SOUTH DUNEDIN FUTURE

WORKSTREAM 3: RISK ASSESSMENT

RISK ASSESSMENT REPORT

6 March 2025

SOUTH DUNEDIN FUTURE
DUNEDIN CITY COUNCIL kaunihera a-rohe o Ōtepoti
Otago Regional Council
WSP
Beca
Tonkin+Taylor

SOUTH DUNEDIN FUTURE

RISK ASSESSMENT REPORT: REV 1 DRAFT

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Revision 0	24 September 2024	
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GLOSSARY

Component	Definitions
Baseline risk assessment	Refers to the assessment of the 'business as usual', 'status quo' or 'do nothing' option of risk to South Dunedin at present day*, mid-century (2060-2070) and late-century (2100-2110) climate scenarios. The baseline risk assessment assumes that risk is not mitigated, which is part of a separate piece of work. *see Present day entry in glossary.
Element at risk	People, places, assets within South Dunedin that are potentially vulnerable to hazards. People and communities are a fundamental consideration in this risk assessment. Risks to people are considered in relation to the elements identified below, either the physical risk of harm to people living, working, and using the buildings of South Dunedin, or through impacts arising from damage or loss to the other elements. Risk elements are adapted from those presented in the Risk Identification Report (Kia Ropine, 2023) as: (1) Buildings (2) Parks and sports fields (3) Ecological areas (4) Roads and associated infrastructure (5) Rail infrastructure (6) Water supply infrastructure (7) Wastewater infrastructure (8) Stormwater infrastructure (9) Contaminated land (10) Telecommunication infrastructure (11) Energy infrastructure Risks relating to mana whenua are acknowledged as an important component of the South Dunedin Future Programme. A separate piece of work is underway to define and incorporate these risks into the programme.
Exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC, 2021). E.g. Buildings located in an area where flooding occurs either now or in the future.
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. E.g. Pluvial flooding.
Impacts	The consequences of realized risks on natural and human systems. Where risks result from the interactions of hazards (including extreme weather/climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure (IPCC, 2021). E.g. The social, cultural, economic, and environmental consequences and cascading risks resulting from risks to buildings.

Component	Definitions
Key feature	Feature within an 'element at risk' that will be assessed as part of the South Dunedin risk assessment. E.g. Element at risk: Buildings; Key Feature: Residential buildings. Key features are elements or parts of an element that are required to inform the adaptation plan and will indicate relative value/consequence/criticality within an element. Some key features may have sub-categories within them. Key features are identified through: • Risk identification report. • Agreement with Workstream 4 – Adaptation Planning. This workstream will develop an adaptation plan for South Dunedin, which shall be informed by the findings of the risk assessment. • Stakeholder engagement.
Present day	Hazard data assessments used to inform this study were carried out using varied 'present day' timeframes for pluvial flood modelling, groundwater, and coastal hazard assessments (2024, 2023, and 2005 sea levels respectively).
Risk outside hazard extent	Physical risk classification for assets that are located outside the modelled hazard extent. The probability of exposure is expected to be lower than locations within modelled hazard extents.
Risk	The potential for adverse consequences for human or ecological systems (IPCC, 2021). Risk includes the following related concepts and terms: Physical risk: Risks that result from dynamic interactions between hazards with the exposure and vulnerability of the affected human or ecological system to the hazards (IPCC, 2021). In this project context, these are also called 'direct risks', and are those that may result from physical contact with the hazard. When realised, results in impacts. e.g. The risk to buildings due to flooding, and the risk to residents due to flooding of buildings. Risk rating: Physical risks are rated as high, medium, or low, or are classified as being *not exposed to the scenarios assessed*. These ratings are a product of exposure and vulnerability scores with this relationship shown in Table 3-11. High risks are typically those that are associated with exposure up to a 1% AEP event and an extreme vulnerability rating of a place or asset, or those associated with extreme exposure (i.e. to a 10% AEP event) and a high vulnerability rating of a place or asset. Medium risks are typically those that are associated with moderate exposure (i.e. up to a 1% AEP event) and a moderate or high vulnerability rating, or extreme exposure (i.e. to a 10% AEP event) with a low or moderate vulnerability rating, or those that are exposed to extremely low probability hazards (i.e. to a >1% AEP event) but are extremely vulnerable. Low risks are typically those that are associate with exposure to extremely low probability hazards (unless they are extremely vulnerable) or exposed to hazards but with low or very low vulnerability.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2021). E.g. Floor level, building materials, or other attributes that influence whether the building is adversely affected by flooding.

EXECUTIVE SUMMARY

RISK ASSESSMENT CONTEXT

South Dunedin is a vibrant and important part of Dunedin city which is home to more than 13,000 people, several hundred businesses, and an array of critical infrastructure. South Dunedin is also exposed to a range of natural hazards, many of which are expected to increase in frequency and severity with the effects of climate change.

The purpose of the South Dunedin Future (SDF) programme is to enable South Dunedin to prepare for, and adapt to, the impacts of climate change, while also realising the opportunities that come with change. This includes investigating, monitoring and predicting the impacts of a changing climate, including natural hazards; working with the community to assess the risks posed to the South Dunedin by these hazards; and exploring a range of options for mitigating these risks and realising associated opportunities.

Purpose of the risk assessment

Within the wider programme context, the purpose of *the South Dunedin Risk Assessment* is to "*assess the potential for elements at risk (people, places, assets) to be negatively affected by pluvial flooding, coastal inundation, coastal erosion, groundwater, landslide and liquefaction natural hazards in South Dunedin*"[1]. This is required to support two aims:

1. Outline the case for change - The baseline risk profile illustrates the consequences of a 'status quo' or 'do nothing' scenario.
2. Spatial adaptation planning - Spatial risk quantification helps identify locations *where* adaptation measures are more likely required to reduce risk. The changing risk profiles over time helps inform *when* adaptation may be required. The risk profile for South Dunedin provides a baseline against which the merits of potential risk mitigations (e.g. adaptation options) can be assessed.

Importantly, the risk assessment is intended to support suburb-level adaptation planning, including dialogue with affected stakeholders about the options for mitigating and adapting to identified risks. The risk assessment is not intended to provide a detailed property-level assessment of risk and using the report in this way could lead to false or misleading conclusions (e.g. high risk areas may include low risk properties, or the reverse).

The risk assessment seeks to identify, classify, and prioritise risks across South Dunedin by assessing exposure to hazards, vulnerability of elements, and assigning corresponding risk scores. The associated impacts of these risks, should they be realised, are also described. The risk assessment does not however seek to prioritise areas for adaptation, which could be influenced by a range factors, including planning, budget, asset management, and other considerations. These factors could be unique to each of the potential futures explored for South Dunedin and will be considered as part of a separate but related workstream on adaptation options.

Establishing a risk baseline for South Dunedin: This report documents the findings of the risk assessment, establishing a baseline risk profile for South Dunedin if the identified risks are not mitigated further. This is informed by natural-hazard, exposure and vulnerability information

[1] This purpose was adopted for the earlier Risk Identification Report, noting that the terminology 'things of value' is changed to 'elements at risk'. Terminology relating to hazards has changed from "rainfall, coastal, groundwater and seismic natural hazards" to "pluvial flooding, coastal inundation, coastal erosion, groundwater, landslide and liquefaction".

regarding “key features” within twelve “elements at risk” that have been used to characterise the physical places and assets of South Dunedin. The direct physical risks are assessed alongside the associated impacts to people, and the resultant social, economic, and environmental impacts.

Risks relating to mana whenua are acknowledged as an important component of the South Dunedin Future Programme. Risks relating to mana whenua are assessed in a separate piece of work by Aukaha, which is in the final stages of completion (expected early to mid-2025). A short summary of the approach and findings is included in this assessment and the ongoing collaboration with mana whenua will work to integrate the full results into subsequent stages of the programme thereafter.

While the risk assessment establishes a risk baseline for South Dunedin, the assessment uses the best available (but imperfect) information, and represents a snapshot in time. As the SDF programme progresses, new information will become available, which may enable refinements and updates to this baseline. Moreover, the purpose of the adaptation options workstream is to test potential adaptation options, exploring how effective and efficient each could be at mitigating risks, and assessing the extent to which they might improve the risk baseline in South Dunedin.

The assessment presents findings representative of the present-day timeframe (i.e. 2024[2]), medium term timeframe (2060-2070) and long-term timeframe (2100) using best available information. For the medium-term and long-term scenarios, two greenhouse gas emissions scenarios were used representing mid-range (SSP2-4.5) and high end (SSP5-8.5) projections.

The results of the spatial risk assessment have been compiled into a geospatial database which has been provided to DCC alongside this report (and will be made publicly available by DCC).

SUMMARY OF RISK ASSESSMENT FINDINGS

South Dunedin is subject to a range of natural hazards, including shallow groundwater, pluvial flooding, coastal inundation, coastal erosion, liquefaction and landslide. Figure E-1 shows that the majority of South Dunedin will be exposed to four hazards at late century under a high-end climate scenario. These hazards present a range of risks to the elements assessed in this report – such as buildings, utilities, and parks – which if realised could have a range of largely negative impacts. Element level risk is communicated based on the exposure of elements at risk to these hazards and their unique vulnerability to that hazard.

As with all risk assessment of the scale and complexity of South Dunedin, the assessed risk ratings presented in this assessment are subject to limitations regarding data availability and confidence. To minimise risk, the outputs of the risk assessment have been shared with local subject matter experts to test the results. It is noted that there is uncertainty regarding the coastal erosion risk assessment in some localised areas, particularly around engineered coastal erosion structures (e.g. sea walls). This is due to the risk assessment reliance on a regional coastal erosion hazard screening study and new hazard information is likely later in 2025. The complete list of limitations is identified in Section 2.5 and the relevant hazard and risk figures identify the localised limitation extents for coastal erosion.

The risk assessment findings can be summarised through a range of different lenses. This section presents an overview of risk, and summaries by element at risk, timeframe, and impact.

[2] Hazard data assessments used to inform this study were carried out using varied ‘present day’ baseline timeframes for pluvial flood modelling, groundwater, and coastal hazard assessments (2024, 2023, and 2005 sea levels respectively)

OVERVIEW OF RISK

A spatial summary of risk to South Dunedin is presented in Figure E-2. The figure shows the locations where buildings[3], roads and parks are at high or medium risk due to one or more hazards. These elements at risk extend across the entire land coverage of South Dunedin and the risk to other elements is provided in the main report (e.g. three waters, telecommunications and energy infrastructure. The maps illustrate that some parts of South Dunedin are currently at high or medium risk due to three hazards, which increases in extent over time, particularly in The Flat[4]. This map series is intended to provide a spatial overview of risk to South Dunedin, where detailed, element specific risks can be explored in the main report.

SUMMARY OF DIRECT PHYSICAL RISK FINDINGS BY ELEMENT AT RISK

Table E-1 summarises the percentage of all elements at risk that were rated high risk[5] across South Dunedin. Many of these risks correspond to complete loss of functionality. Table E-2 provides the same information for high or medium risk[6] where functionality is likely to be compromised or lost. Risks to each element at risk are summarised:

- Buildings: The buildings within South Dunedin generally face high and widespread risk from a range of existing hazards. Notably, 23% of buildings are rated as high risk to pluvial flooding at present day, and 84% of buildings are rated as high risk from groundwater by late-century. These risks, if realised, would negatively impact building performance and functionality, making some buildings uninhabitable. This would have a range of adverse impacts on residents, including to physical health and wellbeing and wider economic and societal impacts.
- Parks: The 56 parks in South Dunedin generally face medium risk from various existing hazards, with only 5% at high risk, mainly those with playgrounds vulnerable to waterlogging due to groundwater. Currently, 95% of parks are at medium risk from groundwater and 57% from pluvial flooding. By late century, medium risk due to coastal inundation and erosion will rise to 29% and 30%, respectively.
- Sports fields: Many of the sports fields within South Dunedin currently face medium risk due to a range of hazards. Groundwater and coastal erosion are the two main drivers of high risk to Sports fields. Groundwater impacts the sports fields due to chronic saturation of the playing turf and grass root zones which causes die-off, and coastal erosion causes a loss of sport field area. At present 17% of fields are at high risk due to groundwater, which

[3] Building risk has not been aggregated to SA1 areas in this map
[4] 'The Flat' is the low-lying flat area to the south of Dunedin's CBD which is built on a former tidal wetland.

[5] High risks are typically those that are associated with exposure up to a 1% AEP event and an extreme vulnerability rating of a place or asset, or those associated with extreme exposure (i.e. to a 10% AEP event) and a high vulnerability rating of a place or asset. Refer Section 3.4 for further information.

[6] Medium risks are typically those that are associated with moderate exposure (i.e. up to a 1% AEP event) and a moderate or high vulnerability rating, or extreme exposure (i.e. to a 10% AEP event) with a low or moderate vulnerability rating, or those that are exposed to extremely low probability hazards (i.e. to a >1% AEP event) but are extremely vulnerable. Refer Section 3.4 for further information.

increases at mid century to 46%. Coastal erosion[7] poses a high risk to parks at mid-(20%) and late century (29%) timeframes, and typically those fields that are at lower risk from groundwater are more impacted by coastal erosion. Consequentially 75% of all fields are at high risk by late century due to either coastal erosion or high groundwater. Loss of sports fields would have widespread impacts on the wide city, as South Dunedin provides for 45% of the Dunedin City playing field area.

- Roads: South Dunedin's 90 km of roads are increasingly at risk due to high groundwater levels and coastal erosion. Currently, 35% of roads are at high risk from groundwater, rising to 76% by 2100, while coastal erosion threatens 2% of roads, increasing to 9% by the end of the century. These conditions will lead to severe road damage, challenging maintenance efforts, and potential road collapses, impacting local and regional transport routes, especially the 3 km of critical routes.
- 3 Waters: Of the 71 km of stormwater pipes in South Dunedin, 22% are currently at high risk from groundwater, increasing to 28% by late century. Medium risk from pluvial flooding affects 28% of pipes today, rising to 38% by mid-century, while coastal inundation will impact 76% by late century. These risks, if realised, will erode the level of service of the stormwater system, resulting in increased flooding.

  Of the 79 km of wastewater pipes in South Dunedin, 50% are currently at high risk from groundwater, increasing to 58% by the end of the century. Pluvial flooding poses a high risk to 51% of pipes today, rising to 72% by century's end. Coastal inundation risks are lower except in the late-century high-range scenario, where 80% of the network is at high risk. These risks threaten the wastewater system's service, potentially causing widespread contamination and public health issues.

  In general, natural hazard risks to the water supply network in South Dunedin is low.
- Contaminated sites: The 236 contaminated sites in South Dunedin are primarily at risk from groundwater, with 7% currently at high risk, rising to 80% by late century. These high-risk sites have the potential for contaminants to be transported, resulting in spread of contamination. Additionally, coastal erosion poses a high risk to 1% of sites, which increases to 4% at late century with further potential for increased spread of contamination.
- Telecommunications: The telecommunications exchange site in South Dunedin is currently at medium risk from groundwater, increasing to high risk by late century. It also faces medium to high risk from coastal erosion by late century. Risks to the wider network haven't been fully assessed, although their dependency on road access and power supply is identified.
- Energy: Risk to energy assets in South Dunedin varies by type. The energy distribution network, with more assets than the transmission network, faces higher risks. Currently, 16% of overhead distribution lines are at high risk from groundwater, increasing to 84% by late century. Pluvial flooding and coastal inundation pose medium risk to most lines by late century (89% and 83%, respectively). The St Kilda Zone Substation and Transpower South Dunedin Substation both become high risk at mid-century[8].

[7] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.
[8] Risk to specific key features (e.g. Wastewater Treatment Plant, Pump stations, Substations, and other features) is shown in Section 5.

Table E-1 Percentage of elements at risk across South Dunedin rated at high risk[1,2]

	Coastal erosion			Pluvial flooding					Coastal inundation					Groundwater					Liquefaction	Landslide
	Present Day	2060	2100	Present Day	2070 SSP2-4.5	2070 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Buildings	1%	1%	2%	23%	31%	39%	37%	47%	0%	0%	0%	1%	83%	3%	9%	32%	49%	78%	0%	2%
Sports fields	0%	20%	29%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	17%	46%	47%	47%	48%	0%	0%
Parks	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	5%	5%	5%	5%	0%	0%
Roads	2%	5%	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	35%	63%	68%	70%	76%	0%	2%
Water supply	1%	1%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Wastewater	0%	0%	0%	51%	59%	67%	66%	72%	1%	1%	2%	2%	80%	50%	51%	52%	54%	58%	0%	0%
Stormwater	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	22%	25%	26%	26%	28%	0%	0%
Contaminated land	1%	1%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	31%	57%	64%	80%	0%	0%
Telecommunications	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	100%	100%	100%	0%	0%
Energy distribution	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	16%	70%	79%	81%	84%	0%	2%

Table E-2 Percentage of elements at risk across South Dunedin rated at high or medium risk[1,2]

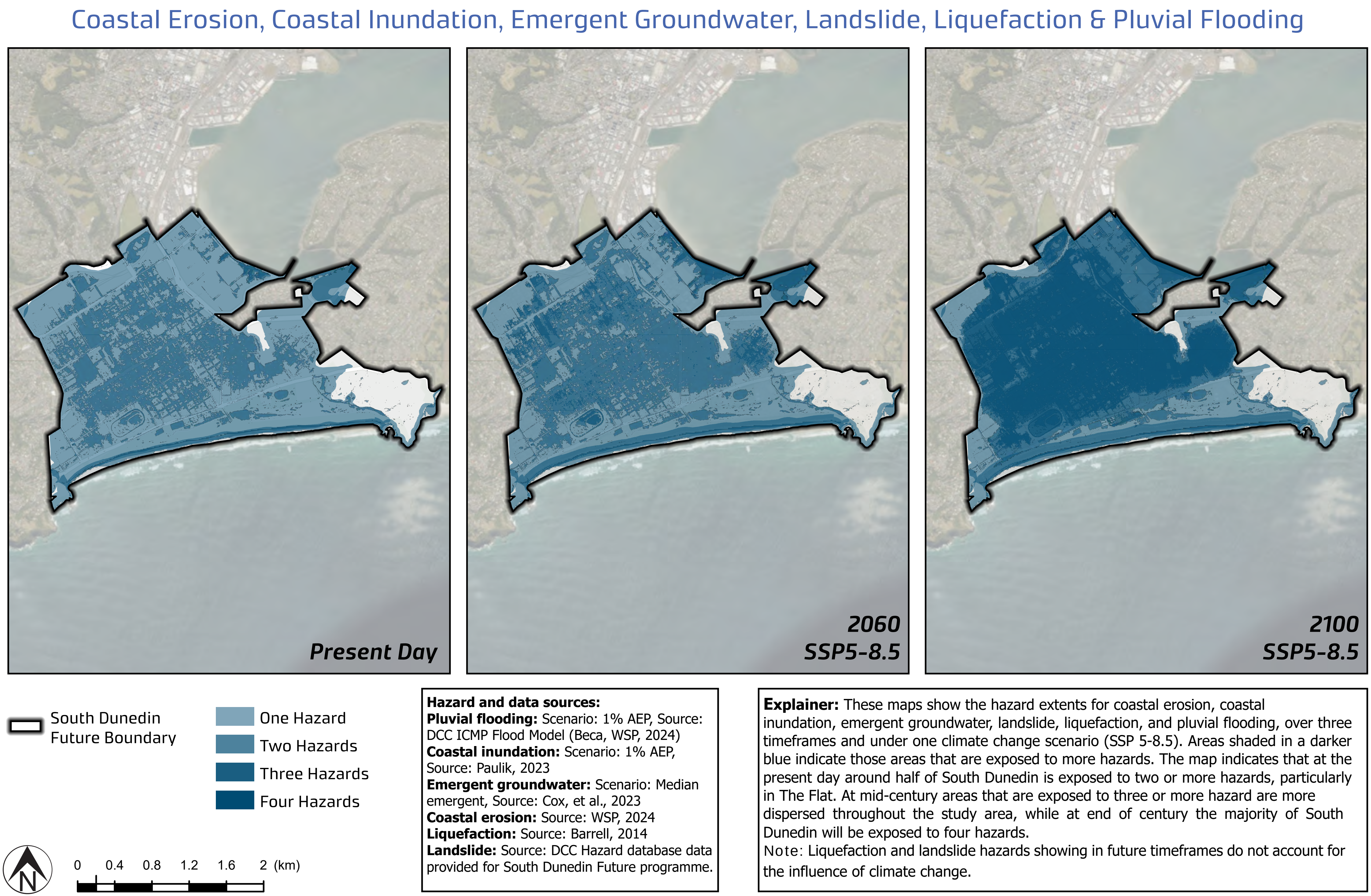
	Coastal erosion			Pluvial flooding					Coastal inundation					Groundwater					Liquefaction	Landslide
	Present Day	2060	2100	Present Day	2070 SSP2-4.5	2070 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Buildings	1%	1%	2%	49%	57%	63%	61%	69%	0%	0%	1%	81%	84%	32%	71%	78%	80%	84%	0%	2%
Sports fields	0%	20%	29%	76%	76%	77%	76%	77%	11%	13%	13%	69%	75%	100%	100%	100%	100%	100%	0%	13%
Parks	21%	25%	30%	57%	61%	63%	63%	66%	13%	14%	14%	16%	29%	100%	100%	100%	100%	100%	0%	7%
Roads	2%	5%	9%	43%	47%	52%	50%	55%	2%	4%	4%	5%	72%	100%	100%	100%	100%	100%	0%	2%
Water supply	1%	1%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%
Wastewater	2%	2%	3%	71%	76%	79%	78%	79%	1%	1%	2%	76%	80%	67%	69%	70%	72%	80%	66%	2%
Stormwater	1%	1%	2%	60%	68%	75%	75%	80%	1%	1%	2%	2%	86%	78%	84%	85%	87%	91%	0%	2%
Contaminated land	1%	1%	4%	65%	72%	80%	81%	87%	3%	5%	7%	7%	92%	19%	36%	60%	67%	80%	0%	3%
Telecommunications	0%	0%	0%	100%	100%	100%	100%	100%	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	0%	0%
Energy distribution	0%	0%	0%	85%	85%	88%	87%	89%	0%	0%	1%	78%	83%	100%	100%	100%	100%	100%	0%	2%

Risk score	Aggregated risk criteria
Very high	≥50% of affected assets within hazard zone have asset level risk rated to be medium or high.
High	21-50% of affected assets within hazard zone have asset level risk rated to be medium or high.
Moderate	11-20% of affected assets within hazard zone have asset level risk rated to be medium or high.
Low	1-10% of affected assets within hazard zone have asset level risk rated to be medium or high.
Not exposed to scenarios assessed	No assets are at risk (due to not being exposed), or <1% of affected assets within hazard zone have asset level risk rated to be medium or high.

[1] Percentages for each element show: buildings: % number of building footprints., sports fields, parks, contaminated land: % number of sites, roads, 3 waters assets and energy: % length of asset.

[2] Risk to specific key features (e.g. Wastewater Treatment Plant, Pump stations, Substations, and other features) is shown in Section 5.

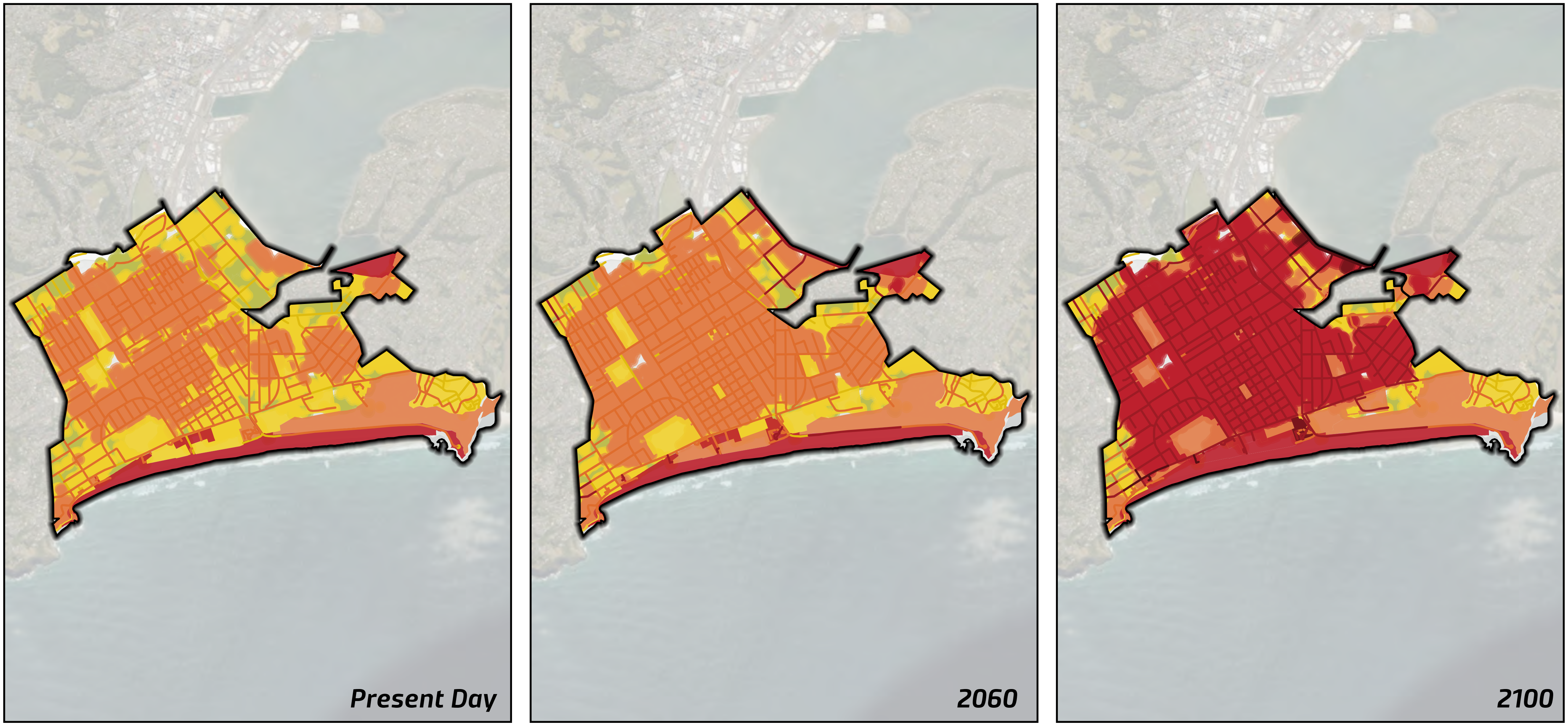
Figure E-1 Exposure of South Dunedin to hazards



Hazard and data sources:
Pluvial flooding: Scenario: 1% AEP, Source: DCC ICMP Flood Model (Beca, WSP, 2024)
Coastal inundation: Scenario: 1% AEP, Source: Paulik, 2023
Emergent groundwater: Scenario: Median emergent, Source: Cox, et al., 2023
Coastal erosion: Source: WSP, 2024
Liquefaction: Source: Barrell, 2014
Landslide: Source: DCC Hazard database data provided for South Dunedin Future programme.

Explainer: These maps show the hazard extents for coastal erosion, coastal inundation, emergent groundwater, landslide, liquefaction, and pluvial flooding, over three timeframes and under one climate change scenario (SSP 5-8.5). Areas shaded in a darker blue indicate those areas that are exposed to more hazards. The map indicates that at the present day around half of South Dunedin is exposed to two or more hazards, particularly in The Flat. At mid-century areas that are exposed to three or more hazard are more dispersed throughout the study area, while at end of century the majority of South Dunedin will be exposed to four hazards.
Note: Liquefaction and landslide hazards showing in future timeframes do not account for the influence of climate change.

Figure E-2 Hotspot summary of risks to South Dunedin: Buildings, parks and transport



Explainer: These hotspot maps show locations in South Dunedin where buildings, roads, and parks are at high or medium risk due to one or more hazards. They show that many areas of South Dunedin are already subject to such risk from two or more hazards, which increases to three or more hazards over time, particularly on The Flat. Note: Illustrating an 'overall picture' of risk can be problematic in a South Dunedin context, given the large number of hazards assessed (6) and elements at risk (11) (i.e. 66 different risk layers would be needed, resulting in a convoluted image). Using a subset of selected risks can help illustrate a clearer overview. For example, buildings, roads, and parks are three elements at risk that collectively represent 100% of the geographical area in South Dunedin, so they offer a useful overview and can act as a proxy for identifying risk hotpots. Disclaimer: These hotspot maps are intended to provide a visual overview of risk in South Dunedin but are not intended to be an accurate property-level assessment of risk, which requires much more detailed information and analysis. Using these hotspot maps in this way could lead to false or misleading conclusions about property-level risk (e.g. high risk areas may include many low risk properties, or the reverse).

SUMMARY OF DIRECT PHYSICAL RISK BY TIMEFRAME

Baseline risk profile

These summaries show that South Dunedin has high exposure to a wide range of natural hazards. This high exposure, when combined with the high vulnerability of some of the elements, results in a correspondingly high baseline risk profile (despite existing risk mitigations). The scale of this risk increases over time in response to increases in hazards due to climate change. By late century the majority of the places and assets of South Dunedin are at high or medium risk to at least three hazards. The location of these risks is concentrated within the flat areas of South Dunedin.

Present day risk

Present day risk across South Dunedin is driven largely by groundwater and pluvial flooding. Approximately 60% of buildings within South Dunedin are rated medium to high risk due to at least one of the assessed hazards but < 1% are at medium to high risk to 3 or more hazards. At the coastal edge, erosion poses a medium to high risk to parks. More broadly, the roads and wastewater assets have the highest proportion of assets rated at high risk (Table E-1). 35% of roads are subject to groundwater levels requiring unsustainable maintenance. 50% of wastewater pipes are leaky and past their useable life, resulting in reduced level of service.

Many of these risks are realised day-to-day across South Dunedin, such as shallow groundwater reducing the liveability of residential properties and negatively affecting the level of service of roads, stormwater, and wastewater. They are also occurring periodically, such as the heavy rainfall events in June 2015 and October 2024, which caused widespread pluvial flooding and damaged buildings and infrastructure across South Dunedin. There are a range of cascading risks and impacts that result from these direct physical risks, many of which are observable at present day. For example, flood damage negatively impacts housing quality, insurability, and market value, and costs of flood repairs can increase cost of living, affect mental health, and increase inequality.

Mid-century risk (2060)

Mid-century (2060) climate change projections indicate that 0.3 - 0.5 m of sea-level rise will occur under mid-range (SSP2-4.5) and high-range (SSP5-8.5) climate change scenarios. This will drive rising groundwater, coastal erosion, and increasing coastal inundation extents. A warmer climate will also drive more frequent and severe rainfall events. These changes are expected to increase exposure to natural hazards, particularly high groundwater, pluvial flooding, and coastal erosion. In both mid- and high-range emissions scenarios, many of the risks identified at present day increase incrementally at mid-century. Additionally, significant increases in medium to high risk arise in sports fields due to coastal erosion (increase from 0% at present day to 20% at mid-century), buildings due to groundwater (increase from 23% at present day to 71%-78% at mid-century) and contaminated land due to groundwater (19% at present day to 36%-60% at mid-century).

At mid-century, approximately 20% of South Dunedin buildings are rated medium or high risk arising from a single hazard, 60% from at least two hazards, but < 1% are at medium to high risk to 3 or more hazards. The chronic effects of high groundwater will cause increasingly widespread decline in building condition, stability, and healthiness, sports fields, and roads, as well as reduction in level of service of stormwater and wastewater systems. Increased spread of contaminants is likely as a result of these risks as well as due to the effect of high groundwater on large number of contaminated sites. Increased event-based impacts will result in damage to increased numbers of buildings. These increasing risks carry cascading impacts, including health risks, environmental damage, significant reduction in sports field area, decline in building performance and increased road maintenance.

Late century risk (2100)

Late century (2100) climate change projections indicate that 0.6 – 1.1 m of sea-level rise will occur under mid-range and high-range climate change scenarios. In combination with a warmer atmosphere, this will further drive rising groundwater, coastal erosion, increased coastal inundation extents and more frequent intense rainfall events. These changes are expected to further increase exposure to natural hazards, particularly high groundwater, pluvial flooding, and coastal erosion, as well as bringing a significant increase in exposure to coastal inundation. Correspondingly, these changes will increase the exposure of people, places and assets to the hazards. The largest increases in exposure are most likely from the groundwater and coastal inundation hazards.

In high-range emissions scenarios, the late-century risk arising from groundwater coastal inundation and pluvial flooding is widespread, with 69-84% of all buildings at high risk to these hazards (refer Table E-1). Additionally, most other elements at risk have a high percentage of assets that are at high or medium risk to these hazards.

At late-century, approximately 90% of South Dunedin buildings are rated at medium or high risk due to one or more hazards. In the case of groundwater, 80-84% of buildings will be subject to medium or high risk, where widespread emergent groundwater could cause instability to foundations, increase dampness and mould, and reduce level of service of stormwater, wastewater, and other utilities servicing these properties. As the number and severity of risks increase, the functionality or level of service of the places and assets within South Dunedin will decline. This will bring complex and interrelated cascading impacts on the social, economic, and environmental systems in South Dunedin. Many of these impacts will affect broader Dunedin City and wider region, given the interconnected nature of activities, services, and infrastructure in South Dunedin (e.g. the majority of Dunedin's wastewater is treated in South Dunedin).

SUMMARY OF IMPACTS, RISKS TO MANA WHENUA, AND CONCLUSIONS

Direct and cascading risk

The direct physical risks arising from natural hazards and climate change also have cascading risks (i.e. impact) for the community, economy, and environment in South Dunedin (and wider Dunedin city). A high-level summary of the relationships between impacts identified through this assessment and gathered through literature (Harrison, et al., 2022) are presented in Figure E-3. The diagram shows the impact pathways that extend across social, environmental, and economic domains from the physical risk. Some of these impacts are compounding, and many have further complex dynamics that are not fully evaluated and quantified within the scope of this report.

Mana whenua risk assessment

A mana whenua risk assessment has been undertaken for the South Dunedin Future programme, which has identified and rated risks through a Kāi Tahu lens. Based on an analysis of cultural values, it takes a broad approach to risk. As well as risks to specific places and features important for the cultural associations to mana whenua, it considers risks to Kāi Tahu perspectives and values relating to wider environmental, social and economic factors in South Dunedin. This mahi was facilitated by Aukaha with guidance and validation from a panel of Kāi Tahu mana whenua representatives.

The mana whenua risk assessment has shown that, from a Kāi Tahu perspective, there is substantial risk resulting from a 'keep doing what we are doing' scenario, where there are no additional interventions to address the issues facing South Dunedin. Risk to the key Te Taki Haruru values is generally significant, ranging from high (mana, whakapapa, tapu & noa) to extreme (mauri) levels of risk. These results outline the case for change in response to the modelled natural hazards and climate risks.

A more detailed summary of the mana whenua risk assessment inputs, methodology, and findings is included in Annex D of this report. The companion workstream on adaptation options also utilised the four key Te Taki Haruru values as a framework to integrate a mana whenua perspective into the assessment criteria, aligning the analysis with that of the risk assessment. This enabled continuity for assessing how well each proposed option mitigates the risks identified in this report.

Conclusion

Analysis in the risk assessment shows that South Dunedin has high exposure to natural hazards and a correspondingly high baseline risk profile. Anticipated changes in climate and associated increases in exposure to natural hazards are expected to materially increase risk across all elements assessed in the risk assessment. As this exposure and direct physical risk increases, the adverse consequences for South Dunedin's buildings, infrastructure, and communities also increase to a point where much of the key infrastructure, functions, and services experience declining functionality, loss of service, or complete failure. These risks will have significant adverse effects on the South Dunedin community, Dunedin city, and the economy unless appropriate risk mitigation is employed.

