Head of Lake Whakatipu
Natural Hazards Adaptation Strategy

Draft report for public feedback | December 2024

COVER ARTWORK: CONNIE ANDERSON

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Thank you to everyone whose time, expertise and inputs have helped to shape the Head of Lake Whakatipu Natural Hazard Adaptation Strategy so far.

We look forward to your feedback and suggestions on this draft.

orc.govt.nz 0800 474 082 Private Bag 1954, Dunedin 9054

1 Introduction

At the head of Lake Whakatipu (Whakatipu-wai-Māori)[1] (Figure 1.1), the townships of Glenorchy (Tāhuna) and Kinloch, and surrounding rural areas of the Dart (Te Awa Whakatipu), Rees (Puahiri/Puahere), Paradise and Greenstone valleys are exposed to a complex range of flooding, landslide, and earthquake related hazards. The landscape is very dynamic and with the changing climate, the natural hazard challenges at Head of Lake Whakatipu are complex resulting in no simple solutions.

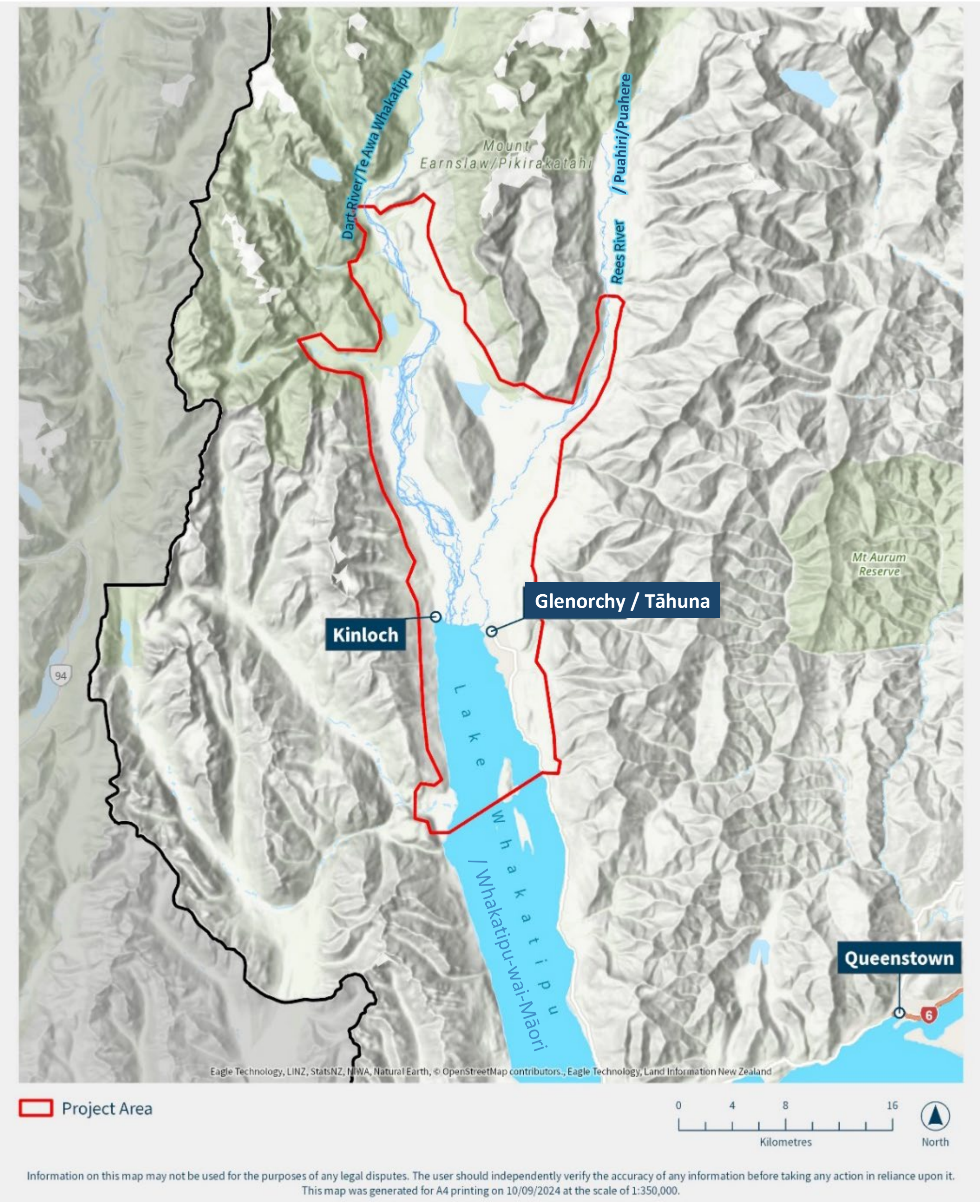

Figure 1.1 Overview of the head of Lake Whakatipu, showing the programme area of interest outlined in red.

[1] The preferred Kāi Tahu spelling of Whakatipu has been adopted throughout report

To develop holistic, longer term natural hazards management plans, Otago Regional Council is using an approach in line with the Ministry for the Environment 10-Step adaptation cycle. This cycle incorporates a method known as Dynamic Adaptative Pathways Planning (DAPP) or 'Adaptation Pathways'. The cycle has been promoted by the Ministry for the Environment as a blueprint for community-influenced decision making in areas affected by natural hazards and considering potential future uncertainties (e.g. landscape and climate changes).

Working together and taking account of natural hazard and climate risk in everything we do sets the foundation for more resilient communities. Current actions form the basis of our efforts to manage hazards, and we will need adjust or pivot as conditions change. We are inspired by the history of the area, which is full of adaption stories, as communities adjusted to changes in economic fortunes and ease of access.

This is the first iteration of a Head of Lake Whakatipu Natural Hazards Adaptation Strategy (The Strategy) and is the result of five years of work. The body of work is broad including; hazards and risk assessments; possible mitigation and management; place, people and economy; and feedback and input from engagement. This detailed report summarizes the work that has been done, integrates the pieces, and places them in a strategic framework that assists implementation through existing systems and processes, as much as possible.

The Strategy is a partnership between ORC, Queenstown Lakes District Council, Civil Defence Emergency Management Otago, and the local community, and has been developed in collaboration with mana whenua representatives. While ORC led the development of this Strategy, it would not be possible without input from our partners, mana whenua, and natural hazards and adaptation experts.

The Strategy is structured as follows:

- Section 2-3 – Defines the vision, goals, and principles to guide natural hazards adaptation
- Section 4 – Defines the scope of the strategy.
- Section 5-8 – Describes the background and context information on the importance of tackling natural hazards and the impacts of climate change together.
- Section 9 – Guides the reader through the adaptation process using the five key questions as a framework: 1) what is happening, 2) what matters most, 3) what can we do about it, 4) how can we implement the strategy, and 5) how is it working?
- Section 10 - Action Plans – Outlines the work that strategy partners are planning to do.

2 Vision and Goals

Our vision is a resilient and sustainable Head of Lake Whakatipu, where proactive natural hazard and climate adaptation enhance community wellbeing and safety, and contribute to a flourishing environment.

Goal 1: Adaptation is woven into our everyday work

- Make plans and recommendations that align with council strategies, policies, and processes, and integrate with business-as-usual workstreams.
- Work in partnership with mana whenua, and coordinate and collaborate with other agencies and communities with a common purpose to incorporate adaptation into what we do.
- Build connections across and between agencies and work together effectively across work programmes.
- Encourage and amplify existing good practice and initiatives.

Goal 2: Lay a robust foundation for decision-making

- Point us in the same direction with a common understanding of the physical environment to build from.
- Continue to build understanding of natural hazard risks, uncertainties and opportunities now and in the future that come with natural hazards and climate change.
- Increase awareness around current and future natural hazards risks and impacts of climate change, as well as effective adaptation responses.
- Build capacity around adaptation and support communities and decision makers to take advantage of opportunities.
- Consider ways to incorporate mātauraka Kāi Tahu into the decision-making frameworks.
- Share new information as it becomes available.

Goal 3: Healthy and resilient communities

- Lead and support others to actively manage and reduce risk to natural hazard and impacts of climate change.
- Support and enable community-led action and behavioural change.
- Promote community safety by managing and reducing risk from natural hazards and impacts of climate change.
- Strengthen communities, businesses, and organisations so that they are well-prepared for natural hazard events and are better able to cope and recover.

Goal 4: Resilient built places, infrastructure, and systems

- Lead the way and support others to increase the resilience of infrastructure, resources, and systems.
- Encourage responsible management of resources and infrastructure that prioritises resilience, sustainability, and avoids maladaptation, such as unintentional negative outcomes.
- Provide information for individuals, businesses, and agencies to consider natural hazard risks and the impacts of climate change as part of planning and development processes.
- Support integration of traditional and modern local knowledge into planning and development of local infrastructure.

Goal 5: A flourishing environment

- Support and enable nature-based solutions and principles to adapt to natural hazard risks and climate change and deliver other socio-economic and environmental benefits.
- Integrate adaptation across Councils' work programmes to deliver natural hazards, biodiversity, and wider environmental outcomes.

3 Principles

In seeking to achieve these goals, the development and implementation of the Head of Lake Whakatipu Natural Hazards Adaptation Strategy is guided by key principles. These principles have been developed with input from best-practice research, national guidance, and what we have heard from partners and the community.

Key principles are as follows:

- Take a **holistic and long-term view** to natural hazards risk management and adaptation efforts.
- **Partner and collaborate** with mana whenua, Queenstown Lakes District Council, Civil Defence Emergency Management Otago, communities, and stakeholders. Work together to maximise the use of resources, expertise, knowledge, and ideas to achieve better outcomes.
- Make **robust decisions** using the best available evidence including mātauraka Māori, local knowledge, western-based science, information, and data.
- **Be community-centered** by enabling and empowering the community to actively participate in the process, by being inclusive, accessible, and transparent.
- **Be flexible** and adjust as we go, but avoid maladaptation.
- Consider **co-benefits** (such as improving community capacity, enhancing biodiversity, emissions reduction, and celebrating and reinforcing Kāi Tahu connections to place) for adaptation efforts to achieve complementary goals, while avoiding maladaptation.
- Promote **fairness and equity** for and between communities and across generations.
- **Uphold te Tiriti o Waitangi** – the adaptation Strategy should ensure Otago Regional Council is fulfilling its obligations as a meaningful Treaty partner, as supported by ORC's He Mahi Rau Rika: Significance, Engagement and Māori Participation policy.
- **Align with national-level direction and policies,** including the 10-step adaptation cycle approach, Dynamic Adaptive Pathways Planning (DAPP) and best-practice research.
- Adaptation efforts should **work with nature** as much as possible to protect, enhance, and restore our natural environment.
- Be **open and accountable.** Ensure progress is transparently communicated to partners, stakeholders, and the community.
- Consider **cost-effectiveness and practicality** to ensure that resources are used efficiently and that they reduce risks to what is reasonable, practicable, and acceptable to partners and the community.

4 Scope

This first iteration of the Strategy has a defined scope that is tied to what the named partners can implement using current systems and processes.

- The Strategy does not have any decision-making power or create any obligations. It is intended to lay a good foundation, provide a common direction, and support the integration of adaptation into partners everyday work.
- The Strategy takes a ***multi-hazard perspective*** to build a holistic understanding of a complex and highly dynamic environment.
- The Strategy focuses on ***adapting to natural hazards only,*** as the partner agencies and systems for implementation are best positioned to deliver effective actions for these risks.
- Action plans describe the ***current commitments and activities of key partners***, namely Otago Regional Council, Queenstown Lakes District Council, Civil Defence Emergency Management Otago, mana whenua and local communities.
- Action plans focus on ***planning time horizons*** to align with councils' 10-year Long-Term Plans and 30-year infrastructure strategies. Where appropriate, longer time horizons are considered for natural hazards impacts and climate change information.
- Action Plans are based on ***currently defined roles and responsibilities*** and are aligned with legislation, systems, processes, and policies.
- The Strategy is ***not an equivalent or substitute for people's ability to participate in other statutory processes*** (such as the statutory frameworks for Regional Policy Statement, regional and district plans, and Councils long-term plans)
- ***Foundational information*** will guide and influence a wide range of stakeholders with interests in adaptation, but only the actions of named partners are identified and tracked.
- ***Possible responses in the future toolbox*** are not commitments, as they do not have business cases or future funding identified at this stage. Some possible responses fall outside the current roles and responsibilities of partner agencies.
- The Strategy is a ***result of a collective effort and belongs to everyone.*** ORC's lead role in its development will continue for monitor, review, and adjust phases. Mana whenua, key stakeholders, and the community are encouraged to influence and advocate throughout its implementation and future iterations. This highlights the collective effort and shared responsibility in managing natural hazards in the area, now and in the future.

5 Setting the Scene

5.1 Geographical

The 'Head of Lake Whakatipu' area, or 'Head of the Lake', as referred to in this Strategy, is the area centered on the Rees-Dart floodplain located at the northern end ('head') of Lake Whakatipu in the Queenstown Lakes District of Otago.

The project area considered by the Strategy is approximated by the boundary shown in Figure 1.1 which is designed to include all significant residential and infrastructure locations in the vicinity. The project area boundary is approximated as the 600-metre elevation contour and upstream in the major valleys (Routeburn, Dart, Rees) to the ends of the roads.

The major geographical features at the head of Lake Whakatipu are the broad braided river systems and floodplains of the Dart and Rees Rivers, which form a combined delta at the lake, lying between the Humboldt and Richardson mountains to the west and east, respectively.

5.2 Mana whenua connections to place

Mana whenua are Māori who hold traditional customary authority and are representatives of Treaty partners within an area and whose traditions and histories are as determined by whakapapa, resource use, and ahikāroa (the long burning fires of occupation). In Otago, Kāi Tahu[2] are mana whenua.

The wider Whakatipu-wai-Māori (Lake Whakatipu) area is of strong significance to mana whenua (Takau, 2021). The histories of Kāi Tahu are embedded throughout the landscapes, as told through creation narratives, pūrakau (stories), ikoa wāhi (place names), and are upheld through values.

According to Kāi Tahu tradition, the Waitaha were the first people to arrive in Te Wai Pounamu (the South Island) (Takau, 2021). It is written that the Waitaha arrived in Te Wai Pounamu on a great canoe called Uruao, which was captained by Rākaihautū. It is said that Rākaihautū used his famous kō (Polynesian digging tool) to form the major lakes of Te Wai Pounamu, which included Whakatipu-Wai-Māori (Takau, 2021). The genealogies of the Waitaha people can be traced from Rākaihautū through to his living descendants, the modern day Kāi Tahu.

- "Ko Rākaihautū te takata nāna i timata te ahi ki tenei motu." (It was Rākaihautū who lit the first fires on this island.)

Kāi Tahu taoka (treasures) cover the landscape; from the ancestral mauka (mountains), large flowing awa (rivers), tūpuna roto (great inland lakes), pounamu, and ara tawhito (traditional travel routes/trails), which connected kāika (settlements) and nohoaka (seasonal settlements) and mahika kai resources (Takau, 2021). These all make the area immensely significant to mana whenua.

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[2] The use of the term 'Kāi Tahu' should be considered to include the four integrate indigenous iwi to the South Island, being Kāi Tahu, Kāti Mamoe, Waitaha and Rapuwai (Takau, 2021). In this Strategy 'ng' is changed to 'k' as is consistent with Kāi Tahu dialect, unless 'ng' is used in the official name of an entity, place name or area, or is directly quoted.

There are many important ikoa wāhi (place names) which are embedded into the landscape of the programme area and beyond. Place names tell stories of Kāi Tahu people. Kā Huru Manu Ngāi Tahu Atlas shows a subset of the traditional names embedded in the landscape of the wider Whakatipu-wai-Māori delta (Te Rūnanga o Ngāi Tahu, 2022) (see Figure 5.1).

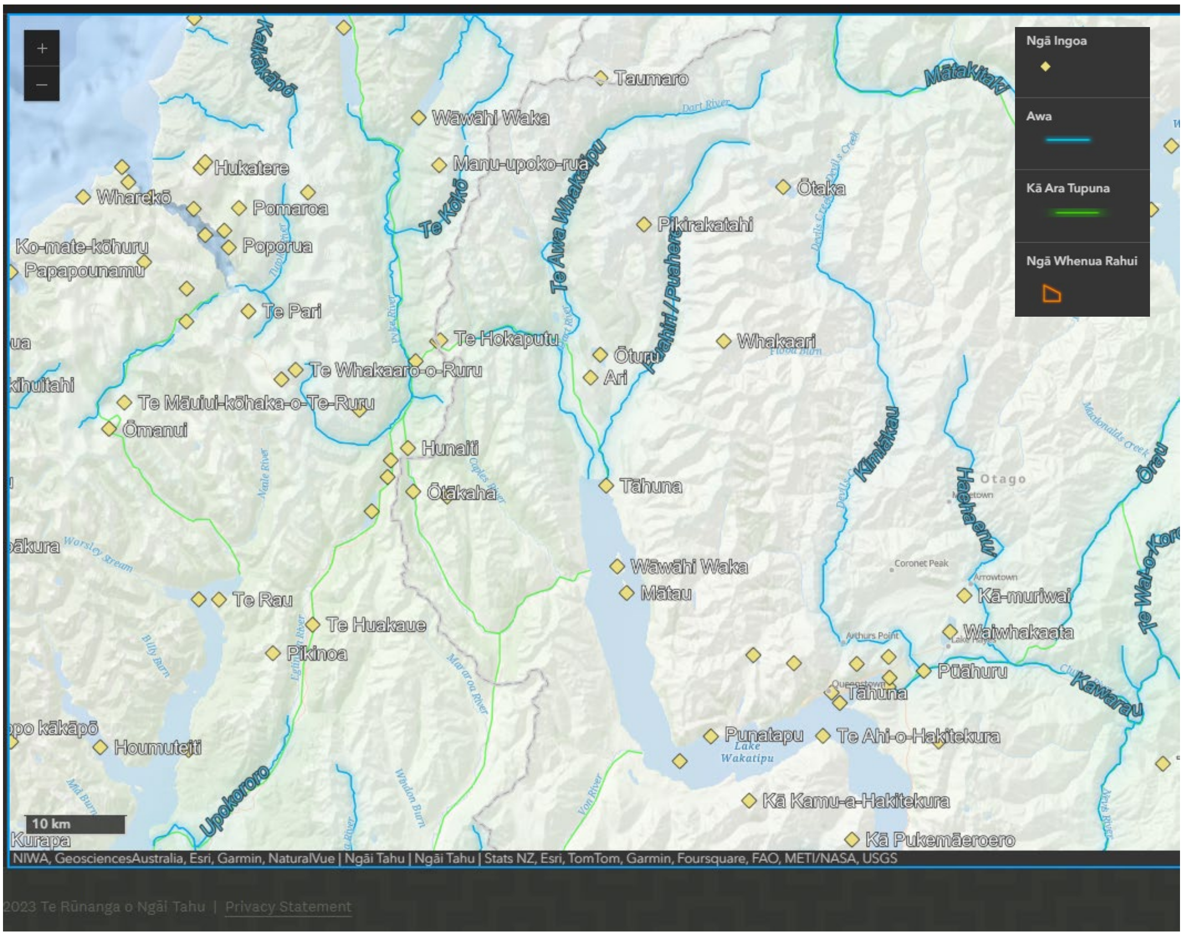

Figure 5.1 Placenames of significance from Kā Huru Manu Ngāi Tahu Atlas (2023)

5.3 Community Profile

The area at the Head of Lake Whakatipu is home to the close-knit townships of Glenorchy and Kinloch, as well as residents living in Paradise, Rees, and Greenstone Valleys, Campbelltown, and Wyuna Preserve. The residential population of the Head of the Lake (Glenorchy SA2) is about 522 people (Stats NZ, 2023).

Influences from European settlement and history are visible in the modern community who live at the Head of the Lake. Since early European settlement in the mid-late 19th century, scheelite mining, gold mining, sawmilling, farming, and tourism have all supported communities at the Head of Lake Whakatipu (see Figure 5.2). Steam ships largely served the community until the construction of the Glenorchy-Queenstown Road in 1962 and was sealed in 1997 (QLDC, 2005 and Glenorchy Community Website, 2018). The wild environment and relative remoteness of the Head of Lake Whakatipu shaped both the economy of the area and the types of people who lived there.

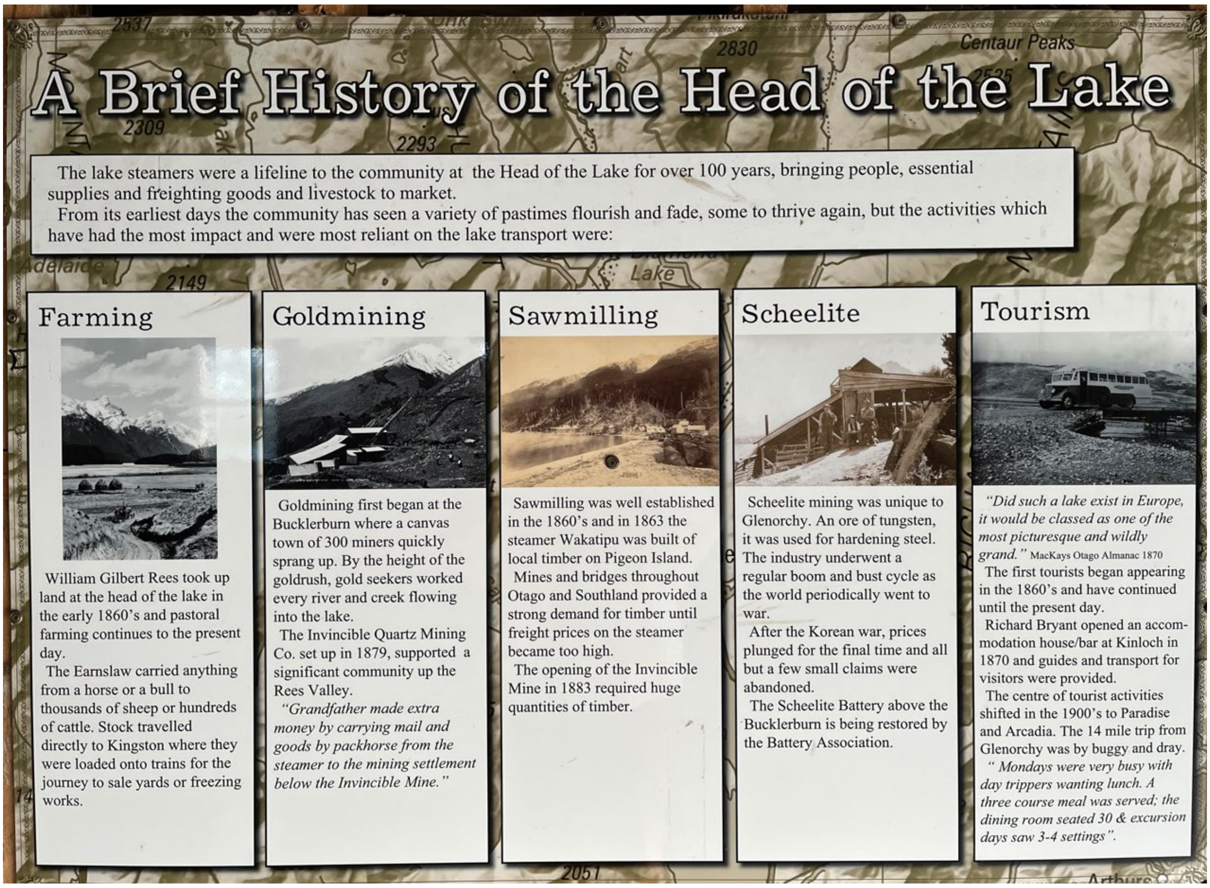

Figure 5.2 Photo of community history poster located in the Glenorchy Wharf Red Shed.

Population data

The project area overlaps with the statistical area 'Glenorchy SA2' (StatsNZ) (see Figure 5.3). This geographic area, defined by Statistics New Zealand, aims to reflect a community that interacts socially and economically. Population and demographic data for the 'Head of the Lake' referred to in this Strategy is reflective of the Glenorchy SA2, unless stated otherwise.

Key demographic data is represented in Figure 5.4 and is based on 2023 Census data. To summarise, the Head of the Lake is predominately a Pākehā settlement, with a reasonable proportion of residents born overseas. While the median age of 41 is higher than the Aotearoa New Zealand median (38), there are relatively fewer older and younger members of the community (Stats NZ, 2023).

The majority of private dwellings are home to permanent residents. However, over a quarter of the dwellings are 'unoccupied' – which includes vacant houses, holiday homes, huts, and cabins (Figure 5.4). A portion of the community are 'temporary residents' such as holiday-home owners or people who live at the Head of the Lake part-time. Anecdotally, there is a relatively stable core part of the community, but there is some turnover of the population due to the nature of work available in the area (seasonal hospitality and tourism work).

Population Growth

There has been rapid growth over time at the Head of the Lake. Between 2006 and 2013 the population grew by 33%, from 272 to 363 people, between 2013 and 2018 it grew by 24% up to 450 people, and between 2018 to 2023 it grew by 16% up to 522 people (Stats NZ, 2023).

Figure 5.3 Outline of the Glenorchy SA2 statistical area (Stats NZ, 2023)

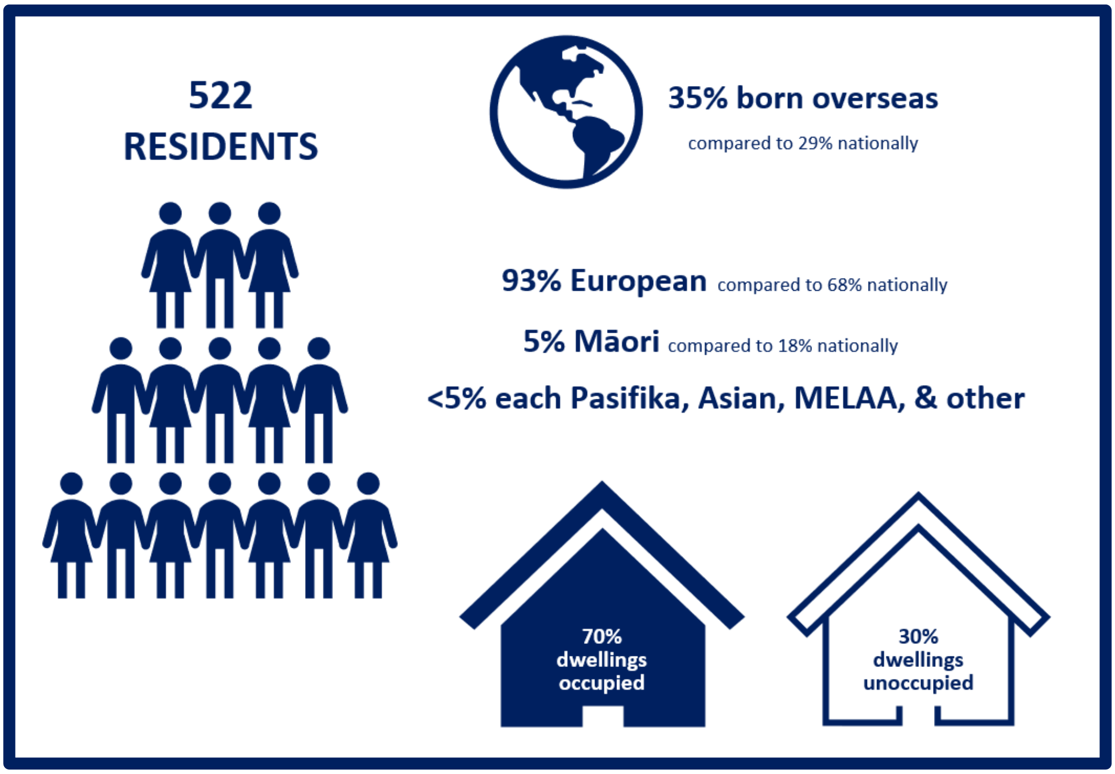

Figure 5.4 Population and demographic data of the Glenorchy SA2 area (Stats NZ, 2023).

The resident population Queenstown Lakes District grew by 38% from 2013 to 2018, and 22% from 2018 to 2023 (StatsNZ, 2023) as the wider district faces growth and development pressures.

From 2023 to 2053, a pattern of residential growth is expected at the Head of the Lake, with an annual estimated increase of approximately 2.5% over the first decade, and then 1.0% over the next two decades, under a medium scenario. By 2053, forecasted growth expects to reach 940 residents (QLDC, 2024). With anticipated growth in the resident population over time, there is the potential for increased development and infrastructure needs.

Health

There is limited physical and mental health data for the Head of the Lake area. About two percent of the Head of the Lake population reported to have one or more activity limitations in the 2023 Census, which is lower than reports for the Otago region (7.4%). Similarly, participants in the QLDC 2023 Quality of Life Survey self-reported relatively high levels of physical health (74%), compared to Queenstown (61%) (Versus Research, 2024).

Glenorchy participants in the QLDC 2023 Quality of Life Survey self-reported relatively high levels of mental health (63%), compared to Queenstown (43%) (Versus Research, 2024).

The availability of primary care at the Head of the Lake is limited. Currently, a Practice Nurse operates a non-funded Registered Nurse-led Health Clinic in Glenorchy fortnightly and provides house visits on request.

Sense of community

Of Glenorchy respondents to QLDC's 2023 Quality of Life Survey, 100% describe their neighborhood as safe, 92% as welcoming, 79% as strong/active, 45% as having a strong sense of belonging, and 33% as having good community participation (Versus Research, 2024). This is supported by community sentiments of the Head of the Lake being a strongly cohesive community.

Community Visioning work completed in 2001 and revised in 2016 sets out a clear set of shared values and aspirations for the future of the Head of the Lake community (Blakely Wallace Associates, 2001 and Shaping Our Future, 2016). Community engagement, as part of the Strategy development, is consistent with these shared values and visions and is elaborated on in Section 9.3.2.

5.4 Economic Profile

Over its history the Head of the Lake has had a changing economy. Today, tourism is the most significant industry to the Head of the Lake, followed by hospitality, film, agriculture, and trade.

In the Head of the Lake, the local Gross Domestic Product (GDP) for 2022 was estimated to be $42.42 million with the tourism industry making up a significant portion of this Head of the Lake GDP (Infometrics, 2023).

The Head of the Lake is a popular tourist destination, hosting activities such as jet boating, tramping (hiking), fishing, hunting, horse trekking, farm tours, 4WD safaris, scenic flights, and Lord of the Rings tours. It also acts as a gateway to Mount Aspiring National Park and some of Aotearoa New Zealand's premier tramping and day-walk attractions, including the Routeburn Track (one of Aotearoa New Zealand's Great Walks), the Rees-Dart Track, and the Greenstone and Caples Tracks.

In 2023, the total number of daily visitors for the Head of the Lake area was estimated to be 339 people on an average day and up to 935 people on peak days (QLDC, 2024). Looking ahead to

2053, with a medium growth scenario, the number of average day visitors is projected to increase to 733 people, and 1919 people on peak days (QLDC, 2024).

The Head of the Lake is also a popular filming location for the film industry. Most production teams are based in Queenstown and travel to and from Glenorchy, while some temporarily basing themselves in Glenorchy.

Hospitality is one of the largest industry employers in the Head of the Lake, with a range of accommodation and food services located across the Head of the Lake area (Healy *et al*., 2024).

Farming in the area is predominately high-country station farming, either in the beef and lamb or wool industries. There are six stations at the Head of the Lake, being a mix of generational family-owned and iwi-owned stations. Most stations have diversified their income in some way, mostly in the hospitality or tourism industries (Healy *et al*., 2024).

Healy *et al*. (2024) reports there is a variety of tradespeople operating or employed within the Head of the Lake or travelling to Queenstown for work. This industry has helped to support recent residential developments in the area (Healy *et al*., 2024).

Employment and income

Healy *et al*. (2024) reports that in 2022 there are estimated to be 349 people employed in the Head of the Lake, with tourism making up 149 of estimated employees. Figure 5.5 shows the industry contribution to employment in 2022 excluding tourism (Healy *et al*., 2024).

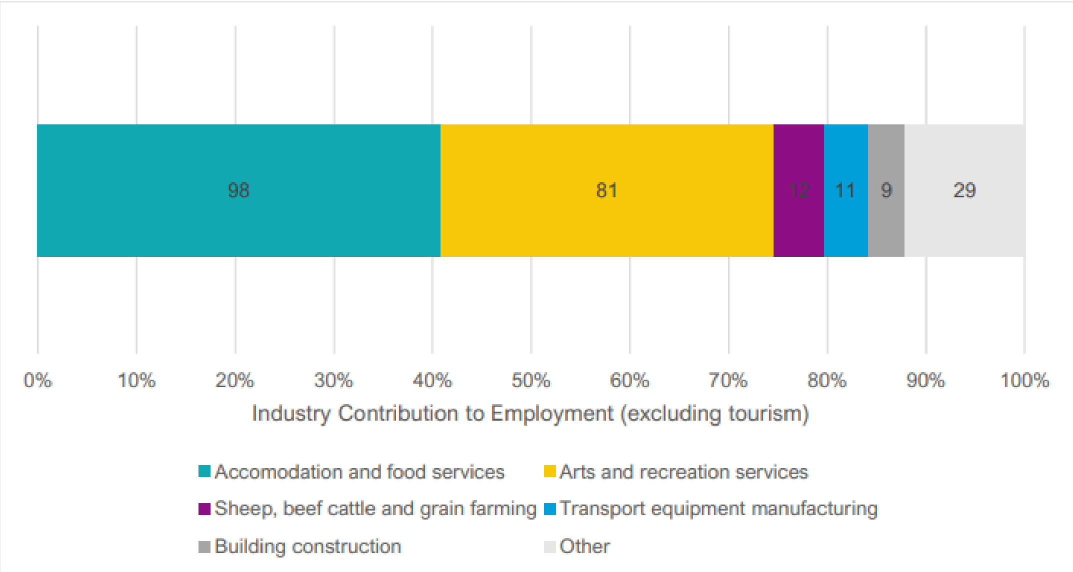

Figure 5.5 Industry contribution to employment in 2022, excluding tourism (from Healy et al 2024, information from Infometrics, 2023]

As of 2023, approximately 64% of the population aged 15 years and older at the Head of the Lake are employed full time, 12% part time, 1.3% are unemployed, and 23% are not in the labour force (Stats NZ, 2023). The largest proportion of workers in the area are categorised as 'Managers', followed by 'Professionals', and 'Technical and trade workers'. The occupation profile of the area is reflected in the large proportion of people that work from home (Healy *et al*., 2024).

As of 2023, the median income at the Head of the Lake was $44,100, which is higher than the median income of Otago ($39,100). However, approximately 33% percent of residents above the age of 15 earn less than$30,000. About 22% of the resident population aged over 15 earn more than $70,000.

Healy *et al*. (2024) reports that around a third of interviewed residents stated that their property is their main source or supports a portion of their income, including from farming, horticulture, or providing accommodation.

5.5 Geomorphic

The Southern Alps are an exceptionally dynamic geomorphological terrain, with complex landscape evolution and geomorphic processes (Cook *et al*, 2014).

The head of Lake Whakatipu lies east from the main divide of the Southern Alps and is part of a large basin glacially carved out by the Dart glacier during the Pleistocene. Lake Whakatipu formed subsequent to glacial retreat, initially with an outlet at Kingston and a water level of 360 masl (approximately 50 metres higher than present-day lake levels). At about 12,000 years ago, the lake outlet switched to drain into the Kawarau catchment and lake levels progressively lowered in response to incision at the outlet, stabilising at its current levels only within the last 500 years (Sutherland *et al*, 2019). Present-day lake levels have a mean level of approximately 309.95 m.

The Rees and Dart catchments have a very high sediment availability, driven by the very high rates of erosion present throughout the catchment areas. The key factors in erosion rates are the high rates of tectonic uplift (up to 5 mm/year) and orographic precipitation which may exceed 5000 mm annually in higher-elevation locations, an unstable ‘paraglacial’ landscape characterised by over-steepened slopes, retreating glaciers, and abundant active landslides (Brasington, 2024).

The Dart and Rees rivers have been estimated to supply sediment to the lake at an average annual gravel bedload supply rate of 300,000 m^3 (Wild, 2012). Because the volumes of sediment available greatly exceed the capacity of the rivers to transport it downstream, this is considered a ‘transport-limited’ catchment system, with an essentially unlimited sediment availability (Brasington, 2024).

The highly erodible schist bedrock in the Rees and Dart catchments is transported down-valley by the river systems, to be eventually deposited into Lake Whakatipu at the Dart-Rees delta. Sediment deposition infilling the glacially-carved bedrock valley over time has formed the broad Dart and Rees floodplains which join together downvalley of Mount Alfred, where the floodplain is up to 4 km in width.

Floodplain and delta evolution – aggradation and erosion

In response to the very high rates of sediment delivery, the braided channel belts, floodplains, and delta of the Dart and Rees Rivers are undergoing continuous and irreversible geomorphic change over time. The geomorphic changes observed are described below and are expected natural behaviour for this type of river system.

Analysis of riverbed change between repeated LiDAR surveys has shown that there is a persistent, widespread aggradation trend in the active riverbeds of the Dart and Rees rivers (Brasington, 2024). This trend is driven by rates of sediment deposition generally outweighing the rate of sediment removal (scour/erosion) within the active riverbed (the areas of flowing channels and unstable gravels).

Riverbed aggradation is an accumulation of sediment that raises bed levels. It impacts on flooding hazards through reducing the flood capacity of the active river channels, in turn reducing available freeboard to riverbanks and floodbank structures, while also increasing rates of lateral migration of the braided riverbed’s active channels.

In several locations, the Rees River's active channel is super-elevated, or 'perched', higher than the surrounding floodplain, notably in the right-bank area upstream of the Rees bridge and adjacent to the Glenorchy wetland. As aggradation of the active riverbeds continues, an avulsion (breakout) of the river channel into these lower elevation floodplain areas becomes increasingly likely and an inevitable outcome over time.

An avulsion is the process where a river channel switches location, often suddenly, re-routing river flows through a new, steeper flow path. It may result in the complete or partial abandonment of the formerly-active channel. An avulsion event, could be triggered by a major high-flow event, or it could result from the cumulative effects of aggradation reaching a 'tipping point'.

Channel migration and bank erosion is most apparent on the lower Dart River floodplain, where there is a long-term bank erosion trend and where the right bank of the river's active channel has migrated westwards by >500 metres since the 1960's. This bank erosion has locally threatened road access to the Kinloch and Greenstone areas by way of Kinloch Road. Potential bank erosion impacts have been managed to date by localised bank protection works, but as bank erosion continues, this may not be a sustainable long-term future approach (Webby, 2022).

