The risk of climate change to the built environment in the Clutha District

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DISCLAIMER

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EXECUTIVE SUMMARY

This report provides a first assessment of climate change risks to the Clutha District's built environment. Specifically, it summarises risks across the transport, Three Waters infrastructure, homes and buildings, public amenities, and waste sectors. The report focuses on the impact of floods, extreme sea level events, heavy rainfall periods or long-term coastal erosion on the maintenance and delivery of Clutha's important infrastructure and services.

Drawing on expert knowledge from council staff obtained through targeted meetings and a group workshop, this assessment has found some climate change risks may cause extreme consequences to the social and economic functioning of the district (see table below). These include risks to potable water treatment plants, road networks, homes and buildings, and flood or coastal defence mechanisms as a result of flood or coastal inundation and heavy rainfall events. Other potential concerns for the district include risks to community facilities (such as halls, libraries, and leisure centres), and contamination from closed landfills as a result of flood or coastal inundation, heavy rainfall events, or ongoing coastal erosion.

While some infrastructure and facilities face significant climate change risk, through informed and proactive planning, these risks can be mitigated and/or alternate adaptation pathways sought. Doing so, will ensure a vibrant and well-serviced district into the future.

Table 0-1 Summary of top climate change risks needing further assessment or adaptation activities across the different infrastructure sectors, as determined during consultation with Clutha District Council staff.

Sector	Risk description	Consequence
Three Waters Infrastructure	Risk to storm-water pipes due to heavy rainfall and increased flood events throughout the district.	**Moderate**
	Risk to potable water intakes and treatment plants due to contamination during heavy rainfall periods, flood events, or coastal inundation (i.e., Balclutha & Kaitangata).	**Extreme**
Transport	Risk to road networks due to coastal or flood inundation (incl. State Highways 1 & 90, Papatowai Highway, and roads throughout Clutha Delta, Pomahaka catchment, Tokomairiro Plain).	**Extreme**
Homes and buildings	Risk to homes, community-housing units and commercial buildings in low-lying areas exposed to coastal or flood inundation.	**Extreme**
Public Amenities	Risk to community facilities (halls, libraries, leisure centres) due to flood or coastal inundation.	**Major**
Waste	Risk of contamination from closed landfills due to flood or coastal inundation.	**Major**
Flood and coastal defence	Risk to flood and coastal defence mechanisms (both ORC and CDC assets) as a result of more frequent inundation caused by floods or coastal hazards.	**Extreme**

1.0 INTRODUCTION

Preparing for, and responding to, the impact of climate change is now regarded as an urgent issue facing the functioning of local governments in New Zealand (LGNZ, 2019). New Zealand has warmed by around 1°C over the last century or so, and is predicted to continue warming by between 0.5 and 5°C by the year 2110 (MfE, 2018). Within the Clutha District, the future climate is generally expected to bring higher temperatures, more frequent and heavier rainfall, higher sea levels, and more flood events (NIWA, 2019a). This changing climate will affect the delivery of various infrastructure services such as water, waste, transport, buildings and public amenities. The Clutha District Council (CDC) is committed to better understanding, and preparing for, changes to our local climate and have therefore commissioned this assessment of climate change risks facing its built environment. The main objectives of this assessment are:

1. *To list and rate the risk of climatic hazards facing elements of the built environment within the Clutha District, including: Three Waters infrastructure, transport infrastructure, houses and buildings, public amenities, flood and coastal defence mechanisms, waste services, and telecommunications and energy (where information is available).*
2. *To prioritise these risks in order of urgency for adaptation and to identify where more information or ongoing monitoring is required.*
3. *To engage and collaborate with council staff and relevant stakeholders in the identification and prioritisation of risks.*
4. *To consider Māori perspectives on climate change risks, and identify issues of particular relevance to Māori.*
5. *To provide the background information needed to support the development of an informed and flexible climate change adaptation plan (Stage 3 of Council's Climate Change Leadership and Response Plan).*

1.1 CONTEXT OF WORK

New Zealand has recently completed its first National Climate Change Risk Assessment (NCCRA). The NCCRA identifies climate change risks and urgency ratings across five domains of: governance, economy, human, built environment, and natural environment (Table 1-1).[1] While this assessment provides an informative overview of risk at the national scale, more detailed assessments are still required at the district level to enable locally informed and targeted adaptation. Accordingly, CDC have identified that a detailed assessment of risks facing its built environment is required for local adaptation planning.

The NCCRA defines the built environment as 'the set and configuration of physical infrastructure, transport and buildings'. It includes built infrastructure across various sectors including housing, public amenity, potable water, wastewater, storm water, energy, transport, communications, waste, coastal and flood defence and Māori cultural assets. CDC's focus on the built environment reflects their operational priorities, and this report builds on the findings

[1] The five value domains used in the NCCRA are a hybrid of The Treasury's *Living Standards Framework* (The Treasury, 2018) and those used in the *National Disaster Resilience Strategy* (Ministry of Civil Defence and Emergency Management, 2019).

of the NCCRA and the Otago Regional Climate Change Risk Assessment (OCCRA) (Tonkin & Taylor, 2021).[2]

Subsequent sections of this report outline the methodology that was undertaken to assess climate change risks to elements of CDC's built environment and summarise the main findings of this risk assessment process.

Table 1-1 New Zealand's 10 most significant climate change risks, based on consequence as identified within the NCCRA (available at: https://www.mfe.govt.nz/climate-change/assessing-climate-change-risk).

Domain	Risk	Consequence
Natural Environment	Risks to coastal ecosystems, including the intertidal zone, estuaries, dunes, coastal lakes and wetlands, due to ongoing sea-level rise and extreme weather events.	**Major**
	Risks to indigenous ecosystems and species from the enhanced spread, survival and establishment of invasive species due to climate change.	**Major**
Human	Risks to social cohesion and community wellbeing from displacement of individuals, families and communities due to climate change impacts.	**Extreme**
	Risks of exacerbating existing inequities and creating new and additional inequities due to differential distribution of climate change impacts.	**Extreme**
Economy	Risks to governments from economic costs associated with lost productivity, disaster relief expenditure and unfunded contingent liabilities due to extreme events and ongoing, gradual changes.	**Extreme**
	Risks to the financial system from instability due to extreme weather events and ongoing, gradual changes.	**Major**
Built Environment	Risk to potable water supplies (availability and quality) due to changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise.	**Extreme**
	Risks to buildings due to extreme weather events, drought, increased fire weather and ongoing sea-level rise.	**Extreme**
Governance	Risk of maladaptation[3] across all domains due to practices, processes and tools that do not account for uncertainty and change over long timeframes.	**Extreme**
	Risk that climate change impacts across all domains will be exacerbated because current institutional arrangements are not fit for adaptation. Institutional arrangements include legislative and decision-making frameworks, coordination within and across levels of government, and funding mechanisms.	**Extreme**

1.2 CLIMATE CHANGE IMPACTS

The Clutha District is predicted to become warmer and wetter in a future climate, with more water likely to flow through the Clutha River/Mata-Au. These changes may bring opportunities, such as improved winter pasture growth; however, they may also bring challenges such as an increase in flood frequency and severity.

[2] A summary of risks in the built environment in the Otago Region, as assessed through the OCCRA, is attached as Appendix 1.

[3] Maladaptation refers to actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas emissions, increased vulnerability to climate change, or diminished welfare, now or in the future. Maladaptation is usually an unintended consequence.

Patterns of change that may be experienced in the Clutha District were described in a previous GHC Consulting report (Griffin & Goldsmith, 2020). The main findings include:

1. *Temperature is expected to warm across the Clutha District by 0.5°C to 3°C between the year 1995 and 2090. Temperature extremes are predicted to increase, with up to 20 more hot days (days >30°C), and up to 50 fewer frost days (days <0°C), expected each year by 2090. The highest increases in temperature are predicted for West Otago.*
2. *Mean annual rainfall is expected to increase (by 0.1 to 20 per cent) by 2090, and the towns of Milton and Waihola are expected to experience the largest increases in precipitation. Heavy rain days (where >25 mm of rain falls in a 24-hour period) are expected to increase (by 0.1 to 5 days) by 2090, with the largest increases felt in The Catlins.*
3. *The number of dry days (or no-rain days) that occur each year will increase in some areas, while decreasing in others. The Catlins and West Otago may experience an increase of 0.1 to 4 dry days per year by 2090 under a high range emissions scenario. However, the Clutha Valley, Milton and Waihola areas are likely to experience fewer dry days and overall wetter conditions.*
4. *Flood risk is expected to increase. The Clutha River/Mata-Au is expected to experience an overall increase in river flow, especially during the winter and spring months, due to more precipitation and less snowfall in the upper catchment. High intensity rainfall depths are predicted to increase across the district, potentially leading to more frequent and heavy localised flood events.*
5. *Sea level is expected to continue to rise. An extreme sea level event (combining storm surge, high tide, wave run-up and higher sea levels) may expose low-lying coastal settlements and the infrastructure that supports them to periods of inundation.*

2.0 METHODOLOGY

Our risk assessment follows the approach developed by MfE in *Arotakenga Huringa Āhuarangi: A Framework for the National Climate Change Risk Assessment for Aotearoa New Zealand* (MfE, 2019). This risk framework is a values-based approach to assessing climate change risk that is centred on local knowledge and engagement. Our approach therefore reflects the operational priorities and values of CDC, focusing on council owned assets and infrastructure. In the section we describe this methodology and the various steps undertaken to complete this risk assessment (Figure 2-1).

1. Establishing context and scope

- The scope of CDC's risk assessment was narrowed to the built environment to reflect council priorities and avoid overlap with other national and regional level work (NCCRA, 2020; Tonkin & Taylor, 2021).
- Key stakeholders (i.e. council staff, contractors) were identified.

2. Screening for hazards and exposed elements

- A long list of assets from council datasets was generated and overlain with known hazard areas (extreme sea level from NIWA & known flood areas from the ORC Natural Hazards Database).
- Expert knowledge was elicited from council staff on how assets are currently impacted by climatic events.
- An exposure rating was applied to all council assets and infrastructure and shared with council staff for review.
- A strength of evidence rating was applied to each asset based on how well we understand the risk (Appendix 2).

3. Defining vulnerability, consequence and urgency for adaptation

- A specialist working group of council staff attended a 1-day workshop.
- The list of exposed elements and their ratings (from step 2 above) was discused and amended.
- Each asset was assigned a vulnerability rating (a combination of sensitivity and adaptative capacity).
- Each asset was assigned a consequence (risk) rating.
- The urgency for adaptation facing each sector was assigned. A discussion around planned or possible actions was also held.
- Workshop results were summarised into sector specific tables and the findings presented throughout this report.

Figure 2-1 Diagram showing the climate change risk methodology process, adapted from the NCCRA guidelines

2.1 HOW WE DEFINE CLIMATE CHANGE RISK

Climate change risk is defined as the interaction between a hazard, exposure, and vulnerability (Figure 2-2). *Hazard* refers to physical events, present or predicted, such as floods, drought and sea level rise. *Exposure* refers to the presence of an element of the built environment in a hazardous location. *Vulnerability* refers to the sensitivity or susceptibility of the built

environment to be harmed by the impacts of climate change, and its capacity to cope and adapt. These three elements interact to create *climate change risk*.

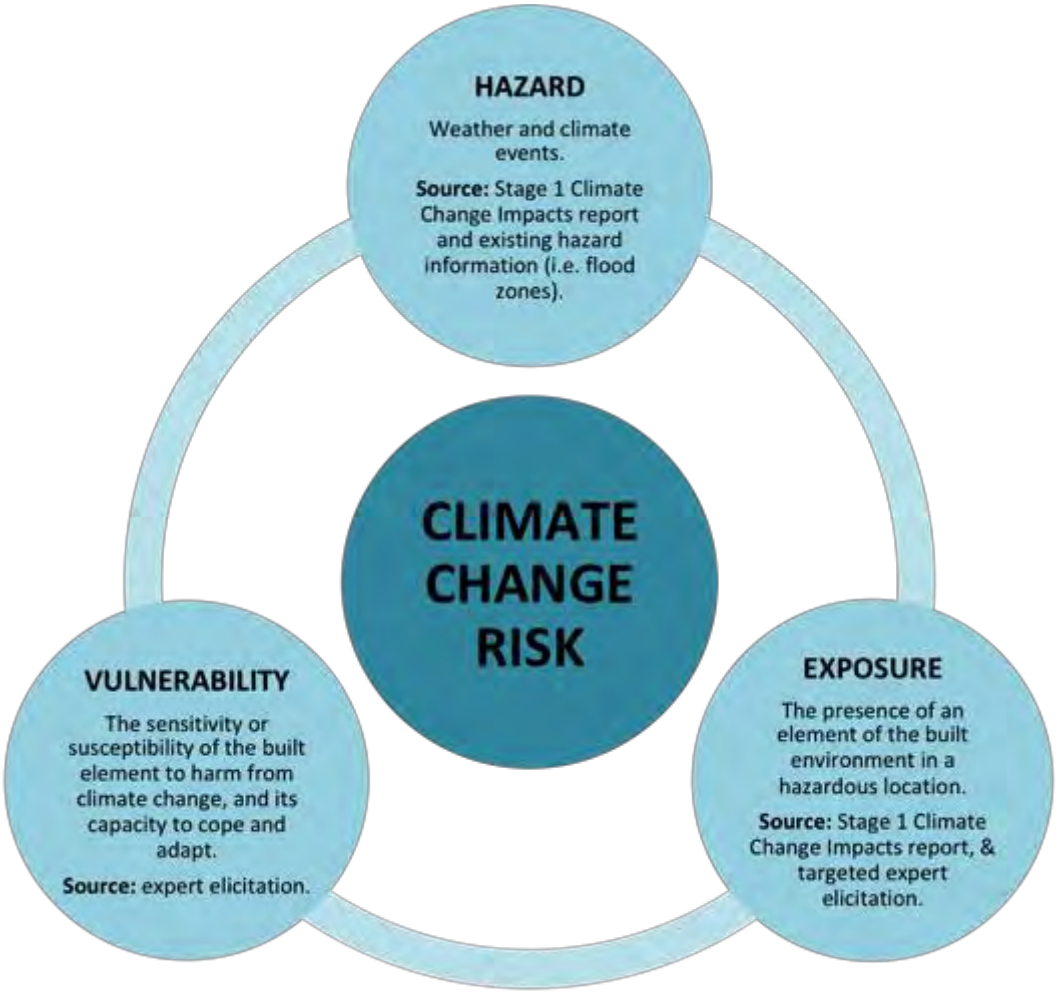

Figure 2-2 The relationship between hazard, exposure, and vulnerability, all of which interact to create climate change risk (adapted from Lavell et al. 2012 and MfE 2019).

2.2 SCREENING FOR HAZARDS AND EXPOSED ELEMENTS

The first step in the risk assessment process (after the scope of work was narrowed down to risks facing the built environment), involved a screening process for hazards and exposed elements. This drew on the results of the Stage One Climate Change Impacts Report (see Griffin and Goldsmith, 2020), flood areas from the ORC Natural Hazards Database, and extensive consultation with council staff. The outcome of this process was a long-list of council infrastructure and community assets that are exposed to climatic hazards. The criteria used to assess exposure for the different elements are found in Appendix 2 (Table A2.1).

In accordance with the NCCRA, we adopted a high range future emissions scenario (RCP 8.5) as a benchmark to provide insights into future potential risks at different timeframes. RCP 8.5 is a high-range 'business as usual' greenhouse gas emission scenario that assumes greenhouse gas concentrations will continue to grow at the current rate. The timeframes and the data sources that were used to define exposure are outlined below (Table 2-1).

Table 2-1 The timeframe, description and data sources used to assess present and future hazards and exposure to climate events.

