REPORT

Tonkin+Taylor

Coastal Hazard Assessment for Christchurch District

Summary Report

Prepared for
Christchurch City Council

Prepared by
Tonkin & Taylor Ltd

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Exceptional thinking together

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Cover photo: The Christchurch District coastline viewed from the International Space Station in 2014 (Credit: ESA/A.Gerst CC BY-SA 2.0. ID: 2014 945_5391).

1 Why is this coastal hazard assessment needed?

Information about coastal hazards is a vital input to support sound adaptation planning discussions between Christchurch City Council (the Council), Ngāi Tahu rūnanga, and communities across Christchurch District.

While various coastal hazards assessments have been undertaken previously, important new data has recently become available, including information on sediment supply, groundwater and sea level statistics, which has implications for the identification of areas prone to coastal hazards. Updating the coastal hazards assessment also presents an opportunity to include parts of the Christchurch District coastline not assessed previously, and to focus on the types of information needed for adaptation planning (such as looking at a wide range of potential future sea level scenarios to help understand the impact of this uncertainty).

The 2021 Coastal Hazard Assessment (2021 CHA) provides important updated information about the potential effects of coastal erosion, coastal flooding and rising groundwater, and how this might change over time with sea level rise. The scope and analysis approach for this assessment is specifically designed for adaptation planning. It has been developed in conjunction with the Council's adaptation planning team, Environment Canterbury coastal experts and an independent technical reviewer.

The 2021 CHA is a broad-scale assessment which provides a general indication of the magnitude and extent of hazards across neighbourhood-sized areas. It does not provide an assessment of the risk to individual properties or provide answers on what can be done to manage those hazards. However, it will help to inform the Council's decision-making through adaptation planning with low-lying and coastal communities.

While the 2021 CHA does not map out a hazard overlay for inclusion in the District Plan, it does provide information to help guide further analysis and engagement to determine if and where a hazard overlay should apply.

More information about coastal hazard adaptation planning and District Plan changes can be found in the links below:

- Adaptation planning: www.ccc.govt.nz/adaptationplanning
- District plan: www.ccc.govt.nz/plan-change-12

2 What areas does the assessment cover?

The 2021 CHA examines current and future coastal hazards across the entire Christchurch District (comprised of Ōtautahi / Christchurch and Te Pātaka-o-Rākaihautū / Banks Peninsula). The assessment area extends from the Waimakariri River mouth in the north, to the outlet from Te Waihora / Lake Ellesmere in the south. The coastal flooding and rising groundwater assessments look at all low-lying land which is close enough to the coast for changes in future flood hazard to be driven mostly by sea level rise. The coastal erosion assessment looks at the immediate coastal shoreline, which includes large open coast beaches, small local beaches, harbours, estuaries, lagoons, cliffs, and banks.

3 Who is involved in this work?

Council engaged Tonkin + Taylor's (T+T's) specialist coastal hazards team, who combined international and national best practice with their extensive local knowledge of Ōtautahi / Christchurch and the wider Canterbury Region, to undertake the assessment.

At each stage, T+T worked with an independent technical reviewer, the Council's adaptation planning team, and technical staff from the Council and Environment Canterbury. The team also considered the recommendations from peer review of previous assessments. This collaborative approach ensures that the 2021 CHA is suitable from both a technical and project needs perspective to support adaptation planning.

The methodology and website design were presented to representatives from community groups with interests in technical hazard information and/or environmental issues. This allowed the approach to be tested more broadly with the intended audience, and for Council staff to receive feedback on communication approaches and supporting information.

4 What international and national guidance is available?

The 2021 CHA follows the Ministry for the Environment (MfE) 2017 Coastal Hazards and Climate Change Guidance (referred to as the 'national guidance' for adaptation planning). This guidance is based on the climate change and sea level rise projections (predictions of what could happen in future) of the 2013 science report by the Intergovernmental Panel on Climate Change (IPCC).

The national guidance introduced new engagement and adaptive approaches for coastal hazards planning and decision-making in Aotearoa / New Zealand, which is informing Council's coastal management approach. Technical hazard assessments form part of the 'what is happening?' phase of the cycle.

The national guidance recommends that these assessments utilise the best available data to describe coastal processes currently acting on the coast and to predict future hazard for a range of scenarios. The assessments should also incorporate uncertainty, due to both data limitations and incomplete scientific knowledge about the processes. The potential effects of climate change should be integrated while also acknowledging uncertainty of projections.

5 What hazards are included in this study?

The 2021 CHA looks at coastal flooding, coastal erosion, and rising groundwater. These are the three hazards most strongly driven by climate change and the uncertainty it presents to the Christchurch District, both now and in the future.

- ***Coastal flooding*** happens when normally dry, low-lying coastal areas are temporarily flooded by the sea. It is usually caused by a severe storm, but rising sea levels could also cause 'sunny day flooding' (where high tides cause flooding even without a storm).
- ***Coastal erosion*** is a natural process that occurs when land is removed by the sea. Some coastal areas experience short periods of erosion, but then recover (build up again) while others continuously erode and never recover. The 2021 CHA reports and maps refer to land which is 'susceptible to erosion'. This includes land that might potentially be affected by coastal erosion at some point over the timeframe considered, even if it might subsequently recover.
- ***Rising groundwater*** can bring the water table close to the ground surface. This wet ground can impact people's health, buildings, infrastructure and how the land can be used. In some cases, groundwater could rise above ground level and cause temporary or permanent ponding of water.

6 How could climate change affect coastal hazards?

Climate change is slowly raising the level of the sea. Water expands with heat, so warmer temperatures are causing our oceans to expand. At the same time, these higher temperatures are melting icesheets and glaciers adding more water to the oceans. The result is a rise in sea level that will not only affect the open coast, but also allow high tides and the effects of storms to reach further inland. This means that more land may be affected by coastal flooding, erosion and rising groundwater in the future, and the severity of those impacts would likely be greater.

7 When could these higher sea levels be reached?

Sea levels have been rising over the past century globally. Scientists are confident that sea levels will continue to rise over the next century and beyond, but the rate and amount of future sea level rise is uncertain. It depends on many unknown factors, such as the rate of future (and past) greenhouse gas emissions and how the sea level responds to these emissions. This means a range of possible sea level rise scenarios should be considered, to understand which areas may be susceptible to different increments of sea level rise and help guide conversations about future adaptation.

- The national guidance considered several potential future emission pathways to develop representative sea level projections for Aotearoa / New Zealand. Details of these scenarios are shown in Table 7.1 and Figure 7.1.
- The analysis for the 2021 CHA establishes a baseline using the shoreline position and sea level in the year 2020, so this means it measures sea level rise starting from this date. In comparison, the projections shown in the national guidance use the sea levels observed between 1986 and 2005 as a baseline. This new 2020 baseline sea level acknowledges that sea levels have now risen about 10 cm compared to the older baseline. For example, a rise of 20 cm (compared to 2020) specified in the 2021 CHA is equivalent to a rise of 30 cm (compared to 1986 – 2005) specified in the national guidance.
- The national guidance recommends focussing on the 'High' sea level rise scenario (the technical term used in climate science is 'RCP8.5 M') for the first stage of risk screening. This reflects global emissions continuing at the present rate and is most aligned with our current trajectory of emissions. For more detailed risk assessment and adaptation planning the full range of scenarios should be considered to understand the range of possible futures. As explained in Section 12, the 2021 CHA looks at many different amounts of sea level rise which provide good coverage across the range of these four recommended scenarios.
- The sea level rise projections used in the national guidance (Figure 7.1) were based on the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report issued in 2013. As the 2021 CHA was being finalised for publication the IPCC released an updated 6th Assessment Report, including updated sea level rise projections. The updated projections broadly align with the previous ones (with some differences in the details), and the various amounts of sea level rise considered for the 2021 CHA still provide good coverage across the range of updated sea level rise projections. This adaptability is one reason why the 2021 CHA considers a wide range of different sea level rise amounts rather than choosing a single fixed scenario. It means that Council can continue to follow the existing national guidance while also being able to check the hazard results against the updated projections.

Table 7.1: Sea level rise scenarios from the national guidance.

High (upper estimate) (Technical term = RCP8.5 H+)	
Emissions:	This scenario assumes continued high emissions, with annual global climate pollution continuing to climb through most of the century if we don't act effectively to reduce emissions. High population growth is also a factor. Consistent with 3 or 4°C of warming.
Sea level response:	This upper estimate 'H+' scenario is at the upper end of the likely range for sea level response to emissions. This reflects the possibility of future surprises, including possible instability of polar ice sheets. In short, warmer temperatures could have a strong effect on sea levels.
Adaptation:	This scenario will be used as a 'stress test' in adaptation planning, to understand implications of sea level rise towards the top end of the projected range.
High (median estimate) (Technical term = RCP8.5 M)	
Emissions:	Continued high emissions (same as 'RCP8.5' scenario above).
Sea level response:	This scenario, and the other 'M' scenarios below, assume that warming has a more moderate effect on sea levels. It uses a projection from the middle of the likely range for sea level response to warming caused by emissions.
Adaptation:	This scenario will be the main point of reference for adaptation planning as it is most aligned with our current trajectory of emissions.
Moderate (Technical term = RCP4.5 M)	
Emissions:	This reflects moderate cuts in global emissions. It shows what would happen if annual global climate pollution peaks near 2040 and then declines to half of current levels. It is consistent with about 2°C of warming, the main target from the Paris Agreement.
Sea level response:	Middle of the likely range (same as other 'M' scenarios).
Adaptation:	This scenario will be used as part of adaptation planning to understand implications for more favourable projections of sea level rise.
Low (Technical term = RCP2.6 M)	
Emissions:	This is the likely outcome if we achieve deep and rapid cuts in global emissions. Annual global heat-trapping pollution peaks near 2020 and then declines to zero within 50 years. It is consistent with about 1.5°C of warming, the most ambitious target from the Paris Agreement. Achieving this will be challenging because of the rapid and large reductions in global emissions required. Removing carbon from the atmosphere (carbon sequestration) would probably be needed.
Sea level response:	Middle of the likely range (same as other 'M' scenarios).
Adaptation:	This scenario will be used as part of adaptation planning to understand implications for optimistic projections of sea level rise.

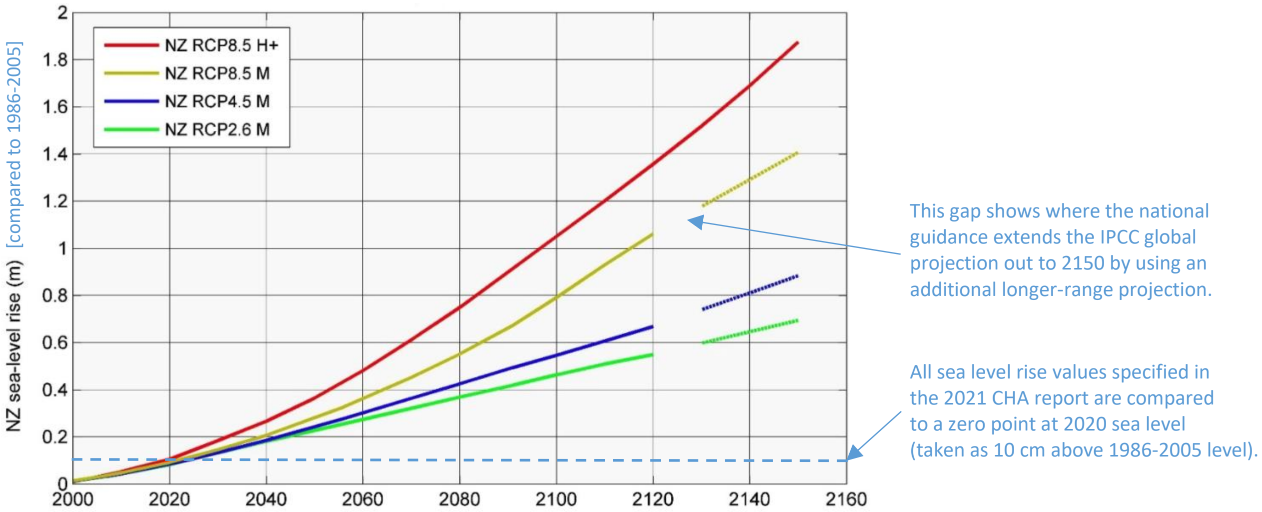


Figure 7.1: Sea level rise projections for New Zealand (relative to 1986-2005) adapted from national guidance.

8 How can ground movement accelerate the effects of sea level rise?

Aotearoa / New Zealand is constantly moving. It is criss-crossed with fault lines which can cause uplift or subsidence of the ground, both as sudden earthquake movement and slow gradual changes. Land movement can also be caused by the natural squeezing of thick soil deposits and changes in groundwater levels. This ongoing change in the level of the land is referred to as 'vertical land movement'.

Global and national projections for sea level rise, such as shown in Figure 7.1, relate to 'absolute sea level rise'. This measures sea level changes sea in relation to the centre of the earth, as would be measured by satellites.

For adaptation planning it is more useful to describe coastal hazards in terms of 'relative sea level rise', which measures changes in the level of the sea relative to the level of the land surface at a particular location. All sea level rise values used for the 2021 CHA are presented in terms of relative sea level rise compared with 2020 sea and land levels for the local coastline.

In Christchurch District, an overall long-term trend of land subsidence is expected. This could mean that a particular amount of relative sea level rise could be reached sooner than suggested by projections of absolute sea level rise such as shown in Figure 7.1. However, detailed monitoring of vertical land movement has only been carried out over the past 10 – 20 years, and only in some locations. This creates considerable uncertainty about the rate and pattern of subsidence across the region. Because of this, the 2021 CHA does not adjust the coastal hazard analysis to include any specific vertical land movement values. Instead, this is noted as an uncertainty to be kept in mind as part of adaptation planning for each individual area.