Delta growth

As sediment is progressively deposited into Lake Whakatipu, the shoreline of the Dart-Rees delta is extending lakewards, advancing at an average rate of 2 m to 3 m per year since 1937 (URS, 2007). Historically, the growth rate of the delta has not been uniform but shown a lot of local variation across the floodplain, due to factors such as the location of the main river channels entering the lake. For example, in the 1890s Kinloch wharf had sufficient depth of water to service the paddle steamer S.S. Mountaineer (Figure 5.7); then the bay at Kinloch was rapidly infilled from the early 2000's (Figure 5.6); and now the Kinloch wharf is now unusable due to sedimentation (Figure 5.8).

Delta growth has caused dramatic landscape changes within the Glenorchy area. Much of the delta shoreline has advanced lakeward by 200-250 metres since the earliest European records. Early surveys at Glenorchy show the present-day wetland area was a large lagoon in the 1860-70's (red shoreline in Figure 5.6) which included the first wharf at Glenorchy. The current wharf at Glenorchy is the third constructed over the township's history. The second having been located at Jetty Street at the Rees Delta (Figure 5.6).

Modelling of future delta growth by Wild (2012) indicates that over the next 100-120 years the delta shoreline is expected to advance an average of ~165 metres, with actual advances across the delta shoreline ranging from 40 to 300 metres (Figure 5.6).

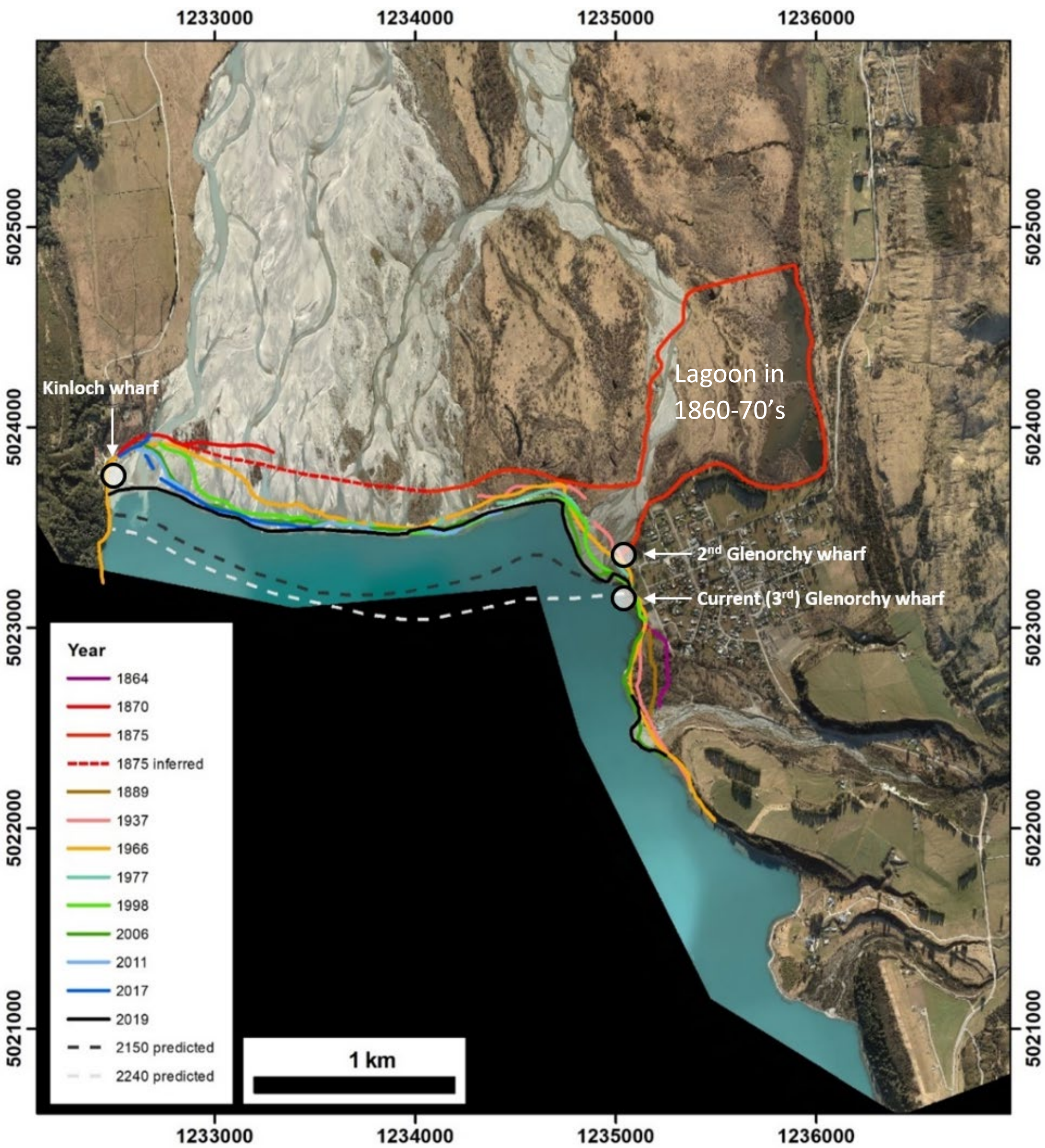

Figure 5.6 Historical and predicted shoreline positions of the Dart-Rees delta, based on compilations of historical maps and photographs by URS (2007) and Wild (2012). Projected delta growth based on modelling by Wild (2012).

Figure 5.7 The S.S. Mountaineer at Kinloch wharf, pictured in the 1890s (Image by Valentine and Sons Ltd, 1892-1893. Hocken collections reference number P2008-073-013).

Figure 5.8 The Kinloch wharf, pictured in October 2019.

Alluvial fans

Alluvial fans are landforms developed by the build up of river or stream sediments over time, typically at the boundary between hillslopes and valleys, for example where a steep gully merges onto a flatter valley floor (Grindley *et al*, 2009).

Many alluvial fan landforms have been developed on the Dart-Rees floodplain by sediments deposited from their tributary streams. For example, the Glacier Burn and Scott Creek (Figure 5.9) alluvial fans on the Dart floodplain, and those formed by Precipice Creek and Ox Burn on the Rees floodplain. At Glenorchy (Buckler Burn), Blanket Bay (Stone Creek) and Greenstone (Greenstone River), alluvial fan-deltas have been formed as sediments are deposited directly into Lake Whakatipu.

Alluvial fans may be subject to a range of natural hazards and geomorphic processes, including inundation by floodwater, debris deposition from debris flow and debris flood events, channel migration, deposition and erosion. Alluvial fan flooding is characterised by a high level of flow-path uncertainty due to the processes of sediment deposition and the lateral displacement of streams during flooding (Grindley *et al*, 2009).

Figure 5.10 shows an example of extensive flooding and sedimentation on the Earnslaw Burn alluvial fan in the January 1994 flooding event, compared to the narrow stream channel present during non-flood conditions.

Figure 5.9 Example of an alluvial fan landform – the Scott Creek alluvial fan formed at the base of the Humboldt Ranges onto the Dart floodplain, showing evidence for recent sediment deposition across multiple sectors of the fan surface (photo dated October 2020).

Figure 5.10 Comparison of the Earnslaw Burn alluvial fan in flood (1994) and non-flood conditions (2021), illustrating the potential for widespread flooding and debris impacts across alluvial fan surfaces.

5.6 Meteorological and Hydrological

Orographically enhanced precipitation is the dominant climatic feature of the alpine regions of the South Island. Orographic precipitation is produced when moist air is lifted and cools as it moves over a mountain range. Due to the prevailing westerly winds, the majority of the precipitation falls on the windward (western) side of the Southern Alps (Figure 5.11). 'Spillover' rainfall occurs on the sheltered (eastern) side of the range when rainfall is blown over from the western side.

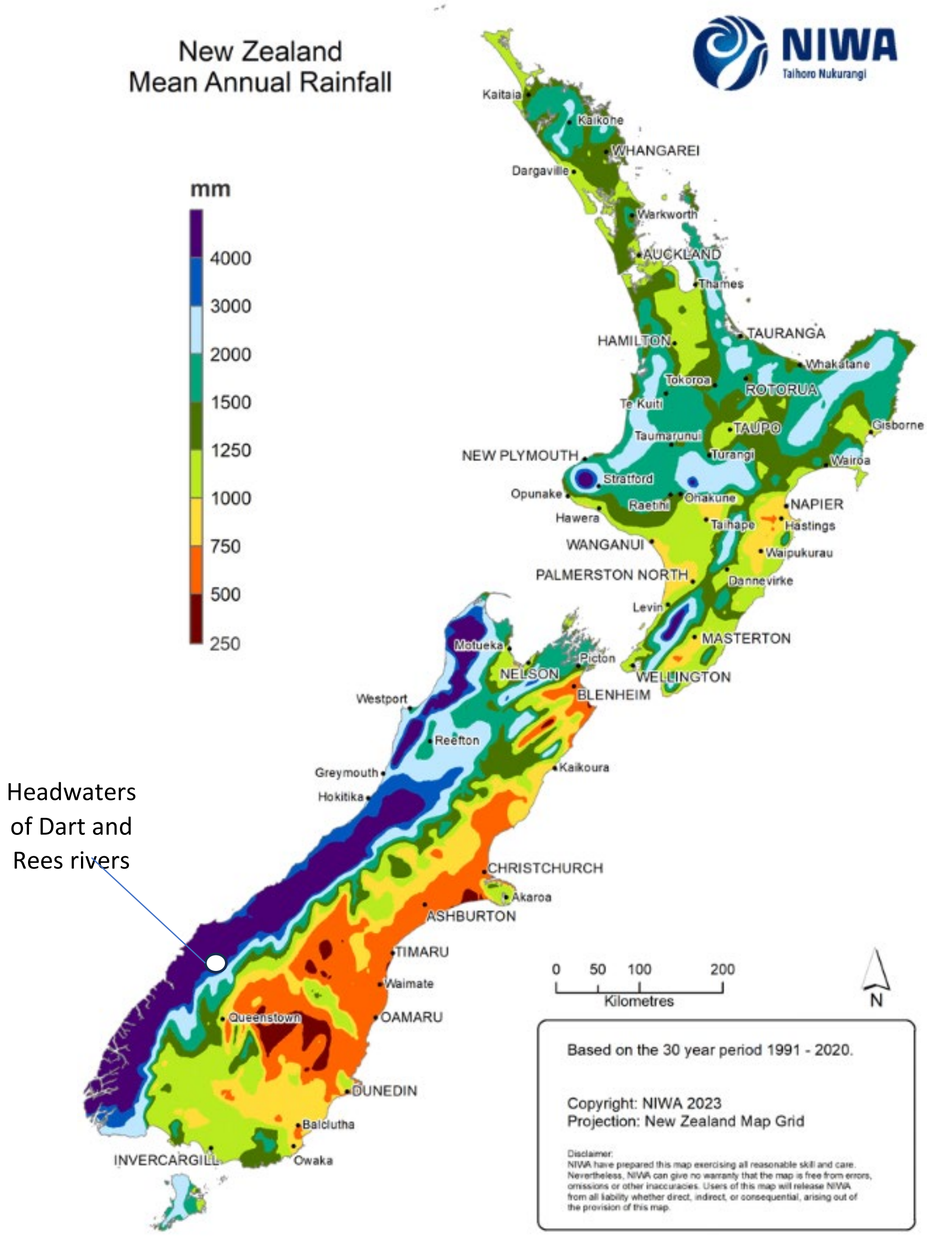

Figure 5.11 Aotearoa New Zealand Mean Annual Rainfall 1991-2020 (NIWA 2023).

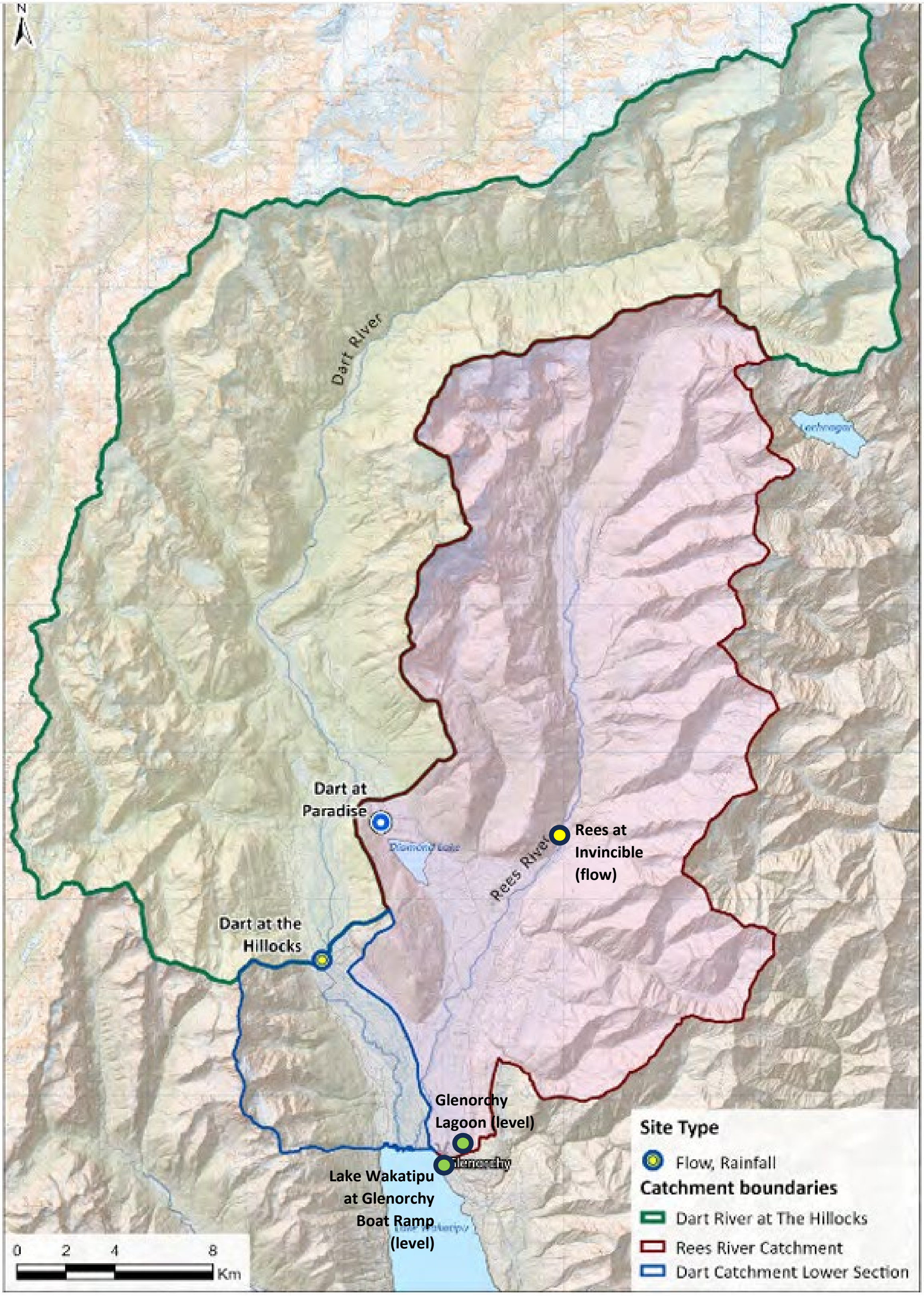

Figure 5.12 Rees and Dart catchments and ORC monitoring sites (Gardner M, 2022)

Dart and Rees Rivers

The two largest river systems are the Rees and Dart Rivers. The Rees (405 km^2) and Dart (632 km^2) catchments (Figure 5.12) make up about one third of the total catchment area of Lake Whakatipu.

The catchments have their headwaters in the high-elevation ranges east of the main divide. Precipitation can exceed 6,000 mm/year (MfE 2017) in the higher-elevation upper portions of the catchments, which regularly receive heavy rainfall as 'spillover'.

ORC currently monitors rainfall in the Head of the Lake area at Paradise (since 2003) and the Hillocks (since 1997). The locations of the stations are shown in Figure 5.12. Summary rainfall statistics for these sites are shown in Table 5-1.

Table 5-1 Summary rainfall statistics for ORC sites.

	Dart at The Hillocks (EM759)	Dart at Paradise (EM619)
Period of record:	Aug 1997 to now	May 2003 to now
Elevation	RL 360 m	RL 1300 m
Mean annual precipitation	1706 mm	2057 mm
Maximum recorded yearly precipitation	2191 mm	2742 mm
Maximum recorded daily precipitation	126.0 mm 21/09/2023	146.5 mm 10/09/2013 and 3/2/2020
Estimated 1% AEP, 24-hour rainfall (NIWA HIRDS)	188 mm (historical) 201 mm (RCP8.5 scenario)	225 mm (historical) 242 mm (RCP8.5 scenario)

Annual Exceedance Probability (AEP) is s the probability of a certain sized event occurring in a single year. If a rainfall has an AEP of 1%, it has a one in 100 likelihood of occurring in any given year.

NIWA's High Intensity Rainfall Design System (HIRDS) tool estimates high intensity rainfall at ungauged locations for a range of return periods, event durations and future time periods. Climate change projections are based on Intergovernmental Panel on Climate Change (IPCC) scenarios called representative concentration pathways (RCPs)

Reduced Level (RL) is a standard term for survey points with reference to a common datum. In this report, the common datum is Dunedin 1958 local vertical datum, unless stated otherwise.

The Dart River has a length of approximately 58 km. Dart River flows have been monitored by ORC since 1997, by a monitoring station located at the Dart River bridge at the Hillocks. The highest river flows documented since that date were in March 2019 and February 2020, both events having peak flows of approximately 1800 cumecs and estimated to be events of around 40-year return period, based on flood frequency analysis by Mohssen (2024). Summary flood frequency statistics for the Dart River at the Hillocks are shown in Table 5-2.

The Rees River has a length of approximately 41 km. Rees River flows have been monitored by ORC since 2021, by a monitoring station located near the confluence with Invincible Creek. The highest river flow documented since that date was 240 cumecs in September 2023. Higher flows of >475 cumecs in the Rees River have also been recorded during research by Williams *et al*. (2015) and an archived 1974 Otago Catchment Board (OCB) gauging card (Wild, 2012).

Summary flood frequency statistics for the Rees River at Invincible have been estimated by Mohssen (2024) using a rainfall-runoff modelling approach (Table 5-2).

Table 5-2 Flood Frequency Statistics for Dart and Rees Rivers, Buckler Burn and Bible Stream (Mohssen 2024).

Location	Catchment area	Frequency Statistics / Design Flows (cumecs)				
		10-year ARI	20-year ARI	50-year ARI	100-year ARI	500-year ARI
Dart at Hillocks station	591 km^2	1559	1694	1849	1952	2153
Rees at Invincible station	230 km^2	620	718	855	962	1223
Buckler Burn (at bridge)	51 km^2	104	121	146	166	217
Bible Stream	0.7 km^2	1.4	1.7	2.0	2.3	3.0

Buckler Burn and Bible Stream

The Buckler Burn is located immediately south of Glenorchy township and has a catchment of 51 km^2 (Figure 5.13). The burn flows westwards from headwaters in the Richardson Ranges and outflows directly into Lake Whakatipu.

Bible Stream is located immediately east of Glenorchy township and has a catchment of 0.7 km^2 (Figure 5.13). The stream flows over Bible Terrace and towards the township through a gully on the northern side of the terrace. A diversion channel at the base of the gully was constructed in early 2000s, and diverts flows around the eastern margin of the township into Glenorchy Lagoon. The diversion floodbank/channel has been described as “poorly formed and not engineered”, likely to be eroded during high flows and offering very little protection during flood events (Woodmansey, 2001; Whyte, 2007).

There has been no measurement of stream flows for either the Buckler Burn or Bible Stream, but summary flood frequency statistics for both catchments have been estimated by Mohssen (2024) using a rainfall-runoff modelling approach (Table 5-2).

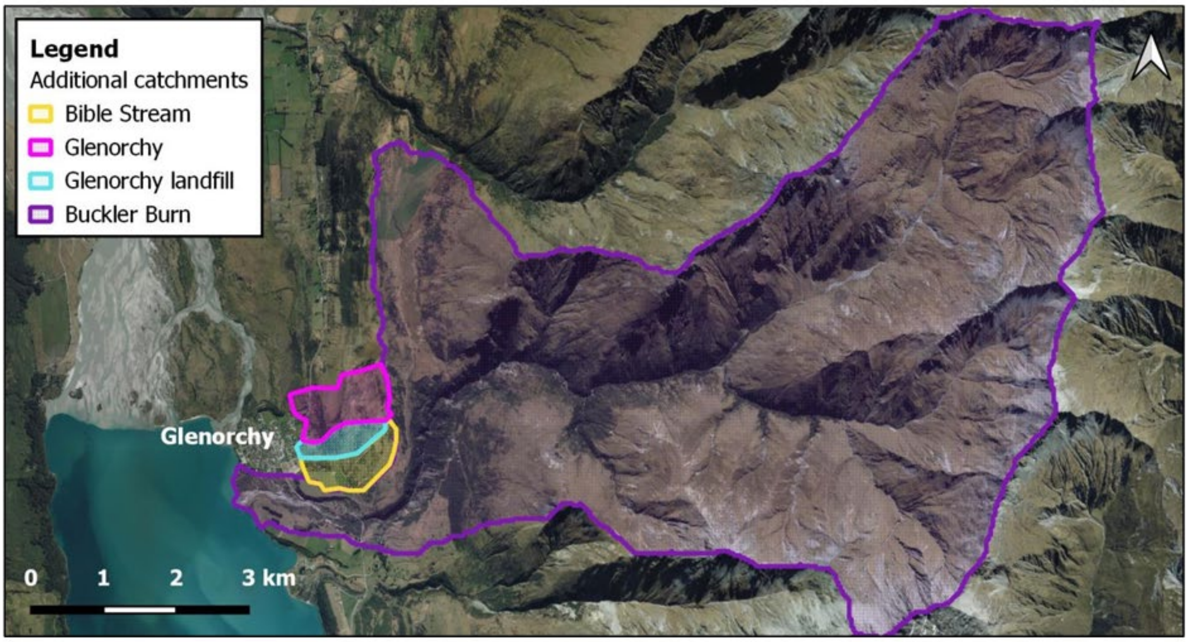

Figure 5.13 Buckler Burn, Bible Stream and local Glenorchy catchments (Beagley R, 2024)

Glenorchy Lagoon

The Glenorchy lagoon (Figure 5.14) is located immediately north of Glenorchy township and has an area of about 16 hectares (0.16 km^2). The lagoon is part of a wider wetland area, 350 ha in area, much of which is administered by the Department of Conservation as a Wildlife Management Reserve. The geomorphic history of the lagoon and wetland area is detailed by Whyte (2007).

The lagoon is fed by local runoff from Bible stream and other small catchments on the slopes immediately east of the wetland. When groundwater levels are high, many small tributary channels feed into the lagoon through the wetland area. There is no direct connection to the Rees River during normal (non-flood) flow conditions, but during high river flows the lagoon is fed by overbank flows spilling eastwards from the Rees River.

The lagoon outflow is a small stream known as Lagoon Creek, which joins with the Rees River on the delta, a short distance upstream from Lake Whakatipu.

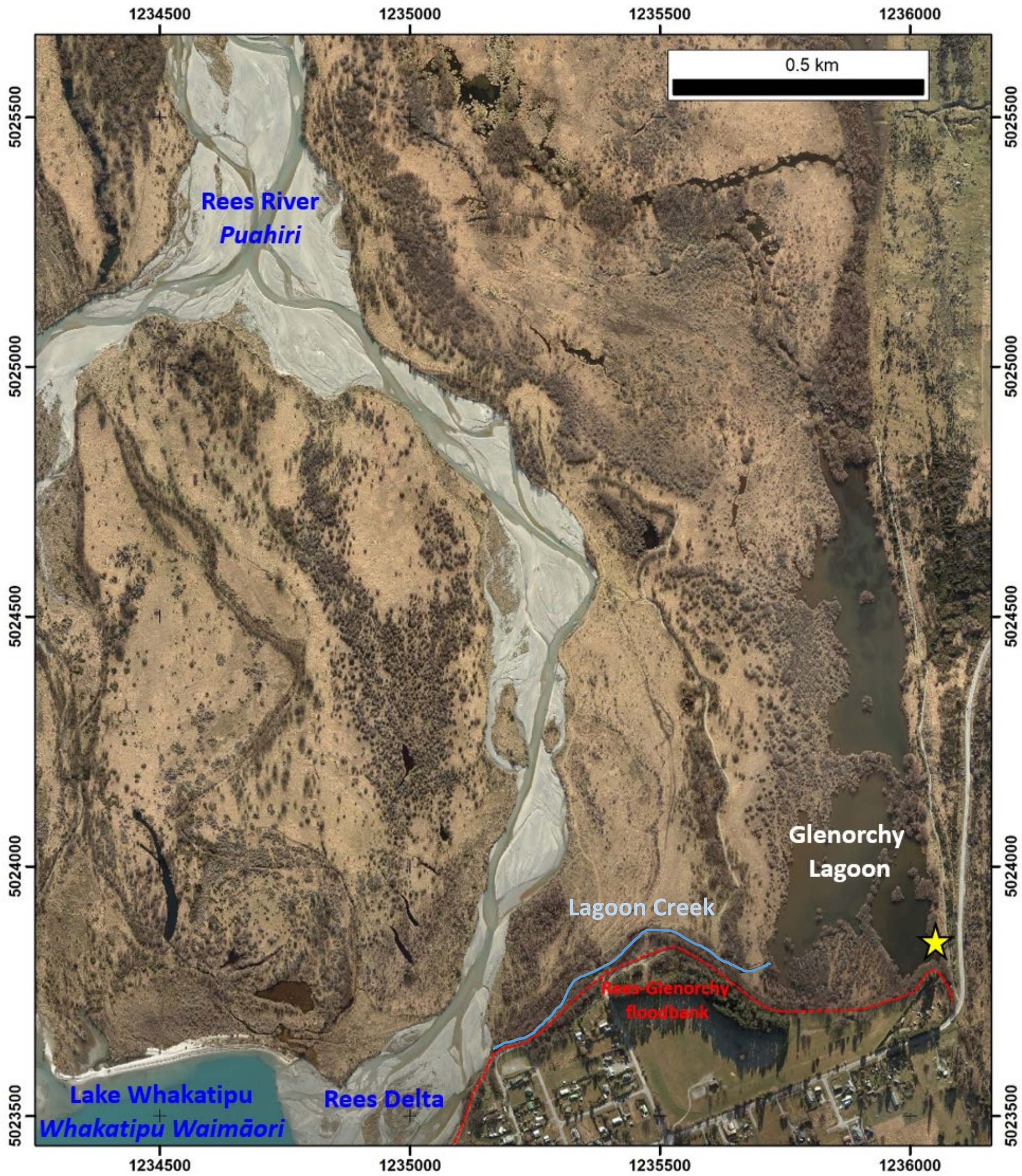

Figure 5.14 Overview map of the lower Rees River and the Glenorchy lagoon/wetland. The locations of the Rees-Glenorchy floodbank (dashed red line) and the ORC water level monitoring station (yellow star) are annotated.

Glenorchy lagoon levels rise in response to rainfall and high Rees River flows, interpreted to be due to the effects of both increased inflows (local runoff, overland flow from Rees) and reduced outflows (backwater effect of high Rees River flows and/or elevated Lake Whakatipu levels on creek outflow). Stream flows in Lagoon Creek may reverse when Rees River flows are high relative to the lagoon water level (e.g. as was observed and reported to ORC in May 2021).

ORC has monitored water levels in the lagoon since October 2020. In that time, the highest recorded level has been 312.49 m in September 2023.

During the February 2020 flooding event, the water level in the lagoon was estimated to have reached 312.7-312.8 m, based on observation of floodwaters overtopping the Rees-Glenorchy floodbank and inspection of silt deposits remaining following floodwater recession.

Lake Whakatipu

Lake Whakatipu has a catchment of 3,067 km^2, fed in the main by the Rees and Dart River catchments, with a combined catchment of 1,037 km^2. The lake outlet, located near Frankton, outflows into the Kawarau River.

The normal water level of Lake Whakatipu is typically at about RL 310 m. Historical records show that the level typically fluctuates between about RL 310 m and RL 312 m. Higher levels result in inundation of parts of Glenorchy and Kinloch, and elsewhere on the lake, cause inundation at Queenstown and Kingston also.

The main cause of high lake levels in Lake Whakatipu is the natural imbalance between the capacity of the lake outlet (Kawarau River) and the magnitude of inflows during heavy rainfall events. Lake Whakatipu outflows may be further impeded by high flows in the Shotover River, due to the perpendicular configuration of the confluence of the Kawarau and Shotover Rivers.

Despite having a large catchment, due to the large surface area Lake Whakatipu rises relatively slowly, even when inflows are high. This characteristic of the lake, in which the lake surface rises slowly and in response to particular weather conditions, means that the development of a high lake level flood event can be reliably monitored and the affected communities generally afforded a lead time, typically of several days, in which to prepare for potential inundation.

High lake levels are often associated with a succession of fronts, where rainfall events occur one after another and without sufficient time for the lake levels to recede, causing cumulative increases in lake level. The lake may remain at high levels for prolonged periods of days to weeks.

During the November 1999 flooding event, the lake reached the highest recorded lake level of RL 312.78 m and remained at levels greater than RL 312 m for around 8 days.

Frequency analysis of Lake Whakatipu levels has been completed by Mohssen (2021), based on a nearly 100-year record of lake levels (continuously monitored since 1962), and daily observations from 1924-1962, plus observations of historical levels in earlier flooding events, such as those occurring in 1878 and 1919 (Table 5-3).

Table 5-3 Frequency Statistics for Lake Whakatipu Water Level (Mohssen, 2021).

Frequency (average recurrence interval, years)	5-year ARI	10-year ARI	20-year ARI	50-year ARI	100-year ARI	150-year ARI
Lake Whakatipu water level (RL, m)	311.13	311.46	311.82	312.38	312.86	313.18

5.7 Built Environment

The built environment in the Head of the Lake area includes existing man-made structures, features and facilities that the community relies on for social and economic well-being.

Settlements – Glenorchy township is the main settlement, and includes critical public infrastructure such as the school, fire station / St Johns and community hall. The greater Head of the Lake area includes the surrounding rural areas of Kinloch, Paradise, Routeburn, Greenstone, Caples, Te Awa Whakatipu / Dart River Valley, and Puahiri/Puahere / Rees River Valley.

Dwellings – At the time of the 2023 Census, there were 261 occupied dwellings, 114 unoccupied dwellings (including residents away and empty dwellings) and 6 under construction (StatsNZ, 2023). More recently areas of residential growth have occurred in Alfred's Terrace; a 60-lot residential development. Some lifestyle blocks have also been developed, particularly around the Glenorchy-Paradise Road area, as well as large homes in private gated communities or estates (largely catering to overseas owners). By 2053, forecasted growth under a medium scenario expects to reach 584 dwellings (QLDC, 2024).

Glenorchy-Queenstown Road – Provides the only road access in and out of Head of the Lake area for residents and visitors. The community relies heavily on the road to access goods, services, employment, education, recreation, and health care outside the area. Over the period 2013-2023 Average Daily Traffic (ADT) ranged from approximately 705 to 5,650 (both lanes) (QLDC, 2023c).

Local roads (such as Glenorchy-Paradise-Kinloch-Routeburn and Rees/Dart bridges) – Provide an important link to people and businesses located in Paradise and the Rees Valley. Provide access to Kinloch, and the Routeburn, Rees-Dart, Lake Sylvan, and Greenstone Caples tracks via the Glenorchy-Routeburn, Kinloch and Routeburn Roads, which are popular tourism and recreation destinations. Over the period 2013-2023, Average Daily Traffic for Glenorchy-Paradise Road ranged from approximately 121 to 1,211 vehicle movements (both lanes) (QLDC, 2023c).

Wharfs – Kinloch and Glenorchy both have wharf structures. Sediment build up has constrained the level of service at Glenorchy Wharf and Kinloch Wharf is unusable (e.g. Figure 5.8).

Power – Aurora Energy is the local electricity distribution company. Aurora Energy is partway through a large, five-year work programme investing over $500 million to upgrade the electricity network in Otago, including Glenorchy network improvements, which are now completed. The Glenorchy generator is in place and can supply past the township. Pioneer Energy Renewables owns the small Oxburn hydro power station (Annual Generation: 2.5 GWh).

Wastewater – Currently households manage and treat their own wastewater at their properties.

Drinking water – Glenorchy has town water supply and two large water reservoirs have recently been installed on Bible Terrace. Rural properties provide their own water supply.

Telecommunications – Service is provided by three telecommunication providers: One NZ, Spark and Lakes Internet. Service reliability is reported to vary across the area. Some residents have access to Starlink, which provides satellite internet access. Approximately 77% of households have access to telecommunications systems (71% have internet and cellphone access, 16% telephone access) (StatsNZ, 2023). Approximately 1.3% have no access to telecommunication systems (StatsNZ, 2023).

Floodbanks – The existing floodbank at the northern margin of Glenorchy township is owned and managed by QLDC and provides flood protection from low-moderate flood events (Damwatch 2022). Privately-owned floodbanks in the Rees River floodplain provide low-level protection for agricultural land and local roads.

5.8 Experience of past natural hazard events

High water levels in Lake Whakatipu can cause flooding issues for the lakeside communities of Glenorchy, Kinloch, Kingston, and the Queenstown CBD (ORC and QLDC, 2006). At Glenorchy, the lakefront reserve and carpark areas begin to be inundated when lake levels reach approximately 311 masl (e.g. December 2019). This has happened 32 times since 1878, and there is a 29% chance the lake will rise above this level each year, and a 97% chance it will happen at least once in any 10-year period (ORC, 2013). The lake starts flooding into residential areas when reaching a level of 311.4 masl. There is a 10% chance that the lake will rise to this level each year, and a 67% chance it will happen at least once in any 10-year period (ORC, 2013).

In November 1999, Lake Whakatipu reached its highest lake level on record at RL 312.8 m (Figure 5.15) (DUN58 vertical datum). The second-highest level recorded was in September 1878 at RL 312.60 m.

At Glenorchy township, past flooding events have occurred due to various sources of flooding, including high flows in the Rees River, Buckler Burn and Bible Stream, and high-water levels in Lake Whakatipu. Some flood events are due to a combination of sources.

A notable recent event was in February 2020, when high Rees River flows caused overtopping of a section of the Rees-Glenorchy floodbank, resulting in flooding of Glenorchy township residential area (Figure 5.16).

Buckler Burn is a very dynamic alluvial fan with high sediment supply. Historical impacts include flooding of properties in southern parts Glenorchy township (late 1970s) and damage to Queenstown-Glenorchy Road (November 1999, Figure 5.17). The present-day alignment of the active channel is along the most southern limit of the fan. The fan surface may build up in the future and, consequently, northwards migration towards the township should be anticipated.

Flooding caused by high flows in the Dart and Rees Rivers can cause widespread inundation of the combined Dart-Rees floodplain area, such as during the January 1994 event (Figure 5.19) and March 2019 event (Figure 5.18). The main impacts of flooding are disruption to road access (e.g. to Kinloch, at the Rees bridge approaches, or at Paradise Road), and damage to infrastructure and land.

In addition to river flooding, major storm events have also caused a range of associated impacts, such as landslide and debris flow activity in January 1994 which also caused disruptions to road access and damage to infrastructure and land (Figure 5.20).

Some community members' experiences of the January 1994, November 1999 and February 2020 flood events are captured in MacKenzie's (2023, p. 97-104) thesis. These stories offer insights into the impacts felt by community members from these events and demonstrate community resilience.

Figure 5.15 November 1999 – significant flooding of Glenorchy township residential area, due to highest water levels on record in Lake Whakatipu.

Figure 5.16 February 2020 – flooding of Glenorchy township residential area, due to high Rees River flows causing overtopping of a section of the Rees-Glenorchy floodbank.

Figure 5.17 November 1999 – Buckler Burn flooding and erosion damages to the Queenstown–Glenorchy Road (photos: Kelly Family).

Figure 5.18 March 2019 – flooding of Dart floodplain, showing inundation of Kinloch Road.

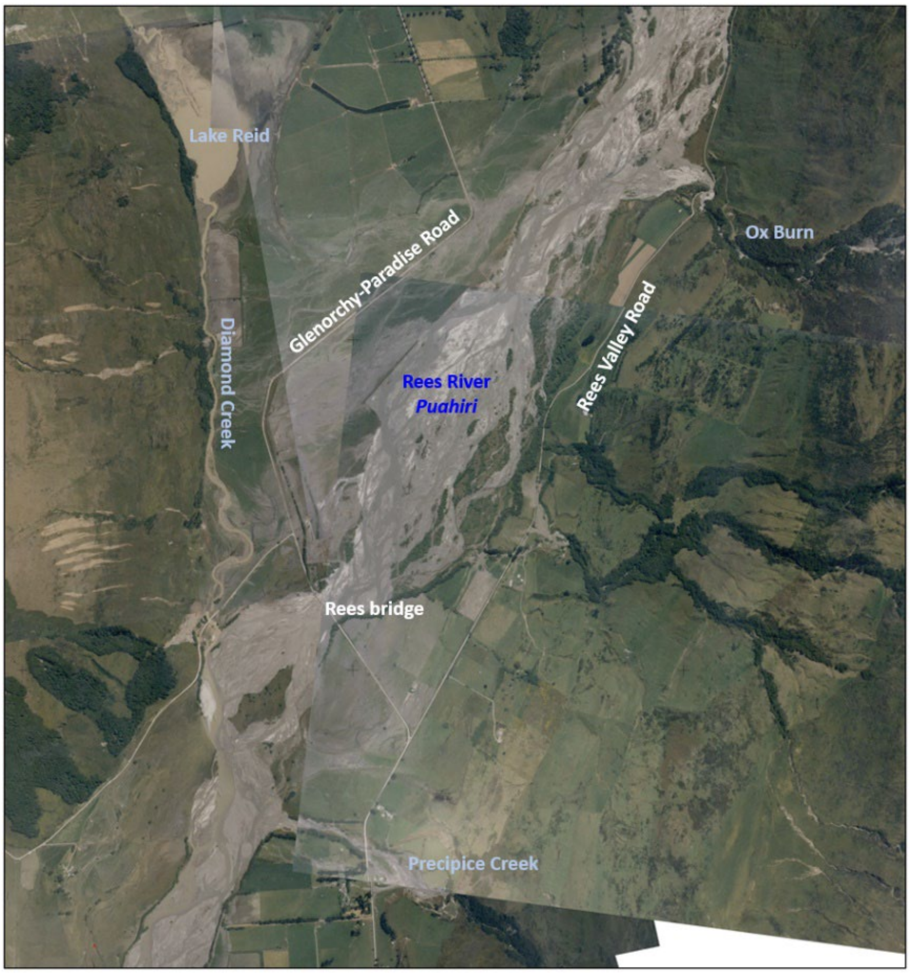

Figure 5.19 January 1994 - disruption to road access and damage to infrastructure and land, caused by flooding of Rees floodplain, and alluvial fan activity at the Precipice Creek and Ox Burn alluvial fans.