Timeframe	Description	Data source
Present	Risks that are already occurring, including those observed over the past 10-20 years.	Council held knowledge on present flood, erosion and sea level issues. Present day flood areas obtained from the ORC Natural Hazards Database.
Near term (2050)	Risks that are predicted to manifest around 2050.	Extreme sea level event scenarios (NIWA, 2019b), predictions of high intensity rainfall events future (https://hirds.niwa.co.nz/) and river flow in the Clutha River/Mata-Au (NIWA, 2018).
Long term (2100)	Risks that are predicted to manifest around 2100.	Extreme sea level event scenarios (NIWA, 2019b), predictions of high intensity rainfall events future (https://hirds.niwa.co.nz/) and river flow in the Clutha River/Mata-Au (NIWA, 2018).

2.2.1 Overlaying spatial information

Where spatial hazard zones were available, these were overlain with council and community assets and infrastructure using Geographic Information Systems (GIS). Specifically, the extreme sea level event scenarios provided by NIWA (2019b) were overlain with the locations of houses, roads, public amenities, and Three Waters infrastructure (see figures in Appendix 3). Likewise current flood hazard areas (from the ORC) were overlain with assets and infrastructure where available, to define present day exposure. As future flood hazard areas were unavailable for this assessment, flood exposure focused on present day conditions. An assumption was made that current flood issues are likely to worsen, rather than improve, without mitigation into the future.

2.2.2 Consultation with local experts

Extensive consultations were conducted with council staff to ascertain the different assets exposed to climate hazards, and how frequently they are impacted. These consultations provided a greater level of detail about the nature of exposed elements, particularly drawing on past experiences of flood impacts. For example, council staff classified all roads and Three Waters infrastructure in the district according to how frequently they are affected by present day flood events.

2.3 WORKSHOP ASSESS VULNERABILITY, CONSEQUENCE AND URGENCY FOR ADAPTATION

A targeted group workshop was held with council experts to define vulnerability and the consequence (risk) of climate change risk facing the exposed elements. Nine council staff attended the workshop, representing the regulatory, policy, and service delivery teams (Figure 2-3). The workshop followed the steps outlined below.

Figure 2-3 Pictures taken during the workshop held at the CDC council chambers, 15 February 2021.

2.3.1 Step 1. Vulnerability analysis

The first stage of the workshop was to assign a vulnerability rating to each element. Vulnerability is defined as an element's 'sensitivity or susceptibility to harm and capacity to cope and adapt' (Oppenheimer et al. 2014). To assign vulnerability we asked participants: 'how sensitive is this particular asset to the impacts of climate change and how easily could it be adapted?'.

Vulnerability represents the combination of sensitivity and adaptive capacity. *Sensitivity* reflects the degree to which an element of the built environment may be affected by the adverse impacts of climate hazards. This may include the assets physical characteristics, including its age, durability, and maintenance condition. *Adaptive capacity* refers to the ability of a system to adapt to climate change and the availability of the resources needed for adaptation to occur. This may include the range of alternative options available and the resources (financial and institutional capability) needed to instigate the change.

The criteria used to define vulnerability are shown in Appendix 2 (Table A2.2). Box 1 lists some of the leading questions that were used to guide discussions around vulnerability and assigning the ratings in the workshop.

Box 1. Key questions to consider during the vulnerability analysis:

- *How old is the asset?*
- *Is it maintained regularly?*
- *Is it built from quality materials?*
- *Is the asset insured?*
- *Is it costly to replace?*
- *Are there alternatives?*
- *Could it be easily modified to withstand additional stresses?*
- *Is it easily repairable?*

2.3.2 Step 2. Risk consequence

During the second stage of the workshop we assigned a consequence rating. Consequence considers how important the asset is and whether it's short-term failure or permanent loss would significantly impact the social and economic functioning of society. Consequence

represents the interaction between the hazard, its exposure and vulnerability. Following the approach of the NCCRA, consequence is our final risk rating.

The criteria used to define consequence are shown in Appendix 2 (Table A2.3). Box 2 lists some of the leading questions that were used to guide discussions around consequence and assigning consequence ratings in the workshop. Consequence depends on the value and importance participants place on each asset. It may also consider cascading risks, such as where failure of the built element may impact negatively on other elements and influence quality of life or economic activity.

Box 2. Key questions to consider during the consequence analysis:

- *Would failure of this infrastructure cause significant disruption to quality of life or economic activity?*
- *Would failure be long lasting, or easily repaired?*
- *Would failure of this element have cascading impacts on the delivery of other infrastructure services, or impact quality of life in other areas (i.e. failure of flood banks, or a bridge carrying other infrastructure)?*
- *Does this element require further assessment for relocation or mitigation?*

2.3.3 Step 3. Urgency for adaptation

The final stage of the risk assessment process focused on assessing the urgency for adaptation. The aim of this stage was to assess what elements require immediate or planned adaptation, and where knowledge gaps exist. The urgency for adaptation criteria is drawn from the NCCRA and the UK Climate Change Risk Assessment (Committee on Climate Change, 2017).

Urgency asks whether action is needed in the short to near term to reduce a risk or realise an opportunity associated with climate change. Urgency is defined as “a measure of the degree to which further action is needed in the next five years to reduce a risk or realise an opportunity from climate change”.[4] The criteria used to define urgency are shown in Appendix 2 (Table A2.4). Box 3 lists some of the leading questions that were used to guide discussions around urgency and assigning of the urgency ratings in the workshop.

Box 3. Key questions to consider during the urgency assessment:

- *Do opportunities for early adaptation or intervention exist?*
- *How difficult would adaptation be?*
- *Would adaptation require a long-lead time?*
- *Is early action required to avoid path dependencies or irreversible consequences?*
- *Are current actions sufficient to manage future risks?*
- *How strong is the evidence?*
- *How flexible is the system to adapt to future changes?*
- *How might existing or future socio-economic trends impact the importance of the asset?*

[4] Committee on Climate Change, 2017 UK Climate Change Risk Assessment

3.0 RESULTS: AN OVERVIEW OF THE SECTORS AT RISK

This section summarises the risks facing assets and infrastructure within the Clutha District, as determined through the methodology described above and the council workshop. The more detailed workshop data that was used to inform this section is provided in Appendix 4.

3.1 THREE WATERS INFRASTRUCTURE

The Clutha District contains an important network of Three Waters infrastructure, much of which is located in low-lying areas exposed to heavy rainfall, flood and coastal inundation events. Our assessment focused on risk to potable water treatment plants, sewer treatment plants, sewer pump stations, storm water pump stations, storm water reticulation and sewer reticulation.

The Clutha District maintains a series of potable water treatment plants and water intakes that provide an important lifeline[5] to communities. Some of this potable water infrastructure is currently exposed to flood inundation or future extreme sea level events (Figure 3-1). Potable water infrastructure is pressurized and designed to deal with some level of inundation. However, their functioning may be compromised during large inundation events when pressure is not maintained and/or the electrical switchboards operating the pumps fail, leading to water contamination. The Balclutha treatment plant and Kaitangata potable water intakes are particularly vulnerable due to their low-lying position adjacent to the Clutha River/Mata Au.

Many of the district's groundwater bores are also susceptible to floods, a problem that may worsen in the future with an overall increase in river flow in the Clutha River/Mata-Au, alongside more heavy rainfall events (NIWA, 2018; HIRDS, 2020). During flood events groundwater bores may experience poor water quality linked to soil loading and farm run-off (e-coli). This is a particular issue for the Waitahuna, Tuapeka, North Bruce (Meggat Burn), Puerua, Pomahaka, and Glenkenich bores. The Owaka and Clydevale-Pomahaka bores are not susceptible to flooding and generally maintain good water quality. None of these bores are currently impacted by water shortages caused by prolonged drought.

The consequence of damage to Clutha's potable water treatment plants was rated by CDC staff as extreme, as it could disrupt the delivery of clean drinking water. The consequence of damage to potable water intakes is major, as disruption may not be as long lasting with alternatives and storage available (Table 3-1).

Sewer treatment plants, reticulation and pump stations are also exposed to flood, extreme sea level and heavy rainfall events. Much of New Zealand's wastewater infrastructure is built in low-lying locations, often designed to meet past climate and sea-level criteria (Hughes et al., 2021). Within Clutha, the Esplanade Playground Sewer Pump Station at Kaka Point and Kaitangata's Sewer Pump Station are both exposed to an extreme sea level event combined with 50 cm or more of sea level rise (Appendix 3, Fig, A3-1, A3-2). These systems are designed to continue operating if inundated; however, the electrical switchboards that service them may fail. While Milton's Sewer Treatment Plant has been raised to manage flood events, it is still exposed to heavy rainfall events. Sewer reticulation and sewer pipes have not been assessed individually, yet many are still at a risk due to flood events that can cause sewerage overflow and damage pipes. During the workshop, the consequence of damage to sewer systems was

[5] Lifeline utilities are entities that provide essential infrastructure services to the community such as water, wastewater, transport, energy and telecommunications. These services support communities, enable business, and underpin the provision of public services (Source: National Emergency Management Agency – link)

rated as *moderate*, with overflows potentially causing environmental contamination (Table 3-1).

During heavy rainfall events, storm water infrastructure is impacted across the district, raising the groundwater level and causing overflows. In particular, the storm water pump station at Taieri Mouth currently isn't designed to withstand a combination of high sea levels alongside a heavy rainfall event. This site also falls within the likely inundation area for an extreme sea level event combined with 50 cm or more of sea level rise. Storm water pipes have not been assessed individually, but these are potentially exposed to more frequent inundation and heavy rainfall events across the district in the future. During the workshop, the consequence of damage to storm water systems was rated as *moderate*, as they may be overwhelmed and create overflows more regularly (Table 3-1).

Various options are available to enable the continued service of Three Waters infrastructure across the district under a changing climate. These options include raising the height of bores, particularly along the Clutha River/Mata-Au to accommodate for increased flood events and relocating switchboards to higher ground. Some adaptation efforts are already underway, such as the Milton Sewer Treatment Plant, which has already been raised to accommodate flood events, and the water scheme amalgamation plan in response to flood and water quality issues at the Waitahuna Water Treatment Plant.

Figure 3-1 Balclutha Water Treatment Plant intake, during a flood event in February 2020 Flood (Source: CDC).

Table 3-1 A summary of key climate change risks facing Three Waters infrastructure in the Clutha District as determined during the council workshop.

Asset	**Exposure**	**Vulnerability**	**Risk** (consequence)
Potable water treatment plants	**Low to moderate** exposure to present and future flood events (e.g., Kaitangata, Balclutha).	Moderate	**Extreme –** access to potable water may be lost.
Potable water intakes	**High to very high** exposure to present and future flood events (e.g., Glenkenich, Balclutha, Kaitangata, Stirling, Milton), or an extreme sea level event (Kaitangata intake pump station).	Major	**Major –** temporary disruption but access to storage and alternatives.
Sewer treatment plants	**High to very high** exposure to present and future flood events (e.g., Glenkenich, Stirling, Milton, Kaitangata, Balclutha oxidation ponds), heavy rainfall (e.g., Milton sewer treatment plant), or an extreme sea level event (Kaitangata oxidation pond).	High	**Moderate** – overflow likely.
Sewer pump stations	**High** exposure to an extreme sea level event (Kaitangata and Kaka Point pump stations), which is expected to become **very high to extreme** in the future.	Very high	**Moderate** – as above.
Sewer reticulation	**Moderate to high** exposure to future flood events, heavy rainfall or extreme sea levels (district wide).	High to very high	**Moderate** – as above.
Storm water reticulation	**Very high** exposure to future flood events, heavy rainfall or extreme sea levels (district wide).	High to very high	**Moderate –** temporary storm water overflow and localised flooding.

3.2 TRANSPORT INFRASTRUCTURE

The Clutha District contains a nationally significant road network, comprising state highways and local roads. With just over 2,900 km of road, Clutha contains the second largest road network in New Zealand. A total of 27 per cent (or 776 km) are sealed, and 78 per cent (or 2, 140 km) are unsealed, the majority of which are classed as rural roads (CDC, 2021). Clutha's road network is already subjected to frequent flood events, and coastal inundation in areas, a situation that is likely to continue or even become exacerbated by the impacts of climate change.

Many of Clutha's roads are inundated by floodwaters on a yearly basis, with varying levels of impact. Some roads are better designed to withstand floods, while others are susceptible to 'wash out', where floodwater washes away the side of the road causing it to collapse. In early 2020, the Clutha District experienced heavy rainfall and localised flooding, which caused the closure of 50 roads at the peak of the flooding and damage to over 1,000 road sites.[6] It is possible that such events will increase in the future, with heavier rainfall events predicted due to an increase in average temperature (HIRDS, 2021).

Presently, State Highway 1 to the south of Milton, State Highway 90 in West Otago and the Papatowai Highway (between Maclennan and Owaka) are all relatively frequently inundated by floodwater. Other sealed roads throughout the Tokomairiro Plain, Pomahaka Catchment, and Clutha Valley are also frequently impacted by floodwater. Unsealed roads throughout the Tokomairiro Plain, Pomahaka Catchment, Clutha Valley, Lawrence, and Waitahuna areas can also be inundated by floodwater on a yearly basis. Hospital Creek Road in Balclutha is also at risk of flood inundation, if the Hospital Creek flood banks fail during a large event.

Alongside the risk of floods, parts of Clutha's road network are also exposed to extreme sea level events (Appendix 3). Low-lying roads potentially at risk of coastal inundation are found in waterfront areas of Kaitangata, Taieri Mouth, Toko Mouth, the lower Clutha Delta, and Pounawea. The Papatowai Highway (between Papatowai and Maclennan) is also at risk of an extreme sea level event, and partial inundation of this road already occurs during king tide events after which it is swept for debris. Likewise, Hina Hina Road to Jacks Bay, parts of the Nuggets Road to the south of Willsher Bay and Taieri Ferry Road are already inundated during king tide events (Figure 3-2), a situation that is predicted to be exacerbated by ongoing sea level rise in the future.

The district also contains a series of bridges, with varying levels of exposure and vulnerability to flood events. Bridges along State Highway 90 and throughout the Pomahaka plains are particularly vulnerable to flood events, with the potential for multiple bridges to be impacted by debris build up and subsequently damaged during a single event. Under an extreme sea level event scenario, it is possible that some bridges (such as those in Taieri Mouth, Papatowai, Catlins River) will be temporarily inundated, while the approaches to them may suffer more permanent damage (Fig. 3-2).

[6] Flooding Cost Expected to top $1m, Clutha Leader, February 20, 2020. http://www.cluthaleader.co.nz/news/flooding-cost-expected-to-top-1m/

Figure 3-2 Inundation from the Taieri River onto Taieri Ferry Road. Photo taken at high tide on a sunny day (i.e., river was not in flood), June 2019 (Source: GHC).

Overall, during the workshops it was agreed that damage to the district's highways or sealed roads as a result of more frequent flood events would create a *major* consequence for people in the Clutha District. Such floods can temporarily disrupt access to homes, services, and the distribution of essential goods. The consequence of an extreme sea level event on the district's coastal roads was rated *extreme*, as the impacts may be longer lasting than flood events (esp. coastal roads that are also exposed to long-term erosion). Disruption to unsealed roads would have a *moderate* consequence, as in many places alternative routes exist. The consequence of damage to bridges from coastal or flood inundation is *extreme*, as their replacement would be extremely resource intensive (Table 3-2).

Various options for adaptation of Clutha's road network to better withstand floods and coastal inundation events exist, and actions will depend on how roads are valued and prioritised. Some adaptation efforts are already progressing as part of routine repair and replacement work. For example, the Hina Hina Bridge over the Catlins River is currently being replaced, with the decking structure of the new bridge raised above any future flood levels, even with the predicted impact of climate change.[7]

Figure 3-3 The Tahakopa River Bridge at Papatowai (October 2019, Source: GHC).

[7] Source: CDC website [link]

Table 3-2 A summary of key climate change risks facing transport infrastructure in the Clutha District as determined during the council workshop.