9 What process does the 2021 CHA follow?

The coastal hazard assessment follows a four-step process, which draws on the international risk management standard ISO 31000:2019. This process is summarised in Figure 9.1, and the key results are summarised in the following sections of this report.

Scoping
- Review of direction, guidance, previous studies and new technical information.
- Gather input data and identify gaps.
- Test and confirm purpose, use, outputs and scenarios.

Method
- Identify uncertainties and implications for use.
- Determine assessment level and spatial extent.
- Develop, test and refine methodology to best suit available information and project needs.

Analysis
- Using the agreed methodology, undertake technical hazard analysis.
- Separate analysis undertaken for each coastal hazard: erosion, flooding and groundwater.

Reporting
- Summary report of findings and supporting background techncial reports.
- Technical review register.
- Interactive website with maps showing modelled hazard for various scenarios.

Figure 9.1: Summary of the process followed for the 2021 coastal hazard assessment.

10 What input data is used?

Before the hazard analysis was undertaken, the team reviewed existing data and research reports to make sure the assessment used the most up to date information about the local coastal environment. This information is summarised in Table 10.1.

Table 10.1: Key environmental data used for the 2021 CHA.

Information	What data was used	What it was used for
Topography (height and shape of land)	Aerial survey of ground levels from 2018 (or 2008 for Kaitorete spit).	Mapping the extent of coastal flooding for a given water level.
Bathymetry (depth of water)	Various marine charts and water depth surveys.	Used as part of the calculation of erosion and coastal flooding levels.
Aerial imagery	Latest imagery for entire coastline from 2019. Historical imagery dating back as far as the 1940s for Christchurch open coast, 1960s for Lyttelton and 1980-1990s for Banks Peninsula.	Defining the current-day shore baseline position. Measuring changes in shoreline position over time.
Beach profiles	Regular surveys of beach cross-section profiles dating back as far as the 1970s or 1990s for the Christchurch open coast and Kaitorete Spit and 2017 for Lyttelton.	Measuring changes in the height of beaches and dunes over time, and how much short-term erosion can occur due to storms.
Water levels	Most recent analysis of water level gauge data for various locations, mostly dating back as far as the 1990s.	Deriving sea level statistics (the highest water level reached in frequent, occasional or rare events) used to calculate coastal flooding levels.
Waves and wind	Models of highest wave heights at various locations dating back as far as the 1970s. Wind data from across Christchurch District, dating back as far as the 1950s.	Calculating the contributions of wind and waves to erosion and coastal flooding levels.
Sediment supply	Most recent analysis of the coastal sand budget for southern Pegasus Bay.	Used as part of the calculation of beach erosion for the Christchurch open coast.

11 How much detail does the hazard analysis go into?

In assessing hazards there are a range of methods that can be used depending on what input data is available, the local coastal environment and the type of hazard information needed.

The national guidance recommends the use of a two-level approach for coastal hazard assessment:

- *A regional hazard screening* is a broad-scale hazard assessment that uses simple methods to identify areas that could be prone to coastal hazards. This approach is recommended in areas where less input data is available and fewer communities or assets are located. It can help to identify higher risk areas where more detailed assessments might be useful in future.
- *A detailed hazard assessment* enables a more thorough understanding of coastal processes, uncertainties, effects of different sea level rise scenarios, and the likelihood of hazard occurrence. To use this approach there needs to be sufficient existing information available about coastal processes in the area, such as beach profiles, water levels, waves and wind. This approach is recommended for areas of more intensive development, where there is a need for more information on how the hazard could change over time.

Figure 11.1 shows where each of these levels of detail are applied for the 2021 CHA.

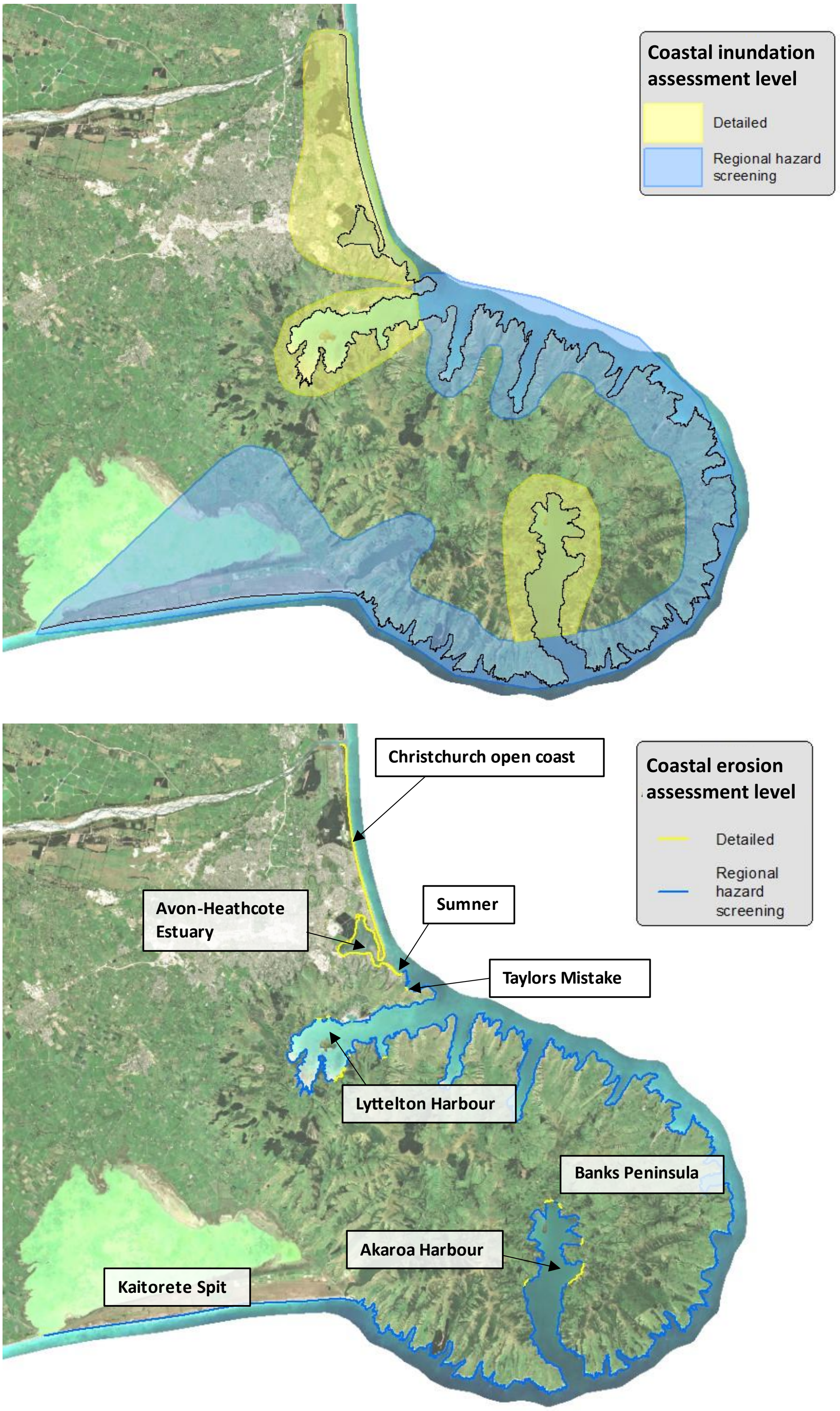


Figure 11.1: Map of Christchurch District, showing the extent of detailed and regional assessment. The detailed erosion assessment covers some parts of Lyttelton Harbour (Corsair, Cass, Rapaki, Charteris, Hays & Purau bays) and Akaroa Harbour (Wainui, Duvauchelle, Takamatua, Childrens, French & Glen bays).

12 How much sea level rise is assumed?

It's important to understand that the 2021 CHA does not predict how much sea level will rise and by when. As shown in Figure 12.1, it looks at many different sea level rise amounts between 0 and 2 metres to understand what could happen across a wide range of scientifically credible possible future sea levels between now and 2150. This approach is more adaptable than the alternative of choosing a fixed sea level rise scenario and timeframe to model. The analysis looks out as far as 2150 because Councils are required to identify what might be at risk from coastal hazards over at least the next 100 years or more.

Flooding analysis

The top chart in Figure 12.1 shows the various amounts of sea level rise modelled for the coastal flooding analysis (the horizontal dashed lines on the chart). The flooding analysis is not fixed to a specific timeframe. For example, a relative sea level rise of 40 cm could occur around 2060 if we follow the 'High – upper estimate' projection, or around 2100 if we follow the 'Low' projection. This allows adaptation planning to first focus on understanding the effect of rising sea level, and then think about when that might occur.

- *The regional hazard screening* (the thick pink dashed lines on the chart) looks at three different sea level rise amounts: 0 cm (current-day), 40 cm and 1.5 m. This provides a simple initial screening to help guide adaptation planning. A sea level rise of 1.5m is just above the most pessimistic national guidance projection for the next 100 years – so areas which are not impacted at this level will likely not be a priority for adaptation planning. A sea level rise of 40 cm is just below the most optimistic projection for the next 100 years – so areas which are impacted at this level are more likely to be a priority for adaptation planning, as they are expected to experience more severe effects sooner.
- *The detailed hazard assessment* (the thin purple dashed lines on the chart) looks at nine different sea level rise amounts: a series of 20 cm steps from 0 to 1.2 m then increasing in larger steps to 1.5 and 2.0 m (to keep the number of models to a manageable number). These steps provide good coverage across the full range between the highest and lowest national guidance projections of sea level rise over the next 100 years or more. The high-end scenario of 2 m of sea level rise (for the year 2150 or beyond) can also be used to 'stress test' for longer time periods or sea level rise exceeding projections.
- *A combined flooding & erosion analysis* (the purple triangle on the chart) looks at the open coast beach from Te Riu-o-Te-Aika-Kawa / Brooklands to Te Karoro Karoro / Southshore, for 1.5 m sea level rise in the year 2130. This is discussed further in Section 13.

Erosion analysis

The bottom chart in Figure 12.1 shows the various amounts of sea level rise modelled for the coastal erosion analysis (the dots and diamonds on the chart). Each erosion analysis is fixed to a specific timeframe as well as a sea level rise amount, as the length of time plays an important part in the long-term shoreline trends. The 2021 CHA considers five points in time, representing approximate current-day (2020), short-term (2050), medium-term (2080), long-term (2130) and beyond (2150+).

- *The regional hazard screening* (the large blue dots on the chart) looks at three of these points in time (2020, 2080 and 2130). Like the flooding analysis, three different sea level rise amounts are considered: 0 cm (current-day), 40 cm and 1.5 m, to provide a simple initial screening to help guide adaptation planning.
- *The detailed hazard assessment* (the small green dots on the chart) looks at all five points in time, with various amounts of sea level rise (using the same steps as the flooding analysis) across the full range between the highest and lowest national guidance projections. For the year 2150 and beyond the assessment looks only at a high-end sea level rise value of 2 m, as a 'stress-test' for longer time periods or sea level rise exceeding projections.
- *A sediment supply sensitivity analysis* (the green diamond on the chart) looks at the open coast beach from Te Riu-o-Te-Aika-Kawa / Brooklands to Te Karoro Karoro / Southshore, for 1.5 m sea level rise in the year 2130. This is discussed further in Section 14.

Rising groundwater analysis

For the Ōtautahi / Christchurch flat-land urban area a detailed groundwater model had already been developed for the Council by Aqualinc. This used sea level rise amounts of 0 cm, 19 cm, 40 cm, 1 m, 1.88 m and 2.4 m. For consistency, the 2021 CHA uses similar sea level rise amounts in the rising groundwater regional hazard screening for Te Pātaka-o-Rākaihautū / Banks Peninsula.