Figure 5.20 January 1994 – disruption to road access and damage to infrastructure and land, caused by flooding of Dart floodplain and alluvial fan and debris flow activity. Includes Scott Creek, Stockyard Creek and Kowhai Creek alluvial fans.

6 Drivers for Adaptation

Adaptation at the Head of the Lake is driven by several key factors. This section provides an overview of these drivers and explain how they relate to and motivate the adaptation efforts for the area.

Community interest – experience of past flooding events has heightened community interest in hazard management.

Dynamic landscape – delta growth, shifting river channels, ongoing sediment deposition and erosion will continue to put pressure on sites of cultural significance; and the sustainability of infrastructure and land use.

Complex hazardscape – Since 2019, we have greatly enhanced our understanding of the natural hazards challenges in the area. The complexity and future uncertainties mean that there is no simple solutions.

Future growth – Population numbers at the Head of the Lake and in the district are expected to keep rising (QLDC, 2024). This is expected to increase demand for infrastructure, housing and services. We need to ensure that future growth happens in the right place and that land use activities are appropriate.

Climate change - Projections of climate variables for the Otago region have been developed by NIWA (2019), under a range of future time periods (mid-century and late-century) and emissions scenarios (Representative Concentration Pathways, RCPs). For the head of Lake Whakatipu catchments, these projections show significant increases in both rainfall and river flow variables, where increases in average temperature due to climate change are expected to produce a 20-40% increase in winter rainfall and more intense storms by 2090, with up to a 100% increase in the mean annual flood flow and up to 15 additional heavy rain days (>25 mm).

Estimations of the climate change effects on flood flows for the Rees and Dart Rivers, are for the 1% AEP flood flows to increase in magnitude by approximately 20% by 2090 under a RCP8.5 scenario, and 13% under a RCP6.0 scenario (Mohssen, 2021)[3].

It is inferred that the projected future increases in mean river flows and flood magnitudes from the Lake Whakatipu catchments will cause an increase in mean and in-flood lake levels and, therefore, an increased likelihood of the lake reaching levels where they have an effect on lakeside communities. Detailed analysis to understand or quantify the potential climate change effects on lake levels has not yet been carried out.

[3] If a flood has an AEP of 1%, it has a one in 100 likelihood of occurring in any given year. Climate change projections are based on Intergovernmental Panel on Climate Change (IPCC) scenarios called representative concentration pathways (RCPs).

7 Legislative and Strategic Context

Natural hazards and associated risks in Aotearoa New Zealand are not managed under a single statute. Rather, their effective management relies on the interplay of many statutes and requires those agencies exercising powers and responsibilities to do so in a coherent and coordinated way (Figure 7.1). These statutes include;

- Civil Defence Emergency Management Act 2002 (CDEMA)
- Resource Management Act 1991 (RMA)
- Local Government Act 2002 (LGA)
- Soil Conservation and Rivers Control Act 1941 (SCRCA)
- Local Government Official Information and Meetings Act (section 44A) 1987 (LGOIMA)
- Building Act 2004

7.1 Otago Regional Policy Statements

The Strategy addresses objectives and policies outlined in the ORC's Otago Regional Policy Statement (RPS) 2019, specifically focusing on:

- Objective 4.1: Risk that natural hazards pose to Otago's communities are minimised;
- Objective 4.2: Otago's communities are prepared for and able to adapt to the effects of climate change;

Also relevant are objectives in the proposed Otago RPS 2021, which was notified in March 2024 and subject to appeal[4].

- HAZ-NH-01: Levels of risk to people, communities and property from natural hazards within Otago do not exceed a tolerable level.
- HAZ-NH-02: Otago's people property and communities are prepared for and able to adapt to the effects of natural hazards, including climate change.

Objectives outlined in the RPS 2019 and proposed PRS 2021 are supported by a number of policies to provide guidance for local communities to address challenges posed by natural hazards and climate change.

[4] proposed RPS is subject to appeal, which means the provisions around natural hazards may change through mediation or hearing.

7.2 Queenstown Lakes District Council District Plan (2015)

The Queenstown Lakes District addresses natural hazards in Chapter 28 of the Proposed District Plan (2015) which contains the following natural hazards objectives:

- 28.3.1 A: The risk to people and the built environment posed by natural hazards is managed to a level tolerable to the community.
- 28.3.1 B: Development on land subject to natural hazards only occurs where the risks to the community and the built environment are appropriately managed.
    - …..
    - 28.3.1.5 Recognise that some areas that are already developed are now known to be subject to natural hazard risk and minimise such risk as far as practicable while acknowledging that the community may be prepared to tolerate a level of risk.
    - ….
- 28.3.2: The community's awareness and understanding of the natural hazard risk in the District is continually enhanced.

Chapter 20 of the Proposed District Plan notes that the low-lying areas at Glenorchy, Kinloch and Kingston that are susceptible to flooding are shown as 'Historical Flood Zone' on the Planning Maps, and specifies a minimum floor level for management of lake level flooding risk in those communities. This rule states that;

- "Buildings with a gross floor area greater than 20m^2 shall have a ground floor level not less than RL 312.8 masl (412.8 Otago Datum) at Kinloch, Glenorchy and Kingston." (20.5.20)."

7.3 Learning to Live with Flooding Strategy (2006)

In 2006 Otago Regional Council (ORC) and Queenstown Lakes District Council (QLDC) jointly developed

- Learning to Live with Flooding: A Flood Risk Management Strategy for the communities of Lakes Wakatipu and Wanaka.

The objective of the strategy is to manage the community's exposure to lake flooding risk and equip Wānaka, and the Whakatipu communities of Queenstown, Glenorchy, and Kingston to understand and learn to live with lake flooding. Development of the Learning to Live with Flooding Strategy was a response to the severe 1999 lake flood, which was the highest lake level on record for Lake Whakatipu.

QLDC and ORC outlined an approach to manage the impacts and risks of lake flooding, rather than trying to avoid or limit them through engineered alteration of the physical environment. This approach, to learn to live with lake flooding at a strategic, local, and individual level is a key principle of both councils' strategic, joint approach to lake flooding.

7.4 Other plans and guidance

Climate change and adaptation planning is informed by these plans:

- National Adaptation Plan (2022) [5]
- Otago Regional Council Strategic Climate Action Plan (2024)[6]
- Queenstown Lakes District Council Climate and Biodiversity Plan (2022)[7]
- Te Rūnanga o Ngāi Tahu - Climate Change Strategy[8]

Natural Hazards Commission Toka Tū Ake (formerly EQC) is Aotearoa New Zealand's natural hazards insurance agency, with a primary objective to 'reduce the impact of natural hazards on people, property and the community'. The following research and guidance published by the NHC has informed this Strategy:

- Natural hazard risk tolerance literature review (2023)
- Risk tolerance methodology (2023)

[5] https://environment.govt.nz/publications/aotearoa-new-zealands-first-national-adaptation-plan/

[6] https://www.orc.govt.nz/media/4alnenfa/draft-strategic-climate-action-plan-scap-august-2024.pdf

[7] https://climateaction.qldc.govt.nz/our-plan/

[8] https://ngaitahu.iwi.nz/assets/Documents/Ngai-Tahu-Climate-Change-Strategy.pdf

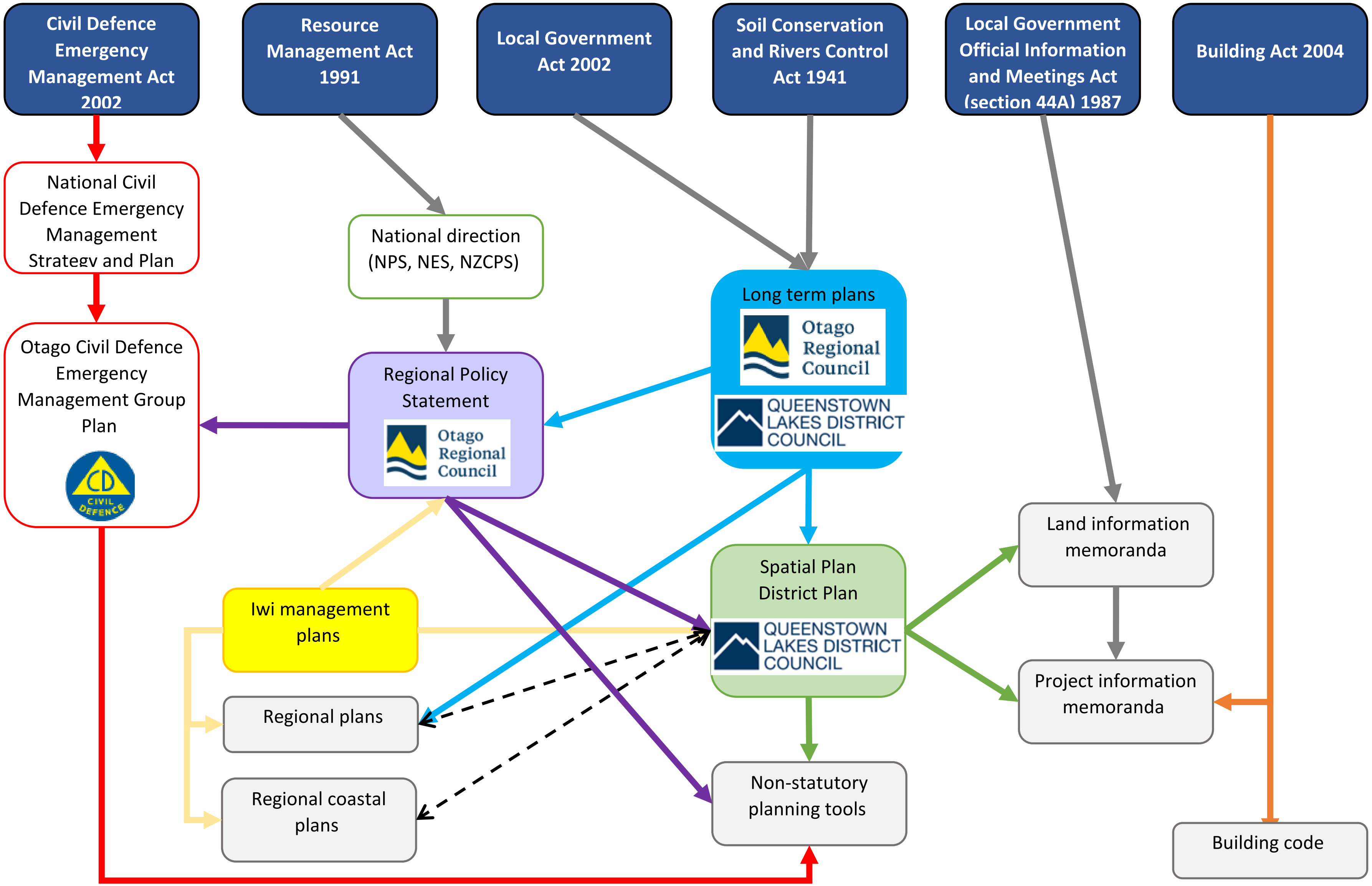

Figure 7.1 Statutes and interactions

8 Strategy Governance

8.1 Partnerships and collaboration

Key partners in the Strategy are Queenstown Lakes District Council, Civil Defence Emergency Management Otago, and the local community. The Strategy has been developed in collaboration with Aukaha and Te Ao Mārama Inc as the mana whenua representatives.

8.2 Roles and Responsibilities for implementing the Strategy

This section outlines the existing roles and responsibilities of partners, community, and other agencies in reducing risks and impacts, and implementing the Strategy. Working collaboratively to manage risks and build resilience.

8.2.1 Otago Regional Council

The ORC's role is to reduce the impact of natural hazards through hazard identification and providing information about the likelihood of an event occurring.

Key responsibilities include:

- Monitoring and maintaining a network of rain and river flow gauges and sharing the data
- Analysing incoming information to provide early warning and awareness of flood events
- River management activities, such as vegetation and gravel management.
- Investigation and decision-making around new flood mitigation measures (including hard or nature-based protection), alongside other parties.
- Conducting planned and reactive monitoring activities to collect up-to-date information on natural hazards, their impacts, and geomorphic changes.
- Updating natural hazard and risk analyses and sharing results with partners and the community.

ORC also has responsibilities as a member of the Otago Civil Defence and Emergency Management Group.

8.2.2 Queenstown Lakes District Council

QLDC is a territorial authority which has responsibility for making decisions about the effects of land use, activities on the surface of rivers and lakes, providing for sufficient development capacity for residential and business growth, noise management, and subdivision. This work is guided through QLDC's strategic framework and investment priorities, and supported through the Queenstown Lakes Operative and Proposed District Plan, Spatial Plan, Climate & Biodiversity Plan, Infrastructure Strategy, and various asset management plans and master plans. Funding and investment decisions for projects, activities, and services for the district are set out in the 10 Year Long Term Plan which is reviewed every 3 years, with an Annual Plan completed in the years between.

At the Head of Lake Whakatipu for example QLDC is responsible for maintaining public roading and three waters assets, the Glenorchy marina and jetty, the Glenorchy flood bank, and ensuring appropriate land use activities through implementation of the District Plan. Natural hazard information for individual properties is provided on the property LIM report.

QLDC is a member of the Otago CDEM Group, which is coordinated by Emergency Management Otago. Emergency Management Otago employs Emergency Management Advisors who are assigned into the district to support emergency planning, deliver training and public education campaigns, lead the development of community response groups and support Council to build its response capability. Council officers support these efforts by volunteering for the Council's Emergency Operations Centre (EOC) and by delivering a broad range of activities that help with community risk reduction and resilience building. These activities include land-use planning, resource and building consenting, resource management engineering, infrastructure planning and operations, climate adaptation planning, and community partnership development.

In the event of a major emergency event, the QLDC Emergency Operations Centre is activated to lead a coordinated, multi-agency response in collaboration with Emergency Services and partner organisations. For major emergency events this may involve a Declaration of a State of Local Emergency which provides access to a range of emergency powers to help coordinate the response and fulfil the objectives outlined in the CDEM Act 2002, National Disaster Resilience Strategy (2019), National CDEM Plan (2015), and Otago CDEM Group Plan.

8.2.3 Head of the Lake communities

The community is responsible primarily for ensuring their own safety; the protection of any dependants and property; reducing their potential for loss; maintaining readiness; and responding appropriately during an event. This requires awareness of both the greater hazards and their specific risk exposure; and adoption of practices and measures to manage this risk (ORC & QLDC, 2006).

8.2.4 Mana whenua

ORC's commitment is to partner with mana whenua and make mātauraka (knowledge, wisdom, and understanding) Kāi Tahi an integral part of our decision-making. Within this Strategy, the roles and responsibilities of mana whenua are represented by two organizations: Aukaha and Te Ao Mārama. In the development of this Strategy ORC have worked with and through Aukaha and Te Ao Mārama (the Papatipu Rūnaka consultancy services, Aukaha, representing Kāi Tahu ki Otago, and Te Ao Mārama Inc, representing Ngāi Tahu ki Murihiku) to ensure the traditions and values of mana whenua and mātauraka Kāi Tahu are embedded in the Strategy and actions.

Some specific responsibilities of Auhaka and Te Ao Mārama for the Strategy:

- Ensure that cultural values and practices of mana whenua are embedded and upheld throughout the Strategy's planning, decision-making processes, as well as implementation phases.
- Provide mana whenua with up-to-date information and knowledge of natural hazard risks at the Head of the Lake Whakatipu.
- Work closely with iwi Māori to foster collective adaptation efforts across the area as well as build trust and relationships.
- Engage with mana whenua to gather input and feedback to ensure their voices are reflected in adaptation strategies and actions within this Strategy.

8.2.5 Civil Defence Emergency Management Otago

The main role of Civil Defence Emergency Management Otago is safeguarding communities across the Head of the Lake area in emergencies.

CDEM Otago has specific responsibilities:

- Take lead on preparedness, response, and recovery from natural hazards events, including development of emergency plans and early warnings.
- Conduct emergency drills and raising awareness of the importance of preparedness for emergency events.
- Coordinate emergency response efforts as well as mobilizing resources and providing logistical support to affected communities at the area.
- Monitor impacts and damages caused by natural disasters as well as developing evacuation and recovery plans.
- Provide essential support to affected communities including foods and medical assistance.
- Implement recovery work for affected communities at Head of the Lake.

8.2.6 Central Government

Central government has roles and responsibilities that contribute to the Strategy:

- Provide legislative and policy frameworks and direction
- Provide information, guidance, and tools to support effective adaptation planning for natural hazards and climate change impacts.
- Publish information on climate change projections and natural hazards impacts.
- Publish funding opportunities and tools to support adaptation.
- Respond to major natural hazards events.

9 Adaptation cycle approach to planning

The approach selected by ORC to develop holistic, longer term natural hazards management plans in line with the Ministry for the Environment **10 Step adaptation cycle**. This adaptation approach is often shown as a circular 10-step decision cycle and can also be simplified as the sequence of five phases shown in Figure 9.1. This process has been promoted by the Ministry for the Environment as a blueprint for community-influenced decision making in areas affected by natural hazards and considering potential future uncertainties (e.g. landscape and climate changes).

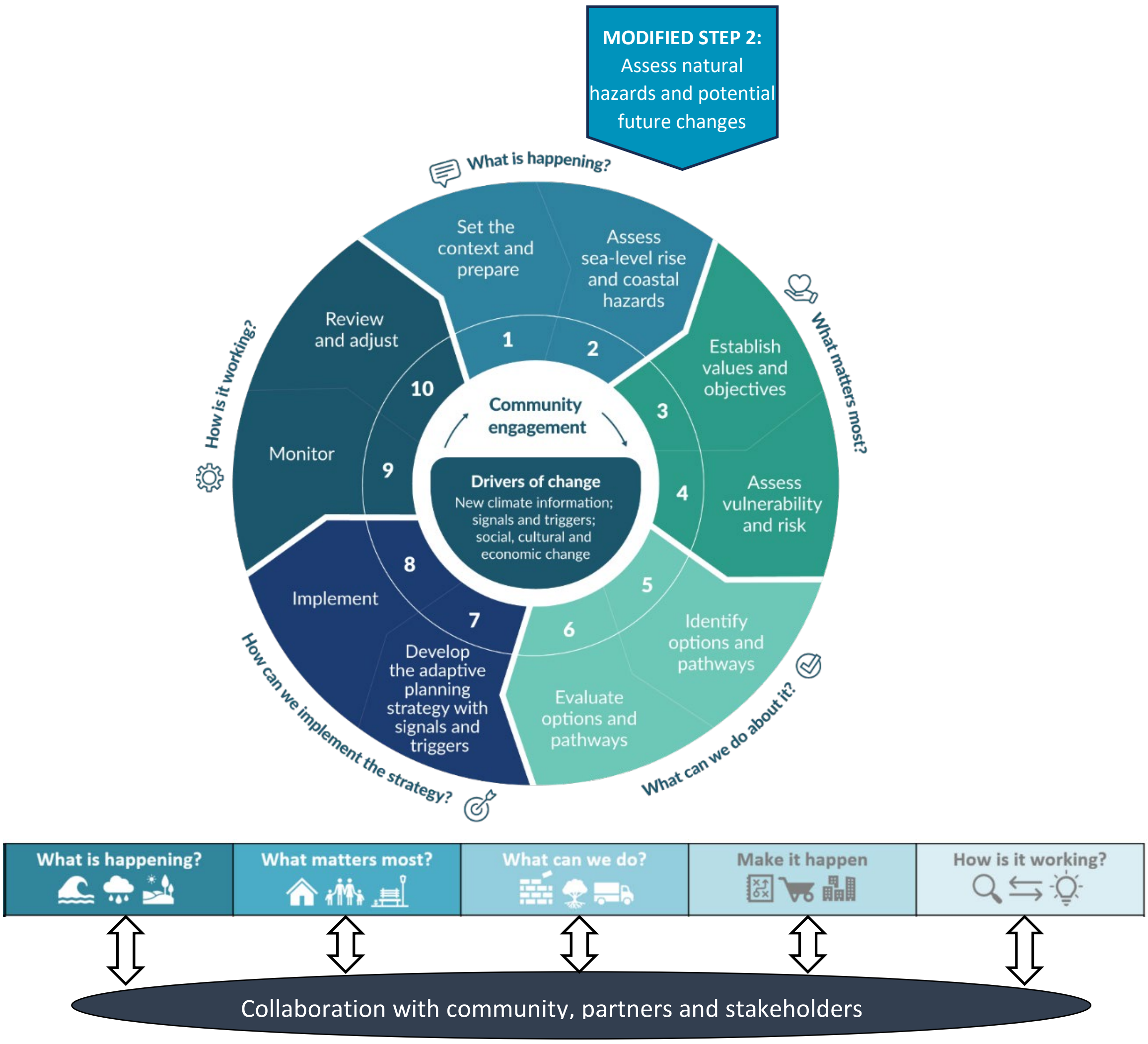

Figure 9.1 The 10-step decision cycle framework (modified from MfE 2024) and a simplified sequence of activities making up the approach.

Adaptation pathways

Within the adaptation cycle is a method known as Dynamic Adaptative Pathways Planning (DAPP) or 'Adaptation Pathways'. A conceptual outline of the adaptation pathways decision-making process in included as Figure 9.2. By using a pathways approach, it becomes clear what suite of adaptation actions can be implemented as change occurs, or a previous adaptation option stops working as it was intended. In situations like the Head of Lake Whakatipu, it is very likely that a series of actions (rather than just a single action) will be needed as the hazards and landscape change. This means that it is important to know how and when to transition between the different responses.

ORC is applying the adaptation pathways approach in a variety of local areas in Otago with complex natural hazard challenges, including Head of Lake Whakatipu, South Dunedin and Clutha Delta. The adaptation pathways approach is also supported by programme partners. Other regions are also applying the approach, including Hawkes Bay, Wellington and Waikato.

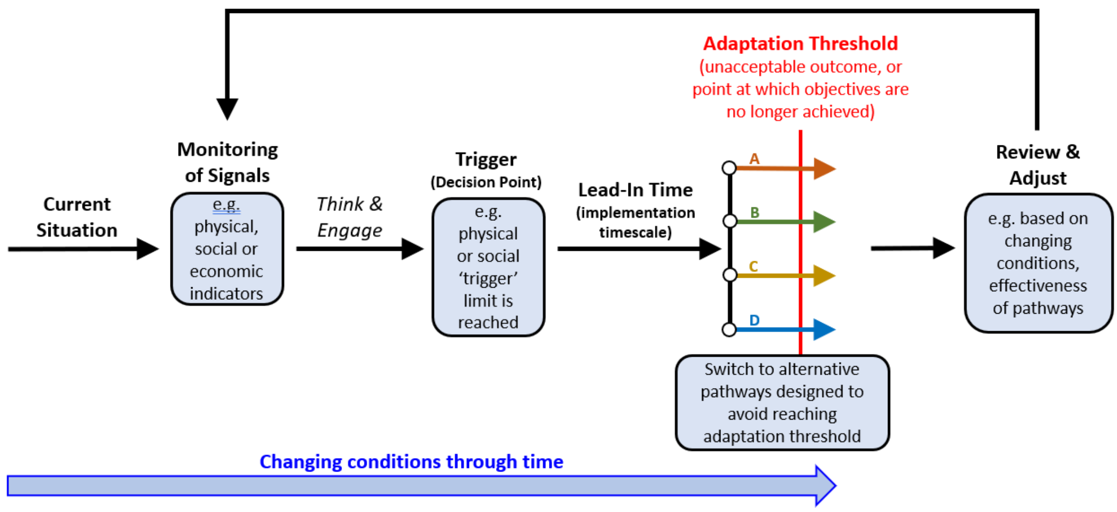

Figure 9.2 Conceptual outline of the adaptation pathways decision-making process.

9.2 Phase 1: What is happening?

The previous sections have set out the context for the Strategy, which is Step 1 of the adaptation cycle approach. Therefore, this section is focused on modified Step 2: *assessing the natural hazards and potential future changes*.

Figure 9.3 "What is happening?" Steps 1 & 2 of the adaptation cycle (modified from MfE 2024).

9.2.1 Natural hazard processes, characteristics, and potential impacts

A thorough understanding of natural hazard processes, characteristics, and their risks is required to ensure a robust basis for decision-making regarding the most appropriate hazard management and adaptation approaches.

To this end, ORC has undertaken more than twenty technical and supporting studies to build the body of knowledge, detailed in Appendix A. These investigations, with detailed modelling and analysis, provide a much better understanding and modelled data of the area's natural hazards challenges. Note that key studies were externally reviewed by independent experts.

It is important to be aware that multiple hazards can also occur at the same time and that one hazard can trigger another in a cascade. Some relevant examples for Head of Lake Whakatipu area:

- Major storms could cause flooding, riverbank erosion, and debris flow.
- Earthquakes could trigger landslides and liquefaction.
- Landslides could increase sediment supply and disrupt access.
- Liquefaction could cause land subsidence, increasing subsequent flood hazard.

9.2.2 Geomorphic processes

Geomorphologic processes in the area are highly dynamic and can be a key influence on natural hazard characteristics. Collection of aerial imagery, LiDAR and on-ground survey information enables comparison with prior surveys, and analysis of change.

For parts of the Glenorchy and Rees River area, archive aerial imagery dates to 1937, so provides an 80+ year record of geomorphic changes in this location. For the Dart River floodplain, archive imagery dates to 1966 so covers a 50+ year period.

LiDAR surveys were collected for the lower Rees and Dart floodplains by ORC in 2011 and 2019. Additional LiDAR surveys were collected by the University of Canterbury for research purposes in 2021 and 2022, with data made available to ORC. The high-resolution topographic information provided by LiDAR survey enables geomorphic change analysis (e.g. Figure 9.5) and provides a detailed topographic base for hydraulic modelling projects (e.g. Gardner, 2022; Beagley and Gardner, 2023; Beagley, 2024).

Geomorphic analysis and assessments for the Dart-Rees floodplain and delta have been completed by Brasington (2021, 2024), and findings from these analyses also included within T+T (2021) and Webby (2023). These studies build on earlier geomorphic assessments by URS (Mabin, 2007) and Wild (2012). These geomorphic assessments have included description of the geomorphic context (drivers, processes and responses), and influences on natural hazards, review of historical changes, and quantification of rates of change. Key outputs from geomorphic analysis are relative elevation modelling, and mapping of geomorphic changes.

Relative elevation models compare the elevation of the valley floor to the adjacent average level of the active river channel (Figure 9.4). This analysis highlights two locations where the floodplain is notably lower in elevation than the adjacent active riverbed and, therefore, vulnerable to a channel breakout event (avulsion):

- the right bank upstream of the bridge (Diamond Creek area)
- left bank downstream of Precipice Creek (Glenorchy wetland area).

Geomorphic change detection (GCD) analysis is used to compare differences over time, between repeat LiDAR topographic surveys (e.g. Figure 9.5). Analysis findings can be used to identify the locations of sedimentation or erosion/scour and to quantify the rates of these processes.

For example, Figure 9.5 illustrates the widespread bank erosion on the right bank of the lower Dart floodplain and the dominant aggradation trend in the lower Rees River. Estimation of net changes provides an indication of the mean rate of aggradation (e.g. 'cm per decade' rate), or the net volume changes between repeat surveys (sedimentation minus erosion, in cubic metres per year).

Maintaining an up-to-date understanding of current conditions is of high importance. The acquisition of up-to-date geomorphic datasets enables:

- revision of geomorphic analysis
- identification and proactive response to potential issues
- enables the updating of flood hazard assessments to ensure they provide accurate representation of current conditions (e.g. riverbed levels)

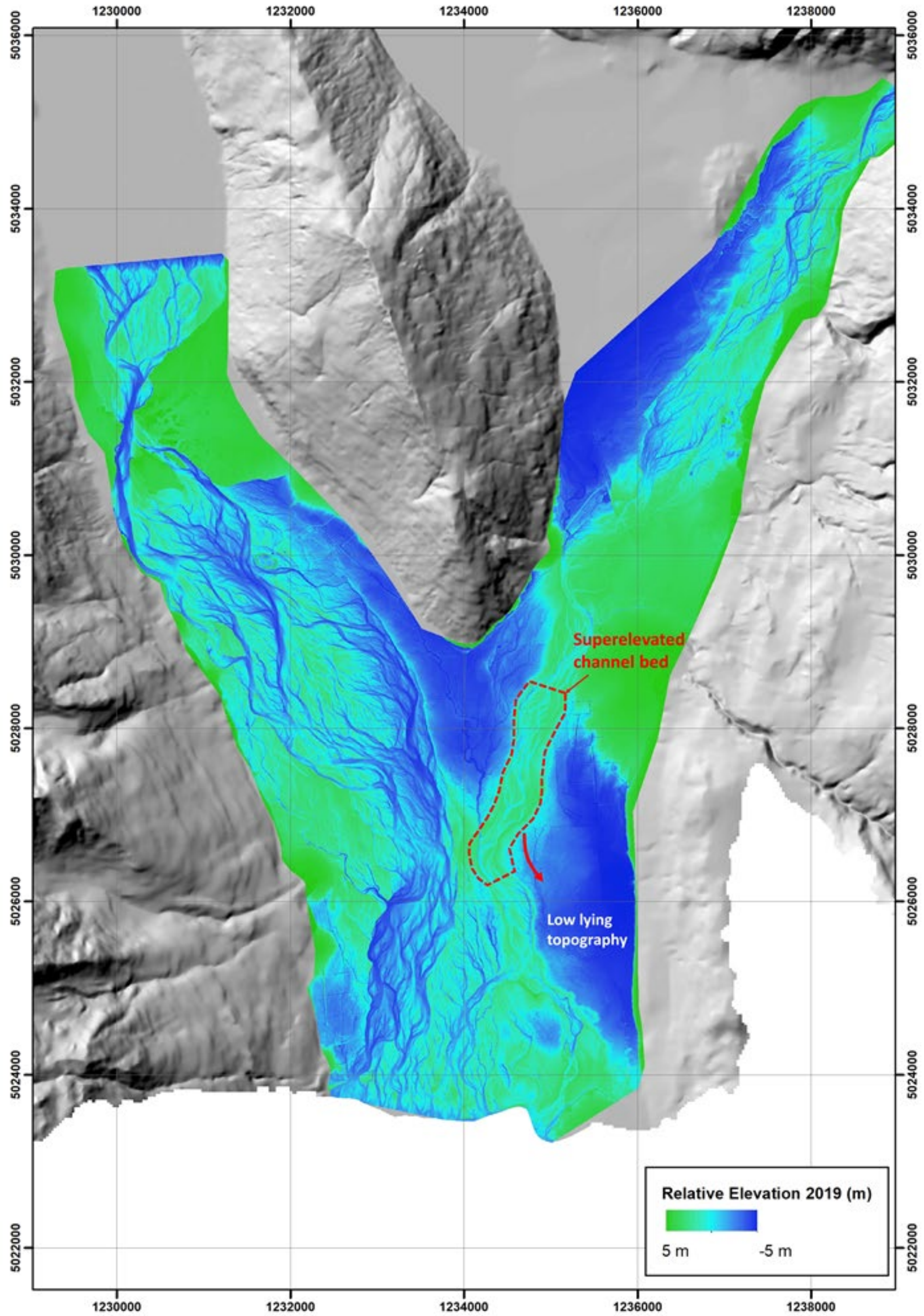

Figure 9.4 Relative elevation model of the Rees-Dart valley floor. This is computed by comparing the valley floor elevations to the adjacent average level of the river bed. The section of super-elevated river bed highlighted is the likely source for a potential channel breakout flood eastwards into the lower-lying topography of the wetland and lagoon area. The analysis is based on a 1 m resolution lidar topographic dataset acquired in 2019 (Analysis by J Brasington).

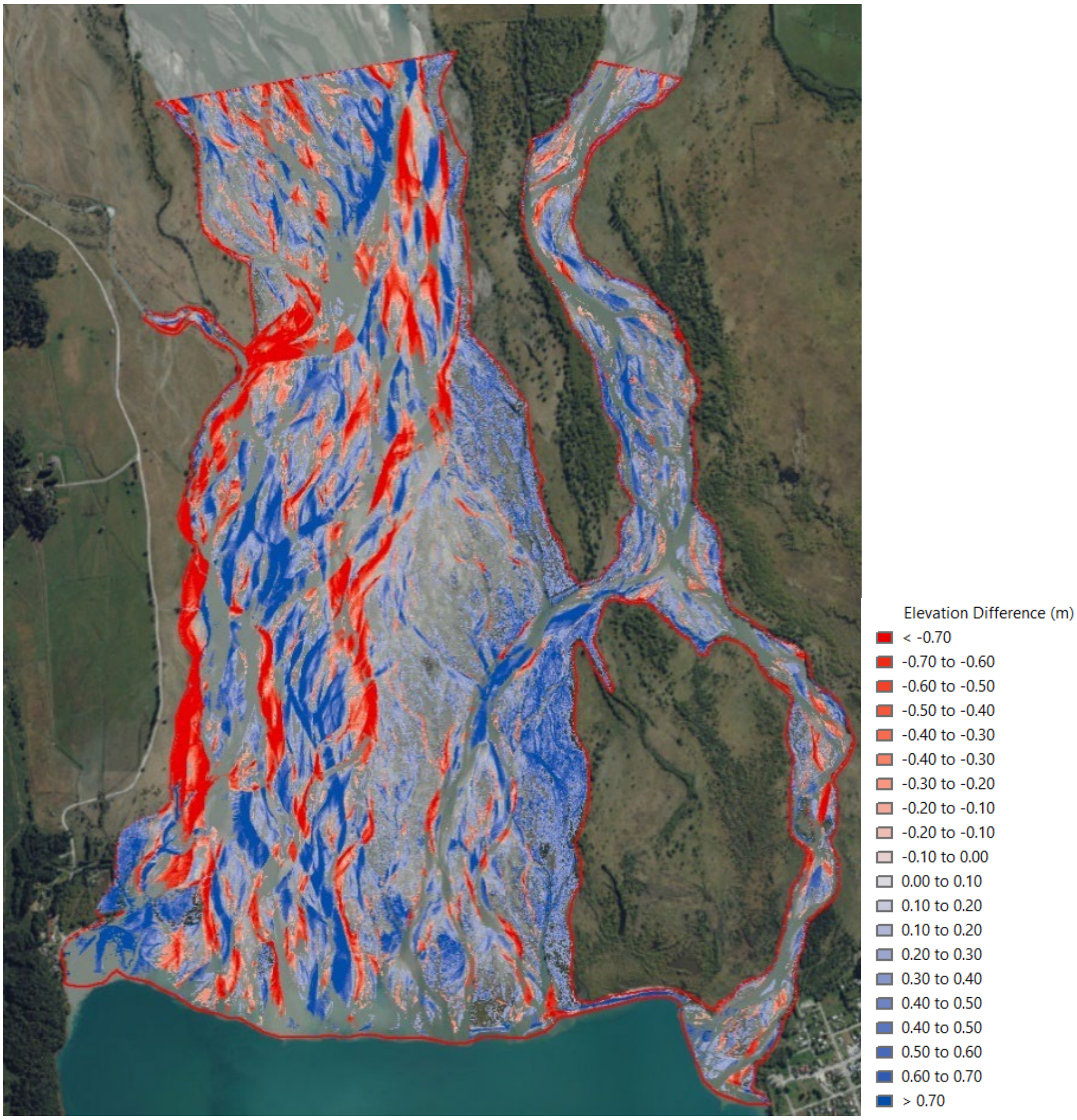

Figure 9.5 Geomorphic change for the lower Dart and Rees rivers (2011-2019). Blue is sedimentation, red is erosion. Showing westwards erosion of the lower Dart floodplain.

9.2.3 Hydrological and flood hazard assessments

Detailed flood hazard analysis has been carried out to understand flood hazard characteristics and the findings were used to inform risk assessment and engineering studies.

Hydraulic modelling and flood hazard analysis has been completed for the Rees and Dart Rivers (Gardner, 2022) and the Buckler Burn (Beagley and Gardner, 2023). In 2024, further hydraulic modelling was undertaken using the previously developed models, to assess a wider range of flooding magnitudes and a combined 'all source' model scenario which included inflows from the Dart and Rees Rivers, Buckler Burn, and Bible Stream (Beagley, 2024).

For the Rees-Dart Rivers, modelled flooding scenarios included combinations of large (up to 100-year ARI) river flows and lake levels, and the effects of climate change on future river flows and flood events. Additional factors modelled include an avulsion of the lower Rees River channel, and a breach of the Rees-Glenorchy floodbank (Gardner, 2022). For the Buckler Burn, modelled flooding scenarios considered a range of river flows, and the effects of alluvial fan aggradation on fan morphology.

Model outputs from these flood hazard assessments typically include floodwater elevation, depth, velocity, and a classification of flood hazard as a function of floodwater depth and velocity. Findings from the Dart-Rees (2022) and Buckler Burn (2023) flood hazard assessments can be viewed in the ORC Natural Hazards Portal.[9]

Key findings from flood hazard assessments are that;

- In larger-magnitude Dart-Rees flooding scenarios, there is widespread overtopping by floodwaters over the Glenorchy floodbank and floodwater inundation of a large northern portion of the township (e.g. Figure 9.6 and Figure 9.7). It is estimated that the Rees-Glenorchy floodbank structure will not prevent flooding in the township for river flow events of a 20-year ARI (average recurrence interval) or greater.
- In the larger-magnitude Buckler Burn flooding scenarios, there is some floodwater spillover northwards from the stream into the township area (e.g. Figure 9.7). However, modelled floodwater depths in the residential parts of the township are generally relatively shallow (<0.5 metre depth), even in the largest magnitude scenarios modelled.
- Buckler Burn active channel is in close proximity to Queenstown-Glenorchy Road (Figure 9.7) and bank erosion is a threat to access.

These flood hazard assessments represent a significant increase in understanding from the previous flood modelling study at Glenorchy (Whyte and Ohlbock, 2007), which used a 1D modelling approach and was completed prior to the availability of LIDAR-derived topography.

Several supporting studies have been undertaken to inform flood hazard assessments;

- Hydrological analysis by Mohssen (2021, 2024). Flood frequency analysis for Dart River flows and Lake Whakatipu levels, development of rainfall-runoff models for Rees River and Buckler Burn, analysis of climate change impacts on flows.
- Geotechnical assessments by T+T (2021) to inform modelling of floodbank breach scenarios at Glenorchy. These build on earlier floodbank stability assessments completed in response to concerns regarding bank erosion and floodbank stability (Jaquin, 2020, 2021).

Additional hydraulic modelling analysis has also been carried out as part of assessments by;

- Wong *et al* (2023): A study completed for QLDC to inform a structural options assessment for the Rees River bridge structure, to help provide direction and guidance towards a long-term asset management strategy. The findings are summarised in Section 0
- Damwatch Engineering Ltd (2024): Assessments completed to inform review of potential floodplain hazard management approaches. The findings are summarised in Section 0.