Asset	Exposure	Vulnerability	Risk (consequence)
Highways	**Extreme** exposure to present and future flood events (SH1 at Milton, SH90 at West Otago, Papatowai Highway), and **high** exposure to an extreme sea level event (Papatowai Highway).	High to moderate	**Major –** significant disruption but not long lasting.
Sealed roads	**High to extreme** exposure to present and future flood events (e.g., Pomahaka Catchment, Tokomairiro Plain, Clutha Valley).	Moderate to high	**Major –** as above.
	High to extreme exposure to present and future extreme sea level events (lower Clutha Delta, Taieri Mouth, Pounawea, Nuggets).	High to extreme	**Extreme** – disruption may be longer lasting than inland flooding.
Unsealed roads	**High to extreme** exposure to present and future floods (Tokomairiro Plains, Clutha Delta, Clutha Valley, Pomahaka, Clinton, Catlins). Exposure to high-tides and extreme sea level events is expected to increase from **high** to **extreme** in the future (Hina-Hina Road, Toko Mouth).	High	**Moderate –** access to alternative routes is likely.
Bridges	**High** exposure to present and future flood events (Balclutha and Pomahaka Bridge), and **low** exposure to future extreme sea level events (Akatore Ck Bridge 10, Washport Ck Bridge no 22).	Low to moderate	**Extreme** – replacing bridges is resource intensive.
Railways	**High** exposure to present and future floods events (Balclutha-Finegand railway).	Moderate	**Major** – access to Finegand may still be possible via road.

3.3 HOMES AND BUILDINGS

Homes and buildings within the Clutha District are at risk of extreme weather-related events, such as floods and coastal inundation during an extreme sea level event. During the workshop, participants noted that losing a home, or access to a livelihood (in the case of commercial buildings), would create an *extreme* consequence to people living in the Clutha District (Table 3-3). This extreme risk rating reflects the NCCRA criteria, as more than 50 buildings across the district are potentially at risk (Appendix 4).

Areas that have historically been impacted by floods include the towns of Milton, Balclutha and the main street of Lawrence. An extreme sea level event (which is modelled as a combination of future sea level rise, storm surge, wave run-up and high tide) may expose some properties in Taieri Mouth, Toko Mouth, Kaitangata, Kaka Point, Willsher Bay, Jacks Bay and Pounawea to inundation (Appendix 3, Figures A3-3 to A3-6, see also Griffin and Goldsmith, 2020).

It is not possible to determine exactly where rising tides or more frequent floods may impact individual homes and buildings in the Clutha District. Future impacts will depend on rates of

change and the level of protection provided by mitigation measures (such as flood banks, seawalls & storm water infrastructure). However, the localities mentioned in the paragraph above - many of which have already historically been impacted by coastal inundation or flood events - provide a useful starting point for more detailed assessments of risk and adaptation planning.

CDC maintains 98 community housing units across the district, and the units located in Balclutha are particularly exposed to future flood events from the Clutha River/Mata-au and Hospital Creek (Figure 3-4). While the community housing units in Kaitangata are located close to the Clutha River/Mata-Au, they are situated approximately 2.5 m above the current flood plain (Goldsmith et al. 2020). Community housing units represent an important community asset, which if damaged could compound the vulnerabilities experienced by an already vulnerable group of people.

As a largely rural area, large expanses of farmland and farm buildings are also potentially exposed to flood and extreme sea level events. Some farmland around the Clutha Delta, Toko Mouth, Tokomairiro Plain and Pomahaka River Catchment areas are already semi-regularly inundated by floodwater, and many farmers already have practices in place to respond to the risk (such as relocating stock early and placing important farm assets on higher ground).

Adaptation of homes and buildings to the impacts of climate change will depend on community engagement in selected priority areas and may require more detailed flood and coastal inundation assessments.

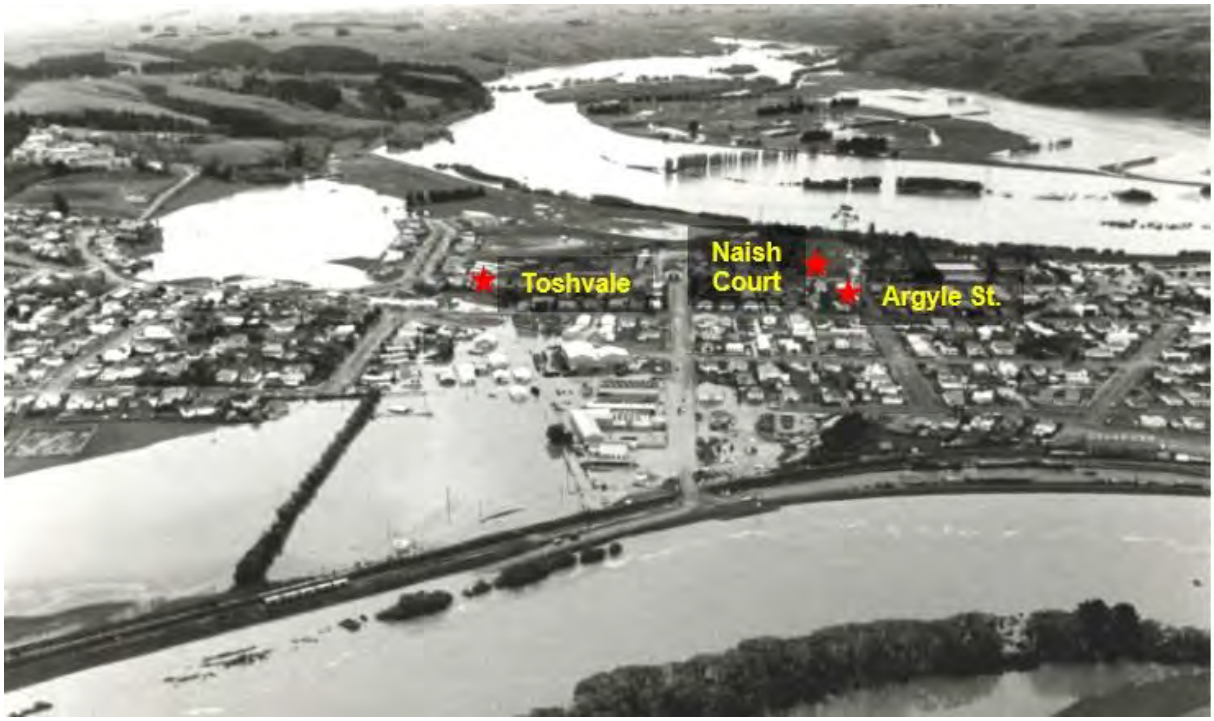

Figure 3-4 Clutha River flood event at Balclutha, October 1978. CDC community housing complexes marked in red. Source: Otago Regional Council.

Table 3-3 A summary of key climate change risks facing homes and buildings in the Clutha District as determined during the council workshop.

Asset	Exposure	Vulnerability	Risk (consequence)[8]
Urban housing	**Moderate to high** exposure to present and future flood events (Milton, Balclutha, Waihola, Lawrence, Tapanui, Heriot & Kaitangata).	High	**Extreme**
	Currently a **low to moderate** exposure to extreme sea level events (Pounawea, Jacks Bay, Kaka Point, & Taieri Mouth), or coastal erosion (Pounawea & New Haven). Exposure to coastal inundation is expected to increase in the future and become **extreme** in some cases (i.e. Pounawea).	High	**Extreme**
Rural housing and farms	**High to extreme** exposure to present and future flood events or an extreme sea level event (esp. Clutha Delta).	High	**Extreme**
Commercial buildings	**High to extreme** exposure to present and future flood events (Balclutha, Milton & Lawrence).	High	**Extreme**
Community housing	**Extreme** exposure to present and future flood events (Balclutha).	High	**Extreme**

3.4 PUBLIC AMENITIES

CDC provides important community amenities to the district, some of which are potentially exposed to floods and extreme sea level events, a situation that may worsen in the future. Some of the district's halls, such as Waihola, Milton, Matau and Balclutha, are located within known flood hazard areas. Public libraries and swimming pools in both Balclutha and Milton are also situated partially within potential flood-prone areas. Parks and reserves are also often located in low-lying areas, prone to flooding (for example Riverside Reserve and Balclutha Showground), with others potentially exposed to an extreme sea level event (for example Taieri Mouth and Kaka Point).

Some amenities will be less affected by the impacts of extreme weather-related events than others. For example, the inundation of parks, reserves and public toilets is likely to create shorter term and less permanent impacts. Conversely, the inundation of halls, schools and libraries may create greater and longer lasting impacts.

During the workshop, the consequence of temporarily losing access to parks, reserves and public toilets was rated as *minor*, as these facilities are not lifelines and would likely regain their functionality after an event. The consequence of temporarily losing access to schools, libraries, leisure facilities and the Balclutha Town Hall was rated as *major* as they represent important community resources (Table 3-4).

[8] Damage to private dwellings, community housing units and commercial buildings will have a range of consequences depending on living arrangements, building type, ownership status and insurance. Extreme represents the upper end of the consequence of damage to buildings due to climate change.

Table 3-4 A summary of key climate change risks facing public amenities in the Clutha District as determined during the council workshop.

Asset	Exposure	Vulnerability	Risk (consequence)
Halls	**Moderate** exposure to present and future flood events (Waihola, Milton).	Moderate	Minor
	Extreme exposure to present and future flood events (Balclutha).	Moderate	Major
	Low exposure to an extreme sea level event, increasing to **moderate** in the future (Kaka Point).	Low	Minor
Libraries	**Moderate to extreme** exposure to present and future flood events (Balclutha & Milton).	Moderate	Moderate
Leisure facilities	**Moderate to extreme** exposure to present and future flood events (Balclutha Centennial Swimming, Milton Pool).	Moderate	Moderate
Parks and reserves	**Extreme** exposure to present and future flood events (Balclutha Showground, Riverside Reserve, Waihola Domain), or an extreme sea level event (Livingstonia Park, Knarlston Park, Esplanade Playground).	Low to moderate	Minor
Public toilets	**High** exposure to present and future flood events or an extreme sea level event (i.e. Taieri Mouth, Pounawea).	Low	Minor
Schools	**Extreme** exposure to present and future flood events (Balclutha & Milton).	Moderate	Major
Hospitals	**Extreme** exposure to present and future flood events (Balclutha).	Moderate	Major

3.5 WASTE

Climate change and extreme weather events may increase the risk associated with open and closed landfills and other waste related infrastructure situated within the Clutha District. Open and closed landfill sites are at risk of leaching contaminants into nearby waterways and aquifers during or following heavy rainfall, flood or coastal inundation events. Some sites are also exposed to coastal erosion, a situation that will likely be exacerbated with higher sea level conditions.

CDC operates one active landfill, Mt Cooee located on the outskirts of Balclutha on the Kaitangata Highway. This site is located in close proximity to the Clutha River/Mata-Au; however, it is elevated above the present flood hazard area. During the workshop, the consequence of damage to the Mt Cooee landfill site was rated as *major* - as while unlikely, it could create significant environmental contamination issues (Table 3-5).

There are also a series of closed landfills and dump sites across the district that may be exposed to flood events or future extreme sea level conditions. This includes an old dump site located on the coast at the southern end of Molyneux Bay, near Kaka Point, which is capped by a rock embankment. A visual inspection of the site in May 2021 indicates that this embankment remains intact (**Figure 3-5**), although flanking erosion could occur at some stage in the future (**Figure 3-6**). The risk associated with erosion at this site was rated as *major*, as

there is likely to be a recurrent environmental impact, with some assessment of remedial actions required (Table 3-5).

A series of waste transfer stations are located throughout the district (Beaumont, Clinton, Clydevale, Lawrence, Maclennan, Milton, Owaka, Papatowai, Taieri Mouth, Tapanui); many of which are near or within present day flood zones. During the workshops, the consequence of coastal or flood inundation to waste transfer sites was rated as *minor*, as these could be easily relocated (Table 3-5). However, some transfer station sites are located on closed landfill sites that may require further assessment (Clinton, Clydevale, Lawrence, Maclennan, Milton, Owaka).

To remove risks associated with the effects of climate change on landfills in the Clutha District, remedial actions could be considered. Further investigations into the integrity of the caps on other closed landfills would provide a better understanding into how they currently respond to heavy rainfall events and are likely to respond to more rainfall and inundation events in the future.

Figure 3-5 Seawall protecting the old dump site near Kaka Point, looking towards the north. May 2021 (Source: GHC).

Figure 3-6 Northern edge of the rock embankment indicating where flanking erosion could occur. May 2021 (Source: GHC)

Table 3-5 A summary of key climate change risks facing waste facilities in the Clutha District as determined during the council workshop.

Asset	**Exposure**	**Vulnerability**	**Risk** (consequence)
Open landfills	**Low** exposure to present and future flood events (Mt Cooee Landfill, Balclutha).	Low	**Major** – landfill elevated above river.
Closed landfills	Potential exposure to heavy rainfall, flood events or extreme sea level (various locations throughout the district).	High	Unknown – priority for further investigations.
	Extreme exposure to present and future coastal erosion/extreme sea level events (Kaka Point dump site).	High	**Major** – this site may be prone to future erosion.
Waste transfer stations	**Low** exposure to present and future flood events (Beaumont; Clinton; Clydevale; Lawrence; Maclennan; Milton; Owaka; Papatowai; Taieri Mouth; Tapanui), or an extreme sea level event (Maclennan).	Low	**Minor** – waste transfer stations can be relocated.

3.6 COASTAL AND FLOOD DEFENCE

Flood and coastal defence mechanisms provide an important line of defence between infrastructure and inland flooding or coastal inundation. The Lower Clutha Flood Protection and Drainage Scheme protects communities living in Balclutha and Kaitangata, alongside farmland on the Inch Clutha and surrounds, from inland flooding. Important assets such as the Balclutha water treatment plant, Balclutha Hall, Kaitangata potable water intake, and Finegand railway to name a few, depend on the functioning of this scheme. Failure of this scheme due to increased flood risk would have devastating social and economic consequences for the district. In a parallel risk assessment undertaken by the ORC (Tonkin and Taylor, 2021), risks to flood protection schemes throughout Otago are rated as *extreme* by the year 2090. Subsequently, targeted studies of the Lower Clutha Flood Protection and Drainage Scheme are ongoing by the ORC.

While responsibility for the Lower Clutha Flood Protection and Drainage Scheme falls to the ORC, CDC does maintain the Hospital Creek and Milton flood banks. The Hospital Creek flood bank in particular protects nearby properties in Balclutha and the Hospital Creek Road, from inland flooding. During the February 2020 flood event, it reportedly came close to overtopping[9].

The district also contains a series of seawalls that protect property or public assets at Taieri Mouth, New Haven and Pounawea (Figure 3-7). During the workshops, participants noted that the seawall at Taieri Mouth is undergoing erosion, while the seawall at Pounawea requires repairs in sections. The consequence of these seawalls failing was rated as *major*, as it would impact nearby properties and other infrastructure (Table 3-6).

Figure 3-7 The Pounawea sea wall (October 2019, Source: GHC).

[9] Balclutha residents told to stay on flood alert. Otago Daily Times 5 February, 2020 https://www.odt.co.nz/regions/south-otago/balclutha-residents-told-stay-flood-alert

Table 3-6 A summary of key climate change risks facing flood and coastal defence mechanisms in the Clutha District as determined during the council workshop. Additional risk information for flood and coastal defence structures is found in Appendix 4 and in the OCCRA (Tonkin and Taylor, 2021).

Asset	**Exposure**	**Vulnerability**	**Risk** (consequence)
Lower Clutha Flood Protection and Drainage Scheme (ORC)	**Extreme** exposure to present and future flood events, and **high** exposure to a future extreme sea level event (Balclutha, Inch Clutha, Kaitangata, Stirling, Lower Clutha Delta, Waitepeka).	Extreme	**Extreme** – failure would severely impact social and economic activities.
Flood banks (CDC assets)	**Extreme** exposure to present and future flood events (Hospital Creek, Milton flood bank).	Extreme	**Extreme** – as above.
Seawalls	**High** exposure to coastal erosion and extreme sea level events (Taieri Mouth, Pounawea, New Haven), which is expected to become **extreme** in the future.	High	**Major** – failure could expose homes and buildings to coastal inundation.