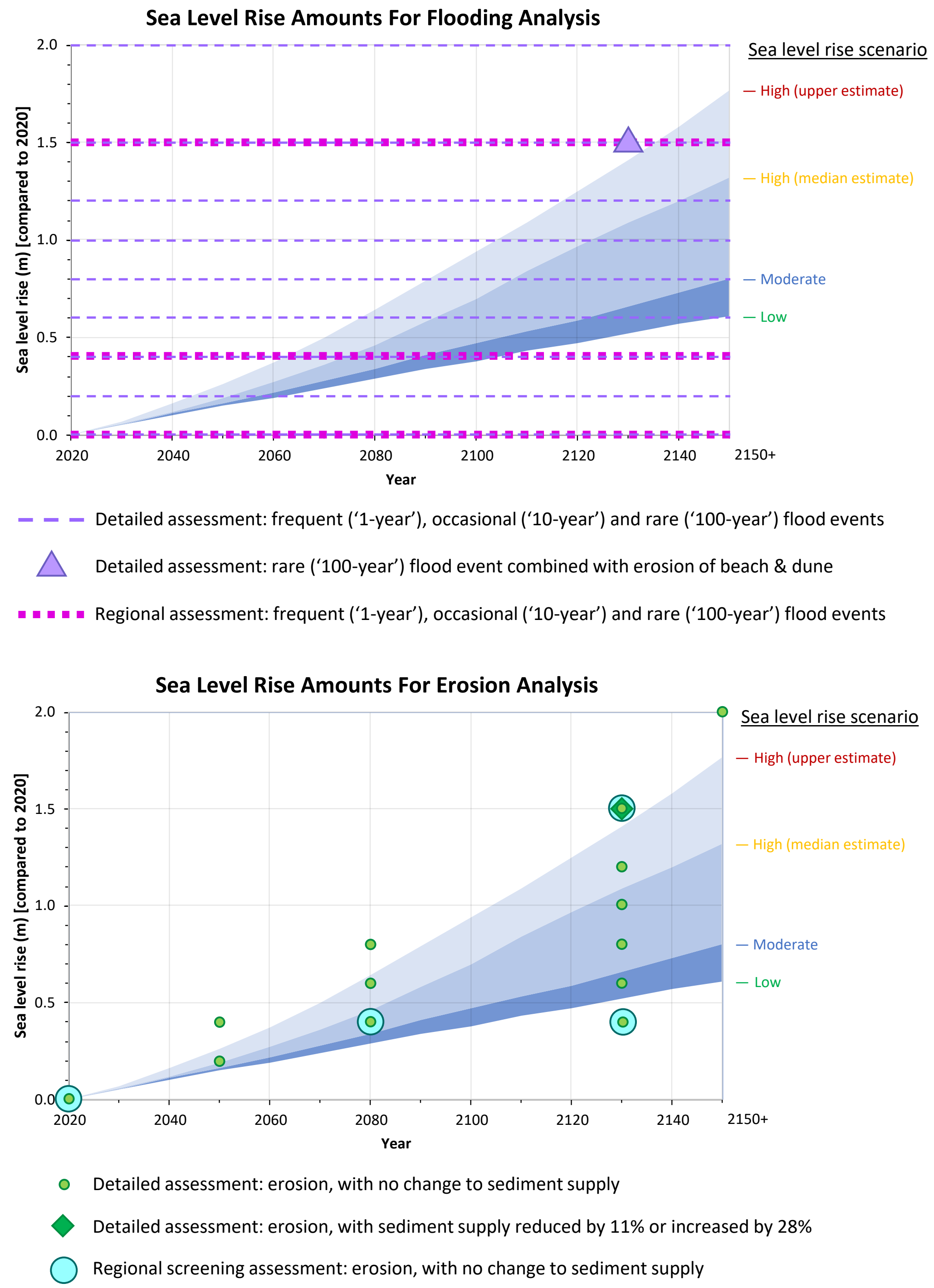


Figure 12.1: The many different sea level rise amounts and timeframes analysed for flooding (dashed horizontal lines in top chart) and erosion (dots on bottom chart), compared to the range of sea level projections recommended for adaptation planning in New Zealand. The national guidance projections from Figure 7.1 have been shifted so the 2021 CHA results are compared to a baseline at 2020 sea levels. Refer to Sections 13 & 14 for more details about the analysis.

13 How is coastal flooding analysed?

A range of factors can contribute to coastal flooding, as illustrated in Figure 13.1 and Table 13.1. This includes normal tides, storm surge from low pressure weather systems, wave effects, long-term sea level rise, and medium-term local sea level fluctuations (from climate cycles such as El Niño).

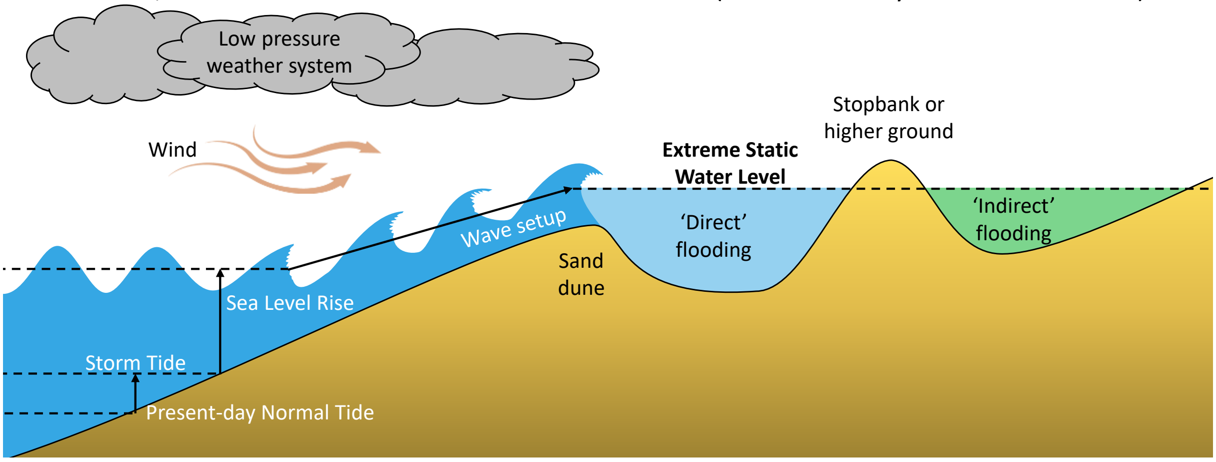


Figure 13.1: Conceptual model for calculating extreme static water levels for coastal flooding analysis.

The 2021 CHA uses a two-step approach to identify areas which could be prone to coastal flooding.

Step 1: Determine coastal flooding water level

The first step is to determine the 'extreme static water level' for each case being assessed:

- While the word 'extreme' might sound like it's unlikely to happen, in this assessment it is a technical term which simply means that the calculations used the highest water levels that have historically occurred. For example, the extreme water level calculated for a current-day occasional ('10-year') event will have occurred several times over the past 50 years.
- The 'static' water level includes the effect of 'wave setup', which is an increase in the average water level as waves approach the beach and break. It does not include 'wave run up' (the extra height waves reach temporarily as they run up the shore) because this usually reaches only about 10 to 30 m inland.
- Coastal flooding levels at a series of locations along the coastline are calculated for current-day (2020) sea levels, based on analysis of water level, wave and wind data. These measured levels already include the complex interactions between the various factors driving coastal flooding levels, such as tide, storm surge, river flows, rainfall, local wind effects and river bars. The coastal flooding levels for the various future scenarios are then calculated by adding the amount of sea level rise on top of the current-day level.

Step 2: Map the extent and depth of coastal flooding

The second step is to map how far inland the flooding from the sea might reach:

- For this a 'bathtub model' is used, which examines the ground topography survey data to identify land that is below the water level for each flood event and then maps the water depth at these locations. The results can be viewed using the online maps on the coastal hazard section of the Council website.
- As coastal flooding is a temporary event, the mapped areas won't be permanently flooded by the sea. However, with sea level rise the frequency and depth of flooding could increase, and rising groundwater could also lead to permanently wet ground or surface ponding (discussed in Section 15).
- The coastal flooding analysis looks only at areas close to the coast, where changes in future flood hazard is driven mostly by sea level rise. Further inland, flooding is driven more by rainfall and rivers, so there is more uncertainty in water levels. For this reason, an inland extent boundary is defined for the analysis and the area inland of this line is greyed-out in the coastal hazard maps. This doesn't mean inland areas won't be affected by sea level rise, just that this flooding is better modelled using different methods which incorporate rainfall and river effects. Council already has information about flood hazard for these areas which can be viewed on the floor level map or District Plan natural hazard maps.

Table 13.1: Key factors influencing coastal flooding.

Flood event severity / frequency	The severity of coastal flood events is described by their Average Recurrence Interval (ARI). Events with longer ARI (e.g., 100-year) result in deeper flooding, but are less frequent on average, than events with shorter ARI (e.g., 1-year). The 2021 CHA looks at three different levels of flood event severity / frequency: • Frequent events (1-year ARI) • Occasional events (10-year ARI) • Rare events (100-year ARI) While a rare ('100-year') flood event sounds like it only occurs once every 100 years, it can actually happen more often. It is an event of a size that will occur on average once every 100 years and is much larger and more significant than a frequent ('1-year') flood event. Because it is an average, several such events might occur within a few years, and then none for a long time afterwards. Another common description is that there is a 1% chance of an event that size or larger in any given year (this is known as an 'annual exceedance probability'). The reason a rare ('100-year') flood event is often used for hazard assessment is that it is likely that a flood event of this size will occur over long-term planning timeframes. Many of our buildings and infrastructure are expected to last well over 50 years and as long as 100 years or more. Looking at a rare ('100-year') flood event gives us a realistic understanding of the hazard that the assets could be exposed to at least once over their lifetime.
Sea level rise	A rise in the everyday sea level means that the water level during flood events can also rise higher. As the sea rises, the depth of flooding for a particular ARI will increase. For example, a rare ('100-year') flood in an area might increase from a depth of 50 cm at present to a depth of 1 m in future. Likewise, the frequency of a particular depth of flooding will increase. For example, flooding deeper than 50 cm in an area might increase in frequency (on average) from once in 100 years at present to once in 10 years in future.
Flood protection structures and indirect flooding	The 2021 CHA analysis is based on a survey of the current-day (2020) ground level, including existing flood protection structures such as stopbanks and bunds. While these structures can help to manage surface flooding, they are less effective at protecting against sea level rise because having permanent water on one side can cause groundwater to rise on the other. Drainage outlets might also allow back-flow during flood events. This means that land can be flooded from below even if the protection structure is higher than the flood level. Because there is no direct connection to the sea, this is called 'indirect flooding' and is shown in green on the hazard maps and Figure 13.1.
Impact of coastal erosion	Erosion can make it easier for flooding to reach further inland. For example, erosion or lowering of dunes might allow waves to run up and flood land further inland. For the 2021 CHA most of the coastal flooding maps assume no change to the current-day shoreline and land levels (i.e., no erosion). But for the section of open coast where the combined impacts of flooding and erosion are most relevant (Brooklands to Southshore) the influence of long-term erosion on the modelled extent and depth of flooding is also checked (shown as the purple triangle in Figure 12.1).

14 How is coastal erosion analysed?

There are various types of shorelines present along the Christchurch District coastline, including sandy beaches and gravel barriers, compacted banks and harder cliffs. So, the first step in the erosion analysis is to divide the shoreline up into 'coastal behaviour cells', which are segments of coastline with similar shoreline types and other factors (such as exposure to waves) which may influence the erosion hazard.

For each shoreline type a conceptual model is used to represent the main processes contributing to erosion, both now and in the future. The contribution of each of these components is then combined to determine the 'Area Susceptible to Coastal Erosion' (ASCE) for each coastal behaviour cell. An example conceptual model for a sand beach shoreline is presented in Figure 14.1. The models for other shorelines follow a similar form, but with some components being more or less relevant.

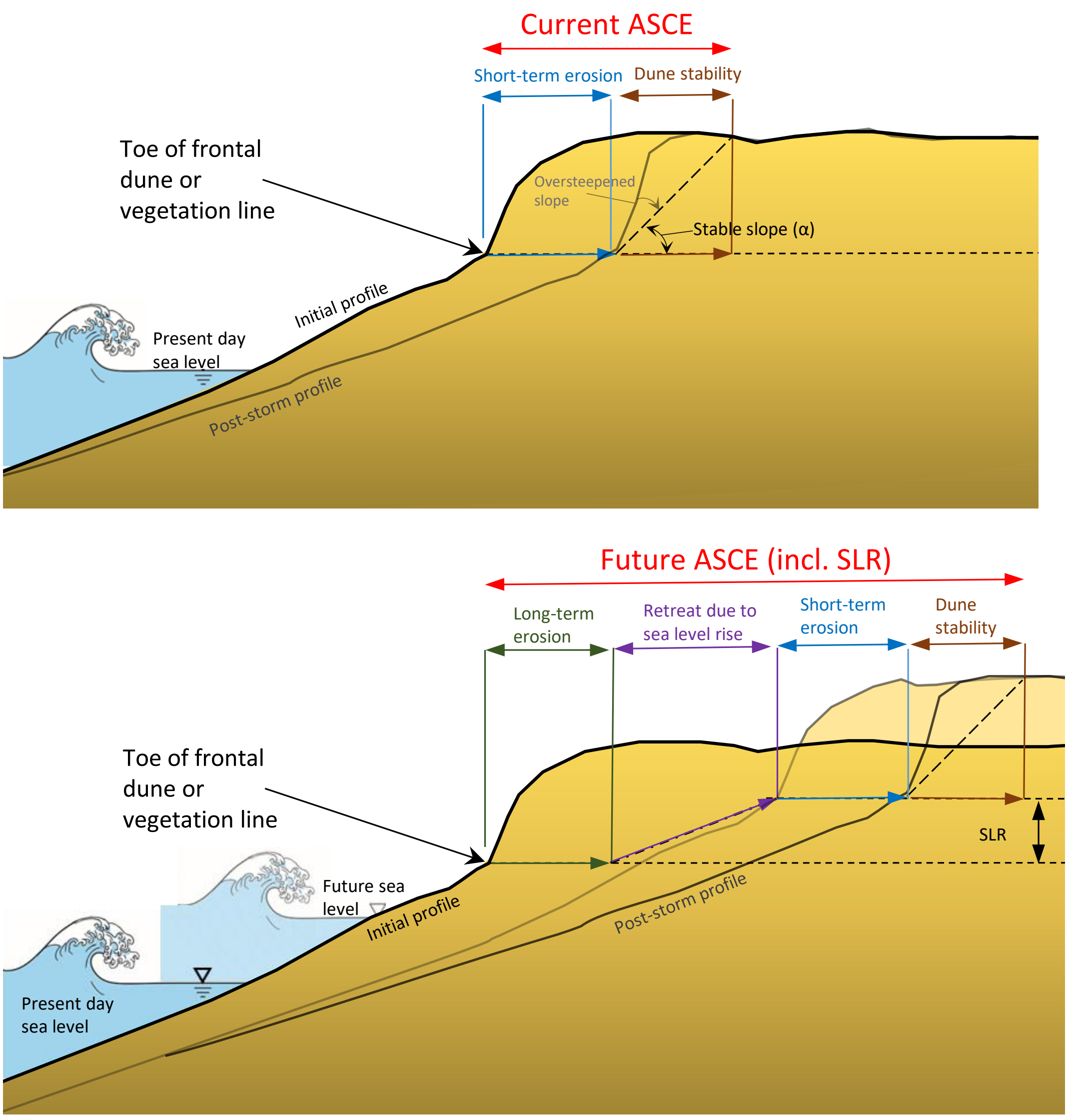


Figure 14.1: Conceptual model for Areas Susceptible to Coastal Erosion (ASCE) on a sand beach shoreline, showing the components contributing to erosion for the current-day (top figure) and in future (bottom figure).