[9] http://hazards.orc.govt.nz

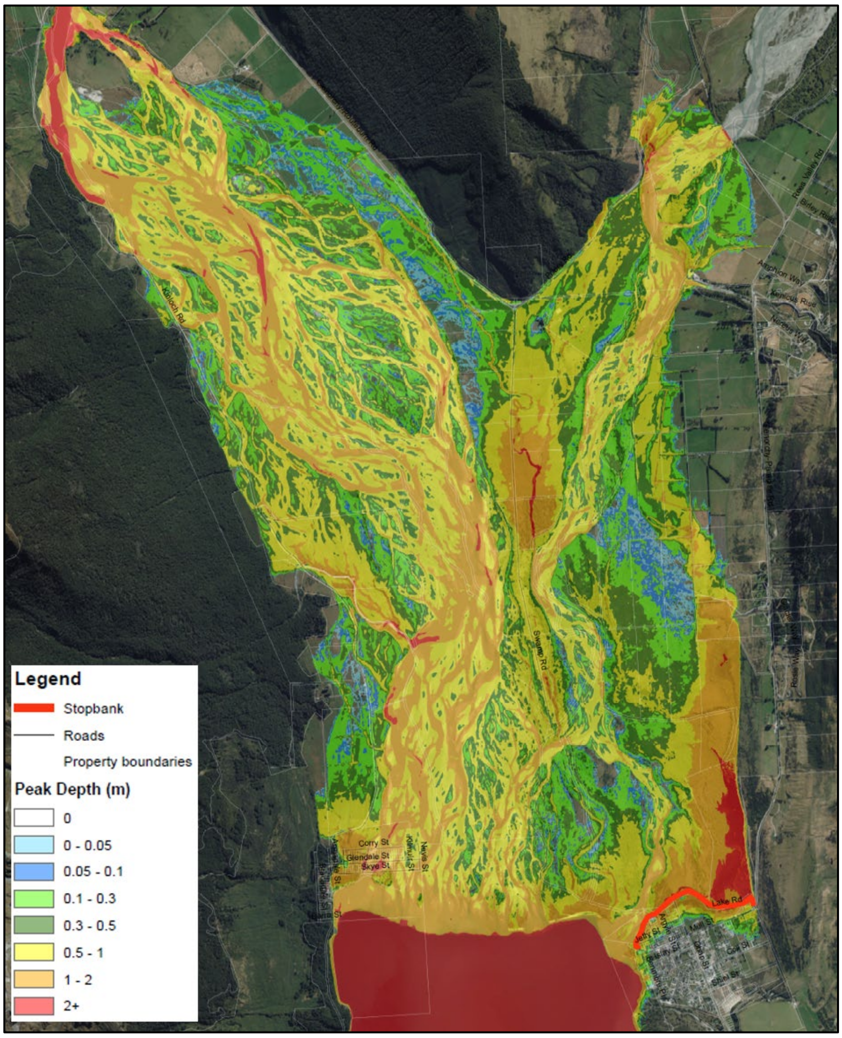

Figure 9.6 Model results for a Dart-Rees flooding scenario with 100-year ARI river flows, and Lake Whakatipu at 10-year ARI levels. Colouring shows peak floodwater depths according to the included legend. Figure 9.7 shows detail of the Glenorchy township area for this scenario.

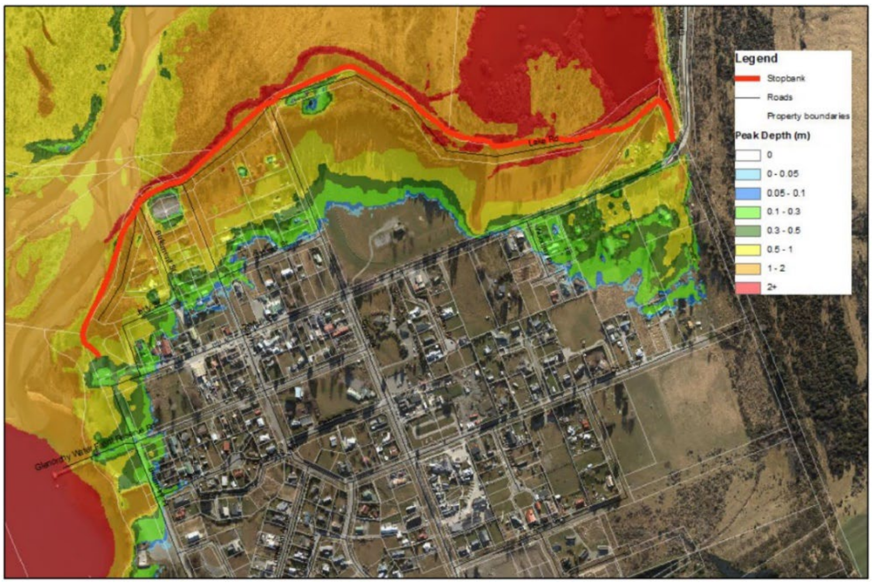

Figure 9.7 Model results for a Glenorchy flooding scenario with 100-year ARI river flows, and Lake Whakatipu at 10-year ARI levels. Colouring shows peak floodwater depths according to the included legend.

Figure 9.8 Model results showing floodwater depths for a Buckler Burn flooding scenario with a 300 m³/s peak flow. In this scenario minor floodwaters flow into the township area, mainly flowing northwards along Oban Street and around the eastern margin of the township.

9.2.4 Alluvial fan hazards

The focus of alluvial fan hazard assessments for this work programme has been the Buckler Burn alluvial fan, on which Glenorchy township is constructed. In addition to the flood hazard assessments completed for the Buckler Burn alluvial fan by Beagley and Gardner (2023), a preliminary assessment of debris flood and debris flow potential was completed by Fuller and McColl (2021). This assessment considers debris flows unlikely to be a threat to Glenorchy, but identified possible high-energy debris flood deposits in drill core from within the township area.

Debris flow hazard modelling for the Buckler Burn using RAMMS software was reported by Faulkner (2021) and Faulkner and Rogers (2021) but was completed only as a test of sensitivity to factors such as failure locations, debris volumes and release mechanisms.

Other alluvial fans in the Head of the Lake area are mapped by Grindley *et al* (2009) and Barrell *et al* (2009),[10] with some known to be subject to flooding or debris inundation (e.g. Figure 5.19 and Figure 5.20), but these hazards have not been assessed in detail.

In April 2022, a debris flow event occurred at Shepherds Hut Creek, located about 8 km southwards from Glenorchy on the Queenstown-Glenorchy Road. Following the event, an assessment was completed by Shaw (2022) to review the event and comment on the debris flow hazard characteristics and risks.

Between Queenstown and Glenorchy, the road also traverses many other locations exposed to debris flow, flooding or landslide/rockfall hazards, but these hazards have not yet been assessed in detail.

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[10] This mapping can be viewed in ORC's Natural Hazards Portal: http://hazards.orc.govt.nz.

9.2.5 Seismic hazard assessments

Seismic Shaking

Seismic shaking hazards were summarised by Menke *et al* (2024) in the Glenorchy and Kinloch Risk analysis. Aotearoa New Zealand is seismically active, with a high frequency of earthquakes. Earthquakes induce strong ground motion (earthquake shaking) in response to rapid release of built-up strain along fault lines. The intensity of shaking depends on the severity of the earthquake, distance from the epicentre, specific ground characteristics and local topography.

Numerous mapped fault systems are present in the wider area and influence seismicity in Kinloch and Glenorchy. Nearby possible active faults include the West Whakatipu Fault located approximately 2 km west of Kinloch and the Moonlight Fault approximately 15 km east of Glenorchy (Barrell, 2019a).

The most notable fault in the area is the Alpine Fault some 55 km to the nearest point from Glenorchy, due to the anticipated magnitude of earthquake and low recurrence interval. earthquake triggering at some point along the 800 km long Alpine Fault over the next 50 years is 75%, with an 80% chance that the earthquake event would exceed magnitude 8 (www.af8.org.nz). The potential AF8 hazards and impacts for Central Otagao include strong shaking triggering snow/ice avalanches, landslides and rockfalls on mountain and hill slopes, making some roads impassable and potentially isolating communities in the area. Central Otago lakes could be affected by landslide-triggered tsunami, making it important for communities to know the 'Long or Strong, Get Gone' messaging. Thousands of tourists may be stranded in the area, unable to get home and will need to be looked after for days due to damage to roads. Some areas may lose power and telecommunication services.

Assessment of shaking hazard for the risk assessment considers a range of probabilistic earthquake scenarios rather than specific fault rupture scenarios.

Menke *et al* (2024) reports that seismic shaking hazard at Kinloch and Glenorchy is expected to pose the greatest risk to buildings and lifelines infrastructure through structural damage, compared to relatively few injuries or deaths. During the 2010/2011 Canterbury earthquakes no deaths were attributed to structural failure of light weight timber frame buildings (being the typical building form within Glenorchy). However, one fatality occurred associated with collapse of a chimney induced by strong ground motion (Canterbury Earthquakes Royal Commission, 2012).

Liquefaction and lateral spreading

Liquefaction and lateral spreading can occur when strong ground shaking during an earthquake disturbs ground sediments, causing them to behave as fluid. This can deform the surface of the ground, affecting buildings, roads and underground infrastructure such as water supply and septic systems at varying degrees (Figure 9.9).

Mapping of liquefaction susceptibility (Barrell, 2019b) has been completed for the Otago region, providing an overview at a regional-scale of the hazard susceptibility. The regional-scale liquefaction hazard assessment is a classed as a Level A investigation in accordance with MBIE/MfE (2017) guidance.

For the Glenorchy township area, a more detailed (Level C) investigation was undertaken by T+T (2022). This study included geotechnical field investigations (boreholes and CPT), and geotechnical analysis for a range of seismic scenarios including an Alpine Fault rupture.

The geological investigations show that Glenorchy township is underlain by a thick sequence of delta and alluvial sediments, overlain by a surficial layer (3-7m thick) of gravels deposited by the

Buckler Burn. All of the sediments underlying the surficial Buckler Burn gravels are highly susceptible to liquefaction.

The assessment developed a liquefaction vulnerability categorization map for the Glenorchy township study area (Figure 9.10 and Figure 9.11), intended to show broad trends in liquefaction vulnerability. For strong earthquake shaking, significant and widespread liquefaction land damage may occur across all the lower lying areas of Glenorchy in the north and west.

Findings show the potential for lateral spreading damage is highest near the lake edge and decreases with an increasing distance from the lake. The magnitude of potential lateral spreading damage increases with earthquake shaking at larger return periods, and for stronger shaking may be comparable or worse to that observed in parts of the residential red zone in Christchurch, which was typically in the order of 1m to 3m.

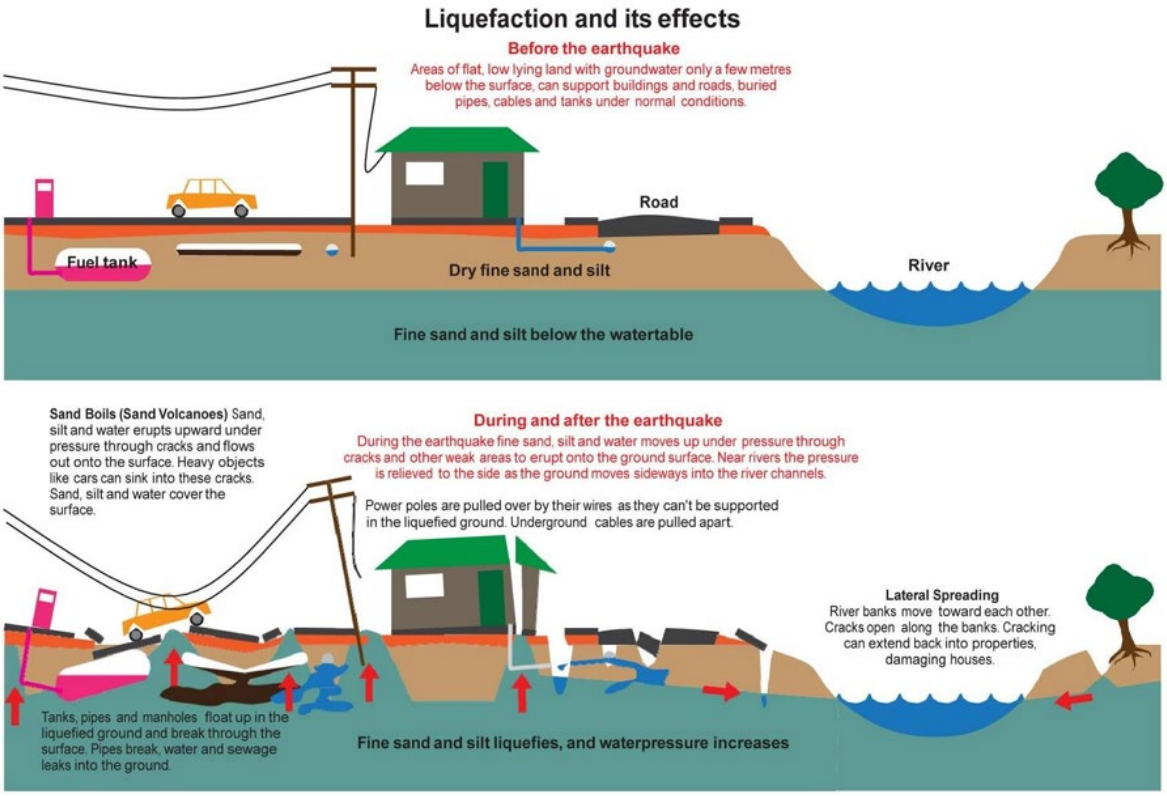

Figure 9.9 An illustration of liquefaction and lateral spreading processes and their effects (IPENZ, 2012).

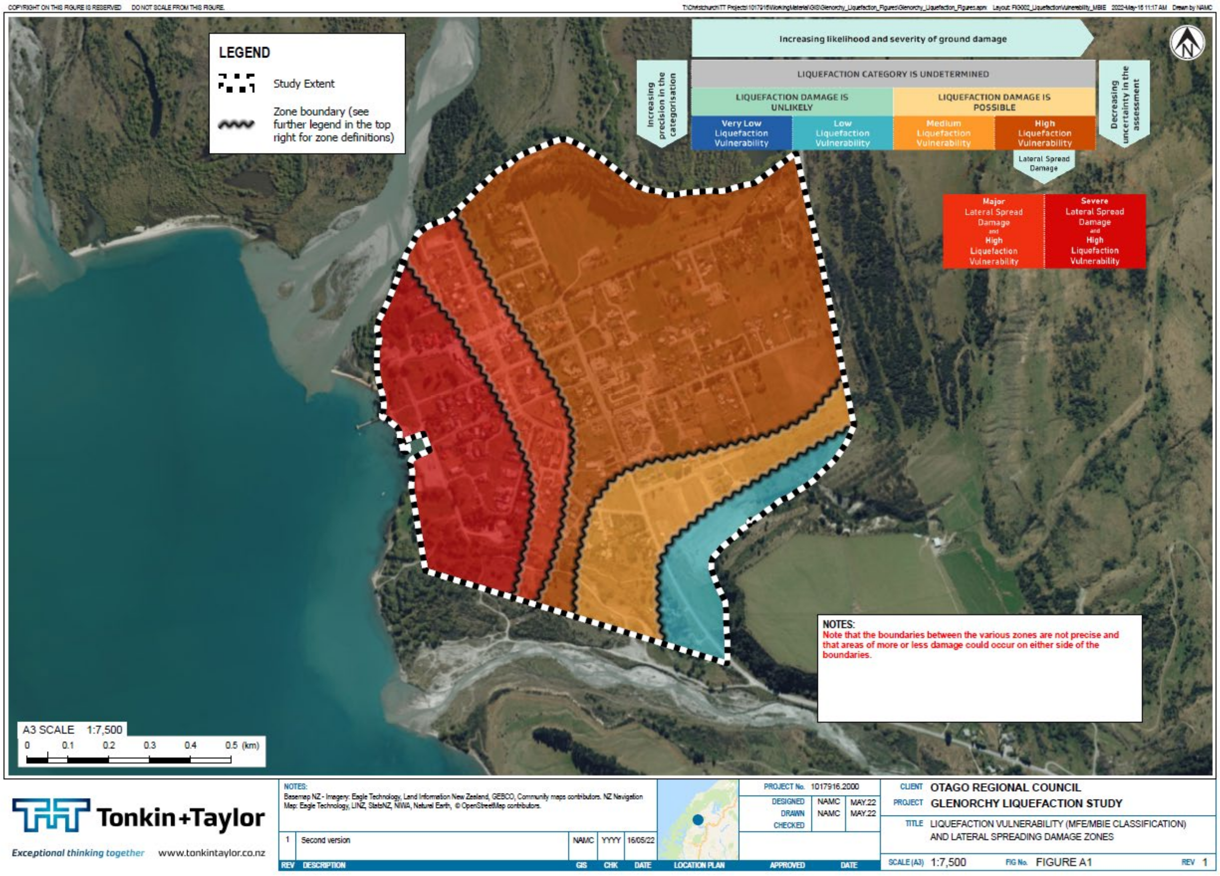

Figure 9.10 Liquefaction vulnerability categorization for Glenorchy township. The boundaries between the hazard categories shown are indicative of the spatial distribution of the liquefaction and lateral spreading vulnerability but are uncertain and not intended as a precise boundary between hazard categories. In reality, areas of damage might well occur on either side of the boundaries illustrated. T+T (2022).

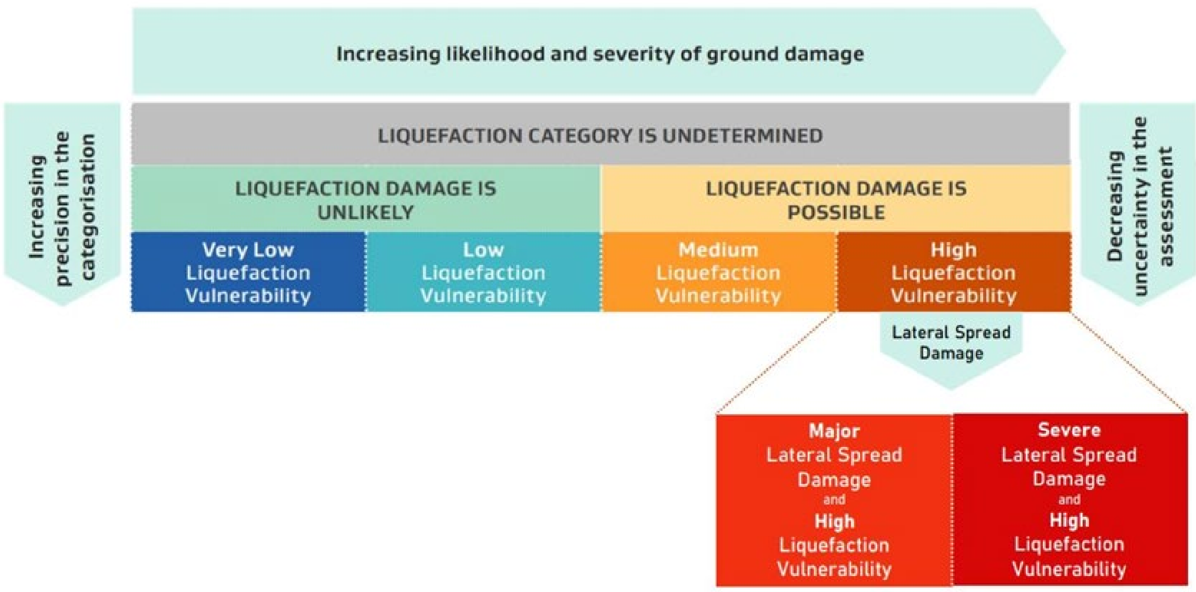

Figure 9.11 Magnified image of the hazard categorisation used for assessment of both liquefaction and lateral spreading hazard. T+T (2022).

9.3 Phase 2: What matters most?

Figure 9.12 "What matters most?" Steps 3 & 4 of the adaptation cycle (modified from MfE 2024).

9.3.1 Collaboration and engagement with community, partners and stakeholders

As highlighted in Figure 9.1, community engagement is central to the adaptation cycle in all steps. The development of the Strategy and ideas for adaptation pathways has involved extensive engagement with communities, experts, mana whenua, and partner agencies. We are immensely grateful for everyone who has contributed to this Strategy. Communications and engagement activities are summarised in Table 9-1 below.

ORC is part of a wider network of people and organisations working to adapt to natural hazards and impacts of climate change at the Head of the Lake. To develop this Strategy, ORC has taken a collaborative approach across and between councils, mana whenua, central government, stakeholders and the local community. These include agencies and organisations such as QLDC, CDEM Otago, Aukaha, Te Ao Mārama, Glenorchy Community Association, Department of Conservation, Enviroschools, as well as consultants and experts.

At an operational level ORC has encouraged partnership and collaboration through:

- Knowledge and information sharing through regular catch up and programme updates.
- Inviting staff to collaborate and input on various programme workstreams, including programme planning, engagement planning, adaptation options assessment.
- Expert advice, input and feedback on hazard investigations and reports.
- Supporting the delivery of technical studies and assessments led by partners.
- Collaborating on the delivery of engagement activities.

Table 9-1 Summary of communications and engagement activities as part of the programme from 2019-2024.

Activity	Date	Summary	Agencies or organisations involved
Presentations to Glenorchy Community Association	2019-2020	Update the Glenorchy Community Association on ORC's completed and planned natural hazards activities.	Otago Regional Council Glenorchy Community Association
Community drop-in session	December 2020	Discuss and provide information on the range of natural hazard events the community is exposed to, and how these events and landscape changes have impacted the community in the past.	Otago Regional Council Queenstown Lakes District Council Tonkin + Taylor Glenorchy Community Association Civil Defense Emergency Management Otago
Public presentation	April 2021	Expert (Prof. James Brasington, University of Canterbury) overview of the river processes and changes of the Dart-Rees floodplain, and their implications for natural hazards.	Otago Regional Council University of Canterbury
Community drop-in session	April 2021	Discuss with the community the natural hazards challenges facing this area in the future, and to initiate discussions about what adaptation to those challenges could look like.	Otago Regional Council Queenstown Lakes District Council Civil Defense Emergency Management Otago University of Canterbury Tonkin + Taylor NIWA
Online presentation	June 2022	Present and update on investigation findings into liquefaction and flood hazards.	Otago Regional Council Tonkin + Taylor Land River Sea Consulting

Activity	Date	Summary	Agencies or organisations involved
Community drop-in session	July 2022	An in-person opportunity to discuss in more detail the investigation findings into liquefaction and flood hazards.	Otago Regional Council Queenstown Lakes District Council Civil Defence Emergency Management Otago Tonkin + Taylor
Community workshop sessions	August 2023	To workshop ideas about community aspirations for the future and have discussions about a long-list of possible adaptation options	Otago Regional Council Queenstown Lakes District Council Civil Defence Emergency Management Otago Glenorchy Parent, Teacher and Friends Association NIWA
Community input into Socio-Economic Impact Assessment	July 2023 – April 2024	Community input into scope of assessment, methodology, data collection phase and draft report.	Glenorchy Community Association Beca
Online survey	September 2023	To get feedback on community values and aspirations for the future, and how we should engage in the future.	Otago Regional Council
Stall at Glenorchy Village Fair	November 2023	To initiate discussions about the natural hazards adaptation programme, community resilience and preparedness.	Otago Regional Council Civil Defence Emergency Management Otago
Adaptation education session at Glenorchy	April-May 2024	To build understanding of landscape changes over time, how people have adapted to these changes in the past and present and what adaptation could look like in the future.	Otago Regional Council Enivroschools
Head of the Lake Youth Art Competition	April-May 2024	To engage children and youth people in the programme and better understand their values.	Otago Regional Council

Activity	Date	Summary	Agencies or organisations involved
Online presentation	May 2024	To present and update on findings of socio-economic impact assessment.	Otago Regional Council Queenstown Lakes District Council Beca
Public (in-person and online) presentation	September 2024	To present and update on findings of risk analysis and assessment of possible Dart-Rees floodplain interventions.	Otago Regional Council Queenstown Lakes District Council Civil Defence Emergency Management Otago NIWA Beca Damwatch Engineering
Community drop-in session	September 2024	An in-person opportunity to discuss in more detail the findings of the risk analysis and assessment of possible Dart-Rees floodplain interventions. Also, to initiate discussions about what adaptation could look like over the short to long term.	Otago Regional Council Queenstown Lakes District Council Civil Defence Emergency Management Otago NIWA Beca Damwatch Engineering
Monthly email newsletter	41 editions since August 2020	To provide progress updates for the work programme and give an indication of upcoming project work.	Otago Regional Council
Media releases and media coverage	Ongoing	To provide updates on key milestones in the programme. Media interest in aspects of the programme.	Otago Regional Council
Communications and advertising channels	Ongoing	Tailored communication and advertising for programme activities (such as Facebook ads and events, Google ads, flyer, letter drop)	Otago Regional Council

Activity	Date	Summary	Agencies or organisations involved
Programme webpage	Ongoing	To provide information about the programme and – site for links and find key materials	Otago Regional Council
Designated programme email address	Ongoing	Easy way for people to contact the team about the programme: headofthelake@orc.govt.nz	Otago Regional Council
Supported two research projects	2021-2023	Masters research project about storytelling and the ORC's community engagement process (MacKenzie, 2023).	University of Otago, Resilience to Nature's Challenges
	2021 - ongoing	Research project about landslide-generated tsunami hazards of the Lake Whakatipu basin.	Massey University, University of Otago, NIWA

Figure 9.13 Community engagement session August 2023

Figure 9.14 Manager Natural Hazards Jean-Luc Payan at the September 2024 community drop-in session

9.3.2 Values and aspirations for the future

The Head of the Lake community has a strong and clear set of shared values and aspirations for the future, as noted in the 'Glenorchy – Head of the Lake 2001 Community Plan' and 'Shaping our Future: Glenorchy Community Visioning Report 2016' (Blakely Wallace Associates, 2001 and Shaping Our Future, 2016). Through engagement people provided many insights into what matters most to them at the Head of the Lake. This has helped to generate a set of shared community values that will provide guidance for decision making at the Head of the Lake now and into the future.

In the 2001 Community Plan, reinforced in the 2016 Visioning process, core resident values included being safe, caring, self-reliant, welcoming, working together, and respecting the environment (Blakely Wallace Associates, 2001). Residents also valued the history of the area, the rural atmosphere, peacefulness, landscapes, and having the wilderness at their doorstep.

The community vision for the area as part of the Shaping our Future (2016) report, is as follows:

- *"A unique, inclusive community that fosters and embraces individuality, diversity and innovation, encourages resilience and promotes community vitality and collaboration. The Glenorchy community has a collective strong voice that advocates for positive change. Glenorchy has the infrastructure to support a thriving boutique local economy in keeping with the rural landscape, actively respects and enhances the natural environment, collectively works towards providing their own resources (self-sufficiency)."*

The 2001 and 2016 values and vision align closely with feedback elicited as part of the engagement process. From all the feedback and engagement, as part of methods outlined in Table 9-1, the following overarching community values emerged:

- **Lifestyle and wellbeing** – people feel safe to do their day-to-day activities. A sustainable, self-sufficient, and resilient community.
- **Environment** – sense of stewardship and connection to nature – mountains, rivers, lake. A place for wildlife and biodiversity to thrive.
- **Belonging** – a feeling of home. A strong sense of community where people support and take care of each other.
- **Recreation** – being able to enjoy recreation and links to the broader environment. A place for residents and visitors to enjoy together.

Additionally, the Head of the Lake Youth Art Competition built upon previous engagement about community values and what matters most to people about Glenorchy. The theme was 'what does the Head of the Lake mean to you?'. Art entries from children and youth emphasised nature, cultural heritage, social connections, and play. These entries are displayed on the front and back cover of the Strategy.

Through the engagement process, we invited people to help develop community outcomes through a workshop exercise and online survey. These outcome statements for the Strategy will inform decision-making and pathways planning discussed in Section 0:

- Outcome #1 – A community that feels safe and supported from the impacts of natural hazards
- Outcome #2 – Residents feel at home, connected to their environment and supported by the experience of community
- Outcome #3 – A beautiful environment and a feeling of connection with nature
- Outcome #4 – Sustainable, functioning ecosystems

- Outcome #5 – The opportunity to make a living
- Outcome #6 – Be resilient and self-determining
- Outcome #7 – Functional, resilient and accessible infrastructure, support services and emergency response
- Outcome #8 – Heritage is safeguarded and accessible
- Outcome #9 – A healthy community that promotes the wellbeing of all

Takau (2021) outlined key values for mana whenua in a Cultural Values Statement to guide planning and decision-making at the Head of the Lake now and into the future.

Ka Uara – Core cultural values:

- **Mana** – mana whenua are leaders, influences and partners.
- **Mauri** – protect and enhance the mauri (life force) of the Head of Lake Whakatipu, now and well into the future.
- **Whakapapa** – The traditional authority of mana whenua at the Head of the Lake is recognised ancestral rights which give mana whenua the mana and kaitiaki responsibilities.

Additional Kāi Tahu values include:

- **Ki Uta ki Tai** – commonly translated to 'from the Mountains to the Sea' but means interconnectedness across the whole environment.
- **Kaitiakitak**a – intergenerational and inherited responsibility and stewardship by mana whenua on behalf of future generations.
- **Maanakitaka** – expressing aroha, hospitality, generosity and mutual respect. Processes and decisions that enable positive social outcomes and support wellbeing.
- **Mahika kai** – ability to, and access to, gather or harvest resources. Ensure a healthy functioning ecosystem and sustainable harvesting practices.
- **Wai Māori and Wai Ora** – importance of protecting and enhancing the wellbeing of all bodies as water is a sacred entity in te ao Māori, and is the source of all life.
- **Maumaharataka** – acknowledging and upholding memories of the past and Kāi Tahu pūrakau (stories)
- **Whakawhanaukataka** – relationship and community building, working together for the benefit of the community.

The Head of the Lake area is immensely significant to mana whenua. To uphold the mana of kā rūnaka, it is crucial that mana whenua have authority over how their manawa (aspirations) for the future are portrayed and represented in this Strategy and in future actions (as outlined in Section 9.4.2.1). Councils need to ensure engagement is open and ongoing with mana whenua as the programme progresses.

9.3.3 Fears and concerns

As the programme has developed, people have also shared some of their fears and concerns about the programme and potential adaptation actions at the Head of the Lake. Concerns and fears include:

- Impact of natural hazard investigations on property values, property owners' ability to get property insurance, or result in rising insurance premiums. In particular, focusing on findings before the Strategy has been developed or decisions on adaptation action have been made.

- Media attention about natural hazards and the programme could result in the reluctance of tourists to visit, further reducing the ability of the resident communities to withstand disruption.
- Media attention putting a negative 'spotlight' on Glenorchy based on the area's natural hazard risk profile compared to other areas around the region.
- Some residents have highlighted parts of the community, including youth, parents of young families, and newer residents to the community, who have not been as engaged in the process. Therefore, their voices and perspectives may be under-represented from the development of the Strategy.
- Some residents have highlighted parts of the community, including newer residents to the community, are less informed about natural hazard risks and adaptation, which consequently impacts their ability to respond and be resilient to natural hazard challenges.

This general feedback has informed ORC's approach throughout the programme and to develop this Strategy. It will continue to inform decision-making and actions relating to the Strategy moving forward.

9.3.4 Potential social and economic consequences of natural hazards

In addition to the socio-economic baseline, Healy *et al* (2024) also examined the potential social and economic consequences of three indicative natural hazard scenarios in relation to the status quo (the current community and the natural hazard management measures currently in place).

9.3.4.1 IN WHAT WAYS IS THE COMMUNITY RESILIENT?

Local groups such as Glenorchy Community Response Group and Community Association play a significant role in disaster preparedness and response. These groups, collaborating with CDEM Otago, regularly organise training sessions and awareness activities to enhance community response skills. They provide information to the Emergency Management Advisor and activate a Community Emergency Hub during crises to coordinate local response efforts. Additionally, they fundraise to support community projects, which strengthens resilience and preparedness (Glenorchy Community Response Group, 2022; Healy *et al*, 2024).

Social cohesion is a defining characteristic of the Head of the Lake, where residents frequently unite to achieve common goals and welcome newcomers (Healy *et al*, 2024). This strong sense of support, cooperation is key to resilience to natural hazards. Social cohesion helps foster networks that aid in adaptation and disasters preparations. It also promotes resource sharing, information exchange and collaboration during emergencies.

9.3.4.2 IN WHAT WAYS IS THE COMMUNITY VULNERABLE?

Healy (2024) noted that there are several sectors of the community that are particularly vulnerable to natural hazards. Namely, the high-needs population, elderly, young people and families, tourists/visitors, people with multiple, low-level, low-income jobs, and temporary workers.

The demands of living in the Head of the Lake requires a level of health and mobility. These demands are likely to increase in a natural hazard event, therefore those with a high level of physical or mental health needs and disability are likely to be vulnerable. There are currently relatively low levels of physical limitations and disability reported in the community (2.4%) (StatsNZ, 2023). However, research participants noted that mental health was as concerns for members of the community.

The Head of the Lake community is a small community and often people “wear many hats”. In a natural hazard event, these people would be susceptible to high levels of fatigue from trying to address both their household and community’s challenges.

The economy of Head of the Lake economy is driven largely by tourism, followed by hospitality and film production. This dependency leaves the community vulnerable to external fluctuations, such as visitor numbers, infrastructure, and natural resources. The impact of reduced visitor numbers causes large financial pressure on both the local economy and people’s livelihoods. Most businesses noted a dependency on roading and telecommunications for operations. Many businesses directly or indirectly depend on Head of the Lakes natural resources (e.g., mountains, lake, rivers, landscapes) for the operation of their businesses.

9.3.5 Glenorchy and Kinloch Natural Hazards Risk Analysis

Assessments were undertaken by Menke *et al* (2024) to better understand and characterise the natural hazards risks at Glenorchy (Tāhuna) and Kinloch.

The purpose of the risk analysis was to;

- Provide the head of Lake Whakatipu community with information on the relative levels of natural hazard risk in the township. This information was specifically requested by the community as feedback during community engagement sessions, and as feedback on behalf of the Glenorchy Community Association.
- To provide a robust evidence base for any future land use decision making, such as if avoidance approaches may be appropriate for higher-risk areas.
- To provide a greater risk understanding for identification and prioritisation of risks to assist adaptation or risk management activities.

The risk analysis made use of all natural hazards assessments previously completed, particularly the more detailed hazard analysis carried out for flooding hazards (Gardner, 2022; Gardner and Beagley, 2023; Beagley, 2024) and for liquefaction hazard at Glenorchy (T+T, 2022).

The analyses considered the risk to life and property from the following natural hazards:

- River flooding from Rees River, Dart River and Buckler Burn.
- Lake Whakatipu flooding
- Seismic shaking.
- Liquefaction and lateral spreading in earthquakes (Glenorchy only).

Risk was initially assessed qualitatively (descriptively), and then quantitatively (providing a numeric risk value) for those hazards warranting further assessment.

A short list of natural hazards potentially impacting Glenorchy and Kinloch was developed and agreed with ORC following a high-level review of hazards and community exposure, as well as suitability of available data to conduct risk analyses.

9.3.5.1 RISK ANALYSIS PROCESS

Qualitative and quantitative risk analyses have been completed for the short-listed natural hazards in accordance with the requirements set out by the proposed Otago Regional Policy

Statement (RPS) - Hearing Panel version (ORC, 2022), which has been notified but is subject to appeal[11]. The proposed RPS presents a framework for the assessment of natural hazards in Otago which considers the interaction between a hazard occurring (likelihood) and the effects on life and the built environment (consequence). The proposed RPS requires three scenarios to be considered for each hazard representing median likelihood, high likelihood, and maximum credible event. The approach uses the following relationship:

Risk = Hazard (likelihood) x Consequence

Risk is assessed for the following elements in accordance with (and using the same terminology as) the proposed RPS (ORC, 2022):

- Qualitative risk:
    1. Health and safety (injuries and death)
    2. Built environment
        - Buildings
        - Lifelines (essential infrastructure services e.g., water, transport, power, telecommunications)
- Quantitative risk:
    1. Life
    2. Property

Qualitative Risk Analysis Process

Qualitative risk analysis uses professional judgement and qualitative observations to evaluate the potential risks of each hazard against a range of prescribed consequence criteria. It is typically used where there is insufficient data for quantitative analysis or as a preliminary screening tool to determine whether quantitative analysis is required.

Qualitative risk is determined using a matrix of likelihood and consequences, as shown in Table 9-2. Each square corresponds to a different combination of likelihood and consequences. Green squares are *Acceptable* risk, yellow are *Tolerable* Risk and red are *Significant* risk.

[11] proposed RPS is subject to appeal, which means the provisions around natural hazards may change through mediation or hearing.

Table 9-2 Qualitative risk matrix from proposed RPS (Table 8).

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Green	Yellow	Yellow	Red	Red
Likely	Green	Green	Yellow	Yellow	Red
Possible	Green	Green	Yellow (example)	Yellow	Red
Unlikely	Green	Green	Green	Green	Yellow
Rare	Green	Green	Green	Green	Yellow
Green, Acceptable *Risk*: Yellow, Tolerable *Risk*: Red, Significant *Risk*					

Proposed RPS appendix (APP6) provides further guidance on how to assess likelihood and consequences of the selected natural hazard scenarios. Guidance on consequence includes descriptions of severity of impact (ranging from insignificant to catastrophic) for Health & Safety (deaths and injuries) and Built Environment (Social/Cultural, Buildings, Critical Buildings and Lifelines) and a list of other considerations.

First step is to determine the likelihood of a natural hazard scenario; second step is to determine the consequence; third step is to plot where they intersect in the Qualitative Risk Category matrix. For the example shown, a scenario with 'possible likelihood' and 'moderate consequences' gives a yellow 'Tolerable' risk category.

Quantitative Risk Analysis Process

Quantitative risk analyses allow for greater consideration of uncertainty and provides a numerical expression of risk for each hazard scenario. The output is natural hazard risk presented as an annualised probability.

The quantitative assessment of life risk considers the probability that an individual most at risk is killed in any one year as a result of the hazards occurring. This is termed the Annual Individual Fatality Risk (AIFR).

The quantitative assessment of property risk considers the probability of total property (i.e., building) loss in any one year as a result of the hazards occurring, and is termed the Annual Property Risk (APR). Total property loss occurs when the cost of repair exceeds the value of the property.

Quantitative risk (AIFR and APR) is calculated from the following equation:

Quantitative Risk = **Annual Probability** x **Spatial Probability** x **Temporal Probability** x **Vulnerability**

Where:

- The ***annual probability*** is the risk of the hazard occurring in any one year.
- The ***spatial probability*** relates to impact by the hazard in a specific location occupied by the person most at risk, or occupied by property.
- The temporal probability for
    a) ***life risk*** incorporates the proportion of the time the person most at risk is present and allowing for the possibility that the person may be able to evade the hazard.

b) ***property risk*** is 1.0 (i.e., the house or building is always present).