3.7 ENERGY AND TELECOMMUNICATIONS

Energy and telecommunications networks provide an important lifeline to the Clutha District. Clutha does not contain any electricity generation infrastructure; however, a critically significant substation is located in Balclutha (Otago Net) (EMO, 2018), within the mapped flood hazard area. A series of electricity transmission lines, of 220Kv and 110Kv, run across the district and further work is needed to understand if these are at risk of future climate hazards. Balclutha is also home to 20 tonne capacity Nova energy gas tanks (EMO, 2018). While also within the flood hazard area, these are not permanent structures and are unlikely to be significantly impacted by inundation.

A Chorus main fibre optic transmission route runs through Clutha, following State Highway 1, and providing connectivity to the rest of the South Island. The district also contains two Vodafone (Balclutha and Waitahuna) and two Kordia critical sites (Clinton and Waitahuna) (EMO, 2018).

Disruption to telecommunications and energy networks represents a critical risk to the Clutha District. However, as both industries are largely privatised and evolve quickly, we were unable to fully assess future exposure to climatic events. For further information on these lifelines, please refer to a recent regional level assessment conducted by Emergency Management Otago (EMO, 2018).

3.8 TE AO MĀORI PERSPECTIVE ON CLIMATE CHANGE

The following section draws on consultation with a local iwi representative with whakapapa from the Clutha District. It does not necessarily represent the views or interests of all Māori but rather reflects a starting point for further conversations around Māori interests and perspectives on climate change.[10]

10 Engagement between local iwi and CDC is ongoing, and this section may be updated and expanded as collaboration around addressing climate change risks occurs in the future.

Hutia te rito o te harakeke.

Kei hea te komako, e ko?

Ki mai ki ahau, he aha te mea nui o te ao?

Maku e ki atu He tangata, he tangata, he tangata.

Pluck the heart from the flax bush

Where will the bellbird be?

Ask me, what is the most important thing in the world?

I will reply, it is people, it is people, it is people.

The whakatauki (proverb) above demonstrates the integrated connectedness between people, their actions, and the environment (Tipene-Matua et al. 2009). During consultation with local Māori, we were asked to include this proverb as a Māori perspective on climate change. In te ao Māori, the earth is personified through Papatūānuku (the earth mother) and should therefore be treated as one would care for a mother. Climate change is Papatūānuku calling for help, and there is an obligation to respond, for the sake of both tipuna and mokopuna (ancestors and grandchildren).

Te ao Māori recognises that all living and non-living entities are interconnected, a view that was not initially reflected in the segregated framework developed in the NCCRA (see also MfE, 2020; Tonkin & Taylor, 2021). From the perspective of Māori, climate change is not just a physical problem, it is related to human health and wellbeing and is better conceptualised through integrated approaches (for example, the Treasury's Living Standards Framework).[11] We have therefore not completed the assessment of risks facing individual Māori cultural assets as initially proposed by the NCCRA and instead we will describe some local climate change issues of particular concern to Māori.

Clutha's coastline contains vast stretches of coastal resource area, which are important for Mahinga Kai - the producing, gathering and protection of food providing resources. These coastal resource areas to the north and south of the Clutha Delta and along the foreshore of Lake Waihola, are exposed to coastal hazards and extreme sea level events. Importantly, the district contains an urupa (burial ground) that while elevated should be actively protected from encroachments of Tangaroa, or rising sea levels. Sections of Māori freehold land are also scattered along the Catlins coastline; however, this is predominantly on cliffs above the ocean.

Māori responses to climate change are centred in Kaitiakitanga (guardianship) and support integrated climate change action (such as reducing emissions, tree planting and reinforcing the shoreline where needed). The Ngāi Tahu climate change strategy aims to understand and prepare for the challenges ahead, to secure the best future possible for people and takiwā (Te Rūnanga o Ngāi Tahu, 2018). Further adaptation plans developed by the CDC could engage more fully with local iwi, mātauranga Māori and focus on understanding the interacting nature of climate change risks.

[11] To address this shortcoming in the NCCRA, further work is now ongoing to develop a parallel approach to assessing risks from a Māori perspective (MfE, 2019).

3.9 CASCADING AND INTERACTING RISKS

In the discussion above, many climate change risks have been treated separately. However, we know that different risks can have cascading impacts on other areas of life, a view that is also very much supported by mātauranga Māori. For example, risks to road networks, homes and public amenities (such as halls and libraries) may create risks to social cohesion, wellbeing, and a person's ability to live and work in a certain area. Risks facing social housing units are of particular importance, as the risk isn't concerned with the physical building alone, but rather that the loss of community-housing infrastructure may exacerbate existing social inequalities. This assessment has not explicitly considered risks to the natural environment; however, water quality will be influenced by risks to Three Waters infrastructure, which may in turn also influence livelihood activities and access to Mahinga Kai.

Future climatic events may also interact with current hazards, such as erosion, creating new risks for the future. One clear example of this process is the long-term erosion of the coastline at the south end of the Clutha Delta, from the Koau Mouth of the Clutha River/Mata-Au to Kaka Point (ORC, 2014). If this pattern of erosion is to continue, or possibly intensify, into the future, the impact of sea level rise may be exacerbated in this area. If left unchecked it may erode farmland, farm buildings and roads.

We acknowledge that the assessment of interacting and cascading risks in this report is limited. However, it is important to note that the risks described above do not necessarily stand in isolation, and many will interact. Risks to governance, human health and wellbeing, the economy, and the natural environment (as described in MfE, 2020) may also create risks to the built environment and vice versa. Council is encouraged to also consider the interacting and sometimes-cascading nature of the additional risks covered by the NCCRA (Table 1-1), as they move towards flexible adaptation planning.

3.10 SUMMARY OF RISKS ACROSS SELECTED TOWNS

The impact of climate change on the infrastructure and assets described above will be experienced differently in different towns in the Clutha District (Table 3-7). Identifying which towns are most exposed to climatic hazards may help CDC to prioritise future adaptation strategies and to target engagement with selected communities.

The township of Balclutha is the regional hub of the Clutha District and unsurprisingly, as it sits on the banks of the Clutha River/Mata-Au, it is exposed to flood events. As the district's largest town, it also contains the greatest amount of people, buildings, infrastructure, and services, which increases its overall risk to climatic hazards. Other low-lying towns with infrastructure at risk of flood events include Milton, Kaitangata and Lawrence. In particular, Milton and Kaitangata's potable water intakes, alongside Lawrence's main street (Ross Place), are all potentially at risk of future flood events.

Infrastructure and buildings within selected towns are also exposed to a future extreme sea level event (the combination of sea level rise with a severe coastal storm). These localities include Taieri Mouth, Kaitangata, and Pounawea, wherein some roads and buildings are exposed to future coastal hazards.

Table 3-7 A summary of the presence of climate change risk (flood, heavy rainfall, or an extreme sea level event) in selected towns throughout the Clutha District. For more detailed information on the vulnerability and consequence of each hazard and asset type see Appendix 4.

Town	Three Waters Infrastructure			Roads			Buildings			Public Amenities				Coastal/ flood defence structure
	Potable water systems	Sewer systems	Storm water systems	Highways	Sealed roads	Unsealed roads	Residential buildings	Community housing	Commercial buildings	Parks/ reserves	Libraries	Halls	Swimming pools	
Waihola		✓	✓		✓				✓	✓		✓		
Taieri Mouth			✓		✓		✓			✓				
Milton	✓	✓	✓	✓	✓	✓	✓		✓		✓			
Kaka Point		✓	✓		✓									
Kaitangata	✓	✓	✓		✓			✓						✓
Balclutha	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Lawrence	✓	✓	✓	✓	✓				✓					
Tapanui	✓	✓	✓											
Clinton		✓	✓											
Owaka	✓	✓	✓											
Pounawea			✓		✓		✓			✓				✓

4.0 CHANGES IN EXPOSURE OVER TIME

Climate change impacts may increase the exposure of some assets to climatic hazards over time. As floods, storms, rainfall, coastal erosion, and inundation become more frequent and potentially more severe into the future, the exposure of some assets will increase. It is important that CDC are aware of where these changes in exposure are likely to occur, in order to monitor changes and develop mitigation and adaptation plans.

As described in section 3.0, the exposure of some key infrastructure elements in the Clutha District is already rated as high to extreme, due to their existing exposure to natural hazards. This exposure is, in general, well understood by asset managers such as CDC, who have taken steps to mitigate the current risk.

However, there are also sites where exposure is currently low but is likely to increase significantly over the long term. In these cases, existing mitigation measures (e.g., a flood bank) may become insufficient, and/or alternative means of providing the utility may need to be found (e.g., relocation of a road). CDC may choose to undertake additional, site-specific investigations in the future, to better understand these potential changes in exposure.

The following tables list the main infrastructure elements within the Clutha District where exposure is likely to increase significantly over the long term (**Table 4-1** to **Table 4-4**). These tables do not necessarily include all assets where the exposure is already high or extreme. Nor do they consider the risk (consequence) of damage to the asset, as this is discussed separately in section 3.0. More detail on the exposure, vulnerability and risk for each asset type is provided in the raw data tables in Appendix A4.0.

Table 4-1 Significant changes in exposure for Three Waters infrastructure

Hazard	Asset	Exposure	
		Current	Long-term (~2100)
Fluvial and pluvial flooding	Timber Creek (Moa Flat) and Meggatburn intakes	Moderate	Very high
	Lawrence water treatment plant	Moderate	Very high
	Waipahi SWS	Moderate	Very high
	Clydevale/Pomahaka water treatment plant	Low	Very high
	Milton: sewer treatment plant & wetlands Balclutha, Kaitangata and Waihola: oxidation ponds Clinton: oxidation ponds & wetland Lawrence, Stirling, Tapanui, Owaka: oxidation ponds & biofiltro units	Low	Very high
	Balclutha and Milton storm water pump stations	Low	Very high
	Stormwater reticulation (district-wide)	Low	Very high
Heavy rainfall events	Heriot Oxidation Pond; Kaka Point and Owaka oxidation pond and biofiltro	Low	Very high

Table 4-2 Significant changes in exposure for transport infrastructure

Hazard	Asset	Exposure	
		Current	Long-term (~2100)
Extreme sea level event	Papatowai to Maclennan Road	High	Extreme
	Some roads on the Clutha Delta	Moderate	Extreme
	Some roads in Taieri Mouth & Kaka Point	Moderate	High
	Roads in Pounawea & the Nuggets Road	Moderate	Extreme
	Hina Hina, Jacks Bay, Toko Mouth Domain, and Coutts Gully roads	High	Extreme

Table 4-3 Significant changes in exposure for housing and buildings

Hazard	Asset	Exposure	
		Current	Long-term (~2100)
Extreme sea level event	Urban housing in Pounawea and Toko Mouth (lower-lying areas in particular)	Moderate	Extreme
Coastal erosion	Rural housing and farms (Molyneux Bay/Clutha Delta shoreline).	Moderate	Extreme
	Some urban housing in Pounawea	Low	Extreme
Fluvial and pluvial flooding	Urban housing, commercial, and industrial buildings located in low-lying areas (across the Clutha District) [12]	Moderate - High	High-Extreme

Table 4-4 Significant changes in exposure for public amenities

Hazard	Asset	Exposure	
		Current	Long-term (~2100)
Extreme sea level event	Livingstonia Park & Knarlston Park (Taieri Mouth); Esplanade Playground (Kaka Point)	Low	Extreme
	Pounawea public toilets	Moderate	Extreme

[12] There are several locations within the Clutha District where buildings are currently exposed to flooding (Griffin & Goldsmith, 2020). It is assumed that climate change will result in more frequent, and potentially more damaging flood events in the future. The change noted here is included as a general comment rather than for specific locations, as it is also assumed that the exposure of buildings to flood events will, in general, increase (particularly in low-lying areas).

5.0 URGENCY FOR ADAPTATION

Following the workshop with council staff, a preliminary discussion around future adaptation planning was held. During this time, the risks facing each sector were ranked in terms of their urgency for adaptation in the short and long term (Table 5-1).

A priority for adaptation in the short term is assessment and potential remediation of the old dump site on the coast near Kaka Point. As this site is currently subjected to erosion into Molyneux Bay - a situation that may worsen in the future with sea level rise - it was identified by staff as requiring more action.

The remaining issues requiring more action for adaptation planning include storm water systems, the districts road network, and private and commercial buildings. It was noted by participants that the districts storm water systems are not necessarily designed to deal with the increase in heavy rainfall and flood events that may be experienced in a future, wetter climate.

The districts vast road network was also rated as a priority for further work. This includes State Highways, sealed and unsealed roads that are currently impacted by frequent flood events, or are exposed to elevated sea level events. Roads have a life expectancy of 20-25 years and are typically raised by 100-125 mm when replaced. Discussions around whether this height should be increased – for example to 300 mm - were held, mindful that increasing the height of some roads may increase the flood risk to adjacent areas. There are also many rural sealed and unsealed roads throughout the district that are already regularly inundated with floodwater. Where alternative access routes exist, discussions around how long these roads should be maintained into the future may be necessary (for example, following the February 2020 flood event maintenance of Burning Plains Road has been withdrawn). Overall, raising the heights of roads is not seen as an overly difficult solution, but discussions around costs and what roads are prioritised may be needed.

A number of commercial and private dwellings are located in low-lying areas exposed to floods or an extreme sea level event, and these buildings were rated as a priority for further work. Priority areas include towns that have been impacted by flood or coastal inundation events in the past, or those that lie within the inundation extent of NIWA's extreme sea level scenario. As houses and buildings are an important asset valued by people, future adaptation to manage the risk of floods and extreme sea level events needs to be done alongside, and in genuine partnership with, the community. It may also be necessary to obtain more detailed and locally precise models of sea level and flood scenarios for selected priority locations.

Coastal and flood defence mechanisms were also rated a priority for further work, noting that some of this will fall under the jurisdiction of the ORC. As the ability of CDC to maintain roads and other assets in certain areas will depend on the functioning of nearby flood stop banks, a coordinated approach between the councils is important. CDC does however maintain the sea wall at Pounawea, an asset that is currently providing this coastal settlement with important protection against long-term erosion and coastal storm events. Likewise, CDC maintains the Hospital Creek stop bank, and this is exposed to flood events along the Clutha River/Mata-Au. Further work is necessary to better understand the risk facing flood and coastal mechanisms throughout the district in collaboration with the ORC.

During the workshops, we discussed how all infrastructure maintained by CDC is monitored and routinely upgraded. For example, participants explained that approximately 90% of

council's Three Waters infrastructure would be replaced over the coming 100 years. The routine upgrade or replacement of infrastructure could provide an opportunity to ensure that what comes next is designed with future, rather than historic, climatic conditions in mind.

Importantly, the uncertain nature of climate change impacts means that future infrastructure decision-making processes need to be flexible. It is also critical that future adaptation planning aims to reduce risk, without increasing social inequality (LGNZ, 2019). It therefore requires a flexible planning process that considers local values, scientific uncertainty, and can be adapted as new insights and information becomes available. The *Dynamic Adaptive Policy Pathways* (DAPP), embedded within the National Coastal Hazards and Climate Change Guidance (MfE, 2017), is one approach that can be utilised to facilitate flexible, proactive and equitable climate change adaptation (see Lawrence et al., 2018). Put simply, this approach involves extensive community engagement, the ongoing use of knowledge as it becomes available, the development of potential future pathways and 'trigger points' of change, all within a framework of constant review and adjustment (Figure 5-1).

Figure 5-1 The 10-step iterative decision cycle as an example of a dynamic pathways approach to climate change adaptation. Figure taken from the 2017 New Zealand coastal hazards and climate change guidance (MfE, 2017).