The results of the coastal erosion analysis for the various scenarios can be viewed using the online maps on the coastal hazard section of the Council website. The maps show the modelled hazard as being the same for all points along a coastal behaviour cell, and then changing suddenly between cells. However, in reality erosion will usually show more of a natural gradual variation, and erosion in any one event might sometimes only affect smaller localised parts of the shoreline.

We can't know for sure what will happen in future, so the maps describe the hazard in terms of the probability (or chance) of land being affected by erosion. Whether or not erosion actually occurs at a particular location could be influenced by the four key factors described in Table 14.1.

Table 14.1: Key factors influencing coastal erosion.

Long-term coastal processes	Various long-term natural processes gradually add and remove sediment (such as sand) over time. One of these processes is sediment from the Waimakariri River, which moves along the coast helping to replenish beaches and reduce erosion. It is uncertain whether the sediment might increase or decrease in future, so for most of the erosion maps the analysis assumes sediment supply reaching beaches will stay the same. The coastal sand budget research recently commissioned by the Council suggests that while a decrease in sediment supply is possible, a slight increase is more likely. So for the section of open coast where sediment supply is most relevant (Brooklands to Southshore) the effect on erosion from a 28% increase or 11% decrease in sediment is also checked (shown as the green diamond in Figure 12.1).
Short-term erosion events	Events such as storms can temporarily remove sediment from the upper beach, often leaving a steep cut in the coast. This sediment generally returns back to the shore over time, rebuilding the coast. For these maps we assumed that the intensity and number of storms and short-term erosion effects remain the same as in the past, including the effect of any existing natural protection such as dunes and vegetation.
Sea level rise	Sea level rise can have various effects on erosion, depending on the type of shoreline at a particular location: • For beaches formed from loose silt, sand or gravel – material is eroded from the upper beach and deposited offshore, which can cause landward retreat of the shoreline. • For banks formed from compacted earth – sea level rise can increase the potential for wave-driven erosion, however as the shoreline retreats landward a shore platform or beach could develop which would dissipate wave energy and slow the rate of erosion. • For hard-rock cliffs without a shore platform – sea level has less influence and erosion is dominated by weathering effects.
Erosion protection structures	At many locations along the Christchurch District coastline there are existing coastal erosion protection structures in place. There is a wide variety in terms of the type, construction, effectiveness, and current condition of these structures. For the 2021 CHA, known structures are shown on the hazard map for context, but the area susceptible to coastal erosion is calculated as if the structure was not present (based on erosion rates of nearby similar shorelines without protection). This allows the long-term importance of these structures to be considered as part of adaptation planning. It acknowledges they may provide some degree of protection against erosion now and into the future but also shows what could be at risk if they were to fail. The exception to this approach is for three sections of coastline where the natural shoreline has been significantly modified with land reclamation and hard protection structures – from Ferrymead to Scarborough, Lyttelton Port and within the Akaroa township. Because these shoreline modifications are so extensive and have been in place for so long, it is not feasible to use past observations to estimate what the long-term erosion rate would be in the absence of structures. In these locations the erosion hazard is mapped as the land immediately behind the structure which could quickly become unstable if the structure were to fail. If the damaged structure was not promptly repaired then the extent of erosion in the longer-term could be greater than mapped.

15 How is rising groundwater analysed?

The national guidance notes that climate change and sea level rise can result in rising groundwater levels in coastal lowlands, and this should be considered as part of a coastal hazards assessment.

As illustrated in Figure 15.1, the 2021 CHA looks at two of the primary groundwater issues which may be worsened by sea level rise in low-lying coastal areas across Christchurch District:

- *Above-ground flooding* due to surface groundwater ponding, either temporary or permanent.
- *Wet ground* due to a rise in the groundwater table, which can impact buildings, infrastructure and how people can use the land. Groundwater rising to within 70 cm of the surface was adopted as an indicator for when these impacts might become more significant.

High groundwater tables also exist in other parts of Christchurch District further inland from the coast, but groundwater in these areas is not expected to be significantly impacted by sea level rise.

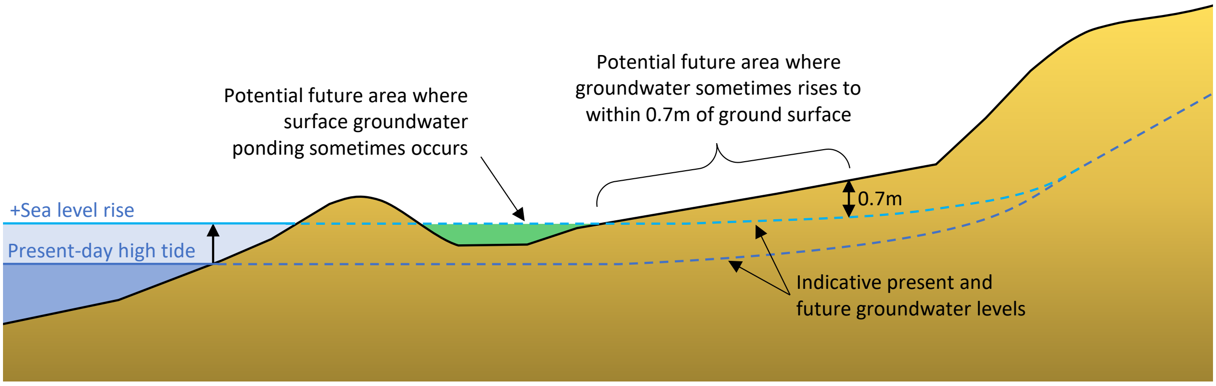


Figure 15.1: Conceptual model for identifying low-lying coastal areas which might be impacted by rising groundwater.

The rising groundwater maps for the 2021 CHA are based on groundwater models:

- Groundwater doesn't stay fixed at the same level all the time, it naturally fluctuates between days, weeks, seasons and years. Peak levels might only happen for a short time and then drop away again for a long time, so the impacts from these peaks might not be particularly significant or long-lasting. Therefore, rather than looking at the maximum groundwater level that might occur, the 2021 CHA follows standard scientific practice of using the 85th percentile groundwater level as a reference point for the groundwater models. Groundwater levels will be higher than this 15% of the time (on average), so it is a more useful indicator of when significant sustained groundwater issues could occur.
- For the Ōtautahi / Christchurch flat-land urban area a detailed groundwater model had already been developed for the Council by Aqualinc. This model was based on long-term monitoring of groundwater at hundreds of locations across the city. It looked at sea level rise amounts of 0 cm, 19 cm, 40 cm, 1.00 m, 1.88 m and 2.40 m. In the eastern half of the city, the model predicts that sea level rise could cause a rise in groundwater up to 1 - 3km inland from the coast and tidal reaches of the rivers.
- For Te Pātaka-o-Rākaihautū / Banks Peninsula there was no previous groundwater model, so the 2021 CHA uses a simple regional hazard screening analysis. Because there is little groundwater data in this area, the model is based only on the height of land above sea level. The 85th percentile groundwater is modelled at a level equivalent to the high tide level at the shoreline, remaining at this same level further inland. The analysis adopts similar sea level rise amounts as the Aqualinc model and assumes the groundwater level rises the same amount as the sea level. These modelling assumptions are reasonable for hazard screening of low-lying land near the coast but become less reliable further inland and at the base of hills.

The results of the rising groundwater analysis for various amounts of sea level rise can be viewed using the online maps on the coastal hazard section of the Council website.

There are some limitations with these groundwater models that are important to understand:

- The models are intended solely to help inform district-wide adaption planning. Their purpose is to identify general areas that are more likely to be impacted by rising groundwater caused by sea level rise. The models are not sufficiently detailed to give a precise prediction of the groundwater level at a particular location or to identify individual property risk.
- The national guidance also identifies various other groundwater-related issues which might worsen with climate change, such as saltwater entering groundwater, reduced soakage capacity for stormwater and increased potential for earthquake-induced liquefaction. The 2021 CHA doesn't look at these issues or other secondary effects, however it may help to identify locations where future efforts could be focussed to help inform adaption planning.

16 What areas could be affected by these hazards, now or in future?

On the following pages are coastal hazard summary sheets for each section of the Christchurch District coastline. These highlight the main areas which could be prone to coastal hazards now or in the future. The description of the shorter-term and longer-term hazard in these summary sheets is based on the scenarios shown in Table 16.1.

The summary sheets highlight key locations where coastal hazards could have more extensive impacts on existing coastal communities. Elsewhere along the coast there are many other locations exposed to coastal hazards – but these have less intensive existing development or a smaller affected area, so are not included in these high-level summary sheets.

For more detail about which areas could be affected by coastal hazards and how they change with different timeframes, amounts of sea level rise and storm events, you can view the full suite of results using the online map viewer in the coastal hazard section of the Council website.

Nobody can be certain what will happen in future, in the short-term or in the long-term. For example, we don't know exactly how severe the next storm will be, or how fast sea levels will rise over the coming years. Different areas could be affected by coastal hazards in different ways depending on how these uncertain factors play out. An important part of adaptation planning is managing this uncertainty. The project team recommends that Council consider the full suite of hazard analysis results, the range of uncertainties involved, and the broader community contexts to help prioritise and guide adaptation planning discussions with potentially affected communities.

Table 16.1: Scenarios for summary sheet descriptions.

	Level of detail	Short-term (ST)	Long-term (LT)
Coastal flooding and rising groundwater	Detailed hazard assessment & Regional hazard screening	20 cm sea level rise	1 m sea level rise
Coastal erosion	Detailed hazard assessment	Year 2050 20 cm sea level rise	Year 2130 1 m sea level rise
	Regional hazard screening	Year 2020 0 cm sea level rise	Year 2130 1.5 m sea level rise

NOTES:

1. The sea level rise values specified in the 2021 CHA are relative to 2020 baseline sea levels, which were about 10 cm higher than the 1986 – 2005 levels used for the national guidance (Figure 7.1). For example, a rise of 20 cm specified in the 2021 CHA is equivalent to a rise of 30 cm in the national guidance.
2. The erosion scenarios are different for detailed and regional analysis, because of the different amount of information available (see Section 11 and Figure 11.1). In locations where a detailed hazard assessment was undertaken there were results available for numerous scenarios, but where a regional analysis was undertaken this only included one low-end and one high-end scenario (to provide an initial hazard screening).

Environmental setting

This part of the Ōtautahi / Christchurch coast includes dunes bordering the open coast beach, the Waimakariri River and mouth to the north, the Pūharakekenui / Styx River which flows into Te Riu O Te Aika Kawa / Brooklands Lagoon, and the adjacent coastal plain.

The open coast is a sandy beach shoreline which faces east and is sheltered from southerly swell by Te Pātaka-o-Rākaihautū / Banks Peninsula. Over the past 6000 years the shoreline has built out seaward several kilometres with sediment (sand and silt) deposited from rivers and the sea. This seaward movement is called accretion, and has created a series of beach deposits, sand hills, swamps, estuaries and lagoons across the low-lying coastal plain. More recently, people have modified the land by draining it, clearing vegetation and flattening out dunes and hollows.

The dynamic nature of this environment is demonstrated by the formation of the Te Riu O Te Aika Kawa / Brooklands Lagoon. This happened when the Waimakariri River mouth shifted to its current position in a large storm in 1940, with the old river channel then filling in to form the lagoon.

Sediment discharged by the Waimakariri River is transported southwards and deposited along the shore, helping replace material removed by other coastal processes. Observations of the beach position since the 1940s show an overall long-term trend of accretion. However, several significant short-term erosion events have also been observed over this time, with single storms causing 10 to 15m width of beach erosion. The shoreline at the northern tip of the Brooklands Spit moves in response to the dynamic influence of the Waimakariri River.

The dune reaches heights ranging from about 5 to 10m above normal high tide level. Minor tracks and access roads have been cut through the dunes, but there has been no larger-scale modification such as dune flattening or seawalls.

How the hazard is assessed

Coastal flooding

The 2021 CHA looks at frequent (‘1-year’), occasional (‘10-year’) and rare (‘100-year’) events. The area and depth of flooding is mapped by comparing the flood level to the current land level (a ‘bathtub analysis’). The analysis combines the effect of:

- Storm tide levels, based on analysis of tide gauge data and a recent (2021) study of tide statistics.
- Set-up (temporary increase in water level along the coast due to wind and breaking waves), assessed using offshore wave data along the open coast.
- The effect of sea level rise on coastal flooding, assessed by adding the projected sea level rise amount on to the 2020 flood level.

Coastal erosion

For the open coast shoreline the 2021 CHA looks at the overall erosion hazard by combining the effect of:

- Long-term accretion and erosion trends, assessed using historic air photos (1941 to 2019) and beach profile data (1990 to 2020). The assessment also considers how these trends could change if more or less sediment was supplied from the Waimakariri River in future.
- Short-term erosion events, assessed using beach profile data (1990 to 2020).
- Erosion of dunes, assessed based on their height and how steeply they can stand before they become unstable.
- The effect of sea level rise on erosion, assessed based on a sandy beach response model. A rise in sea level causes material to be eroded from the upper beach and deposited offshore, which can cause landward retreat of the shoreline (or slow the rate of accretion).