- The vulnerability for
  a) ***life risk*** is the probability of death of the person most at risk, in the event of an interaction with the hazard.
  b) ***property risk***, it is the vulnerability of the property to the damage, or the expected proportion of property value lost in the event of being impacted by the hazard (typically termed the damage ratio).

The assessment does not consider specific locations of people or buildings, and assumes they could be present anywhere across the study area, to allow for relative comparison of risk levels.

Quantitative risk levels are categorised in accordance with Table 9-3 following quantitative analysis. The defined risk levels apply to both life (AIFR) and property (APR), for existing developments.

Table 9-3 Quantitative risk levels in accordance with the proposed RPS (ORC, 2022).

Risk Category	Risk Value
Acceptable	Less than $1x10^{-5}$
Tolerable	$1x10^{-4}$ to $1x10^{-5}$
Significant	Greater than $1x10^{-4}$

9.3.5.2 RISK ANALYSES RESULTS

A summary showing the risk levels results are shown in Table 9-4. The qualitative analysis was used as a screening tool to identify risks that required further analysis, and these were carried forward to the quantitative analysis.

The qualitative analysis considered:

- All scenarios or scales of hazard,
- Any location within the study area, and
- All built environment sub-categories, where assessed (e.g., lifelines, buildings etc).

Qualitative analysis findings include some *Acceptable* and *Tolerable* risks that do not require further assessment:

- Lake Whakatipu flooding health and safety risk is *Acceptable* for all areas due to the slow speed that lake levels typically rise and the prolonged warning times.
- Seismic shaking health and safety risk is *Acceptable*, as the potential for collapse of the typical timber-framed building in Glenorchy and Kinloch is relatively low and would not necessarily lead to fatality or serious injury. Built environment risk is considered as *Tolerable* due to potential for structural damage of lifeline infrastructure, such as water supply wells. Predicted damage to buildings is considered to result in *Acceptable* levels of risk.
- Liquefaction and lateral spreading health and safety risk for Glenorchy is *Acceptable*, as this hazard generally does not cause death or injury.

Table 9-4 Summary of risk analysis findings (Menke et al, 2024)

Hazard	Qualitative Assessment		Quantitative Assessment	
	Health and Safety Risk	Built Environment Risk	Life Risk (AIFR)	Property Risk (APR)
River flooding – Buckler Burn	☑	☑	Acceptable	Significant
River flooding – Rees/Dart	☑	☑	Acceptable	Significant
River flooding – Joint (multiple sources)	n/a	n/a	Acceptable	Significant
Lake Whakatipu flooding	Acceptable	☑		Significant
Liquefaction and lateral spreading - Glenorchy	Acceptable	☑		Significant
Seismic shaking	Acceptable	Tolerable		

☑ risks carried forward for quantitative analysis

Acceptable and *Tolerable* risks that do not require further analysis

Other qualitative findings:

- Large Buckler Burn flood events are expected to flood Queenstown-Glenorchy Road, cutting off access to Glenorchy and Kinloch.
- Liquefaction is predicted to be widespread for Glenorchy, with lateral spread displacements up to 3m predicted along the shoreline. Such large displacements would lead to the development of both wide and frequent cracking of the ground sub-parallel to the lake edge and lateral stretch across buildings. Such ground displacements would lead to significant structural damage and potential for building collapse. Lifeline risk is also considered *Significant*.

On the basis of the qualitative results, the following **hazards were identified and carried forward to quantitative analysis**, as agreed with ORC:

- Buckler Burn flooding – life risk (AIFR) and property risk (APR)
- Rees/Dart flooding – life risk (AIFR) and property risk (APR)
- Joint flooding scenario – life risk (AIFR) and property risk (APR)
- Lake Whakatipu flooding – property risk (APR)
- Liquefaction and lateral spreading (Glenorchy) – property risk (APR)

Note, the 'joint flood' event is a modelled scenario where Buckler Burn, Dart/Rees Rivers, Bible Stream, and two small Glenorchy catchments flood at the same time. This was assessed during the quantitative analysis only due to the availability of additional flood modelling data.

The impacts of liquefaction in Kinloch were not assessed as there is insufficient data available to inform a risk assessment.

A summary of the quantitative analysis results are shown in Table 9-4 and discussed below. Quantitative risk levels are categorised in accordance with the proposed RPS defined risk levels for existing developments (Table 9-3).

Annual Individual Fatality Risk (AIFR) - River Flooding

Results of the river flooding life risk (AIFR) analysis are shown in Figure 9.14. Each map shows the combined risk, being the sum of risk from all three scenarios assessed for each hazard.

The risk to life (AIFR) from river flooding hazards has been assessed as *Acceptable* for developed areas in Glenorchy and Kinloch. The *Significant* effects of flooding are concentrated on the margins adjacent to the rivers and lake, and outside the developed areas. This lower level of risk is partly a function of the ability of people to evade slow rising floodwaters.

In Glenorchy, the primary river flooding risk come from flooding of the Rees/Dart Rivers. However, Buckler Burn also poses some risks within the township. The areas with the highest life risk (AIFR) are the Glenorchy lagoon, the lakefront (including Jetty Street and Benmore Place), and the Glenorchy golf course. Areas behind the floodbank, near the confluence of the Rees River and the lagoon, show the highest estimated AIFR values but are considered *Acceptable*.

The highest risks in Kinloch are also caused by Rees/Dart flooding. Existing buildings west of the Kinloch Road are in low flood risk areas. Areas east of the Kinloch Road have the highest life risk (AIFR) values but are still considered *Acceptable*.

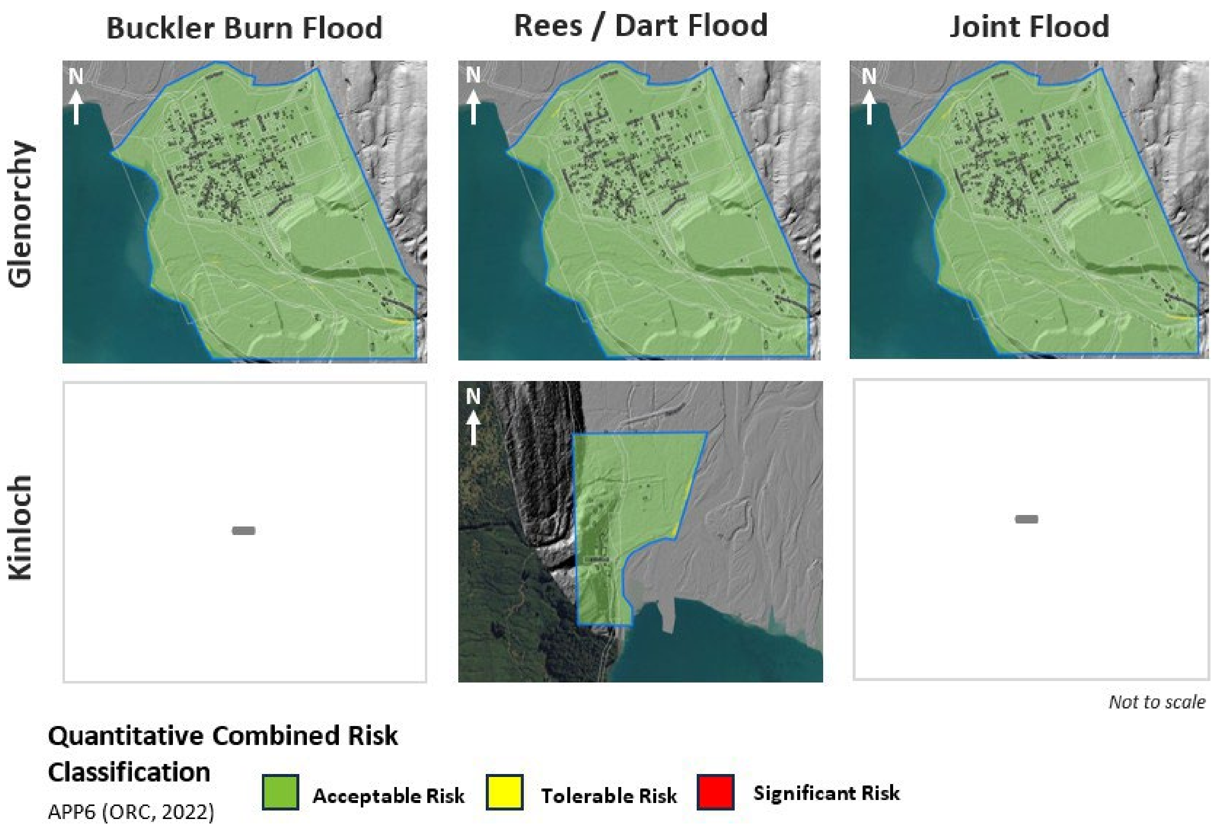

Figure 9.15 River flooding life risk (AIFR) levels

Annual Property Risk (APR) - River Flooding

Results of the combined river flooding annual property risk (APR) analysis are shown in Figure 9.15.

Quantitative property risk levels vary spatially between hazards, with the risk to property being *Significant* along the river and lake margins, and *Acceptable* outside of these areas. A large proportion of the land area that is most prone to flooding and within the *Significant* risk categorisation is used for community recreation and does not house a permanent population (including recreation reserve/parks and the golf course).

A Dart/Rees River flood poses the highest risks to property, having the highest APR values and the greatest extent of potential damage to property. In Glenorchy, this leads to potential damage around the lagoon and the Rees River mouth, with the highest property risk (APR) values on the golf course, in areas of *Significant* risk. In Kinloch a Rees/Dart River flood could potentially damage areas to the east of Kinloch Rd with APR calculated to be *Significant*.

The potential damage caused by the Buckler Burn is limited to a few areas within its modelled overland flow path along the Glenorchy-Queenstown Road and Shield Street. Overall, the Buckler Burn has low property risk (APR values) and a small flood extent within the township area. Consequently, the additional damage caused by flooding from the Glenorchy catchments and the Buckler Burn in a joint flood scenario is minimal. The joint flooding scenario shows higher property risk (APR) values along Coll Street and the Glenorchy Cemetery, resulting in areas of *Significant* risk.

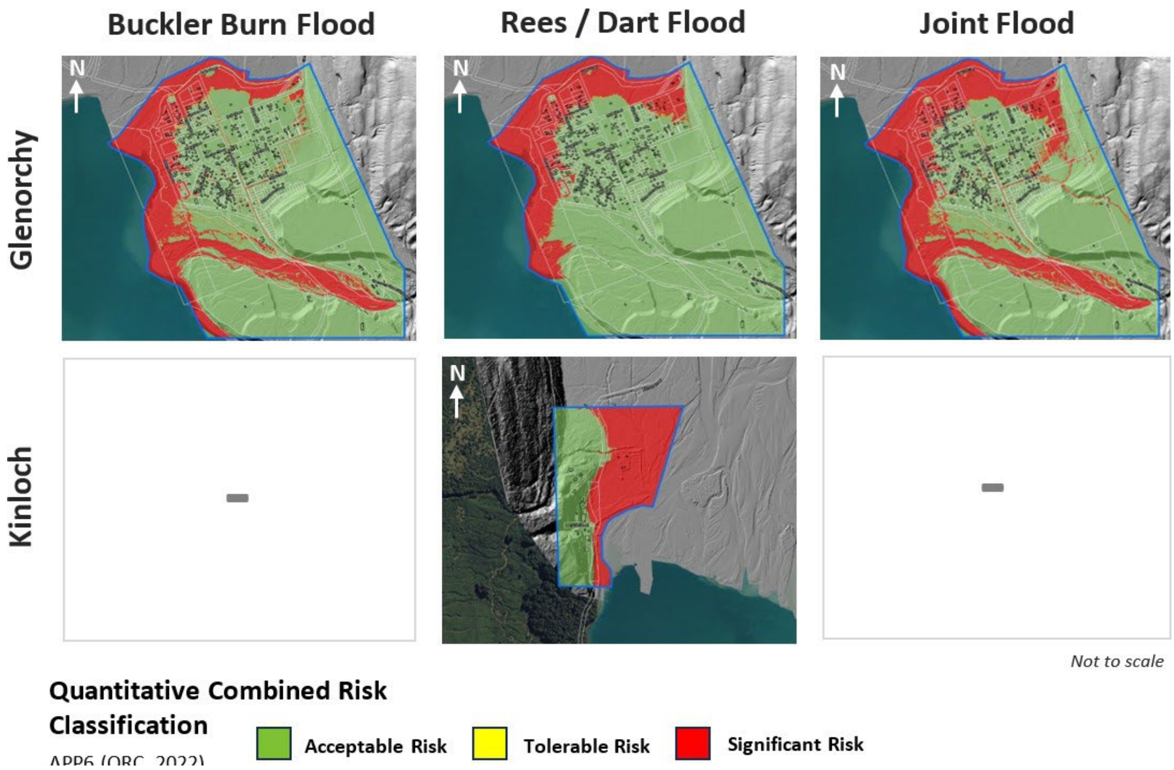

Figure 9.16 River flooding property risk (APR) levels.

Annual Property Risk (APR) - Lake Flooding

Results of the lake flooding property risk (APR) analysis are shown in Figure 9.16. Quantitative property risk levels show areas of *Significant* risk along the lake front at both Glenorchy and Kinloch, and the Rees River margin in Glenorchy.

The level of damage caused by a lake flood follows the topography of Glenorchy and Kinloch. The low-lying areas along the Rees lagoon and the lake are the areas most affected (e.g. Jetty Street and Butement Street). In Kinloch, APR values on Kinloch Road equate to a *Significant* risk.

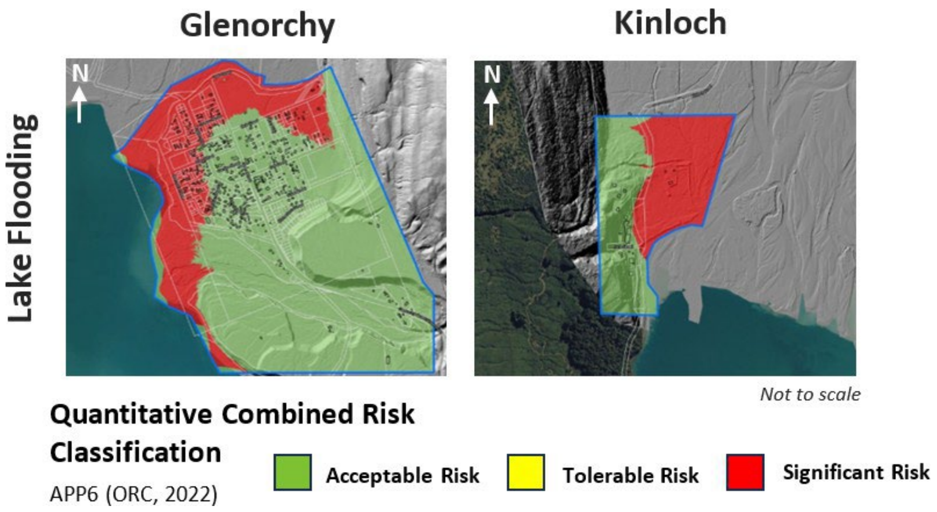

Figure 9.17 Lake flooding property risk (APR) levels.

Annual Property Risk (APR) - Liquefaction and Lateral Spread

Results of the liquefaction and lateral spread property risk (APR) analysis for Glenorchy are shown in Figure 9.17. Quantitative property risk levels from liquefaction and lateral spread are *Significant* for the whole of Glenorchy township.

The hazards that affect the greatest area to the built environment in Glenorchy are liquefaction and lateral spread-inducing land damage affecting property. While damage associated with liquefaction is expected to be substantial, lateral spreading is anticipated to result in the most significant damage focused along the lake margins, due to an approximately 25m high free face (where the land is not physically constrained and extends down to the lake bed).

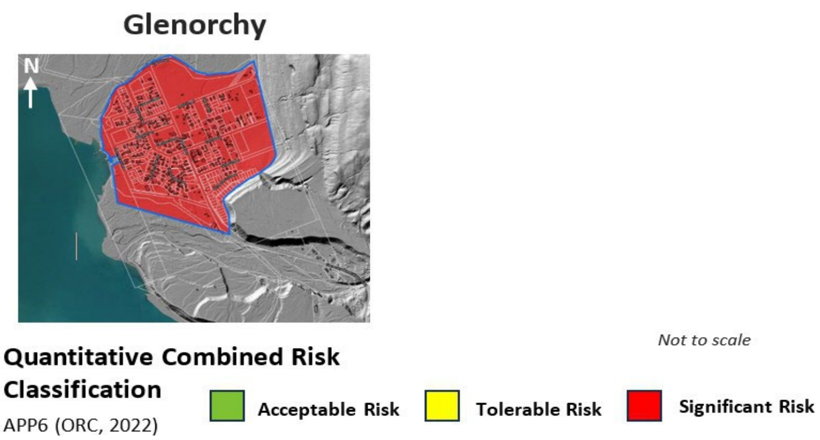

Figure 9.18 Liquefaction and lateral spread property risk (APR) levels

9.3.6 Risk Tolerability

Risk to property (APR) from flooding and liquefaction hazards exceeds the Tolerable threshold listed in the proposed RPS (ORC, 2022) in parts of both Kinloch and Glenorchy. It is noted in the proposed RPS that it is ultimately the responsibility of local authorities (i.e. both ORC and QLDC) to undertake a consultation process with communities, stakeholders and partners regarding risk level thresholds. The Action Plan (Section 10) outlines next steps for ORC and QLDC.

How much risk is tolerable?

Toka Tū Ake Natural Hazards Commission (2023) notes that 'once we understand a risk, we must consider whether we are willing to tolerate the consequences', and offers guidance on assessing tolerance to risk, as shown in Figure 9.18.

T+T (2023) makes the following points about risk tolerability and liquefaction hazard management:

- Before discussing potential options for managing liquefaction hazard, it is useful to ask the question "how much risk is tolerable". This helps to set a benchmark level of performance that the various different options can be compared against.
- When it comes to natural hazards risk management and adaptation planning, there are no fixed rules about exactly how much risk is tolerable. Rather than being a purely technical engineering or legal question, this becomes a balance between costs and benefits, recognising that communities have many other objectives in addition to managing natural hazards. Finding the balance that best suits a particular situation requires a collaborative approach including the community, stakeholders, technical experts and decision-makers. To help with these discussions, Table 9-5 includes various factors that may be relevant when deciding how much liquefaction-related risk is tolerable.
- "Residual risk" is the risk that remains even after all adopted risk management measures are implemented. It is usually not practical or affordable to completely eliminate all risks. One of the goals of risk management is to find the point where the residual risk is reduced to a level which is acceptable, or the point of "diminishing returns" where further investment in risk management measures does not give a worthwhile reduction in the overall level of residual risk.

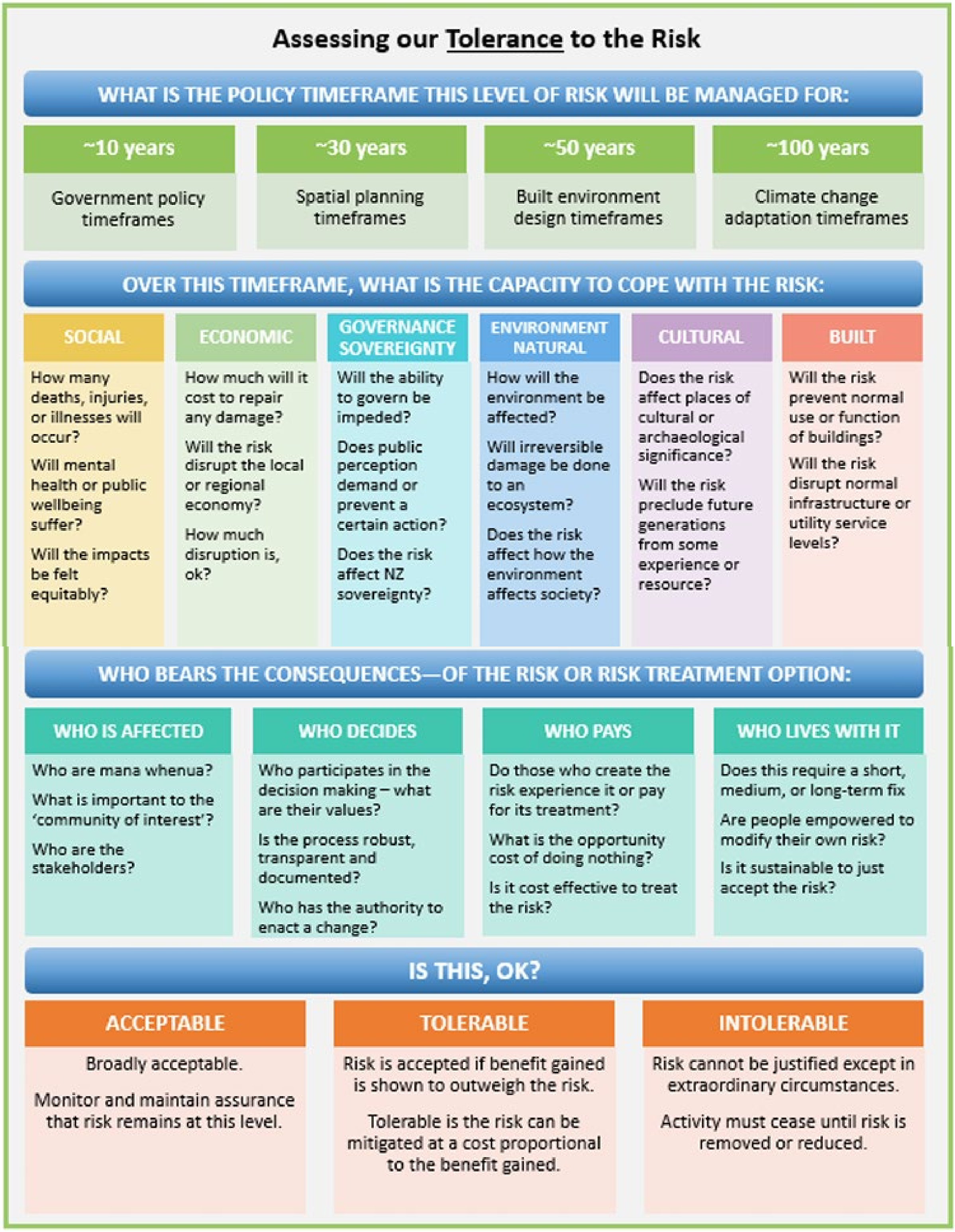

Figure 9.19 Assessment of Risk Tolerance (Toka Tū Ake Natural Hazards Commission, 2023)

Table 9-5 Relevant factors when deciding how much liquefaction-related risk is tolerable (T+T 2023)

Factor	Comments
Life safety during an earthquake	Lateral spreading damage to buildings is the main life safety concern related to liquefaction. While there were no deaths caused by lateral spreading in the 2010 – 2011 Canterbury Earthquakes, this was more a matter of good luck rather than good design – if the shaking had been stronger or longer then building collapse could have occurred.
Habitability in the days and weeks after an earthquake	If buildings are severely damaged, it may not be possible to use them after the earthquake so people would need alternative accommodation. Damage to electricity, water supply, stormwater and sewer networks would also impact on habitability, potentially for many months (or longer) after the earthquake. These issues could be worsened if earthquake damage cuts off the only road in and out of the town.
Long term recovery after an earthquake	While it is the most severe damage which often attracts most attention immediately after an earthquake, a more significant issue for long term recovery can sometimes be the minor and moderate damage (as it can be much more extensive). While it may be possible to continue living with this damage until it is eventually repaired, there can be far-reaching economic, social and environmental consequences.
Other hazards	Some locations may also be exposed to other hazards (e.g. flood) and cascading hazards (e.g. liquefaction settlement leaves building more flood-prone).
Building Act	All building work must comply with the Building Code regardless of whether a building consent is required, and irrespective of whether it is to construct a new building or to repair or alter an existing building. In the case of alterations or repairs it is only the new work that must comply with the current Building Code. If existing parts of the building do not comply, then the main requirement (with some exceptions) is that the alterations or repairs do not result in the building complying with the Building Code to a lesser extent than before. The Building Act requires councils to refuse building consent if the land is likely to be subject to natural hazards, unless adequate steps are taken to protect against the hazard. However, the Act provides a specific list of hazards that this applies to, and it is unclear whether this includes earthquakes and liquefaction. Nonetheless, it is useful to note that the test of whether a hazard is considered “likely” has been defined as a “100 year” event (which has a 40% chance of occurring over the next 50 years).
Building Code minimum requirements	For most “normal” buildings (and other structures) the Building Code mandates minimum acceptable performance for two earthquake scenarios: The Serviceability Limit State (SLS) is assessed for “25 year” earthquake shaking levels (a 90% chance of occurring over the next 50 years). The building should suffer little or no structural damage and remain accessible and safe to occupy. There may be minor damage to building fabric that is readily repairable. The Ultimate Limit State (ULS) is assessed for “500 year” earthquake shaking levels (a 10% chance of occurring over the next 50 years). The building is expected to suffer moderate to significant structural damage (which might not be repairable), but not to collapse.
Resource Management Act (RMA)	The RMA identifies management of significant risks from natural hazards as a matter of national importance, which means it needs to be considered at all levels of planning and decision-making. The RMA also gives councils power to refuse or place conditions on subdivision consents where there is a significant natural hazard risk.

Factor	Comments
Insurance and mortgages	Insurers each make their own decisions about natural disaster risk, often balancing many different factors. The availability and cost of insurance is subject to these decisions. In Aotearoa New Zealand there is an increasing trend of insurers moving toward more “risk-based” pricing where specific attributes (such as location and presence of hazards) are taken into account in both deciding whether to offer cover, and in determining the cost of providing that cover. Following the Christchurch earthquakes, most insurers adopted an approach where new dwellings would be provided insurance cover on the basis that compliance with the Resource Management Act and Building Act/Code largely provided mitigation of the hazards potentially affecting the dwelling. In general, insurers were more concerned with existing dwellings on land that was revealed to be both liquefaction and flood prone, as there was little opportunity to mitigate the hazards for existing buildings. In the past banks have typically provided mortgage lending as long as insurance was in place, however in future banks may also undertake their own independent assessment of natural hazard risk before offering lending.
Chance of an earthquake occurring	The T+T May 2022 liquefaction assessment report concluded that significant damage due to liquefaction and lateral spreading could be expected at a “50 to 100 year” level of earthquake shaking (a 40 – 60% chance of occurring over the next 50 years). The Alpine Fault is particularly relevant, as it passes relatively close to Glenorchy (55km at its nearest point). There is a 75% chance of a large earthquake occurring on the Alpine Fault within the next 50 years. It is likely that a large Alpine Fault earthquake would cause significant liquefaction and lateral spreading damage in Glenorchy, however there is some uncertainty in the severity and extent of damage that could occur.
Type of land use activity	There are many different ways that land can be used, such as for housing, commercial activity, infrastructure, recreation, environmental purposes etc. Because each of these different land uses has different consequences if damaged in an earthquake, they each have different risk profiles. This means that a particular degree of liquefaction-induced damage might be tolerable for some types of land uses but not for others.

9.4 Phase 3: What can we do about it?

The natural hazard challenges at Head of Lake Whakatipu are complex and there is no simple solution. The community has a long history of 'living with the hazards' and adapting along the way, and this approach will continue to be necessary. This section of the Strategy focuses on identification and high-level evaluation of responses (Figure 9.19).

There are a variety of existing and possible future responses that offer potential benefits for adaptation. One framework for understanding some of these responses is: Protect, Accommodate, Retreat, Avoid (PARA) (Figure 9.20).

Figure 9.20 "What can we do about it?" Steps 5 & 6 of the adaptation cycle (modified from MfE 2024).

PROTECT - Refers to engineering works to mitigate the threat of erosion and flooding. Protection options may be "soft" or "hard". Soft measures may include 'enhancing' natural defences through gravel and vegetation management, and stabilisation via planting. Hard measures may include rock armouring, improving existing flood banks, or constructing new flood banks.

ACCOMMODATE - Refers to accommodating ("living with") the hazards and changes. Responses focus on reducing impacts (e.g., retrofitting buildings, raising floor levels) and maintaining natural defences (e.g. wetland function and "room for the river"). Emergency readiness, response and recovery are also a key component.

RETREAT / RELOCATION - Refers to a process of withdrawal from a location when the risk associated with staying becomes intolerable. This could require a change in planning practices and the relocation of public infrastructure and private assets. May provide space for nature to roll back. Retreat can also be a reaction to a hazard event with intolerable outcomes (e.g. red-zoning).

AVOID - Refers to identifying future areas that are suitable to build, and using planning tools to prevent inappropriate, new (or infill) development in a higher hazard zone. Appropriate or adapted development may be possible.

Figure 9.21 The PARA framework; Protect, Accommodate, Retreat, Avoid (MfE, 2023).

At a high level, Phase 3 involved the following steps:

a) Identify a range of possible responses, including crowdsourced ideas from community and local knowledge,
b) Screen out responses that are not technically feasible,
c) Develop a ‘long-list’ of adaptation responses; including existing and planned responses, and a future toolbox with both standard ways to manage hazards, and innovative ideas,
d) Community engagement on the long-list,
e) High-level socio-economic screening and mana whenua assessment of possible responses,
f) Technical evaluation of some responses (i.e. potential responses for liquefaction management and floodplain management).

9.4.1 Identify a range of possible responses

9.4.1.1 LOCAL KNOWLEDGE AND COMMUNITY INSIGHTS

We have heard many ideas, insights and observations from the community about what we can do to adapt to natural hazard challenges and impacts of a changing climate in the Head of Lake Whakatipu area. Thank you to community members for sharing. Appendix B Table 13-2 collates the ideas and comments on how they were considered further.

Community feedback on possible responses can be grouped in the following general themes:

- Responses that provided more natural solutions such as wetlands, trees and greenspace were liked for their wider benefits to the community.
- Large-scale, engineered responses to manage liquefaction and lateral spreading hazards were not preferred due to their cost, and residual risk.
- Significant interest in emergency readiness and response, including community-led action.
- Combination of responses working together.
- Consideration of cost, who will pay for the response and what impact would it have on the individual property owner and the ratepayer in terms of rates increases.
- Generally, people expressed that people living in the area had a high-level of tolerance to flood risk. But that there were more vulnerable parts of the community with lower risk tolerances, and that the community would still need support in response and recovery to a disaster.
- Retreat was largely considered as a long-term future action, with some opposition to this response as they believe Glenorchy township is worth protection.
- There is a lack of clarity about roles and responsibilities for implementation of any potential managed retreat, and what a proactive or reactive retreat process could look like. People would like further clarity to be able to give more meaningful feedback on this option and how to ensure it is a fair and equitable process for community.

9.4.1.2 LONG LIST OF RESPONSES

After screening, sorting and collating ideas there is a long list of responses (Table 9-6) which includes 13 existing responses, and a future toolbox of 24 responses that might be useful when we face future challenges.

Table 9-6 Long list of responses (October 2024).

CATEGORY	EXISTING OR FUTURE TOOLBOX?	LONG LIST OF RESPONSES (OCTOBER 2024)	TYPE OF RESPONSE	CURRENT AREA OF RESPONSIBILTY	WHAT IS THE MAIN OBJECTIVE OF THE RESPONSE?
Hazard awareness and mitigation	Existing **	Societal, behavioural, and institutional changes (improve over time) when considering natural hazards and changes to the physical environment	Accommodate	Everyone	Support awareness and informed decision-making
	Future Toolbox **	➢ Review and accept residual risk for existing development	Accommodate	ORC, QLDC, community	Informed decision-making
	Existing	Emergency readiness and response (improve over time)	Accommodate	CDEM, ORC, QLDC, community	All hazards emergency response
Road access	Existing	Maintenance, reactive repair and planned works for the Glenorchy-Queenstown Road	Accommodate / protect	QLDC	Maintain resilience of regional road access to flood, erosion and alluvial fan hazards
	Existing	Maintenance, reactive repair and planned works for the Kinloch and Glenorchy-Paradise local road system	Accommodate / protect	QLDC	Maintain resilience of local road access to flood, erosion and alluvial fan hazards
	Future Toolbox	➢ Small scale improvement to existing Kinloch and Glenorchy-Paradise local road system road (as well as maintenance and reactive repair)	Accommodate / protect	QLDC	Reduce impacts of flood, erosion and alluvial fan hazards on local road access
	Future Toolbox	➢ Reduced level of service of existing Kinloch and Glenorchy-Paradise local road system (e.g. some parts 4WD only)	Accommodate	QLDC	Maintain local road access at a lower level of service
	Future Toolbox	➢ Major works to increase resilience of Kinloch and Glenorchy-Paradise local road system (e.g. protect, raise, realign)	Protect	QLDC	Reduce impacts of flood, erosion and alluvial fan hazards on local road access
	Future Toolbox	➢ Reactive re-design Kinloch and Glenorchy-Paradise local road system for changed conditions (e.g. post event)	Protect	QLDC	Post-event replacement to restore local road access
Boat access	Existing	Existing boat access at Kinloch and Glenorchy (limited by existing and ongoing sediment accumulation)	Accommodate	QLDC	Maintain alternative access
	Future Toolbox	➢ Short-term improvements to existing boat access (e.g dredging)	Accommodate	QLDC	Improve alternative access
	Future Toolbox	➢ Upgrade boat access with resilient solution (e.g. relocatable wharfs)	Protect	QLDC	Provide alternative access with higher level of service
	Future Toolbox	➢ Relocate wharfs periodically to maintain future access	Protect	QLDC	Maintain alternative access with higher level of service
Flood mitigation and protection	Existing	Maintain the flood monitoring network (rainfall and water level stations) and flood data history	Accommodate	ORC	Flood hazard readiness and emergency response
	Existing	Flood monitoring, forecasting and warning (improve over time)	Accommodate	ORC	Flood hazard emergency response
	Existing	Existing low level Rees River flood protection by Glenorchy floodbank (maintenance and reactive repair)	Protect	QLDC	Maintain existing Rees River flood protection
	Future Toolbox	➢ Small scale improvements to Glenorchy floodbank to maintain/reduce flood risk	Protect	QLDC	Increase resilience of Rees River flood protection
	Future Toolbox	➢ Major works to increase level of service of Glenorchy floodbank	Protect	QLDC	Reduce impacts of Rees River flood hazard on Glenorchy township
	Future Toolbox	➢ Redesign Rees flood protection for changed conditions (e.g. post event)	Protect	ORC, QLDC	Post-event replacement to restore protection
	Existing	Existing river management (vegetation and gravel)	Accommodate	ORC, QLDC	Maintain resilience to flood, erosion and alluvial fan hazards
	Future Toolbox	➢ River management and nature-based interventions (e.g. targeted planting)	Accommodate	ORC	Reduce impacts of flood, erosion and alluvial fan hazards
	Future Toolbox	➢ Redesign nature-based interventions for changed conditions	Accommodate	ORC	Post-event replacement
	Future Toolbox	➢ Small scale works to reduce Buckler Burn erosion and/or flood risk	Protect	ORC	Reduce impacts of Buckler Burn flood, erosion and alluvial fan hazards
Public asset resilience	Future Toolbox	➢ Improve resilience of critical assets in higher hazard areas (such as floodproofing, floor raising, ground or structure strengthening, retrofit, move elsewhere)	Accommodate	Asset owner	Reduce impacts on critical assets
Community-wide resilience (public and private)	Future Toolbox	➢ Community-wide improvement works for liquefaction hazard (such as ground improvement and strengthening existing buildings).	Accommodate	Not defined	Reduce impacts from seismic hazards on Glenorchy township
Private property resilience	Existing	Household emergency planning	Accommodate	Household	Reduce impacts on existing development
	Existing	Property and business insurance (adjust coverage as needed)	Accommodate	Property/business owner	Support recovery
	Future Toolbox	➢ Improve property and land resilience (such as floodproofing, floor raising, ground or structure strengthening)	Accommodate	Property owner	Reduce impacts on existing development
	Existing	Consider local risk and hazard information when property decisions are required (e.g. buying/selling) are required	Accommodate	Property owner	Informed decision-making

CATEGORY	EXISTING OR FUTURE TOOLBOX?	LONG LIST OF RESPONSES (OCTOBER 2024)	TYPE OF RESPONSE	CURRENT AREA OF RESPONSIBILTY	WHAT IS THE MAIN OBJECTIVE OF THE RESPONSE?
Policy	Existing	Policy - Existing land use zoning, rules and building controls	Accommodate	ORC, QLDC	Reduce impacts on future development
	Future Toolbox **	➢ Policy – Review hazard and risk information and set appropriate requirements for new development	Accommodate	ORC, QLDC	Reduce impacts on future development
	Future Toolbox	➢ Policy - Strengthen land use controls in higher hazard areas to avoid additional exposure	Avoid	ORC, QLDC	Avoid impacts on future development
	Future Toolbox	➢ Policy and services – identify and make available lower hazard land for new building and/or relocation	Avoid	QLDC	Avoid impacts on future development
	Future Toolbox	➢ Recovery plan improvement	Accommodate	CDEM, QLDC, community	Support effective recovery
	Future Toolbox	➢ Proactive relocation plan	Retreat	Not defined	Support effective relocation
	Future Toolbox	➢ Voluntary proactive relocation from higher hazard areas	Retreat	Not defined	Avoid / reduce impacts on existing community (by relocating before an event)
	Future Toolbox	➢ Voluntary reactive post event retreat from higher hazard areas	Retreat	Multi-agency, property owners	Avoid repeat impacts

** Three additional responses have been added to the long list since March 2024 (when it was shared with Aukaha for mana whenua assessment and Beca for Phase 2 socio-economic impact assessment)

9.4.2 Evaluate possible responses and pathways

9.4.2.1 HIGH LEVEL EVALUATION

The Coastal Hazard Guidance (MfE 2024) identifies factors that to consider in evaluating responses, depending on the objectives and level of evaluation effort.

At this early stage it is useful to have a high level evaluation as a basis for further discussion. The following high level evaluation criteria provide a way to compare and contrast the responses in Table 9-7:

- Effectiveness to reduce risk (or achieve main objective)
- Scale of cost
- Complexity to implement
- Timeframe to implement (after decision)
- Impact on social resilience and adaptive capacity

Head of Lake Whakatipu Social & Economic Impact Assessment - Phase 2: *Social & Economic Impact Assessment of Existing and Future Potential Natural Hazard Adaptation Responses* was used to inform the evaluation. Healy *et al* (2024) notes that the existing adaptation responses in the Head of the Lake are likely to have a large, positive impact on social resilience and adaptive capacity. This is because they address multiple vulnerabilities (e.g., resilience of access, household readiness) and hazards (e.g., flooding, earthquakes).

