provided in Section 13. Assumptions specific to each costs and benefit are presented throughout the remainder of this appendix.

3.1 Sensitivities

Sensitivities have been used for the value of compensation across all options and the location for where extracted gravel will be placed in Option 3 Defend. This has been carried out to provide end users with a better understanding as to what the various sub option could shape up like and what consequences could be caused by selecting a certain path of policy.

4 Average Annualised Loss

An important characteristic of many of the benefit assumptions under the flooding and earthquake scenarios is the concept of 'average annualised loss', which is the expected loss, on average, per year, from the full range of different likelihood events. In reality, in any one year, the loss value may be significantly below or above this average, as events have a large loss range. Most commonly there will be minor or no loss per year, until a significant event occurs.

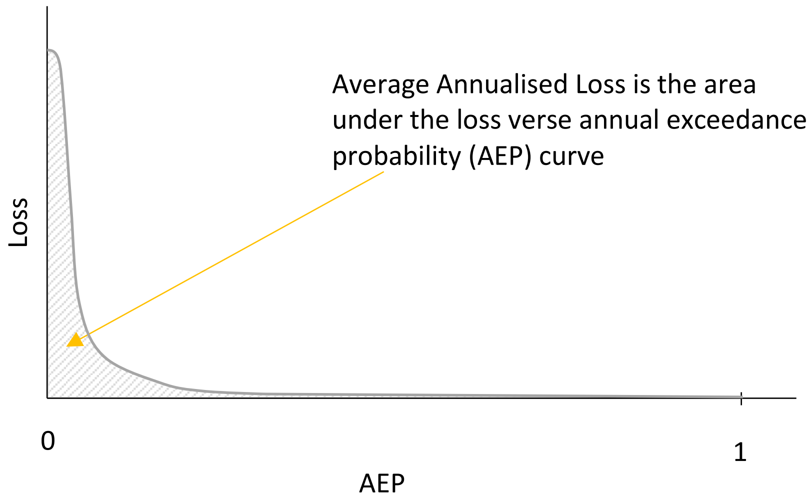
The average annual losses estimated are approximate based on a portfolio level assessment. They are used to determine the benefits for each investment option over the base case. Therefore the relative nature of how each loss is treated is important and a consistent approach has been applied to both the base case and the options.

Mathematically Average Annualised Loss is expressed as:

$$AAL = \int_0^1 D(p)dp$$

Where p is the Annual Exceedance Probability with a value between 0 and 1, covering all possible likelihood events and D is the damage which is the function of the likelihood p. This represents the area under the loss verse the annual probability of exceedance (AEP) curve as shown in Figure 15-32.

Figure 15-32 Annual Average Loss is calculated as the area under the loss verse annual exceedance probability curve



For this assessment, only key points on the curve have been assessed. For earthquake, the loss for an Alpine Fault Rupture earthquake (1 in 150 year) has been assessed as illustrated in Figure 15-33. For flood the approximate 1 in 20 year and 1-in-100 year flood in the Waiho River using the Gardner (2016) model has been assessed. For the base case the ever changing river bed level has been considered by assessing the flood extent for 0m, 4m, 5m and 6m bed aggradation for the 2016 levels (Gardner, 2016). These points are illustrated on Figure 15-34. The 'shape' of the rest of the curve has been approximated using judgement.