Rising groundwater

For this area a detailed groundwater model had already been developed for the Council by Aqualinc:

- The 2020 groundwater model was based on data from water level monitoring in the Pūharakekenui / Styx River and 18 groundwater monitoring wells across Brooklands and Spencerville.
- The model looks at groundwater levels that will only sometimes be reached (about 15% of the time) and could last for days to months.
- In future, sea level rise is predicted to cause a rise in groundwater up to 1 - 3km inland from the coast and tidal reaches of the rivers.

Key findings

Short Term = now to 2050; 0 to 20cm sea level rise. *Long Term* = 2100 and beyond; 1 to 1.5m sea level rise.

Overall hazard context

This area can be affected by storm surge, which is a temporary rise in sea and lagoon water level due to a low-pressure weather system. The open coast is also exposed to open ocean swell and wind-generated waves which can further elevate water levels. The dunes are currently high enough to limit waves running up over the dune crest, protecting the coastal plain further inland from the higher dynamic water levels at the coast. However, much of the inland coastal plain is low-lying so is prone to coastal flooding from Te Riu O Te Aika Kawa / Brooklands Lagoon and Pūharakekenui / Styx river. With sea level rise this area could be prone to rising groundwater, which could sometimes rise close or up to the surface (especially near the river and lagoon).

This northern section of the open coast beach is more prone to erosion than the beach further south. This is because the northern section has lower accretion rates (much of the sediment from the Waimakariri River is transported further down the coast) and greater short-term erosion in storms (it is more exposed). This means that compared to the beach further south, this northern section is more sensitive to shoreline changes caused by sea level rise, but less sensitive to changes in sediment supply from the Waimakariri River.

① Ōtautahi / Christchurch Open coast beach – northern section

Short Term The dunes are high enough to protect the inland area from direct flooding by the open sea in a rare (‘100-year’) event. Up to 20 - 25m width of coastline is prone to short-term storm erosion, or up to 35m at the Waimakariri River mouth.

Long Term The current dune height would be enough to protect the inland area from direct flooding by the open sea in a rare (‘100-year’) event, however if there is significant erosion of dunes along Brooklands Spit then this could allow the sea to flood into the lagoon. While the shoreline currently has an overall long-term trend of accretion, how the shoreline position moves in future depends on the balance between supply of sediment from rivers, erosion in storms and shoreline changes caused by sea level rise. For most of this coast, if sea level rise exceeds about 40 – 60 cm over the next 100 years then a switch to a long-term trend of erosion is more likely than continued accretion. Up to 30 - 50m width of beach shoreline could be prone to erosion, or up to 100m at the Waimakariri River mouth.

② Brooklands

Short Term Most of this area (both east and west of the river) is low-lying land which is prone to coastal flooding from the lagoon in an occasional (‘10-year’) event. Groundwater could sometimes rise close or up to the surface on the lower terraces adjacent and to the west of the river, and close to the surface in some locations between the river and lagoon.

Long Term Almost all this area (both east and west of the river) could become prone to coastal flooding in a frequent (‘1-year’) event, with groundwater sometimes rising close or up to the surface.

③ Spencerville

Short Term Coastal flooding from the lagoon and river could reach 300 - 500m inland in an occasional (‘10-year’) event, increasing to cover most of the area (both east and west of the river) in a rare (‘100-year’) event. Groundwater could sometimes rise close to the surface in lowest-lying areas alongside the river.

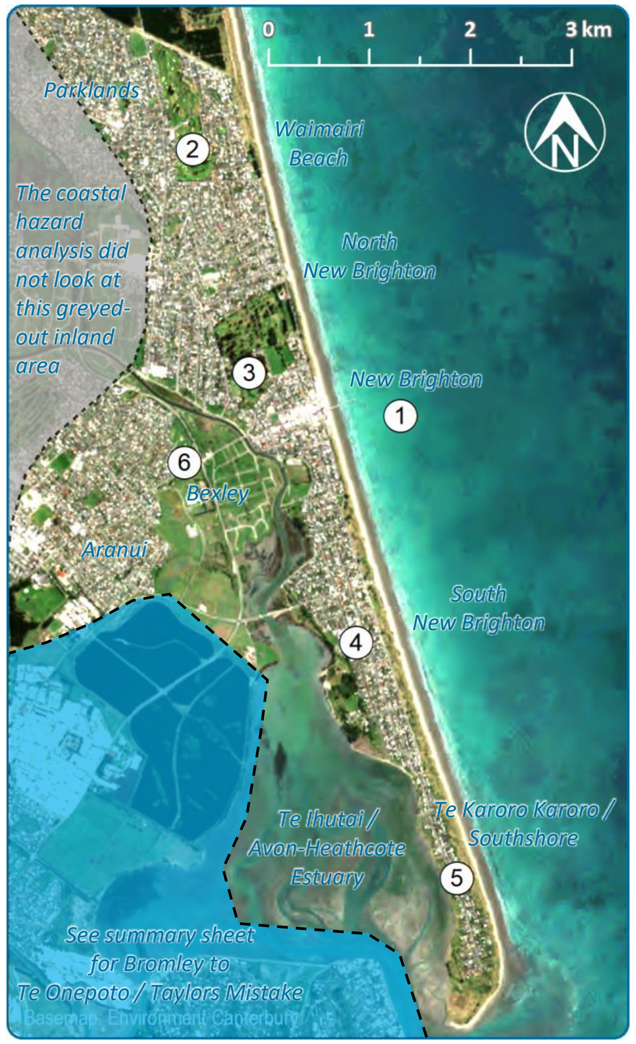
Long Term Almost all this area (both east and west of the river) could become prone to coastal flooding in a frequent (‘1-year’) event, with groundwater sometimes rising close to the surface.

④ Bottle Lake Forest

Short Term Lower-lying land within about 500m of the beach could experience flooding from groundwater in an occasional (‘10-year’) event.

Long Term Lower-lying hummocky land within about 500 - 1000m of the beach could become prone to coastal flooding from the river and lagoon in an occasional (‘10-year’) event. Groundwater could sometimes rise close or up to the surface at some locations within about 1.5km of the beach.

To see the hazard maps and explore a range of future scenarios, you can use the online map viewer on the Council website.



Environmental setting

This part of the Ōtautahi / Christchurch coast includes dunes bordering the open coast beach, the adjacent low-lying coastal plain, and the Ōtākaro / Avon River which flows into Te Ihutai / Avon-Heathcote Estuary to the south.

The open coast is a sandy beach shoreline which faces east and is sheltered from southerly swell by Te Pātaka-o-Rākaihautū / Banks Peninsula. Over the past 6000 years the shoreline has built out seaward several kilometres with sediment (sand and silt) deposited from rivers and the sea. This seaward movement is called accretion, and has created a series of beach deposits, sand hills, swamps, estuaries and lagoons across the coastal plain. More recently, people have modified the land by draining it, clearing vegetation and flattening out dunes and hollows.

Sediment discharged by the Waimakariri River is transported southwards and deposited along the shore, helping replace material removed by other coastal processes. Observations of the beach position since the 1940s show an overall long-term trend of accretion. However, several significant short-term erosion events have also been observed over this time, with single storms causing 10 to 15m width of beach erosion. The shoreline at the southern tip of Te Karoro Karoro / Southshore Spit moves in response to the dynamic influence of Te Ihutai / Avon-Heathcote Estuary.

The dune reaches heights ranging from about 6 to 8m above normal high tide level, except at North Beach and New Brighton where dunes were historically removed for beach-side development and are as low as 2m above high tide level. Flood and erosion protection structures (of varying type, effectiveness and condition) are present at some locations along the river, estuary and beach shorelines.

How the hazard is assessed

Coastal flooding

The 2021 CHA looks at frequent ('1-year'), occasional ('10-year') and rare ('100-year') events. The area and depth of flooding is mapped by comparing the flood level to the current land level (a 'bathtub analysis'). The analysis combines the effect of:

- Storm tide levels, based on analysis of tide gauge data and a recent (2021) study of tide statistics.
- Set-up (temporary increase in water level along the coast due to wind and breaking waves), assessed using offshore wave data along the open coast and computer software which models the waves generated across the estuary by wind.
- Flood protection structures may provide a degree of protection now and into the future. To show what could be at risk, the 2021 CHA identifies land behind these structures that could be flooded indirectly (e.g., by drainage back-flow) or if the structure was not present.
- The effect of sea level rise on coastal flooding, assessed by adding the projected sea level rise amount on to the 2020 flood level.

Coastal erosion

For the open coast and estuary shoreline the 2021 CHA looks at the overall erosion hazard by combining the effect of:

- Long-term accretion and erosion trends, assessed using historic air photos (1941 to 2019) and beach profile data (1978 to 2020). The assessment also considers how these trends could change if more or less sediment was supplied from the Waimakariri River in future.
- Short-term erosion events. For the open coast this is based on beach profile data (1978 to 2020). For the estuary shore this is based on storm response models, which consider storm tide levels, wave heights, and how the tidal flats can help to reduce erosion.
- Erosion of dunes and banks, assessed based on their height and how steeply they can stand before they become unstable.
- The effect of sea level rise on erosion, assessed based on a sandy beach response model. A rise in sea level causes material to be eroded from the upper beach and deposited offshore, which can cause landward retreat of the shoreline (or slow the rate of accretion).
- Coastal protection structures may provide a degree of protection against erosion now and into the future. To show what could be at risk, the 2021 CHA identifies land that could be prone to erosion if the structure was not present.

Rising groundwater

For this area a detailed groundwater model had already been developed for the Council by Aqualinc:

- The 2020 groundwater model was based on water level monitoring in the Ōtākaro / Avon River and 250 monitoring wells across this area.
- The model looks at groundwater levels that will only sometimes be reached (about 15% of the time) and could last for days to months.
- Sea level rise is predicted to cause a rise in groundwater up to 1 - 3km inland from the coast and tidal reaches of the rivers.

Key findings

Short Term = *now to 2050; 0 to 20cm sea level rise.* *Long Term* = *2100 and beyond; 1 to 1.5m sea level rise.*

Overall hazard context

This area can be affected by storm surge, which is a temporary rise in sea and estuary water level due to a low-pressure weather system. The open coast is also exposed to open ocean swell and wind-generated waves which can further elevate water levels. The dunes are currently high enough (where not removed) to limit waves running up over the dune crest, protecting the coastal plain further inland from the higher dynamic water levels at the coast. However, parts of the inland coastal plain are low-lying so are prone to coastal flooding from Te Ihutai / Avon-Heathcote Estuary and the Ōtākaro / Avon River, and to rising groundwater caused by sea level rise.

This southern section of the open coast beach is less prone to erosion than the beach further north. This is because the northern section has lower accretion rates (much of the sediment from the Waimakariri is transported further down the coast) and greater short-term erosion in storms (it is more exposed). This means that compared to the beach further north, this southern section is less sensitive to shoreline changes caused by sea level rise, but more sensitive to changes in sediment supply from the Waimakariri River.

① Ōtautahi / Christchurch open coast beach – southern section

Short Term The dunes are high enough to protect the inland area from direct flooding by the open sea in a rare ('100-year') event. Up to 10 - 20m width of beach is prone to short-term erosion caused by storms between periods of gradual accretion.

Long Term The current dune height would be enough to protect the inland area from direct flooding by the open sea in a rare ('100-year') event. However, storms may be able to break through the locations at North Beach and New Brighton with no (or very low) dunes, especially if there is significant long-term erosion. This could increase the area and depth of flooding inland. While the shoreline currently has an overall long-term trend of accretion, how the shoreline position moves in future depends on the balance between supply of sediment from rivers, erosion in storms and shoreline changes caused by sea level rise. For most of this beach, if sea level rise exceeds about 40 - 60cm over the next 100 years then a switch to a long-term trend of erosion is more likely than continued accretion. In the long term, up to 10 - 60m width of shoreline could be prone to erosion.

② Parklands, Waimairi Beach and North New Brighton

Short Term Not prone to coastal flooding in a rare ('100-year') event, as dunes provide protection from the sea and it is away from the river.

Long Term Coastal flooding through breaks in the dunes, and indirect flooding via groundwater or stormwater pipe backflow, could reach 150 - 300m inland from the dunes in a rare ('100-year') event, as well as affecting lower-lying parts of Parklands. Groundwater could sometimes rise close to the surface in lower-lying areas.

③ New Brighton & ④ South New Brighton

Short Term Coastal flooding from the estuary and river could reach 150 - 550m inland in an occasional ('10-year') event, increasing to 250 - 600m in a rare ('100-year') event. In lowest-lying areas within 150 - 250m of the river groundwater could sometimes rise close to the surface. Up to 15m width of estuary shoreline is prone to short-term storm erosion.

Long Term Coastal flooding from the estuary and river could reach 300 - 800m inland in a frequent ('1-year') event, increasing in depth and covering much of this area in a rare ('100-year') event. Groundwater could sometimes rise close or up to the surface over much of this area. Up to 35m width of estuary shoreline could be prone to erosion.

⑤ Southshore / Te Karoro Karoro

Short Term Coastal flooding from the estuary could reach 150 - 400m inland from the estuary in an occasional ('10-year') event, with a similar area but greater depth in a rare ('100-year') event. In lowest-lying areas groundwater could sometimes rise close to the surface. Up to 15m width of estuary shoreline is prone to short-term storm erosion.