- Phase 1 (Healy *et al,* 2024) identified the importance of access to the wider community, both in terms of access to/from Queenstown, and around and within the community. Existing responses to maintain and repair the Glenorchy-Queenstown Road, local road system, and boat access are therefore likely to have a large positive impact on the resilience and adaptive capacity of the community. Access to recreation, education, employment, goods, services, and consumers of goods and services (i.e., to support local businesses), supports the social and economic wellbeing of the community. A resilient connection between Queenstown and the Head of the Lake may also increase the resilience and adaptive capacity of the Otago Region, by enabling economic activity in the Head of the Lake to recover quickly following a natural hazard event.
- The impact of road and boat access on resilience and adaptive capacity is further enhanced by existing responses to reduce exposure to natural hazards, such as flood monitoring and protection and building controls in high hazard areas, as well as measures to improve the resilience of critical public building assets (e.g., community facilities). Household-level responses such as property insurance and household emergency planning also contribute to overall resilience and adaptive capacity, as households that are prepared are likely to reduce strain on community resources during and after an event.
- Whilst the existing responses are likely to have a large, positive impact on social resilience and adaptive capacity, a high level of risk still remains, and certain groups have been identified as more vulnerable than others.

Healy *et al* (2024) assessed the future responses for potential impact on social resilience and adaptive capacity (Table 9-7).

Table 9-7 High level evaluation of responses (October 2024).

Category	Existing or Future Toolbox?	Long list of responses (October 2024)	What is the main objective of the response?	Scale of effectiveness	Scale of cost	Scale of complexity	Timeframe to implement (after decision)	Impact on social resilience and adaptive capacity
Hazard awareness and mitigation	Existing **	Societal, behavioural, and institutional changes (improve over time) when considering natural hazards and changes to the physical environment	Support awareness and informed decision-making	★	$	medium		
	Future Toolbox **	➢ Review and accept residual risk for existing development	Informed decision-making	★	$	low	1 year	
	Existing	Emergency readiness and response (improve over time)	All hazards emergency response	★	$	low		
Road access	Existing	Maintenance, reactive repair and planned works for the Glenorchy-Queenstown Road	Maintain resilience of regional road access to flood, erosion and alluvial fan hazards	★★★	$ $	low		
	Existing	Maintenance, reactive repair and planned works for the Kinloch and Glenorchy-Paradise local road system	Maintain resilience of local road access to flood, erosion and alluvial fan hazards	★	$ $	low		
	Future Toolbox	➢ Small scale improvement to existing Kinloch and Glenorchy-Paradise local road system road (as well as maintenance and reactive repair)	Reduce impacts of flood, erosion and alluvial fan hazards on local road access	★	$ $ $	low	3+ year	Minor improvement
	Future Toolbox	➢ Reduced level of service of existing Kinloch and Glenorchy-Paradise local road system (e.g. some parts 4WD only)	Reduce cost by maintaining local road access at a lower level of service	★	$	low	1 year	Moderate negative
	Future Toolbox	➢ Major works to increase resilience of Kinloch and Glenorchy-Paradise local road system (e.g. protect, raise, realign)	Reduce impacts of flood, erosion and alluvial fan hazards on local road access	★★	$ $ $	medium	5+ year	Major improvement
	Future Toolbox	➢ Reactive re-design Kinloch and Glenorchy-Paradise local road system for changed conditions (e.g. post event)	Post-event replacement to restore local road access	★★	$ $ $ $	medium	5+ years	Moderate improvement
Boat access	Existing	Existing boat access at Kinloch and Glenorchy (limited by existing and ongoing sediment accumulation)	Maintain alternative access	★	$	low		
	Future Toolbox	➢ Short-term improvements to existing boat access (e.g dredging)	Improve alternative access	★	$ $	medium	3+ year	Minor improvement
	Future Toolbox	➢ Upgrade boat access with resilient solution (e.g. relocatable wharfs)	Provide alternative access with higher level of service	★★★	$ $	medium	5+ years	Moderate improvement
	Future Toolbox	➢ Relocate wharfs periodically to maintain future access	Maintain alternative access with higher level of service	★★★	$ $	medium	5+ years	Minor improvement
Flood mitigation and protection	Existing	Maintain the flood monitoring network (rainfall and water level stations) and flood data history	Flood hazard readiness and emergency response	★	$ $	low		
	Existing	Flood monitoring, forecasting and warning (improve over time)	Flood hazard emergency response	★	$ $	low		
	Existing	Existing low level Rees River flood protection by Glenorchy floodbank (maintenance and reactive repair)	Maintain existing Rees River flood protection	★	$	low		
	Future Toolbox	➢ Small scale improvements to Glenorchy floodbank to maintain/reduce flood risk	Increase resilience of Rees River flood protection	★	$	low	3+ years	Minor improvement
	Future Toolbox	➢ Major works to increase level of service of Glenorchy floodbank	Reduce impacts of Rees River flood hazard on Glenorchy township	★★	$ $ $	medium	5+ years	Moderate improvement
	Future Toolbox	➢ Redesign Rees flood protection for changed conditions (e.g. post event)	Post-event replacement to restore protection	★★	$ $ $	medium	5+ years	Minor improvement
	Existing	Existing river management (vegetation and gravel)	Maintain resilience to flood, erosion and alluvial fan hazards	★	$	low		
	Future Toolbox	➢ River management and nature-based interventions (e.g. targeted planting)	Reduce impacts of flood, erosion and alluvial fan hazards	★	$	low	3+ years	Minor improvement
	Future Toolbox	➢ Redesign nature-based interventions for changed conditions	Post-event replacement	★	$ $	low	3+ years	Minor improvement
	Future Toolbox	➢ Small scale works to reduce Buckler Burn erosion and/or flood risk	Reduce impacts of Buckler Burn flood, erosion and alluvial fan hazards	★★	$	low	3+ years	Minor improvement
Public asset resilience	Future Toolbox	➢ Improve resilience of critical assets in higher hazard areas (such as floodproofing, floor raising, ground or structure strengthening, retrofit, move elsewhere)	Reduce impacts on critical assets	★★	$	low to medium	3+ years	Moderate improvement
Community-wide resilience (public and private)	Future Toolbox	➢ Community-wide improvement works for liquefaction hazard (such as ground improvement and strengthening existing buildings).	Reduce impacts from seismic hazards on Glenorchy township	★★	$ $ $ to $ $ $ $	high	10+ years	Minor improvement
Private property resilience	Existing	Household emergency planning	Reduce impacts on existing development	★	$	low		
	Existing	Property and business insurance (adjust coverage as needed)	Support recovery	★	$	low		
	Future Toolbox	➢ Improve property and land resilience (such as floodproofing, floor raising, ground or structure strengthening)	Reduce impacts on existing development	★	$	low to medium	3+ years	Moderate improvement
	Existing	Consider local risk and hazard information when property decisions are required (e.g. buying/selling) are required	Informed decision-making	★	$	low		

Category	Existing or Future Toolbox?	Long list of responses (October 2024)	What is the main objective of the response?	Scale of effectiveness	Scale of cost	Scale of complexity	Timeframe to implement (after decision)	Impact on social resilience and adaptive capacity
Policy	Existing	Policy - Existing land use zoning, rules and building controls	Reduce impacts on future development	★	$	low		
	Future Toolbox **	➢ Policy – Review hazard and risk information and set appropriate requirements for new development	Reduce impacts on future development	★	$	low	3+ years	Minor improvement
	Future Toolbox	➢ Policy – Strengthen land use controls in higher hazard areas to avoid additional exposure	Avoid impacts on future development	★★	$	medium	5+ years	Minor improvement
	Future Toolbox	➢ Policy and services – identify and make available lower hazard land for new building and/or relocation	Avoid impacts on future development	★★	$ $	medium	5+ years	Minor improvement
	Future Toolbox	➢ Recovery plan improvement	Support effective recovery	★	$ $	medium	3+ years	Minor improvement
	Future Toolbox	➢ Proactive relocation plan	Support effective relocation	★	$ $	medium	3+ years	Minor improvement
	Future Toolbox	➢ Voluntary proactive relocation from higher hazard areas	Avoid / reduce impacts on existing community (by relocating before an event)	★★★	$ $ $	high	10+ years	Moderate improvement
	Future Toolbox	➢ Voluntary reactive post event retreat from higher hazard areas	Avoid repeat impacts	★★★	$ $ $ $	high	3+ years	Minor improvement

Notes:

** Three additional responses have been added to the long list since March 2024 (when it was shared with Aukaha for mana whenua assessment and Beca for Phase 2 socio-economic impact assessment)

Scale of effectiveness – more stars indicates greater effectiveness at reducing risk (or achieving the main objective)

Scale of cost (10-year CAPEX & OPEX) – scale is non-linear: '$' less than one million, '$$' millions, '$$$' tens of millions, '$$$$ 'more than fifty million, typically based on high level relative estimates (Healy *et al* 2024).

9.4.2.2 HEAD OF LAKE WHAKATIPU WAIMĀORI MANA WHENUA ASSESSMENT

Aukaha carried out a Mana Whenua assessment of an early draft long list[12] of 34 possible responses for Head of Lake Whakatipu Waimāori adaptation (Aukaha 2024).

Sites of Cultural Significance

The approximate area within scope for the ORC project includes a number of wāhi tupuna, wāhi tapu and wāhi taoka, including:

- over 20 archaeological sites (Pā, terraces, ovens, middens, pits, tauraka waka, cave shelters, artefacts),
- two Ara Tūpuna (Tarahaka-Whakatipu, Greenstone River),
- two statutory acknowledgement areas (Whakatipu-wai-māori, Pikirakatahi),
- the wāhi and awa labelled on Figure 5.1.

Analysis of responses

The 34 hazard responses considered by ORC were grouped into the categories shown to the right of Figure 9.21. The relevant mana whenua guiding principles identified by Aukaha are shown on the left.

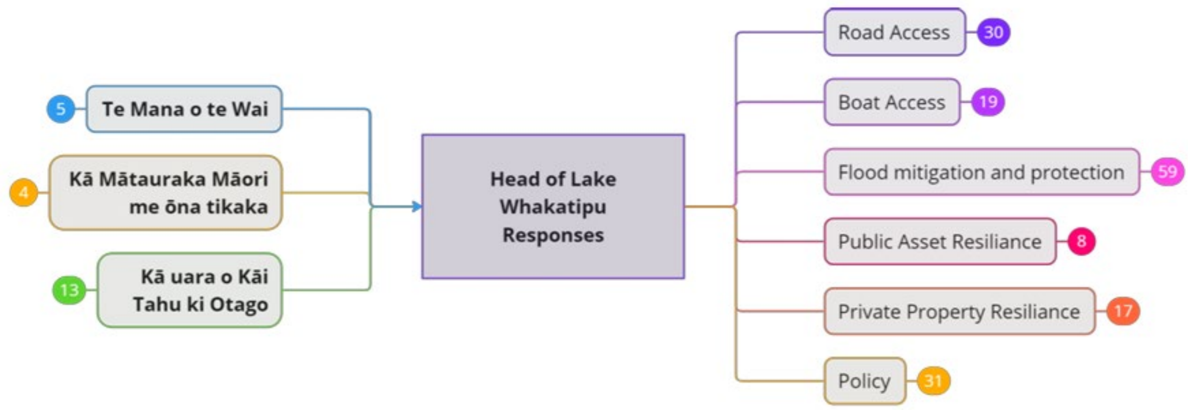

Figure 9.22 Mana whenua principles (left) and ORC adaptation response categories (right) related to the project.[13]

Each response was scored based on its alignment to the mana whenua values, policies, and objectives from the KTKO NRMP 2005, mātauraka Māori and associated tikaka, and with the principles laid out in Te Mana o Te Wai. The scoring favoured responses which allowed for mana whenua to maintain rakatiratаka and kaitiakitaka, and which abided by the tribal pepeha: mō tātou, ā, mō kā uri a muri ake nei. Scoring factored in the implications of each response on Wāhi Tūpuna, Wāhi Taoka, and Ara Tawhito, including accessibility and preservation of these culturally significant sites. Comments and provisos were made about each individual response, and these

[12] The current long-list includes 3 additional responses that were not on the early list

[13] The numbered balloons in Figure 9.21 represent how many pieces of information are associated with each of the broader categories. These include all responses, response scores, supporting details, and justifications for scoring.

were then considered holistically to give an overall score between -3 and +3. The scoring scale is detailed below, with respect to the mana whenua guiding principles.

-3: Strongly misaligned w/	-2: Moderately misaligned w/	-1: Somewhat misaligned w/	0: Unrelated to	+1: Somewhat aligned w/	+2: Moderately aligned w/	+3: Strongly aligned w/

After analysing all the responses, the following themes were observed across them. The number shown in brackets after each theme indicates that it relates to a specific policy, objective or issue in the KTKO NRMP 2005. These numbers are further referenced below in Table 9-8.

A response which **scored poorly** tended to:

- Consider habitat factors narrowly (1.5-)
- Favour structures which are located close to mahika kai or areas of dynamic river/ coastal processes (3.1-)
- Favour structures to be built right next to river or coastal margins (3.2-)
- Rely on structures and system designs that are no longer fit for purpose (3.5-)
- Promote channel straightening and subsequent flow changes (3.6-)
- Promote short term solutions that lack an intergenerational view

A response which **scored well** tended to:

- Consider habitat needs holistically (1.5+)
- Provide greater kaitiakitaka opportunities for mana whenua to be involved in the management of wai māori through cultural health monitoring (1.6+)
- Harness the cleansing/ purifying processes of the whenua to remove contaminants (2.1+)
- Promote the use of natural processes for stormwater management (2.2+)
- Locate structures away from culturally sensitive areas (3.1+)
- Design for a changing environment (especially due to climate change) (3.5+)
- Promote water quality in the Otago Catchment that are healthy enough to support Kāi Tahu ki Otago customs (4.2+)
- Reduce the contaminants being discharged directly or indirectly to water (4.4+)
- Be consistent with a long term view of upholding the environment for following generations (mō tātou, ā, mō kā uri ā muri ake nei)
- Promote natural river flows and movements

Table 9-8 shows scoring and comments for a response from each different category to demonstrate the analysis conducted. Those examples also show a range of scores. The entirety of the scoring is included in Table 9-9.

Commentary

Discussion with Rūnaka representatives reinforced the extent of significant sites in the area, and how vulnerable these sites are to flooding and other natural hazard risks. It was acknowledged:

1. how sensitive the area is and the difficulty in establishing pragmatic controls and structures.
2. the difficulties in planning for a fast-changing mountain environment.
3. that ancillary infrastructure would need to be implemented to compliment significant infrastructure changes made.

The intention of the cultural scoring by Aukaha was to prioritise cultural links to the roto, awa, wāhi tapu, wāhi taoka, and ara tūpuna. The cultural lens on these would have to be represented through the scoring.

Some responses scored poorly despite providing safeguards for the local community. These responses tended to favour changes which were either not aligned with enhancing the mana of the natural environment, or not providing safeguards for the sites of cultural significance.

Table 9-8 Detailed scorings and analysis of one response from each category (demonstrating the analysis conducted).

Category	Response	Score	Provisos, comments, references to guiding principles
Road Access	A2 Small scale improvement, maintenance & reactive repair to existing Kinloch & Glenorchy-Paradise local road system	-1	'Mō tātou, ā, mō kā uri a muri ake nei'. Acknowledging the pepeha above, this response involves reactive repair work to keep an asset in place that is likely to suffer more flooding inundation over time. It scores higher than A1 as has specific resilience measures in mind, but still accepts the continuing risk of gradual and abrupt river changes. This response does not fully acknowledge the changes that the river is tending toward, and aims to maintain a level of service that prioritises human interests over the natural flow of the river
Boat Access	B2 Improve existing boat access temporarily (e.g. dredge sediment periodically)	-3	Dredging causes continual upheaval and homogenisation of the sediment profile, invertebrate populations will be affected and there will be flow on effects on larger organisms, this pathway does not prioritise the health of the environment over human usages. Refer to (1.5-), (3.5-)
Flood Mitigation and Protection	F9 River management and nature-based interventions (i.e. targeted planting)	+3	With the requirement that re-vegetation with locally sourced indigenous plants for all disturbed areas. Re-vegetation should be monitored by an assessment of the vegetative cover at one growing season after establishment and again at three seasons from establishment. Refer to (1.5+), (1.6+), (2.1+), (2.2+), (3.5+), (4.2+)
Public Asset Resilience	PA1 Community-wide improvement works for liquefaction hazard (i.e. ground improvement, strengthening existing buildings)	-2	Highly complex and requires extensive works in and around the buildings. ORC has stated: - this will only be partially effective and not reduce the liquefaction hazard category below 'medium', - the remaining risk is still high. Successful implementation would help reduce impacts of flooding and liquefication events, but the response is still favouring maintaining the built environment over the direction of the natural environment. Not well aligned with the tribal pepeha written above in A2.
Private Property Resilience	H3 Improve property resilience (such as floodproofing, floor raising, ground or structure strengthening)	-1 / +1	On one hand, it would allow damage and clean-up cost from a flood / storm / weather event to be minimised. Conversely, the climatic impacts are unpredictable and the effectiveness of these (bespoke) solutions would vary by property. Some properties are in locations that will not be viable in the long-term, in which case, these resilience measures will only buy time, not mitigate the risk. It needs to be weighed up whether the resources are best spent here or diverted elsewhere. Refer to the tribal pepeha written above in A2.
Policy	P2 Policy- Strong land use controls in higher hazard areas to avoid additional exposure (e.g. Plan change to restrict activities)	+2	This response is still constrained by existing policy and governance frameworks, but having specific controls in place to restrict activities in higher hazard areas helps to minimise risk exposure to both people and environment. This policy change puts higher priority on appropriate land use than existing policy, and favours the natural form of the environment. Refer to (3.5+)

Table 9-9 Condensed scoring of each response.

Hazard Category	Code	Individual Response Desciption	Score
Road access (Kinloch - Glenorchy - Paradise roads)	A1	Continue maintenance, planned works, and reactive repair	-2
	A2	Implement Small scale improvements	-1
	A3	Implement Major protection / raising / realignment works	+1
	A4	Reduce the level of service (i.e. 4WD only)	-3
	A5	Implement reactive (post event) redesign	-2
Road Access (Queenstown - Glenorchy road)	R1	Continue maintenance, planned works, and reactive repair	+1
Boat access	B1	Maintain existing boat access	-2
	B2	Implement periodic improvement (i.e. via dredging)	-3
	B3	Upgrade with resilient solution (i.e. relocatable wharves)	+2
	B4	Periodically relocate wharves	+1
Flooding mitigation and protection	F1	Implement flood network stations	+3
	F2	Integrate flood monitoring, forecasting & warning stations	+3
	F3	Develop emergency readiness and response	+3
	F4	Continue existing maintenance and reactive repair of Rees River	-1
	F5	Implement small scale protective works to reduce Rees River flood risk	-1
	F6	Implement major protective works to reduce Rees River flood risk	-2
	F7	Implement reactive (post event) flood protection for Rees River	+3
	F8	Continue existing river management through vegetation and gravel	-1 / +1
	F9	Implement nature-based river management interventions	+3
	F10	Implement reactive (post event) nature-based interventions	+3
	F11	Implement small scale works to reduce Buckler Burn erosion / flood risk	-2 / +2
Public Asset Resiliance	PA1	Improve resilience of critical public building assets in high hazard areas	-1 / +1
	PA2	Implement community wide improvement works for liquefaction hazard	-1
Private Property Resiliance	H1	Implement household emergency planning	+2
	H2	Adjustment property insurance cover	0 / +1
	H3	Improve property resilience	-1 / +1
	H4	Provide info. to assist house sales / purchases based on individual risk tolerance	-1 / 0
Policy	P1	Continue with existing land use zoning and building controls	-1
	P2	Implement strong land use controls in higher hazard areas	+2
	P3	Make lower hazard land available for relocation and / or new builds	+1
	P4	Develop and implement a proactive relocation plan	+3
	P5	Promote proactive voluntary relocation from higher hazard areas	+3
	P6	Develop a recovery plan	+1
	P7	Promote reactive (post-event) voluntary relocation from higher hazard areas	+1 / +2

9.5 Phase 4: How can we implement the Strategy?

Figure 9.23 "How can we implement the Strategy?" Steps 7 & 8 of the adaptation cycle (modified from MfE 2024).

9.5.1 Adaptation pathways with signals and triggers

An adaptation threshold is 'what people do not want to happen' (an unacceptable condition). Based on what we have heard from the community and partners through this programme, the following adaptation thresholds are unacceptable conditions:

- Extended disruption to road access from Queenstown
- Frequent or severe damaging or disruptive events
- Loss of amenity and cultural values
- Lengthy displacement of people following extreme events
- Withdrawal of maintenance, decline in levels of service and increasing cost of repairs
- Unaffordable or high-excess insurance premiums or withdrawal of insurance and bank finance

An advanced "signal" is something we can monitor that helps to avoid an adaptation threshold being reached and being unprepared. Signals help us get ready to move to new pathways with enough time for decision-making and implementation. They give us a heads up and flag the need for collective effort on social, behavioural and institutional changes to support adaptation. However, surprise situations can still occur and so signals are not a guarantee that an adaptation threshold will be avoided.

There are huge numbers of different signals that could be monitored to track change at Head of the Lake area, across the domains of natural, built, social and economic. Guided by our goal of weaving adaptation into our everyday work, and our principle of cost-effectiveness, we have selected relevant and measurable signals that are aligned with current business-as-usual activities for Strategy partners:

- **SIGNAL #1. Growth in costs to maintain and repair assets**
- **SIGNAL #2. Lower level of service** (e.g. due to delta growth, river bed aggradation, channel movement)
- **SIGNAL #3. Frequency, number or impacts of flooding events reaching nuisance level** (this signal includes residential areas, roads and agricultural land)
- **SIGNAL #4. Movement of active river channel towards high value areas and assets**
- **SIGNAL #5. Negative impacts on community wellbeing** (e.g. concern and anxiety, increased demand for protection or for doing things differently)
- **SIGNAL #6. Insurance affordability or coverage** – this is outside the control of Strategy partners. Regional or national trends could be tracked by discussions and engagement with local government and insurance sector, and local trends with community members and Councillors.

"Triggers" denote decision points when a review and decisions are made as to whether to change responses or pathways. Triggers that occur ahead of an adaptation threshold are the most useful for forward planning.

- **TRIGGER #1. Decision-making cycles (3-year, 10-year, 30-year)** – this is the usual timing to consider partner agencies priorities, level of investment and business cases for changes. These timelines are suitable for staying ahead of gradual changes at Head of the Lake. Up-to-date analysis and reporting of the signals are important to feed into and inform the decision-makers. Public consultation is also required by agencies.
- **TRIGGER #2. Opportunities** – is about keeping adaptation goals in front of mind, looking out for opportunities to take action and make progress. Some example: funding opportunities; opportunities for integration with other projects; and opportunities to influence other decision-makers.
- **TRIGGER #3. Significant natural hazard event with unacceptable outcomes –** an integrated, multi-agency approach will be required for effective recovery. A one-off plan would be developed to support integrated decision-making.

9.5.2 Implementation Framework

The responsible agencies for the current natural hazard responses already in place are shown in Figure 9.23. The current responses are implemented through well-established planning processes, such as Long Term Plans, QLDC District Plan and Otago CDEM Group Plan. Many of the possible future responses are also standard ways of managing natural hazards. The plans have a regular update cycles and this is when decisions on continuing and future investment are made by the agencies.

Some possible future responses are out-of-the-ordinary. Implementation of uncommon responses would require one-off, specialised planning, funding and governance arrangements.

If there is severe damage as a result of a natural hazard event, then it is likely that a tailored recovery plan would be put in place.

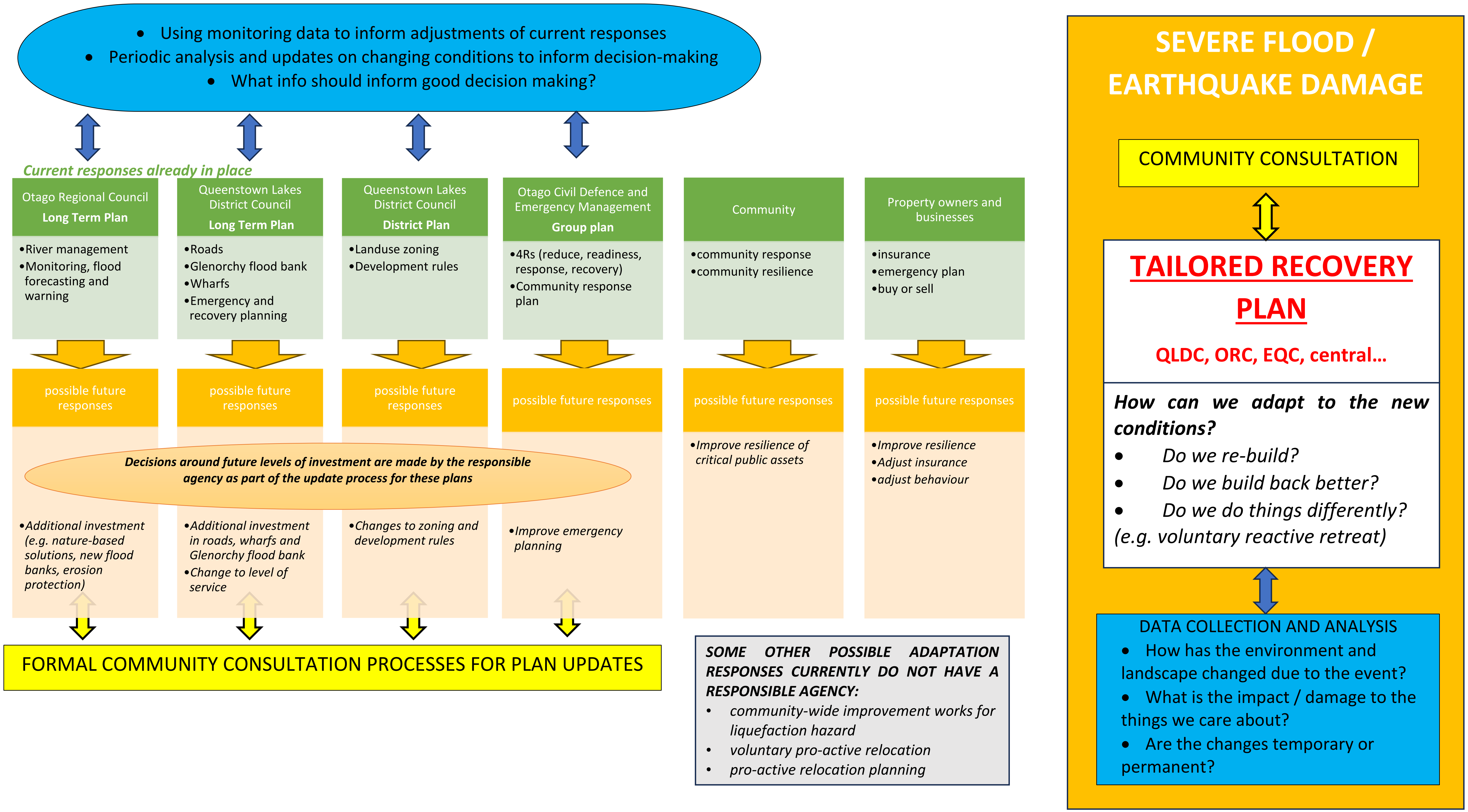

Figure 9.24 Current framework for implementation

9.6 Phase 5: How is it working: A review framework

Figure 9.25 "How is it working?" Steps 9 & 10 of the adaptation cycle (modified from MfE 2024).

Strategy partners already collect and track most of the information we would need to monitor how the Strategy is working, as part of our existing business practices. The following types of information can be used to track changes of social, economic, institutional and environmental conditions:

- Wellbeing surveys
- Community consultations
- Physical monitoring (e.g., hydrological data, aerial imagery, LiDAR topography, and cross-section surveys)
- Reporting on costs associated with services and activities
- Emergency and disaster damage/needs assessments
- Reporting on local disruptions, such as road closures
- Channels for the community to share observations and concerns regarding adaptive capacities, vulnerabilities, and awareness
- Updates and analyses of international and national trends on hazards adaptation and resilience

- Updates on central government direction or legislation related to natural hazards decision-making and climate change adaptation
- Reports on cultural values and aspirations of mana whenua embodied within this Strategy
- Community submissions and feedback on ORC and QLDC planning and decision-making processes
- Open dialogue on potential changes, risks, or opportunities
- Updates on insurance policies for property owners

We will track the progress of the Strategy by monitoring the implementation of the actions listed in the Action Plan (Section 10).

Every six years, ORC will conduct a comprehensive review to ensure the Strategy is updated appropriately in light of new information gathered from monitoring activities, or earlier if there is an urgent need.

10 Action Plan

This is the first iteration of the Action Plan, which shows what Strategy partners are doing and plan to do over current planning timeframes, to progress towards our Strategy goals.

Despite the resilience and adaptation work we already do at the Head of the Lake, we may need to do more and do some things differently to adapt to future changes.

We will update this action plan every 6 years, or more often if required, to reflect our progress and adjust. Between updates, we will track progress on actions and report back to the community via established communications channels (such as the newsletter and website).

Actions are organised by themes:

- Governance and collaboration
- Advice, information and education
- Addressing impacts and risks of hazards
- Emergency Management
- Information gathering and monitoring
- Policy and planning processes

Governance and collaboration

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
Underway or planned	Otago Regional Council (ORC) and Queenstown Lakes District Council (QLDC) collaborate to develop a governance framework or memorandum of understanding (MoU) for addressing adaptation issues at the Head of the Lake and/or across the district, including the implementation of adaptation actions to improve resilience.	1	Otago Regional Council (Natural Hazards) Queenstown Lakes District Council	
Underway or planned	ORC to partner with mana whenua to ensure mana whenua values and aspirations and mātauraka Kāi Tahu is embedded into decision-making and implementation of the Strategy, following the lead of Aukaha and Te Ao Mārama.	All goals	Otago Regional Council (Natural Hazards) Aukaha and Te Ao Mārama Inc	
Underway or planned	Work together with QLDC, Civil Defence Emergency Management Otago (CDEM), mana whenua and local community to ensure co-ordinated and consistent approach to implementation of actions aligning with this Strategy.	All goals	Otago Regional Council (Natural Hazards) Queenstown Lakes District Council Civil Defence Emergency Management Otago Aukaha and Te Ao Mārama Inc Glenorchy Community Association	
Underway or planned	Work together to mainstream adaptation across ORC work programmes and ensure our work aligns with this Strategy and towards achieving each goal.	All goals	Otago Regional Council (Natural Hazards, Environmental Implementation, Engineering, Integrated Catchment Management)	Ongoing

Information gathering and monitoring

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
Existing	ORC to Investigate hazards and risks as part of usual business	1, 2	Otago Regional Council (Natural Hazards)	Ongoing
New	Geomorphic change monitoring and assessment Maintain an awareness of locations and scale of geomorphic changes (e.g. active river channel position, bed levels and rates of change) which may have direct impacts, or exacerbate natural hazard characteristics. • Collect LiDAR, aerial imagery - spatial extent to include at least Dart, Rees and Buckler (at least extent of 2019 survey). • Cross section survey and/or bathymetric LiDAR • Undertake geomorphic change detection analysis. This information will; • Enable proactive response to issues • enable the updating of flood hazard assessments to ensure they provide representation of current conditions (e.g. bed levels).	2	Otago Regional Council (Natural Hazards) with external support	Periodic (at least every 5 years) or when new LiDAR is available

Information gathering and monitoring

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
Existing	Data collection to document major flooding (or other hazard) events Improve the recording and understanding of hazard event characteristics (e.g. floodwater extents, depths and flow pathways), and the impacts of those events. The types of data collected will depend on the hazard and the impact and may include the following: • Post-event LiDAR • During-event or immediately post-event aerial imagery • During-event or post-event observations (on-ground inspections and/or drone imagery) • Develop an online data portal to enable collation of crowdsourced natural hazard event observations (e.g. photographs) • On-ground post-event survey (debris survey) • Assessments/observations of damages/impacts (infrastructure, or residential) • Geotechnical assessments • Post-earthquake assessments (landsliding, liquefaction, subsidence …) This information will; • Assist with hazard/risk assessments by providing ground-truthed observations of hazard events. • be valuable for calibration/validation of future hazard modelling, helping to ensure models represent reality.	2, 3	Otago Regional Council (Natural Hazards) with external support	After hazard events

Information gathering and monitoring

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
	<u>Monitoring and analysis of signals/triggers/thresholds</u> SIGNALS – give us a heads up about changes • Growth in costs to maintain and repair assets • Lower level of service (e.g. due to delta growth, river bed aggradation, channel movement) • Frequency, number or impacts of flooding events reaching nuisance level (this signal includes residential areas, roads and agricultural land) • Movement of active river channel towards high value areas and assets • Negative impacts on community wellbeing (e.g. concern and anxiety, increased demand for protection or for doing things differently) • Insurance affordability or coverage TRIGGERS – points where review and decisions are made • Decision-making cycles (3-year, 10-year, 30-year) • Opportunities • Significant natural hazard event with unacceptable outcomes THRESHOLDS – unacceptable conditions we are trying to avoid • Extended disruption to road access from Queenstown • Frequent or severe damaging or disruptive events • Loss of amenity and cultural values • Lengthy displacement of people following extreme events • Withdrawal of maintenance, decline in levels of service and increasing cost of repairs • Unaffordable or high-excess insurance premiums or withdrawal of insurance and bank finance	2	Otago Regional Council (Natural Hazards) with input from Queenstown Lakes District Council and external support	Periodic (at least every 5 years)

Information gathering and monitoring

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
	Communication and reporting of physical environment monitoring • Data collection and analysis findings will be communicated to key project partners and stakeholders. • A brief environmental monitoring update report will be prepared every 3 years summarising any notable natural hazards event/impacts (e.g. peak flows/lake levels observed) within that time period, and any post-event data collection or analysis completed. • One-off standalone event reports may be prepared for any natural hazards events which causes significant impact – summarising event causes, characteristics, effects/impacts, and ORC responses. • Reports will be distributed to key contacts, through existing communication channels (e.g. ORC e-newsletter and project website), and appended to any councillor update reports.	2	Otago Regional Council (Natural Hazards)	3 yearly updates One-off reporting for significant events

Emergency Management

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
New	Develop a long-term recovery plan for a potential major hazard event, including ways to minimise maladaptation post-event and ensure recovery considers long-term adaptation opportunities.	1, 3, 5	Otago Regional Council (Natural Hazards) Civil Defense Emergency Management Otago Queenstown Lakes District Council	Ongoing

Emergency Management

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
Existing	Operate a network of near real-time rainfall and water level stations across the region to support flood forecasting and emergency response with a 24/7 duty roster to support forecasting duties and any necessary response.	2, 3	Otago Regional Council (Natural Hazards, Engineering, Environmental Monitoring) Civil Defense Emergency Management Otago	Ongoing
Existing	Monitor and ensure ORC's network of environmental monitoring stations remains fit for purpose; providing information for flood response, for documentation of flood events, and for public awareness of river flow, lake and lagoon levels). • Review of performance of the flood forecasting systems (lake level and lagoon level forecasting) • Review of hydrological monitoring network (any opportunities for improvement?) • New/temporary monitoring in some circumstances (e.g. landslide dam formation) This action is intended to ensure the monitoring network and forecasting systems provides the most suitable coverage.	1, 2	Otago Regional Council (Natural Hazards, Environmental Monitoring)	Periodic reviews One-off temporary monitoring
Existing	Capability development and awareness raising • Undertake public/internal education to develop knowledge and raise awareness of risks and natural hazards to communities and Community Response Group's members. • Share lessons learned from emergency response with communities • Introduced and organised training sessions for Community Response Group members of how to use Community Emergency Hub Guide.	1, 2, 3	Civil Defense Emergency Management Otago	As needed Annually

Emergency Management

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
Existing	Engagement with communities and stakeholders • Communicate prior to forecast weather events to have a common understanding around Lake and Lagoon levels, river flows and potential outcomes of the forecast weather • Communicate with communities about changes in risk and readiness • Work with Community Response Group to coordinate emergency support before, during and after an emergency • Organised consultations with communities on emergency proposed plans and guidelines. • Convene meetings with communities and stakeholders to decide a scale of an emergency event.	1, 2, 3	Civil Defense Emergency Management Otago Community Response Group	As needed Annually
Existing	Risk communication and early warnings • Provide right and trusted information about natural disasters to communities so that they can prepare effectively to emergency events.	3	Civil Defense Emergency Management Otago Queenstown Lakes District Council	Frequently Per event

Emergency Management

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
Existing	Provide community resilience equipment • Provide communications equipment to not only communicate locally but also communicate to the Emergency Operations Centre in Queenstown if BAU communications systems have failed. • Provided equipment for communities to better prepare for emergency events: ✓ 4000W Petrol Inverter Generator ✓ Petrol Container ✓ Extension cords ✓ Multi boxes ✓ Rechargeable LED light 20Watt Work-lights ✓ Tripod LED light 60Watt Work-lights ✓ Handheld torches and spare batteries	3	Queenstown Lakes District Council Civil Defense Emergency Management Otago	As needed One-off
Existing	Develop and share emergency guides and plans and update annually • Glenorchy Community Resilience Guide (draft in progress) • Glenorchy Community Response Plan (draft in progress) • Developed Glenorchy Flood Guide • Developed Community Emergency Hub Guide • Developed Community Emergency Preparedness Brochure	3	Civil Defense Emergency Management Otago Community Response Group	Update annually

Emergency Management

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
Existing	Training and exercises for Community Response Group and Emergency Hub implementation • Provided trainings to help Community Response Group set up Emergency hubs, operating radios and community response planning. • Exercise the implementation of the Community Emergency Hub to gain an understanding of expectations of the community, emergency services and local government as well as clarify any ambiguity or operational expectations that may present during an actual emergency.	3	Civil Defense Emergency Management Otago Community Response Group	One-off As needed

Advice, information and education

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
Underway or planned	Ensure the ORC Natural Hazards Portal includes up-to-date information on natural hazards and the impacts of climate change, to provide the community with a single location for information.	2, 3	Otago Regional Council (Natural Hazards)	
Underway or planned	Maintain ORC Head of Lake Whakatipu adaptation webpages with relevant and up-to-date information, including latest reports, Council updates and key programme milestones.	2	Otago Regional Council (Natural Hazards and Communications)	Ongoing
Underway or planned	Provide newsletter updates about programme milestones and or progress towards actions to inform community members, and be accountable to the Strategy.	2	Otago Regional Council (Natural Hazards and Communications)	As needed
New	ORC to attend Glenorchy Community Association (GCA) meetings as and when required, at least annually, to provide updates about programme	2, 3	Otago Regional Council (Natural Hazards)	Annually or as needed

Advice, information and education

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
	milestones and progress towards actions and act as a check-in with the community.			
Underway or planned	Ensure that ORC's messaging about natural hazards adaptation and adaptation workstreams is communicated in a way that is understood by a wide audience.	2	Otago Regional Council (Natural Hazards and Communications)	Ongoing
Underway or planned	Monitor the headofthelake@orc.govt.nz inbox for public enquiries and information relating to the programme. Consider other methods and tools for capturing community feedback.	2	Otago Regional Council (Natural Hazards)	Ongoing

Policy and planning processes

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
Underway	Consider natural hazard property information for resource and building consents.	4	Queenstown Lakes District Council	Ongoing (BAU)
Underway or planned	ORC and QLDC to collaborate to ensure common adaptation priorities, information and actions identified in this Strategy inform and input into the next ORC and QLDC Long-Term Plan, Spatial Plan, District Plan and other relevant policies and plans.	1, 2	Otago Regional Council Queenstown Lakes District Council	Every LTP cycle
	Natural hazard information included on LIM reports	1, 2	Queenstown Lakes District Council	
New	ORC and QLDC to collaborate on path forward for assessing risk tolerance with the community (once the proposed RPS is operative)	1, 2, 3, 4	Otago Regional Council Queenstown Lakes District Council	once the proposed RPS is operative

Addressing impacts of natural hazards and climate change

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
Underway	Routine maintenance of transport network, including QLDC roading assets, Glenorchy jetty and marina.	1, 4	Queenstown Lakes District Council	Ongoing/BAU
Underway	Glenorchy Area Bridge Resilience (24-34 LTP): Non-routine work required to protect the serviceability of the Glenorchy, Paradise, Rees River bridge assets following damage, and to minimise threat of road closure due to natural phenomena.	1, 4	Queenstown Lakes District Council	As required, budgeted biennially
Underway	Raising Kinloch Road (24-34 LTP) Raising Kinloch Road in conjunction with two-yearly gravel extraction under the Rees River bridge.	1, 4	Queenstown Lakes District Council	As required, budgeted biennially
New	Develop Operational River Management Plans, including the Dart and Rees floodplains. • Operational Management Plans that outline the activities undertaken for river management. • These plans will be developed in 2025.	1, 4	Otago Regional Council (Engineering and Natural Hazards)	2025 Reviewed every 2 years
New	Develop a gravel management plan for the Buckler Burn • ORC, Engineering held consent of Buckler gravel management plan. • This plan will be developed in 2025.	1, 4	Otago Regional Council (Engineering and Natural Hazards)	2025 Reviewed every 2 years
Underway	Annual vegetation management, rock armouring and gravel management • Ongoing river management activities (such as regular vegetation control in Lagoon Creek/Lagoon area)	3, 4, 5	Otago Regional Council (Engineering)	Ongoing/Annually
Existing	Maintenance of Rees River floodbanks • Maintain (not renew or increase) the existing banks – (Rees River floodbanks are not owned by ORC)	1, 4	Otago Regional Council (Engineering and Natural Hazards)	Every 1 year

Addressing impacts of natural hazards and climate change

Status	Action	Goal this contributes towards	Agency responsible	Timeframe
New	Floodplain and rivers • Create/trial NBS groynes	1, 4, 5	Otago Regional Council (Engineering and Natural Hazards)	Every 2 years
New	Glenorchy Adaptation Pathways (30 Yr Infrastructure strategy) Work on Social Infrastructure required to address selected adaptation pathways, as budgeted in the QLDC 30 year Infrastructure Strategy.	1, 3, 4	Queenstown Lakes District Council	2034-2054
New	Provide information and support property owners to undertake property-level interventions to improve their resilience to natural hazards risks.	3, 4	Otago Regional Council (Natural Hazards)	
New	Head of the Lake Adaptation (24-34 LTP) Strategy to inform responses to identified hazards, providing scoped and costed solutions for input to the next LTP (27-37) and other key planning documents	1, 2, 4	Queenstown Lakes District Council	2034-2054

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12 Glossary of Terms

Key Term	Definition
Adaptation	Adaptation in this Strategy is defined as a proactive response to anticipate and adjust to ongoing and future environmental changes. It is an ongoing process that involves identifying, assessing and managing risk while continually evaluating the effectiveness of actions and making necessary adjustments. This proactive, long-term approach enables planning and response in situations where the future is uncertain including variability in the rate, timeframe and magnitude of change.
Adaptation options / responses	The wide range of strategies and measures that are available and appropriate for addressing adaptation. They can take the form of structural, institutional, ecological or behavioural actions.
Adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences.
Aggradation	Net accumulation of sediment in the stream channel or land surface.
Alluvial fan	An alluvial fan is a triangle-shaped deposit of gravel, sand and even smaller pieces of sediment, such as silt. This sediment is called alluvium.
Annual Exceedance Probability	Annual Exceedance Probability (AEP) is the probability of a certain sized flood occurring in a single year. For example, a 0.5% AEP flood has a 0.5 per cent, or 1 in 200 chance of occurring in any year. Large, infrequent floods have a low AEP and smaller, more frequent floods have a higher AEP. 200-year ARI and 0.5% AEP are different ways to describe the same event.
Average Recurrence Interval	The Average Recurrence Interval (ARI) is the average time between floods of a certain size. Large, infrequent floods have higher ARIs than smaller, more frequent floods. For example, a 200 year ARI flood will occur on average once every 200 years. A 50 year ARI flood will occur on average once every 50 years and be a smaller flood than a 200 year ARI. While a 200 year ARI flood may happen once every 200 years on average, every year there is still a 1-in-200 chance that a flood of this size might occur. 200-year ARI and 0.5% AEP are different ways to describe the same event.
Avulsion	An avulsion is the process where a river channel switches location, often suddenly, and may result in the complete or partial abandonment of the formerly active channel.
Capacity building	The practice of supporting an individual, community, society or organisation to respond to change by enhancing their strengths and attributes and improving the resources available to them.