Figure 15-33: Earthquake AAL estimate illustration

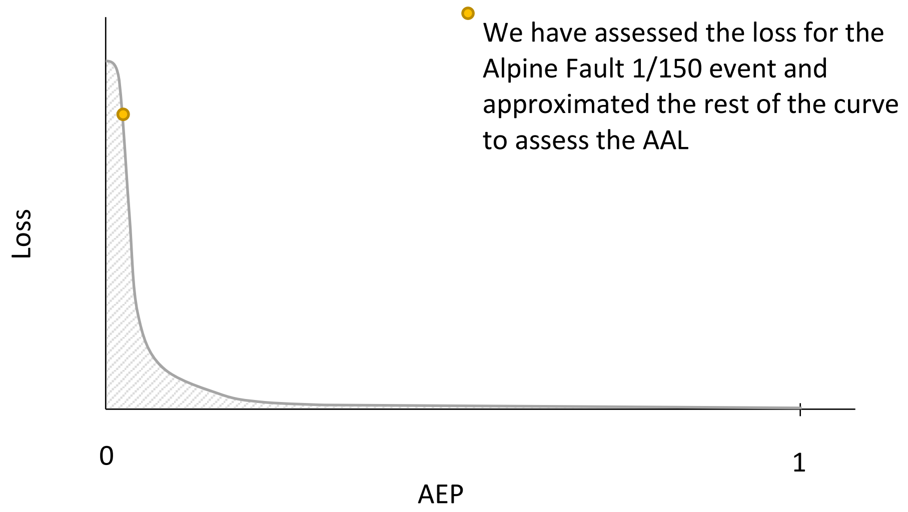
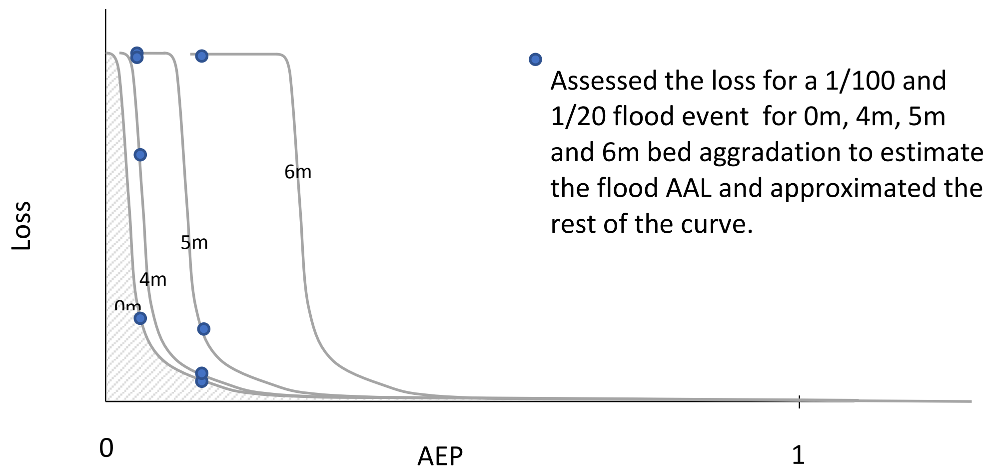
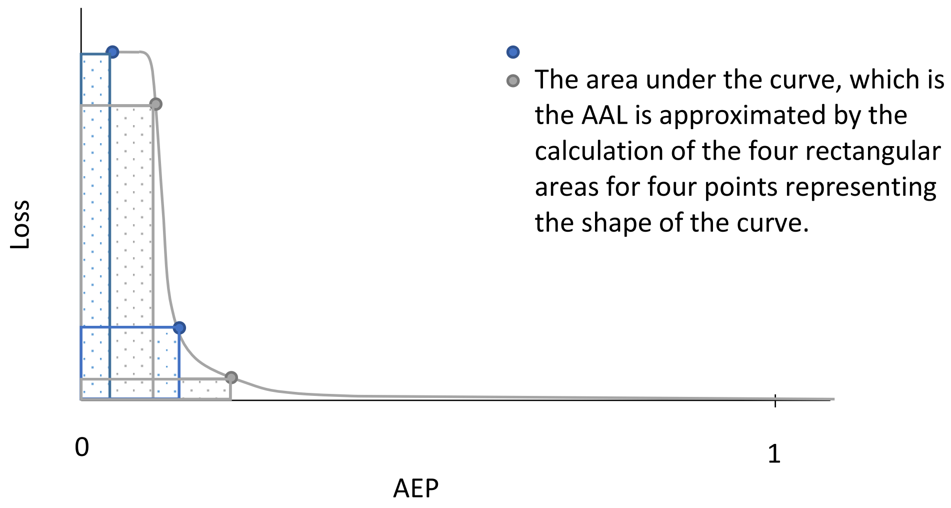


Figure 15-34: Flood AAL estimate illustration



To simplify the calculation of the area under the curve the area of four rectangles has been summed based on four points on each curve as shown in Figure 15-35. The four rectangular areas overlap. This simplification, which would over estimate the AAL in the areas of the overlap, is balanced by the areas missed beneath the curve due to the shape of the curve. There may be value in a more detailed calculation if a more refined/detailed CBA was undertaken, however this is not necessary for this stage of the analysis.

Figure 15-35: Calculation of the area under the curve AAL. We have summed the area of four rectangles based on four points on each curve



The annualised annual loss approach has also been used for direct loss and to calculate tourism revenue losses.

5 *Costs assumptions*

Table 15-24 describes the key cost line items for each package of options used in the CBA base model. Timing implications, including the split of costs over multiple years, is included in the CBA base model. The programme is shown on the Figures. A business case would refine these cost estimates further.

Table 15-24 Cost assumptions for *avoid nature's most significant challenges*

Item	Cost Element	Line Items	Value	Estimate basis	Key assumptions
1	Transition WWTP	-	$3.2m	Franz Josef Working Group	Assumes proposed upgrade to new plant, over just oxidation ponds.
2	Purchase of land at Lake Mapourika	-	$1.7m	WDC Capital Valuations	Based on CVs.
3	Development of new township	Masterplanning	$2m	Lump sum estimate	Lump sum estimate.
		Infrastructure construction	$23.6m	WDC Valuations	3-waters, roads, power, telecommunications and flood protection + earthworks.
		Public building construction	$8m	Rawlinsons	School, kindergarten, community hall, health centre, 2x churches, Police station, fire station. Improvement value. Cost based on new build rates.
		Private building construction	$480m	Rawlinsons	Commercial accommodation, commercial businesses, residential. Cost based on 'new build' rates (2017).

		New heli operation area	$1m	Lump sum estimate	Sum estimate.
4	Management of existing township land	-	$23.4m	Rawlinsons	Assumes split of clean fill and contamination and transportation to Hokitika.
5	SH6 realignment(R) and bridge(B) raising	-	$22.8m	NZTA pricing manual	~$22.8m for 8km (north and south) of new road. +$1.6m every 10 years to raise the Waiho Bridge. Land acquisition assumed to be part of compensation programme.
6	Compensation programme for loss of land utility to the south	South side - Upper Waiho	$1.9m-$12.5m	WDC Valuations	Assumed to be 15 to 100% of CV of properties.
		South side - Lower Waiho	$4.4m - $29.3m	WDC Valuations	Includes area which loses access. $7.8m + $21.5m. Assumed to be 15 to 100% of CV of properties.
7	Relocate Aerodrome to Whataroa	-	$4.7m	WDC Valuations Rawlinsons	Relocate Aerodrome to Whataroa when NZTA south side stopbanks are removed.