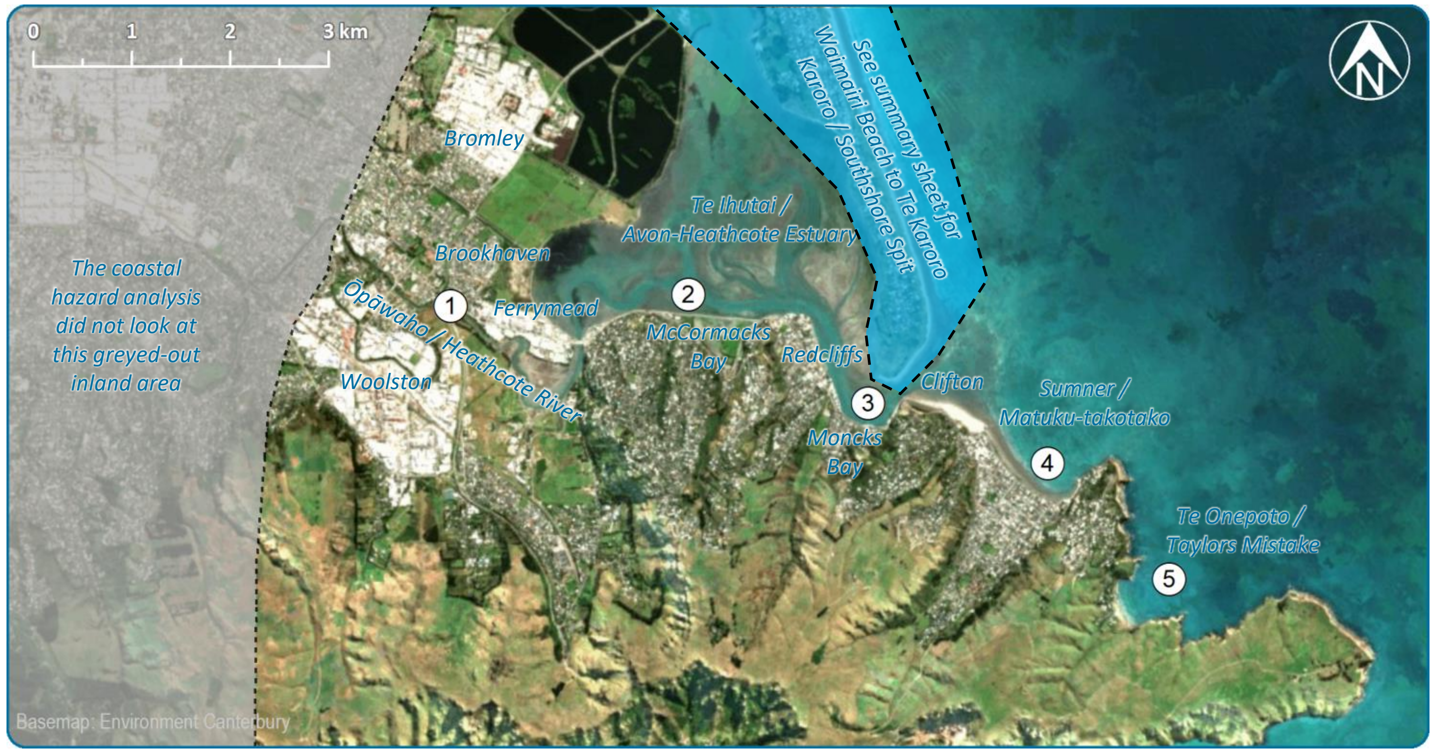
Long Term Most of the area could be prone to coastal flooding from the estuary in a frequent ('1-year') event. Groundwater could sometimes rise close or up to the surface over much of this area. Up to 15 - 40m width of estuary shoreline could be prone to erosion, depending on long-term trends along the spit (long-term erosion rates at the south end of the spit are particularly uncertain).

⑥ Bexley and Aranui

Short Term Coastal flooding from the river could reach 300 - 900m inland in an occasional ('10-year') event, with a similar area but greater depth in a rare ('100-year') event. In the lowest-lying areas groundwater could sometimes rise close to or up to the surface.

Long Term Coastal flooding from the river could reach 300 - 1000m inland in a frequent ('1-year') event, increasing to 600 - 1200m with greater depth in a rare ('100-year') event. In the lowest-lying areas groundwater could sometimes rise close or up to the surface.

To see the hazard maps and explore a range of future scenarios, you can use the online map viewer on the Council website.



Environmental setting

This area includes the Ōpāwaho / Heathcote River which flows into Te Ihutai / Avon-Heathcote Estuary, flat-land areas to the east, the southern estuary shoreline, and fine sand open coast beaches at Matuku-takotako / Sumner and Te Onepoto / Taylors Mistake. The sometimes-narrow coastal margin is bounded by the steep rock hills of Te Pātaka-o-Rākaihautū / Banks Peninsula, which also help to shelter the area from southerly storms. The low-lying coastal plain was historically swamp and grasslands, but people have drained the land and cleared vegetation. Most of the shoreline from Ferrymead to Sumner has been modified with coastal protection structures (of varying type, effectiveness and condition), with some areas of reclamation.

How the hazard is assessed

Coastal flooding

The 2021 CHA looks at frequent ('1-year'), occasional ('10-year') and rare ('100-year') events. The area and depth of flooding is mapped by comparing the flood level to the current land level (a 'bathtub analysis'). The analysis combines the effect of:

- Storm tide levels, based on analysis of tide gauge data and a recent (2021) study of tide statistics.
- Set-up (temporary increase in water level along the coast due to wind and breaking waves), assessed using offshore wave data along the open coast and computer software which models the waves generated across the estuary by wind.
- The effect of sea level rise on coastal flooding, assessed by adding the projected sea level rise amount on to the 2020 flood level.

Coastal erosion

For the open coast and estuary shoreline the 2021 CHA looks at the overall erosion hazard by combining the effect of:

- Long-term accretion and erosion trends, assessed using historic air photos (1941 to 2019) and beach profile data (1990 to 2020).
- Short-term erosion events. For the open coast this is based on beach profile data (1990 to 2020). For the estuary shore this is based on storm response models, which consider storm tide levels, wave heights, and how the tidal flats can help to reduce erosion.
- Erosion of dunes, banks and cliffs assessed based on their height and how steeply they can stand before they become unstable.
- The effect of sea level rise on erosion, assessed based on a sandy beach response model. A rise in sea level causes material to be eroded from the upper beach and deposited offshore, which can cause landward retreat of the shoreline (or slow the rate of accretion).
- Coastal protection structures may provide a degree of protection against erosion now and into the future. To show what could be at risk, the 2021 CHA identifies the land immediately behind the structure which could quickly become unstable if the structure were to fail.

Rising groundwater

For this area a detailed groundwater model had already been developed for the Council by Aqualinc:

- The 2020 groundwater model was based on water level monitoring in the Ōtākaro / Avon River and 160 monitoring wells across this area.
- The model looks at groundwater levels that will only sometimes be reached (about 15% of the time) and could last for days to months.
- In future, sea level rise is predicted to cause a rise in groundwater up to 1 - 3km inland from the coast and tidal reaches of the rivers.

Key findings

Short Term = now to 2050; 0 to 20cm sea level rise. *Long Term* = 2100 and beyond; 1 to 1.5m sea level rise.

Overall hazard context

This area can be affected by storm surge, which is a temporary rise in sea and estuary water level due to a low-pressure weather system. The open coast is also exposed to open ocean swell and wind-generated waves which can further elevate water levels. Parts of the inland coastal plain and the valleys at the base of the Port Hills are low-lying so are prone to coastal flooding, and to rising groundwater caused by sea level rise. The steep hills are close to the shoreline in some places – in these locations flooding could cover most of the flat land between the estuary/sea and the hills.

The beach at Clifton moves in response to the dynamic influence of the estuary, while the beach at Te Onepoto / Taylors Mistake currently shows a long-term trend of maintaining a stable position or slight erosion. For the coastal protection structures from Ferrymead to Sumner, about 10m width of shoreline could be prone to erosion if the structures were to fail (or more if the damaged structure was not promptly repaired). For cliff and steep rocky shorelines the width that could be prone to instability usually varies between 20 and 100m depending on slope angle and height.

① Bromley, Brookhaven, Ferrymead & Woolston

Short Term Much of the bare land between SH74 and the estuary is prone to coastal flooding from the estuary and river in a frequent ('1-year') event, and groundwater could sometimes rise close to the surface. Flooding in an occasional ('10-year') event could cover low-lying land (especially roads) in Brookhaven and Ferrymead, with a greater area and depth of flooding in a rare ('100-year') event. About 10m width of estuary shoreline is prone to short-term storm erosion.

Long Term Most of Bromley, Brookhaven and Ferrymead, and large parts of Woolston, could be prone to coastal flooding from the estuary and river in a frequent ('1-year') event – with a similar area of flooding but greater depth in a rare ('100-year') event. Groundwater could sometimes rise close or up to the surface. Up to 35m width of estuary shoreline could be prone to erosion.

② McCormacks Bay

Short Term Coastal flooding from the estuary could reach 30 - 100m inland in an occasional ('10-year') event, with a similar area of flooding but greater depth in a rare ('100-year') event.

Long Term Coastal flooding could reach 30 - 200m inland in a frequent ('1-year') event, with a similar area of flooding but greater depth in a rare ('100-year') event. Groundwater could sometimes rise close to the surface in the lowest-lying areas near the estuary.

③ Redcliffs & Moncks Bay

Short Term Coastal flooding from the estuary could reach 80 - 250m inland in an occasional ('10-year') event, with a similar area of flooding but greater depth in a rare ('100-year') event.

Long Term Coastal flooding could reach 90 - 280m inland in a frequent ('1-year') event, with a slightly larger area of flooding (by about 20 - 30m) and greater depth in a rare ('100-year') event. Groundwater could sometimes rise close to the surface.

④ Matuku-takotako / Sumner

Short Term While the Sumner seawall is more than 2 m above normal high tide level, flooding from the sea is able to pass around the ends of the wall at Marriner St and Heberden Ave. This means large areas (both near the beach and further up the valley) are prone to coastal flooding in an occasional ('10-year') event, with a larger area and depth of flooding in a rare ('100-year') event. About 5 - 10m width of beach shoreline is prone to short-term storm erosion.

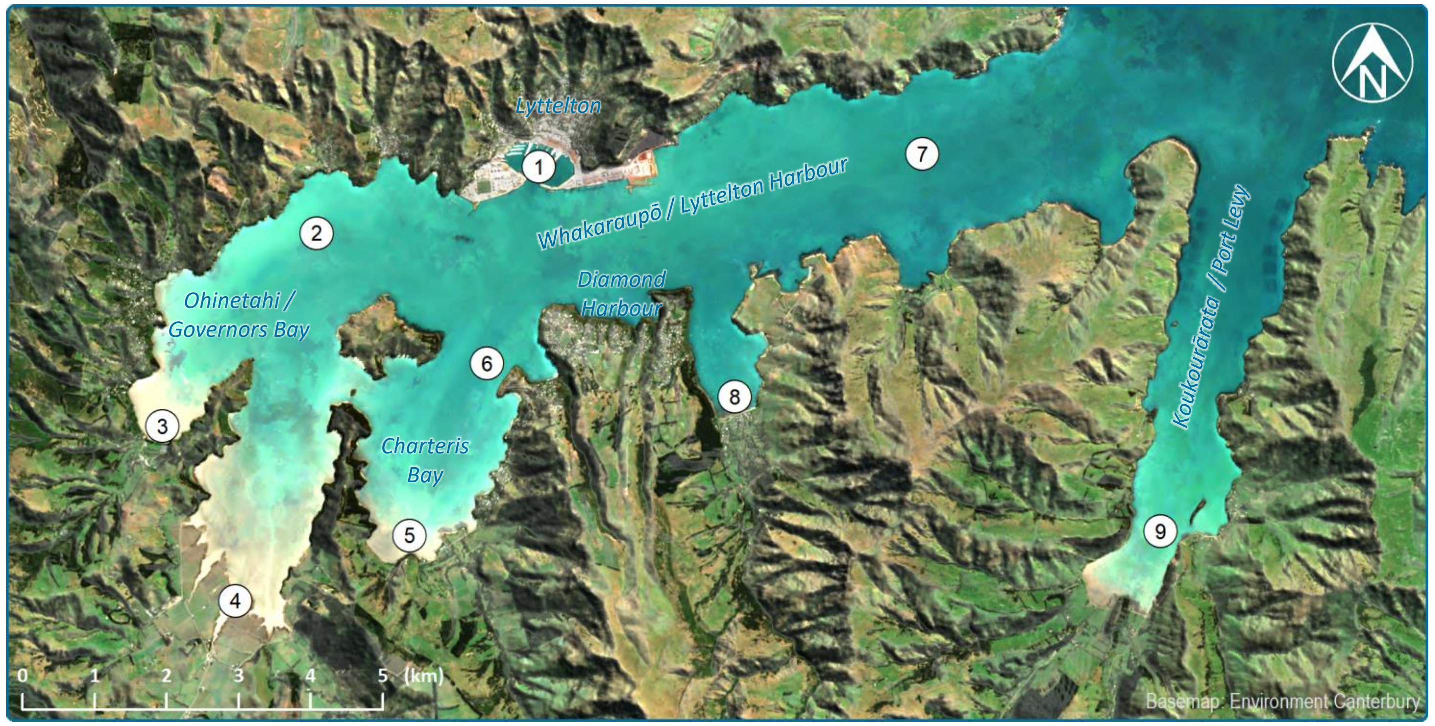
Long Term Large areas could be prone to flooding in a frequent ('1-year') event, increasing to most of the valley floor in a rare ('100-year') event. Groundwater could sometimes rise close to the surface in the lowest-lying areas near the beach. At Clifton Beach up to 40m width of shoreline could be prone to erosion.

⑤ Te Onepoto / Taylors Mistake

Short Term The lowest-lying land south of the carpark is prone to coastal flooding from the sea in a rare ('100-year') event, and groundwater could sometimes rise close to the surface. About 20m width of beach shoreline is prone to short-term storm erosion.