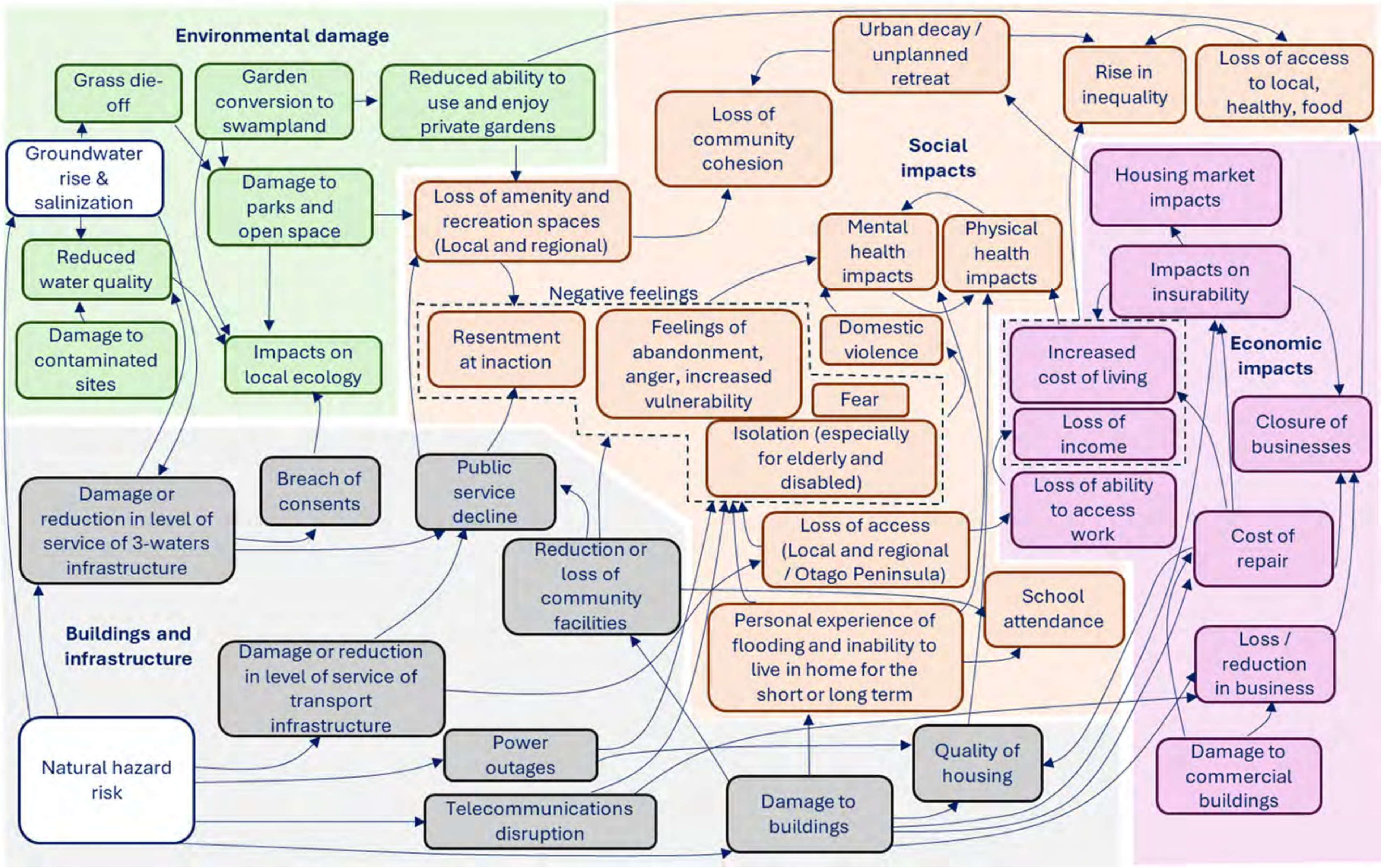


Figure E-3. Overview of cascading risk arising from natural hazard and climate change risk to South Dunedin (colour scheme: grey = buildings and infrastructure damage and impacts, orange = social impacts, purple = economic impacts, green=environmental damage)

1 INTRODUCTION

South Dunedin is exposed to a range of hazards, many of which are expected to increase with the effects of climate change. South Dunedin is also home to more than 13,000 people and it is a vibrant and important part of Dunedin City.

The South Dunedin Future (SDF) programme is underway to enable South Dunedin to prepare for, and adapt to, the impacts of climate change, while also realising the opportunities that come with change. The strategic objectives are presented in Section 1.1. The programme includes the suburbs of South Dunedin, St Kilda North and St Kilda South, parts of St Clair, Caversham, Tainui, and Musselburgh, shown in Figure 1.1[9].

South Dunedin comprises a large area of flat land close to the city centre. In particular, it is centred around the low-lying flat area to the south of Dunedin's CBD which is built on a former tidal wetland, termed 'The Flat'[10]. The physical characteristics of South Dunedin include its flat, low-lying topography, poorly consolidated underlying sediments, proximity to the ocean and harbour, and shallow groundwater. Land-use is primarily residential, commercial and industrial. The area contains key transport networks and a range of important city services and amenities. As such, it plays a key role in the functioning of the wider city, and it will feature prominently in considerations of Dunedin's future growth and development.

This document presents the findings of the South Dunedin Climate Change and Natural Hazard Risk Assessment at the present day, mid-term (2060-2070) and long term (2100) timeframes under mid-end climate change scenarios (SSP2-4.5) and high-end climate change scenarios (SSP5-8.5).

A parallel Mana Whenua Risk Assessment within the SDF programme has explored their risks to people, places, and assets due to climate change. This parallel assessment provides a key contribution to the overall programme to allow for adaptation responses to be made in partnership with mana whenua. This is important because mana whenua are generally considered more likely to be disproportionately affected by climate change (Ministry for the Environment, 2020). The summary findings from the Mana Whenua Risk Assessment are noted in various sections of this report and are included in Appendix D. Further work will be undertaken to integrate findings from the Mana Whenua Risk Assessment into adaptation planning for South Dunedin. .

This risk assessment focused only on South Dunedin; discussion of regional risks is covered in the Otago Regional Climate Change Risk Assessment (Tonkin and Taylor, 2021), and discussion of national scale and international risks is covered in the National Climate Change Risk Assessment (Ministry for the Environment, 2020).

[9] Note that the time of writing this report, the South Dunedin Future adaptation options are being developed for South Dunedin Programme area excluding the St Clair to St Kilda Coastal area.
[10] https://www.orc.govt.nz/get-involved/projects-in-your-area/south-dunedin/a-reclaimed-history/

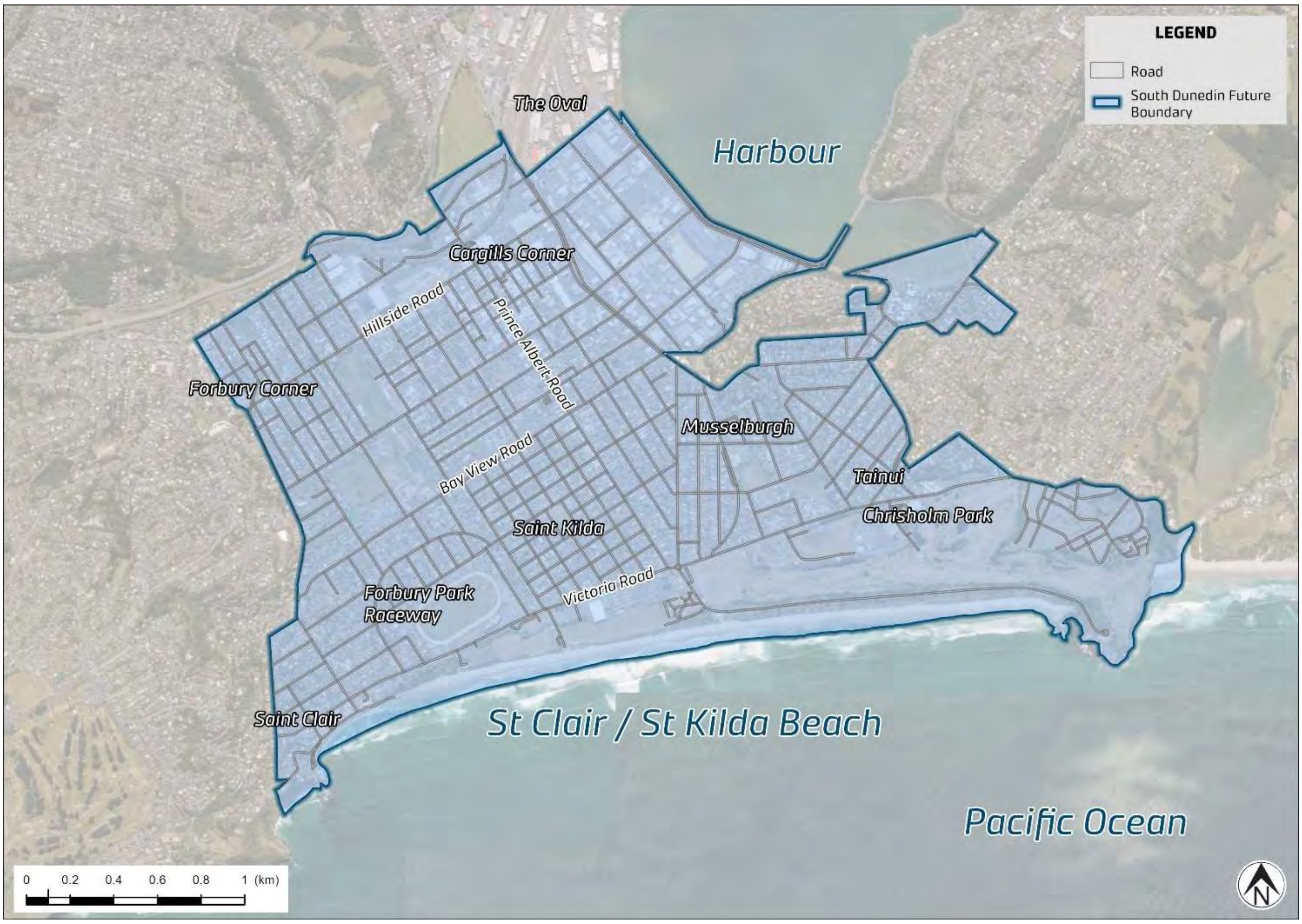


Figure 1.1. South Dunedin Future programme focus area

1.1 STRATEGIC OBJECTIVES OF THE SOUTH DUNEDIN FUTURE PROGRAMME

The Strategic Operational Objectives of the South Dunedin Future (SDF) Programme are displayed in (Figure 1.2) and include the Vision, Purpose and specific objectives related to outcomes that are sought for South Dunedin (programme focus area shown in Figure 1.1). The SDF Strategic Objectives guide the risk assessment.

Strategic Objectives					
	Vision: A safer and better South Dunedin, where sustainable urban regeneration leads to improved community resilience and wellbeing.				
	Purpose: To enable South Dunedin to prepare for, and adapt to, the impacts of climate change, while also realising the opportunities that come with change.				
	Just transition Respond to climate change in ways that empower communities and promote fairness and equity.	**Community safety** Promote community safety in South Dunedin by reducing flood and other risks, despite increasing natural hazards	**Environmental & cultural restoration** Restore and regenerate natural environments, renew urban spaces, and re-energise cultural connections to place.	**Social & economic resilience** Strengthen communities and businesses so they are well-prepared for floods and other hazards, better able to cope and recover.	**Sustainable urban development** Urban development accounts for the changing environment, providing better spaces for people, water and wildlife.

Figure 1.2. SDF Strategic Objectives

2 REPORT CONTEXT

This section of the report provides a summary of important contextual information for the risk assessment. It includes identification of the assessment purpose, aims and output requirements. It also identifies who the report is intended for (i.e. the audience), and some principles that were established to support progress whilst recognising important uncertainties and limitations, particularly regarding input data.

Some additional background information, not included in the summarised version of this section, is provided in Appendix A.

2.1 PURPOSE & AIMS OF THE RISK ASSESSMENT

The purpose of the Risk Assessment is to "*assess the potential for elements at risk (people, places, assets) to be negatively affected by pluvial flood, coastal (inundation and erosion), groundwater, landslide and liquefaction natural hazards in South Dunedin*".[11] This is an important component for achieving the SDF Strategic Operational Objectives because it identifies what may happen if nothing is done. It also provides a framework for the future efficacy assessment of adaptation options.

In order to meet this purpose, there are two aims for the risk assessment component of the SDF programme:

1 Outline the "case for change" in response to current and increasing natural hazard risks
The risk assessment outlines the "case for change" by providing an overview of natural hazard risks drawing together the results and conclusions from the spatial risk assessment. The risk baseline can be used to illustrate the implications of a 'status quo' or 'do nothing new' option. It also identifies and discusses non-spatial risks and their potential impacts. These impacts relate strongly to the Strategic Objectives of the SDF programme, particularly posing risks to social and economic resilience, and environmental and cultural restoration. This will identify what may occur if South Dunedin does not adapt, which is a critical component of the case for change.

2 Support spatial adaptation planning
The risk assessment supports spatial adaptation planning aim by providing a spatial representation of risk to twelve *elements at risk* for a range of timeframes and climate scenarios[12]. This helps to:

- Inform *where* adaptation is required to reduce risk.
- Identify how risk profiles change over time, which informs *when* adaptation may be required.
- Identify *key features* as these are the features that are most likely to influence *what type* of adaptation options are most appropriate for different areas (e.g. residential buildings are a key feature and their location in some areas will influence the choice of adaptation option).
- Establish a risk baseline against which potential risk mitigations can be assessed through the adaptation planning workstream.

[11] This purpose is stated in the RFP and has been adopted in the Risk Identification Report, noting that the terminology 'things of value' is changed to 'elements at risk'.
[12] Timeframes and climate scenarios are discussed in Section 3.2.6.

2.2 RISK ASSESSMENT STAKEHOLDERS

The primary stakeholder for risk-related information to support spatial adaptation planning are those involved in developing the adaptation response (i.e. SDF programme Workstream 4). Therefore, the risk assessment methodology, and information outputs were primarily guided by the needs of SDF Workstream 4.

It is also acknowledged that the case for change has a wide range of stakeholders who can draw on the risk assessment results for general adaptation and development decision-making purposes. These stakeholders include Councillors, asset owners and the broader 'community'.

Additional information regarding the programme stakeholders and partners can be found in the South Dunedin Future Communications and Engagement Strategy (Kia Ropine, 2024).

2.3 RISK ASSESSMENT OUTPUTS

The risk assessment outputs have been identified through a three-stage process which is shown in Figure 2.1 (i.e. this report is the culmination of Stage 3).

In collaboration with the adaptation response workstream, the following outputs have been identified by the process:

- Identification of key features within each element at risk.
- Assessment of exposure to the hazards for each 'element at risk'.
- Assessment of vulnerability of each 'element at risk' to the hazards.
- Assessment of risk based on the exposure and vulnerability assessments.
- Presentation of spatial mapping of risk, where outputs are presented by hazard and by element.
- Documentation to support the spatial data which identifies the impacts arising from risks to key features.
- Description of the impacts and presentation of relevant supporting spatial data where available.

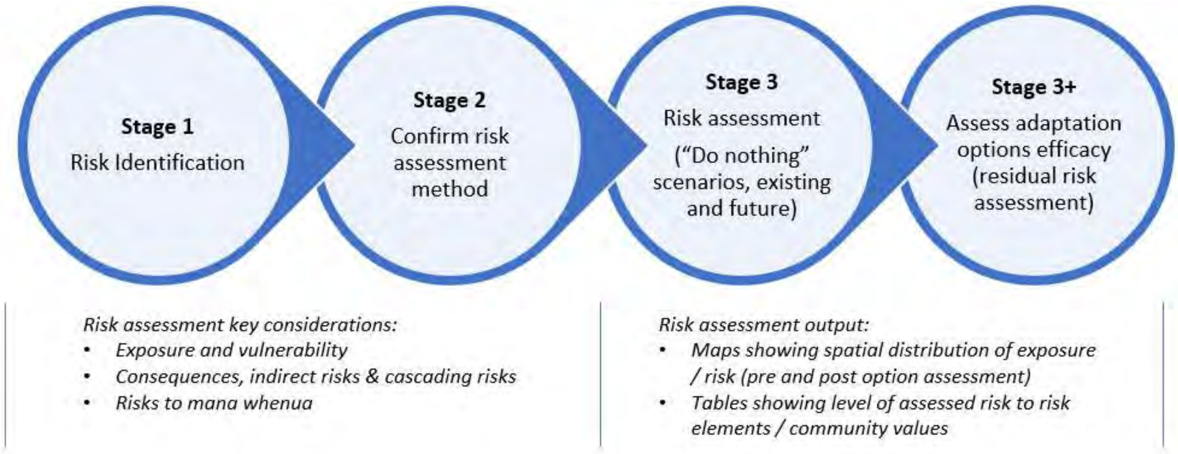


Figure 2.1 Risk assessment stages, considerations and high level outputs

Further information regarding the Stage 1 and Stage 2 aspects of the risk assessment process can be found in Appendix A. This report supersedes previous reports.

Stage 3+ provides an assessment of efficacy of adaptation options against the baseline risk assessment documented in this report. Stage 3+ is not covered in this report.

2.3.1 GEOSPATIAL DATABASE

The results of the spatial risk assessment have been compiled into a geospatial database which has been provided to DCC and ORC alongside this report. The database holds spatial files relating to each element at risk with metadata holding risk ratings and some supporting information (e.g. identification of key features) (Refer to Appendix E for a summary of geospatial files). Some of the geospatial information is reproduced in figures contained within this report, and it has been used to analyse and interpret the risk assessment results.

2.4 PRINCIPLES

Risk assessments are inherently carried out in an imperfect environment, where limitations of data availability, data quality, budget and timeframes influence the outcomes of the risk assessment. To support decision making for the risk assessment, the following principles are adopted, and are particularly important because they have underpinned progress for the risk assessment:

- Make best use of available data.
- Ensure effort is proportionate to outcome.
- Identify risks and opportunities arising from the above including recommendations for additional studies where necessary.

2.5 UNCERTAINTY AND LIMITATIONS

There are inherent limitations and sources of uncertainty regarding the risk assessment, due to the scope, scale, and complexity of what it needs to cover. Additionally, data gaps relating to exposure, hazard and element/asset vulnerability introduce limitations and sources of uncertainty. This report is intended to transparently document what has been done. It is beyond the scope of this report to record all the limitations, uncertainties and project risk management decisions which have been discussed and agreed with the project sponsors (DCC and ORC) and wider project stakeholder group. As appropriate, attention is drawn throughout this document to key limitations or assumptions, particularly where the outcomes of the programme could be affected. There is also additional information provided through the Appendices that help support some of the summarised text throughout the main body of this report.

Importantly, the risk assessment is intended to support suburb-level adaptation planning, including dialogue with affected stakeholders about the options for mitigating and adapting to identified risks. The risk assessment is not intended to provide a detailed property-level assessment of risk and using the report in this way could lead to false or misleading conclusions (e.g. high risk areas may include low risk properties, or the reverse).

This risk assessment involved incorporating current spatial hazard and asset data, knowledge and research available at the time, augmented by stakeholders and subject matter experts with knowledge of South Dunedin using the principles of the assessment (Section 2). This baseline risk assessment does not consider:

- Socio-economic projections: i.e. present day social demographic and economic profile is considered when evaluating risk under all scenarios.

- New adaptation measures (also referred to as mitigation measures or risk treatment). However, the risk assessment does assume that business as usual maintenance and renewals programmes continue.
- Transition risks: i.e. risks associated with societal and economic shifts toward a low-carbon future.

Changes in our future climate are dependent on atmospheric greenhouse gas concentrations. These concentrations are dependent on global efforts as well as local efforts to reduce greenhouse gas emissions, all of which are subject to socio-political influence. Potential greenhouse gas concentrations and the associated uncertainty is captured through the development of future emissions scenarios (detailed in Section 3.2.6). Between these scenarios, there is a comparatively narrow range of uncertainty in the near term, where the range in projected greenhouse gas concentrations is relatively small between scenarios. However, uncertainty increases for longer-term planning horizons, where the range in projected greenhouse gas concentrations increases significantly between scenarios over time.

There is a wide range of limitations and uncertainties for each of the asset classes, hazard types and vulnerability classifications. The limitations and assumptions applied in this assessment could lead to the under- or over-estimation of risk presented in this report. The reader is referred to the respective reports for a full understanding of the key input data and limitations. A number of key limitations are identified below:

- Many of the inputs used to inform this study are of a high-level nature and have a number of limitations associated with them. Notably the findings of this risk assessment should not be used for detailed, property and infrastructure specific risk.
- Risk to assets is assigned at the parcel scale (i.e. land parcel, road section, pipe section). This means that if any part of the parcel is exposed to a hazard, risk is assigned to the whole parcel. In some cases, particularly for larger parcels, this means that large areas are assessed as being at risk despite a relatively small proportion of the parcel actually being exposed.
- Coastal inundation modelling is based on a 'bathtub' approach that assumes inundation of all areas lower than the calculated extreme sea level (while also assuming no connectivity/permeability of the raised land/dune systems within the proximity of the coast). This may be conservative (i.e. result in higher risk) as it does not account for the time varying nature of a storm event (i.e. when modelled to represent the time limited nature of a storm event, the level may be lower). It also does not account for any potential influence of permeability of the dunes or connectivity of the raised land around Andersons Bay Road area and therefore may underestimate the inundation potential. Further investigations would be required to determine a higher degree of confidence in coastal inundation extent and / or depths (refer Appendix B1 for further information).
- The coastal erosion assessment is based on a district scale screening assessment and therefore may not be fully reflective of localised coastal environments, particularly where there have been engineering interventions (e.g. seawalls). Accordingly, the Coastal Erosion risk assessment at this stage of the South Dunedin Future Programme is not being used to inform adaptation planning along St Clair-St Kilda. More detailed South Dunedin specific coastal erosion modelling of the St –lair - St Kilda coastline is underway as part of the St Clair-St Kilda Coastal Plan, (refer Appendix B1). This will be completed in late-2025, after which coastal erosion risk ratings will be reviewed.

- The landslide hazard assessments do not currently allow for climate change influences of groundwater level rising or increased rainfall intensity (refer Appendix B1 for further information). The landslide extent is based on known landslide areas and does not account for other potential sources of landslide nor represent the extent of the area of deposition/runout. It also does not account for future changes in landuse or human activity that could trigger landslides.
- Liquefaction potential mapping does not reflect the known high level of variability across the area (Hornblow, 2020), for which a suitable spatially mapped dataset is not available. The liquefaction hazard assessment has not considered the influence of raised groundwater levels as a result of climate change (refer Appendix B1 for further information).
- Spatial vulnerability data for all elements at risk is generally unavailable, with a few exceptions (this exception relates to three waters infrastructure which uses physical characteristics of the pipe network to establish asset vulnerability to some hazards). Therefore, vulnerability information has been gathered through elicitation with relevant subject matter experts (refer Appendix C for further information).
- Building floor level information is sourced from observation-based estimates carried out by DCC in late 2024. Refer Appendix C1 for further information.

3 RISK ASSESSMENT APPROACH

3.1 CONCEPTUAL RISK FRAMEWORK

The conceptual risk framework selected for the South Dunedin risk assessment considers risk arising from three components:

- Hazards (which can be physical events or trends, such as sea-level rise or seasonal climate changes).
- The degree to which *elements at risk* are exposed to the hazard. This includes peoples' interactions with the elements at risk, whether they are living, working or visiting South Dunedin
- Elements at risk and their vulnerability to the effects of hazards, including effects on people.

The framework is presented in Figure 3.1 and definitions and interpretations of the terms are provided in the glossary for the purposes of this risk assessment.

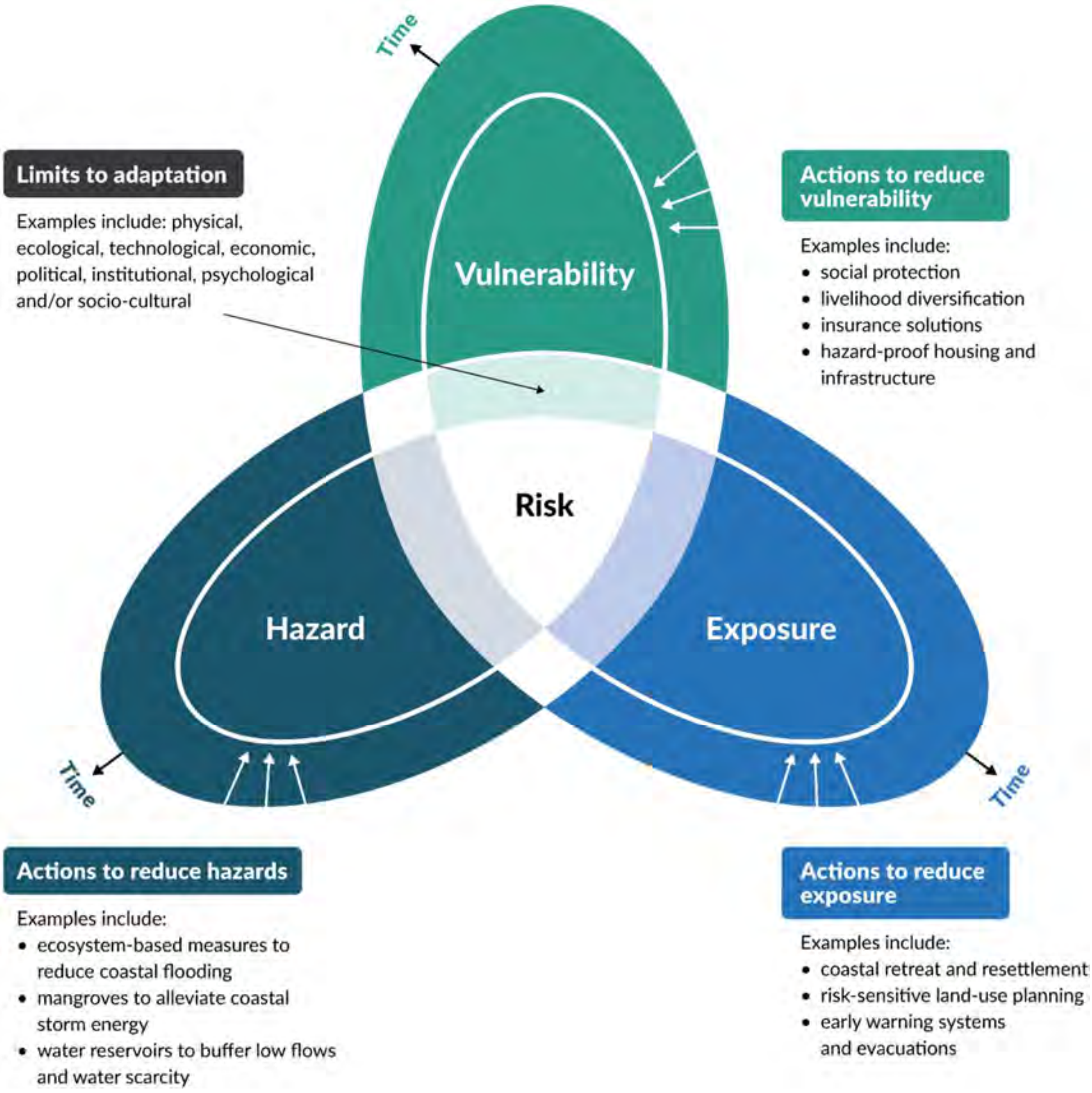


Figure 3.1 Conceptual risk framework used for this assessment (reproduced from MfE (2024)[13])

[13] Adapted from Garschagen et al 2019 https://doi.org/10.1016/j.crm.2021.100357.

Note: actions to reduce the hazards, exposure and vulnerability are not included in this risk assessment report.

Importantly, there are many social, economic, environmental and cultural impacts which are not directly caused by the hazard. For this reason, the risk assessment approach considers:

- Physical risk (also termed 'direct risks') i.e. through contact with the hazard/s.
- Impacts (also termed 'consequences, indirect risks, and cascading risks') i.e. an upstream or downstream consequence of the hazard/s.

The framework aligns with MfE (Ministry for the Environment, 2024) and IPCC guidance (Reisinger, et. al, 2020). This approach was chosen as it is tailored to address the unique and complex nature of climate risks while also being well suited to assess the influence of adaptation actions on risk. It is also aligned with the principles of the approach described in APP6 of the proposed Otago Regional Policy Statement (pORPS) (i.e. a risk assessment based on consideration of event likelihood and consequences) (Otago Regional Council, 2022) although adjustments were required to reflect the needs of the risk assessment for the South Dunedin Future programme. The pORPS methodology has been modified to allow specific assessments for the different elements at risk whereas the scale in the consequence classification of the RPS is designed to be applied over broad areas and is not directly applicable to specific assets. The adjustments are related to the definitions of likelihood, to the description of the consequences and to the risk rating scale. These adjustments are detailed in the following sections where relevant.

3.2 HAZARDS, SCENARIOS AND TIMEFRAMES

The following information provides a description of the key hazards (i.e. one of the three components of the risk framework), the availability of hazard data and spatial mapping of the hazard data.

Additional information regarding the hazards, exposure and vulnerability is provided in Appendix B (e.g. includes data availability, materiality/assumptions, data gaps, data sources, exposure criteria, Spatial definition). It is important to understand that hazard data used in the risk assessment is based on modelled results and are subject to limitations as discussed further in Section 2.5.

3.2.1 KEY HAZARDS

An overview of the key hazards facing South Dunedin included in SDF programme are described in Table 3-1. Further detail regarding hazards is included in the Risk Identification Report (Kia Ropine, 2023), which includes references to the numerous detailed hazard assessments which have been carried out in the South Dunedin area.

Table 3-1 Key hazards facing South Dunedin

Hazard	Description of hazard
Pluvial flooding	South Dunedin is prone to rainfall induced flooding. The area has no major watercourses or natural connection to the coast. All stormwater is piped and discharged into the harbour via the Portobello Stormwater Pump Station (Otago Regional Council, 2016). The South Dunedin Future Programme Area comprises the stormwater catchment of South Dunedin, with parts of St Clair, and Portsmouth Drive. Stormwater runoff from the wider St Clair catchment discharges into South Dunedin (DCC, 2011).

Hazard	Description of hazard
	South Dunedin has experienced severe flooding on numerous occasions (1923, 1929, 1960, 2015, 2018, and 2024). With climate change, extreme rainfall events are projected to become more severe. The hydrodynamic flood model of South Dunedin has recently been updated (Beca, 2024). Amongst the updates is additional consideration regarding the influence of groundwater on pluvial flooding for existing and future scenarios. Results show modelled flooding extents throughout much of South Dunedin Figure 3.5. This broadly aligns with experiences of the recent October 2024 flood event that caused widespread flooding and damage to buildings within South Dunedin. Preliminary review (led by DCC) of this event shows broad alignment between the modelled results and actual flood extents, however further investigation is underway. In parts of South Dunedin, rising sea levels will drive an increase in the ordinarily very shallow groundwater table. Areas with emergent groundwater (levels permanently at the surface) may begin to emerge in the near future and become more defined and widespread over time. This is likely to be problematic in itself, but is also likely to exacerbate the extent and severity of pluvial flooding. Modelling of future scenarios shows the extent and frequency of pluvial flooding will increase in response to climate change and associated increases in sea level, groundwater, and rainfall intensity Figure 3.5.
Coastal inundation (includes sea level rise)	South Dunedin is positioned between two major water bodies: The Otago Harbour (to the north), and the Pacific Ocean (St Clair and St Kilda beaches) to the south. This position means South Dunedin is potentially exposed to hazards from two coastal sources. Sea level rise (SLR) is projected to occur as a result of increased atmospheric and oceanic warming, the rate of this increase is uncertain (discussed further in Section 2.5). The influence of vertical land movement (VLM) at the coast is accounted for by representing sea level rise relative to land movement. Relative sea level (RSLR) rise is considered in this assessment by inclusion of vertical land movement estimates taken from NZ SeaRise (NZ SeaRise, 2022). Previous work has modelled the potential coastal inundation extent of South Dunedin under a range of return events and sea level rise increments (Paulik, et al., 2023). Under these scenarios coastal inundation of South Dunedin occurs via inundation from the Harbour once sea level rise drives storm surge to overtop the reclaimed land along on the Otago Harbour backshore (occurs with approximately 0.6 m RSLR in the 1% annual exceedance probability (AEP) event, as shown in Figure 3.3). These models have a number of limitations discussed in Section 2.5. Under these scenarios, the St Clair and St Kilda dune system continues to provide protection from inundation of South Dunedin arising from the Pacific Ocean. Inundation of South Dunedin arising from the Pacific Ocean would require a breach of the St Clair/St Kilda dunes. The conditions required for this are currently unknown. However, this work is planned for 2025. Modelling of associated coastal inundation arising from a dune breach is not currently procured. Sea level rise will drive corresponding increases in mean high water springs (MHWS). Modelling of MHWS (WSP, 2024) shows parts of inland South Dunedin are lower than MWHS at present day. The potential for tidal inundation of inland South Dunedin as a result of SLR is dependent on hydraulic connectivity (e.g. through the stormwater network). DCC is in the process of installing flap gates on all outfalls, which is thought to effectively prevent sea water from being conveyed within the stormwater network. The extent of tidal inundation is limited to localised areas around Portsmouth Drive

Hazard	Description of hazard
	with 0.6 m RSLR. Beyond this, a direct overland connection between the coast and inland South Dunedin occurs with 1.5 m RSLR, after which point the South Dunedin area may become permanently tidal or inundated if flood water is not prevented from entering, drained or pumped.
Coastal erosion	The coastal erosion potential of Dunedin has been evaluated as part of the District Coastal Hazards Screening (WSP, 2024). This study is of a high-level nature and has a number of limitations associated with it, notably it should not be used for the assessment of the erosion hazard for individual properties and infrastructure (refer Section 2.5 for further details). Accordingly, the Coastal Erosion risk assessment at this stage the South Dunedin Future Programme is not being used to inform adaptation planning along St Clair-St Kilda. This indicates that coastal erosion risk is relatively low along the Otago Harbour coastline but higher along the St Kilda to St Clair dune system (Figure 3.2). Previous storm events have had significant erosion effects on coastal dunes and beaches and future events may continue to do so. Should the St Clair to St Kilda dune system diminish, its ability to provide a buffer against the coastal hazards will also reduce therefore increasing the likely exposure of people and property in South Dunedin to coastal hazards (Otago Regional Council, 2014). More detailed coastal hazard assessments are underway as part of the St Clair-St Kilda Coastal Plan, these will be completed in late-2025, after which coastal erosion risk ratings will be reviewed.
Groundwater	The groundwater table is usually very shallow within South Dunedin. In some areas groundwater levels are tidally influenced, where the tidal signal increases with proximity to the Pacific Ocean and Otago Harbour. Groundwater fluctuations are also dominated by short term rainfall variability. Increasing levels of salinity in groundwater approaching the coastal edge are detected, reflecting direct mixing of groundwater with inland flow from the ocean (Cox, et al., 2020). Groundwater has been found to be contaminated in some locations due to the former Dunedin Gasworks in the area (DCC, 2011). Present day groundwater and the influence of sea level rise on groundwater levels within South Dunedin has been assessed as part of previous work (Cox, et al., 2023). This shows that areas with chronic emergent groundwater (levels permanently at the surface) may begin to emerge in the next few decades and become more defined with approximately 0.5 m RSLR (Figure 3.4). These areas of chronic emergent groundwater are broadly constrained to three areas roughly skirting the perimeter of The Flat, with smaller increments of sea level rise but become increasingly widespread and connected over time (Cox, et al., 2023).
Landslide	Landslides are not a common issue in South Dunedin due to the flat topography although neighbouring hills are prone to shallow landslides after heavy rainfall. Landslide mapping shows potential land instability areas are generally confined to the hillsides at the edges of South Dunedin, with notable locations near Forbury Corner and Saint Clair (Figure 3.2 source: DCC Hazard database data provided for South Dunedin Future programme)[14]. Increased rainfall intensity associated with climate change is expected to result in increased landslide occurrence. The specific impact of climate change on landslides in South Dunedin has not yet been assessed.
Liquefaction	There are numerous potential earthquake sources that could cause shaking within South Dunedin. The Kaikorai Fault which runs through South Dunedin is potentially active and has an estimated average recurrence interval (ARI) of 22,000 years. Other

[14] DCC Hazard database data provided for South Dunedin Future programme.