Table 15-25 Cost assumptions for *live with nature's challenges*

Item	Cost Element	Line Items	Value	Estimate basis	Key Assumptions
	Phase 1: Open up river to north				
1	Hold existing stopbank position (excluding WDC access embankment)	-	$1.0m	2011 WCRC costings	Maintain existing NZTA, Franz Josef and helicopter base stopbanks with minor raising to minimise risk of breach.
2	Relocate WWTP	-	$3.2m	Franz Josef Working Group	Build new WWTP away from Waiho River flooding.
3	Relocate key assets	-	$5.6m	WDC Capital Valuations	Kindergarten, school, electrical substation to the growth area at north end of township. CVs, estimate of substation value.
4	Compensation programme for loss of land utility to the north	-	$5.7m	WDC Capital Valuations	Assistance for commercial and residential properties as flooding erodes value of land. 15 - 100% of property CV.
5	Remove WWTP access road embankment releasing river north	-	Negligible	-	Flatten embankment.
6	Relocate key community buildings off Alpine Fault	Relocate petrol station	$0.70m	WDC Capital Valuations	CV of petrol station.
		Relocate fire station	$0.385m	WDC Capital Valuations	CV of fire station.
		Relocate DoC workshop and fire depot	$0.44m	WDC Capital Valuations	CV of DoC workshop and fire depot.
		Relocate police station	$0.5m	WDC Capital Valuations	CV of Police station.
		Relocate community hall	$1.2m	WDC Capital Valuations	CV of community.
		Relocate churches	$0.425m	WDC Capital Valuations	CV of churches.
7	Programme for relocation of private building from Alpine Fault	CV of land and buildings	$20.8m	WDC Capital Valuations	Work with commercial and residential properties to relocate from Alpine Fault. CV of private properties.

Item	Cost Element	Line Items	Value	Estimate basis	Key Assumptions
8	Relocate helicopter operation area and utilities	Cost for new helipad	$1m	Lump sum estimate	Relocate helicopter operation area, power and communication utilities out of flood area when Franz Josef and heli stopbanks are removed. Lump sum estimate.
		Power and telecommunication relocation	Negligible	-	Negligible
9	Build new town-side stopbank	-	$3.8m	2015 WCRC costings	1-in-100 year flood design level stopbank to provide protection to the Town area.
10	Realign State Highway 6 - North side	-	$11.4m	NZTA pricing manual	~4km realigned. Realign SH6 east away from the Waiho River and through the growth area of town.
11	Remove NZTA 55km stopbank	-	Negligible	-	Remove the NZTA 55km stopbank to allow river maximum width to north.
12	Remove the Franz Josef and heli stopbanks further releasing north	-	Negligible	-	Remove the Franz Josef and heli stopbanks to return helicopter operation area to river and allow aggregate aggradation to the north. Flatten embankments.
	Phase 2: Open up river to south				
13	Realign State Highway 6 - South side	-	$11.4m	NZTA pricing manual	~4km. Realign SH6 south away from the Waiho River along the base of hills.
14	Compensation programme for loss of land utility to the south	South side - Upper Waiho	$1.8m - $12.5m	WDC Valuations	Assistance for commercial and residential properties as flooding erodes value of land. 15 - 100% of property CV.
		South side - Lower Waiho	$4.4m - $29.3m	WDC Valuations	$7.8m + $21.5m. 15 to 100% of property CVs.
15	Remove the NZTA stopbanks - south side	CAPEX	Negligible	-	Negligible
16	Relocate Aerodrome	Aerodrome	$4.5m	WDC Valuations Rawlinsons	Relocate Aerodrome to Whataroa when NZTA south side stopbanks are removed.
	Long-term: 20+ years - Manage return to bed aggradation				
17	Raise stopbanks in the future	-	$0.38m	2011 WCRC costings	Upgrade town-side stopbanks to maintain 1-in-100 year level of service.
18	Gravel management programme	Land purchase for fill area	$0.8m	WDC Valuations	

Item	Cost Element	Line Items	Value	Estimate basis	Key Assumptions
		Haul road	$2.6m	WCRC standard rates	
		Gravel extraction	$40m	WCRC standard rates	Gravel extraction programme to maintain existing bed elevation and stopbank level of service. Fill location assumed to be to the south of the Waiho River behind Canavans Knob. Gravel extraction rate required assumed to be 150,000m3/yr. Cost ~$2.0m/yr x 20 years = $40m

Table 15-26 Cost assumptions for *defend against nature's challenges*

Item	Cost Element	Line Items	Value	Estimate basis	Key assumptions
	Phase 1: 1 to 10 years - Defend with stopbanks				
1	Upgrade stopbanks	-	$7.7m	2011, 2015 WCRC costings	Upgrade of Franz Josef, heli and NZTA stopbanks to maintain 1-in-100 year flood design levels. Design, consent and build cost.
	Build in safe-to-fail location in stopbanks	-	$1m	Lump sum estimate	Creation of a safe to fail plug/spillway in the south stopbank at 1-in-100 year flood design level. Lump sum estimate.
2	Relocate WWTP	-	$3.2m	Franz Josef Working Group	Build new WWTP away from Waiho River flooding. Estimate from Apex rates plus allowance for new site costs.
3	Build new school stopbank	-	$0.5m	2011, 2015 WCRC costings	Build new 1-in-100 year flood design level stopbank to provide protection to NZTA road, school, kindergarten and substation.
4	Remove WWTP access road embankment	-	Negligible	-	Allow river to go north by removing the access road embankment.
5	Compensation programme for loss of land utility to the north	-	$0.86m-$5.7m	WDC Valuations	Assistance for commercial and residential properties as flooding erodes value of land. 15 - 100% of property CV.
6	Relocate key buildings on Alpine Fault	Petrol station	$0.70m	WDC Valuations	CV of petrol station.
		Fire station	$0.385m	WDC Valuations	CV of fire station.
		DoC workshop and fire depot	$0.44m	WDC Valuations	CV of DoC workshop and fire depot.
		Police station	$0.5m	WDC Valuations	CV of Police station
		Community hall	$1.2m	WDC Valuations	CV of community hall
		Churches	$0.425m	WDC Valuations	CV of church
7	Programme for relocation from Alpine Fault	-	$20.8m	WDC Valuations	CV of private properties. Work with commercial and residential properties to relocate from Alpine Fault.
	Phase 2: 11 to 50 years - Gravel management				