Long Term Much of the lower valley floor (the carpark area) could be prone to flooding in a rare ('100-year') event. Up to 70m width of beach shoreline could be prone to erosion.

To see the hazard maps and explore a range of future scenarios, you can use the online map viewer on the Council website.



Environmental setting

Whakaraupō / Lyttelton Harbour and Koukourārata / Port Levy are long rock-walled inlets on the northern side of Te Pātaka-o-Rākaihautū / Banks Peninsula, formed from a collapsed volcanic cone and valleys which have been eroded over millions of years and filled by the sea. At the head of the bays shallow tidal flats have gradually built up from silt washed down from the surrounding hills. Between headlands, small beaches have formed from sandy gravel or fine sand, surrounded by steep cliffs or banks. Elsewhere steep rocky slopes descend to a near-flat seabed with a maximum water depth of about 15m.

How the hazard is assessed

Coastal flooding

The 2021 CHA looks at frequent ('1-year'), occasional ('10-year') and rare ('100-year') events. The area and depth of flooding is mapped by comparing the flood level to the current land level (a 'bathtub analysis'). The analysis combines the effect of:

- Storm tide levels, based on a recent (2021) study of tide statistics.
- Set-up (temporary increase in water level along the coast due to wind and breaking waves), assessed using computer software to model the waves generated across the harbour by wind.
- The effect of sea level rise on coastal flooding, assessed by adding the projected sea level rise amount on to the 2020 flood level.

Coastal erosion

For beach and bank shorelines the 2021 CHA looks at the overall erosion hazard by combining the effect of:

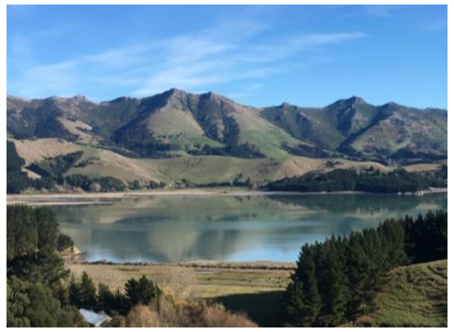
- Long-term erosion trends, assessed using historic air photos (1965 to 2019) and inspections to confirm evidence of ongoing erosion.
- Short-term erosion events, assessed based on storm tide levels and wave heights. Where tidal flats are present, they can reduce erosion.
- Erosion of dunes and banks, assessed based on their height and how steeply they can stand before they become unstable.
- The effect of sea level rise on erosion, assessed based on the shoreline type at each location.
- Coastal protection structures (of varying type, effectiveness and condition) are present at some locations. These may provide a degree of protection against erosion now and into the future. To show what could be at risk, the 2021 CHA identifies land that could be prone to erosion if the structure was not present.

For the steep rocky coastlines:

- Coastal processes could worsen broader hillside instability, so this is assessed based on slope angle and height, and cliff-collapse setback.
- The specific influence of sea level rise on hillside instability is not separated out from the other coastal processes, as this requires site-specific analysis and is unlikely to significantly change the overall erosion hazard results for steep rocky shorelines.

Rising groundwater

- The 2021 CHA uses ground height survey data to identify areas where the land is only slightly above high tide level. These areas are more likely to experience flooding or wet ground from shallow groundwater, which could worsen as sea levels rise.
- The model looks at groundwater levels that will only sometimes be reached (about 15% of the time) and could last for days to months.



Key findings

Short Term = now to 2050; 0 to 20cm sea level rise. *Long Term* = 2100 and beyond; 1 to 1.5m sea level rise.

Overall hazard context

This area can be affected by storm surge, which is a temporary rise in sea and harbour water level due to a low-pressure weather system. It can also be affected by open ocean swell entering through the harbour entrance, and wind-generated waves within the harbour, which can further elevate water levels at the shore. The present-day coastal flooding and groundwater hazard in this area mostly affects low-lying land at the heads of the bays. Most of this land is surrounded by hill slopes, so the area of flooding usually increases only slightly as water levels rise. Much of the remaining coast is cliff or steep rocky shore, so is less susceptible to flooding or rising groundwater.

The present-day and shorter-term coastal erosion hazard is dominated by short-term events (storm erosion on beaches or bank instability). Over longer timeframes, ongoing long-term erosion and sea level rise have a greater influence on the hazard.

① Lyttelton port

Short Term Not prone to flooding in a rare ('100-year') event.

Long Term Low-lying areas could be prone to flooding from the harbour in a frequent ('1-year') event. Groundwater could sometimes rise close to the surface. About 15m width of port edge could be prone to erosion if seawalls/revetments were to fail (or more if the damaged structure was not promptly repaired).

② Steep rocky coastline, banks and beaches from Motukauatiiti / Corsair Bay to Ohinetahi / Governors Bay

Short Term Up to 10 - 30m width of rocky, bank and beach shoreline is prone to erosion or instability.

Long Term Up to 20 - 35m width of rocky, bank and beach shoreline could be prone to erosion or instability.

③ Allandale & ④ Teddington & ⑤ Beaches from Te Wharau / Charteris Bay to Hays Bay

Short Term Low-lying land at the head of the bay is prone to coastal flooding from the harbour in an occasional ('10-year') event – within 200m of the shore for Allandale, 300 - 600m for Teddington, and 100m for Charteris Bay. Groundwater could sometimes rise close to the surface. About 10m width of beach and bank shoreline is prone to short-term storm erosion.

Long Term Flooding could affect a slightly larger area (by about 30m in Allandale and Charteris Bay, and 100m in Teddington), become deeper and happen more often, eventually becoming a frequent ('1-year') event and covering the main road in places. Groundwater could sometimes rise close or up to the surface. Up to 20 - 30m width of beach and bank shoreline could be prone to erosion.

⑥ Steep cliff and rocky coastline from Te Wharau / Charteris Bay to Purau Bay & ⑦ Outer harbour

Short & Long Term Up to 30 - 60m width of steep cliff and rocky coastline is currently prone to erosion or instability, depending on the slope angle and height. In many cases sea level rise is unlikely to significantly increase the area of land prone to erosion.

⑧ Head of Purau Bay

Short Term Low-lying land within 130m of the shore at the head of the bay is prone to coastal flooding from the harbour in an occasional ('10-year') event. Groundwater could sometimes rise close to the surface in lowest-lying areas. About 10m width of beach and bank shoreline is prone to short-term storm erosion.

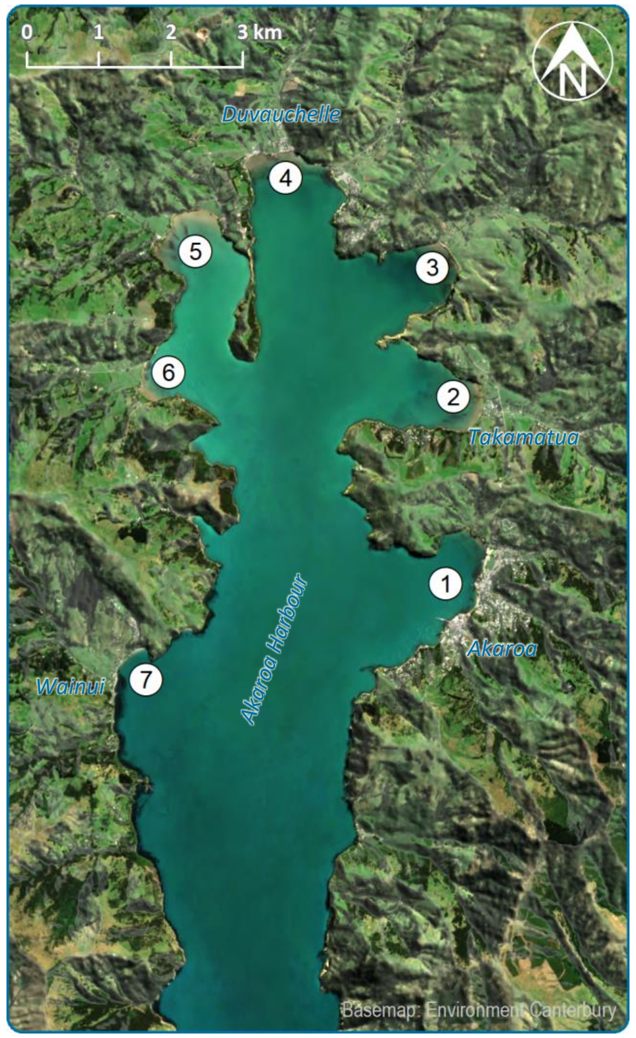
Long Term Flooding could affect a slightly larger area (by about 30 – 50m), become deeper and happen more often, eventually becoming a frequent ('1-year') event. Groundwater could sometimes rise close or up to the surface. Up to 25m width of beach and bank shoreline could be prone to erosion.

⑨ Head of Koukourārata / Port Levy and Puāri

Short Term Low-lying land within 160m of the shore at the head of bay and 30 - 60m of the shore at Puāri is prone to flooding in an occasional ('10 year') event. Groundwater could sometimes rise close to the surface. About 5 - 10m width of beach and bank shoreline is prone to short-term storm erosion.

Long Term Flooding could affect a slightly larger area (by about 30 – 80m), become deeper and happen more often, eventually becoming a frequent ('1-year') event. Groundwater could sometimes rise close or up to the surface. Up to 25m width of beach and bank shoreline could be prone to erosion.

To see the hazard maps and explore a range of future scenarios, you can use the online map viewer on the Council website.



Environmental setting

Akaroa Harbour is a long rock-walled inlet on the southern side of Te Pātaka-o-Rākaihautū / Banks Peninsula, formed from a collapsed volcanic cone and valleys which have been eroded over millions of years and filled by the sea. In the bays at the head of the harbour shallow tidal flats have gradually built up from silt washed down from the surrounding hills. In the middle section of the harbour the beaches are mostly sand and gravel. The southern part of the harbour has mostly cliff and steep rocky shorelines, with small gravel beaches surrounded by steep cliffs or banks.

Almost all the Akaroa Township shoreline from Glen Bay to Ōtāhuahua / Childrens Bay has been heavily modified with continuous concrete seawalls and rock revetments. At some locations elsewhere around the harbour there are more localised coastal protection structures (of varying type, effectiveness and condition).

How the hazard is assessed

Coastal flooding

The 2021 CHA looks at frequent ('1-year'), occasional ('10-year') and rare ('100-year') events. The area and depth of flooding is mapped by comparing the flood level to the current land level (a 'bathtub analysis'). The analysis combines the effect of:

- Storm tide levels based on a recent (2021) study of tide statistics, adjusted for different normal tide levels around the peninsula.
- Set-up (temporary increase in water level along the coast due to wind and breaking waves), assessed using computer software to model the waves generated across the harbour by wind.
- The effect of sea level rise on coastal flooding, assessed by adding the projected sea level rise amount on to the 2020 flood level.

Coastal erosion

For beach and bank shorelines the 2021 CHA looks at the overall erosion hazard by combining the effect of:

- Long-term erosion trends, assessed using historic air photos (1980 to 2019) and inspections to confirm evidence of ongoing erosion.
- Short-term erosion events, based on previous research and historic observations. Where tidal flats are present, they can reduce erosion.
- Erosion of banks, assessed based on their height and how steeply they can stand before they become unstable.
- The effect of sea level rise on erosion, assessed based on the shoreline type at each location.
- Coastal protection structures may provide a degree of protection against erosion now and into the future. To show what could be at risk, the 2021 CHA identifies land that could be prone to erosion if the structure was not present, except for the seawalls at Akaroa Township where the maps show the land immediately behind the structure which could quickly become unstable if the structure were to fail.

For steep rocky coastlines:

- Various coastal processes could worsen hillside instability, so this is assessed based on slope angle and height, and cliff-collapse setback.
- The specific influence of sea level rise on hillside instability is not separated out from the other coastal processes, as this requires site-specific analysis and is unlikely to significantly influence the overall erosion hazard results for steep rocky shorelines.

Rising groundwater

- The 2021 CHA uses ground height survey data to identify areas where the land is only slightly above high tide level. These areas are more likely to experience flooding or wet ground from shallow groundwater, which could worsen as sea levels rise.
- The model looks at groundwater levels that will only sometimes be reached (about 15% of the time) and could last for days to months.

Key findings

Short Term = now to 2050; 0 to 20cm sea level rise. *Long Term* = 2100 and beyond; 1 to 1.5m sea level rise.

Overall hazard context

This area can be affected by storm surge, which is a temporary rise in sea and harbour water level due to a low-pressure weather system. It can also be affected by swell entering through the harbour entrance, and wind-generated waves within the harbour, which can further elevate water levels. The coastal flooding and rising groundwater hazard is concentrated in low-lying land at the heads of bays. This land is surrounded by hill slopes, so the area of flooding usually increases only slightly as water levels rise. The rest of the harbour has cliff or steep rocky shores, so is less susceptible to flooding and rising groundwater.

Around the harbour, soil banks are more sensitive than beaches to short-term erosion in storms (because banks can't build up again), but the beaches are more sensitive to long-term erosion caused by sea level rise. For cliff and steep rocky shorelines, the width that could be prone to instability usually varies between 20 and 100m depending on slope angle and height.

① Akaroa Township

Short Term Low-lying land within 80m of the shore near the main wharf and 50 - 200m of shore near the sports field is prone to coastal flooding from the sea in an occasional ('10-year') event. Groundwater could sometimes rise close to the surface.

Long Term Flooding could affect a slightly larger area (by about 20 - 50m), become deeper and happen more often, eventually becoming a frequent ('1-year') event. Groundwater could sometimes rise close or up to the surface. About 5 - 10m width of shoreline could be prone to erosion if coastal protection structures were to fail (or more if the damaged structure was not promptly repaired).