Table 5-1 An overview of the urgency for adaptation associated with each infrastructure sector as determined during the workshop. The criteria behind the urgency scales are taken from the NCCRA (Appendix 2).

Sector	Asset description	Urgency for adaptation
Three Waters Infrastructure	Potable water and sewer systems	Sustain current action
	Storm water systems	More action needed
Transport Infrastructure	Highways, roads, unsealed roads	More action needed
	Bridges	Sustain current action (include climate change in future design).
Buildings	Private dwellings and commercial buildings.	More action needed
Public amenities	Halls, libraries, parks, reserves, public toilets	Sustain current action
Coastal and flood defence	Flood stop banks and coastal seawalls.	Priority for further work (assessment of Clutha flood banks undertaken by ORC).
Waste Management	Closed landfills	Priority for further work.
	Old dump site on the coast near Kaka Point.	More action and investigations needed

6.0 LIMITATIONS

While this assessment of climate change risks has endeavored to use the best available information, there are still limitations. Our assessment has prioritised climatic hazards that the district has either experienced in the past, or have been modelled or mapped by NIWA and the ORC. This means the risk of droughts, fire and landslides to the district's infrastructure has not been assessed to the same extent as floods, heavy rainfall, coastal erosion and extreme sea-level events. While the latter hazards are more likely to cause concerns into the future, the risk of drought, fire and landslides cannot be eliminated without more information.

Due to the availability of data, our assessment of flood hazard has also been restricted to known present day flood areas, and an assumption made that these will worsen, rather than improve in the future. There may also be additional unforeseen risks that have not been addressed. Furthermore, we do not yet know how periods of drought or sea level rise might impact groundwater, and so these potential risks have not been considered. Many interdependencies and interactions will occur between the hazards, and due to limited information, these have also not been addressed in detail (as also per the NCCRA and OCCRA).

Further work is also needed to better incorporate mātauranga Māori and Māori perspectives on climate change risk, a limitation noted within the NCCRA and OCCRA. Such work would likely require an integrated framework that recognises the interconnected nature of climate change risks within the context of social and environmental well-being.

Finally, the risk assessment presented within this report reflects the knowledge and priorities of council staff. As per the scope of work, its focus is on how CDC can maintain and deliver infrastructure and services into the future. However, it is useful to note that if the same process was conducted with members of the public, who may possess different priorities, it is probable that some of the findings would vary.

7.0 OPPORTUNITIES

While this risk assessment has not explicitly examined the opportunities that may come with climate change, some opportunities for adaptation of the built environment do exist. For example, the OCCRA identified reduced heating costs, and the increased potential for wind and hydropower electricity generation as potential opportunities (OCCRA, 2021). The future may also hold the potential for more electric vehicle charging stations, public transport networks, and cycling and walking infrastructure (see Climate Commission, 2021), opportunities that if harnessed may contribute to a more climate resilient district.

8.0 SUMMARY

This report has provided a first climate change risk assessment of Clutha's built environment. The report focuses on how council assets and infrastructure such as Three Waters, transport, homes and buildings, public amenities, and waste might be impacted by floods, extreme sea level events, heavy rainfall periods or long-term coastal erosion into the future. The exposure and vulnerability of different infrastructure is rated, followed by a consequence score that reflects what would happen if the infrastructure was to suffer long-term damage.

Overall, the most extreme risks facing the district, as determined during the council workshop, include risks to potable water treatment plants, road networks, homes and buildings, and flood or coastal defence mechanisms. These risks are created by exposure to flood, coastal inundation or heavy rainfall events, all of which are predicted to increase as a result of climate change (see Griffin and Goldsmith, 2020). Road networks, buildings and potable water treatment plants are important lifelines that if damaged would significantly disrupt the social and economic functioning of the district. Flood and coastal defence mechanisms provide protection to some of this critical infrastructure, particularly along the Clutha River/Mata-Au, and so the consequence of these systems failing is also extreme. Other potential concerns for the district include risks to community facilities (such as halls, libraries & leisure centres), and contamination from closed landfills as a result of flood or coastal inundation, heavy rainfall events, or ongoing coastal erosion.

During the council workshop, the top issues requiring more action for adaptation planning included the old dump site near Kaka Point, the districts storm water systems, road networks, and private and commercial buildings. Addressing these issues should form the basis for future investigations and climate change adaptation planning in the Clutha District.

Despite the significant risks facing some of the district's infrastructure and facilities, mitigation and adaptation may be achieved through informed and targeted planning. One example of this is the Dynamic Adaptive Policy Pathways (DAPP) approach, which can be utilised to facilitate flexible, proactive and equitable climate change adaptation (see Lawrence et al., 2018). Alongside this informed and flexible planning approach, CDC's wealth of experience responding to flood and heavy rainfall events will prove critical as it potentially responds to more extreme events into the future.

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APPENDICES

A1.0 APPENDIX 1: SUMMARY OF RISKS IN THE BUILT ENVIRONMENT IN OTAGO

Table A1.1 Summary of risks in the built environment domain in the Otago Region (Source: Tonkin & Taylor, 2021)

Risks		Risk Rating* (highest per category)		
		Present	2040	2090
B1	Risk to buildings and open spaces from climate change hazards including inland and coastal flooding, coastal erosion, and sea level rise and salinity stress	H	E	E
B2	Risk to flood management schemes from inland and coastal flooding, and sea level rise and salinity stress	M	E	E
B3	Risk to water supply infrastructure and irrigation systems due to drought, fire weather, flooding and sea level rise and salinity stress	H	E	E
B4	Risk to stormwater and wastewater networks from increased temperature, sea level rise and salinity stress, extreme weather events and flooding	H	H	E
B5	Risks to linear transport (roads and rail) from flooding, coastal erosion, extreme weather events and landslides	M	E	E
B6	Risk to airports and ports from flooding and extreme weather events	M	E	E
B7	Risk to solid waste (landfills and contaminated sites) to flooding and sea level rise and salinity stress	M	E	E
B8	Risks to electricity (generation, transmission and distribution) networks from changes in rainfall, extreme weather events and flooding	M	H	E
B9	Risks to telecommunications infrastructure due to sea level rise and salinity stress and extreme weather events	L	M	H

* Highest risk rating per category and hazard relationship highlighted. Refer individual risk discussions for detailed ratings

A2.0 APPENDIX 2: RISK ASSESSMENT CRITERIA FROM NCCRA (MFE, 2019)

Table A2.1 Criteria for assessing the exposure of elements at risk (adapted from the NCCRA to suit the Clutha District context).

Element	Extreme	High	Moderate	Low
Three Waters Infrastructure	Water infrastructure currently impacted by climatic hazards on a regular basis or located immediately within a known hazard zone (present day flood or future extreme sea level).	Water infrastructure sometimes impacted by climatic hazards, or located partially within a hazard zone (present day flood or future extreme sea level).	Water infrastructure occasionally impacted by climatic hazards or located adjacent to or within 100 m distance of a hazard zone (present day flood or future extreme sea level).	Water infrastructure rarely or never impacted by climatic hazards and is unlikely to be exposed by extreme sea level or floods in the future.
Transport Infrastructure	Transport infrastructure currently impacted by climatic hazards on a regular basis (yearly or more frequent) or located immediately within a hazard zone (present day flood or future extreme sea level).	Transport infrastructure currently impacted by climatic hazards on a semi-regular (every 2-3 years) basis or located partially within a hazard zone (present day flood or future extreme sea level).	Transport infrastructure currently impacted by climatic hazards on an occasional basis (every 5-10 years), or located adjacent to, or within 100 m distance of, a hazard zone (present day flood or future extreme sea level).	Transport infrastructure rarely or is yet to be impacted by climatic hazards and is unlikely to be exposed by extreme sea level or floods in the future.
Houses and Buildings	>50% of buildings, or rural productive farmland, situated immediately within a known hazard zone (present day flood or future extreme sea level).	20-50% of buildings, or rural productive farmland, situated immediately within a known hazard zone (present day flood or future extreme sea level).	Up to 20% of buildings, or rural productive farmland, situated immediately within a known hazard zone (present day flood or future extreme sea level).	Buildings, or rural productive farmland, unlikely to be exposed by extreme sea level or floods.
Public Amenities	Amenity situated immediately within a known hazard zone (present day flood or extreme future sea level).	Amenity situated partially within a known hazard zone (present day flood or extreme future sea level).	Amenity situated adjacent to, or within 100 m distance of, a known hazard zone (flood or extreme sea level).	Amenity unlikely to be exposed by extreme sea level or floods.

Waste	Contaminated site situated immediately within a known hazard zone (present day flood or future extreme sea level).	Contaminated site situated partially in within a known hazard zone (present day flood or future extreme sea level).	Contaminated site situated adjacent to, or within 100 m distance of, a known hazard zone (flood or future extreme sea level).	Contaminated site unlikely to be exposed by extreme sea level or floods.
Energy and Telecommunications	Asset immediately within a known hazard zone (present day flood or future extreme sea level).	Asset situated partially within a known hazard zone (present day flood or future extreme sea level).	Asset situated adjacent to, or within 100 m distance of, a known hazard zone (flood or future extreme sea level).	Asset unlikely to be exposed by extreme sea level or floods.
Flood and Coastal Defence	Structure situated immediately within a known hazard zone (present day flood or future extreme sea level).	Structure situated partially within a known hazard zone (present day flood or future extreme sea level).	Structure situated adjacent to, or within 100 m distance of, a known hazard zone (flood or future extreme sea level).	Structure unlikely to be exposed by an increase in extreme sea level or flood events.

Table A2.2 Vulnerability rating scales (take from the NCCRA)

Description of vulnerability	Definition
Extreme	Extremely likely to be adversely affected, because the element or asset is highly sensitive to a given hazard and has a low capacity to adapt.
High	Highly likely to be adversely affected, because the element or asset is highly sensitive to a given hazard and has a low capacity to adapt.
Moderate	Moderately likely to be adversely affected, because the element or asset is moderately sensitive to a given hazard and has a low or moderate capacity to adapt.
Low	Low likelihood of being adversely affected, because the element or asset has a low sensitivity to a given hazard and has a high capacity to adapt.

Table A2.3 Consequence rating scales (adapted from the NCCRA to suit the Clutha District context)

Element	Insignificant	Minor	Moderate	Major	Extreme
Housing and buildings	Negligible damage to residential dwellings, commercial, government, and non-commercial buildings expected.	More than 5 residential, commercial or government buildings need to be assessed for relocation by 2050, or 10 buildings by 2100.	More than 10 residential, commercial or government buildings need to be assessed for relocation by 2050, or 20 buildings by 2100.	More than 20 residential, commercial or government buildings need to be assessed for relocation by 2050, or 50 buildings by 2100.	More than 50 residential, commercial or government buildings need to be assessed for relocation by 2050, or 100 buildings by 2100.
Public amenities	Negligible damage to public amenity expected, or amenity unlikely to be important in the future or easily adapted.	Minor damage to a public amenity expected, and amenity deemed likely to be reasonably important in the future.	Moderate damage to a public amenity expected, and amenity deemed likely to be reasonably important in the future.	Major damage to a public amenity expected, and amenity deemed likely to be very important in the future.	Extreme damage to a public amenity expected, and amenity deemed likely to be very important in the future.
Water	Negligible disruption to 3 waters infrastructure expected.	Short-term disruption to water infrastructure during climatic event with easy repair or solution.	Short to medium-term disruption to water infrastructure during climatic event with need to assess for future relocation.	Regular disruption to water infrastructure during climatic event with need to assess for future relocation.	Permanent disruption to water infrastructure (provision of potable water or maintenance of water quality) with immediate need to assess for relocation.
Transport infrastructure	Minor or insignificant disruption to transport infrastructure at the local level.	Isolated and short-term disruption to transport infrastructure. No permanent damage. Some minor restoration work required.	Short-term disruptions to transport infrastructure. Damage recoverable by maintenance and minor repair.	Short-to-medium term disruption to transport infrastructure. Extensive infrastructure damage requiring major repair.	Long-term disruption to transport infrastructure. Significant permanent damage and/or complete loss of the infrastructure and its service.

Coastal and flood defence	Minor or insignificant impact on coastal or flood defence mechanisms.	Minor impact on coastal or flood defence mechanisms with an assessment of future needs required.	Coastal or flood defence mechanism subject to more frequent weather events and an assessment of future needs required. Failure would have moderate flow-on or cascading effects.	Coastal or flood defence mechanism subject to more frequent weather events and in need of assessment for upgrade or replacement. Failure would have high flow-on or cascading effects.	Coastal or flood defence mechanism subject to more frequent extreme weather events and in need of assessment for immediate upgrade or replacement. Failure would have extreme flow-on or cascading effects.
Waste management	Insignificant impact on contaminated sites.	Minor short-term impact on contaminated sites, with an assessment of remedial actions required.	Moderate recurrent impact on contaminated sites, with an assessment of remedial actions required.	Major or recurrent impact on contaminated sites, with assessment of remedial actions required.	Permanent impact on contaminated sites, with immediate assessment of remedial actions required.
Energy services and telecommunications networks	Negligible disruption to energy services or telecommunication networks.	Isolated and short-term energy or telecommunications disruption. No permanent damage. Some minor restoration work required.	Multiple short-term disruptions to energy or telecommunications. Damage recoverable by maintenance and minor repair.	Widespread short-to-medium term disruption to energy or telecommunications. Extensive infrastructure damage requiring major repair.	Widespread, long-term disruption to energy or telecommunications. Significant permanent damage and/or complete loss of the infrastructure and its service.

Table A2.4 Urgency for adaptation criteria (adapted from NCCRA framework and UK Climate Change Risk Assessment)

More immediate action needed	New, stronger or different government policies or implementation activities - over and above those already planned - are needed in the next five years to reduce long-term vulnerability to climate change.
More action needed	New, stronger or different government policies or implementation activities - over and above those already planned - are needed in the next five to 20 years to reduce long-term vulnerability to climate change.
Priority for further work	Risks are potentially high but significant evidence gaps exist and more research is needed to assess the need for additional action.
Sustain current action	Current of planned levels of activity are appropriate, but continued implementation of these policies and plans is needed to ensure that the risk continues to be managed in the future. This includes existing plans to increase or change the current level of activity.
Watching brief	The evidence in these areas should be kept under review, with long-term monitoring of risk levels and adaptation activity so that further action can be taken if necessary.