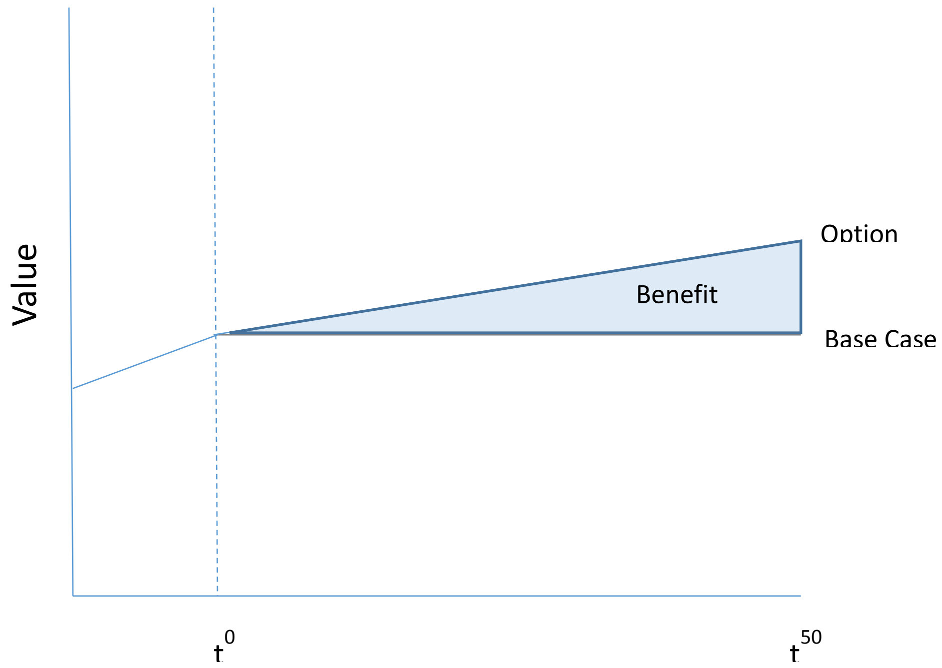
Item	Cost Element	Line Items	Value	Estimate basis	Key assumptions
8	Gravel management programme – fill disposal location in the wider Lower Waiho area	Land purchase for fill area	$1.4m	WDC Valuations	Gravel extraction programme to maintain existing bed elevation and stopbank level of service. Fill location assumed to be somewhere in the Lower Waiho area. Gravel extraction rate required assumed to be 300,000m3/yr. Cost ~$3.6m/yr x 40 years = $144m.
		Haul road	$2.6m	WCRC standard rates	
		Gravel extraction	$144m	WCRC standard rates	
9	Gravel management programme – alternative fill disposal location against Canavans Knob and the terminal moraine (used for sensitivity testing)	Land purchase for fill area	$1.4m	WDC Valuations	Gravel extraction programme to maintain existing bed elevation and stopbank level of service. Fill location assumed to be to the south of the Waiho River behind Canavans Knob and/or against Terminal Moraine. Gravel extraction rate required assumed to be 300,000m3/yr. Cost ~$3.0m/yr x 40 years = $120m.
		Haul road	$0.4m	WCRC standard rates	
		Gravel extraction	$120m	WCRC standard rates	

6 Benefits assumptions

The following chapter describes the key benefit line items for each package of options used in the CBA base model.

In general, the delta between the base case trajectory for each benefit category and the projected benefit path following investment in packages of options, underpins each calculation. A graphical depiction of this consideration is provided in below where the 'benefit wedge' is what is trying to be determined for each option.

Figure 15-36: Stylised depiction of benefit calculation



Six specific benefit categories have been used in the benefit analysis owing to their materiality to the overall assessment. A summary of the relevant methodological considerations are noted below. Specific assumptions under each scenario is then provided in Table 15-27, Table 15-28, Table 15-29.

6.1 Tourism benefits protected

At a local, regional and national level, this benefit category is fundamentally affected by assumptions around:

- Probability of an event occurring: In the case of earthquakes and flooding, this is an annual probability accounted for in average annual loss figures.
- Consequence of an event: There are a range of elements that are considered when determining the consequence of flooding and earthquake events on tourism numbers:
  - Inflow of tourists affected by event, i.e. the number of tourists expected to alter travel plans based on the presence of a hazard event (New Zealand/West Coast/Franz Josef)
  - Ability to spend money in Franz Josef: This can be affected by
    - Access for tourists into Franz Josef
    - Proportion of commercial buildings affected by event, and the speed of recovery

  - o Expected expenditure levels per day and expected length of stay in Franz Josef (the region or New Zealand)
- Duration of the hazard event
- For earthquake, consequences grow only in line with business-as-usual forecasts but flooding consequences also grow with bed aggradation

6.2 Capital value protected | commercial and residential properties and infrastructure assets

This benefit category is assumed to accrue at the local level and is fundamentally affected by assumptions around:

- Probability of an event occurring: In the case of earthquakes and flooding, this is an annual probability accounted for in average annual loss figures.
- Consequence of an event: Hazard maps have been developed to indicate the potential extent of disruption under various hazard scenarios, overlaid with expected potential disruption avoided under different packages of options. Earthquake consequences grow only with BAU, and flooding losses grow in line with bed aggradation and BAU.