② Takamatua & ③ Kākakaiau / Robinsons Bay

Short Term Low-lying land within 80 - 140m of shore is prone to coastal flooding from the sea in an occasional ('10-year') event. Groundwater could sometimes rise close to the surface. Up to 10 - 15m width of beach and bank shoreline is prone to short-term storm erosion.

Long Term Flooding could affect a slightly larger area (by about 20 - 40m), become deeper and happen more often, eventually becoming a frequent ('1-year') event. Groundwater could sometimes rise close or up to the surface. Up to 25 - 30m width of beach and bank shoreline could be prone to erosion.

④ Duvauchelle

Short Term Low-lying land within 80m of the shore is prone to coastal flooding from the sea in an occasional ('10-year') event. Groundwater could sometimes rise close to the surface. Up to 10m width of beach and bank shoreline is prone to short-term storm erosion.

Long Term Flooding could affect a slightly larger area (by about 20 - 60m), become deeper and happen more often, eventually becoming a frequent ('1-year') event. Groundwater could sometimes rise close or up to the surface. Up to 15 - 25m width of beach and bank shoreline could be prone to erosion.

⑤ Barrys Bay & ⑥ French Farm

Short Term Low-lying land within 50 - 150m of shore is prone to coastal flooding from the sea in an occasional ('10-year') event. Groundwater could sometimes rise close to the surface. Up to 5 - 15m width of beach and bank shoreline is prone to short-term storm erosion.

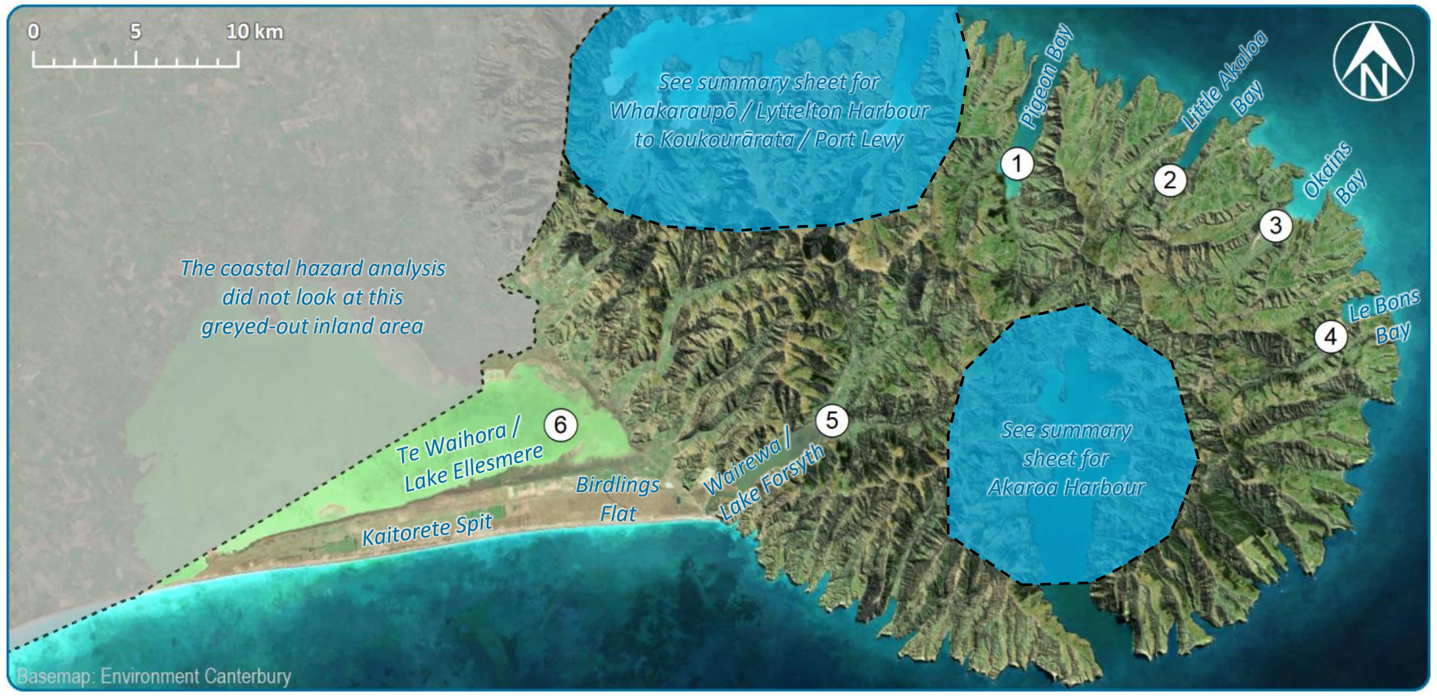
Long Term Flooding could affect a slightly larger area (by about 20 - 60m), become deeper and happen more often, eventually becoming a frequent ('1-year') event. Groundwater could sometimes rise close or up to the surface. Up to 20 - 35m width of beach and bank shoreline could be prone to erosion.

⑦ Wainui

Short Term Low-lying land near the stream within 100m of the shore is prone to coastal flooding from the sea in an occasional ('10-year') event. Groundwater could sometimes rise close to the surface. Up to 5 - 15m width of beach and bank shoreline is prone to short-term storm erosion.

Long Term Flooding could affect a slightly larger area (by about 50m), become deeper and happen more often, eventually becoming a frequent ('1-year') event. Groundwater could sometimes rise close or up to the surface. Up to 25m width of beach and bank shoreline could be prone to erosion.

To see the hazard maps and explore a range of future scenarios, you can use the online map viewer on the Council website.



Environmental setting

Te Pātaka-o-Rākaihautū / Banks Peninsula is formed from volcanic cones which eroded over millions of years to create cliffs and valleys which were filled by the sea to become bays. At the head of many bays shallow tidal flats have gradually built up from silt washed down from surrounding hills. Between headlands, small beaches have formed from sandy gravel or fine sand, surrounded by steep cliffs or banks. On the southern side of the peninsula Kaitorete Spit has formed from gravels moving northwards along the coast over thousands of years, creating lakes Wairewa / Forsyth and Te Waihora / Ellesmere. Both lakes are often manually opened to the sea to prevent flooding of surrounding low-lying land and allow movement of migrating fish.

How the hazard is assessed

In this area the 2021 CHA provides a ***regional hazard screening***, a broad-scale assessment to identify areas that could be prone to coastal hazards. This helps identify higher risk areas where more detailed assessment might be useful in future.

Coastal flooding

The 2021 CHA looks at frequent ('1-year'), occasional ('10-year') and rare ('100-year') events. The area and depth of flooding is mapped by comparing the flood level to the current land level (a 'bathtub analysis'). The analysis combines the effect of:

- Storm tide levels based on a recent (2021) study of tide statistics, adjusted for different normal tide levels around the peninsula. For the lakes this is based on statistical analysis looking at historic water levels (1994 to 2020).
- Set-up (temporary increase in water level along the coast due to wind and breaking waves), assessed using offshore wave data.
- The effect of sea level rise on coastal flooding, assessed at the coast by adding the projected sea level rise on to the 2020 flood level.

Coastal erosion

For beach and bank shorelines the 2021 CHA looks at the overall erosion hazard by combining the effect of:

- Long-term erosion trends, assessed using historic air photos (1980/1995 to 2019) and inspections to confirm evidence of ongoing erosion.
- Short-term erosion events, based on previous research and historic observations. Where tidal flats are present, they can reduce erosion.
- Erosion of dunes and banks, assessed based on their height and how steeply they can stand before they become unstable.
- The effect of sea level rise on erosion, assessed based on the shoreline type at each location.
- Coastal protection structures (of varying type, effectiveness and condition) are present at some locations. These may provide a degree of protection against erosion now and into the future. To show what could be at risk, the 2021 CHA identifies land that could be prone to erosion if the structure was not present.

For steep rocky coastlines:

- Various coastal processes could worsen hillside instability, so this is assessed based on slope angle and height, and cliff-collapse setback.
- The specific influence of sea level rise on hillside instability is not separated out from the other coastal processes, as this requires site-specific analysis and is unlikely to significantly influence the overall erosion hazard results for steep rocky shorelines.

Rising groundwater

- The 2021 CHA uses ground height survey data to identify areas where the land is only slightly above high tide level. These areas are more likely to experience flooding or wet ground from shallow groundwater, which could worsen as sea levels rise.
- The model looks at groundwater levels that will only sometimes be reached (about 15% of the time) and could last for days to months.

Key findings

Short Term = now to 2050; 0 to 20cm sea level rise. *Long Term* = 2100 and beyond; 1 to 1.5m sea level rise.

Overall hazard context

This area can be affected by storm surge, which is a temporary rise in sea and harbour water level due to a low-pressure weather system. It is also exposed to open ocean swell and wind-generated waves which can further elevate water levels along the coast, especially the south side of the peninsula and Kaitorete Spit which are exposed to severe southerly storms. The coastal flooding and rising groundwater hazard is concentrated in low-lying land at the heads of bays. Most of this land is surrounded by hill slopes, so the area of flooding usually increases only slightly as water levels rise. Much of the remaining coast is cliff, steep rocky shore or steep gravel beach, so is less susceptible to flooding and rising groundwater.

Most beaches around the peninsula currently show an overall long-term trend of maintaining a stable shoreline or accreting (building out towards the sea), but storm events can still cause short-term erosion. With sea level rise the current overall trend of accretion could slow or switch to erosion. For cliff and steep rocky shorelines, the width that could be prone to instability usually varies between 20 and 100m depending on slope angle and height.

① Pigeon Bay

Short Term Low-lying land close to the shore (within 90m at Holmes Bay, 190m alongside the stream at the head of Pigeon Bay, and 60m at the domain and boat ramp) is prone to coastal flooding from the sea in an occasional ('10-year') event. Up to 10m width of beach shoreline is prone to storm erosion.

Long Term Flooding could affect a slightly larger area (by about 10 - 50m), become deeper and happen more often, eventually becoming a frequent ('1-year') event. Groundwater in the lowest-lying areas could sometimes rise close to the surface. Up to 30m width of beach shoreline could be prone to erosion.

② Little Akaloa

Short Term Low-lying land within 100m of the shore (especially on the north side of the stream) is prone to coastal flooding from the sea in an occasional ('10-year') event. Up to 20m width of beach shoreline is prone to storm erosion.

Long Term Flooding could affect a slightly larger area (by about 10 - 30m), become deeper and happen more often, eventually becoming a frequent ('1-year') event. Groundwater in the lowest-lying areas could sometimes rise close to the surface. Up to 40m width of beach shoreline could be prone to erosion.

③ Okains Bay

Short Term Low-lying land in the floor of the valley up to 3km inland from the shore is prone to coastal flooding from the sea, estuary and stream in an occasional ('10-year') event. Groundwater in the lowest-lying areas could sometimes rise close to the surface. Up to 20m width of beach shoreline is prone to storm erosion.

Long Term Flooding could affect a similar area but become deeper and happen more often, eventually becoming a frequent ('1-year') event. Groundwater could sometimes rise close to or up to the surface. The overall trend of accretion could continue moving the beach seawards, but this may slow with sea level rise, and storms could still cause short-term erosion of up to 20m width of shoreline.

④ Le Bons Bay

Short Term Low-lying land in the floor of the valley up to 2.3km inland from the shore (especially towards the head of the valley) is prone to coastal flooding from the sea and stream in an occasional ('10-year') event. Groundwater in the lowest-lying areas could sometimes rise close to the surface. Up to 25m width of beach shoreline is prone to storm erosion.

Long Term Flooding could affect a similar area but become deeper and happen more often, eventually becoming a frequent ('1-year') event. Groundwater could sometimes rise close to or up to the surface. Up to 85m width of beach shoreline could be prone to erosion.

⑤ Wairewa / Lake Forsyth & ⑥ Te Waihora / Lake Ellesmere

Short Term Low-lying land up to 1.5km inland from the lake shore is prone to coastal flooding from the lakes in an occasional ('10-year') event, and groundwater could sometimes rise close to the surface. On the sea side of Kaitorete Spit, up to 30m width is prone to erosion.

Long Term Lake water levels are driven by rainfall and streams, and are controlled by manually opening them to the sea. If this continues then 1m sea level rise is unlikely to cause a significant increase in coastal flooding, but groundwater could sometimes rise close or up to the surface. The orientation of Kaitorete Spit could change, with up to 120m erosion in the west and 40m accretion in the east.

To see the hazard maps and explore a range of future scenarios, you can use the online map viewer on the Council website.

17 Applicability

This report has been prepared for the exclusive use of our client Christchurch City Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

The 2021 CHA was undertaken at a broad scale across the entire Christchurch District and is intended to approximately describe the magnitude and extent of current-day and future hazards across neighbourhood-sized areas. It is not intended to precisely describe hazards at individual-property scale, and in many cases there will be other sources of information which provide more relevant site-specific details (such as District Plan controls for Resource Consent and minimum floor levels for Building Consent). As recommended by the national guidance, the analysis considers a range of potential likelihoods, sea level rise scenarios and effects, to help understand the impact of uncertainty both due to data limitations and incomplete scientific knowledge about the processes.

Tonkin & Taylor Ltd

Assessment undertaken by:

Rebekah Haughey, Coastal Scientist

Patrick Knook, Senior Coastal Engineer

Mike Jacka, Technical Director

Technical review by:

Dr Tom Shand, Technical Director

Mark Pennington, Technical Director

Report authorised for Tonkin & Taylor Ltd by:

....

Peter Cochrane

Project Director

Document Control

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Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
September 2021	1	Report issue	RHAU, PPK, MEJ	TDS, MSP	PRC

MEJ
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