Key Term	Definition
Climate change	A change in the state of the climate that can be identified (eg, by using statistical tests) by changes or trends in the mean and/or the variability of its properties, and that persists for an extended period, typically decades to centuries. Includes natural internal climate processes and external climate forcings such as variations in solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. The United Nations Framework Convention on Climate Change (UNFCCC) definition of climate change specifically links it to direct or indirect human causes, as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes.
Co-benefit	A positive effect that a policy or measure aimed at one objective has on another objective, thereby increasing the total benefit to society or the environment.
Cumecs	The unit of volumetric rate of flow, equal to one cubic metre per second.
Delta	Deltas are landforms at the mouths of rivers. They are formed when rivers drop their sediment upon entering another body of water.
Disaster	A serious disruption of the functioning of a community or a society, at any scale, that occurs because hazardous events interact with conditions of exposure, vulnerability and capacity, leading to human, material, economic and/or environmental losses and impacts.
Disaster risk management	Processes for designing, implementing and evaluating strategies, policies and measures to improve understanding of current and future disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, prevention and protection, response and recovery practices. The aim is to increase human security, wellbeing, quality of life and sustainable development.
Dynamic adaptive pathways planning	A framework that supports climate adaptation decision-making by developing a series of actions over time (pathways). It is based on the idea of making decisions as conditions change, before severe damage occurs, and as existing policies and decisions prove no longer fit for purpose.
Flood	An event where the normal boundaries of a stream or other water body overflow, or water builds up over areas that are not normally underwater. Floods can be caused by unusually heavy rain – for example, during storms. Floods include river (fluvial) floods, flash floods, urban floods, rain (pluvial) floods, stormwater floods, coastal floods and glacial lake outburst floods.
Free face	Regarding liquefaction hazard, a free face occurs where the land is not physically constrained, such as riverbanks and the front face of deltas. Part of the free face may be underwater.
Freeboard	An allowance in engineering design to account for uncertainties and other effects above an estimated floodwater level.

Key Term	Definition
Geomorphic/geomorphology	Geomorphology is the study of landforms and the processes that shape them.
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.
Hapū	Within each iwi (tribes) are many hapū (clans or descent groups), each of which is made up of one or more whānau (extended families).
Impact	The consequences of realised risks on natural and human systemsy. They are generally effects on human lives, livelihoods, health and wellbeing; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure. They can be harmful or beneficial. Also known as consequences or outcomes.
Iwi	Generations ago, waka sailed by Māori ancestors set out from East Polynesia and landed in New Zealand. From these founding peoples came the iwi (tribes) that form the structure of Māori society. Within each iwi are many hapū (clans or descent groups), each of which is made up of one or more whānau (extended families). The bond that holds them together is one of kinship, both with a founding ancestor and with the many members of their iwi, hapū and whānau today.
Lateral spreading	Lateral spread is defined as the horizontal movement of ground towards the free-face or downslope as a result of the liquefaction of shallow underlying soil deposits. Liquefaction primarily occurs as a result of earthquake shaking of loose sands and soils. Free faces include river channels and fan deltas.
Liquefaction	Liquefaction causes wet, sandy, and silty soils to behave more like a liquid than a solid during strong earthquake shaking. To liquefy, soil must be loose, sandy or silty, and wet (below the water table). Clay and gravel tend not to liquefy.
Maladaptation	Actions that are unsustainable and may lead to increased risk of adverse climate-related outcomes, including increased greenhouse gas emissions, increased vulnerability to climate change and reduced welfare, now or in the future. Maladaptation is usually an unintended consequence. Some actions may be effective in some ways but maladaptive in others.
Mana whenua	Mana whenua are Māori who hold traditional customary authority and are representatives of Treaty partners within an area and whose traditions and histories are as determined by whakapapa, resource use, and ahikāroa (the long burning fires of occupation). In Otago, Kāi Tahu are mana whenua.
Mātuaraka Māori	Kāi Tahu knowledge
Nature-based solutions	Solutions that are inspired and supported by nature and are cost effective, and at the same time provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features (eg, vegetation and water features) and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. For example, using vegetation (eg, street trees or green roofs) or water elements (eg,

Key Term	Definition
	rivers or water treatment facilities) can help reduce heat in urban areas or support stormwater and flood management.
Natural hazard	Natural hazards are defined as environmental phenomena that have the potential to impact societies and the human environment.
Pathways	NIWA describes pathways thinking as follows: Pathways thinking is a planning approach that allows for the uncertainty and change by encouraging us to imagine many different futures. It does this by focussing on planning and that there will be many ways to find our way through the challenges of our future climate. It takes into account what is important to individuals, whānau and communities. It helps us to consider the many different options in front of us; how long these might be effective for and when we might need to change tack. Pathways thinking supports decision-making and investments in stages. It encourages people to identify triggers (for example a flood), and to make decisions in advance about what to do if that trigger occurs. Using pathways thinking allows us to develop strategies for expected climate impacts, while not compromising or shutting-off other options. This flexible approach recognises that conditions can change and means we avoid being locked in to any one course. Pathways thinking is an approach that is in the Ministry for the Environment's coastal hazards guidance and is being used by councils and others around Aotearoa as they plan how to adapt to a changing climate.
Delta growth	Delta growth (progradation) is defined as the forward extension of shoreline systems due to the deposition of sediment
Qualitative risk	Qualitative risk analysis is a subjective approach that is based on descriptive measures. It uses words to describe the magnitude of potential consequences, and the likelihood that the event will occur. An example of this is a risk matrix, which can be colour-coded to make it easier to understand the level of associated risk
Quantitative risk	A quantitative risk analysis is focused on numerical values of the risks present, based on quantifiable data
Reduced level	Reduced Level (RL) is a standard term for survey points with reference to a common datum. In this report, the common datum is Dunedin 1958 local vertical datum, unless stated otherwise.
Resilience	Resilience has a broad range of definitions. In our context, it is the capacity and ability to withstand and/or recover quickly from difficult conditions. It also includes planning for unexpected events and supporting the wellbeing of our communities in adverse times.
Risk management	The process of making plans, actions, strategies or policies to reduce the likelihood and/or scale of potential adverse consequences, based on assessed or perceived risks.
Rūnaka	A Māori tribal council, assembly, board or administrative group

Key Term	Definition
Te ao Māori	The Māori world
Te Tiriti o Waitangi	The Treaty of Waitangi
Tolerable risk	A risk that society is willing to live with so as to secure certain benefits. Kept under review and may be further reduced as and when possible.
True left bank/true right bank	The sides of the river when facing downstream, meaning the direction the river is flowing.
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may occur for many reasons. For example, the data may be imprecise, definitions of concepts or terminology may be ambiguous, understanding of critical processes may be incomplete, or projections of human behaviour may be in doubt.
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.
whānau	Within each iwi are many hapū (clans or descent groups), each of which is made up of one or more whānau (extended families).

List of acronyms and abbreviations

Acronym	Full name
ARI	Annual Recurrence Interval
AEP	Annual Exceedance Probability
GIS	Geographic Information System
ORC	Otago Regional Council
QLDC	Queenstown Lake District Council
CDEM	Civil Defence Emergency Management Otago
LTP	Long Term Plan
LiDAR	Light Detection and Ranging
RL	Reduced Level
RPS	Regional Policy Statement

13 Appendices

Appendix A – Programme Deliverables

Table 13-1 Deliverables completed for Head of Lake Whakatipu natural hazards adaptation work programme (October 2024)

Programme Deliverables	Details
3 flooding hazards assessments	• Gardner M, 2022. Dart/Rees Rivers flood hazard modelling. Prepared by Land River Sea Consulting Ltd. • Gardner M and Beagley R, 2023. Buckler Burn flood hazard modelling. Prepared by Land River Sea Consulting Ltd • Beagley R, 2024. Glenorchy flood modelling – flood hazard scenarios. Prepared by Land River Sea Consulting Ltd
1 liquefaction hazard assessment	• Tonkin + Taylor Ltd (T+T), 2022. Glenorchy Liquefaction Vulnerability Assessment.
9 supporting studies (e.g. hydrology, geotechnical, geomorphic)	• Brasington J, 2024. Geomorphic Character and Dynamics of the Rees-Dart Fluvial Systems. Prepared by the Waterways Centre University of Canterbury for Otago Regional Council. • Fuller I and McColl S, 2021. Key notes and observations from preliminary assessment of debris flood and flow hazard potential at Glenorchy, Otago, Prepared by Massey University. • Jaquin P, 2020. Glenorchy Floodbank Rees River. Prepared by WSP. • Jaquin P, 2020. Glenorchy Rees Floodbank - Floodbank Assessment. Prepared by WSP • Mohssen M, 2021. Analysis of Flood Hazards for Glenorchy. • Mohssen M, 2024. Glenorchy Catchments Hydrology and Design Flows. Prepared by HydroScience • Morris T and Ashfield D, 2021. Rees-Glenorchy floodbank structure failure modes assessment. Prepared by Tonkin + Taylor Ltd • Shaw M, 2022. Shepherds Hut Creek debris flow hazard report. Prepared by WSP • Tonkin + Taylor Ltd, 2021. Head of Lake Wakatipu Natural Hazards Assessment.
1 social and economic impact assessment (two phases)	• Healy J, Stringer K and Goodall, 2024. Socio-economic Impact Assessment - Head of Lake Whakatipu Adaptation Strategy - Phase 1. Prepared by Beca Ltd • Healy J, Stringer K and Goodall, 2024. Socio-economic Impact Assessment - Head of Lake Whakatipu Adaptation Strategy - Phase 2. Prepared by Beca Ltd
1 natural hazards risk assessment	• Menke R, Hoetjes, and Punt A, 2024. Glenorchy and Kinloch Natural Hazards Risk Analysis Report. Prepared by Beca Ltd
5 natural hazards mitigation studies	• Menéndez Arán D and Shrestha J, 2024. Assessment of Floodplain Intervention Options – Dart River. Prepared by Damwatch Engineering Ltd. • Veale B and Shrestha J, 2024. Assessment of Floodplain Intervention Options – Lower Rees River & Glenorchy. Prepared by Damwatch Engineering Ltd • Veale B, Shrestha J and Webby G, 2024. Assessment of Floodplain Intervention Options – Upper Rees River. Prepared by Damwatch Engineering Ltd • Tonkin + Taylor Ltd (T+T), 2023. Engineering Approaches for Managing Liquefaction-Related Risk. Prepared by Tonkin + Taylor Ltd • Webby G, 2022. Dart-Rees Floodplain Adaptation - Report on 23-24 February 2022 Workshop.
1 cultural values statement	• Takau Y, 2024. Cultural Values Statement, prepared by Aukaha.

Programme Deliverables	Details
1 mana whenua assessment	• Aukaha, 2024. Head of Lake Whakatipu Waimāori Mana Whenua assessment
10 Otago Regional Council Safety & Resilience Committee papers or workshops	• 2021 - May • 2022 - June • 2023 - May, August, November • 2024 – February, May, August (workshop & paper), November
2 Queenstown Lakes District Council workshop or briefings for councillors	• May 2021 (jointly with ORC) • September 2024
15 community engagement activities	• 2019-2020 – Updates at Glenorchy Community Association meetings • December 2020 – Community drop-in session • April 2021 – Public presentation • April 2021 – Community drop-in session • June 2022 – Online presentation • July 2022 – Community drop-in session • August 2023 – Community workshops • July 2023 – April 2024 – Community involvement in SEIA (from scope to review stages) • September 2023 – Online survey • November 2023 – Stall at Glenorchy Village Fair • April-May 2024 – Two adaptation classroom sessions at Glenorchy School • April-May 2024 – Head of the Lake Youth Art Competition • May 2024 – Online presentation • September 2024 - Public presentation (in-person and livestreamed) • September 2024 – Community drop-in session
41 editions of a community newsletter	• Commencing in August 2020 and ongoing
Programme webpage	• Webpage on ORC website from December 2020, regularly updated
3 environmental monitoring stations installed	• Glenorchy lagoon (water level) • Rees River at Invincible (flow) • Lake Wakatipu at Glenorchy marina (water level)
1 flood forecast model developed and tested	• Mohssen M, 2023a. Flood Forecasting for Glenorchy Township. Prepared by HydroScience for Otago Regional Council. • Mohssen M, 2023b. Analysis of Glenorchy Lagoon Levels for Event September 2023 and its FFM Model's Performance. Prepared by HydroScience
2 research projects supported	• MacKenzie J, 2023. Telling Stories: Community engagement in a complex and dynamic natural hazards adaptation context at the Head of Lake Whakatipu. Masters Thesis, University of Otago. • Coursey S, PhD research project, in progress. Massey University, NIWA, University of Otago.

Most reports are available online: https://www.orc.govt.nz/get-involved/projects-in-your-area/head-of-lake-whakatipu/ or can be provided on request

Appendix B – Supporting information about existing responses and future toolbox

This appendix provides details and supporting information about responses in three sections:

a) Local knowledge and community insights
b) What responses are already in place?
    - Social, behavioural, and institutional changes
    - Current plans and policy that guide land use and development
    - Investment in assets, services, and activities
    - Emergency management - reduction, readiness, response and recovery
    - Responses by property owners
c) Future toolbox
    - Review and adjust existing responses
    - Investigation of possible engineering and floodplain responses
    - Land use planning and governance measures
    - Retreat / Relocation

LOCAL KNOWLEDGE AND COMMUNITY INSIGHTS

We have heard many ideas, insights and observations from the community about what we can do to adapt to natural hazard challenges and impacts of a changing climate in the Head of Lake Whakatipu area. Thank you to community members for sharing. Table 13-2 collates the ideas and comments on how they were considered further.

Table 13-2 General community ideas or insights and how they were considered further.

Type of response	General community ideas or insights	How was it considered?	Is it part of the Strategy?
Protect	Minor repair to Glenorchy floodbank after the February 2020 flood event.	QLDC completed September 2020.	n/a
Protect	Maintenance of existing Glenorchy floodbank.	QLDC maintains the floodbank as asset owner	Yes, existing response in Section **Error! Reference source not found.**
Protect	Raise existing Glenorchy floodbank	Considered as a possible future response.	Yes, discussed in Section **Error! Reference source not found.**
Protect	New long floodwall alongside the true left bank of the Rees River.	Investigated but found unfeasible (Webby 2022).	Not taken forward.
Protect	Lake flooding protection, including a lake floodbank	Unfeasible	Not taken forward.
Protect	Floodable infrastructure and dedicated areas for water storage during flood events (wetland, canals or channels, greenspaces)	Existing Glenorchy wetland and lagoon fulfils this role	Yes, retain its function, see Action Plan
Protect	Floodbank, rock revetment or vegetation to prevent erosion of Kinloch Road	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**
Accommodate	Clearance of thick willow growth alongside Lagoon Creek which drains the Glenorchy Lagoon to the Rees River in response to February 2020 flood event.	Completed by ORC in August 2020 in collaboration with DOC.	n/a
Accommodate	Short-term improvements to drainage of Rees River into Lake Whakatipu during high river flows in response to February 2020 flood event.	Short-term, local realignment of the Rees River channel to assist drainage completed in August 2020.	n/a

Type of response	General community ideas or insights	How was it considered?	Is it part of the Strategy?
Accommodate	Install additional lake level recorders and river flow models near Glenorchy, in the Glenorchy Lagoon and at the Rees River.	Lake Whakatipu at Glenorchy marina (water level) site established January 2021. Glenorchy Lagoon (water level) site established October 2020. Rees River at Invincible (river flow) site established December 2021.	Yes, existing response in Section **Error! Reference source not found.**
Accommodate	Behavioural and societal changes to help people prepare, respond, cope and recover from natural hazard events.	Ongoing work in collaboration with CDEM Otago to increase community resilience and understandings of natural hazards.	See action plan.
Accommodate	Create a flood response plan	CDEM Otago has developed and is developing number of emergency guides and plans, which are updated annually.	See action plan.
Accommodate	Install sensors, monitoring recorders or warning system at the Buckler Burn to warn about heavy rainfall or rapidly rising river levels.	ORC reviews its monitoring network regularly and will consider the case for Buckler Burn monitoring	See action plan.
Accommodate	Property level improvements and interventions to existing houses (such as raising floor levels, waterproofing)	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**
Accommodate	Raise land levels in town and low-lying farmland	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**
Accommodate	Raise and/or realign Kinloch Road	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.** See Action Plan for current commitment

Type of response	General community ideas or insights	How was it considered?	Is it part of the Strategy?
Accommodate	Alternative transport access to Kinloch and DOC tracks	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**
Accommodate	Boat access to Glenorchy and Kinloch	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**
Accommodate	Planting and willow clearing in Rees floodplain	Considered as part of Upper Lakes Catchment Action Plan (in development)	See action plan.
Accommodate	Extract gravel from the Rees River under the Rees Bridge.	QLDC currently extracts gravel periodically	Yes, discussed in Section **Error! Reference source not found.**
Accommodate	Gravel extraction in Dart-Rees Delta to re-direct Rees flows through the split or create a secondary channel for high flows.	Not feasible for flood flows	n/a
Retreat	Managed relocation from high-risk areas in the long-term	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**
Retreat	Reactive retreat after a disaster	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**
Retreat	Council(s) should proactively purchase land for the purposes of future relocation of properties.	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**
Retreat	Relocate critical assets in high-risk areas (i.e. fire station)	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**
Avoid	No new development/redevelopment or change of land use that will exacerbate risk	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**
Avoid	More restrictive building development standards in high-risk areas	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**

Type of response	General community ideas or insights	How was it considered?	Is it part of the Strategy?
Avoid	Use planning and zoning mechanisms to define and ‘protect’ areas of low-risk land for future relocation processes.	Considered as a possible future response	Yes, discussed in Section **Error! Reference source not found.**
Other	We want to understand our risk in comparison to others	Refer to Risk Assessment for Glenorchy and Kinloch	Yes Discussed in Section 9.3.5
Other	We want the social and economic worth of our community to be considered in decision-making	Refer to Socio-economic Impact Assessment Phase 1	Yes iscussed in Section 5.4

WHAT RESPONSES ARE ALREADY IN PLACE?

The long-list in Table 9-6 identifies 13 responses that are already in place and contributing to hazard management at Head of Lake Whakatipu. Further discussion of details and implementation is provided below.

EXISTING SOCIAL, BEHAVIOURAL, AND INSTITUTIONAL CHANGES

There are several ways ORC, partners, community and stakeholders are improving awareness of natural hazard risks and impacts of climate change. This Strategy recognises that knowledge sharing is a two-way process, and so it is essential to have open and transparent dialogue between councils and communities. These efforts aim to improve individual, community and organisational awareness and build their adaptive capacity to natural hazard risks and future changes. Existing and ongoing actions in this category, include:

- Making all information (including technical reports, Council update reports) publicly available on the Head of Lake Whakatipu webpage[14].
- Making technical reports more accessible for a public audience, by providing 'plain-language' summaries.
- Updating the Otago Natural Hazards Portal[15] with the latest natural hazard mapping information.
- Coordinating public talks and recorded presentations on findings of key hazards studies.
- Attending community events to allow opportunities for people to talk with ORC staff and for two-way knowledge sharing and learning.
- Hosting engagement events to provide opportunities for people to talk with ORC staff and consultant experts for two-way knowledge sharing and learning.
- Providing responses to natural hazard enquiries from members of the public.
- Providing QLDC with hazard information, for QLDC to update Land Information Memorandums (LIM).
- Capturing local knowledge, observations and experiences through engagement and feedback from community members.

EXISITNG PLANS AND POLICY THAT GUIDE LAND USE AND DEVELOPMENT

2021 Queenstown Lakes District Spatial Plan (the Spatial Plan) – was developed in partnership with the Queenstown Lakes District Council (QLDC), central Government, Aukaha, and Te Ao Mārama inc. (Kāi Tahu). It is noted that the Otago Regional Council have since joined the Grow Well Whaiora Partnership and are jointly responsible for implementing the Spatial Plan. The Spatial Plan sets out a vision and framework for how and where the district will grow out to 2050. It is focused on ensuring that future growth happens in the right place and is supported by the right infrastructure. It does this by:

- Aligns decision making and investment across local, regional and central government.

[14] https://www.orc.govt.nz/get-involved/projects-in-your-area/head-of-lake-whakatipu/investigations-reports-and-presentations/

[15] https://maps.orc.govt.nz/portal/apps/MapSeries/index.html?appid=b24672e379394bb79a32c9977460d4c2

- Identifies existing and future urban areas and infrastructure needs.
- Identifies priority areas for investment and action; and other strategically significant priorities.
- Identifies areas to protect and enhance; and areas subject to natural hazards.

QLDC District Plan (QLDC) – guides land use and development in the district. It contains objectives, policies and rules for resource management activities. It sets out what activities can be done as of right, what activities need resource consent for, and how certain activities may be carried out. It covers things like residential development; noise; location and height of buildings; activities on the surfaces of rivers and lakes; and protection of indigenous vegetation.

The District Plan defines rules for permitted activities. Chapter 28 of the Proposed District Plan provides a policy framework to address natural hazards throughout the District. Currently, low-lying areas at Glenorchy and Kinloch that are susceptible to flooding from high lake levels are shown as 'Historical Flood Zone' on the Planning Maps, with corresponding rules relating to building levels: *"buildings with a gross floor area greater than 20m^2 shall have a ground floor level not less than RL 312.8 masl (412.8 Otago Datum) at Kinloch, Glenorchy and Kingston"*.

EXISTING INVESTMENT IN ASSETS, SERVICES, AND ACTIVITIES

Long-term plans (LTP) are Ten Year Plans, adopted by councils every three years. They are the blueprint for investment in the region's (ORC) and district's (QLDC) infrastructure, services and activities over the next ten years. LTPs also include 10-year Financial Strategies and 30-year Infrastructure Strategies. The current long-term plans that are relevant to this Strategy are:

- QLDC 2024-2034 Long Term Plan
- ORC 2024-2034 Long Term Plan

The Action Plan (Section 10) outlines existing and planned actions for the following assets, infrastructure and activities relevant to the Strategy:

- Road network (including Rees and Dart Bridges) (QLDC)
- Glenorchy floodbank (QLDC)
- Kinloch and Glenorchy wharfs (QLDC)
- River management (ORC)
- Integrated catchment management (ORC)
- Monitoring, forecasting and warning (ORC)

QLDC undertakes asset and infrastructure management activities, such as inspection, operational repair and maintenance, as well as planning and decision-making regarding improvements and renewals. QLDC's Asset and Activity Management Plans (https://www.qldc.govt.nz/your-council/council-documents/asset-management-plans/), such as Land Transport Asset Management Plan 2021-2031, provide additional details.

In response to the February 2020 flood event, erosion mitigation actions were carried out for Glenorchy floodbank.

ORC undertakes river and floodplain management activities, such as vegetation and gravel management, as well as associated planning and decision-making.

EXISTING EMERGENCY MANAGEMENT - REDUCTION, READINESS, RESPONSE AND RECOVERY

In alignment of the four principles of the National Disaster Resilience Strategy (2019) and the National Civil Defence Emergency Management Plan (2015): *reduction, readiness, response and recovery*, Otago CDEM has implemented various actions over recent years to enhance the capacity of communities at the Head of the Lake to manage and recover from emergencies. These principles are presented in the Otago Civil Defence Emergency Management Group 10-year Plan (2018-2028)[16]. Specific actions of Otago CDEM at Head of the Lake are detailed in Action Plan (Section 10).

To reduce risks from natural hazards, Otago CDEM is collaborating with ORC teams, including the Natural Hazards team, as well as communities and stakeholders, to identify and analyse risks to life and property, lifelines and critical infrastructure. This is being achieved through a combination of technical studies, workshops and consultations in the area. Otago CDEM is also developing a Catastrophic Event Plan: Alpine Fault (CATPLAN) to assist emergency managers and responding agencies prepare for this complex emergency scenario (Otago CDEM, 2024). This plan is in the consultation phase with stakeholders and is expected to be ratified by Otago CDEM Chief Executive's Group and Joint Committee in March 2025.

To get ready for emergencies, Otago CDEM is collaborating with communities, Community Response Group members and QLDC to develop emergency guidelines and plans. Recent initiatives have been completed, including the Glenorchy Community Response Plan (CDEM and Community Response Group, 2022) and the Community Emergency Preparedness Brochure (CDEM and QLDC, no date). Otago CDEM has also conducted workshops and training sessions to build capacity and improve the emergency preparedness and response skills of communities and community groups.

To respond to emergencies, Otago CDEM has developed evacuation plans to facilitate the safe relocation of people across the Head of the Lake area, including designated evacuation centres in Glenorchy and Kinloch. In the September 2023 weather event, the lagoon reached a high-water level (312.49m) and came close to overtopping the floodbank crest into the township area. A precautionary evacuation of flood-prone properties was undertaken. Although no flooding occurred on that occasion, the event and response provided a test of CDEM planning.

For emergency recovery, Otago CDEM has guided the Community Response Group in incorporating this objective into the Glenorchy Community Response Plan. The recovery plan emphasizes coordinated efforts to support community recovery after an emergency. It also outlines immediate, medium and long-term outcomes that the community aims to achieve following such events.

Environmental monitoring

Timely and relevant flood warning and emergency response can be considered a primary means of increasing the preparedness of the community and thus reducing the economic and social impact of a flood event.

ORC's current environmental monitoring stations in the head of Lake Whakatipu area are shown in Figure 13.1.

[16] https://www.otagocdem.govt.nz/media/1388/emergency-manangement-otago-group-plan-adopted-june-2019.pdf

All ORC monitoring data is publicly available in near real-time through ORC's online data portal,[17] allowing the community to proactively monitor river/lagoon/lake levels and take action if required. The monitoring data is also invaluable to the ORC flood response team, and to inform hydrological analysis for hazards assessment and development of flood forecasting models.

In response to the February 2020 flooding event, three new environmental monitoring stations were installed in the Glenorchy and Rees River area, designed to provide improved monitoring coverage and understanding of hydrological responses to major weather events.

- Rees River at Invincible (river flow), site established December 2021.
- Glenorchy Lagoon (water level), site established October 2020.
- Lake Whakatipu at Glenorchy marina (water level), site established January 2021.

Following installation of the new Rees River and Glenorchy Lagoon sites, further work was also carried out to increase the resilience of the recorders, such as building redundancy into the station's sensor and communications systems.

Early-warning alarm levels are set for Lake Whakatipu and Glenorchy Lagoon sites to provide near real-time notification to the ORC's flood response team when water level thresholds are exceeded. This supports timely advice to CDEM Otago and complements flood forecasting tools.

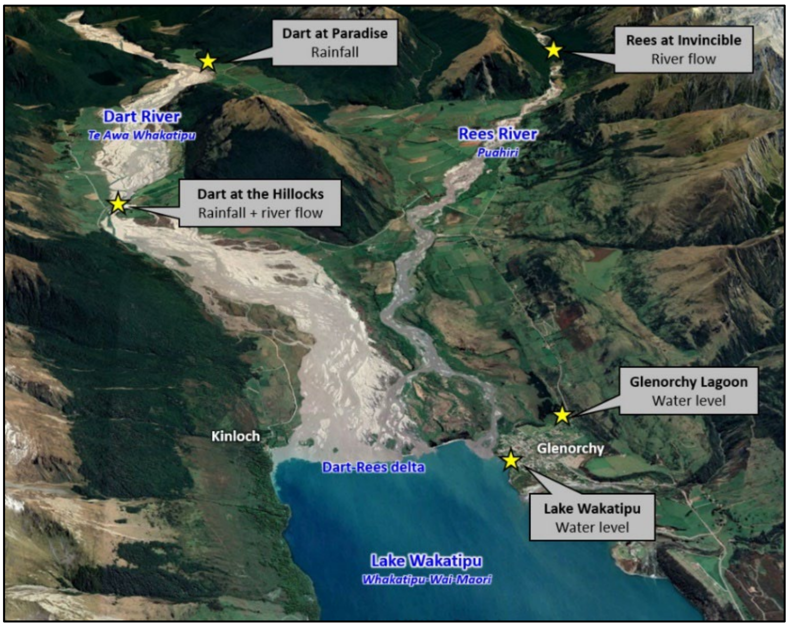


Figure 13.1 ORC environmental monitoring stations in the head of Lake Whakatipu area.

Flood warning systems

ORC has a key role in the flood monitoring and warning process to:

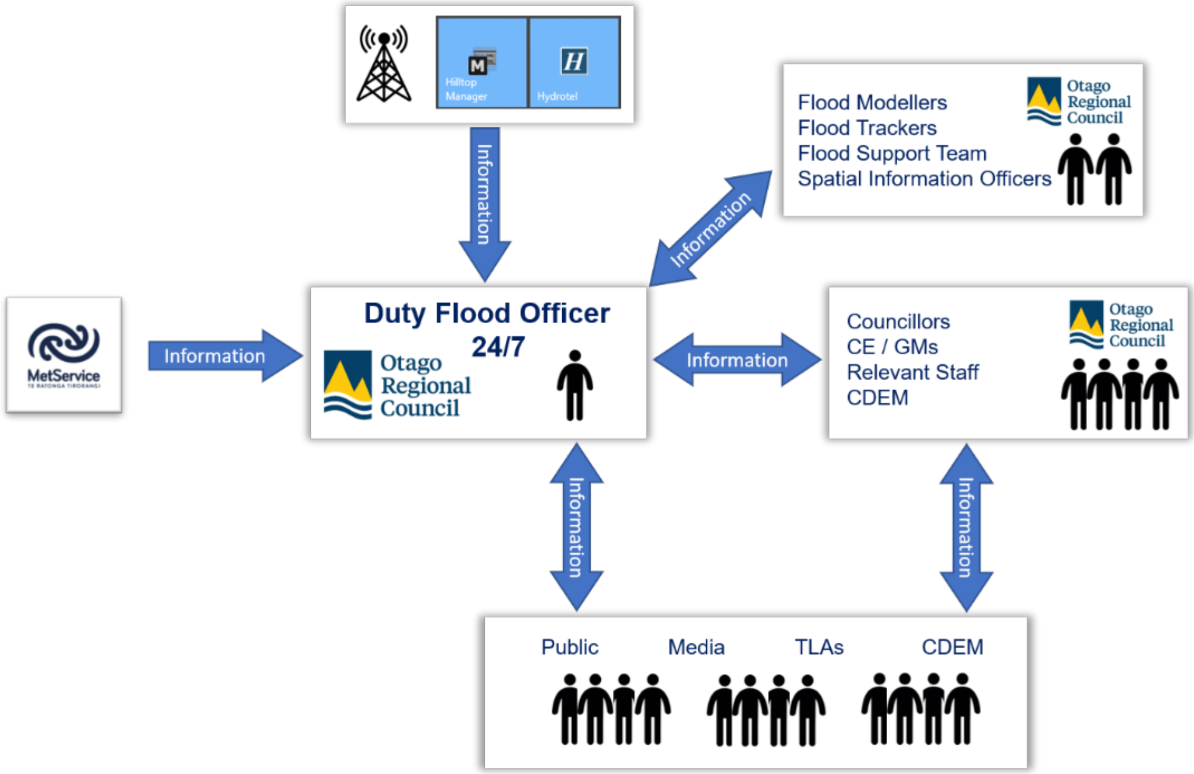
- Maintain an operational flood monitoring telemetry network and telemetry base computer.
- Provide near real-time environmental monitoring data.

[17] https://envdata.orc.govt.nz/AQWebPortal/Data

- Carry out flood forecasting where possible to give greater warning time.
- Provide information on a flood event to territorial authorities, CDEM, community, Councillors, and media.
- Answer public enquiries before, during and after a flood event.
- Carry out flood measurements/observations during a flood event.
- Carry out operational works during a flood event.

ORC maintains a 24/7 on-call flood duty team. The role of this team is to liaise with MetService regarding weather forecast information, to monitor and forecast river flows and lake levels, and to provide information to other agencies (e.g. CDEM, QLDC).

For the head of Lake Whakatipu area, the team makes use of weather forecast, environmental monitoring information, and forecasting tools which enable estimation of likely water levels for Lake Whakatipu and the Glenorchy Lagoon. ORC provides this information to CDEM Otago and QLDC, who provide the communications link to the community.



Glenorchy Lagoon flood forecasting model –

The model is used to forecast possible water levels at Glenorchy Lagoon when significant rainfall totals are forecast for the Rees catchment. The model can provide up to about three days early warning and estimates the final lagoon level for a rainfall event.

This is a relatively new model and still in a testing phase. Consequently, it requires application in a wider range of future rainfall and flood events to better evaluate model performance and accuracy. The model will be evaluated and revised following large flood events and when a longer period of monitoring data is available. For example, the model was evaluated and revised following the September 2023 high-flow event where observed lagoon levels significantly exceeded those used in the model development (Mohssen, 2023b).

Lake Whakatipu flood forecasting model – estimates high lake levels for Lake Whakatipu based on forecast or recorded rainfall totals and recorded river flows.

EXISTING RESPONSES BY PROPERTY OWNERS

Property and business owners make decisions about appropriate levels of insurance coverage for their own situation.

Property owners are free to buy and sell based on their own risk tolerance, and make decisions about investment in property-level resilience to reduce potential damages (e.g. retrofit, floor raising, flood proofing).

Household readiness contributes to effective emergency management.

FUTURE TOOLBOX

The long-list in Table 9-6 includes possible responses that make up the future toolbox. Possible responses in the future toolbox are not commitments, as they do not have business cases or future funding identified at this stage. Some possible responses fall outside the current roles and responsibilities of partner agencies. There should be no expectation that the strategy partners will or will not undertake any particular mitigation works.

FUTURE TOOLBOX - REVIEW AND ADJUST EXISTING RESPONSES

Reviewing the suitability of existing responses is part of planning processes and happens periodically. Reviews consider factors such as; performance, costs and benefits, changes to risks and conditions, opportunities, and sustainability of current responses.