6.3 Lives, injuries avoided

This benefit category is assumed to accrue at the local level and is fundamentally affected by assumptions around:

- Probability of an event occurring: In the case of earthquakes and flooding, this is an annual probability accounted for in average annual loss figures.
- Consequence of an event: Hazard maps and modelling about expected occupancy rates across all buildings within Franz Josef have been developed to indicate the potential impact on life and injuries under various hazard scenarios, overlaid with expected potential lives lost and injuries avoided under different packages of options. Earthquake consequences grow only with BAU, and flooding losses grow with bed aggradation step ups and BAU.

6.4 GDP impacts

GDP impacts are often used as the basis for economic value lost, however outside of the tourism sector, GDP have been explicitly ignored for this assessment. There are three reasons for this:

- GDP impacts of disasters are ambiguous, particularly for small areas. There are often short-term uplifts in GDP during a rebuild phase, but these are offset by slowdowns after the fact. Longer term changes to output are driven by changes in industry make-up and productivity of capital / labour.
- In order to understand 'true' impacts on GDP, computable general equilibrium modelling should be undertaken, which is a level of analysis too detailed for this stage of assessment.
- To the degree that GDP impacts do occur, they will be trivial at the national level (e.g. an approximate $20m economy Franz Josef, against a $250b economy all of New Zealand) – the impacts locally and regionally will be much more severe, but again, this is largely captured through the impact on tourism.

Future assessments may look to develop GDP impacts.

6.5 Methodology assumptions

There are a range of detailed methodology assumptions, logic flows and decisions that have gone into the establishment of the base model. In the interests of readability, only the material decision points for benefits are described in the tables below.

The fundamental nature of 'benefits' in the base model is that they consist of losses avoided. Benefits are therefore the delta between the base case losses and the new losses based on the interventions in the proposed option(s).

As the following benefit items are considered, it is important to reiterate the introduction chapter of this paper. *"There is a natural limit to the extent to which modelling and economic analysis can be used as a formal projector of future outcomes. Throughout this study we have sought to balance the competing tensions between what might happen in reality, vs what can we justify for the purposes of modelling."*

A prime example of this in the case of earthquake risk as the consequences from a fault rupture event have only been modelled – NOT a large rock landslide event. The functional effect of this distinction between modelling and reality is that inclusion of the consequence of a large rock landslide event would be expected to tilt towards the *Avoid nature's most significant challenges* as the scale of the benefit would be considerably larger.

Table 15-27: Benefit assumptions for *Avoid nature's most significant challenges*

Benefit Element	Methodological Considerations	Sources

Tourism | Local	*Flood*
	• Moving the town (which is on the north side of the river) out of the significant risk area to Lake Mapourika will significantly relieve the potential local tourism losses from a flood event, as the flooding risk from the Waiho River is avoided
	• Potential losses owing to local tourist expenditure have been presented in the base case in terms of annual average loss, and take into consideration:
	  o The fundamental assumption that tourists will only spend money at the local level if there are commercial premises in which to do so
	  o Expectations around timeframes for capital repair or rebuild to return to operation following a flood event have been used as a proxy for the proportion of daily expenditure that can be expected
	  o An average daily tourist expenditure figure for Franz Josef has been employed and pro-rated to the level of capital rebuild and return to operation
	  o Estimates around the length of time and the rate of recovery for the commercial rebuild and return to operation of Franz Josef following a significant flood event or untenable increase in flood hazard avoided have been based on estimates under an earthquake scenario
	• Benefits therefore represent the delta between the base case and the expected average annualised loss curve under this option and are fundamentally affected by the revised probability and spatial extent of the flood risk
	• Residual risk from flooding from Potters Creek has explicitly not been included in this analysis and is considered outside the scope of this report
	Earthquake
	• Moving the north side of the town out of the significant risk area to Lake Mapourika will be expected to have minor benefits accruing to tourism as the level of damage to commercial buildings is slightly lower than under the base case, as buildings still experience strong shaking however they are no longer situated on the Alpine Fault rupture zone
		MBIE Tourism West Coast spend and length of stay data
		Tourism inflows and growth rates from NZ Statistics
		T+T estimates for capital repair or rebuild and return to operation times based on Reese and Ramsay (2010) for Flood and FEMA (2015) for earthquake
		Robinson et al. (2015) for EQ road closure duration

Tourism | Regional	*Flood* • Losses at a regional level are expected to be much smaller than at the local level • Potential losses owing to regional tourist expenditure have been presented in the base case and fundamentally rest on assumptions of:	As per above Information relating to Kaikoura earthquake economic impacts (Market Economics, 2016)