Hazard	Description of hazard
	active faults in proximity to South Dunedin include Akatore Fault classified as a "definite active fault" with an estimated ARI of 1,700 years, and the Titri Fault classified as a "potentially active fault" with an estimated ARI of 19,000 years (Barrell, 2021). These faults have the potential to generate ground shaking of sufficient strength to cause surface rupture, liquefaction, and lateral spreading in susceptible soils. Hornblow (2020) conducted a site-specific assessment in South Dunedin which revealed considerable variability in liquefaction potential across the examined locations. For a 100-year return period design level of ground shaking, Liquefaction Severity Numbers (LSNs) were generally below 10, corresponding to indicative settlements of only a few centimetres (typically less than 40 mm). In contrast, a 2500-year return period design level of ground shaking produced LSNs generally below 25. This level of severity indicates predominantly minor liquefaction effects, with occasional sand boils and, in some cases, localised moderate to severe liquefaction that could result in settlements sufficient to cause structural damage. Spatial representation of the most recent site specific assessment of South Dunedin (Hornblow, 2020) is not available. Therefore, desktop assessment of liquefaction susceptibility data has been used (Barrell, 2014). This shows that liquefaction potential across South Dunedin is classified as moderate to high in areas classified as 'Domain C' (Figure 3.2). This reflects the geomorphic history of the area (shallow marine/estuarine with some reclaimed land) which entails a high likelihood of fine-grained soils and a shallow groundwater across the area (Barrell, 2014). This regional scale assessment may not be suitable to identify exposure at the local scale of South Dunedin. The influence of rising groundwater (associated with climate change induced sea level rise) on liquefaction potential has been assessed. The assessment showed that generally across the South Dunedin area an increase in groundwater level does not translate to a material increase in liquefaction risk. Minor to moderate sensitivity may exist at specific sites due to localised near-surface soil conditions (e.g. local surface fill or infilled channels), however it would not be practical to undertake a sufficient density of ground investigation across South Dunedin to be able to confidently delineate areas of higher sensitivity. Refer to T+T Report[15] for more information on the influence of groundwater on the liquefaction hazard in South Dunedin.

3.2.2 HAZARD DATA AND AVAILABILITY

The available data to support the spatial risk assessment is discussed in Appendix B. It includes a visual comparison of the spatial data availability for different timeframes and climate scenarios.

3.2.3 MAPPED HAZARDS

Spatial hazard extents of the key hazards used in the risk assessment are presented in the following figures:

- Figure 3.2 Coastal erosion extents (source: WSP (2024)), land instability (source: DCC Hazard database data provided for South Dunedin Future programme) and liquefaction (source: (Barrell, 2014)). There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures).

[15] Tonkin & Taylor Ltd (2025). South Dunedin Liquefaction Hazard. Data review and high-level groundwater sensitivity assessment.

More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

- Figure 3.3 Modelled coastal inundation extents within South Dunedin (Source: (Paulik, et al., 2023)
- Figure 3.4 Modelled emergent groundwater (groundwater level is at the surface) extents within South Dunedin under the following scenarios: median (50th percentile), mean high water springs (MHWS), extreme sea level (ESL), 95th percentile (source Cox, et al., (2023))
- Figure 3.5 Modelled pluvial flood extents within South Dunedin (source: Beca (2024))

Other Hazards

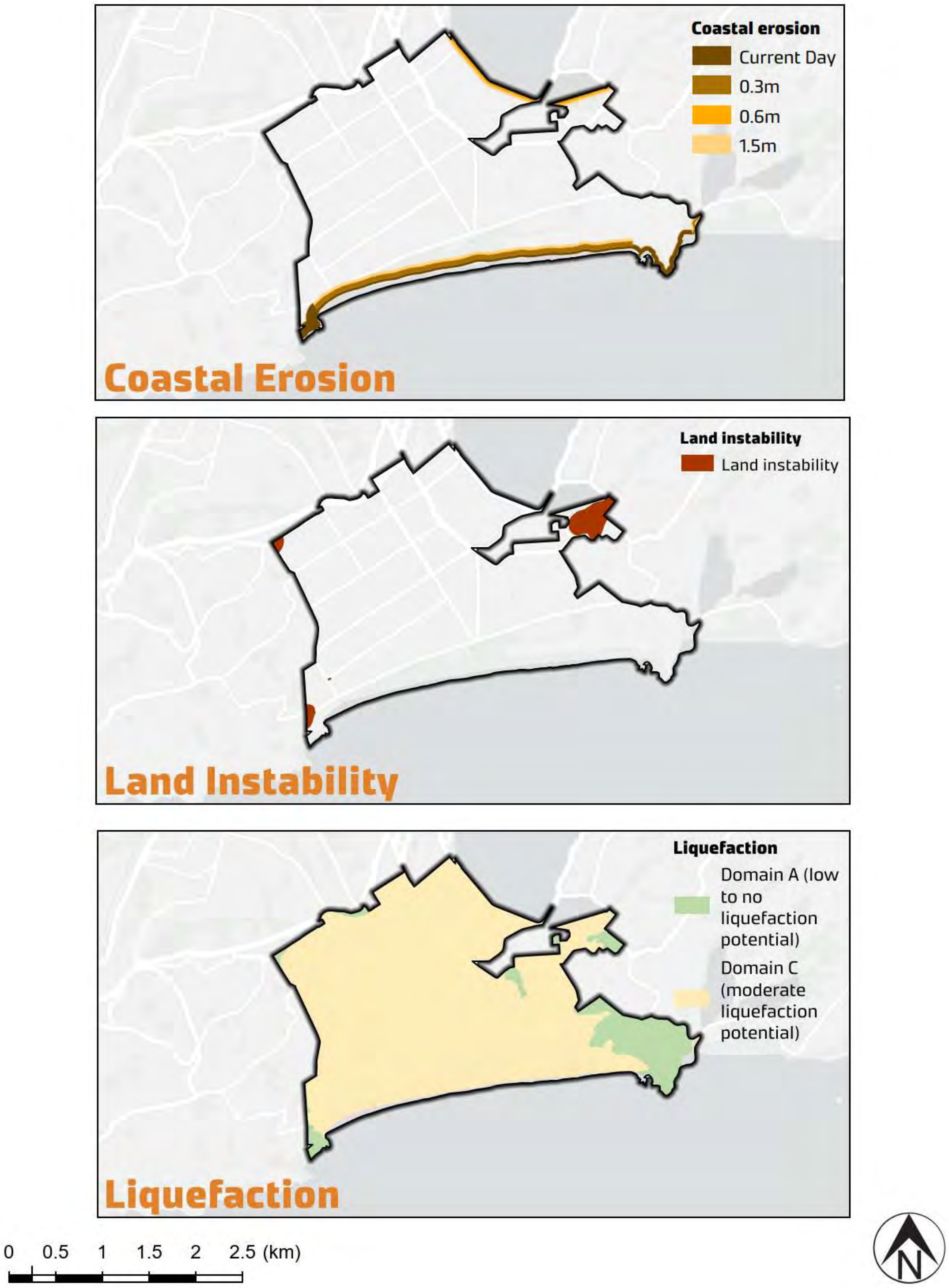


Figure 3.2 Coastal erosion extents (source: (WSP, 2024)), land instability (source: DCC Hazard database data provided for South Dunedin Future programme) and liquefaction (source: (Barrell, 2014)[16]

[16] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

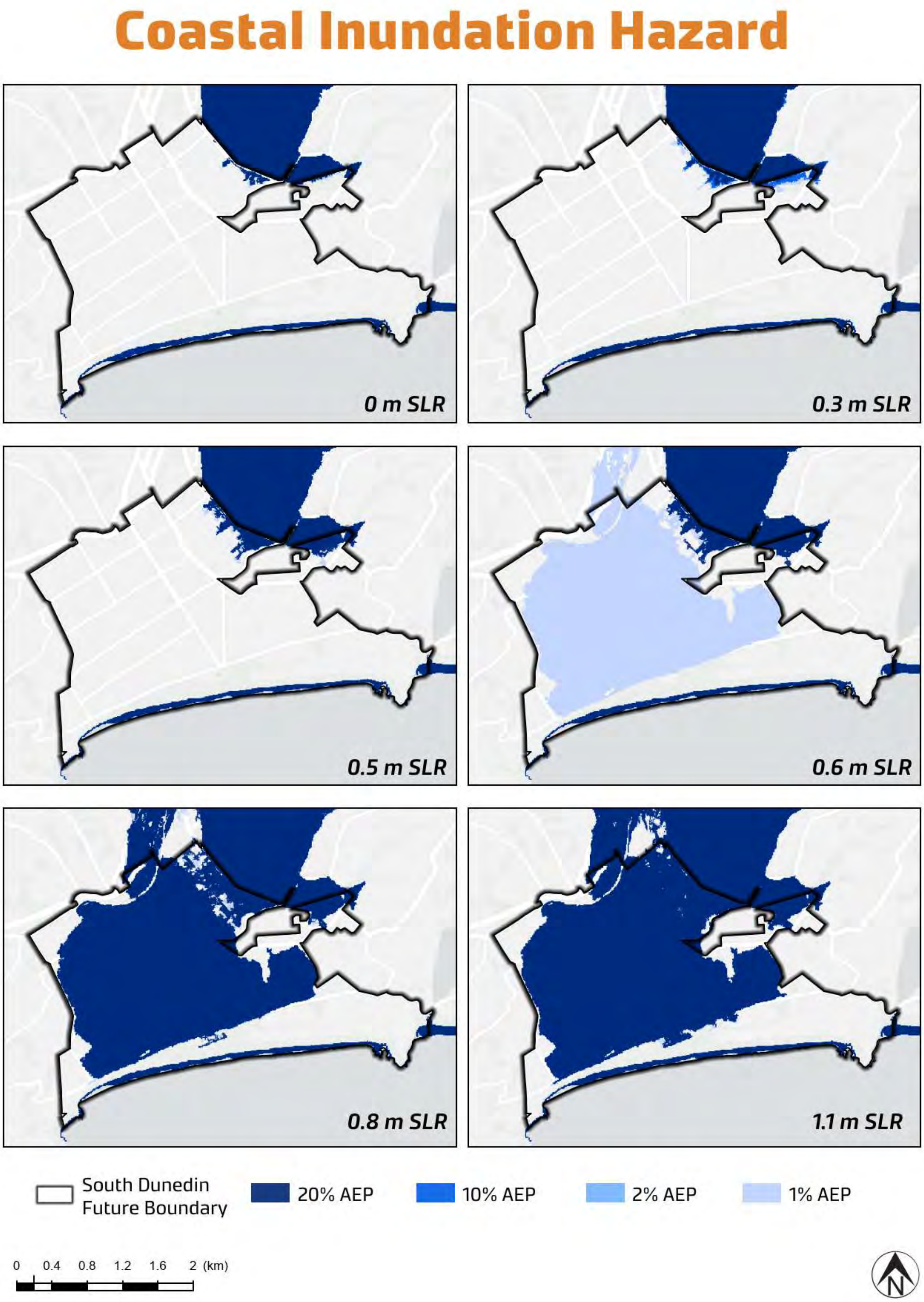


Figure 3.3 Modelled coastal inundation extents within South Dunedin (Paulik, et al., 2023)

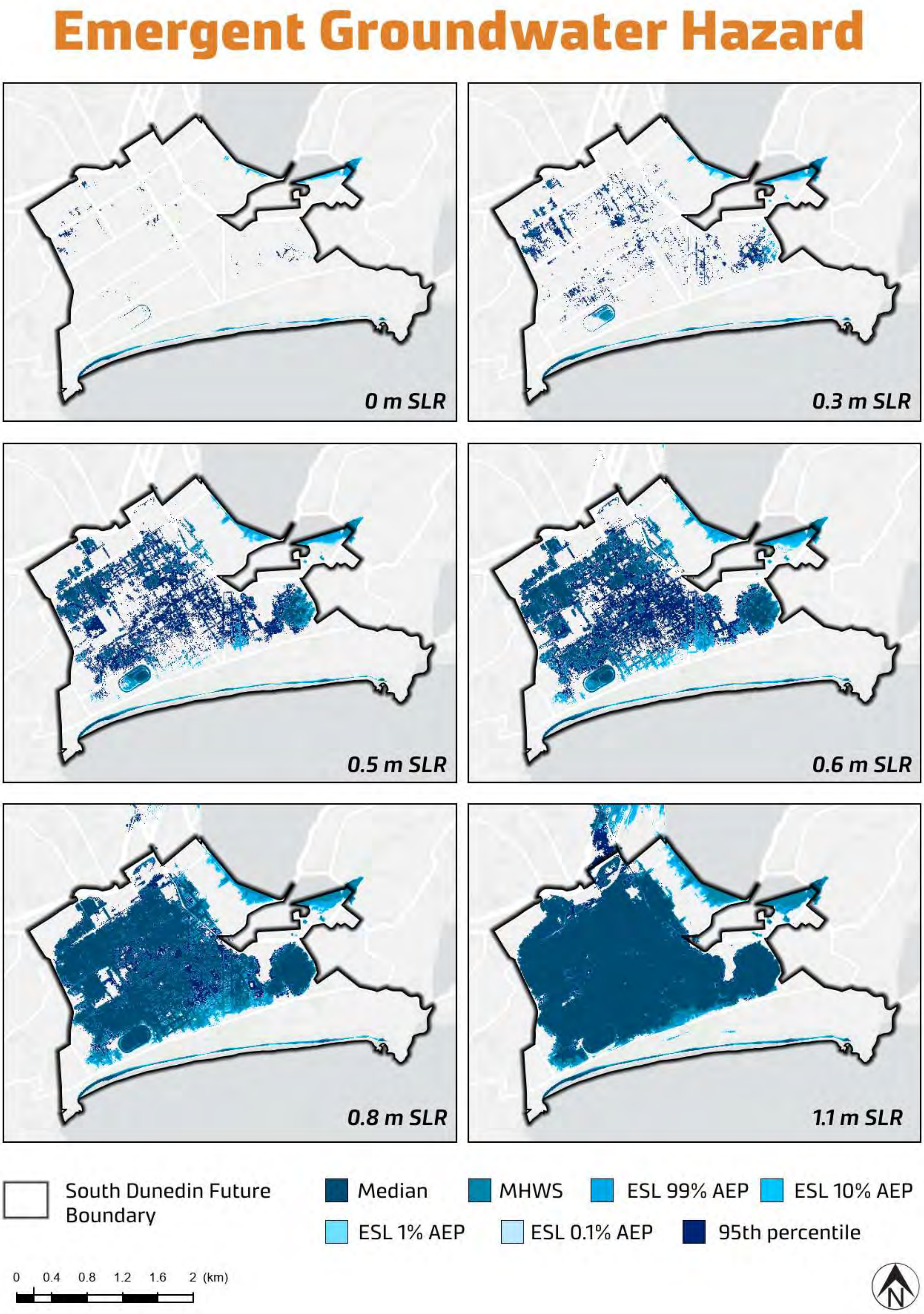


Figure 3.4 Modelled emergent groundwater (groundwater level is at the surface) extents within South Dunedin under the following scenarios: median (50th percentile), mean high water springs (MHWS), extreme sea level (ESL), 95th percentile (Cox, et al., 2023)

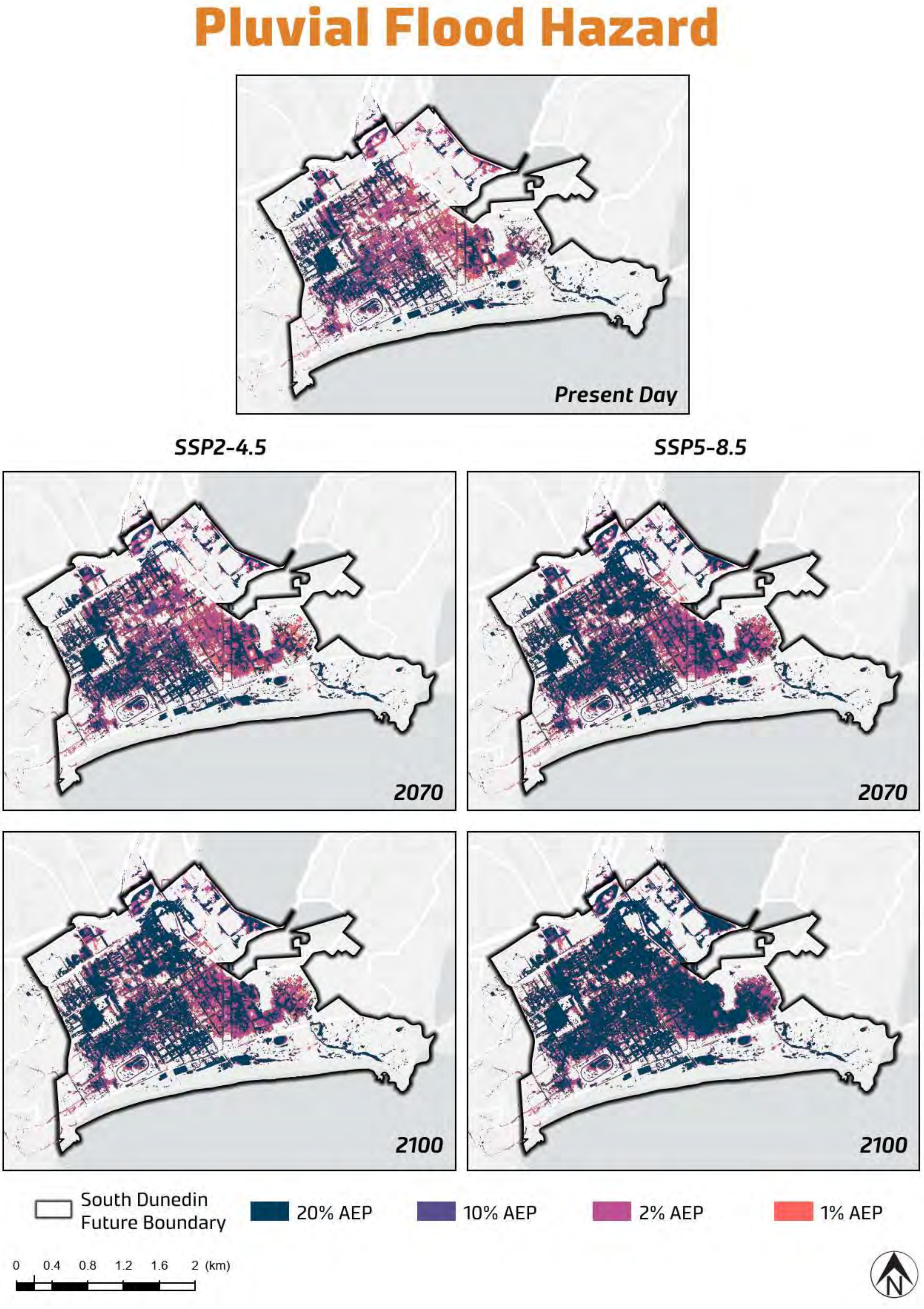


Figure 3.5 Modelled pluvial flood extents within South Dunedin (Beca, 2024)

3.2.4 COMPOUNDING HAZARDS AND INCLUSION OF THE EFFECTS OF CLIMATE CHANGE

Compounding hazards occur when a combination of hazards occur at the same time; for example, there is potential for coastal inundation and erosion, higher groundwater levels, and intense rainfall impacts to occur simultaneously. Where these hazards occur independently, joint probability analysis is required to determine the likelihood and scale of the compounding hazards. This is not generally available for all hazards within South Dunedin but in some instances compounding hazard information is available, as follows:

- Pluvial flood hazard modelling includes the influence of groundwater rise, increased rainfall intensity and Sea Level Rise due to climate change.
- Coastal inundation modelling includes Relative Sea Level Rise.
- Groundwater modelling includes Relative Sea Level Rise and pluvial flooding.

Where information is available it has been incorporated into the risk assessment. The following identified gaps relate to compounding hazards that will occur simultaneously (opposed to those that occur independently and are therefore subject to joint probability analysis such as pluvial flooding and coastal inundation). These identified compounding hazards have the potential to significantly increase the hazards facing South Dunedin:

- Coastal inundation modelling has no information regarding the likelihood of dune breach (erosion), or the influence of groundwater rise.
- Landslide does not include the effects of climate change (e.g. to identify whether these is increased landside potential associated with increasing rainfall intensity and rising groundwater).
- The liquefaction assessment does not include the effects of increased groundwater levels as a result of climate change.

3.2.5 HAZARDS NOT INCLUDED IN THE RISK ASSESSMENT

The following hazards have been excluded from the risk assessment:

- Temperature: out of scope of South Dunedin Future Programme.
- Tsunami: Not included on the grounds that available hazard extents associated with 1% AEP tsunami (NIWA, 2007) are smaller than those associated with a 1% AEP coastal inundation storm event. Therefore, no further benefit is expected from assessing Tsunami separately.
- Earthquake hazard (other than liquefaction): Not included on the grounds that earthquake risk is unlikely to drive adaptation options as the level of risk is similar across the wider Dunedin area. Risk mitigation measures to be included in all adaptation options where appropriate.

3.2.5.1 GROUND BEARING CAPACITY AND LAND SUBSIDENCE

Site specific ground stability and land subsidence have not been considered as part of the risk assessment. Noting that larger scale vertical land movement is included in this assessment through incorporation into relative sea level rise (Section 3.2.1). An awareness of site specific ground stability and land subsidence issues in South Dunedin is important for adaptation planning as these issues may strongly influence construction cost or engineering feasibility.

Much of the soils encountered in the Hornblow (2020) assessment of South Dunedin were plastic (i.e. moderately plastic silts or clays). These soils are soft and compressible and therefore only provide low bearing capacities with associated high rates of settlement for shallow foundations. This may pose a significant geotechnical challenge for development. Hornblow (2020) note significant areas in South Dunedin do not meet the definition of 'good ground' as per NZS3604:2011.

In addition to low bearing capacity, there are a number of areas within South Dunedin that are likely prone to land subsidence (Figure 3.6) This potential land subsidence is primarily related to the placement of fill and land reclamation.

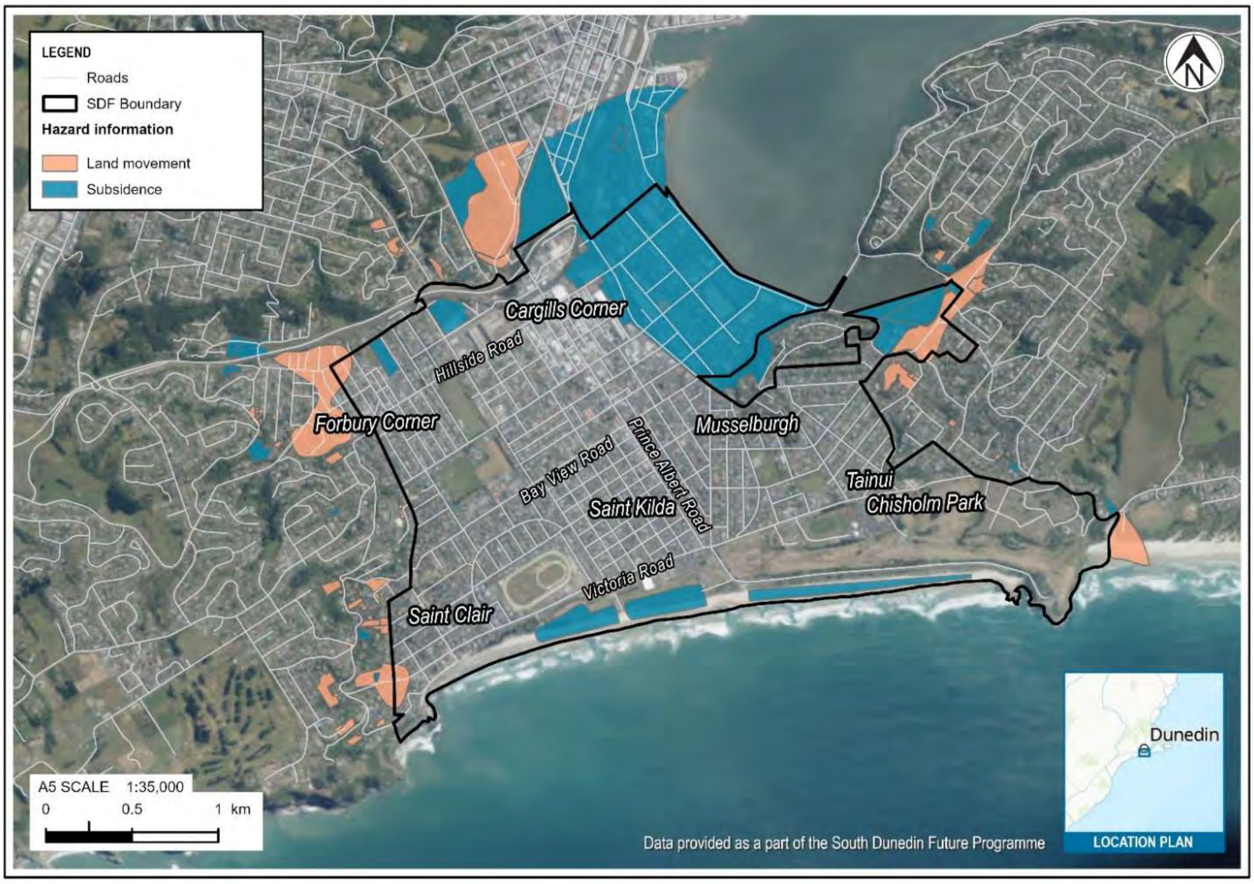


Figure 3.6 Land subsidence and landslide (land movement) in South Dunedin (source: DCC Hazard database data provided for South Dunedin Future programme)

3.2.6 TIMEFRAMES AND CLIMATE SCENARIOS

Present day and future timeframes (also referred to as Planning Horizons) and their associated uncertain climate scenarios are used to represent the future hazardscape to inform the risk assessment and subsequent adaptation planning. Scenarios used in this risk assessment are in line with the recommended minimum shared socio-economic pathway (SSP) scenarios for risk assessments[17]:

- The 'Middle of the road' scenario, SSP2-4.5, assumes that the world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. It assumes that warming reaches 2.7˚C by 2100 (Ministry for the Environment, 2024)

[17] Recommended scenarios as described in Table 9 from Coastal Hazards and Climate Change Guidance (Ministry for the Environment, 2024)

- The 'Fossil-fuelled development' scenario, SSP5-8.5, represents the high end of the range of future scenarios. It assumes that the world places increasing faith in competitive markets, innovation, and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development, with warming of more than 4 ˚C by 2100 (Ministry for the Environment, 2024).

The timeframes, climate scenarios and projected sea level rise increments used in this risk assessment are presented in Table 3-2. These values are based on projections and vertical land movement (VLM) estimates available at the time of assessment (January 2024, NZ SeaRise (2022)). Selection of the timeframes and climate scenarios were strongly influenced by available spatial hazard data and an aim to use consistent scenarios across all hazards.

Further information on the available spatial hazard data is presented in Appendix B.

Refer to Section 3.2.6.1 for specific discussion regarding coastal hazard scenarios and recent MfE guidance. Furthermore, additional information regarding uncertainty and limitations (including climate uncertainty) is provided in Section 2.5.

Table 3-2 Timeframes and climate scenarios

Timeframe	Date range[1]	Increment of sea level rise (m)[2]	
		Mid-range: SSP2-4.5	High end: SSP5-8.5 H+
Present day	2005-2023	0	0
Mid-term	2060-2070	0.3	0.5
Long term	2100	0.6	1.1

[1] Date ranges are presented as a range to reflect differences in 'present day' timeframes used in pluvial flood modelling, groundwater, and coastal hazard assessments (2024, 2023, and 2005 sea levels respectively) [18].

[2] H+ is the top of the likely range for the SSP5-8.5 scenario (83rd percentile), representing widening future deep uncertainties associated with SLR

3.2.6.1 COASTAL HAZARDS GUIDANCE DISCUSSION

Specific coastal hazard guidance released earlier this year (Ministry for the Environment, 2024) recommends consideration of hazards to 2150, using medium confidence climate scenarios. This includes consideration of high-end emissions scenario SSP5-8.5 H+ (the 83rd percentile) to provide an upper-bound of the likely range.

In the South Dunedin context, this scenario equates to Relative SLR of 2.31 m (NZ SeaRise, 2024) to 2150. This is 1.2 m higher than the high-end scenario that has been currently adopted to 2100. Coastal inundation levels are available up to 2.0 m for South Dunedin if a coastal-specific assessment needs to be carried out, however there is no other information available for other hazards for this timeframe and scenario (i.e. the intent to be consistent across the hazards for all timeframes/climate scenarios would not be possible).

[18] Sea level rise increments are presented as relative sea level rise at Kitchener Street (VLM of -0.44 mm/ year) from a baseline of approximately 2005 (1994-2014) as used widely in national projections (NZ SeaRise, 2022) and supported by coastal inundation extents (Paulik, et al., 2023).

Currently the risk assessment has not considered 2.31 m Relative SLR and it is recommended that further consideration of this scenario is given for stress testing adaptation pathways. This approach is in line with the MfE (2024) guidance:

"Scenarios are not 'predictions' but rather a description (narrative) of how different futures might unfold, and they can be used to stress-test adaptation options, dynamic adaptive pathways, plans or strategies. They can help inform the development of objectives and policies and inform the effectiveness (or otherwise) of risk management strategies, including any lock-in dependencies relying on a single type of option."

In addition, we highlight a major sea level rise 'tipping point' in South Dunedin with approximately 0.6 m RSLR, when widespread emergent groundwater is likely across South Dunedin and coastal inundation of inland South Dunedin is modelled to occur during the 1% AEP storm event.

3.2.7 HAZARD EXPOSURE WITHIN SOUTH DUNEDIN

South Dunedin is exposed to all of the key hazards to varying degrees, some of which change in extent over time. The extent of hazard exposure is an important factor in determining the risk to the people, places and assets in South Dunedin. Figure 3.7 shows the percentage of South Dunedin Future land area exposed to hazards, and how this changes over time under different climate change scenarios. This figure shows that the dominant hazard at present is pluvial flooding due to the 1% AEP event. Coastal inundation associated with the 1% AEP event exposes a significant proportion of South Dunedin with 0.6 m RSLR. At a similar timeframe, the extent of emergent groundwater under the median scenario also begins to increase. Pluvial flooding, emergent groundwater, and coastal inundation are modelled to cover extensive proportions of South Dunedin with 1.1 m RSLR. No future climate scenario information is available for landslide or liquefaction. Groundwater modelling scenarios are not available for RSLR increments greater than 1.1 m (adjusted to 2005 baseline timeframe). Figure 3.8 shows similar information by mapping the hazard extents for coastal erosion, coastal inundation, emergent groundwater, landslide, liquefaction, and pluvial flooding, over three timeframes and under one climate change scenario (SSP 5-8.5). Areas shaded in a darker blue indicate those areas that are exposed to more hazards. The map indicates that at the present day around half of South Dunedin is exposed to two or more hazards, particularly in The Flat. At mid-century areas that are exposed to three or more hazard are more dispersed throughout the study area, while at end of century the majority of South Dunedin will be exposed to four hazards.

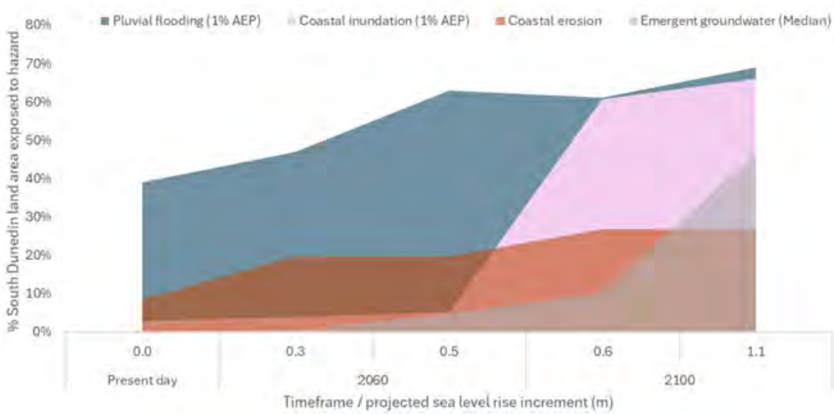


Figure 3.7 Percentage of South Dunedin Future land area exposed to hazards showing change over time under climate change scenarios (landslide and liquefaction hazards are excluded due to a lack of information regarding future timeframes).

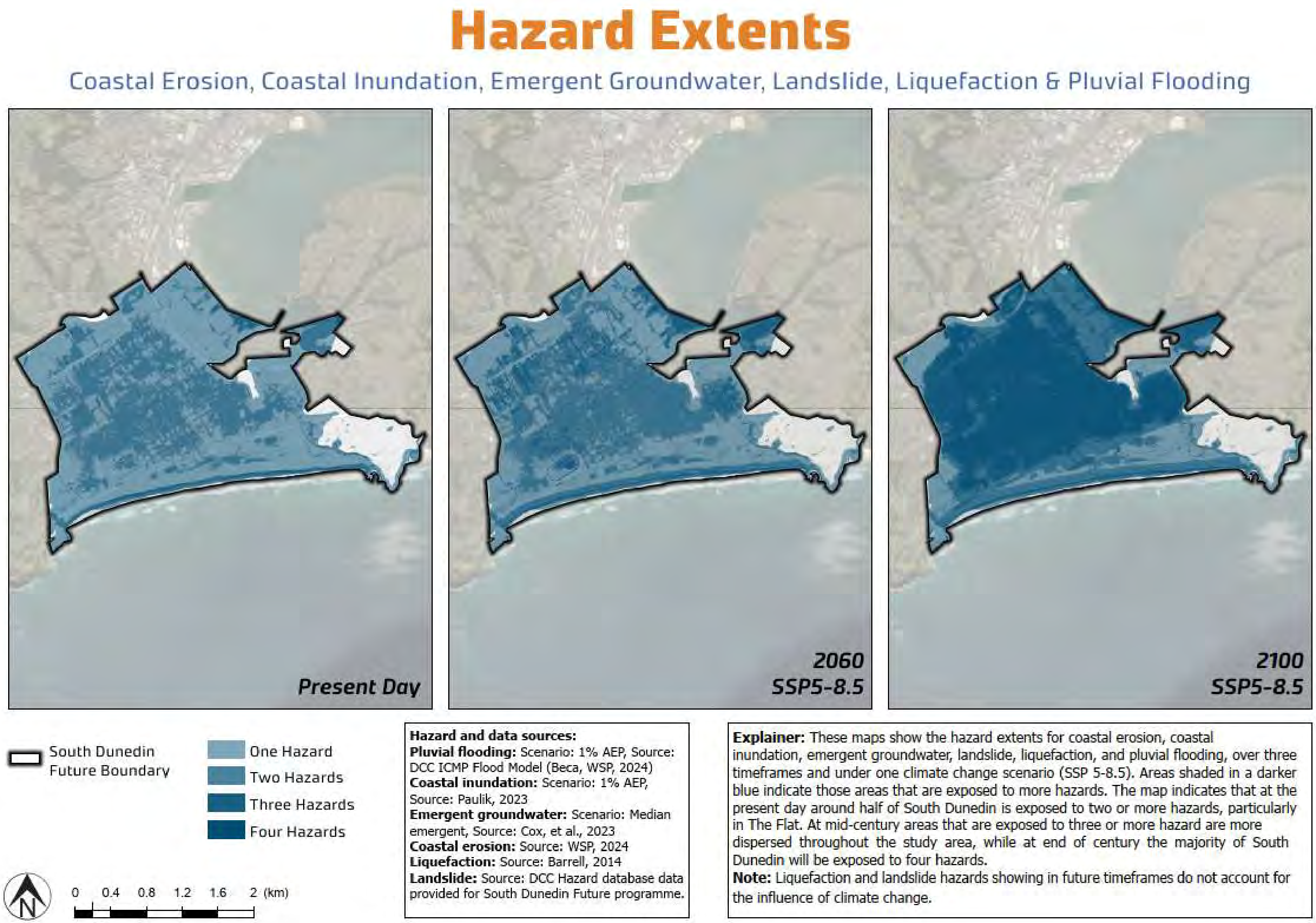


Figure 3.8 Exposure of South Dunedin Future area to coastal erosion, coastal inundation, emergent groundwater, landslide, liquefaction, and pluvial flooding hazards, over three timeframes under SSP 5-8.5 climate change scenario

3.3 EXPOSURE AND VULNERABILITY

The following information provides a description of the exposure and vulnerability components of the risk framework. They have been reported together because they both require an understanding of the 'elements at risk' in terms of how they are characterised. The exposure requires understanding of where the elements at risk are located (relative to the hazards), and the vulnerability indicates their propensity to be adversely affected.