A3.0 APPENDIX 3: SELECTED MAPS OF EXTREME SEA LEVEL AND FLOOD AREAS WITH COUNCIL ASSETS AND INFRASTRUCTURE

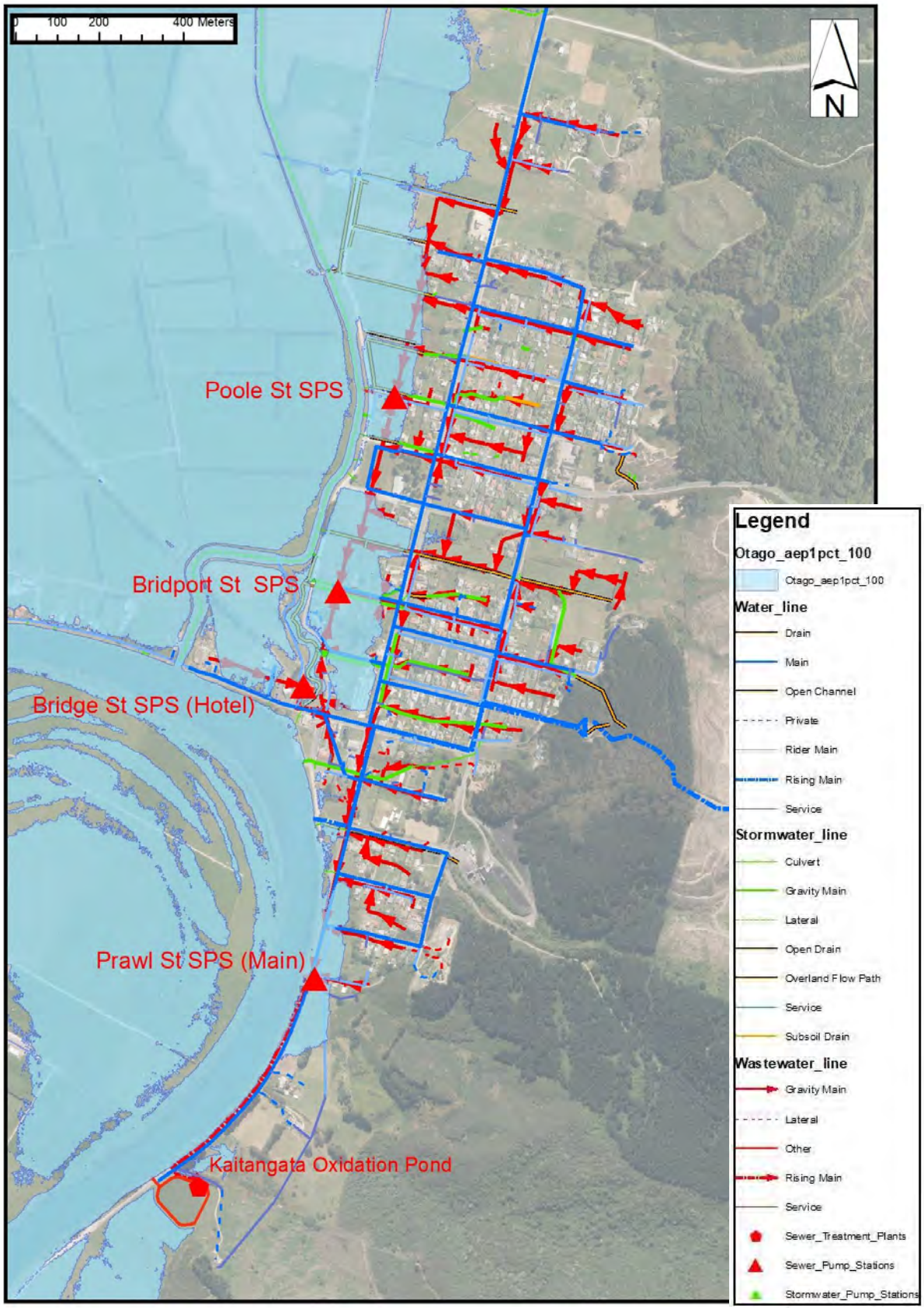

Figure A3.1 A 1 in 100-year extreme sea level event with 1 m of sea level rise (NIWA, 2019), overlain with the location of Three Waters infrastructure in Kaitangata. Image courtesy of CDC.

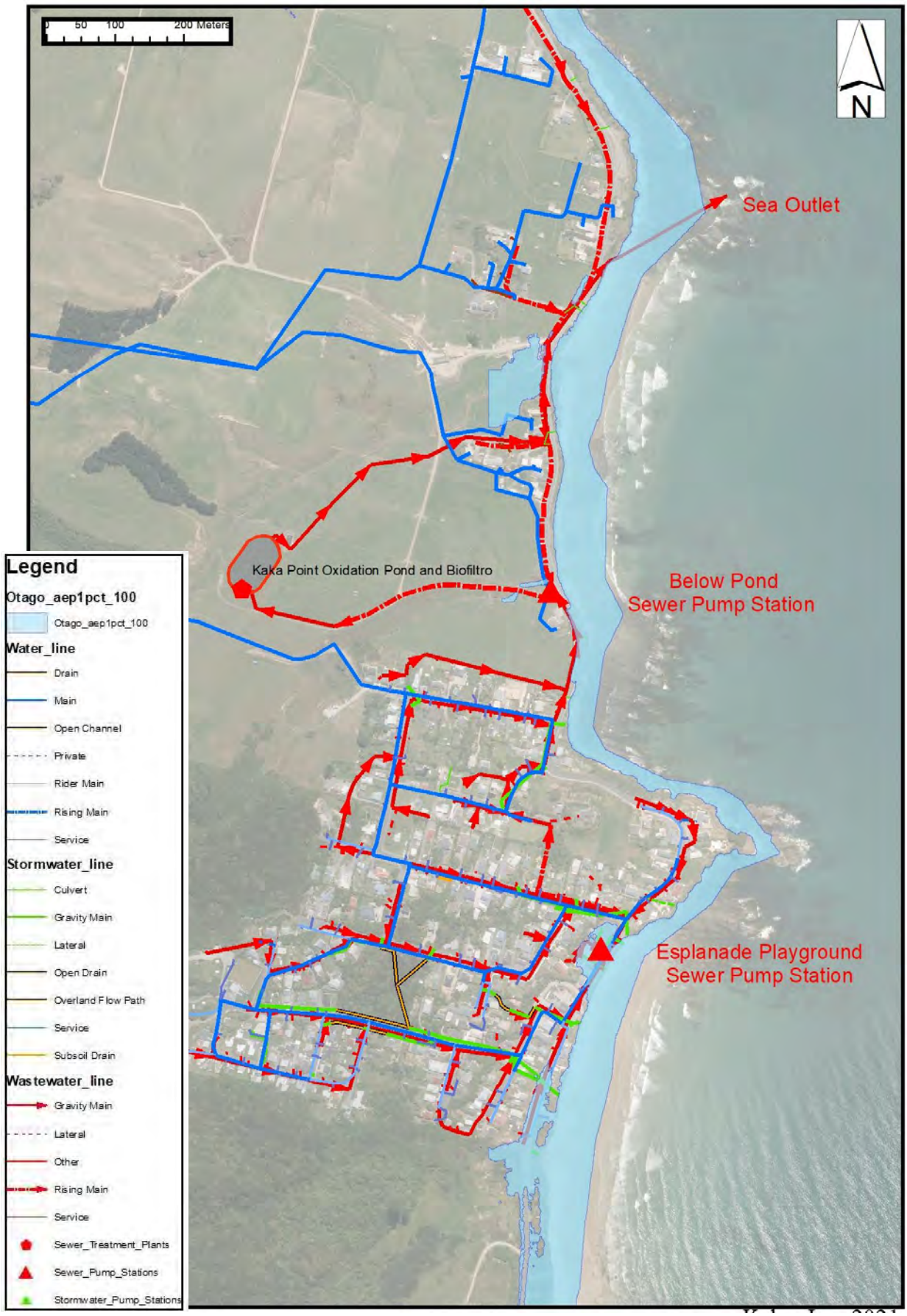

Figure A3.2 A 1 in 100-year extreme sea level event with 1 m of sea level rise (NIWA, 2019), overlain with the location of Three Waters infrastructure in Kaka Point. Image courtesy of CDC.

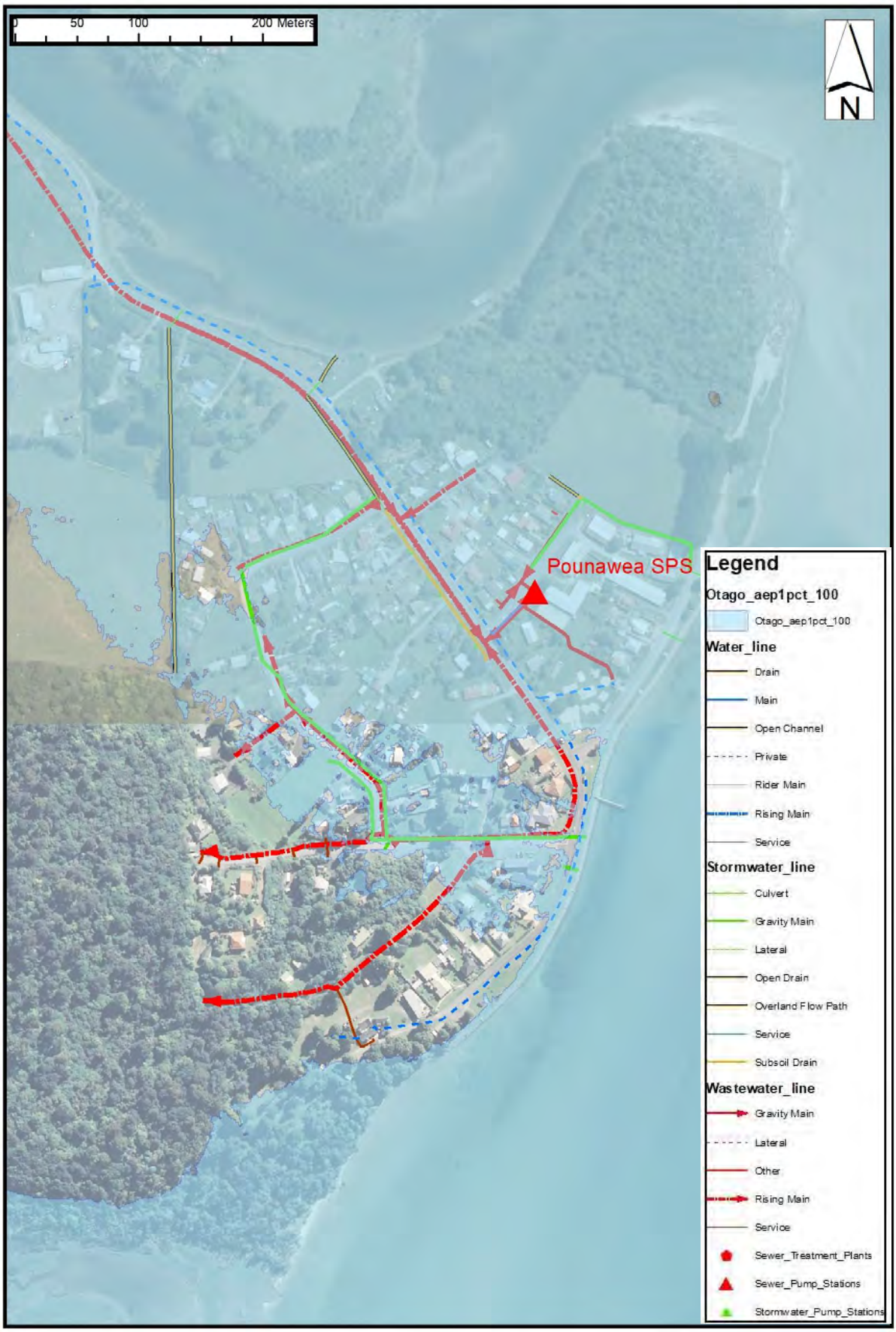

Figure A3.3 A 1 in 100-year extreme sea level event with 1 m of sea level rise (NIWA, 2019), overlain with the location of Three Waters infrastructure in Pounawea. Image courtesy of CDC.

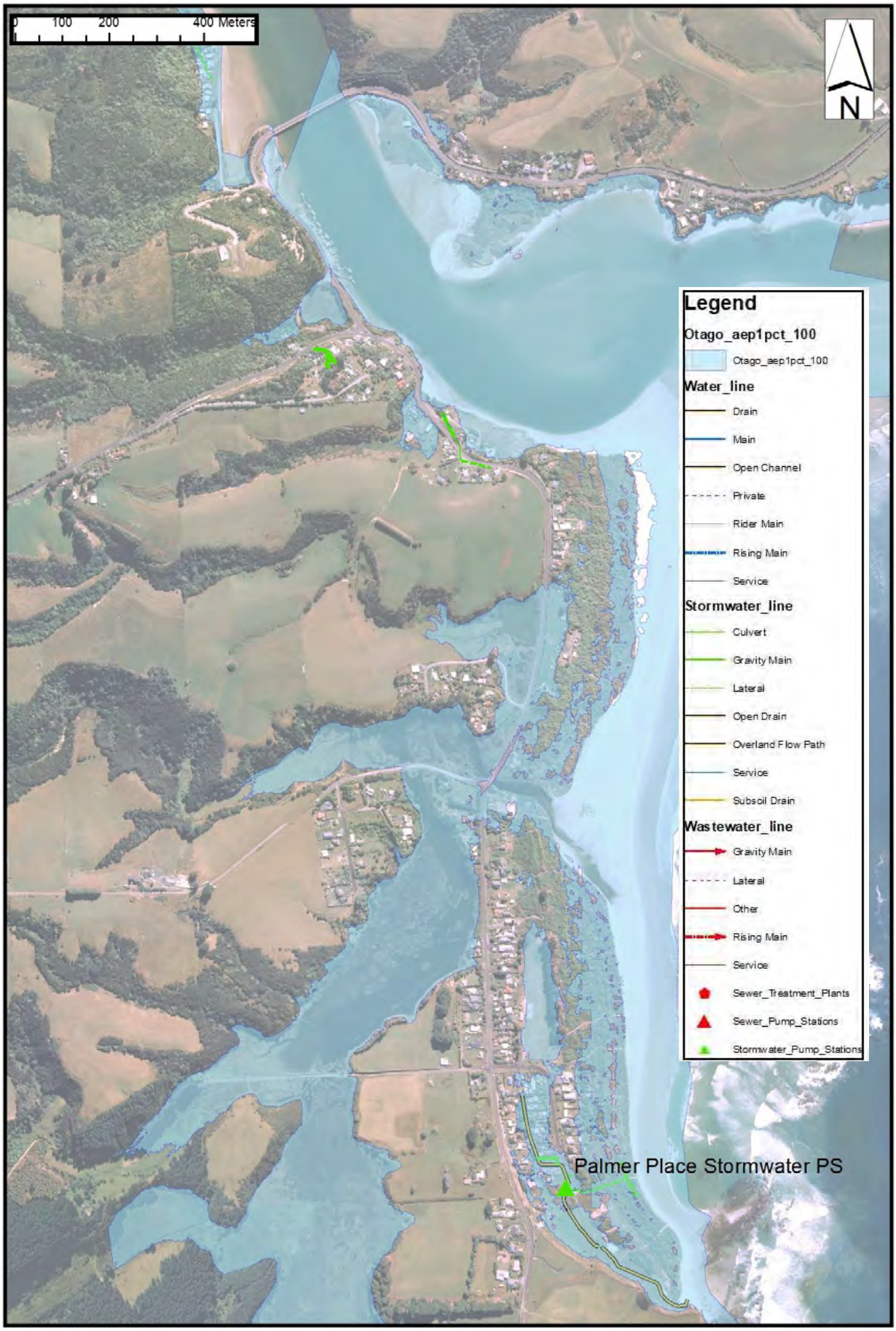

Figure A3.4 A 1 in 100-year extreme sea level event with 1 m of sea level rise (NIWA, 2019), overlain with the location of Three Waters infrastructure in Taieri Mouth. Image courtesy of CDC

Figure A3.5 Flood hazard area (sourced from the ORC Natural Hazards Database) in Kaitangata overlain with the location of contaminated sites, public toilets, swimming pool, libraries, community housing, cemeteries, reserves and parks. Image courtesy of CDC.

Figure A3.6 Flood hazard area (sourced from the ORC Natural Hazards Database) in Milton overlain with the location of contaminated sites, public toilets, halls, swimming pool, libraries, community housing, cemeteries, reserves and parks. Image courtesy of CDC.

Figure A3.7 Flood hazard area (sourced from the ORC Natural Hazards Database) in Waihola overlain with the location of contaminated sites, public toilets, halls, swimming pool, libraries, community housing, cemeteries, reserves and parks. Image courtesy of CDC.