Benefit Element	Methodological Considerations	Sources
	○ Access to the glacier. Given that access to Fox Glacier (where there are air facilities) and near (enough) to Franz Josef is still possible, it is expected the general demand for glacier country to be prominent still ○ Global perception of access. It is not expect for there to be any major international publicity about the presence of a major flood affecting Franz Josef, therefore it is not expect to see any meaningful reduction in tourists coming to New Zealand • Regardless, a 15% displacement rate avoided on the back of a significant flooding event has been assumed based on calculations related to the Kaikoura earthquake experience and discussions with stakeholders • Benefits therefore represent the delta between the base case and the expected average annualised loss curve under this option and are fundamentally affected by the revised spatial extent of the flood risk *Earthquake* • There are expected to be negligible benefits from an earthquake perspective as losses, at a regional level, in the base case are equivalent across all options	Robinson et al. (2015) for EQ road closure duration Stakeholder discussions
Tourism | National	*Flood* • Losses at a national level are expected to be negligible • Potential losses owing to regional tourist expenditure have been presented in the base case and fundamentally rest on assumptions of: ○ Access to the glacier. Given that access to Fox Glacier (where there are air facilities) and near (enough) to Franz Josef is still possible, it is expected the general demand for glacier country to be prominent still ○ Global perception of access. It is not expected for there to be any major international publicity about the presence of a major flood affecting Franz Josef, therefore it is not expect to see any meaningful reduction in tourists coming to New Zealand • Benefits therefore are negligible. *Earthquake* • There are expected to be no benefits from an earthquake perspective as losses, at a national level, in the base case are equivalent across all options	As per above
Capital Values | Residential and Commercial	*Flood* • Moving town out of the significant risk area to Lake Mapourika will significantly relieve expected losses for commercial (and residential) property for those properties on the north side of the Waiho River. For those properties on the south side of the Waiho River, there will be no additional benefits.	Residential building forecasts have been completed using forecasted Franz Josef population and Franz Josef

Benefit Element	Methodological Considerations	Sources

	• Benefits have been measured in terms of annual average loss avoided, and takes into consideration:
	  ○ The capital value of the properties expected to be impacted
	• Residual risk from flooding from Potters Creek has explicitly not been included in this analysis and is considered outside the scope of this report
	
	Earthquake
	• Moving the town out of the significant risk area to Lake Mapourika will be expected to have minor benefits as the level of damage to commercial and residential buildings is slightly lower than under the base case, as buildings still experience strong shaking however they are no longer situated on the Alpine Fault rupture zone
	• These benefits have been measured in terms of annual average loss avoided, and take into consideration:
	  ○ The capital value of the properties expected to be impacted
	  ○ The level of damage expected
		Tourism numbers for commercial buildings
		Capital values provided by Westland District Council
		EQ building damage based on Uma et al. (2008) and FEMA (2015)
		Flood building damage based on Reese and Ramsay (2010)

Capital Values | Infrastructure	*Flood*
	• Moving the town out of the significant risk area to Lake Mapourika, as well as associated options around road realignment and waste water treatment plan for instance, will significantly relieve expected losses for infrastructure assets affected by flooding risk
	• Benefits have been measured in terms of annual average loss avoided, and takes into consideration:
	  ○ The geographical spread of the flooding risk
	  ○ The value of the infrastructure assets expected to be impacted
	Earthquake
	• Moving the north side of the town out of the significant risk area to Lake Mapourika will be expected to have minor benefits as the level of damage to infrastructure is slightly lower than under the base case, as buildings still experience strong shaking however they are no longer situated on the Alpine Fault rupture zone
	• These benefits have been measured in terms of annual average loss avoided, and take into consideration:
	  ○ The value of the assets expected to be impacted
	  ○ The level of damage expected
		Valuations for three water network provided by Westland District Council
		Values for roads and bridges estimated using the NZTA pricing manual
		Values for the stopbanks estimated using WCRC rates
		No flood damage three waters pipes or water supply treatment plant assumed
		On flooding, damage to treatment plant approximated at between 70 and 100%
		Flood damage to roads approximated at 5% for length flooded
		Flood damage to stopbanks approximated at 5 to 50% for

Benefit Element	Methodological Considerations	Sources
		flooding between 20 year ARI and 100 year ARI flow, depending on bed aggradation EQ damage to three waters pipe network based on the Cousins (2013) repair rate curves EQ damage to water supply and wastewater treatment approximated as between 30 and 100% EQ damage to roads approximated on 4 to 20% for shaking only. 100% in damage in fault rupture zone. Bridges based on FEMA (2015) EQ damage to stopbanks based on Murashev et al. (2006) curves

Lives lost avoided	*Flood*
	• There are expected to be minor benefits from a flooding perspective as the amount of lives lost and injuries are expected to be low
	Earthquake
	• Moving the town out of the significant risk area to Lake Mapourika, will have minor benefits to life (large rock landslide has not been considered here) as the level of damage to commercial and residential building, which present a life risk, is lower
	• These benefits have been measured in terms of annual average loss avoided, and take into consideration:
	  ○ The number of people potentially residing in these affected properties in the day and night
	  ○ The statistical value of life and injury
		Population forecasts are based on NZ Statistics estimates
		Tourist forecasts are based on NZ Statistics estimates and MBIE West Coast visitor data
		Flood casualties based on historic flood records NIWA (2017)
		For earthquake, Riskscape casualty states applied based on damage state to the building
		Building Occupancy based on Cousins 2014 day and night occupancies and 67% occupancy for Franz Josef specific accommodation beds