3.3.1 ELEMENTS AT RISK

Through the 3-stage risk assessment process (refer Appendix A) the following 'elements at risk' have been identified in South Dunedin:

(1) Buildings.
(2) Parks and sports fields.
(3) Ecological areas.
(4) Roads and associated infrastructure.
(5) Rail infrastructure.
(6) Water supply infrastructure.
(7) Wastewater infrastructure.
(8) Stormwater infrastructure.
(9) Contaminated land.
(10) Telecommunication infrastructure.
(11) Energy infrastructure.
(12) Risks to mana whenua – part of a separate mana whenua risk assessment (key findings noted in this report).

Within each of the elements at risk, there are an array of key features (Table 3-3) which are typically the places or assets that characterise the element at risk and are also most likely to influence the adaptation planning pathway. Further details on element data used in the assessment is contained in Appendix B. Further discussion on the elements at risk and key features is provided in the risk assessment results (Section 5).

Risks to people are considered in relation to how they interact with the elements at risk identified above. This can arise through direct harm (physical or mental) to people living, working or visiting South Dunedin, or through impacts arising from damage or loss to the other elements.

Table 3-3 Elements at risk and associated key features

Element at risk	Key features
Buildings	• Residents and community members. • Residential buildings. • Non-residential buildings (inc. commercial, schools, churches, heritage buildings, rugby clubs and sports facilities). • Important or essential buildings (as identified by the community, also covering those identified in the pORPS (Otago Regional Council, 2022)).
Parks and sports fields	• St Clair - St Kilda beach.

Element at risk	Key features
	• Tahuna Park. • Marlow Park (especially the Dinosaur Playground). • Other parks & playgrounds. • Sports grounds (Bathgate Park, Tonga Park, West Kettle Park, Culling Park). • Caledonian gym and sporting facilities.
Ecological areas	No spatial data (i.e. no areas identified in the spatial plan). Qualitative discussion included.
Roads and associated infrastructure	• Identified by their criticality rating (vital to local). • Cycle lanes.
Rail	• Rail corridor. • Rail transport buildings.
Water	• Somerville Street Water Pumping Station. • Somerville Distribution mains (from treatment plant that feeds Somerville). • High criticality pipes.
Wastewater	• Musselburgh WW pump station. • Tahuna WWTP. • Marne St Pump station (overflow pump station which pumps to Musselburgh). • All flap gates. • High criticality pipes.
Stormwater	• Tainui SW pump station. • Portobello stormwater pump station. • Portobello Road Screens. • All flap gates. • High criticality pipes.
Contaminated land	• HAIL sites within industrial areas. • HAIL sites within residential areas. • Kettle Park (Ocean Beach Domain Landfills). • Gas Works.
Tele-communications infrastructure	• Exchange site.
Energy	• Transpower South Dunedin Substation. • Transpower: Transmission line.

Element at risk	Key features
	• Aurora Substations: Andersons Bay, Carisbrook, St Kilda. • Aurora 33kV Buried lines. • Aurora Overhead lines. • Genesis bulk LPG Facility.
Mana whenua	Assessed separately (refer Section 4)

3.3.2 EXPOSURE

Evaluation of exposure is carried out through a spatial assessment of asset locations relative to hazard extents, where those within a hazard extent are exposed. The exposure rating criteria used in the risk assessment is shown in the following tables: groundwater (Table 3-4), pluvial flooding (Table 3-5), coastal inundation (Table 3-6), coastal erosion (Table 3-7), landslide (Table 3-8), and liquefaction (Table 3-9). For most hazards, exposure rating thresholds are related to the likelihood of a hazard event occurring. These thresholds have been adapted from pORPS Risk Assessment Hazard likelihood scale[19]. Exposure is assessed under the present day, medium, and long-term timeframes, and mid-range and high-end climate change scenarios where hazards information is available to support this assessment. A single rating is applied to each land parcel or asset length. Additional information regarding the percentage of area or length exposed is recorded and has been used for some interpretation of data. Hazard extents and data sources are discussed in Section 3.2. Locations of assets are shown indicating asset specific risk rating in Section 3.4.3.

Table 3-4 Hazard exposure: groundwater

Exposure	Present day 0 m SLR	Medium-term 0.3, 0.5 m SLR	Long-term 0.6, 1.1 m SLR
Extreme	Median groundwater level: • All non-buried assets have extreme exposure to the median groundwater level as a default rating. Depth thresholds that determine the level of risk are recorded in the vulnerability rating. • All buried assets (three waters) have extreme exposure to the median groundwater level if their invert levels intersect with the groundwater level.		
Not exposed	Assets located outside the modelled hazard extent		

Table 3-5 Hazard exposure: pluvial flooding

Exposure	Present day	Medium-term	Long-term
Extreme	10% AEP current	10% AEP future (2060-2070)	10% AEP future (2100)
High	2% AEP current	2% AEP future (2060-2070)	2% AEP future (2100)
Moderate	1% AEP current	1% AEP future (2060-2070)	1% AEP future (2100)
No rating	Assets located outside the modelled hazard extent of the scenarios assessed		

[19] ORC (2021) Proposed Regional Policy Statement APP6 Methodology for natural hazard risk assessment Hazard likelihood (Table 6). This table has been adapted by adding a new class 'up to once every 10 years', and combining the 100-1000 and 1000-2500 year classes.

Table 3-6 Hazard exposure: coastal inundation

Exposure	Present day 0 m SLR	Medium-term 0.3, 0.5 m SLR	Long-term 0.6, 1.1 m SLR
Extreme	10% AEP current	10% AEP + SLR	10% AEP + SLR
High	2% AEP current	2% AEP + SLR	2% AEP + SLR
Moderate	1% AEP	1% AEP + SLR	1% AEP + SLR
No rating	Assets located outside the modelled hazard extent of the scenarios assessed		

Table 3-7 Hazard exposure: coastal erosion

Exposure	Present day 0 m SLR	Medium-term 0.3, 0.6 m SLR	Long-term 0.6, 1.5 m SLR
Extreme	Exposed	Exposed	Exposed
No rating	Assets located outside the modelled hazard extent	Assets located outside the modelled hazard extent	Assets located outside the modelled hazard extent

Table 3-8 Hazard exposure: landslide

Exposure	Present day	Medium-term	Long-term
Moderate	Exposed	No data therefore not assessed	No data therefore not assessed
No rating	Assets located outside the modelled hazard extent	No data therefore not assessed	No data therefore not assessed

Table 3-9 Hazard exposure: liquefaction

Exposure	Present day	Medium-term	Long-term
Low	Exposed	No data therefore not assessed	No data therefore not assessed
No rating	Assets located outside the assessed hazard extent	No data therefore not assessed	No data therefore not assessed

3.3.3 VULNERABILITY

The physical risk assessment is informed by people, place, or asset specific (i.e. elements at risk) vulnerability information, such as design, condition, and age. The availability and materiality of this information was tested with owners, managers and those responsible for the elements at risk. Vulnerability was rated qualitatively where necessary using input from with owners, managers and those responsible for the elements at risk and the rating guidance shown in Table 3-10 (discussed further in Appendix B5). Vulnerability ratings and supporting background information for each element at risk is documented in Appendix C.

Table 3-10. Example vulnerability attributes by hazard

Vulnerability	Description
Extreme	Sudden collapse or failure likely, causing potential risk to life. For example house/culvert collapse putting people's lives at risk.
High	High damage likely. Loss of service with lengthy time to restore to operation (months).
Moderate	Moderate damage likely or possible. Short to medium time to restore to operation (less than one month).
Low	Minor damage sustained although it does not impact the operation of the asset.
Very low	No damage or loss of service.

3.3.3.1 RISK TO RESIDENTS OF SOUTH DUNEDIN

The physical risk of harm to the residents of South Dunedin is presented through the relationship between risk to buildings and the social demographics of South Dunedin. Spatial data regarding people working and visiting South Dunedin was not available, however impacts on these people are discussed in Section 6.

3.3.3.1.1 Background

The population of South Dunedin is roughly 13,500[20], living within approximately 6,000 households in the area (Statistics NZ, 2018). The South Dunedin community is approximately 84% New Zealand European, 12% Māori, 7% Asian, 6% Pacific peoples, and 1% other. 4% of the population report a lot of difficulty walking and 1% cannot walk at all (Figure 3.9). Relative to Dunedin, the population is slightly older, with approximately 21% of the population over 65 year-olds (relative to 16% in Dunedin) but similar proportion of over 30-65 years of age (approximately 43%). In the younger age groups, South Dunedin has approximately 19% of the population within the ages of 15-29 years (relative to 26% in Dunedin) with around 17% of the population under 15 years age group (similar to Dunedin) (Figure 3.10).

The New Zealand Index of Social Deprivation provides one example of a measure of social vulnerability across communities. The Index rank's locations on a scale of decile 1 (least deprived) to decile 10 (most deprived) based on prescribed criteria by Statistical Area 1 using averaged data (Statistics NZ, 2018). Figure 3.11 shows that a large proportion of South Dunedin is classified as 'most deprived'. However, it is worth noting that there are also portions of South Dunedin that are decile 1 and 2 (richest 20% of New Zealand), particularly focused around the St Clair area. The median income for people in South Dunedin is $26,000 which is slightly higher when compared to the wider Dunedin area ($25,500). However, when considering those with an income of greater than $70,000, South Dunedin has a lower percentage with 9%, compared to the rest of Dunedin (14%).

[20] Population and demographic information is based on 2018 Census data as this was available at the time of analysis (June – December 2024).

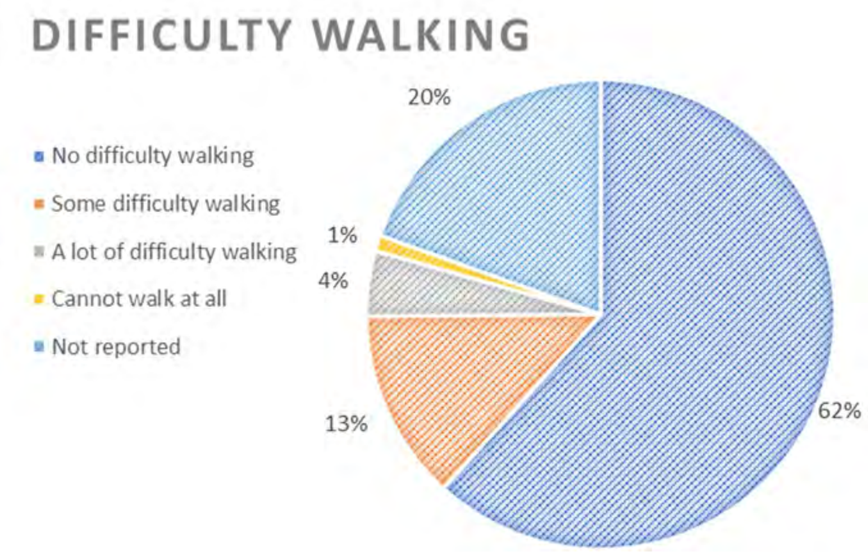


Figure 3.9 Proportion of population with a disability within South Dunedin (Statistics NZ, 2018)

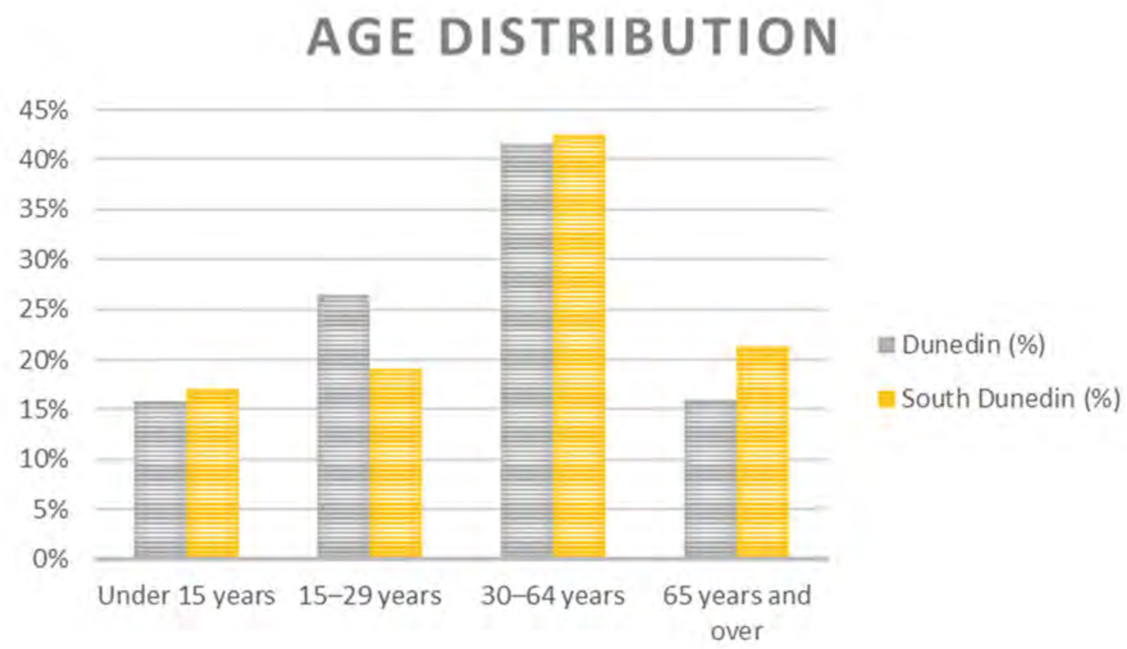


Figure 3.10 Age distribution of population within South Dunedin (Statistics NZ, 2018)

3.3.3.1.2 Vulnerable groups within social demographics

South Dunedin has a higher population of vulnerable groups than the wider Dunedin area. For the purpose of this assessment, these groups are considered to be those with disabilities, in rental accommodation, over 65 years old, or classified as having higher Social Deprivation Index. The population distribution across South Dunedin of these groups is shown in Figure 3.11 based on Census data (2018) statistical areas (SA1) within the approximate SDF project extent where:

- Social Deprivation provides one example of a measure of social vulnerability across communities. The Index ranks locations on a scale of decile 1 (least deprived) to decile 10 (most deprived) based on prescribed criteria by Statistical Area 1 using averaged data.

- The number of households in South Dunedin living in rental accommodation is roughly 2450, this represents 42% of the South Dunedin households. This group is determined as those who do not own or partly own the home they reside in.
- The population of South Dunedin who experience difficulty communicating is 198, this represents 1.5% of the South Dunedin population. This group is determined by those who have a lot of difficulty or cannot communicate.
- The population of South Dunedin who experience difficulty walking is roughly 770, this represents 6% of the South Dunedin population. This group is determined by those who have a lot of difficulty or cannot walk.
- The population of South Dunedin who are aged over 65 is 2853, this represents 21% of the South Dunedin population.

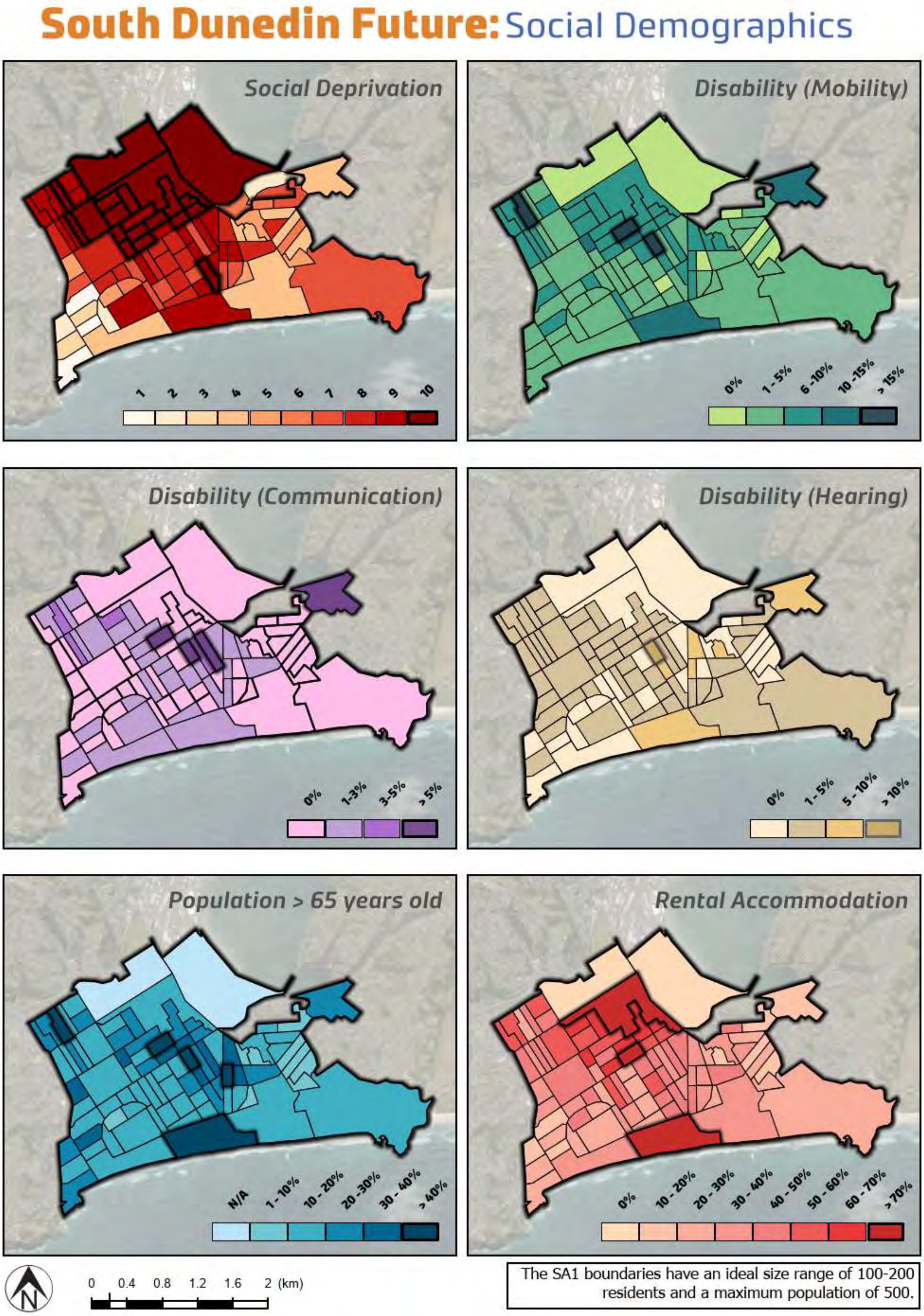


Figure 3.11 Social demographics of South Dunedin showing SA1 unit boundaries (Statistics NZ, 2018).

3.4 ASSESSMENT OF RISK

Risk ratings are presented in two different ways to reflect the two scales at which risk is reported. The two methods are discussed in the following two sub-sections.

3.4.1 ELEMENT LEVEL RISK ASSESSMENT

The direct physical risk is assessed for each element at risk. It is presented using a rating established by assessing exposure and vulnerability for each hazard. The risk categories have been adapted[21] from pORPS (Otago Regional Council, 2022), and are based on the three class matrix shown in Table 3-11. Assets that are not exposed were not processed in the risk assessment and were therefore rated as 'not at risk'.

Element level risk is communicated based on the exposure of elements at risk to a hazard and their unique vulnerability to that hazard. High risks are typically those that are associated with exposure up to a 1% AEP event and an extreme vulnerability rating of a place or asset, or those associated with extreme exposure (i.e. to a 10% AEP event) and a high vulnerability rating of a place or asset.

Medium risks are typically those that are associated with moderate exposure (i.e. up to a 1% AEP event) and a moderate or high vulnerability rating, or extreme exposure (i.e. to a 10% AEP event) with a low or moderate vulnerability rating, or those that are exposed to extremely low probability hazards (i.e. to a >1% AEP event) but are extremely vulnerable.

Low risks are typically those that are associate with exposure to extremely low probability hazards (unless they are extremely vulnerable) or exposed to hazards but with low or very low vulnerability.

Table 3-11. Element level physical risk matrix

Exposure	**Vulnerability**				
	Very low	Low	Moderate	High	Extreme
Extreme	Green	Yellow	Yellow	Red	Red
High	Green	Green	Yellow	Yellow	Red
Moderate	Green	Green	Yellow	Yellow	Red
Low	Green	Green	Green	Green	Yellow
Very low	Green	Green	Green	Green	Yellow

Green = low risk   Yellow = medium risk   Red = high risk

3.4.2 AGGREGATION OF RISK RATINGS

In order to support broader risk reporting needs, an aggregation of risk scores is sometimes required within a larger defined spatial area.

Aggregation of risk ratings has been applied for two spatial extents:

- Risk to Buildings: Aggregated to Statistical Area 1.
- Risk to all elements at risk: aggregated to South Dunedin Future area for summary statistics.

Categories for the aggregated risk reporting were aligned with thresholds used to establish 'severity of impact' in the proposed Otago Regional Policy Statement[22] (RPS) (Otago Regional

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[21] Terminology has been changed 'consequence' is now 'vulnerability', 'likelihood' is now 'exposure'
[22] based on Table 7 from the pORPS.

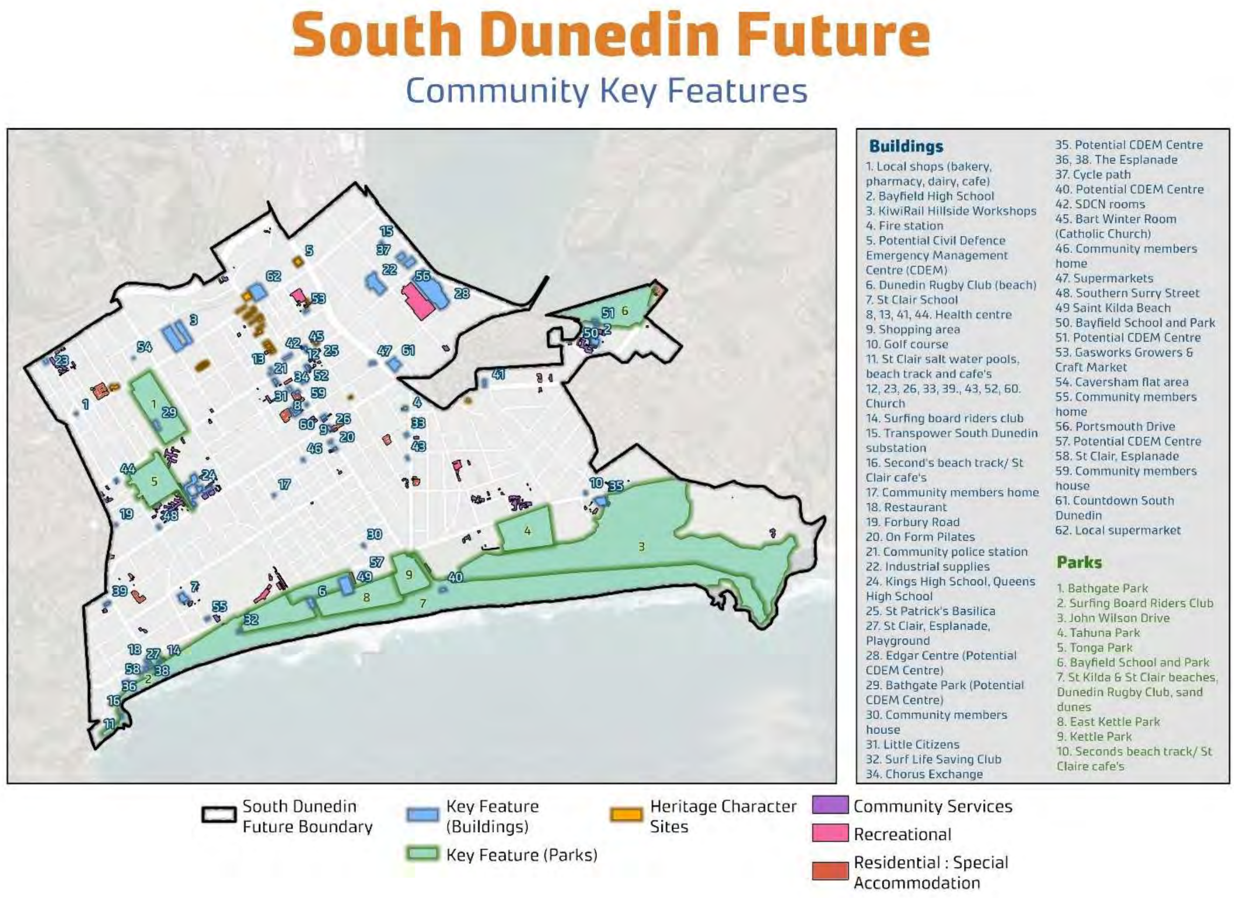
Council, 2022). Within the RPS, these thresholds are used to define the proportion of 'assets that have functionality compromised' and have been interpreted to relate to 'medium' and 'high' risk categories within this risk assessment. The categories, thresholds and colour schemes used to communicate risk are presented in Table 3-12.

Table 3-12 Risk aggregation thresholds

Risk score	Aggregated risk criteria
Very high	≥50% of affected assets within hazard zone have asset level risk rated to be medium or high.
High	21-50% of affected assets within hazard zone have asset level risk rated to be medium or high.
Moderate	11-20% of affected assets within hazard zone have asset level risk rated to be medium or high.
Low	1-10% of affected assets within hazard zone have asset level risk rated to be medium or high.
Not exposed to scenarios assessed	No assets are at risk (due to not being exposed), or <1% of affected assets within hazard zone have asset level risk rated to be medium or high.

3.4.3 HOTSPOT MAPPING OF RISK

Illustrating all risks to all elements in a single graphic can be problematic. In the context of this risk assessment, such a graphic will need to show 66 different yet often overlapping risks (one for each of



. underground utilities generally follow the same transport corridor as roads), so they offer a useful overview and can act as a proxy for identifying risk hotpots.

Hotspot maps have been developed to demonstrate an overview of spatial physical risk to South Dunedin. Risk to buildings, roads and parks have been included in the map.

To evaluate the hotspot score, the risk arising from all hazards to each asset (building, road, or park) has been reviewed. The hotspot score is a tally of the number of hazards that have resulted in a high or medium risk rating to the asset (Table 3-13). In each map, risk to the asset is included in the count if it is rated high or medium at any scenario within each timeframe. Hotspot maps have been developed for three timeframes.

Table 3-13 Hotspot risk criteria

Hotspot score	Hotspot risk criteria
4 hazards	An asset (building, road, or park) is rated at medium or high risk due to 4 hazards*.
3 hazards	An asset (building, road, or park) is rated at medium or high risk due to 3 hazards*
2 hazards	An asset (building, road, or park) is rated at medium or high risk due to 2 hazards*
1 hazard	An asset (building, road, or park) is rated at medium or high risk due to 1 hazards*
0 hazards	An asset (building, road, or park) is not rated at medium or high risk to any hazards*

*Risk is due to any of the following hazards: coastal inundation, coastal erosion, groundwater, landslide, liquefaction, pluvial flooding)

3.5 IDENTIFICATION OF IMPACTS

Cascading impacts arising from risks to South Dunedin have been identified through community engagement and discussion with subject matter experts (Refer to Appendix B7 for details). Many of the issues identified align with the findings of previous in-depth research into the cascading impacts of flooding on the South Dunedin community (Harrison, et al., 2022). Findings of this previous study have been incorporated into the discussion of cascading impacts of climate risk on South Dunedin. Findings are presented through a description of impacts, casual maps, and where available, relevant supporting data is presented spatially.

Refer to the South Dunedin Future Engagement Report: Risk and Long List of Adaptation Approaches for details of the engagement activities.

4 MANA WHENUA RISK ASSESSMENT

A mana whenua risk assessment has been undertaken for the South Dunedin Future programme, which has identified and rated risks through a Kāi Tahu lens. Based on an analysis of cultural values, it takes a broad approach to risk. As well as risks to specific places and features important for the cultural associations to mana whenua, it considers risks to Kāi Tahu perspectives and values relating to wider environmental, social and economic factors in South Dunedin. This mahi was facilitated by Aukaha with guidance and validation from a panel of Kāi Tahu mana whenua representatives.

The mana whenua risk assessment has shown that, there is substantial risk resulting from a 'keep doing what we are doing' scenario, where there are no additional interventions to address the issues facing South Dunedin. Risk to the key Te Taki Haruru values is generally significant, ranging from high (mana, whakapapa, tapu & noa) to extreme (mauri) levels of risk. These results outline the case for change in response to the modelled natural hazards and climate risks.

A more detailed summary of the mana whenua risk assessment inputs, methodology, and findings is included in Appendix D of this report. A similar exercise has been undertaken within the companion workstream on adaptation options, where mana whenua values are also integrated into the criteria for assessing potential options for mitigating the risks identified in this report.

5 DIRECT PHYSICAL RISK ASSESSMENT RESULTS

This section of the report presents the direct physical risks to eleven of the twelve *elements at risk* in South Dunedin arising from coastal inundation, coastal erosion, pluvial flooding, groundwater, landslide and liquefaction. Risks to Mana Whenua (the twelfth *element at risk*) are discussed in Section 4. The subsequent section (Section 6) discusses the impacts resulting from the direct physical risk.

5.1 RISK TO BUILDINGS AND RESIDENTS

There are 4796 property parcels across the South Dunedin Future area of interest. Within these, there are 9091 buildings located on the properties, and 7990 buildings are located on land zoned for residential land use. Many properties have one or more buildings on them, and the maximum number of buildings on a single property is 52. All buildings are assessed, which also include non-habitable buildings (e.g. sheds, garages).

Key features used to understand 'building' assets include:

- Residents and community members.
- Residential buildings.
- Non-residential buildings:
  - Commercial.
  - Schools and other educational facilities.
  - Church.
  - Built Heritage (heritage zoning).
  - Sports clubs (members tend to be very attached to home turf, could move fields but could not relocate clubs).
  - Sport facilities.
- Important or essential buildings (as identified by the community).

Risk is assessed and analysed through the following lenses:

- Risk to all buildings aggregated to Statistical Area 1.
- Risk to buildings presented by building use.
- Risk to important or essential buildings of South Dunedin.
- Risk to residents of South Dunedin presented by considering building risk alongside the social demographics of Statistical Areas.
- Property values of buildings at risk.

Further discussion on impacts and interconnections between these is contained in Section 5.8. Further detail regarding building vulnerability is contained in Appendix C.

5.1.1 RISK TO BUILDINGS

Figure 5.1 shows the percentage of buildings at risk within South Dunedin, and how this changes over time with each hazard. Spatial representation of risk to buildings is shown in Figure 5.19, Figure 5.21, Figure 5.22, and Figure 5.23.

Of the 9091 buildings in South Dunedin pluvial flooding poses the highest rated risk at the present day and steadily increases over time. At the present day, pluvial flooding poses a high risk to 23% (2070 buildings) of buildings. At the late century under a high end climate scenario pluvial flooding, groundwater and coastal inundation pose a high risk to large proportion of the building stock (47% (4250) buildings, 78% (7110) buildings, and 83% (7562) buildings respectively).

Buildings at high and moderate risk due to groundwater may not be habitable over the long term. These buildings will be exposed to extremely high (shallower than 0.3 m below ground level) or emergent groundwater which can cause instability in building foundations, lead to issues of dampness and mould in housing, and may cause various environmental problems such as pollution and salinity stress in properties.

A small proportion of buildings are rated high risk due to coastal erosion[23] and landslide at present day. At late century 2% (151) buildings are rated to be at high risk due to coastal erosion. Landslide poses a risk to 2% (161) of buildings.

Buildings at high or medium risk to pluvial flooding and coastal inundation are those that have floor levels exposed to flooding during 10% AEP (high risk) and 10%-1% AEP (medium risk) events. These buildings are expected to sustain damages resulting in the building being uninhabitable for longer than one month following an event. Flooding above building floor levels can cause the need for extensive repairs and can lead to complete loss or damage to buildings. South Dunedin has a high proportion of ageing and poor condition buildings, which are particularly sensitive to flood damage and the chronic effects of high groundwater.

Modelled flood depths associated with the 1% AEP coastal and pluvial flood events at building footprint locations are summarised in Figure 5.2 and Figure 5.3 respectively. This shows the number of buildings exposed to each flood depth band at present day and under available climate change scenarios. At present day, buildings are exposed to a range of pluvial flood depths during a 1% AEP event. These depths reach over 0.55 m in places, with most flood depths ranging between 0.05 m and 0.3 m. At late century under a high end climate scenario these depths increase in range with more buildings exposed to deeper flood depths. At late century under a high end climate scenario the majority of buildings exposed during a 1% coastal inundation scenario are modelled to experience flood depths greater than 0.5 m, with a small number at greater than 2 m depth[24].

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[23] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

[24] This is potentially a conservative depth. The limitations of the coastal inundation modelling are discussed in Section 2.5.