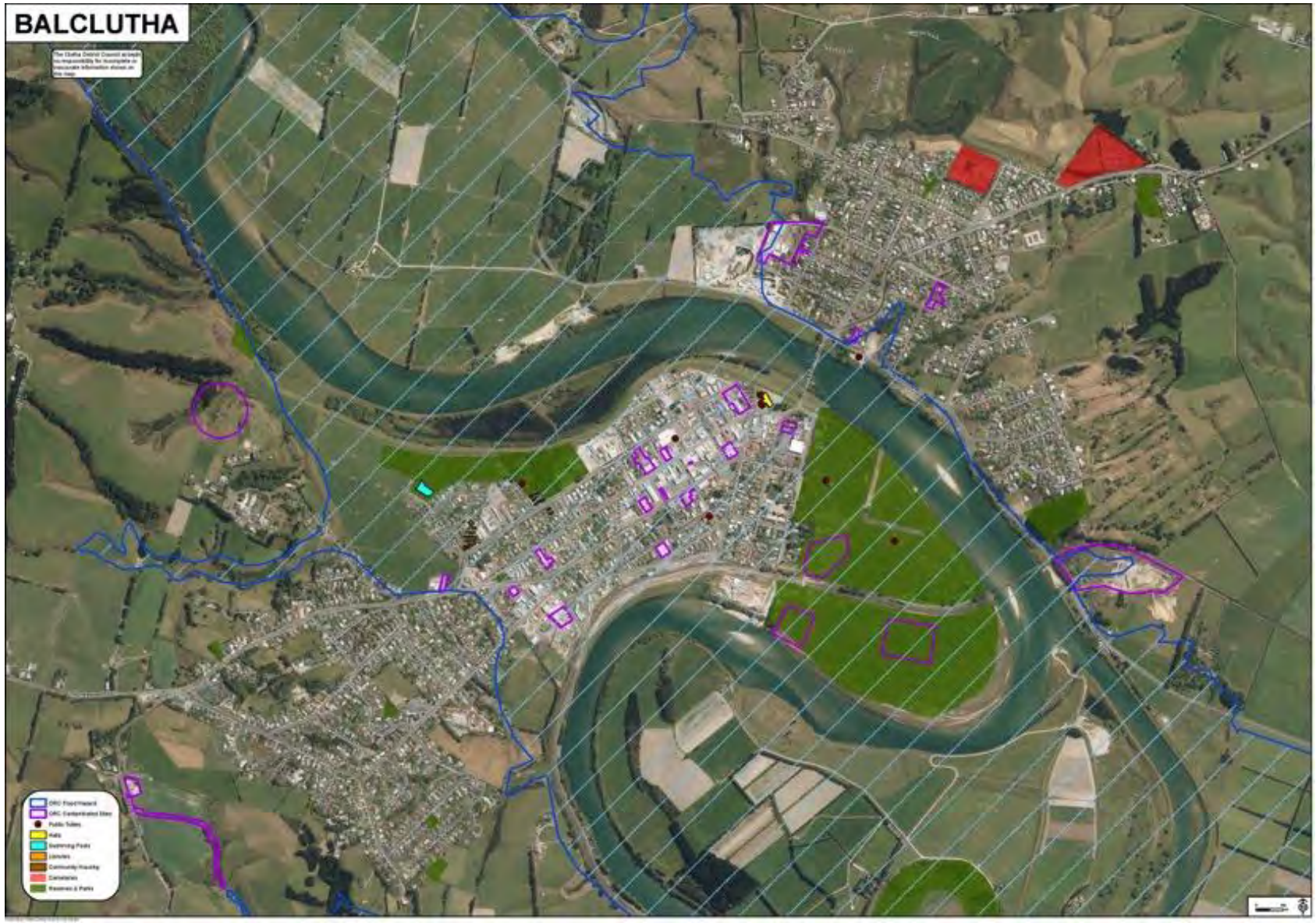

Figure A3.8 Flood hazard area (sourced from the ORC Natural Hazards Database) in Balclutha overlain with the location of contaminated sites, public toilets, halls, swimming pool, libraries, community housing, cemeteries, parks and reserves. Image courtesy of CDC.

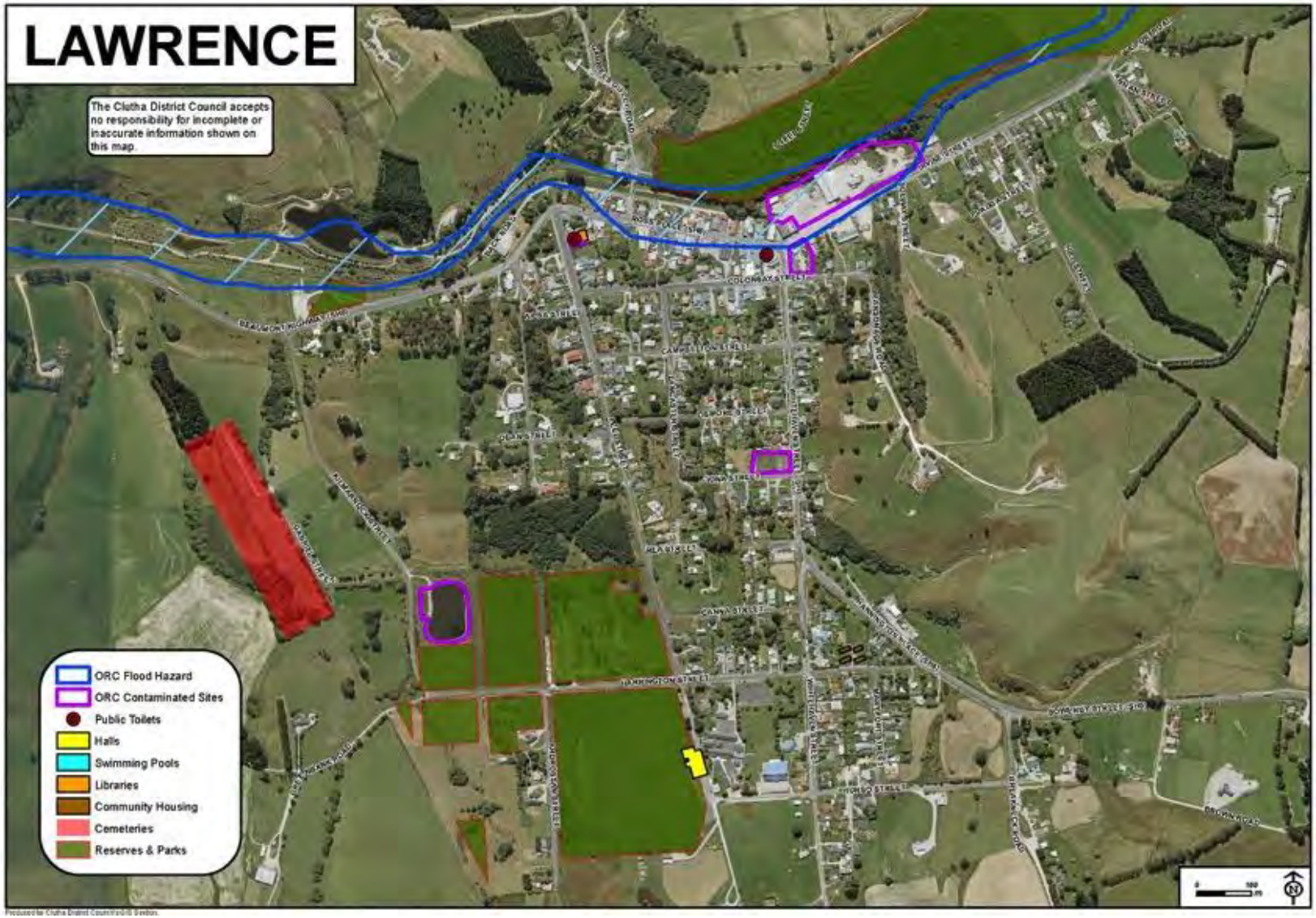

Figure A3.9 Flood hazard area (sourced from the ORC Natural Hazards Database) in Lawrence overlain with the location of contaminated sites, public toilets, halls, swimming pool, libraries, community housing, cemeteries, reserves and parks. Image courtesy of CDC.

A4.0 APPENDIX 4. SUPPLEMENTARY MATERIAL, EXPOSURE, VULNERABILITY AND CONSEQUENCE RISK TABLES

This material was determined through council consultation and a workshop.

Table A4.1 Exposure, vulnerability and consequence risk tables – Three Water Infrastructure

Element	Hazard Information	Spatial Information	Exposure Present	Exposure Near-term (~2050)	Exposure Long-term (~2100)	Vulnerability	Consequence (risk)	Strength of evidence	Notes	Current or planned adaptation?
Potable water treatment plant	Fluvial and pluvial flooding	Waitahuna WTP	Moderate	Nil	Nil	Nil	Nil	Very high	Floods could damage intake pumps and create dirty water. Poses operational risk.	Plan in place to replace this infrastructure. New greenfield bore source will replace these plants.
		Evans Flat (Tuapeka West)	Moderate	Nil	Nil	Nil	Nil	High	Old system to be replaced.	As for Waitahuna, a new bore source will replace this plant.
		Owaka bores PS; Balclutha, Stirling, Tapanui, Puerua and Milton WTP's; Waipahi SWS Treatment plant; Clydevale-Pomahaka Treatment plant; Whitelea Rd WTP; Moa Flat; North Bruce; Lawrence.	Low	Moderate	Moderate	Moderate	Extreme	High	If Balclutha flood banks fail, the Balclutha WTP is at risk.	A new greenfield bore source will replace the Lawrence plant.
		Glenkenich WTP	Moderate	Moderate	Moderate	Moderate	Major	Very high	Flood events affect operations at old plant	New plant under construction, completion estimated late 2021
Potable water intake	Fluvial and pluvial flooding	Waitahuna WTP intake	Extreme	Nil	Nil	Nil	Nil	High	Will soon be gone	
		Glenkenich WTP; Puerua WTP; Tapanui WTP; Evans Flat PS	High	High	Very high	High	Major	High	System exposed to floods and debris in river water. Includes river surface intakes for small to medium rivers/streams.	
		Timber Creek Intake (Moa Flat); Meggatburn Water Intake (Nth Bruce); Lawrence WTP	Moderate	High	Very high	High	Major	High	Rural water reservoirs, less risk of direct flood, fed from remote locations away from intensive farming.	
		Waipahi SWS;	Moderate	High	Very high	High	Minor	High	Small stream, debris and dirty water	
		Milton	Low	Low	Low	Low	Major	High		
		Whitelea Road; Balclutha; Stirling	High	High	Very high	High	Major	High	Come from Clutha River, damage and dirty water	
		Clydevale/Pomahaka WTP (bore); new bore to source Waitahuna and Evans Flat	Low	High	Very high	High	Major	High	Bore water collected near the river, if large flood goes over the bore there is a risk of dirty water entering pipes.	Current discussions are focusing on how to raise bore head to eliminate present risk. New bores to source Waitahuna and Evans Flat.
		Owaka WTP (bore)	Moderate	Moderate	Moderate	Low	Major	High	Exposed to flooding.	Has received a recent upgrade.
		Kaitangata Intake PS	High	High	Very high	High	Major	High		
	Extreme sea level event	Kaitangata Intake PS		High	Very high	High	Major	Medium		
Sewer treatment plant	Fluvial and pluvial flooding	Milton Sewer Treatment Plant and Wetlands; Balclutha Oxidation Pond; Clinton Oxidation Ponds + Wetland; Kaitangata Oxidation Pond; Lawrence Oxidation Pond and Biofiltro; Stirling Oxidation Pond and Biofiltro; Tapanui Oxidation Pond and Biofiltro; Waihola Oxidation Pond; Owaka Oxidation Ponds and Biofiltro	Low	High	Very high	High	Moderate	High		
	Heavy rainfall events	Milton Sewer Treatment Plant and Wetlands	Extreme	High	Very high	High	Moderate	High		
		Balclutha, Waihola & Kaitangata Oxidation Ponds; Clinton Oxidation Ponds + Wetland; Lawrence, Stirling, and Tapanui Oxidation Pond and Biofiltro units	Moderate	High	Very high	High	Moderate	High		
		Heriot Oxidation Pond; Kaka Point Oxidation Pond and Biofiltro; Owaka Oxidation Ponds and Biofiltro	Low	High	Very high	High	Moderate	High		
	Extreme sea level event	Kaitangata Oxidation Pond	High	High	Very high	High	Moderate	Medium		
Sewer pump station	Extreme sea level events	Esplanade playground sewer pump station (Kaka Point); Kaitangata Sewer Pump Stations (Bridport SPS, Poole St SPS, Prawl St SPS, Bridge St SPS)	High	High	Extreme	Very high	Moderate	Medium	System would continue to work if inundated, however the switchboards would fail. Access to Kaka Point ocean outfall difficult if sea level higher.	
Storm water pump station	Fluvial and pluvial flooding	Balclutha, Milton	Low	High	Very high	High	Major	Medium		Milton more vulnerable than Balclutha
	Extreme sea level event	Taieri Mouth		High	Extreme	Very high	Moderate	Medium		
	Heavy rainfall event	Taieri Mouth	High	High	Very high	Very high	Moderate	Medium	Infrastructure is not designed to withstand the combination of a heavy rainfall event with high sea levels.	
Storm water reticulation	Fluvial and pluvial flooding	District wide	Low	High	Very high	High	Moderate	Medium	If inundated, storm water wouldn't flow and possibly cause more flooding upstream	
	Extreme sea level event	District wide	Low	High	High	High	Moderate	Medium		
	Heavy rainfall event	District wide	Low	High	Very high	Very high	Moderate	Medium		
Sewer reticulation	Fluvial and pluvial flooding	District wide	Moderate	Moderate	High	High	Moderate	Medium	If inundated, sewerage wouldn't flow and possibly cause more flooding upstream	
	Extreme sea level event	District wide	Low	Moderate	Moderate	High	Moderate	Medium	If inundated, sewerage wouldn't flow and possibly cause more flooding upstream	Milton, Kaitangata and Kaka Point at the highest risk.
	Heavy rainfall event	District wide	Moderate	High	High	Very high	Moderate	Medium	Infrastructure not designed to withstand heavy rainfall events	Already a priority to identify and fix

Table A4.2 Exposure, vulnerability and consequence risk tables – Transport Infrastructure