Table 15-28: Benefit assumptions for *Live with nature's challenges*

Benefit Element	Key Methodological Considerations	Sources
Tourism | Local	*Flood* • Enabling the river to return to a more natural state by removing stopbanks protecting the south side will significantly relieve the potential local tourism losses from a flood event, as flooding risk is better managed • Potential losses owing to local tourist expenditure have been presented in the base case in terms of annual average loss, and take into consideration: ○ The fundamental assumption that tourists will only spend money at the local level if there are commercial premises in which to do so ○ Expectations around timeframes for capital repair or rebuild and return to operation following a flood event have been used as a proxy for the proportion of daily expenditure that can be expected ○ An average daily tourist expenditure figure for Franz Josef has been employed and pro-rated to the level of capital rebuild ○ Estimates around the length of time and the rate of recovery for the commercial rebuild and return to operation of Franz Josef following a significant flood event or untenable increase in flood hazard avoided have been based on estimates under an earthquake scenario • Benefits therefore represent the delta between the base case and the expected average annualised loss curve under this option and are fundamentally affected by the revised probability and spatial extent of flooding *Earthquake* • Moving the part of the town off the Alpine Fault Rupture Zone will be expected to have minor benefits accruing to tourism as the level of damage to commercial buildings is slightly lower than under the base case	As per notes for avoid nature's most significant challenges package
Tourism | Regional	*Flood* • Losses at a regional level are expected to be much smaller than the local level • Potential losses owing to regional tourist expenditure have been presented in the base case and fundamentally rest on assumptions of: ○ Access to the glacier. Given that access to Fox Glacier (where there are air facilities) and near (enough) to Franz Josef is still possible, it is expected the general demand for glacier country to continue to remain prominent	As per notes for avoid nature's most significant challenges package

Benefit Element	Key Methodological Considerations	Sources
	○ Global perception of access. It is not expected for there to be any major international publicity about the presence of a major flood affecting Franz Josef, therefore it is not expect to see any meaningful reduction in tourists coming to New Zealand • Regardless, a 15% displacement rate avoided on the back of a significant flooding event has been assumed based on calculations related to the Kaikoura earthquake experience • Benefits therefore represent the delta between the base case and the expected average annualised loss curve under this option and are fundamentally affected by the revised probability and spatial extent of flooding *Earthquake* • There are expected to be negligible benefits from an earthquake perspective as losses, at a regional level, for base case are equivalent across all options	
Tourism | National	*Flood* • Losses at a national level are expected to be negligible • Potential losses owing to regional tourist expenditure have been presented in the base case and fundamentally rest on assumptions of: ○ Access to the glacier. Given that access to Fox Glacier (where there are air facilities) and near (enough) to Franz Josef is still possible, it is expected the general demand for glacier country to continue to remain prominent ○ Global perception of access. It is not expected for there to be any major international publicity about the presence of a major flood affecting Franz Josef, therefore it is not expect to see any meaningful reduction in tourists coming to New Zealand • Benefits therefore are negligible *Earthquake* • There are expected to be negligible benefits from an earthquake perspective as losses, at a national level, for base case are equivalent across all options	As per notes for avoid nature's most significant challenges package
Capital Values | Residential and Commercial	*Flood* • Enabling the river to return to a more natural state by removing stopbanks protecting the south side will significantly relieve expected losses for most commercial (and residential) property • These benefits have been measured in terms of annual average loss avoided, and takes into consideration: ○ The delta between the geographical spread of the flooding risk ○ The value of the properties expected to be impacted	As per notes for avoid nature's most significant challenges package

Benefit Element	Key Methodological Considerations	Sources

	Earthquake
	• In addition to the primary option of enabling the river to return to a more natural state by removing stopbanks protecting the south side, this option models the transfer and relocation of the assets that currently sit directly on the Alpine Fault. By removing these assets, there are expected to be benefits that accrue to approximately 30 to 40 properties as they will likely experience a lower level of capital value damage.
	• These benefits have been measured in terms of annual average loss avoided, and take into consideration:
	  ○ The value of the properties expected to be impacted
	  ○ The delta between level of damage expected	

Capital Values | Infrastructure	*Flood*
	• Enabling the river to return to a more natural state by removing stopbanks protecting the south side will significantly relieve the potential losses for infrastructure assets within the township
	• These benefits have been measured in terms of annual average loss avoided, and takes into consideration:
	  ○ The delta between the geographical spread of the flooding risk
	  ○ The value of the assets expected to be impacted
	Earthquake
	• There are expected to be negligible benefits from an earthquake perspective as losses for base case are equivalent across all options
		As per notes for avoid nature's most significant challenges package

Lives lost and injuries avoided	*Flood*
	• There are expected to be minor benefits from a flooding perspective as the loss of life in the base case and all options is expected to be minor
	Earthquake
	• In addition to the primary option of enabling the river to return to a more natural state by removing stopbanks protecting the south side, this option includes the transfer and relocation of the assets that currently sit directly on the Alpine Fault. By removing these assets from the fault, there are expected to be minor benefits to life as the level of damage to commercial and residential building, which present a life risk, is lower.
	• These benefits have been measured in terms of annual average loss avoided, and take into consideration:
	  ○ The number of people potentially residing in these affected properties
	  ○ The statistical value of life and injury
		As per notes avoid nature's most significant challenges package

Table 15-29: Benefit assumptions for *Defend against nature's challenges*

Benefit Element	Methodological Considerations	Sources

Tourism | Local	*Flood*
	• Maintaining flood protection with a long term management programme of engineered stopbanks and gravel-management will significantly relieve the potential local tourism losses from a flood event, as flooding risk is better managed
	• Potential losses owing to local tourist expenditure have been presented in the base case in terms of annual average loss, and take into consideration:
	  ○ The fundamental assumption that tourists will only spend money at the local level if there are commercial premises in which to do so
	  ○ Expectations around timeframes for capital repair or rebuild and return to operation following a flood event have been used as a proxy for the proportion of daily expenditure that can be expected
	  ○ An average daily tourist expenditure figure for Franz Josef has been employed and pro-rated to the level of capital rebuild
	  ○ Estimates around the length of time and the rate of recovery for the commercial rebuild and return to operation of Franz Josef following a significant flood event or untenable increase in flood hazard avoided have been based on estimates under an earthquake scenario
	• Benefits therefore represent the delta between the base case and the expected average annualised loss curve under this option and are fundamentally affected by the revised probability and spatial extent of flooding
	Earthquake
	• Moving the part of the town off the Alpine Fault Rupture Zone will be expected to have minor benefits accruing to tourism as the level of damage to commercial buildings is slightly lower than under the base case
		As per notes for avoid nature's most significant challenges package