One way to think about the possible future pathways for existing responses:

- **Is it sustainable to keep doing the same?**
- **Are there things we can do better?**
- **Is it time to consider doing things differently?**

Over time we might choose to improve, adjust or expand our current approaches – these are the "do better" responses in our future toolbox (from Table 9-6):

1. Small scale improvement to existing Kinloch and Glenorchy-Paradise local road system road (as well as maintenance and reactive repair)
2. Major works to increase resilience of Kinloch and Glenorchy-Paradise local road system (e.g. protect, raise, realign)
3. Short-term improvements to existing boat access (e.g. dredging)
4. Small scale improvements to Glenorchy floodbank to maintain/reduce flood risk
5. Major works to increase level of service of Glenorchy floodbank
6. River management and nature-based interventions (e.g. targeted planting)
7. Small scale works to reduce Buckler Burn erosion and/or flood risk
8. Improve property and land resilience (such as floodproofing, floor raising, ground or structure strengthening)
9. Improve resilience of critical assets in higher hazard areas (such as floodproofing, floor raising, ground or structure strengthening, retrofit)
10. Policy – Review hazard and risk information and set minimum requirements for new development
11. Recovery plan improvement

In the future we might reach a point where our current approaches are unsustainable or unsuitable for changed conditions and we will need to consider "doing things differently" (from Table 9-6):

12. Reduced level of service of existing Kinloch and Glenorchy-Paradise local road system (e.g. some parts 4WD only)

13. Reactive re-design Kinloch and Glenorchy-Paradise local road system for changed conditions (e.g. post event)
14. Upgrade boat access with resilient solution (e.g. relocatable wharfs)
15. Relocate wharfs periodically to maintain future access
16. Redesign Rees flood protection for changed conditions (e.g. post event)
17. Redesign nature-based interventions for changed conditions
18. Policy - Strengthen land use controls in higher hazard areas to avoid additional exposure
19. Policy and services – make lower hazard land available for new building and/or relocation
20. Proactive relocation plan
21. Voluntary proactive relocation from higher hazard areas
22. Voluntary reactive post event retreat from higher hazard areas

FUTURE TOOLBOX - INVESTIGATION OF POSSIBLE ENGINEERING AND FLOODPLAIN RESPONSES

This section describes investigation reports completed as part of the Strategy work programme, in order to help ORC, QLDC, and the local community understand potential engineering responses or interventions for managing the liquefaction and flooding hazards identified in Glenorchy and in the Dart-Rees floodplain area.

The reports do not give recommendations for which hazard management interventions may be feasible or should be investigated further, but for each intervention considered, aims to outline the challenges and constraints as a starting point to inform continued discussions.

Rees Bridge Options Assessment

The floodplain assessment by Webby (2023) identified potential risks to the Rees River Bridge from continued bed aggradation and the potential for the Rees River to avulse upstream of the bridge.

QLDC engaged WSP to undertake a structural options assessment to help provide direction and guidance towards a long-term asset management strategy for the Rees Bridge structure. The study scope included: existing bridge structure; current levels of service; hydraulic assessment (including scour); morphological issues and options; structural options; and preliminary planning assessment.

Key findings (Wong, 2023):

- There is no simple solution to the sediment transport issue, and it is expected to continue to aggrade and potentially worsen under certain future scenarios (such as a major earthquake effecting the catchment).
- Due to predicted and observed outflanking of the bridge, there is also potential for the approaches to be damaged or washed away. However, this is preferable to a bridge pier being damaged. The approaches (and hence the bridge) should not be raised in the absence of lengthening the total span as this would potentially increase the risk and extent of scour at the bridge itself by forcing more flow through the bridge.
- It is evident that the aggradation risk at the Rees River Bridge is reliant on wider geomorphological behaviours and the hydraulic characteristics of the wider floodplain. While structural options such as raising the existing bridge and early bridge replacement were considered, the feasibility of both options remain subject to further assessment and

not considered to be of priority. The bridge raising option is also likely to be cost prohibitive and unlikely to be favoured particularly given the potential closure that would be required given that alternative crossings are not available. A full bridge replacement also carries a significant cost and is unlikely to be favoured given the considerable remaining life (~40 years) of the structure.

Wong (2023) recommends ongoing monitoring and data collection, and the following measures to manage the aggradation risk and help inform longer term plans for the Rees Bridge:

- In the short term, managing ongoing aggradation through continued gravel extraction measures appear most appropriate to minimise the rate of gravel build up.
- In the short to medium term, narrowing the channel (e.g. groynes) in the location of the bridge to increase flood velocity and sediment transport should be considered. This would be expected to provide a short-term benefit in the range of 5 – 10 year.
- In the longer term, collaborate between ORC and QLDC on a river management plan for the Rees River is recommended.

How does this link with responses in our future toolbox (Table 9-6)?

- ➢ Small scale improvement to existing Kinloch and Glenorchy-Paradise local road system road (as well as maintenance and reactive repair)
- ➢ Major works to increase resilience of Kinloch and Glenorchy-Paradise local road system (e.g. protect, raise, realign)

Floodplain hazards management

There are three areas of interest on the Dart-Rees floodplain where flooding or erosion may impact the community or infrastructure in the head of Lake Whakatipu area. These areas are shown in Figure 13.2:

- The lower Rees floodplain and Glenorchy township.
- The Dart floodplain and Kinloch access.
- The upper Rees floodplain and the Rees bridge

An assessment by Webby (2023) was undertaken to identify and review, at a high-level, the potential engineering or river management responses available for management of flooding and floodplain hazards. This included consideration of suggestions by community members. For each area of interest, the report also outlined information gaps identified, and gives recommendations for monitoring and additional analysis to address those gaps.

The Webby (2023) report was followed by more detailed technical feasibility studies (Veale and Shrestha, 2024; Menéndez Arán and Shrestha, 2024; Veale, Shrestha and Webby, 2024) to further explore potential responses. The scope and objectives of the most recent 2024 assessments were to:

- Assess the viability of potential options that mitigate existing flood hazards
- Provide an evidence base to rule out various floodplain management options
- Test viable options for their alignment with a Nature-based Solutions (NbS) approach to floodplain management
- Viable options were taken forward to a concept level design stage (i.e. drawings and costings)

The following items were out of scope: backwater flooding hazard to Glenorchy from high water levels in Lake Whakatipu; options to raise and/or lengthen the existing Rees River Bridge; options to raise or re-route the existing Kinloch Road; and any options previously discounted in 2022 floodplain adaption workshop.

Raising the existing Rees-Glenorchy floodbank structure **–** was found to be potentially viable as a response for lower Rees floodplain and Glenorchy township flood hazard. Raising the existing floodbank crest levels by approximately 0.75 to 1.1 m could increase the level of service for Rees flooding to 1 in 100 AEP flood (including climate change and freeboard), potentially reducing the flood hazard extent and depth in the township (Figure 13.3). The concept level design, key benefits, costs and residual risks for the raising option are shown in Figure 13.4.

How does this align with responses in our future toolbox (Table 9-6)?

- ➢ Major works to increase level of service of Glenorchy floodbank

Rockfill and vegetated buffers protections for Kinloch Road erosion hazards – The scale of the flood hazard is very challenging to defend against with conventional engineering solutions (e.g. floodbanks) and so the focus was on mitigation of existing flood hazards and providing room-for-the-river.

The intervention options carried forward were a combination of rockfill and vegetated buffer protections (prioritised to allow staged implementation) (Figure 13.5). These interventions were focused on:

a) Mitigating river-bank migration
b) Preventing damage to Kinloch Road
c) Reducing rate of farmland loss between the road and the riverbank to provide protection for the road

How does this align with responses in our future toolbox (Table 9-6)?

- ➢ River management and nature-based interventions (e.g. targeted planting)
- ➢ Major works to increase resilience of Kinloch and Glenorchy-Paradise local road system (e.g. protect, raise, realign)

Managed floodway on north (right bank) approach to the Rees bridge **–** Under flood conditions, there is insufficient conveyance capacity through the bridge waterway. The river naturally wants to break-out on the true left and right bank floodplains (but primarily on the right bank floodplain). There existing floodbank system on the right bank is outflanked and overtopped in large flood events.

The Rees River Bridge was constructed in c.1950. A floodbank system on the right bank (privately owned) was constructed in c.1980. The floodbank system diverts right bank floodplain flows and increases the flood discharge passing through the Rees River Bridge waterway. In conjunction with channel bed aggradation, this has lowered the level of service of the bridge.

The scale of the flood hazards is very challenging to defend against with conventional engineering solutions (e.g. floodbanks) and so the focus was on the following:

- 1. Providing a managed floodway on the left and/or right bank approaches to the bridge.
    - ➢ Guide floodplain flows in defined areas past the bridge

  - ➢ Reduce flood discharge through the Rees River Bridge waterway.
- 2. Alignment with NbS strategies that provide "room for the river"
  - ➢ Floodplain widening and embankment removal or retreat, rather than construction of new floodbanks

A right bank floodway was found to be potentially viable and carried forward for costing, with and without road raising.

- Option A - Develop Right Bank Floodway & Raise Roads – indicative cost range $6,050,000 to $8,470,000
- Option B - Develop Right Bank Floodway, No Road Raising – indicative cost range $470,000 to $660,000

How does this align with responses in our future toolbox (Table 9-6)?

- ➢ Major works to increase resilience of Kinloch and Glenorchy-Paradise local road system (e.g. protect, raise, realign)

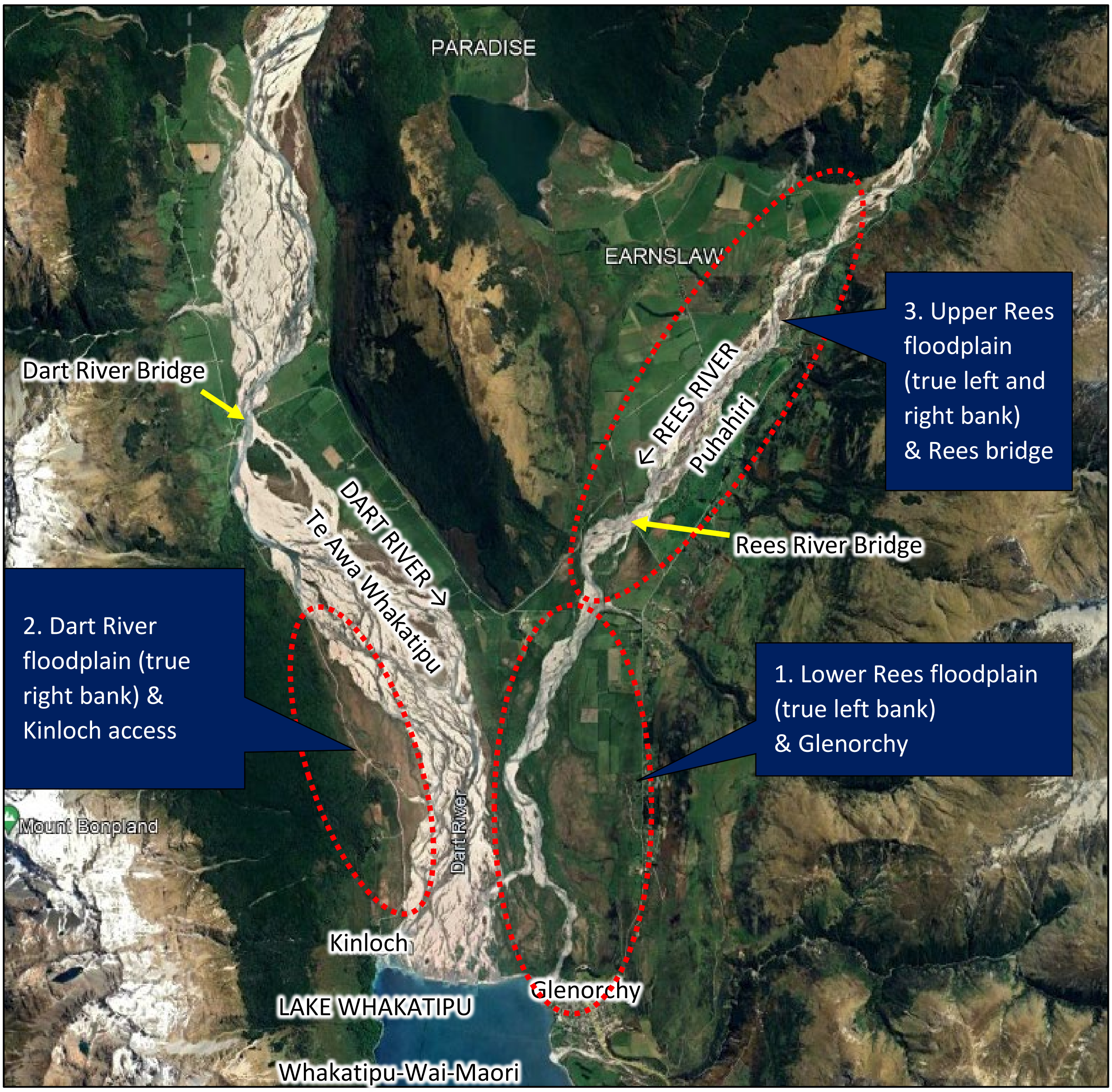
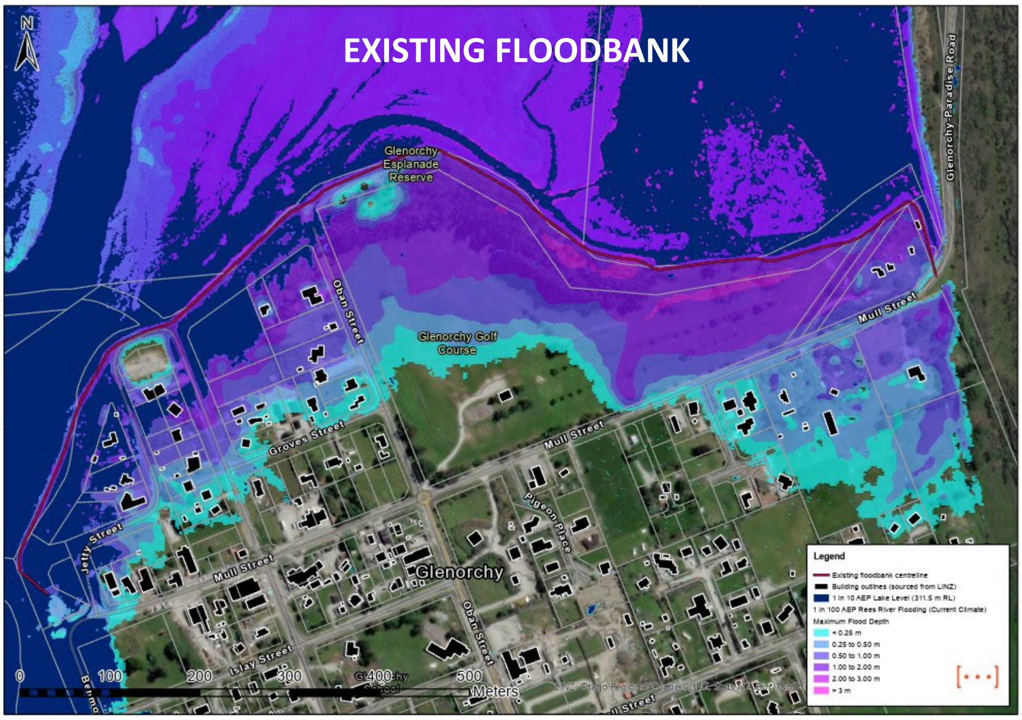
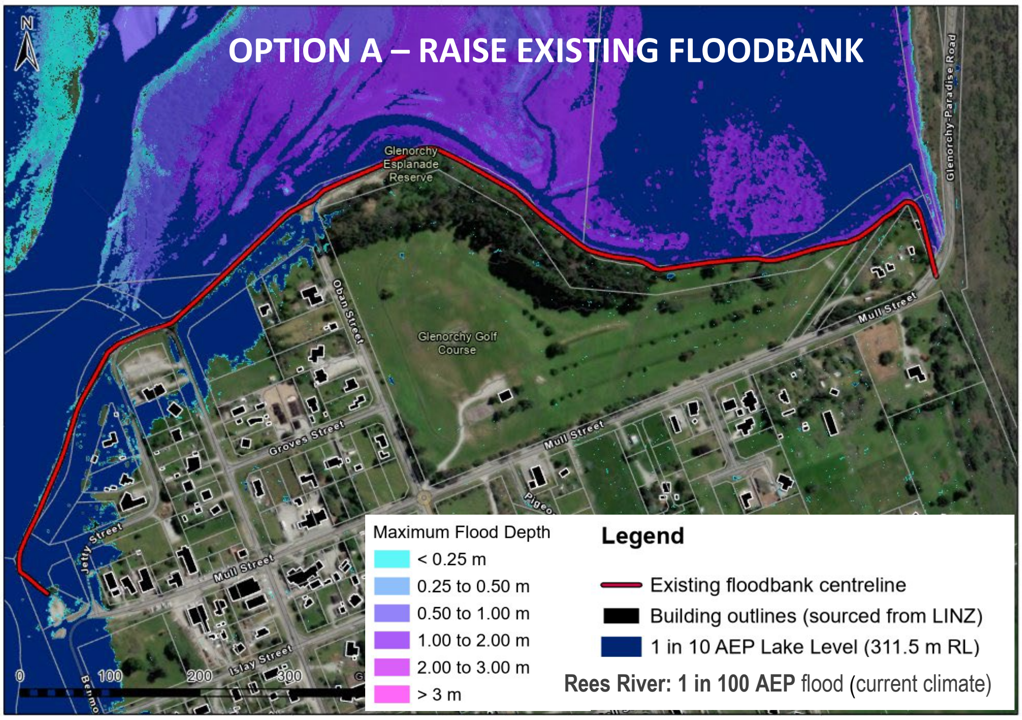


Figure 13.2 Three areas of interest on the Dart-Rees floodplain (modified from Veale presentation 2024

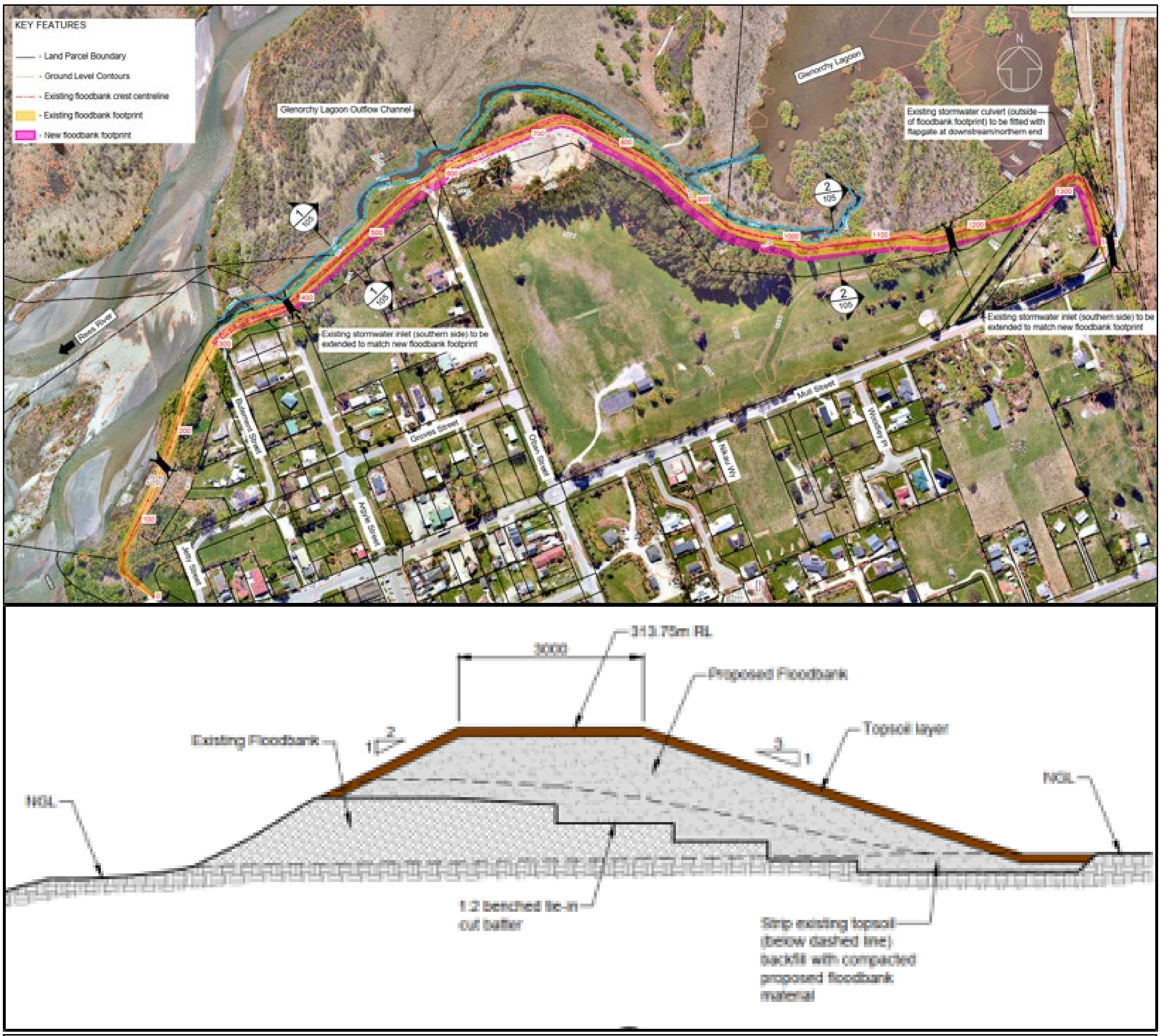


Flood depth information sourced from:
2022 Land Sea River report "Dart / Rees Rivers Flood Hazard Modelling"



Flood depth information sourced from: Current 2024 Damwatch assessment

Figure 13.3 Comparing 1 in 100 AEP Rees flood extent and depth with existing floodbank (top) and Option A: Raise Existing Floodbank (bottom) (Veale, 2024).



Key Benefits of Raising Existing Floodbank:

- ➢ Increase level of service of existing floodbank from 1 in 20 AEP (current climate) to 1 in 100 AEP (including climate change effects)
- ➢ Reduction in number of properties directly impacted from river flooding.

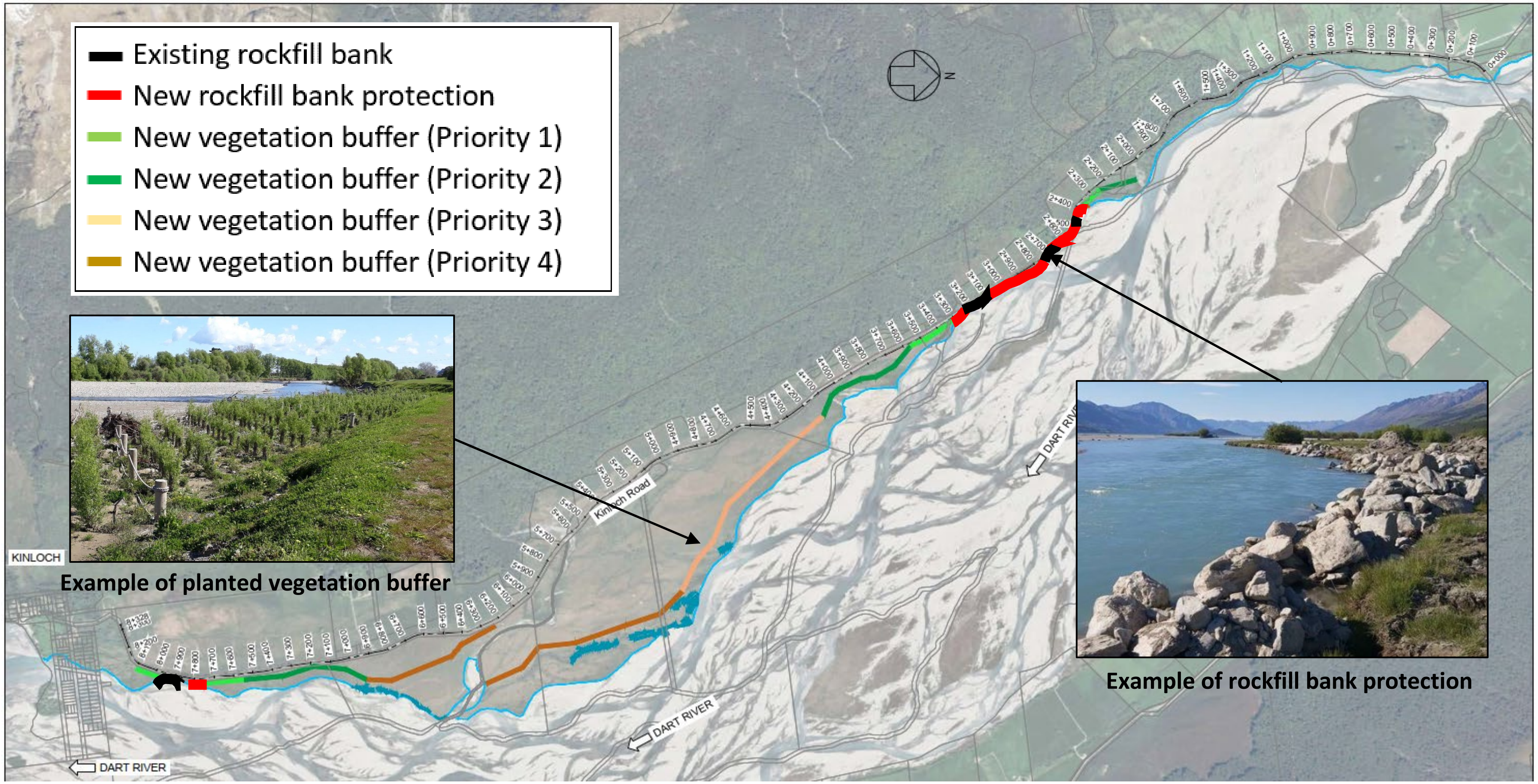
Indicative cost range: $1.6M to $2.3M

- ✓ Includes design, consenting and construction costs
- × Excludes any required land purchase costs

Residual risks:

- × No defence against lake level flooding (floodbank outflanked)
- × No defence against over-design floods (floodbank overtopped/breached)
- × Potential erosion of existing floodbank by Rees River flood events

Figure 13.4 C Conceptual design for raising existing Glenorchy floodbank (Veale, 2024).



Indicative Cost Range for Dart River Bank Erosion Protection Measures - includes design, consenting and construction costs (excludes any land purchase costs)				
New Rockfill $2,360,000 to $3,300,000	**Vegetation Buffer (Priority 1)** $162,000 to $230,000	**Vegetation Buffer (Priority 2)** $260,000 to $360,000	**Vegetation Buffer (Priority 3)** $230,000 to $320,000	**Vegetation Buffer (Priority 4)** $300,000 to $420,000
Residual risks: No defence against road inundation				

Figure 13.5 Combination of rockfill and vegetated buffer protections (prioritised to allow staged implementation) (Veale, 2024)

Liquefaction hazard management

A report by Tonkin + Taylor (2023) identifies a range of engineering mitigation techniques that could be considered for the management of liquefaction and lateral spreading hazard at Glenorchy township. Mitigation techniques, detailed in Appendix B, focus on reducing damage to land; buildings; and infrastructure; and span from very robust options through to a "do nothing" option:

- deep and shallow ground improvement; and geogrid-reinforced crushed gravel rafts are techniques that can reduce damage to land.
- new TC3-type and TC2-type foundation options; and proactive retrofit strengthening of existing buildings are techniques that can reduce damage to buildings.
- new infrastructure should incorporate resilient detailing to better accommodate displacement; and targeted upgrades of critical weak links can improve overall resilience of existing infrastructure.

The report then shows how these techniques could be applied across the township, provides a preliminary high-level assessment of how effective these mitigation works could be in reducing damage, and an indicative relative cost comparison.

The report notes that the more robust end of the range might be impractical or unaffordable, while the less robust end of the range might not satisfy Building Code or insurability requirements. However, for completeness, the report includes these options to provide context for discussion about the range of potential improvements that could be considered.

At the more robust end of the range, the mitigation options incorporate a strip of deep ground improvement constructed on public land running along the edge of the lake. This ground improvement would need to be in the order of 15 – 20m deep, 30 – 40m wide, and approximately 1.5km in length (information provided by Mike Jacka, T+T). Based on the indicative relative cost estimates presented in the February 2023 T+T report, T+T advise that the construction cost for this edge-treatment work alone would likely be many tens of millions of dollars.

In addition to this, many of the mitigation options include ground improvement across the wider township (under both public and private buildings and infrastructure), and there would also be additional coordination and enabling works costs associated with such a large programme of community-wide works. T+T advise that this could bring the overall cost into the hundreds of millions of dollars.

Aside from cost, these engineered interventions considered also have other significant challenges associated with their implementation and effectiveness;

- These interventions do not provide a complete reduction in the natural hazard impacts. It is estimated that 25-30% of buildings and infrastructure in the lateral spreading hazard areas would suffer severe liquefaction damage in a large earthquake, even if comprehensive mitigation works were undertaken.
- These interventions involve the undertaking of large-scale engineering works and would likely be highly disruptive to the local community.
- Some of the area vulnerable to liquefaction and lateral spreading damage is also exposed to other types of natural hazard, such as flooding hazards from Lake Whakatipu, the Rees River or Buckler Burn. Consideration of any potential hazard management interventions for liquefaction and lateral spreading should be part of an integrated response considering the full natural hazard risk profile, not just the seismic-induced hazards.

How does this align with responses in our future toolbox (Table 9-6)?

- Improve property and land resilience (such as floodproofing, floor raising, ground or structure strengthening)
- Community-wide improvement works for liquefaction hazard (such as ground improvement and strengthening existing buildings)
- Review and accept residual risk for existing development
- Policy – Review hazard and risk information and set mininmum requirements for new development

Table 13-3 Liquefaction mitigation techniques for reducing damage to land (T+T, 2023)

Works	Description of mitigation techniques for reducing damage to land
15 – 20m deep by 30 – 40m wide perimeter treatment ground improvement alongside lake	A long vibrating probe is used to compact the ground and inject gravel to form columns about 1m in diameter, in a grid pattern at about 2m spacings. This strip of very deep improvement along the lake edge acts like an "underground dam" of solid ground which helps to hold back the liquefied ground and reduce lateral spreading ground displacements. Perimeter treatment can help reduce the lateral spreading hazard for areas further inland (but the inland ground could still experience settlement damage if the underlying ground liquefies).
12m deep ground improvement, all land	Ground compaction and gravel columns as above, covering all land in an area (e.g. under buildings, roads and the land in between). Only 12m deep so there is still potential for the ground deeper than this to liquefy. This means that liquefaction settlement and lateral spreading could still occur, but the magnitude of displacement should be less.
12m deep ground improvement, land under buildings & infrastructure only	Ground compaction and gravel columns as above, but only covering land under buildings & infrastructure (no improvement of land in between). This will form individual "islands" of ground improvement which can help to reduce settlement and lateral spreading (but less effective at controlling lateral spreading that the options above).
12m deep ground improvement, land around buildings & infrastructure where accessible	This ground improvement approach could be considered where there are existing buildings & infrastructure, to avoid the need relocate them to improve underneath. The main benefit of this is reducing lateral spreading by improving a block of surrounding ground. Significant ground settlement could still occur due to liquefaction of the unimproved ground beneath.
4m deep ground improvement, land under buildings & infrastructure only	There are various shallow ground improvement methods which could be used to compact the upper 4m of the soil profile, including gravel columns (as above), dynamic compaction (a crane drops a weight on the ground) and impact compaction (a square roller or hammer hits the ground). This will have little effect on lateral spreading displacements, but can help reduce the severity of differential ground settlement due to liquefaction and ejected soil. Therefore this option is more applicable in areas further inland where less lateral spreading is expected, or in conjunction with perimeter treatment to reduce lateral spreading displacements.

Works	Description of mitigation techniques for reducing damage to land
1.2m deep geogrid-reinforced crushed gravel raft, under buildings & infrastructure only	This method provides a stiff platform of well compacted and reinforced gravel beneath buildings & infrastructure. The main benefit of this is to help reduce the severity of differential ground settlement due to liquefaction and ejected soil. The geogrid can help reduce the magnitude of lateral ground stretching to some degree (encouraging cracks to instead form on either side), but is less effective than deep ground improvement for controlling lateral spread. Therefore this option is more applicable further inland where less lateral spread is expected, or in conjunction with perimeter treatment which reduces lateral spreading.
No improvement	Ground remains in its current state within an area. However, in some mitigation scenarios ground improvement in a neighbouring area may help to provide some reduction in lateral spreading ground displacement, so we have made allowance for this in our damage estimates where appropriate.
NOTE: The details quoted in this table (such as depth and extent of treatment) are intended to be indicative only, to provide a general picture of the relative scale of the various options. Actual details would need to be determined as part of the design process, to meet agreed target performance requirements.	

Table 13-4 Liquefaction mitigation techniques for reducing damage to buildings (T+T, 2023)

Works	Description of mitigation techniques for reducing damage to buildings
New TC3 surface structure foundations	The MBIE Canterbury rebuild guidance provides five concepts for raised platform foundations designed to accommodate significant ground settlement and lateral spreading while limiting deformation of the overlying structure. Settlement and damage is still expected to occur, but the aim is for this to be readily repairable. Existing buildings would need to be temporarily lifted, and possibly relocated, for the new foundation to be constructed underneath. This foundation type also has the added benefit of raising floor levels higher above flood levels.
New TC2 waffle slab foundation or enhanced lightweight platform on timber piles	The MBIE Canterbury rebuild guidance provides numerous TC2-type foundation options, however the most commonly adopted are waffle slab foundations (for concrete slabs) and enhanced lightweight platforms (for timber floors). Existing buildings would need to be temporarily lifted, and possibly relocated, for the new foundation to be constructed underneath. Enhanced lightweight platforms also have the added benefit of raising floor levels higher above flood levels.
Retrofit to strengthen existing foundations and buildings	While the primary focus of the MBIE Canterbury rebuild guidance is on robust design of new buildings and repair of damaged buildings, some of the same concepts could be applied for proactive retrofit strengthening of existing buildings. This would avoid the need to lift/relocate existing buildings, but might not provide the same performance as a new TC2 or TC3 foundation.

Works	Description of mitigation techniques for reducing damage to buildings
	For timber floor foundations this could include subfloor sheet bracing, bolt-spliced bearers, and enhanced connections between piles and bearers. Retrofit strengthening may be more difficult for concrete slab foundations, but could include internal and perimeter tie beams and edge stiffening. There may also be opportunities to enhance the superstructure, such as sheet claddings/linings, lightweight roof/cladding, stiffening walls, and enhanced connections between walls and roof framing.
No improvement	Foundation and building remain in their current state.
NOTE: The foundation concepts in this table are for simple lightweight timber-frame buildings (such as typical houses, or small commercial buildings of similar construction). It might be possible to apply similar concepts to other types of building, but this would need specific engineering assessment. For all buildings, actual details would need to be determined as part design, to meet Building Code performance requirements for building consent.	

Table 13-5 Liquefaction mitigation techniques for reducing damage to infrastructure (T+T, 2023)

Works	Description of mitigation techniques for reducing damage to infrastructure
New infrastructure with resilient detailing	New infrastructure should incorporate resilient detailing to better accommodate displacement. This includes avoiding higher hazard areas, providing redundancy within a system, adopting appropriate technology (e.g. pressure sewer), careful selection of pipe/cable materials, robust/flexible connections, utilising details that resist uplift, and granular/cemented trench backfill.
Retrofit to strengthen existing infrastructure	For existing infrastructure, opportunities to enhance the entire network can be more limited (short of complete replacement). However, detailed assessment of the system may identify critical "weak links" where targeted upgrades can improve the overall resilience of the wider network.
No improvement	Infrastructure remains in its current state.

FUTURE TOOLBOX - LAND USE PLANNING AND GOVERNANCE MEASURES

The Coastal Hazard Guidance (MfE 2024) identifies planning responses to avoid (or reduce where appropriate) greater exposure to coastal hazards and risk. These responses could also be considered for other natural hazards:

- Down-zoning can prevent intensification or exclude areas from further development or redevelopment (Policy 25, NZCPS, DOC, 2010).
- Create rules to discourage or limit specified activities in identified hazard areas, using the full range of Resource Management Act 1991 activity classifications, including prohibited activities. When used in association with hazard lines, zoning or overlays, this can ensure that development occurs only in accordance with a consenting process and subject to conditions, or it may prohibit further development entirely. For example, 'restricted' or 'full discretionary' activity status is an opportunity for a consent authority to set controls

through conditions on building location or design in specified zones or certain sites, or to decline consent. 'Prohibited' activity status means that no consent can be sought for specified activities in the identified locations. The district plan must specify the discretions and prohibitions.

- Land filling and raising floor levels are temporary adaptation measures and can be prohibited in specified locations to avoid further development that will create legacy effects.
- Other methods and techniques that can be used in statutory planning to manage natural hazards and risk include:
  - designation of protection or buffer areas, which may be used to provide for infrastructure
  - no subdivision areas
  - temporary development or land-use consents
  - covenants, easements and consent notices
  - specifying types of construction and building design and use (e.g., relocatable buildings)
  - land information memoranda (LIM) or project information memoranda (PIM)
  - bonds
  - land purchase
  - special rating areas for funding capital and maintenance of protection, applied under the Local Government Act 2002, could be used to fund capital or maintenance of protection. The areas to which a special rate is applied, and the rate itself, need to be justified on the basis of benefit obtained from the council activity
  - grants and information support

FUTURE TOOLBOX - RETREAT / RELOCATION

Retreat (or relocation) is the process of moving away from high-risk areas. There are no current opportunities for voluntary buy-outs or funding for land acquisition in Head of the Lake area. However, these responses remain in the future pathways in case of future need. Responsibilities for retreat are not defined in this first iteration of the Strategy, due to a lack of legislative clarity.

Reactive retreat describes retreat from affected (or unsafe) land after a natural hazard event has occurred. Aotearoa New Zealand examples tend to be one-off programmes coming out of disaster recovery:

- Land acquisition in Christchurch residential red zone – in response to the 2010/2011 earthquakes and liquefaction events
- Future of Severely Affected Locations (FOSAL) buy-out programme – in response to 2023 North Island floods and Cyclone Gabrielle.

Managed relocation describes a planned relocation of people, buildings and infrastructure out of harms way before damage is suffered.

- Recent review of current law and policy by Environmental Defense Society (EDS, 2022-2024) has identified that the current legislative tools in Aotearoa New Zealand are not fit for the purpose of managed relocation. EDS highlighted various concerns, such as: a lack of clear rules around development in areas subject to risk; gaps in responsibilities; lack of a legal framework linking adaptation plans to funding; and problems with acquisition of affected land under current law.

Back page placeholder for kid's art competition prizewinners

(design in progress)