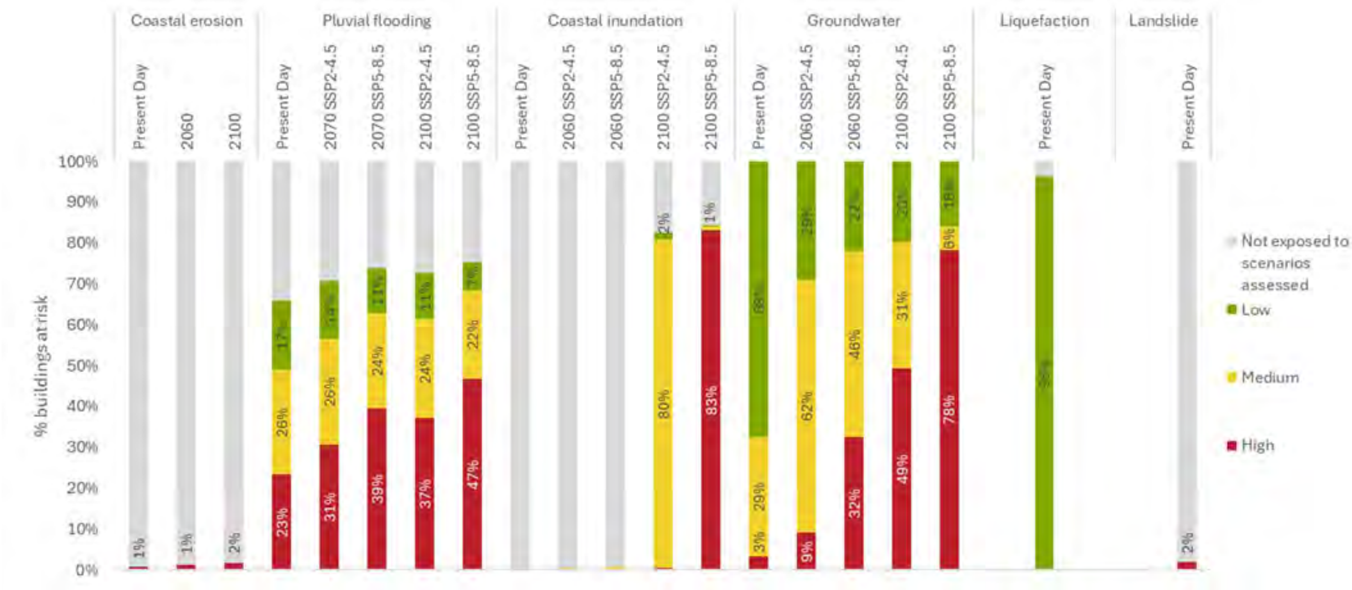


Figure 5.1 Risk to all buildings within South Dunedin presented as percentage of buildings (by number) at each risk rating[25]

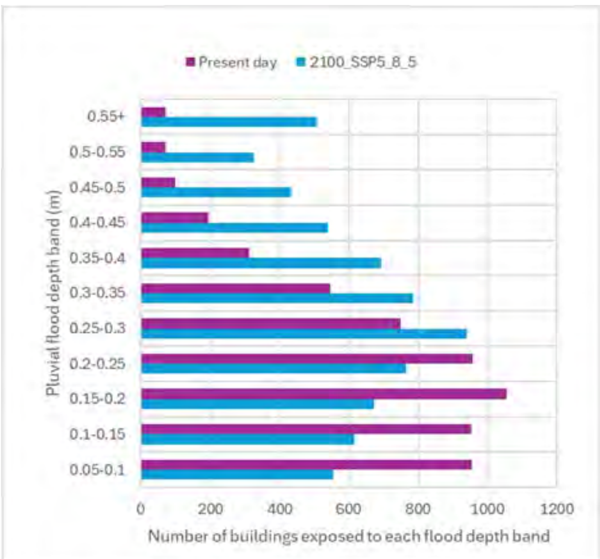


Figure 5.2 Number of buildings exposed to flood depth bands for pluvial flooding. Zero flood depth excluded

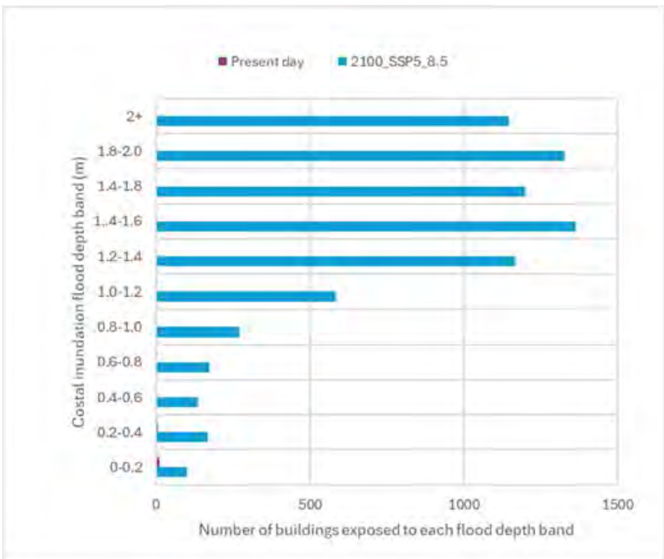


Figure 5.3 Number of buildings exposed to flood depth bands for coastal inundation. Zero flood depth excluded

5.1.1.1 RISK TO IMPORTANT OR ESSENTIAL BUILDINGS

South Dunedin is home to a range of important community buildings including churches, community halls, medical centres, rest homes, parks, recreational grounds, heritage structures and social housing (Figure 5.5). 65 specific buildings were identified through community and subject matter expert engagement, with a further 340 buildings included on account of having

[25] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

heritage classification, being a community facility, or an aged care facility (use category: 'special accommodation'). Risk to key features follows similar trends to the wider building stock..

The combined high and medium risk to important buildings is shown for present day and at late century scenarios under high-end climate projections (Figure 5.4). The number of buildings in each building use category is summarised in Table 5-1. This figure shows that by late century, most important buildings are rated at high or medium risk due to pluvial flooding, coastal inundation and groundwater rise regardless of their use.

High or medium risk to important buildings indicates they are likely to be uninhabitable in the long term due to the effects of groundwater, and/or may be uninhabitable for extended periods following increasingly frequent pluvial flooding and coastal inundation events. The short and long term loss of these important buildings is likely to have wide ranging impacts on the community. These are discussed further in Section 6.

Table 5-1 Categories of important buildings within South Dunedin and associated risk at 2100

Building use category	Number of buildings within each category[1]	Percentage at high or medium risk by late century		
		Pluvial flooding	Groundwater	Coastal inundation
Church	32	94%	97%	94%
Commercial	968	66%	73%	82%
Residential	7972	69%	86%	84%
Residential Institution (e.g. rest homes)	18	67%	78%	83%
School	97	45%	63%	74%

[1] summary excludes 4 null values

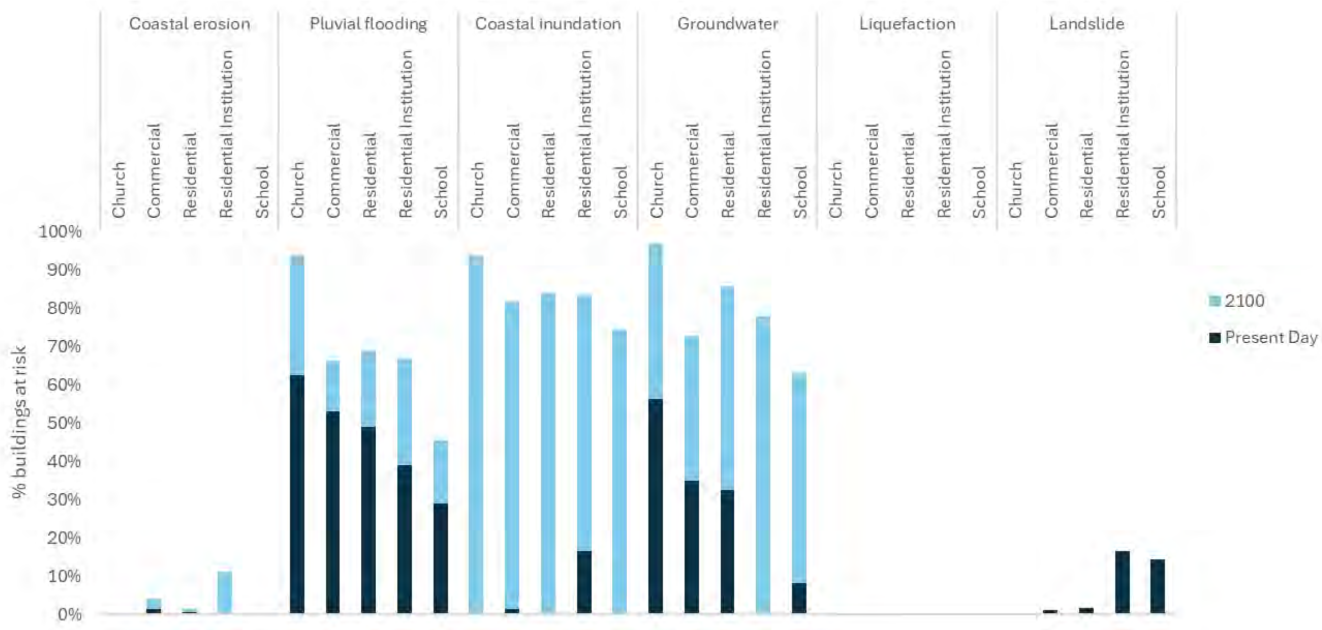


Figure 5.4 Risk to buildings showing percentage of important buildings in each building use category at either medium or high risk at present day and 2100 (note that no future timeframe information is available to evaluate liquefaction and landslide risk)

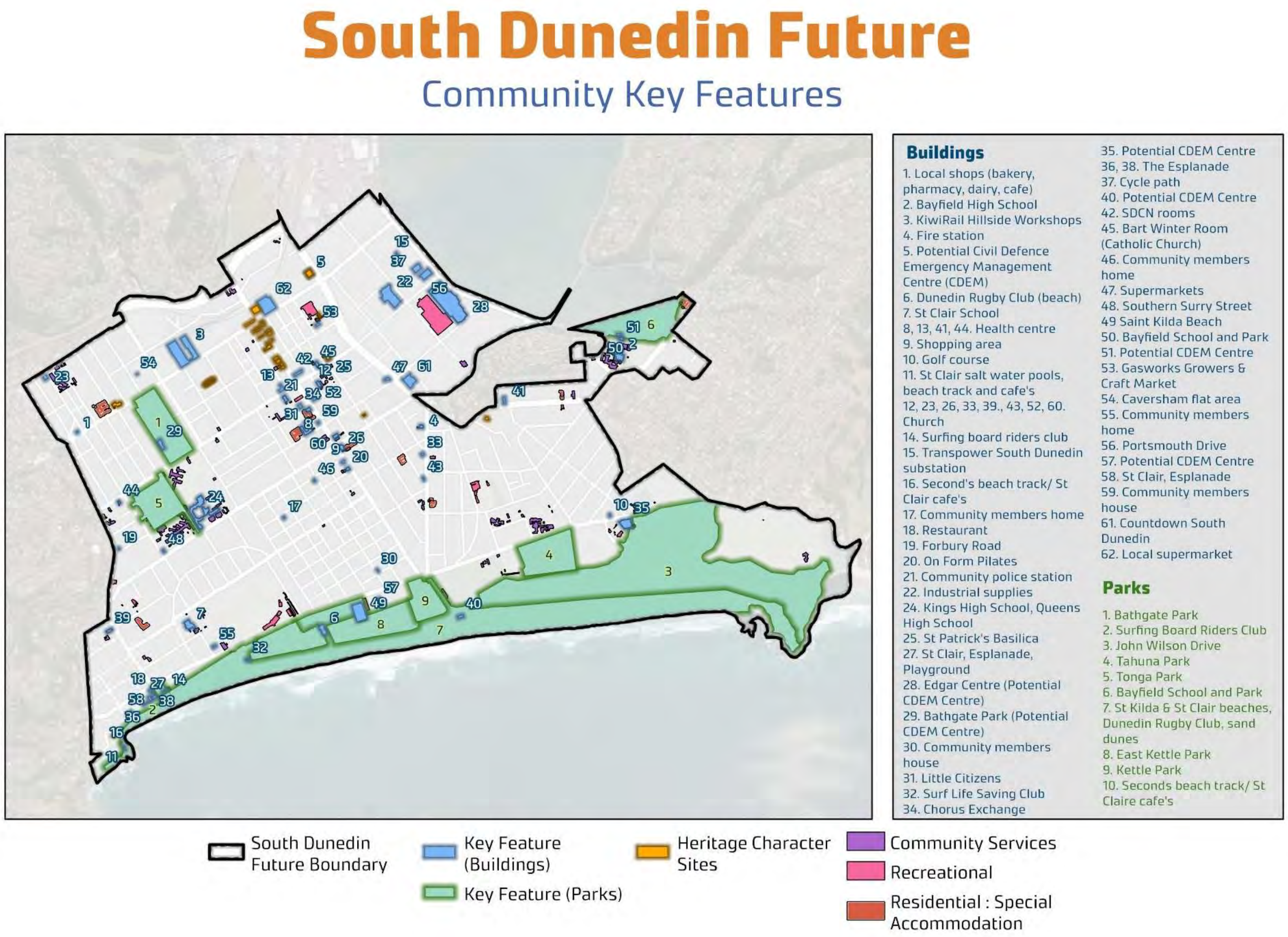
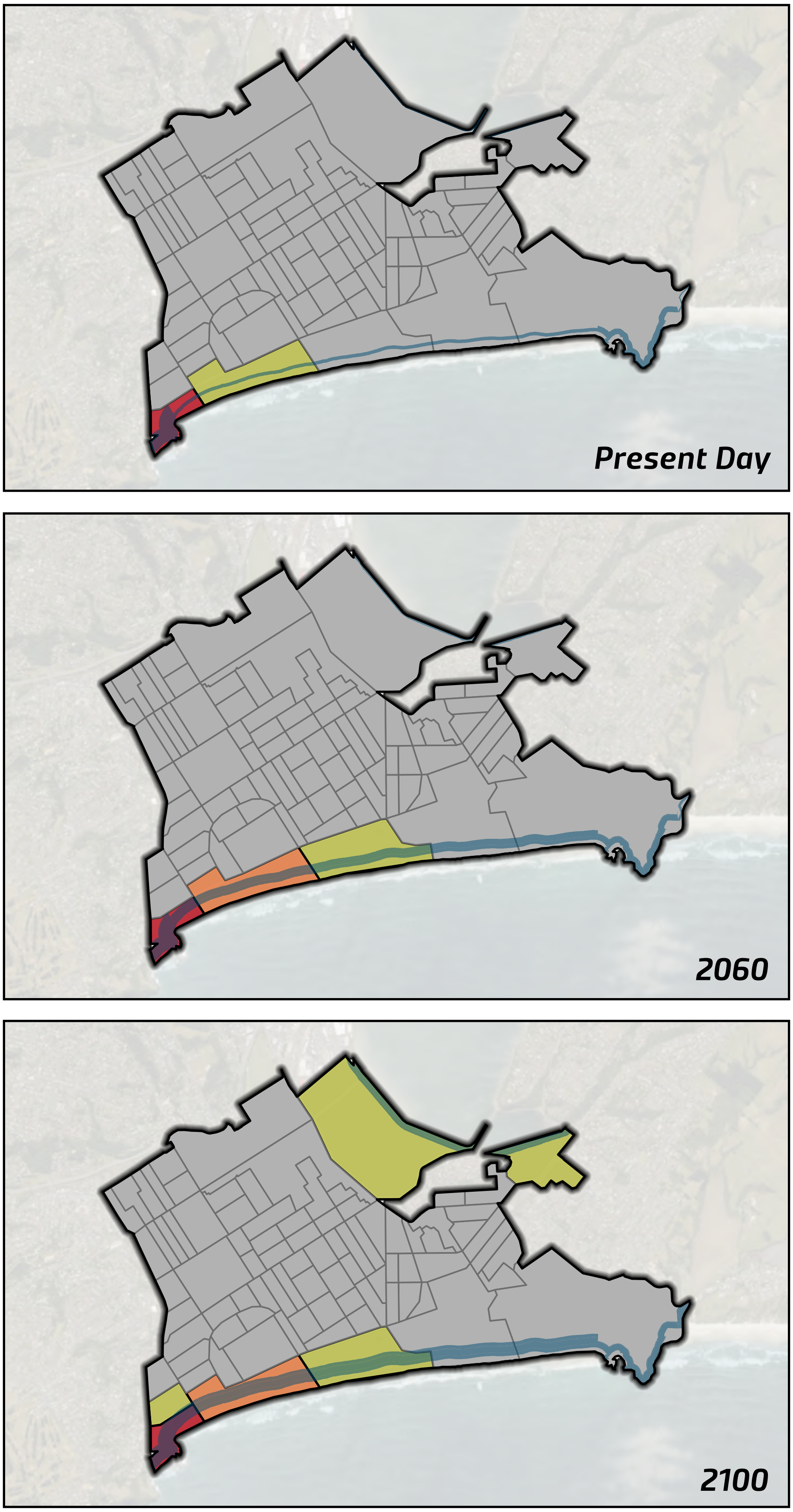


Figure 5.5 Key features and important buildings within South Dunedin

Figure 5.6 Building risk due to coastal erosion aggregated to SA1 units



Explainer: These maps show the risk to buildings due to coastal erosion (blue shading), where risk ratings for individual buildings have been aggregated up to SA1 area level, to reflect available information and confidence levels. The maps indicate that coastal erosion risk to buildings is confined to the St Clair-St Kilda coastline at present day and mid-century, with higher risk of erosion at the St Clair end of the beach. There is a high level of uncertainty regarding coastal erosion risk due to data limitations at present e.g. scale of screening study and accounting for the impact of engineered structures). More detailed coastal hazard assessments are underway as part of the St Clair-St Kilda Coastal Plan, these will be completed in late-2025, after which the coastal erosion risk ratings will be reviewed.

Disclaimer: The aggregation or site specific risk supports the purposes of the South Dunedin Risk Assessment, including by enabling adaptation planning at a suburb-level, however it is not intended to assess risk at an individual building level – which requires more detailed hazard data and consideration of a range of building-specific factors (e.g. foundation type).

Hazard data source: WSP, 2024

South Dunedin Future Boundary

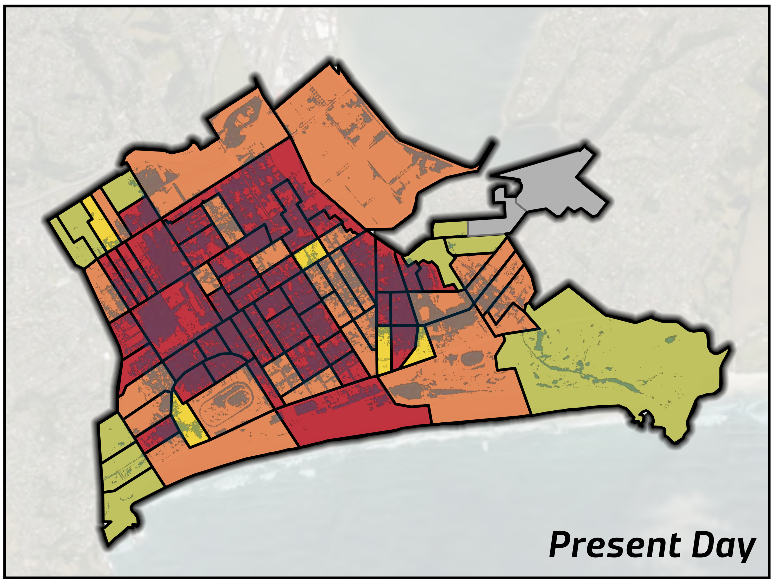
Coastal erosion

0 0.4 0.8 1.2 1.6 2 (km)

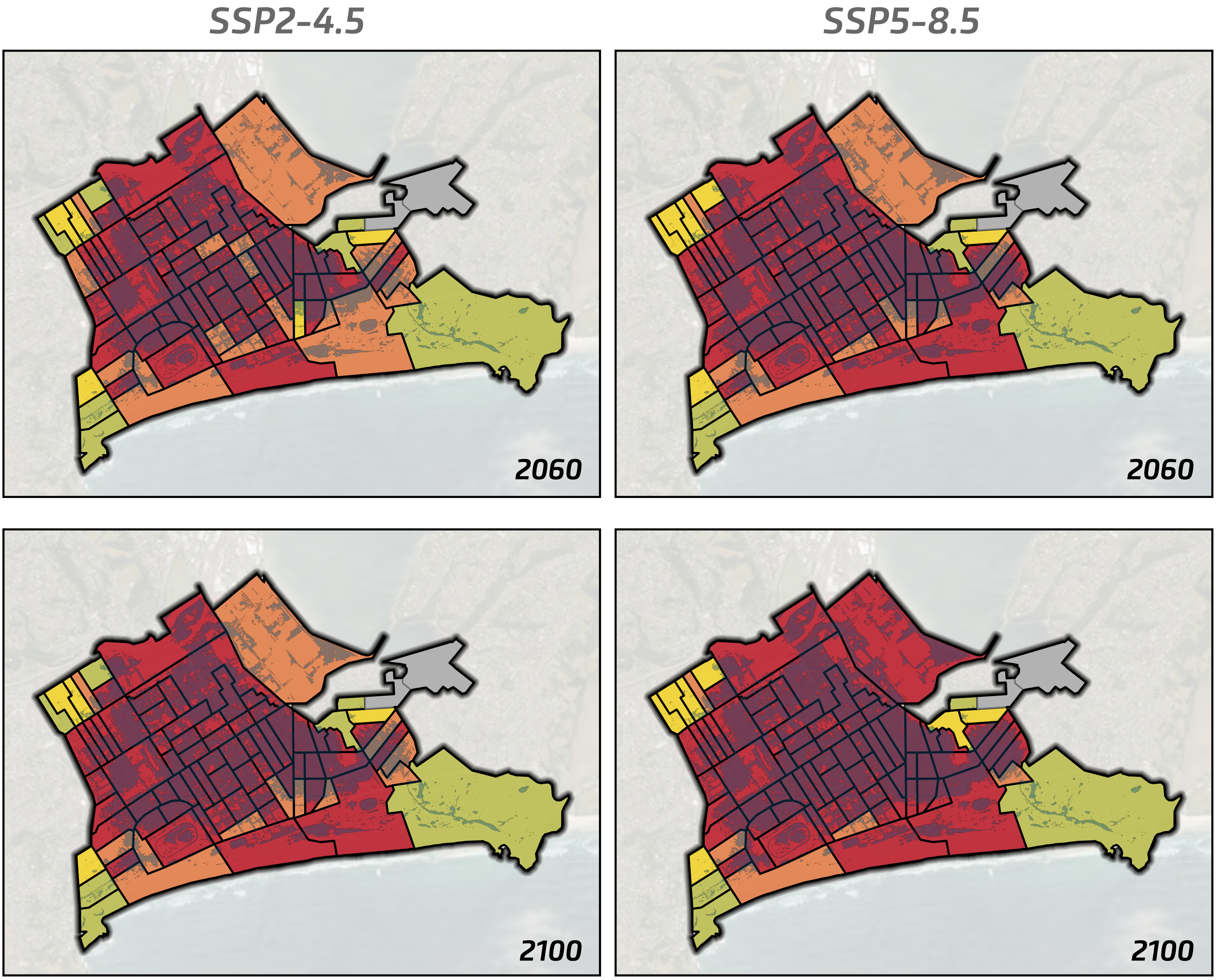
N

Building (SA1 Boundary) Risk					
Risk Description	Very High	High	Moderate	Low	Not Exposed
Percentage of buildings in SA1 area located within a coastal erosion zone (high risk).	≥ 50%	21% - 49%	11% - 20%	1% - 10%	< 1%

Figure 5.7 Building risk due to pluvial flooding aggregated to SA1 units



Explainer: These maps show the risk to buildings due to pluvial flooding (blue shading), where risk ratings for individual buildings have been aggregated up to SA1 area level, to reflect available information and confidence levels. The maps illustrate pluvial flood risk is already medium or high for most SA1 areas in South Dunedin, expanding to nearly all SA1 areas by 2100, particularly on The Flat. Flooding above floor level can result in significant damage to affected buildings, rendering them temporarily uninhabitable and in need of extensive and costly repairs. Flood damage can negatively impact building quality, value, and insurability, among other impacts (as outlined in Figure 6.1).
Disclaimer: The aggregation of site specific building risk to SA1 areas supports the purposes of the South Dunedin Risk Assessment, including by enabling adaptation planning at a suburb-level. However, it is not intended to assess risk at an individual building level – which requires consideration of a range of building-specific factors (e.g. floor level, construction material, building age, adjacent property, etc).
Hazard data source: DCC ICMP Flood Model (Beca, WSP, 2024)



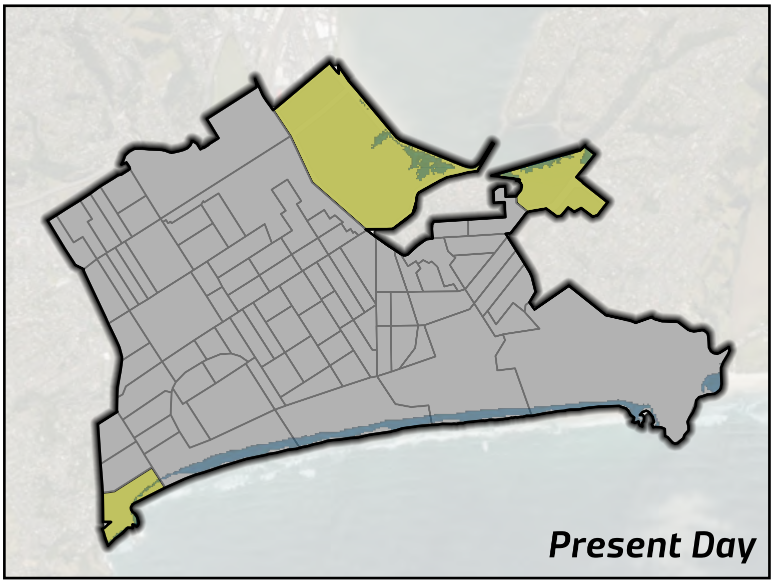
South Dunedin Future Boundary

1% AEP pluvial flood extent

0 0.4 0.8 1.2 1.6 2 (km)

Building (SA1 Boundary) Risk					
Risk Description	Very High	High	Moderate	Low	Not Exposed
Percentage of buildings in SA1 area rated high or medium risk for flooding above floor level in 10% AEP event (high) and 10-1% AEP event (medium)	≥ 50%	21% - 49%	11% - 20%	1% - 10%	< 1%

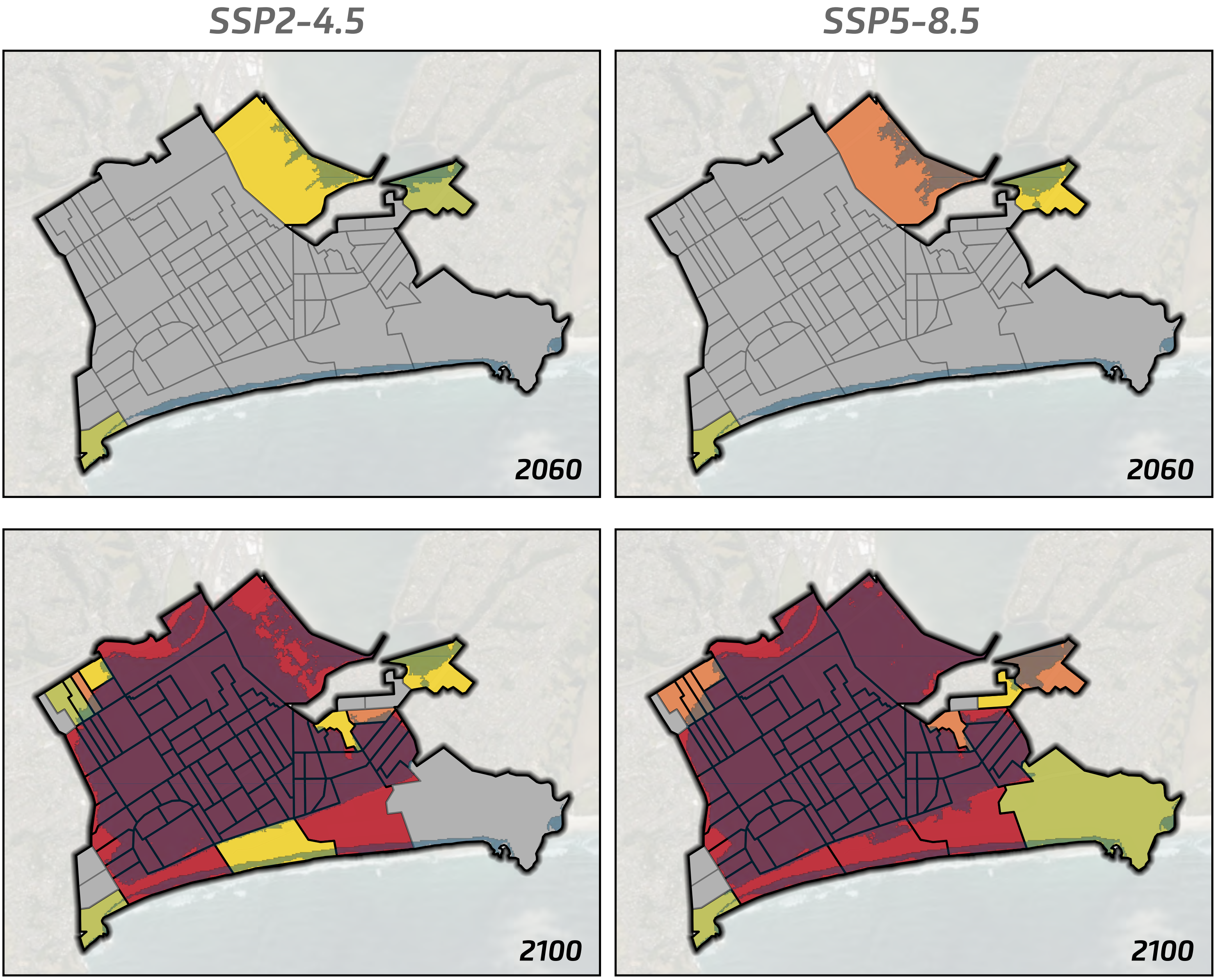
Figure 5.8 Building risk due to coastal inundation aggregated to SA1 units

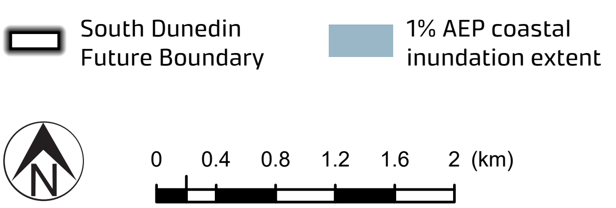


Explainer: These maps show the risk to buildings due to coastal inundation (blue shading), where risk ratings for individual buildings have been aggregated up to SA1 area level, to reflect available information and confidence levels. The maps illustrate a small area of low coastal inundation risk near the Portsmouth Drive and St Clair coastal edge at present day, with risk around Portsmouth Drive increasing to moderate and high at mid-century. At late century, coastal inundation rises to very high across the majority of South Dunedin due to potential overtopping at Portsmouth Drive flowing into The Flat. Flooding by salt water can result in significant damage to affected buildings, rendering them temporarily uninhabitable and in need of extensive and costly repairs. Flood damage can negatively impact building quality, value, and insurability, among other impacts (as outlined in Figure 6.1).

Disclaimer: The aggregation of site specific building risk to SA1 areas supports the purposes of the South Dunedin Risk Assessment, including by enabling adaptation planning at a suburb-level. However, it is not intended to assess risk at an individual building level – which requires consideration of a range of building-specific factors (e.g. floor level, construction material, building age, etc).

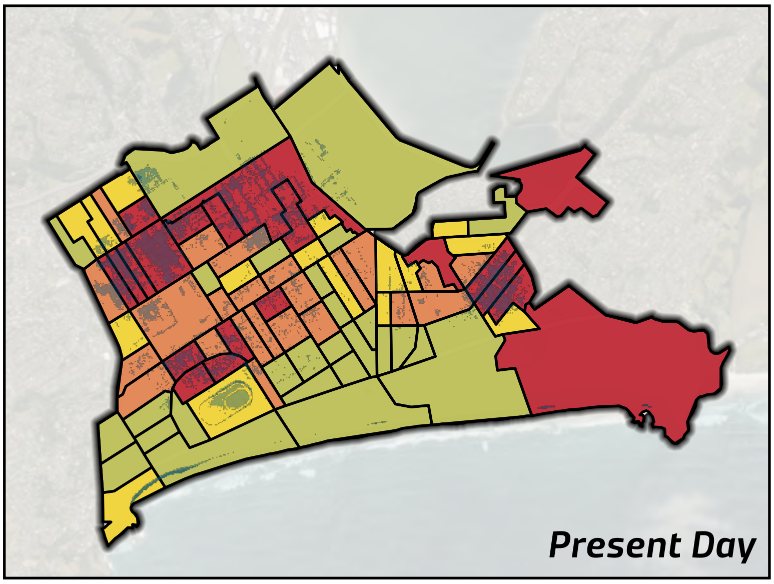
Hazard da**ta source:** Paulik, et al., 2023





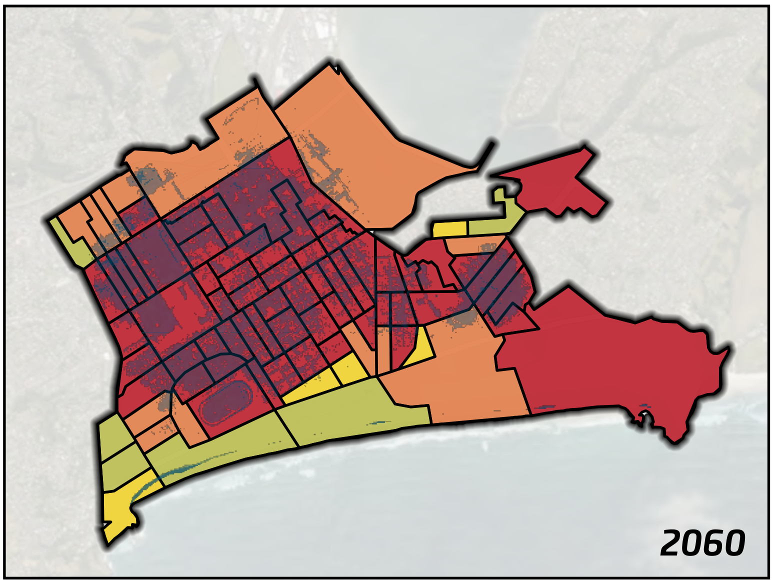
Building (SA1 Boundary) Risk					
Risk Description	Very High	High	Moderate	Low	Not Exposed
Percentage of buildings in SA1 area rated high or medium risk for flooding above floor level in 10% AEP event (high) and 10-1% AEP event (medium)	≥ 50%	21% - 49%	11% - 20%	1% - 10%	< 1%

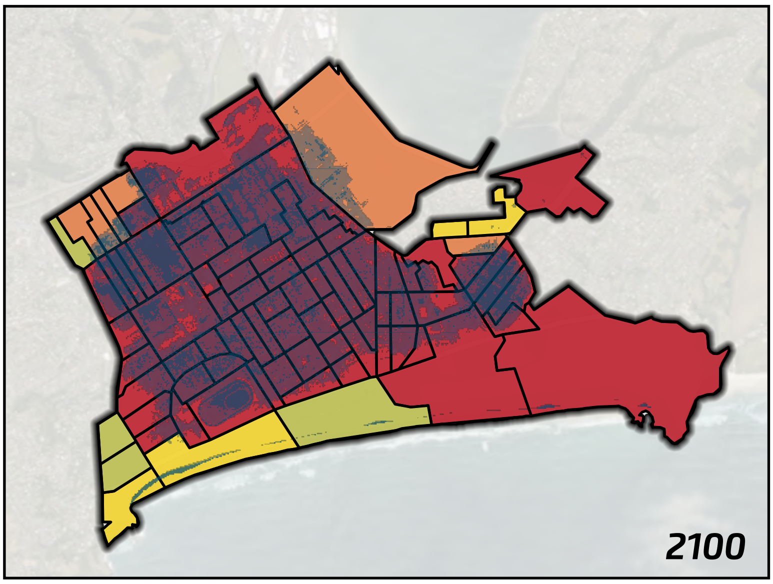
Figure 5.9 Building risk due to groundwater aggregated to SA1 units



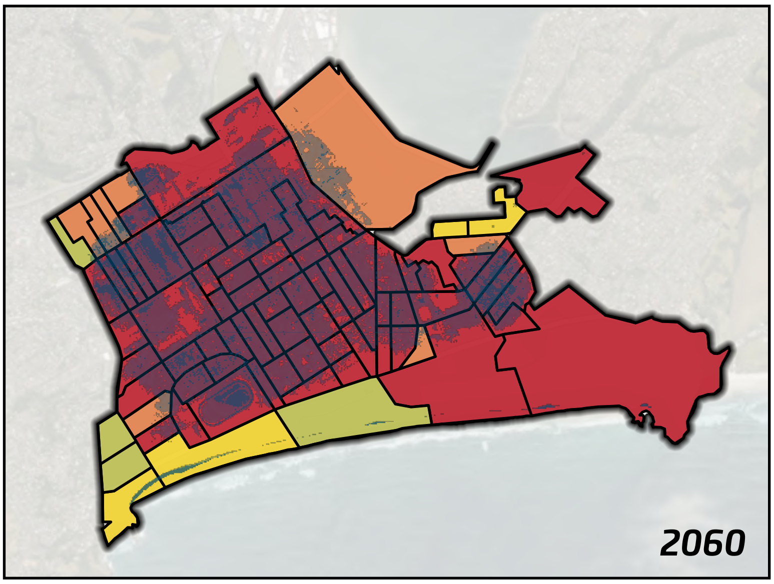
Explainer: These maps show the risk to buildings due to groundwater hazard (blue shading), where risk ratings for individual buildings have been aggregated up to SA1 area level, to reflect available information and confidence levels. The maps illustrate groundwater risk is already medium or high for many SA1 areas in South Dunedin, expanding to nearly all SA1 areas by 2100, particularly on The Flat. High risk to buildings is driven by exposure to emergent groundwater (dark blue shading), which can cause instability in building foundations, lead to issues of dampness and mould in housing, and may cause various environmental problems such as pollution and salinity stress in properties. Where groundwater is high but not yet emergent (light blue shading), groundwater is unlikely to damage building condition, but will impact the liveability of homes. These issues can negatively impact building quality, value, and insurability, among other impacts (as outlined in Figure 6.1).
Disclaimer: The aggregation of site specific building risk to SA1 areas supports the purposes of the South Dunedin Risk Assessment, including by enabling adaptation planning at a suburb-level. However, it is not intended to assess risk at an individual building level – which requires consideration of a range of building-specific factors (e.g. floor level, moisture barriers, etc).
Hazard data source: Cox, et al., 2023