Element	Hazard Information	Spatial Information	Exposure Present	Exposure Near-term (~2050)	Exposure Long-term (~2100)	Vulnerability	Consequence (risk)	Strength of evidence	Notes & current or planned adaptation
Highways	Fluvial & pluvial flooding	State Highway 1 (Milton)	Extreme	Extreme		Moderate	Major	High	
		State Highway 90 (West Otago);				High	Moderate	High	
		Whitehaven St (Lawrence)	High	Low		Low	Minor	High	
		Ross Place (Lawrence)	Moderate			Moderate	Minor	High	
		Manuka Gorge Highway	High			Low	Moderate	High	
	Extreme sea level event	Papatowai Highway (between Papatowai and Maclennan)	High	Extreme	Extreme	High	Moderate	High	
Local Roads	Fluvial & pluvial flooding	Hospital Ck Rd (Balclutha)	High			Nil	Nil	High	This road is exposed to floods only if Hospital Creek flood banks fail
		Papatowai Highway (between Owaka and Maclennan)	Extreme	Extreme		High	Moderate	High	
		Owaka Highway Rd (Owaka)	Med			Low	Moderate		
		Sealed roads on the Clutha Delta	Moderate			Low	Moderate	High	
		Sealed roads in the Tokomairiro Plain	Extreme			Moderate	Moderate	High	
		Karoro Creek (off Nuggets Rd)	High			Moderate	Minor	High	
		Sealed roads in the Pomahaka catchment (Pomahaka Rd-West Otago Rd (at Conical Hill), Koi Flat Rd, Dalvey Rd, Cameron Rd (Tapanui), Wooded Hill Rd, Walker Rd, Park Hill Rd, Greenvale, Paradise Flat Rd, Miller Rd,	Extreme			High	Moderate	High	
		Black Gully Rd; Glenshee, Mill, Walker	High			High	Moderate	High	Rain from hills causes localised flooding
		Titri Rd (Lake Waihola)	High			High	Minor	High	
		Clutha Valley Rd and Clutha River Rd	Extreme			High	Major	High	
		Allangrange Rd (Clutha Valley)	High			High	Major	High	
		Tahakopa Valley Rd (Catlins)	High			Low	Minor	High	
		Lakeside Rd, rail underpass				Low	Minor		
	Extreme sea level event	Most sealed roads on the lower Clutha Delta	Moderate	Extreme	Extreme	High	Extreme	Medium	
		Taieri Mouth (Riverside, Marine Pde, Motuara Rd)	Moderate	High	High	High	Major	Medium	
		Kaitangata (Lakeside Rd, Water St, Clyde Terrace)		High	Extreme	Low	Minor	Medium	
		Pounawea (Park Lane, Noble St, Pounawea Rd, Wratten Rd, Arthur Rd)	Moderate	High	Extreme	Extreme	Major	Very high	
		Kaka Point (Kaka Point Rd & Esplanade)	Moderate	Moderate	High	Extreme	Major	Very high	
		The Nuggets Rd	Moderate	High	Extreme	Extreme	Extreme	High	
Unsealed roads	Fluvial & pluvial flooding	Unsealed roads on the Tokomairiro Plain (incl. the Milton end of Toko Mouth Rd)	Extreme			Moderate	Moderate	High	
		Unsealed roads on the Clutha Delta	Moderate			Moderate	Major	High	
		Unsealed roads in the Clutha Valley (Whitelea Rd, Black Bridge Rd, Traumata Rd, Lambourne Rd, King Rd, Burning Plain Rd, Ross Rd, McFarlane Rd)	Extreme			High	Moderate	High	
		Kilhastie Rd (Clutha Valley)	High			High	Moderate	High	
		Unsealed roads in the Catlins (Puerua Valley Rd, Burnt Flat Rd, Purakaunui Falls Rd, Chloris Pass Rd, Cairns Rd)	High			Moderate	Moderate	High	
		Puketiro Rd (Catlins)	Extreme			Moderate	Minor	High	
		Unsealed roads in the Waitepeka area	Extreme			High	Moderate	High	
		Unsealed roads in the Clinton area (Kaihiku Rd, Hillfoot Rd)	Extreme			Moderate	Minor	High	
		Unsealed roads in the Clinton area (Old Lake Rd, Three Stones Rd, Wairuna Siding, Clarke, Quartermain)	High			Moderate	Moderate	High	
		Unsealed roads in the Pomahaka catchment (Beatties Rd)	Extreme			Extreme	Moderate	High	
		Unsealed road in West Otago - Park Hill area (Station Rd, Switzers Rd), Deep Dell Rd (Kelso), Maider, Cleghorn, Glenshee	Extreme			Moderate	Moderate	High	
		Unsealed roads in the Lawrence area (Tuapeka Flat; Matheson Rd; Clarks Flat Rd)	Extreme			High	Moderate	High	
		Unsealed roads in the Lawrence area (Franklin Rd)	High			High	Moderate	High	
		Unsealed roads in the Waitahuna area (Ashton Rd. Lockharts Rd, Coghill Rd; Waitahuna West Rd, Waitahuna Cemetery Rd, Cowan; Roberts Rd, Waitahuna Gully)	Extreme			Moderate	Moderate	High	
		Unsealed roads in the Waitahuna area (Waipori Rd, Mitchells Flat, Nuggets Stream Rd)	High			Moderate	Moderate	High	
		Unsealed roads in the Awamangu area (Wingfield Rd, Blackburn Rd, Queens Hill Rd)	Extreme			High	Minor	High	
		Mount Wallace Rd (Benhar)	Extreme			Moderate	Minor	High	
		Unsealed roads in Hillend area (Hukarere Station Rd, Bloxham Rd, Fallaburn Rd)	High			Moderate	Minor	High	
	High tide & heavy rainfall	Taieri Ferry Road; Coutts Gully Rd (Taieri Mouth); Akatore Creek Rd; Puaho Rd (Catlins)	Extreme			Extreme	Minor	High	
		Berwick Rd	Low			High	Major	High	
	Extreme sea level event	Hina Hina Rd & Jacks Bay Rd (Catlins)	High	High	Extreme	Extreme	Extreme	Very high	
		Toko Mouth Domain Rd; Coutts Gully Rd (Taieri Mouth)	High	High	Extreme	Extreme	Major	Medium	
		Toko Mouth Rd				Extreme	Extreme		
	River undercutting of road	Riverbank Rd (Inch Clutha); Burning Plain Rd (Tuapeka)	High			High	Extreme	High	
	Coastal erosion	New Haven Rd; Kaka Point Rd; Park Lane (Pounawea) (?)	Moderate	High	High	Extreme	Major	Medium	
Bridges	Fluvial & pluvial flooding	Pomahaka bridges	High	High		Moderate	Extreme	High	Extreme risk only if all Pomahaka bridges damaged, which is unlikely.
		Balclutha Bridge	High	Extreme	Extreme	Low	Extreme	Unknown	Bridge due for renewal in ~40 years' time.
	Extreme sea level event	Morgan's Bridge at Sawmill Ck (bridge no. 7, near Taieri), Taieri Mouth (bridge no. 8); Puerua River Bridge (Molyneux); Catlins River; Papatowai Bridge		Moderate	High	Low	Extreme	Medium	Roads will be inundated before the bridges. Hina Hina Bridge being replaced and raised ~1 m. should last 100+ years
		Bridge 22 Washport Ck (Coast Rd)	Low	High		Low	Extreme	Medium	
		Akatore Creek Bridge (Bridge no 10)	Low	High		Low	Extreme	Medium	
Rail	Fluvial & pluvial flooding	Balclutha - Finegand railway line	High	High	High	Moderate	Major	Medium	
Airports	Fluvial & pluvial flooding	Balclutha aerodrome	High	Extreme	Extreme	Extreme	Minor	Medium	

Table A4.3 Exposure, vulnerability and consequence risk tables – Homes and Buildings

Element	Hazard Information	Spatial Information	Exposure Present	Exposure Near-term (~2050)	Exposure Long-term (~2100)	Vulnerability	Consequence (risk)	Strength of evidence	Notes	Current or planned adaptation?
Urban housing	Fluvial and pluvial flooding	Balclutha	High		Extreme to high??	High	Extreme	Low	Hospital Creek Flood bank	ORC assessing climate change / SLR impacts on Clutha Delta? Investigations may inform future decisions?
		Kaitangata; Lawrence	Moderate		Moderate	High	Moderate	Medium		
		Waihola	Moderate		High	High	Major	Medium		
		Milton	High		High [will increase]	High	Extreme	Medium		
		Heriot	Moderate		Moderate	High	Moderate	Medium		
		Tapanui	Moderate		Moderate	High	Major	Medium		
	Extreme sea level event	Pounawea	Moderate	High	Extreme	High	Extreme	High		
		Kaka Point	Low	Low	Moderate	High	Moderate	Medium		
		Willsher Bay	Low	Moderate	Moderate	High	Insignificant	Medium		
		Taieri Mouth	Low - Moderate	Low - Moderate	Moderate - High	High	Extreme	Medium	Low lying areas more prone.	
		Toko Mouth	Moderate	High	Extreme	High	Major	Medium		
		Kaitangata	Low	Moderate	Moderate	High	Moderate	Medium		
		Waihola	Low	Moderate	Moderate	High	Major	Medium	Not included in NIWA models. Comparable to Kai as most of town on elevated, sloping land. A low-lying marginal area.	
		Jacks Bay	Moderate	Moderate	High	High	Moderate	High		
	Erosion	New Haven	Moderate		Extreme	High	Major	Medium	Community and regional council reinforced the shoreline - currently effective and being repaired annually	
		Pounawea	Low		Extreme	High	Moderate	Medium	District council look after seawall, effective for now.	
Rural housing and farms	Fluvial and pluvial flooding	Clutha Delta	Extreme		Extreme	High	Extreme	Medium		
		Tokomairiro Plain	High [should be the same as Milton -->]		Extreme	High	Moderate	Medium		
		Pomahaka Floodplain	High		Extreme	High	Minor	Medium		
	Extreme sea level event Erosion	Clutha Delta	High	Extreme	Extreme	High	Extreme	Medium		
		Koau Mouth to Port Molyneux shoreline	Moderate	Extreme	Extreme	High	Moderate	Medium	Shoreline eroded at 3.3m/year (1946-2012 average). Rate of retreat increasing, and at current rate, flood banks could be affected in less than 3 decades. This is a cascading risk – see section 3.9.	
Commercial buildings	Fluvial and pluvial flooding	Balclutha	High		Extreme	High	Extreme	Medium		
		Ross Place (Lawrence)	Extreme		Extreme	High	Extreme	Medium		
		Milton	Moderate	Moderate	Extreme	High	Major	Medium		
Community housing	Fluvial and pluvial flooding	Balclutha	Extreme	Extreme	Extreme	High	Extreme	Medium	Hospital creek area, exposed from 2 sources (Clutha and hospital Ck)	
		Milton	Low	Low	Low	High	Minor	Medium	Need to confirm location of Milton's community housing	
	Extreme sea level event	Kaitangata	Nil	Low	Moderate	High	Minor	Medium		

Table A4.4 Exposure, vulnerability and consequence risk tables – Public Amenities

Element	Hazard Information	Spatial Information	Exposure Present	Exposure Near-term (~2050)	Exposure Long-term (~2100)	Vulnerability	Consequence (risk)	Strength of evidence	Notes	Current or planned adaptation?
Halls	Fluvial and pluvial flooding	Balclutha	Extreme			Moderate	Major	Medium		Based on new floor level (new building)
		Waihola	Moderate			Moderate	Minor	Medium		
		Matau Hall, Inch Clutha Small Hall	Extreme			Extreme	Minor	Medium		
		Milton No CDC Owner	Moderate					Medium		
	Extreme sea level event	Kaka Point	Low	Moderate	Moderate	Low	Minor	Medium	Hall sits close to the area likely to be inundated by an extreme sea level event (see Griffin & Goldsmith 2020)	
Libraries	Fluvial and pluvial flooding	Balclutha	Extreme			Moderate	Major	Medium		
		Milton (Proposed new building)	Moderate			Moderate	Moderate	Medium		New Building (Service centre, Pool, Library complex)
Leisure facilities	Fluvial and pluvial flooding	Balclutha centennial swimming pool;	Extreme			Moderate	Minor	Medium		
		Milton swimming pool (proposed new building)	Moderate			Moderate	Major	Medium		
Parks and reserves	Extreme sea level event	Livingstonia Park & Knarlston Park (Taieri Mouth); Esplanade Playground (Kaka Point)	Low	High	Extreme	Moderate	Minor	Medium		
	Fluvial and pluvial flooding	Balclutha showground	Extreme		Extreme	Low	Minor	Medium	The showgrounds area is a designated ponding area as part of the Lower Clutha Flood Protection and Drainage Scheme.	
		Riverside Reserve	High			Low	Minor	Medium		
	Sea level rise	Waihola Place and Waihola Domain	Nil	Low	Moderate	Moderate	Minor	Medium		
	Fluvial and pluvial flooding	Kaitangata Cemetery	Nil	Nil	Low			Medium		Not in flood zone - up hill
Public toilets	Fluvial and pluvial flooding	Waihola; Lawrence; Balclutha; Milton	High	High	High	Low	Minor	Medium		
	Extreme sea level event	Livingstonia Park (Taieri Mouth);	Low	Moderate	High	Low	Minor	Medium		
		Pounawea	Moderate	Extreme	Extreme	Low	Minor	Medium		
Hospitals	Fluvial and pluvial flooding	Clutha Health First	Extreme			Moderate	Extreme	Medium		
Schools	Fluvial and pluvial flooding	Balclutha Primary School	Extreme			Moderate	Major	Medium		
		Milton St Mary's Catholic School	High			Moderate	Major	Medium		
		Milton Primary & High Schools	Moderate			Moderate	Major	Medium		

Table A4.5 Exposure, vulnerability and consequence risk tables – Waste Management

Element	Hazard Information	Spatial Information	Exposure Present	Exposure Near-term (~2050)	Exposure Long-term (~2100)	Vulnerability	Consequence (risk)	Strength of evidence	Notes	Current or planned adaptation?
Open landfills	Fluvial and pluvial flooding	Mount Cooee Landfill (Kaitangata Highway)	Low	Low	Low	Low	Major	Low-medium	Landfill elevated above River	
Waste transfer stations	Fluvial and pluvial flooding	Beaumont; Clinton; Clydevale; Lawrence; Maclennan; Milton; Owaka; Papatowai; Taieri Mouth; Tapanui	Low	Moderate	Moderate	Low	Minor	Low-medium	Waste transfer station infrastructure can be shifted; however many of the sites are located on old landfills (except for Lawrence, Beaumont, Papatowai)	
	Extreme sea level event	Maclennan	Low	Moderate	Moderate	Low	Minor	Low-medium		
Closed landfills	Extreme sea level event	Kaitangata	Low	Moderate	Moderate	Low	Unknown (priority for further work)	Low	Site sitiated near extreme SLR zone; site shows non-compliance with ANZECC water quality guidance	
		Maclennan	Low	Moderate	Moderate		Unknown (priority for further work)		Sites show non-compliance with ANZECC water quality guidance, landfill located above river on slope	
		Kaka Point Beach	Extreme	Extreme	Extreme		Major	High		CDC have spent $500K on rock embankment to protecting this old dump site.
		Kaka Pont (Brookdale Road)	Low	Low	Low	Low	Minor			
	Coastal erosion	Kaka Point Beach	Extreme				Major	Very high		
	Fluvial and pluvial flooding	Lawrence; Milton; Tuapeka Mouth; Clydevale	Moderate				Unknown (priority for further work)	Low-medium	Sites show non-compliance with ANZECC water quality guidance	
		Maclennan	High				Unknown (priority for further work)	Low-medium	Upstream water quality exceeds ammoniacal nitrogen for lowland rivers (ANZECC 2000). Site located on river bank. Need investigation on lining and capping.	
		Tahakopa	Extreme				Unknown (priority for further work)	Low-medium	Upstream and downstream water quality exceeds ammoniacal nitrogen for lowland rivers (ANZECC 2000). Site located on river bank, contaminants would be flushed in large flood event but possible effect on groundwater after flood dries. Not lined or capped.	
		Kaitangata	Low				Unknown (priority for further work)	Low-medium	Site located uphill of town.	
		Coronation Park Landfill	Extreme				Unknown (priority for further work)	Low-medium	Site located adjacent to Balclutha showground.	
		Contaminated gun sites Balclutha	Extreme				Unknown	Low-medium	Low impact lead contamination	

Table A4.6 Exposure, vulnerability and consequence risk tables – Coastal and Flood Defence

Element	Hazard Information	Spatial Information	**Exposure** Present	**Exposure** Near-term (~2050)	**Exposure** Long-term (~2100)	Vulnerability	Consequence (risk)	Strength of evidence	Notes	Current or planned adaptation?
Coastal protection structures	Extreme sea level event	Sea wall at mouth of Koau branch of Clutha River	High	Extreme	Extreme	Extreme	Major	Low-Medium	ORC Asset	
		Sea wall at Pounawea	High	Extreme	Extreme	Extreme	Moderate	Low-Medium		
		Seawall at Taieri Mouth	High	Extreme	Extreme	High	Moderate			
Flood banks	Extreme sea level event	Lower Clutha Flood Protection Scheme (Otanomomo, Port Molyneux, Matau, Paretai, Stirling)	Moderate	Extreme	Extreme	Extreme	Extreme	Low-Medium	ORC Assets	
	Fluvial and pluvial flooding	Hospital Rd (Balclutha), flood banks near bridge	Extreme	Extreme	Extreme	Extreme	Extreme	Low-Medium	Water would rise faster at this point than further downstream on the Clutha Delta, as the river is constrained by the flood banks and approaches to the bridge at this point.	
	Fluvial and pluvial flooding	Clutha Delta; Waitepeka Flood Bank; Kaitangata	High	Extreme	Extreme	Extreme	Major	Low-Medium		
Pump stations	Extreme sea level event								ORC Asset	
	Fluvial and pluvial flooding								ORC Asset	
Drains	Extreme sea level event								ORC Asset	
	Fluvial and pluvial flooding								ORC Asset	