Tourism | Regional	*Flood*
	• Losses at a regional level are expected to be much smaller than at the local level
	• Potential losses owing to regional tourist expenditure have been presented in the base case and fundamentally rest on assumptions of:
	  ○ Access to the glacier. Given that access to Fox Glacier (where there are air facilities) and near (enough) to Franz Josef is still possible, it is expected the general demand for glacier country to continue to remain prominent
	  ○ Global perception of access. It is not expected for there to be any major international publicity about the presence of a major flood affecting Franz Josef, therefore it is not expect to see any meaningful reduction in tourists coming to New Zealand
		As per notes for avoid nature's most significant challenges package

Benefit Element	Methodological Considerations	Sources
	• Regardless, a 15% displacement rate avoided on the back of a significant flooding event has been assumed based on calculations related to the Kaikoura earthquake experience • Benefits therefore represent the delta between the base case and the expected average annualised loss curve under this option and are fundamentally affected by the revised probability and spatial extent of flooding *Earthquake* • There are expected to be negligible benefits from an earthquake perspective as losses, at a regional level, for base case are equivalent across all options	
Tourism | National	*Flood* • Losses at a national level are expected to be negligible • Potential losses owing to regional tourist expenditure have been presented in the base case and fundamentally rest on assumptions of: ○ Access to the glacier. Given that access to Fox Glacier (where there are air facilities) and near (enough) to Franz Josef is still possible, it is expected the general demand for glacier country to continue to remain prominent ○ Global perception of access. It is not expected for there to be any major international publicity about the presence of a major flood affecting Franz Josef, therefore it is not expect to see any meaningful reduction in tourists coming to New Zealand • Benefits therefore are negligible *Earthquake* • There are expected to be negligible benefits from an earthquake perspective as losses, at a national level, for base case are equivalent across all options	As per notes for avoid nature's most significant challenges package
Capital Values | Residential and Commercial	*Flood* • Maintaining flood protection with a long term management programme of stopbanks and gravel-management will significantly relieve the potential losses for commercial (and residential) property • These benefits have been measured in terms of annual average loss avoided, and takes into consideration: ○ The delta between the geographical spread of the flooding risk ○ The value of the properties expected to be impacted • This option has the same benefit calculations as for option 1, but has an additional premium for the capital values protected on the South side of the Waiho River *Earthquake*	As per notes for avoid nature's most significant challenges package

Benefit Element	Methodological Considerations	Sources

	• In addition to the primary option of maintaining flood protection with a long term management programme of stopbanks and gravel-management, this option models the transfer and relocation of the assets that currently sit directly on the Alpine Fault. By removing these assets, there are expected to be benefits that accrue to approximately 30 to 40 properties as they will likely experience a lower level of capital value damage.
	• These benefits have been measured in terms of annual average loss avoided, and take into consideration:
	  ○ The value of the properties expected to be impacted
	  ○ The level of damage expected	

Capital Values | Infrastructure	*Flood*
	• Maintaining flood protection with a long term management programme of stopbanks and gravel-management will significantly relieve the potential losses for infrastructure assets within the township
	• These benefits have been measured in terms of annual average loss avoided, and takes into consideration:
	  ○ The delta between the geographical spread of the flooding risk
	  ○ The value of the assets expected to be impacted
	Earthquake
	• There are expected to be negligible benefits from an earthquake perspective as losses in base case are equivalent across all options
		As per notes for avoid nature's most significant challenges package

Lives lost and injuries avoided	*Flood*
	• There are expected to be minor benefits from a flooding perspective as the loss of life in the base case and all options is expected to be minor
	Earthquake
	• In addition to the primary option of maintaining flood protection with a long term management programme of stopbanks and gravel-management, this option includes the transfer and relocation of the assets that currently sit directly on the Alpine Fault. By removing these assets from the fault, there are expected to be minor benefits to life as the level of damage to commercial and residential building, which present a life risk, is lower.
	• These benefits have been measured in terms of annual average loss avoided, and take into consideration:
	  ○ The number of people potentially residing in these affected properties
	  ○ The statistical value of life and injury
		As per notes for avoid nature's most significant challenges package

6.6 CBAx

To help compare different options in a New Zealand context, the Treasury has developed a CBA tool called CBAx. CBAx is a spreadsheet model that contains a common database to help agencies monetise impacts and do return on investment analysis.

Like any model, CBAx has natural limitations. In this context of this study, the most relevant limitation is the difficulty in presenting costs and benefits across different stakeholder sets (local, regional and national). CBAx is often concerned with policy implications at a national level, and therefore the explicit 'local' focus of this study combined with a desire to understand impacts across regional and national considerations presents some challenges.

To remedy this situation, a stand-alone CBA analysis ('base model') has been developed which captures all of the information that is needed for the purposes of this study. The base model has allows for easy extraction of inputs for inclusion in CBAx – which would be an expectation for the development of any future business cases. In this sense, the work done to date for this project, will support the development of any future business case to support the pathway forward for Franz Josef.