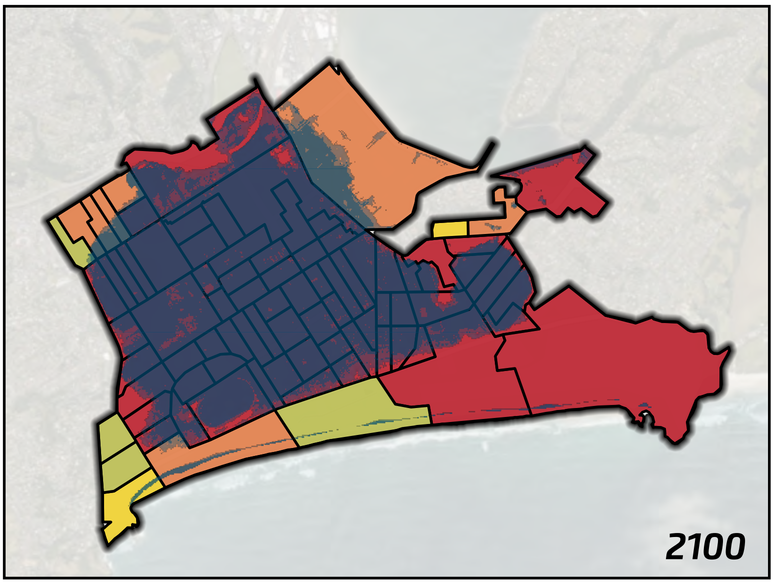
SSP2-4.5





SSP5-8.5





South Dunedin Future Boundary

Emergent groundwater (median)

Median groundwater level (at 0.5 m below ground level)

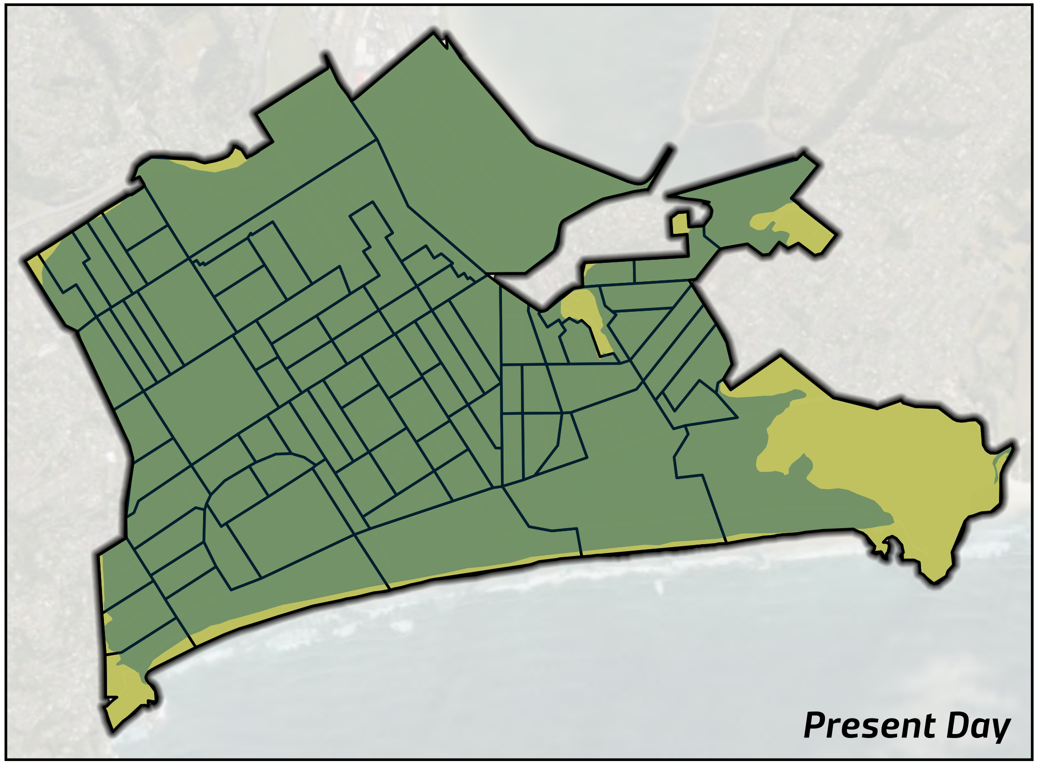
N

0 0.4 0.8 1.2 1.6 2 (km)

Building (SA1 Boundary) Risk					
Risk Description	Very High	High	Moderate	Low	Not Exposed
Percentage of buildings in SA1 area rated high or medium risk for emergent groundwater (high), groundwater within 0.5 m of surface (medium).	≥ 50%	21% - 49%	11% - 20%	1% - 10%	< 1%

Figure 5.10 Building risk due to landslide and liquefaction aggregated to SA1 units

Liquefaction

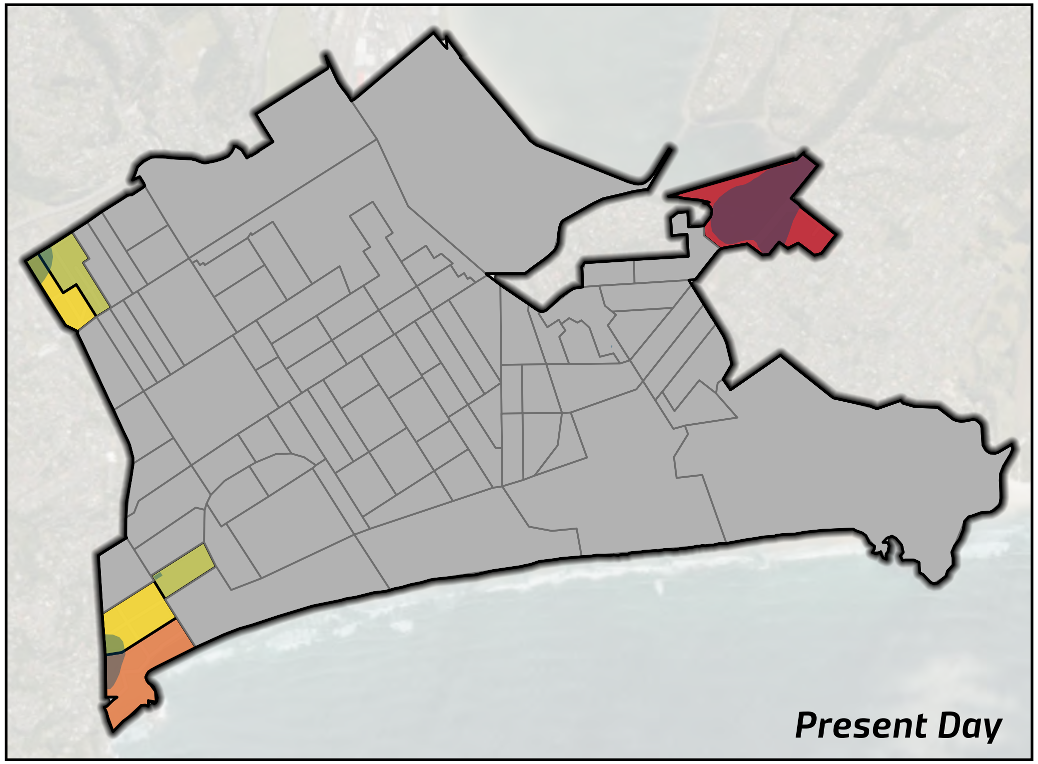


Explainer: These maps show the risk to buildings due to liquefaction (blue shading), where risk ratings for individual buildings have been aggregated up to SA1 area level, to reflect available information and confidence levels. The maps illustrate liquefaction risk is low across South Dunedin at the present day. Liquefaction risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of sea level rise on liquefaction potential. If it were to occur, liquefaction can cause differential settlement and lateral spreading that distorts structures, reduces foundation-bearing capacity, and damages pile supports and service connections. Liquefaction damage can negatively impact building quality, value, and insurability, among other impacts (as outlined in Figure 6.1).

Disclaimer: The aggregation of site specific building risk to SA1 areas supports the purposes of the South Dunedin Risk Assessment, including by enabling adaptation planning at a suburb-level. However, it is not intended to assess risk at an individual building level – which requires consideration of a range of building-specific factors (e.g. foundation design, construction material, building age, etc). Liquefaction hazard information is based on a high level desktop review, where subsequent site specific assessment (Hornblow, 2020) has found that liquefaction potential is highly variable across sites analysed.

Hazard data source: Hornblow, 2020

Landslide



Explainer: These maps show the risk to buildings due to landslide, where risk ratings for individual buildings have been aggregated up to SA1 area level, to reflect available information and confidence levels. The maps illustrate that this type of landslide risk is confined to areas around the South Dunedin boundary. Landslides can severely damage buildings resulting in sudden collapse or failure and posing a potential risk to life. Landslide damage can negatively impact building quality, value, and insurability, among other impacts (as outlined in Figure 6.1). Landslide risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of climate change (groundwater level rising or increased rainfall intensity) on landslide.

Disclaimer: The aggregation of site specific building risk to SA1 areas supports the purposes of the South Dunedin Risk Assessment, including by enabling adaptation planning at a suburb-level. However, it is not intended to assess risk at an individual building level – which requires consideration of a range of building-specific factors (e.g. foundation design, construction material, building age, etc). The landslide extent is based on known landslide areas and does not account for other potential sources of landslide nor represent the extent of the area of deposition/runout.

Hazard data source: DCC Hazard database data provided for South Dunedin Future programme

South Dunedin Future Boundary

Land instability

Liquefaction (Domain C: moderate liquefaction potential)

Building (SA1 Boundary) Risk

Risk Description	Very High	High	Moderate	Low	Not Exposed
Percentage of buildings in SA1 area rated high or medium risk for landslide and liquefaction	**≥ 50%**	**21% - 49%**	**11% - 20%**	**1% - 10%**	**< 1%**

5.1.2 PHYSICAL RISKS TO PEOPLE

The hazards facing South Dunedin have potential to cause direct physical injury as well as causing a range of impacts and cascading risks as discussed in Section 6. Exposure to hazards may cause health impacts such as:

- Damp indoor living and working environments due to high groundwater or flooding. These can cause higher incidence of respiratory diseases such as asthma, hypersensitivity pneumonitis, rhinosinusitis, bronchitis, and respiratory infections.
- Exposure to unsafe and contaminated water (due to wastewater overflows or mobilised contaminants).
- Loss of life or injury due to structural failure of buildings (primarily landslide, coastal erosion, liquefaction).
- Drowning during flooding.
- Risk of injury due to electrocution (primarily due to flooding, landslide, liquefaction.
- Loss of life or injury resulting from mobilised debris or landslides caused by heavy rainfall.
- Injuries from fires started in an event (flooding, landslide, liquefaction).

Risk to people arising from flood hazard are related to flood velocity and depth (Australian Institute for Disaster Resilience, 2014). Very low flood water velocities (typically <0.3 m/s) across South Dunedin due to the flat terrain within South Dunedin. Modelled pluvial flood depths are generally shallower than 0.25 m, with the exception of a few localised areas of greater flood depth. Direct loss of life in low velocity environments (<2 m/s) is unlikely at depths below 0.3 m, Inundation depths indicated in coastal inundation modelling reach 2.5 m in places. Even in a low velocity environment this depth of water would be unsafe for all people exposed (Australian Institute for Disaster Resilience, 2014).

Increasing direct physical risk to the elements at risk of South Dunedin is likely to lead to increased physical harm to people living, working, and using the buildings of South Dunedin. Figure 5.11 shows the proportion of the population living in areas at risk. These values mirror the risk to buildings and show that a large proportion of the usually resident population of South Dunedin live in areas where over 50% of the buildings are rated to have medium or high risk due to groundwater rise and/or coastal inundation by late century.

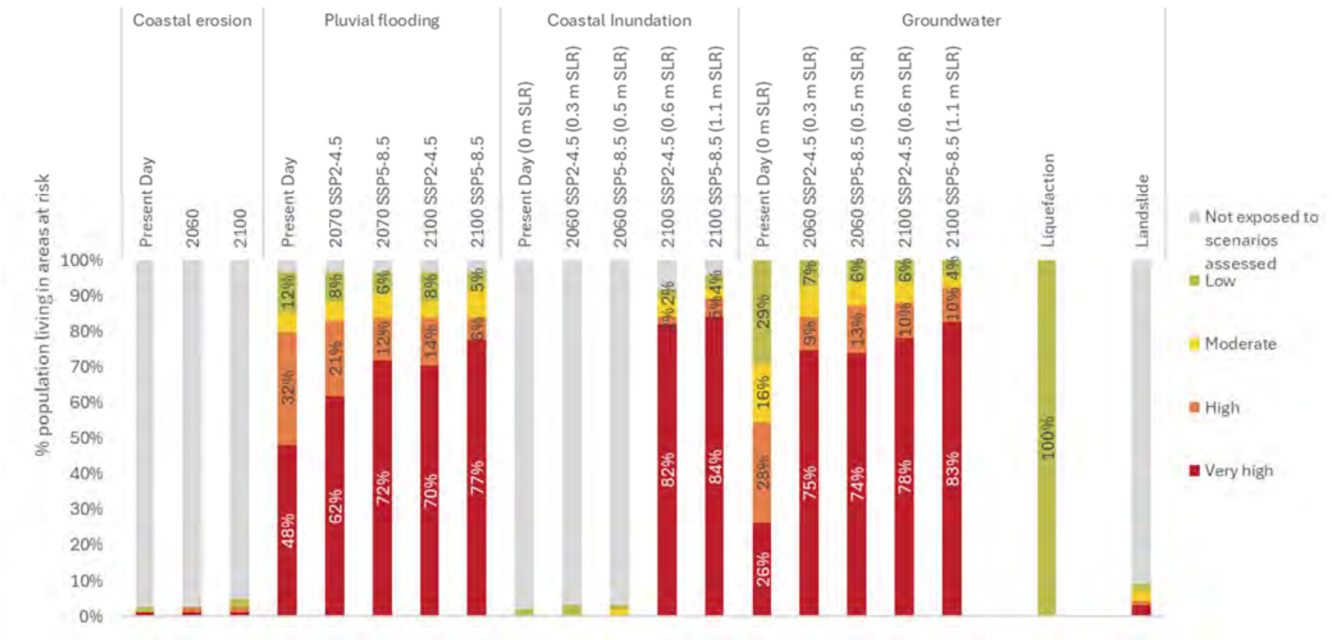


Figure 5.11 Proportion of usually resident population of South Dunedin living in areas at risk (Statistics NZ, 2018)

5.1.2.1 RISK TO VULNERABLE GROUPS

South Dunedin has a relatively high proportion of residents with mobility difficulties, who are over 65, or have other (non-mobility related) disabilities. The proportion of these vulnerable populations living in areas at risk has been analysed. The profile of risk to each group is shown in the series of figures: Figure 5.12 (living in rental accommodation), Figure 5.13 (some difficulty communicating), Figure 5.14 (some difficulty walking), Figure 5.15 (aged over 65).

This analysis shows that a large proportion of the more vulnerable population of South Dunedin live in areas where over 50% of the buildings are rated to have medium or high risk due to groundwater rise and/or coastal inundation by late century. While there are small variations between these subsets of the South Dunedin population, this trend is consistent between all vulnerable groups and with the wider population. The population of more vulnerable groups are distributed widely across South Dunedin (Figure 3.11), and therefore tend to have similar risk profiles to that of the general population.

The people within these groups are likely to be more sensitive to increasing natural hazard risk than the general population. This issue is discussed further in Section 6.2.

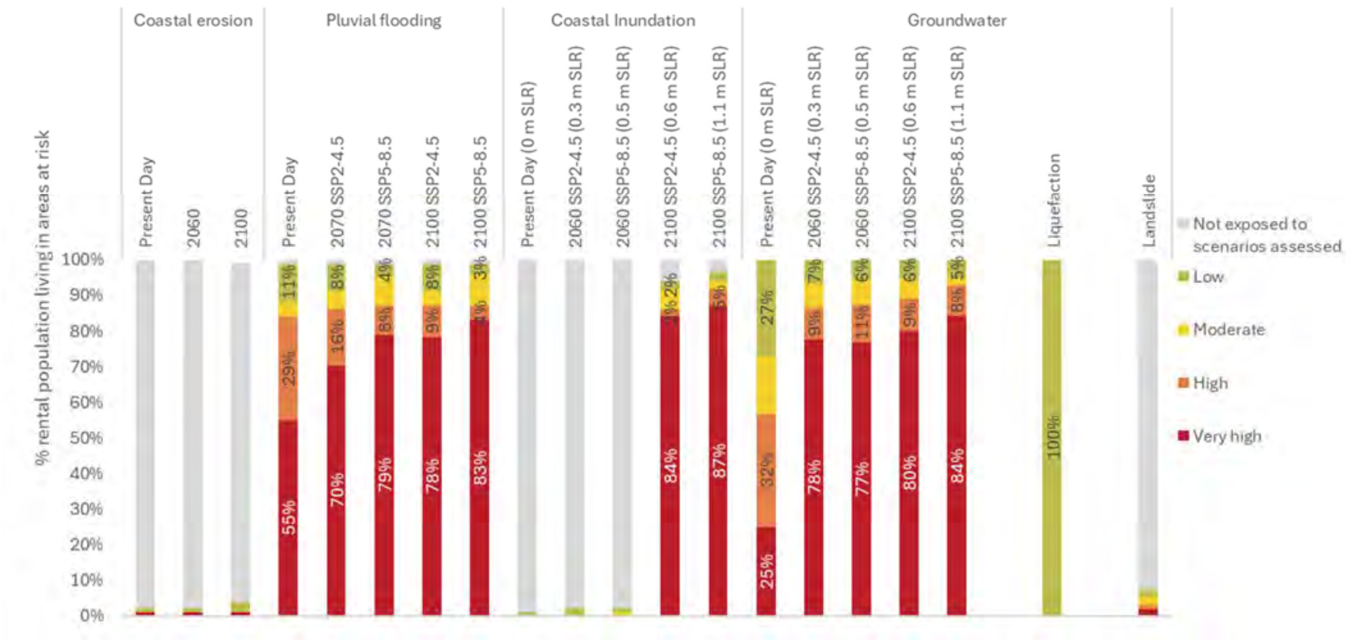


Figure 5.12 Proportion of renters living in areas at risk

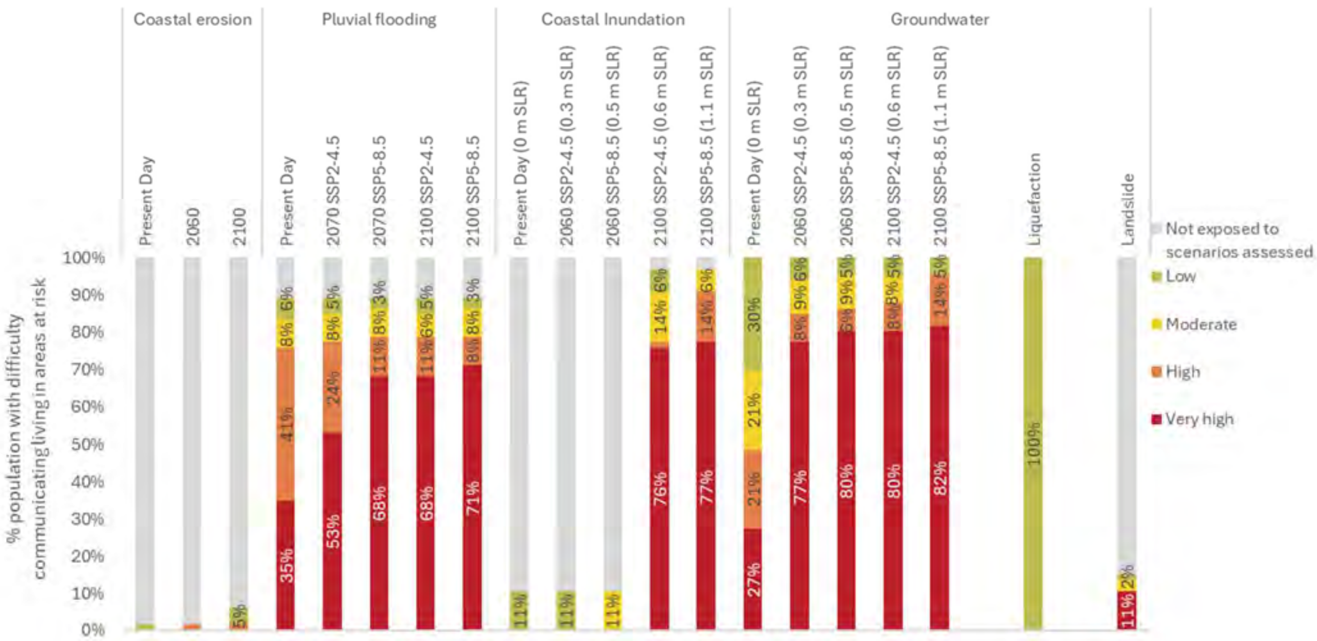


Figure 5.13 Proportion of population with some difficulty communicating living in areas at risk

Figure 5.14 Proportion of population with difficulty walking living in areas at risk

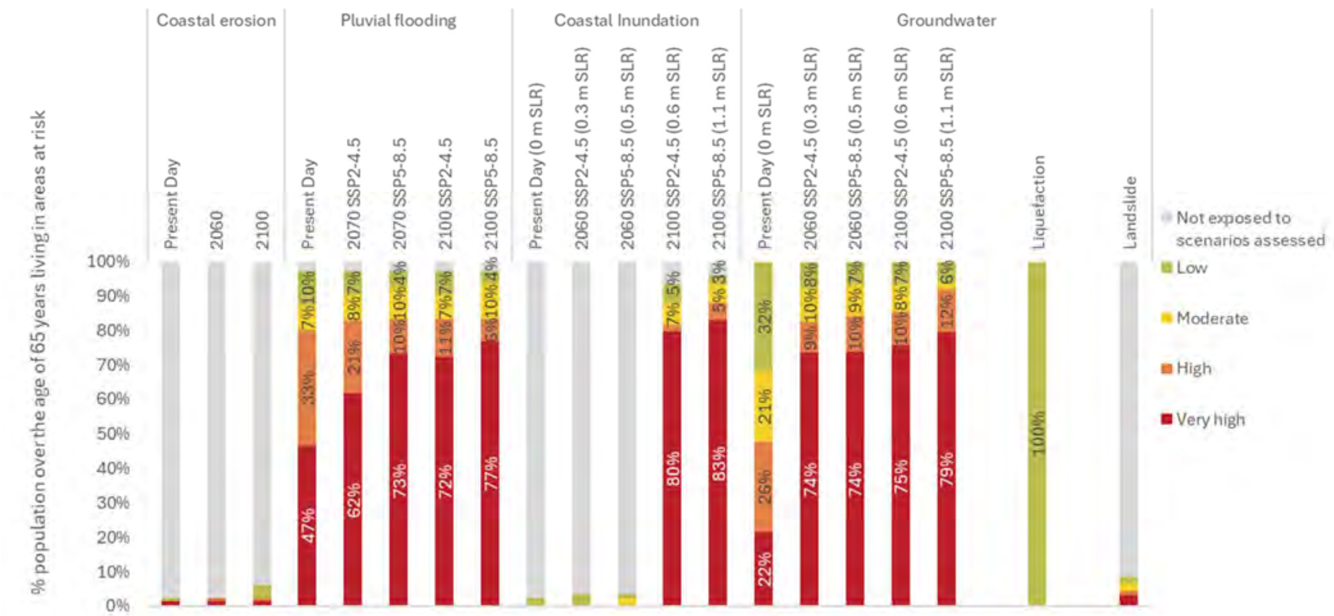


Figure 5.15 Proportion of population aged over 65 living in areas at risk

5.1.3 PROPERTY VALUES

The number of properties in South Dunedin is 4796. Many properties have one or more buildings on them, where the maximum number of buildings on a single property is 52. Of this building stock, the estimated total value is $3.5 billion based on 2023-2024 rateable values.

Figure 5.16 shows the value of properties at risk due to each hazard (values are unadjusted for inflation). These trends are consistent with the proportion of buildings at risk (by number of buildings), as shown in Section 5.1.1.

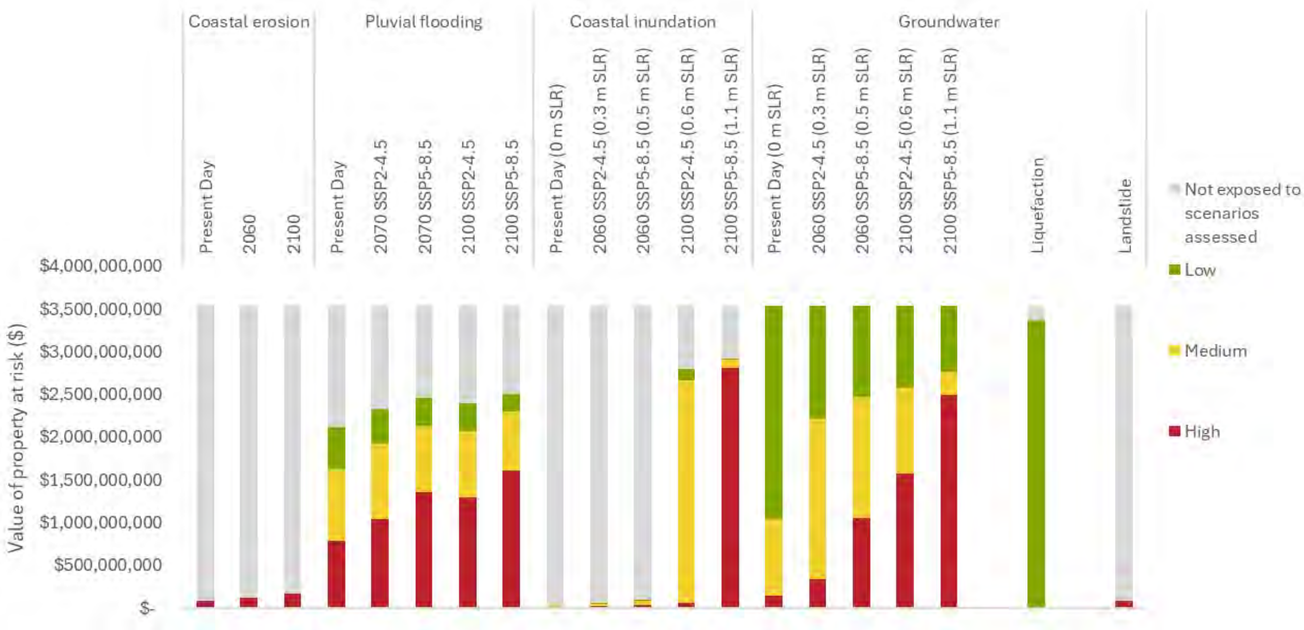


Figure 5.16 Values of properties at risk[26]

5.2 RISK TO PARKS AND SPORTS FIELDS

There are 56 parks and 87 sports fields within South Dunedin (most sports fields are located within parks, and some are overlapping).

The parks and sports fields of South Dunedin were frequently identified as features of high value to the community during in-person engagement sessions. They are also known to provide amenity to the wider Dunedin population because a high proportion of the city's sporting facilities are located within South Dunedin. The total sports field area within the South Dunedin area comprises approximately 230,000 m^2, which is 45% of the entire sports field area of Dunedin (an area of approximately 500,000 m^2). Parks and playing field key features include:

- St Clair - St Kilda beach.
- Tahuna Park.
- Marlow Park (especially the Dinosaur Playground).
- Sports grounds at Bathgate Park, Tonga Park, West Kettle Park, Culling Park.
- Caledonian gym and sporting facilities.

It should be noted that all parks and playgrounds were generically identified as key features of importance through the engagement sessions. Refer Figure 5.5 for locations.

The graphs presented in Figure 5.17 and Figure 5.18 identify how the natural hazard risks to parks and playing fields change over time. Spatial mapping of the risk to parks and playing fields (grouped as 'open space') is shown in Figure 5.19 (risk due to coastal erosion and pluvial flooding), Figure 5.21 (risk due to coastal inundation), Figure 5.22 (risk due to groundwater), and Figure 5.23 (risk due to landslide and liquefaction). Risk ratings are tabulated for the key features in Table 5-2. Further detail regarding parks and sports field vulnerability is contained in Appendix C.

[26] Figures show a count of property values using building footprint risk ratings. No aggregation of risk to SA1 areas has been applied in this calculation

Of the 56 parks within South Dunedin, risk due to groundwater is the only hazard that generates a high rating (Figure 5.17). This high rating occurs at late century under a high end scenario and applies to parks that contain playgrounds (5% of parks).

Of the 87 sports fields[27] within South Dunedin the highest rated risks are due to coastal erosion and groundwater (Figure 5.18)[28]. Groundwater poses a high risk to 15 sports fields at present day, which increases to 40 with a modest increase in sea level rise (0.3 m). Fields that are rated high risk are expected to become permanently unusable. Playing fields that are at high risk are generally those that are within the flat in locations where groundwater is modelled to be above 0.3 m below ground level. When groundwater is permanently this high, it is expected to cause waterlogging of the root zone making the fields unusable. The number of playing fields at high risk due to groundwater stays relatively constant in all future scenarios.

Fields that are rated medium risk due to groundwater at late century are located primarily near the dunes, where groundwater does not become emergent. Fields are moderately sensitive to any rise in groundwater as this is expected to compound the impact of rainfall by making fields more susceptible to waterlogging. The currently high groundwater in South Dunedin means any increase in groundwater or frequency of rainfall is expected to be damaging to fields. Waterlogging of fields is also related to recent rainfall and the frequency of use, where fields can be closed to reduce damage from playing.

Coastal erosion poses a high risk to 17 playing fields under the mid-century scenario which increases to 25 fields in late century[29]. Fields at high risk from coastal erosion may experience direct damage leading to the permanent complete loss of field function. Four of South Dunedin's largest parks; Kettle Park, Tahuna Park, Hancock Park, and Ocean Grove are located along the Coastal Dune area of St Clair, St Kilda and Tomahawk Beaches. Bayfield Park is directly adjacent to the Andersons Bay Harbour Inlet.

Significantly, the fields at risk from coastal erosion are those that are at lower risk due to groundwater. The Ocean Beach Reserve acts as a buffer for the dune system. Parks and playing fields around this area are vulnerable to being buried by shifting dunes, where sand is excavated from these areas at present. The landward migration of the dunes is not included in this assessment (as these areas are not spatially mapped) but may further increase the number of fields at risk.

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[27] Some fields are overlapping due to seasonal arrangement of fields. All fields have been included in this assessment.

[28] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

[29] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

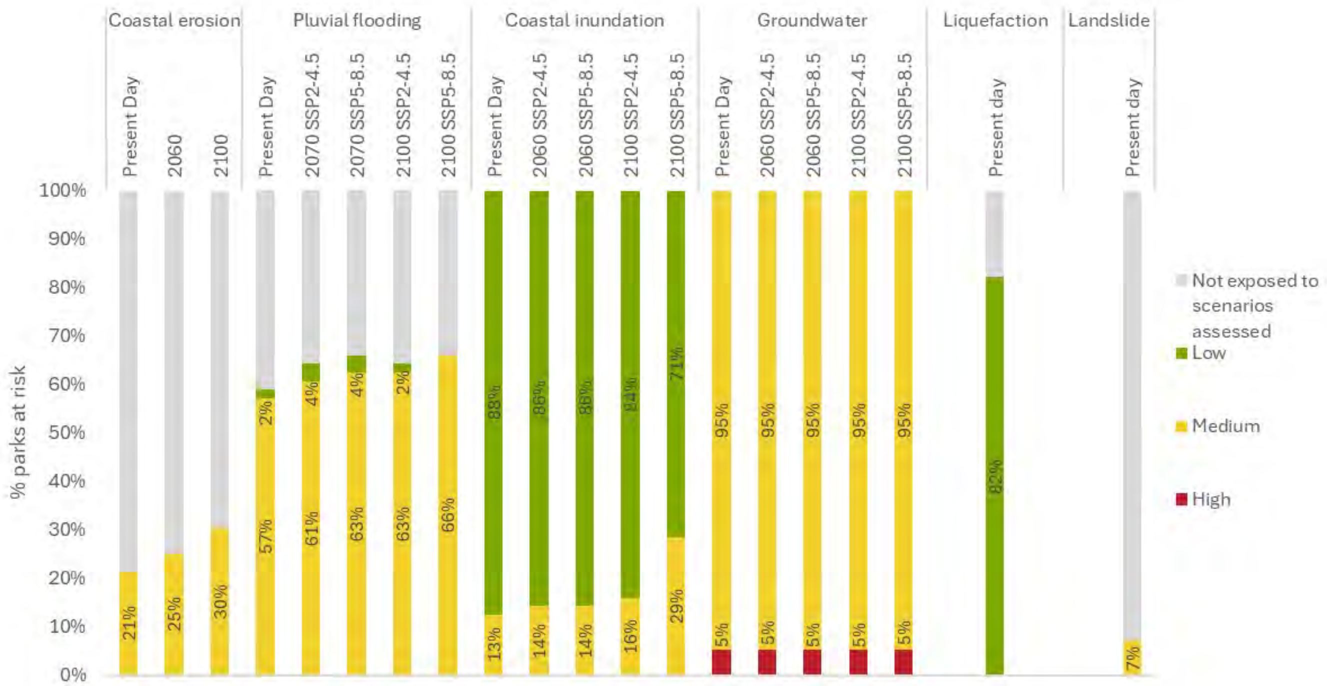


Figure 5.17 Risk to parks presented as percentage of parks (by number) at each risk rating[30].

Figure 5.18 Risk to sports fields presented as percentage of fields (by number) at each risk rating[31].

[30] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

[31] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

Table 5-2 Risk to parks and playing field key features[1,2]

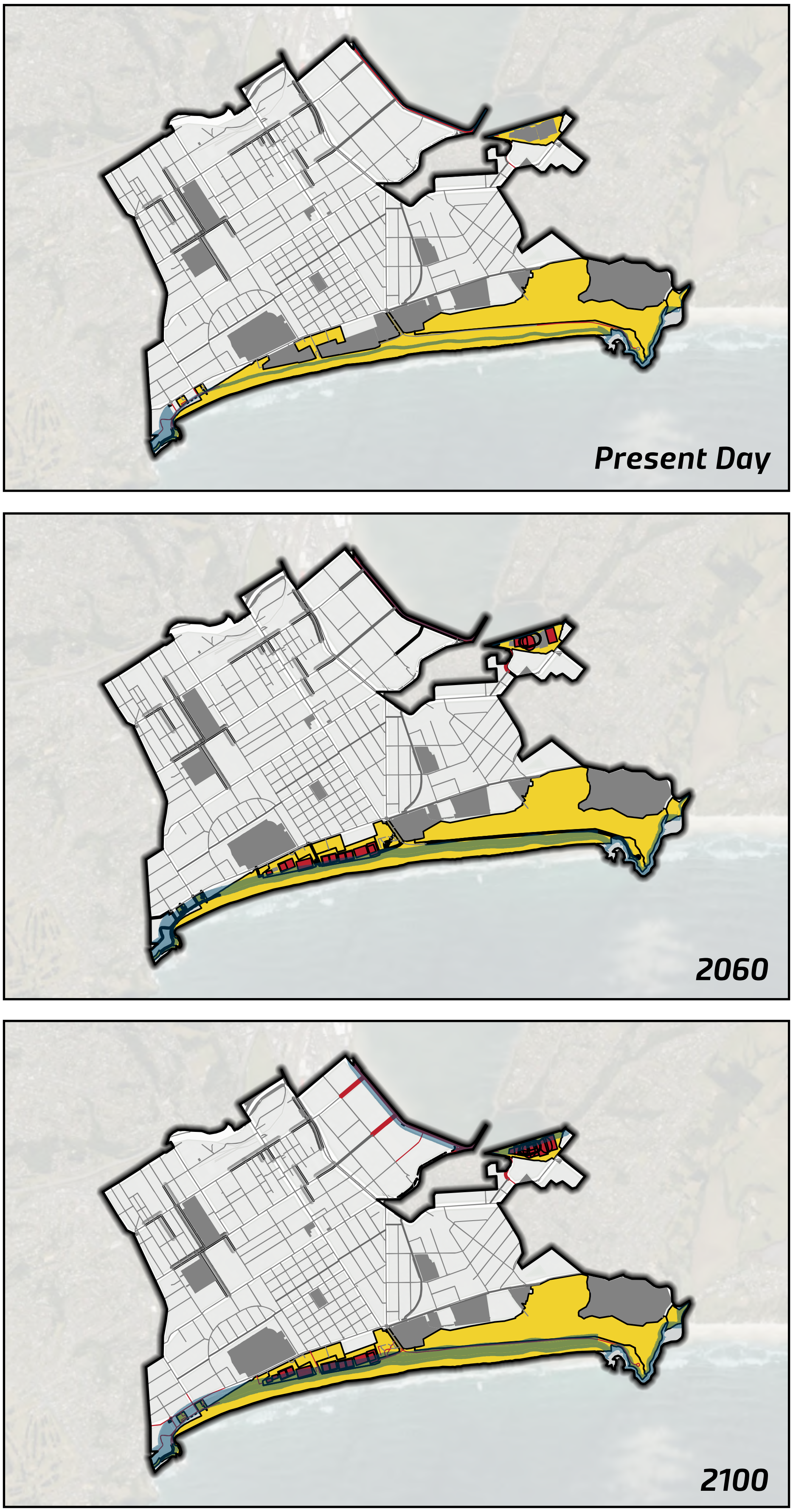
	Coastal erosion			Coastal inundation					Groundwater					Pluvial flooding					Land-slide	Lique-faction
	Present Day	2060	2100	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2070 SSP2-4.5	2070 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Bathgate Park	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	High	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
Bayfield Park	Medium	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Low
Culling Park	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	Medium	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
De Carle Park	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	Medium	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
Hancock Park	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
Kettle Park	Not exposed	High	High	Not exposed	Not exposed	Not exposed	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
Tahuna	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
Tahuna Park	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
Tonga Park	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	Medium	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
St Clair Playground	Medium	Medium	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	High	High	High	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
OB - Chisholm Park Golf Club	Medium	Medium	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Not exposed	Not exposed
St Clair Esplanade	Medium	Medium	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	Medium	Medium	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
Ocean Beach Domain	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Not exposed	Not exposed
OB - Marlow Park Playground	Not exposed	Medium	Medium	Not exposed	Not exposed	Not exposed	Low	Medium	High	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
St Clair Salt Water Pool	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed
Caledonian Gymnasium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Medium	Medium	Medium	Medium	Not exposed	Low

Low | Medium | High | Not exposed to scenarios assessed

[1]Where parks or playing fields have multiple fields, the highest risk across all fields is presented to show a single risk score for each location

[2]There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

Figure 5.19 Open spaces and roads risk due to coastal erosion



Explainer: These maps show the risk to transport and open spaces due to coastal erosion, noting that there is a high level of uncertainty regarding coastal erosion risk due to data limitations at present (e.g. scale of screening study and accounting for impact of engineered structures). The maps indicate that coastal erosion risk to transport and open spaces is identified at the Otago Harbour coastal edge and the St Clair-St Kilda coastline at present day and mid-century, with high risk to some playing fields emerging at mid century.
Disclaimer: These maps are not intended to assess coastal erosion risk to specific assets, which requires more detailed hazard data and consideration of a range of building specific factors (e.g. foundation type). More detailed coastal hazard assessments are underway as part of the St Clair-St Kilda Coastal Plan, these will be completed in late-2025, after which coastal erosion risk ratings will be reviewed.
Hazard data source: WSP, 2024

South Dunedin Future Boundary

Coastal erosion*

Roads (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

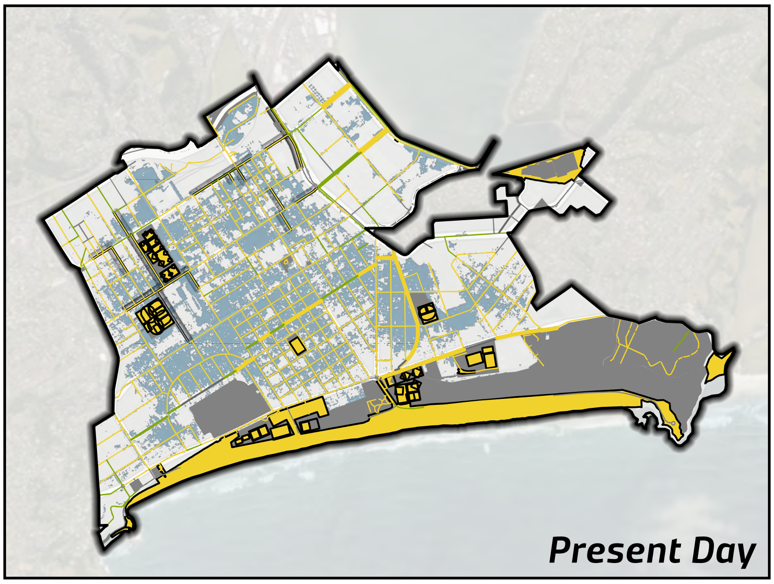
Open Spaces (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

Major criticality route

0 0.4 0.8 1.2 1.6 2 (km)

N

Figure 5.20 Open spaces and roads risk due to pluvial flooding



Explainer: These maps show the risk to roads and open spaces due to pluvial flooding (blue shading). Risk ratings for individual roads and open spaces are based on exposure of each asset to modelled pluvial flood plains, combined with the vulnerability of the park or road to flooding. Many roads and open spaces are extremely e posed, due to relatively frequent severe flooding (>10 % AEP). However, roads are rated to have low vulnerability to pluvial flooding as they tend to sustain minor damage that can be repaired through regular maintenance, as a result, they are typically rated medium risk. Parks are rated to have moderate vulnerability to periodic flooding, and are typically rated medium risk. Playing fields have higher vulnerability to increased seasonality (i.e. wetter winters), however this hazard is not assessed. The maps illustrate present day pluvial flood risk is medium for most roads and many open spaces within South Dunedin, expanding to nearly all roads and open spaces by 2100, particularly on The Flat. Flooding of roads may disrupt 'major criticality' transport routes (grey shadow on road) which may impact essential services or have wider social or economic impacts (as outlined in Figure 6.1).
Disclaimer: These maps are not intended to assess pluvial flooding risk at individual asset level, which requires consideration a range of site and asset specific factors.
Hazard data source: DCC ICMP Flood Model (Beca, WSP, 2024)

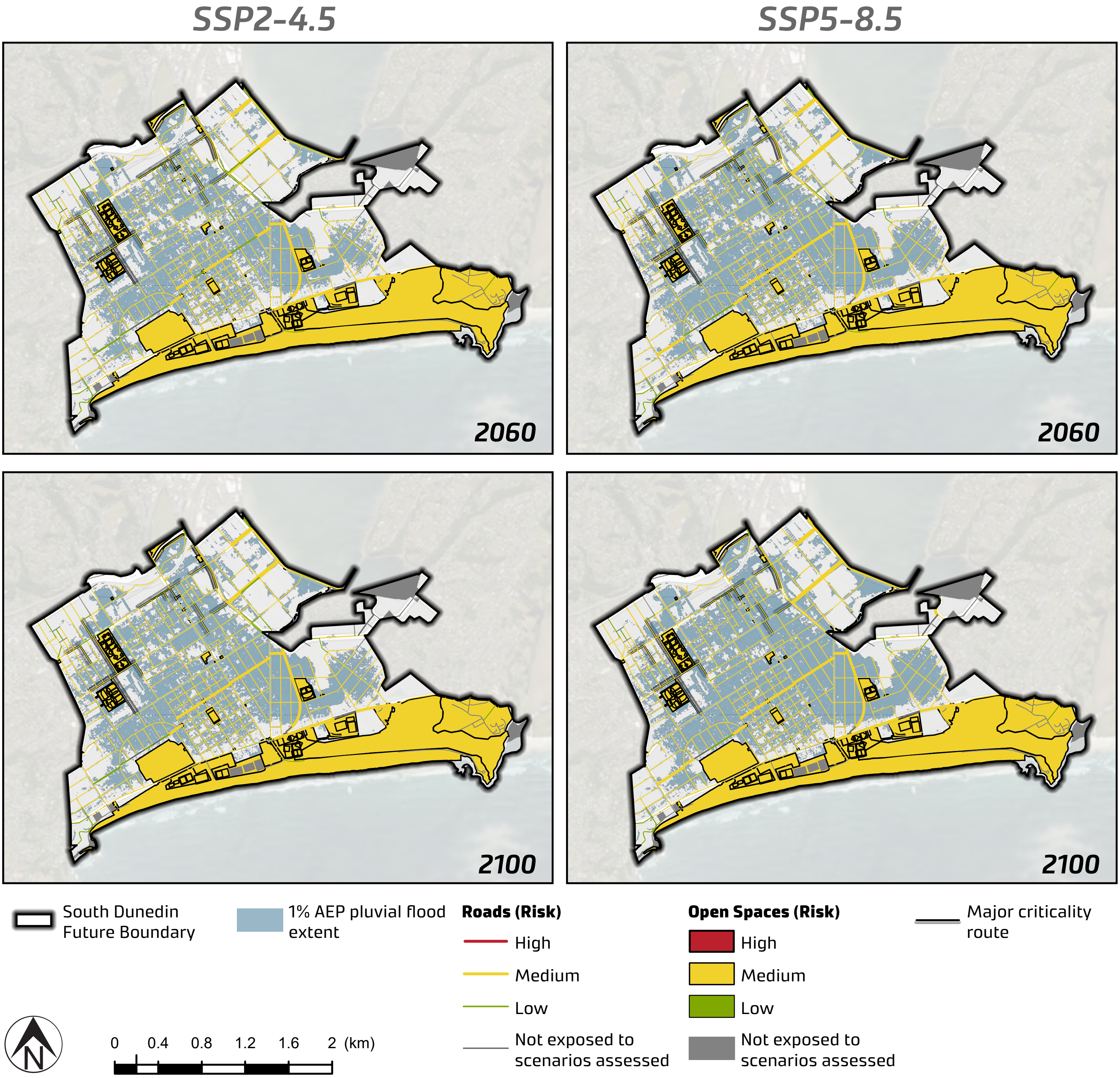
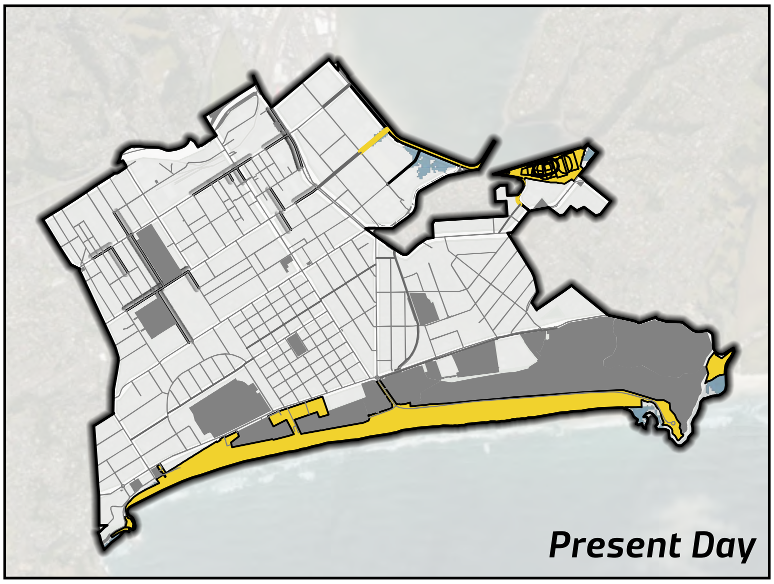


Figure 5.21 Open spaces and roads risk due to coastal inundation



Explainer: These maps show the risk to roads and open spaces due to coastal inundation (blue shading). Risk ratings for individual roads and open spaces are based on exposure of each asset to modelled inundation at a range of return intervals, combined with the vulnerability of roads, parks and playing fields to inundation. While many roads and open spaces are extremely exposed, due to relatively frequent severe flooding (>10% AEP), road assets are rated to have low vulnerability to inundation as they tend to sustain minor damage that can be repaired through regular maintenance. Playing fields are rated to have moderate vulnerability to coastal inundation as they are likely to sustain damage, but can recover between events. The maps illustrate very little coastal inundation risk for most roads and many parks and playing fields until late century, at which time nearly all roads and open spaces are rated to have medium risk by 2100, particularly on The Flat. Inundation of roads may disrupt 'major criticality' transport routes (grey shadow on road) which may impact essential services or have wider social or economic impacts (as outlined in Figure 6.1).

Disclaimer: These maps are not intended to assess coastal inundation risk at the individual asset level, which requires consideration of site specific flooding risk as well as a range of other factors.

Hazard data source: Paulik, et al., 2023

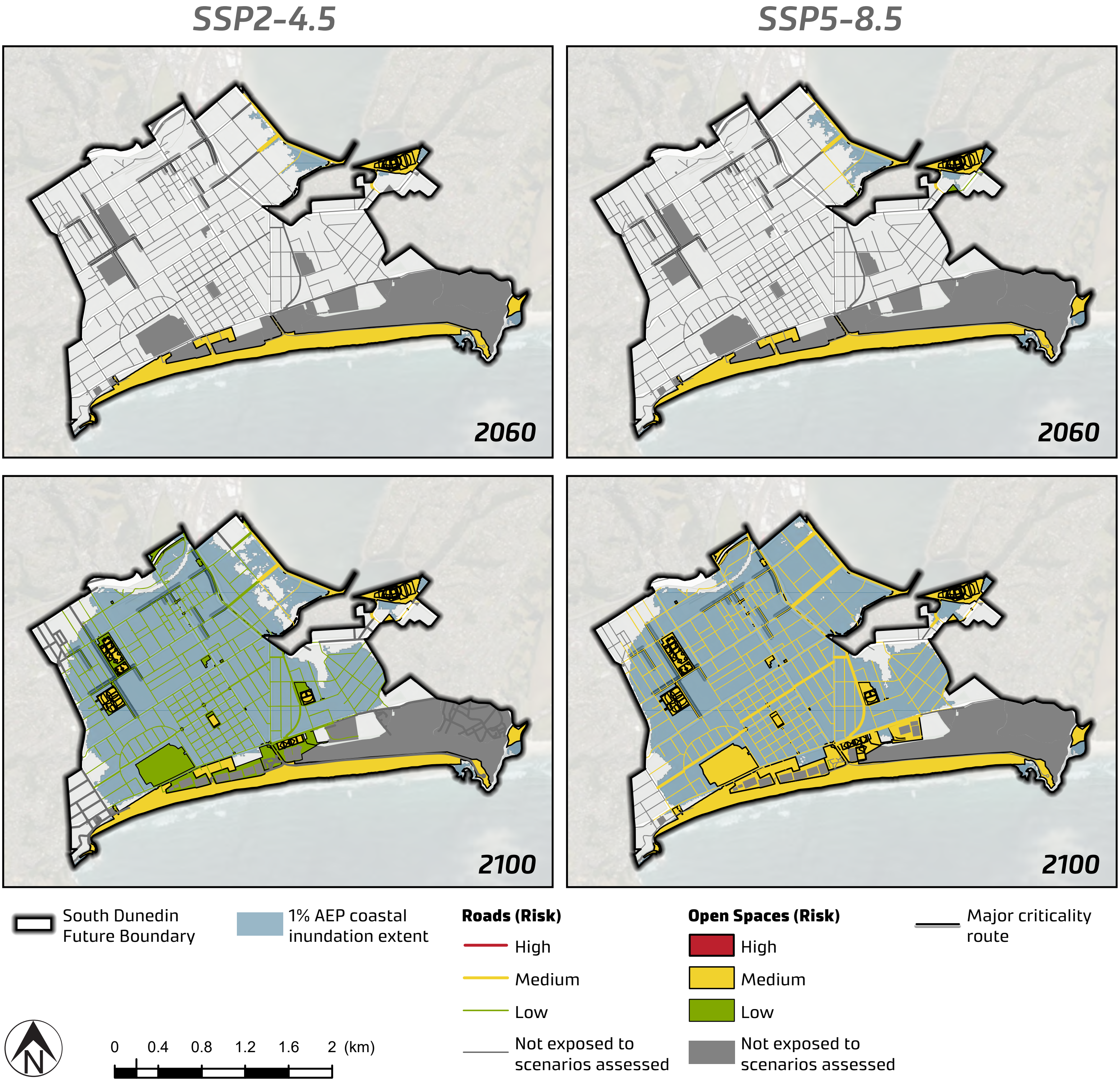
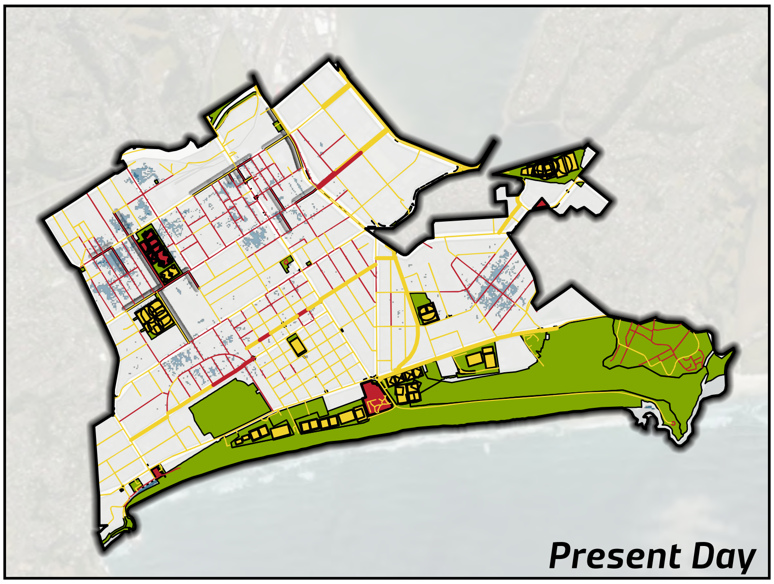


Figure 5.22 Open spaces and roads risk due to groundwater



Explainer: These maps show the risk to roads and open spaces due to groundwater hazard. Risk ratings for road sections and open spaces are based on exposure of each asset to the modelled median groundwater level (blue shading), where roads are assessed to be highly vulnerable if groundwater rises to within 0.4 to 0.6 m of the ground surface (light blue shading). Playing fields and playgrounds are extremely vulnerable if groundwater rises to within 0.3 m of the ground surface, though all other parkland is less vulnerable due to greater adaptive capacity. The maps illustrate some roads, parks and playing fields are already at high risk, and by late century the majority of roads and many playing fields are at high risk. High groundwater may cause deterioration of the road basecourse and loss of function of playing fields. This may disrupt ‘ major criticality’ transport routes (grey shadow on road) which may impact essential services or have wider social or economic impacts. As approximately 45 % of Dunedin’s playing fields are located within South Dunedin, loss of these would place pressure on facilities across the wider city, as well as impacting social and community networks within South Dunedin (as outlined in Figure 6.1). Disclaimer: These maps are not intended to assess groundwater risk at individual asset level, which requires consideration of site specific groundwater risk as well as a range of other factors.
Hazard data source: Cox, et al., 2023

SSP2-4.5 | SSP5-8.5

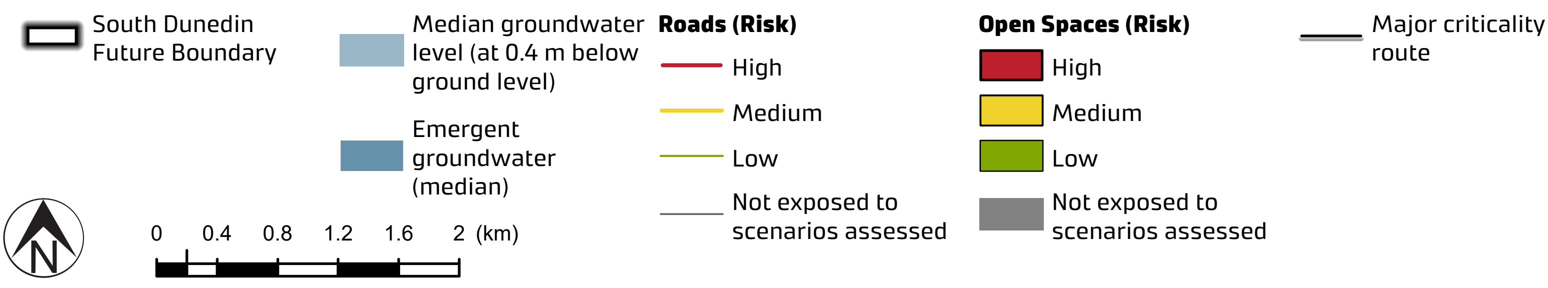
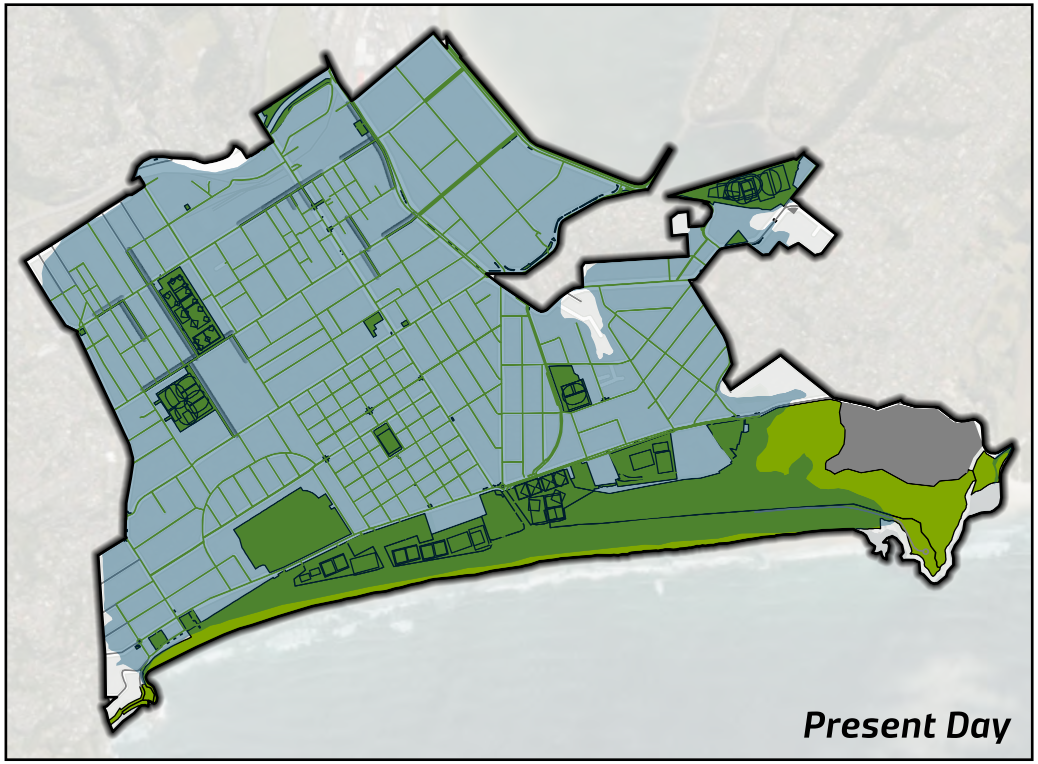


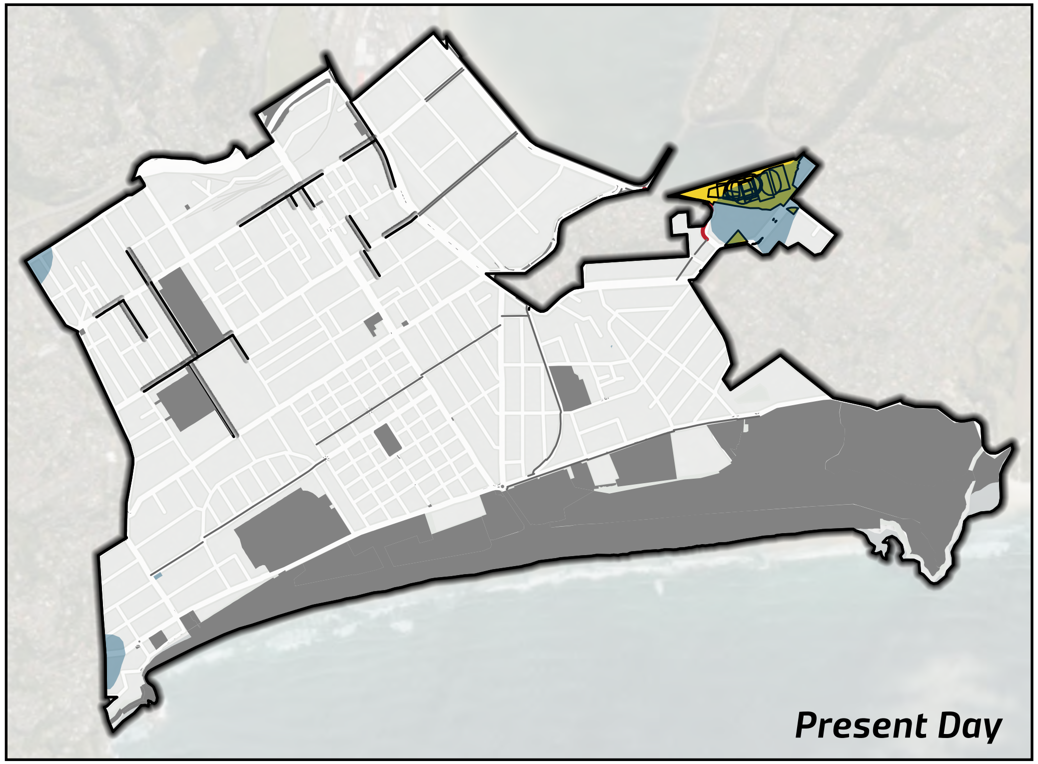
Figure 5.23 Open spaces and roads risk due to landslide and liquefaction

Liquefaction



Explainer: These maps show the risk to roads and open spaces due to liquefaction. Risk ratings for individual roads and open spaces are based on exposure of each asset to liquefaction potential, combined with their vulnerability rating (high). The maps illustrate liquefaction risk is low across South Dunedin at the present day. Liquefaction risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of sea level rise on liquefaction potential. If it were to occur, liquefaction may induce ground settlement and undulation of roads, resulting in uneven surfaces. Sand boils can occur, posing hazards and necessitating cleanup, while lateral spreading near free faces may lead to ground cracking. Liquefaction may induce ground settlement and undulation in parks and sports fields, resulting in uneven surfaces. Sand boils can occur, posing hazards and necessitating cleanup, while lateral spreading near free faces may lead to ground cracking.
Disclaimer: These maps are not intended to assess liquefaction risk at individual asset level, which requires consideration of site specific liquefaction risk as well as more detailed asset information. Liquefaction hazard information is based on a high level desktop review, where subsequent site specific assessment (Hornblow, 2020) has found that liquefaction potential is highly variable across sites analysed.
Hazard data source: Barrell, 2014

Landslide



Explainer: These maps show the risk to roads and open spaces due to landslide. Risk ratings for individual roads and open spaces are based on exposure of each asset to landslides, combined with their vulnerability rating (roads – extreme, open spaces - high). The maps illustrate that this type of landslide risk is confined to areas around the South Dunedin boundary. Landslide risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of climate change (groundwater level rising or increased rainfall intensity) on landslide. Landslides can severely damage transport and open spaces resulting in sudden collapse or failure and posing a potential risk to life. Landslide damage to parks can cause loss of field function, with potentially prohibitively high repair costs.
Disclaimer: These maps are not intended to assess landslide risk at individual asset level, which requires consideration of a site specific landslide risk as well as more detailed asset information. The landslide extent is based on known landslide areas and does not account for other potential sources of landslide nor represent the extent of the area of deposition/runout.
Hazard data source: DCC Hazard database data provided for South Dunedin Future programme

South Dunedin Future Boundary

Land instability

Liquefaction (Domain C: moderate liquefaction potential)

Roads (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

Open Spaces (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

Major criticality route

N

0 0.4 0.8 1.2 1.6 2 (km)

5.2.1 ADAPTIVE CAPACITY – PARKS AND SPORTS FIELDS

The adaptive capacity of parks and sportsfields is important in the consideration and development of adaptation options. The following factors are highlighted and were incorporated into the consideration of asset vulnerability where appropriate:

- Options to improve park performance under increasing flooding and groundwater rise are to change parks to turf or re-lay fields to improve drainage. These measures are limited in their effectiveness when exposed to very high or emergent groundwater levels.
- When considering adaptation of playing fields, parks that are also HAIL sites should be preferentially removed because these need higher maintenance due to re-levelling (land subsidence) and potential increase in contamination with groundwater rise.
- Playgrounds have a 30 year renewal lifespan, and many are comprised of equipment that can be relocated, making them very adaptable if other areas are available to relocate to. Playgrounds can also adapt to reflect their changing environment, for example creating water features where groundwater is high.
- Many of the buildings that are associated with parks are community led, which means they have less funding. These buildings are likely to have lower adaptive capacity compared to private commercial buildings. Loss of these facilities would be a major community loss.
- The Andersons Bay Cemetery is the single main Cultural and Heritage Park in South Dunedin. There are significant cultural and Waahi Tapu implications related to moving this reserve or repurposing it. It is therefore considered an area that is a non-negotiable asset to remain in its current form by the DCC Parks Team. The Cemetery has low exposure to hazards, with groundwater modelled to remain greater than 13 m below the surface at late century and no other hazards modelled to encroach on the grounds.

5.3 RISK TO ECOLOGICAL AREAS

There are no formally classified ecological areas within South Dunedin therefore a spatial risk assessment has not been undertaken. A short discussion regarding ecological areas relevant to South Dunedin based on literature review and the findings of engagement is provided in Appendix C4. The broader environmental impacts caused by the natural hazards are also discussed in Section 6.4.

5.3.1 ADAPTIVE CAPACITY – ECOLOGICAL AREAS

Groundwater rise may present an opportunity to restore some of the historical wetlands or salt marshes within South Dunedin. If opportunities to re-establish wetlands are undertaken within South Dunedin, it may restore ecological resilience, build amenity and strengthen mana whenua values for the benefit of the wider Dunedin area.

Creation of additional ecological areas as part of restoration or blue-green corridors will need to be mindful of the role that South Dunedin currently plays in separating ecological habitats, potentially reducing pathways for invasive pests to access ecologically important areas. For example, the Otago Peninsula and town belt are almost possum free and South Dunedin plays an important role in reducing predator pathways to the Peninsula.

5.4 RISK TO TRANSPORT INFRASTRUCTURE

The South Dunedin transport components that were considered for the risk assessment include roads (and their associated infrastructure), cycle lanes, and rail. The risk to SH1 was not assessed.

The risk assessment results are presented in the following sub-sections.

5.4.1 RISK TO ROADS

There are 90 km of roads in South Dunedin, roading key features include:

- Roads (and associated infrastructure[32]).
- Cycle lanes.
- Critical routes.

Of these, most associated infrastructure and cycle lanes have the same risk profile as the road network, they are generally located within the road corridor (with exception of some cycle ways) and therefore are not presented as separate risk profiles. The associated roading infrastructure that do not have a similar risk profile to roads are:

- Below ground stormwater infrastructure which is expected to have the same risk profile as the local stormwater network. Due to this, roading stormwater infrastructure has not been separately assessed but may be inferred from nearby stormwater risk.

The graph shown in Figure 5.24 identifies the risk to all roads (ex. SH1) within South Dunedin over time for each hazard. Figure 5.25 presents the risk to major criticality roads (~3 km of road length) over time for each hazard.

A spatial representation of risk to roads and associated infrastructure is shown in Figure 5.19, Figure 5.21, Figure 5.22, and Figure 5.23. Further detail regarding road vulnerability is contained in Appendix C.

[32] Associated infrastructure includes, but is not limited to electrical assets (e.g. street lights, signals), stormwater infrastructure (e.g. kerbs, catch pits, cross drainage and culverts), structures (e.g. retaining walls, sea wall, causeway) and footpaths.

Figure 5.24 Risk to roads presented as percentage of road length at each risk rating[33]

Figure 5.25 Risk to roads with 'major' criticality rating presented as percentage of roads (by number of roads at risk).

Across South Dunedin, risk to roads due to groundwater is the highest rated risk at present (35% roads are at risk) and is projected to increase over time. Groundwater remains the hazard posing the highest risk to roads over all scenarios and time periods. By late century, 76% of roads are rated to be at high risk (Figure 5.24).

Roads that are at high risk due to groundwater are expected to sustain damage to a level where the road is not functional until repairs are made. With a chronic hazard such as groundwater,

[33] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

repairs will become increasingly difficult. Roads and cycle lanes are highly vulnerable to high groundwater, where groundwater within the roading basecourse causes deterioration of the road structure. This drives increased maintenance and can ultimately lead to road failure. Already, in some areas within South Dunedin, high groundwater poses a threat to road condition. Roads with higher traffic loading are sensitive to groundwater earlier in time (median groundwater level above 0.6 m below ground level) to lower traffic loading roads (median groundwater level above 0.4 m below ground level). With only a modest increase in sea level (0.3 m), groundwater levels are modelled to reach the road basecourse depth across extensive parts of South Dunedin.

Roads are also extremely vulnerable to landslide and coastal erosion; roads exposed to these hazards are expected to experience sudden collapse or failure that will cause a potential risk to life. However, the relatively small extent of exposure to these hazards means the length of road at risk to these hazards across South Dunedin is relatively small compared to groundwater risk.

Many roads within South Dunedin are extremely exposed to widespread pluvial flooding at present (43% of roads by length), the extent of which increases with time. At late century, roads are also extremely exposed to widespread coastal inundation (72% of roads exposed by length). Although roads were rated to have low vulnerability to pluvial flooding and coastal inundation, this extreme exposure means many roads are rated to be at moderate risk to pluvial flooding and coastal inundation.

South Dunedin has 20 major criticality routes (shown as grey shading on Figure 5.19 to Figure 5.23 which are defined by their:

- Economic or social significance to more than one region.
- Lifeline significance for providing access or continuity of supply of essential services during an emergency event.

All major criticality routes are at high risk due to groundwater at timeframes beyond present day (Figure 5.25). All major criticality routes are at medium risk due to coastal inundation at late century and 13 are at medium risk at present day and mid-century. None are exposed to coastal erosion or landslide.

The high risk posed by groundwater to the major criticality routes of South Dunedin indicates that these roads will lose functionality in the absence of adaptive measures. Loss of critical transport routes may:

- Have a significant economic or social impact.
- Disrupt access to the Otago Peninsula.
- Disrupt a regionally significant lifeline.
- Interfere with access or continuity of supply of essential services.

Loss or damage of transport routes will have a range of local and regional impacts. These are discussed further in Section 6.2.2.

5.4.2 ADAPTIVE CAPACITY – ROADS

The adaptive capacity of roads is important in the consideration and development of adaptation options. The following factors are highlighted as further considerations for the adaptation planning:

- Measures to adapt roads to high groundwater include raising roads or changing the road material to concrete. However, there are potential adverse effects on others caused by raising roads which will need close consideration (e.g. through changes to overland flowpaths or floodplains). Feedback from roading managers indicated that the use of concrete to improve road resilience to groundwater was not expected to be effective in South Dunedin.

- Road performance is interdependent with the stormwater network as roading drainage provides stormwater management and connects to the wider stormwater network.
- Road performance is interdependent with parks as these influence stormwater generation, where greater parkland coverage results in comparatively lower stormwater runoff generation (i.e. due to low impervious area).

5.4.3 RAIL INFRASTRUCTURE EXPOSURE ASSESSMENT

Rail infrastructure within South Dunedin comprises the following key features:

- Rail corridor.
- Hillside Workshops.

Rail infrastructure is in important regional asset, however a detailed risk assessment was not carried out because railway adaptation to climate risks is managed through KiwiRail's national resilience planning. It was also considered by project stakeholders and partners that rail adaptation was unlikely to influence the South Dunedin Future adaptation planning.

An exposure assessment of the rail corridor was carried out (i.e. not a risk assessment because there is no consideration of vulnerability). This shows that the rail corridor is exposed to pluvial flooding, coastal inundation, high groundwater and liquefaction.

Risks to the Hillside Workshop buildings were assessed as part of the building risk assessment (Section 5.1), with results summarised in Table 5-3. Risk to most buildings located within Hillside Workshop KiwiRail Facility are rated high due to groundwater and coastal inundation under late century.

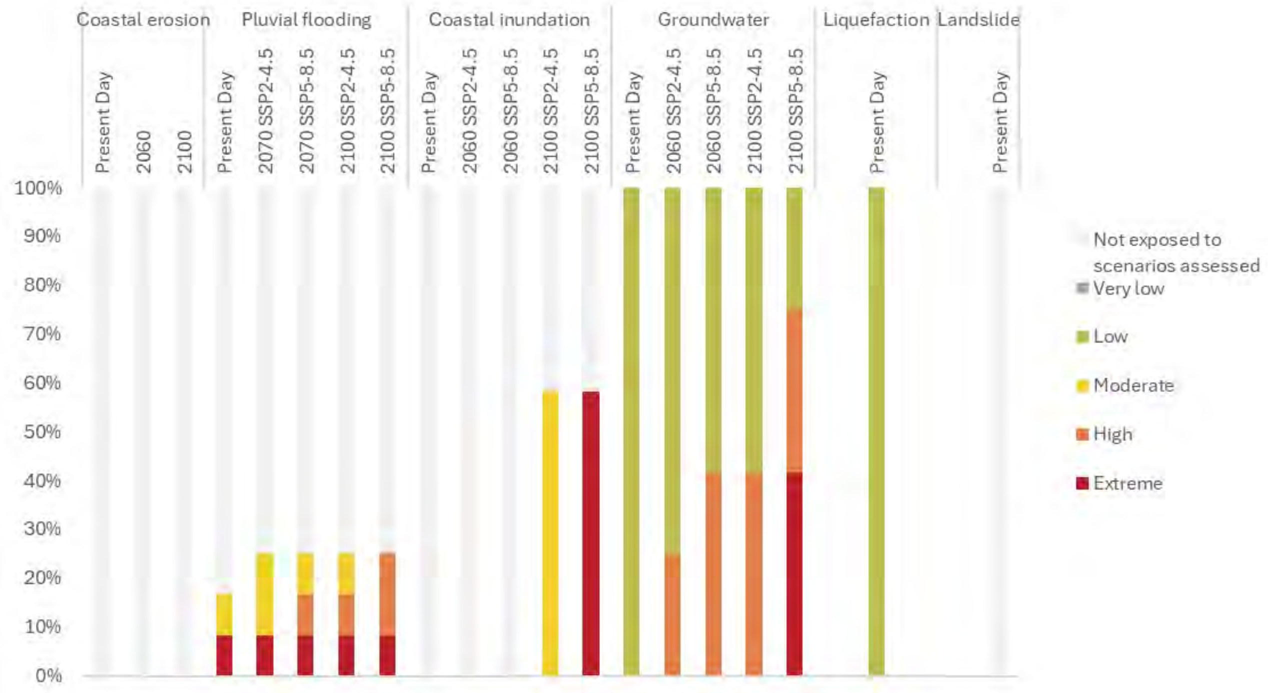


Figure 5.26 Exposure to rail infrastructure presented as percentage of rail corridor exposed

Table 5-3 Risks to buildings located within Hillside Workshop KiwiRail Facility

	Coastal erosion			Coastal inundation					Groundwater					Pluvial flooding					Land-slide	Lique-faction
	Present Day	2060	2100	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2070 SSP2-4.5	2070 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Hillside workshops: Risk rated for 24 buildings located at 13 Strathallan Street Dunedin. Ratings applied based on building risk criteria.	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Medium	Medium	High	High	High	High	High	High	High	High	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Medium	Medium	Medium	High	Low	Low	Low	Low	Low	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Medium	Medium	Medium	High	Low	Low	Medium	Low	Medium	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Low	Medium	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Low	Low	Low	Low	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Low	Not exposed	Low	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Medium	Medium	Medium	High	Not exposed	Medium	Medium	Medium	Medium	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Low	Low	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Medium	Medium	High	High	Medium	Medium	High	Medium	High	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Medium	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Medium	Medium	High	High	High	Not exposed	Low	Low	Low	Low	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Medium	Medium	Medium	High	Low	Low	Low	Low	Low	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Medium	Medium	Medium	High	High	High	High	High	High	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Low	Medium	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
Storge yard: Pallet handling (property ID 90119)	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Medium	Medium	High	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low	Low	Low	Medium	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low

Low | Medium | High | Not exposed to scenarios assessed

5.5 RISK TO THREE WATERS INFRASTRUCTURE

This section covers the risk assessment to three waters infrastructure, which includes water supply, wastewater and stormwater infrastructure.

5.5.1 RISK TO WATER SUPPLY INFRASTRUCTURE

There are 97 km of water supply pipes in South Dunedin, key features include:

- Somerville Street Water Pumping Station.
- Somerville Distribution mains (from treatment plant that feeds Somerville).

High criticality pipes were discussed, however a review of criticality information identified that there are no high criticality water pipes in South Dunedin.

-The graph shown in Figure 5.27 shows how the risk to water supply infrastructure within South Dunedin changes over time with each hazard. Spatial representation of risk to water supply infrastructure is shown in Figure 5.28, Figure 5.30, and Figure 5.32. Risk ratings for the Somerville

Street Water Pumping Station is shown in Table 5-4. Further detail regarding water supply infrastructure vulnerability is contained in Appendix C.

In general, natural hazard risks to the water supply network in South Dunedin is low due largely to very low vulnerability of all water supply infrastructure within South Dunedin. However, there are some noteworthy observations:

- There is some coastal erosion (high) risk to 0.6 km (0.6%) of the water pipe network, increasing to 2 km (2%) later this century[34].
- Landslide hazard poses a minor risk to water supply infrastructure, with 3 km (3%) of the pipe network at medium risk.
- During floods, access to pump stations may be limited or restricted, thereby increasing operational risks during times of need.

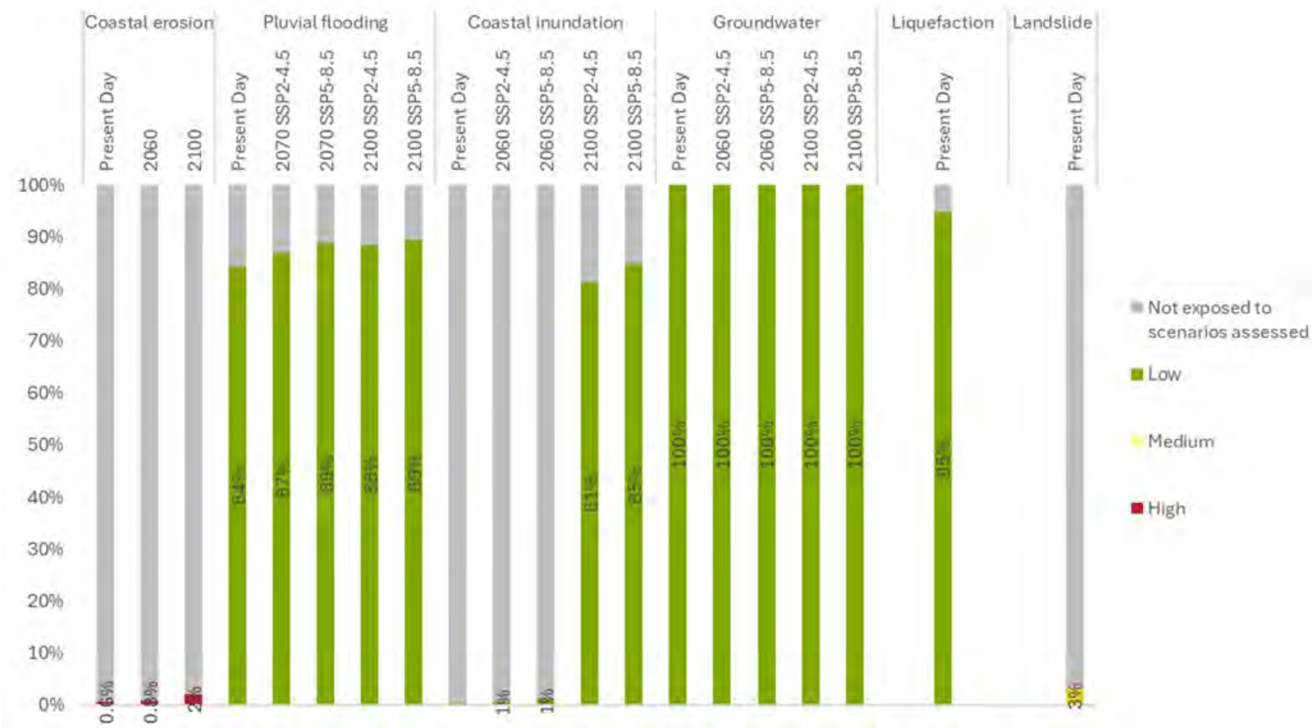


Figure 5.27 Risk to water supply pipes presented as percentage of pipe length at each risk rating[34]

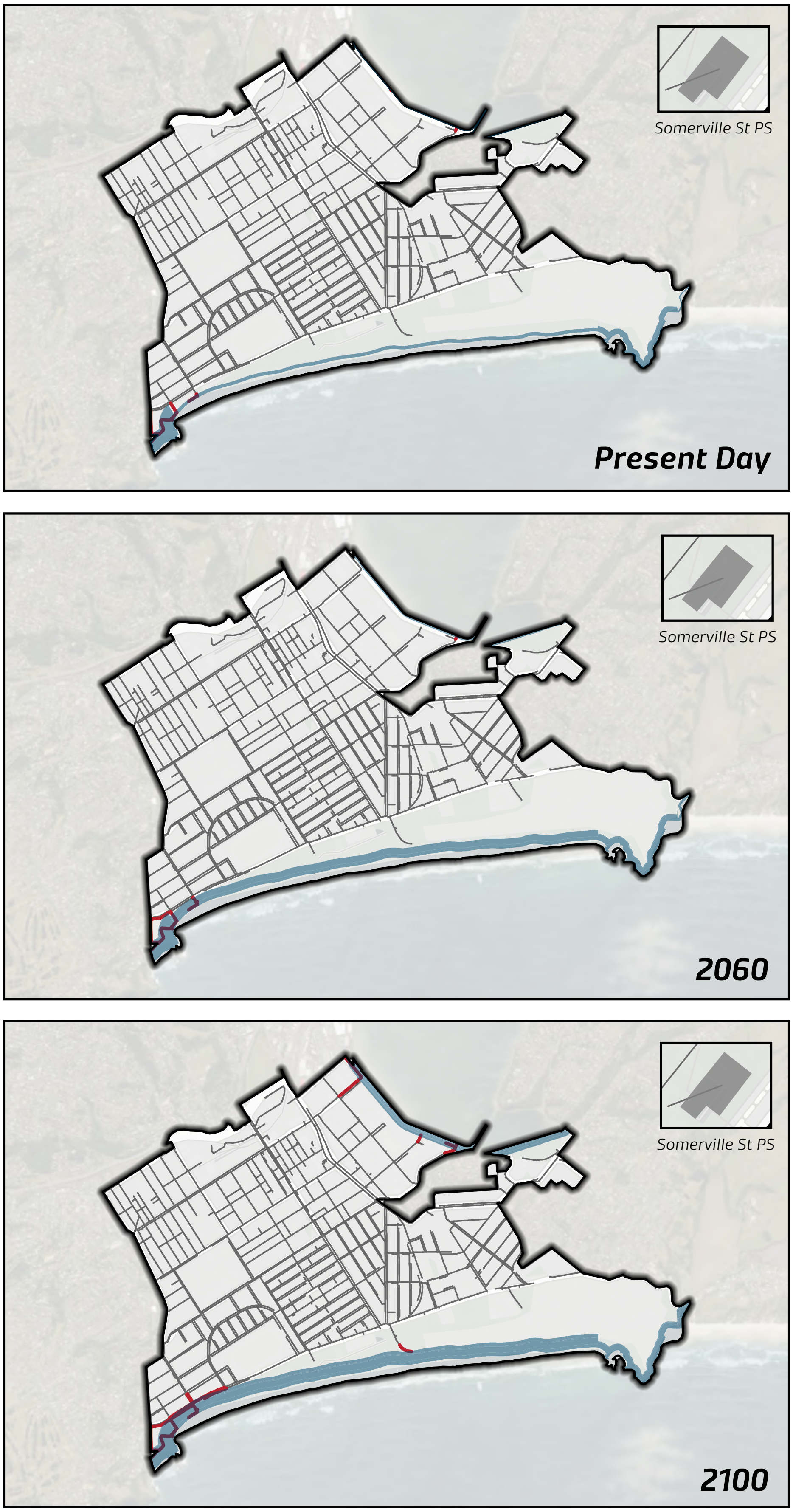
Table 5-4 Risk to Sommerville Street Pump Station

	Coastal erosion			Coastal inundation					Groundwater					Pluvial flooding					Land-slide	Lique-faction
	Present Day	2060	2100	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2070 SSP2-4.5	2070 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Sommerville Street Pumping Station (W)																				

Low Medium High Not exposed to scenarios assessed

[34] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

Figure 5.28 Water supply infrastructure risk due to coastal erosion



Explainer: These maps show the risk to water supply due to coastal erosion (blue shading), noting that there is a high level of uncertainty regarding coastal erosion risk due to data limitations at present (e.g. scale of screening study and accounting for impact of engineered structures). The maps illustrate that coastal erosion risk to water supply is largely confined to the St Clair-St Kilda coastline at present day with risk to some pipe sections arising from the Otago Harbour at late-century.

Disclaimer: These maps are not intended to assess coastal erosion risk to specific assets, which requires more detailed hazard data and consideration of a range of building specific factors (e.g. foundation type). More detailed coastal hazard assessments are underway as part of the St Clair-St Kilda Coastal Plan, these will be completed in late-2025, after which coastal erosion risk ratings will be reviewed.

Hazard data source: WSP, 2024

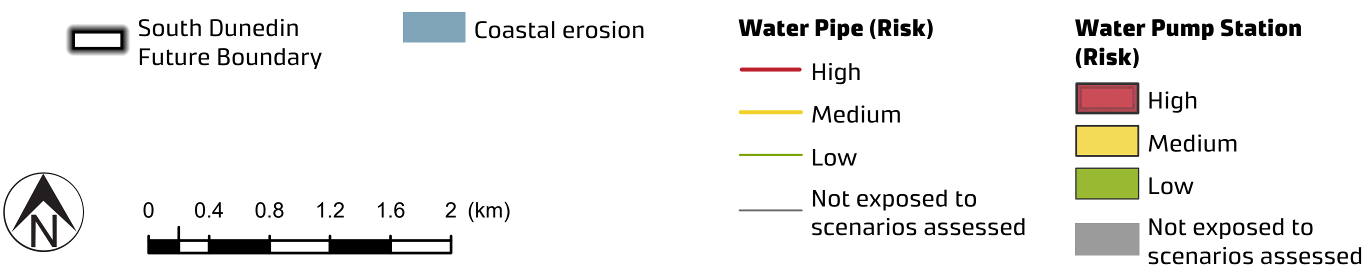
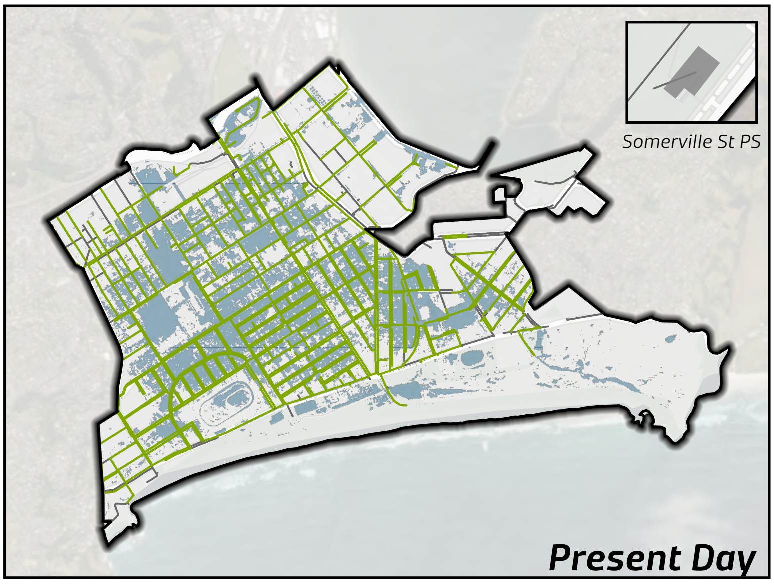


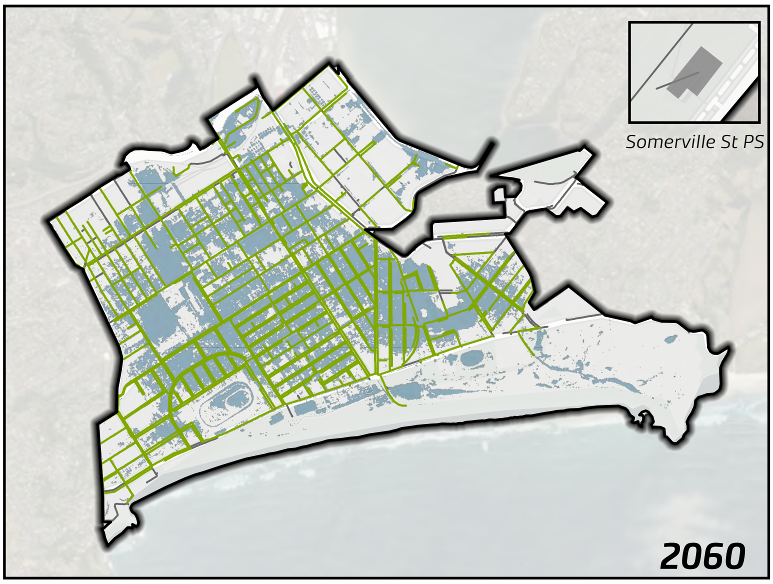
Figure 5.29 Water supply infrastructure risk due to pluvial flooding

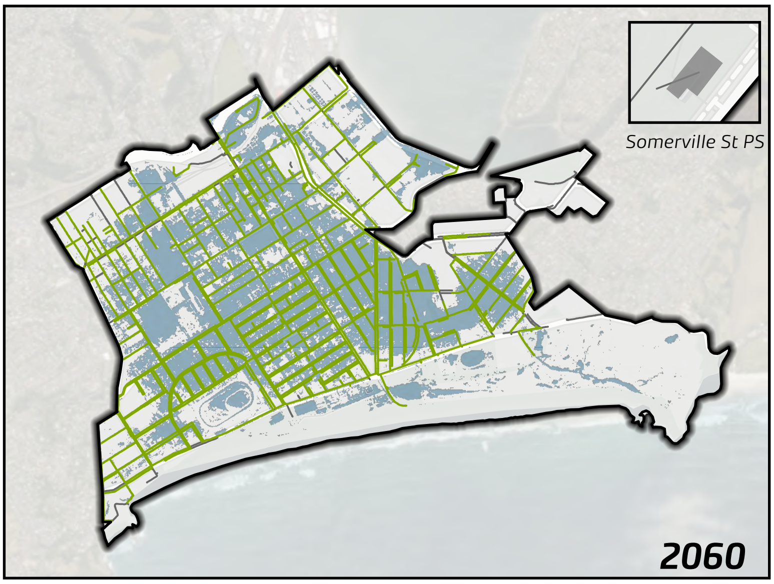


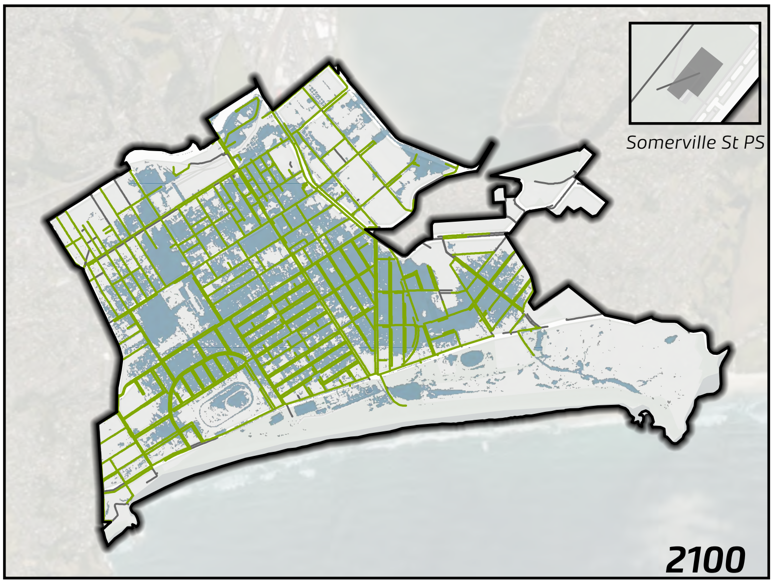
Explainer: These maps show the risk to water supply infrastructure due to pluvial flooding (blue shading). Risk ratings for individual water supply pipe sections are based on exposure of each asset to modelled pluvial flooding combined with the asset's vulnerability to flooding. Although many water supply pipes and the associated above ground infrastructure (pump stations, valves etc) are extremely exposed to frequent, severe, flooding (>10% AEP), they are rated as having very low vulnerability to pluvial flooding as they typically do not sustain damage during such events. The maps illustrate pluvial flood risk is low for all water supply pipes within South Dunedin under the assessed timeframes.
Disclaimer: Note these maps are not intended to assess pluvial flooding risk at individual asset level, which requires consideration of site specific flooding risk as well as more detailed asset information.
Hazard data source: DCC ICMP Flood Model (Beca, WSP, 2024)

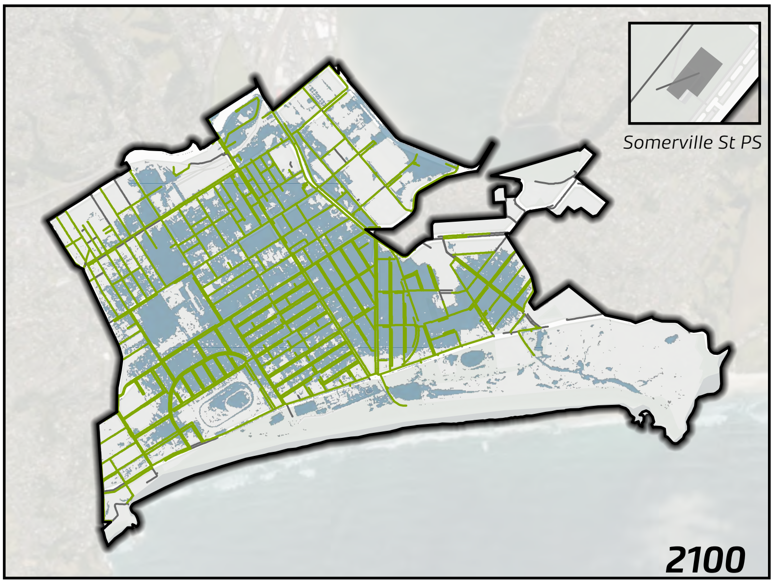
SSP2-4.5

SSP5-8.5









South Dunedin Future Boundary

1% AEP pluvial flood extent

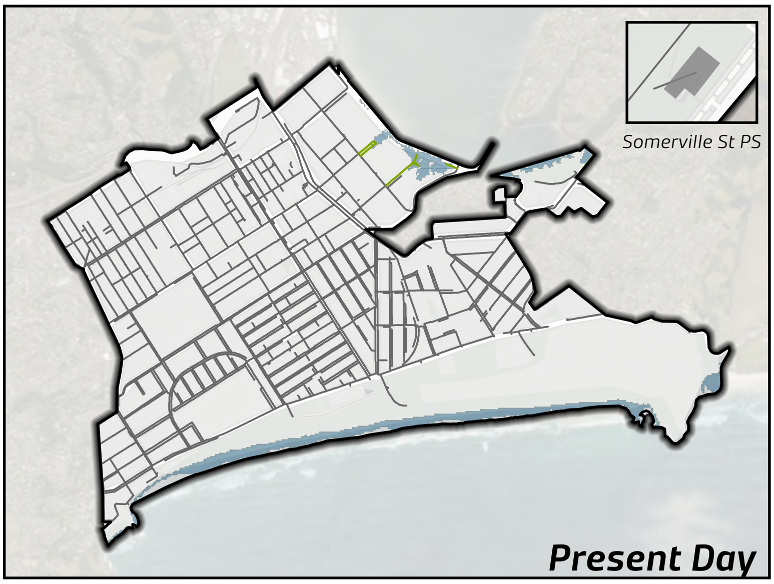
Water Pipe (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

Water Pump Station (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

0 0.4 0.8 1.2 1.6 2 (km)

N

Figure 5.30 Water supply infrastructure risk due to coastal inundation



Explainer: These maps show the risk to water supply infrastructure due to coastal inundation (blue shading). Risk ratings for individual water supply pipe sections are based on exposure of each asset to modelled coastal inundation extents, combined with the vulnerability of the asset to inundation. Although many water supply pipes and the associated above ground infrastructure (pump stations, valves etc) are extremely exposed to frequent, severe, flooding (>10 % AEP) at late century, they are rated as having very low vulnerability coastal inundation as they do not tend to sustain damage during such events. The maps illustrate coastal inundation risk is low for most water supply pipes within South Dunedin under the assessed timeframes.

Disclaimer: These maps are not intended to assess coastal inundation risk at individual asset level, which requires consideration of site specific flooding risk as well as more detailed asset information.

Hazard data source: Paulik, et al., 2023

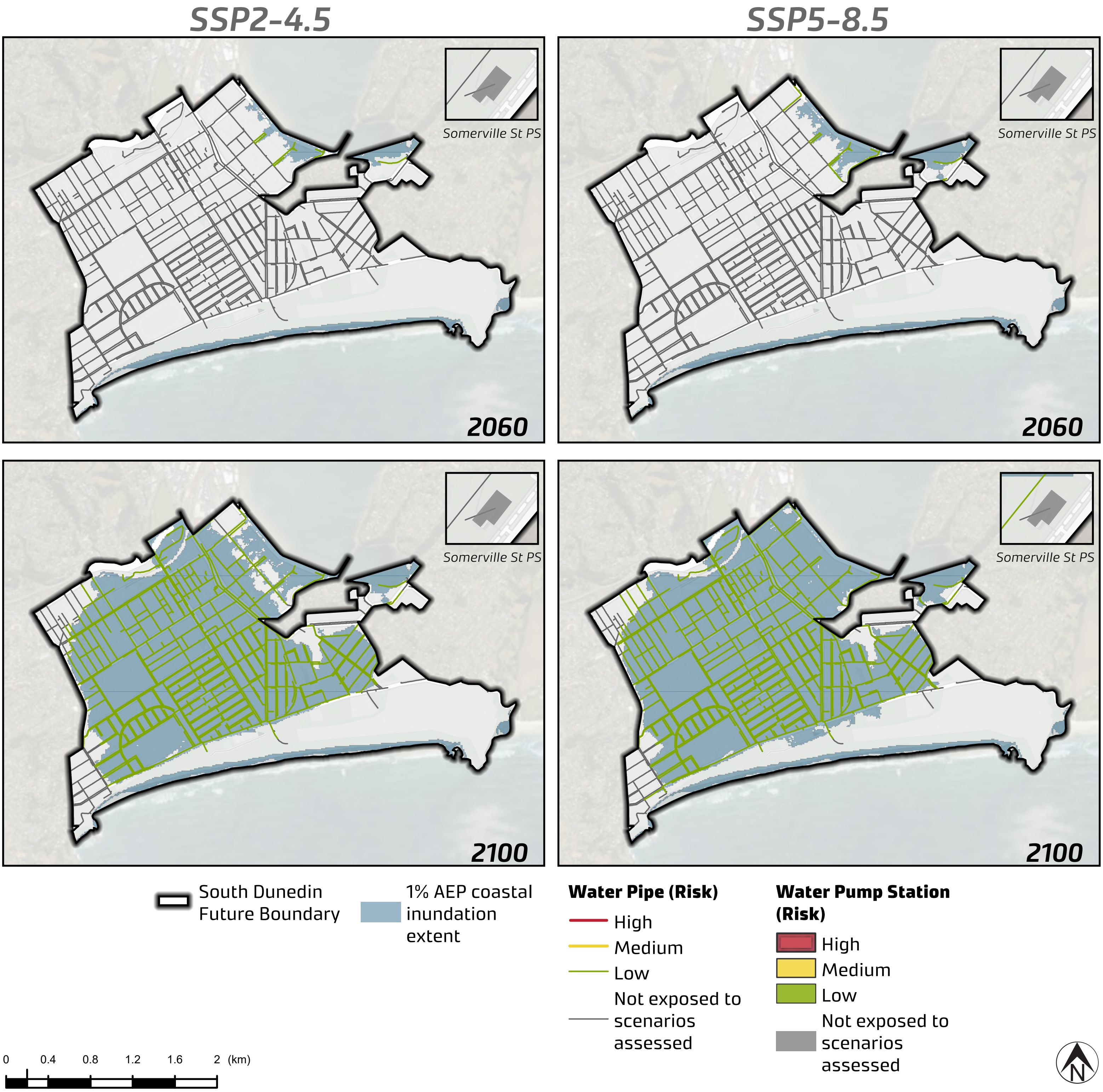
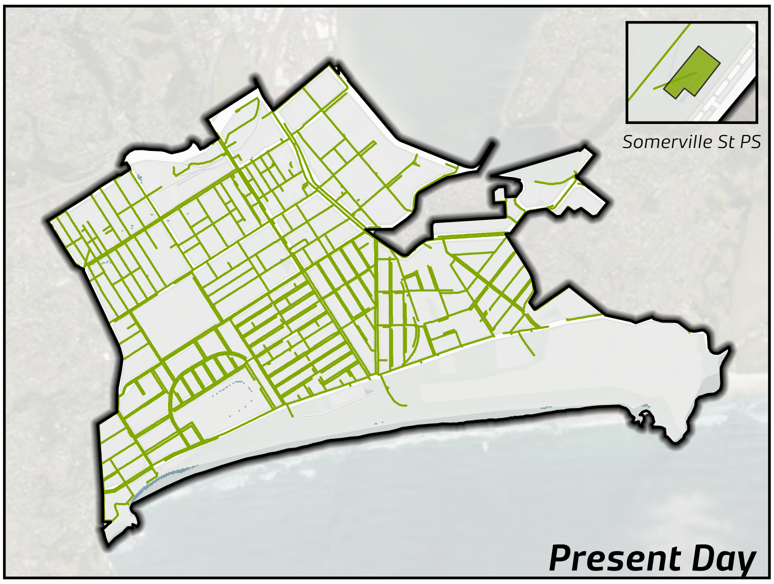


Figure 5.31 Water supply infrastructure risk due to groundwater



Explainer: These maps show the risk to water supply infrastructure due to groundwater (blue shading). Risk ratings for individual water supply pipe sections are based on exposure of each asset to the modelled median groundwater level (using the pipe invert level to test whether the pipe is exposed). While many water supply pipes are extremely exposed as they are below the groundwater level, water supply pipes are rated to have very low vulnerability to groundwater as they do not tend to sustain damage from groundwater exposure. The maps illustrate groundwater risk is low for most water supply pipes within South Dunedin under the assessed timeframes.

Disclaimer: These maps are not intended to assess ground water risk at individual asset level, which requires consideration of site specific groundwater risk as well as more detailed asset information.

Hazard data source: Cox, et al., 2023

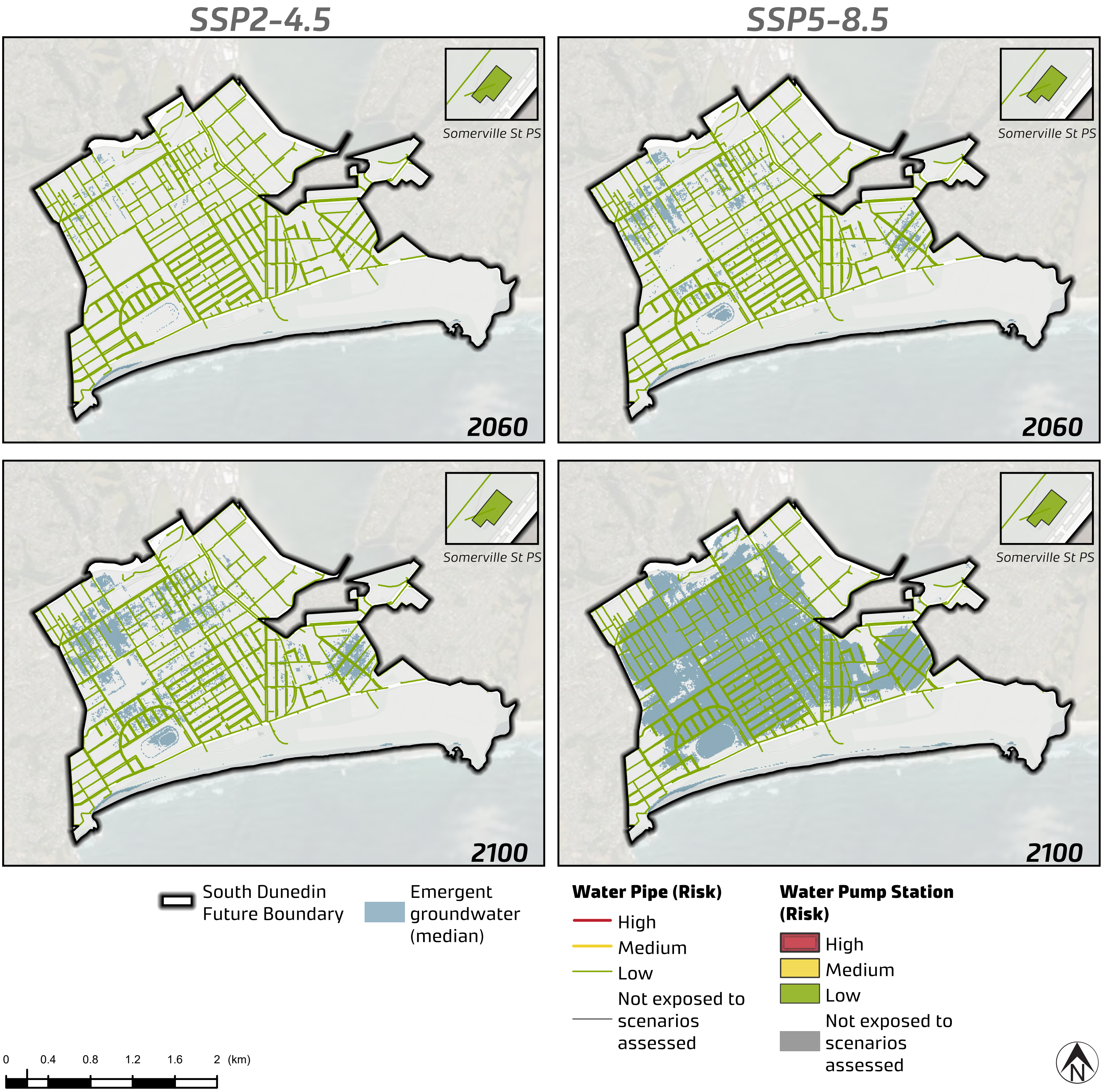
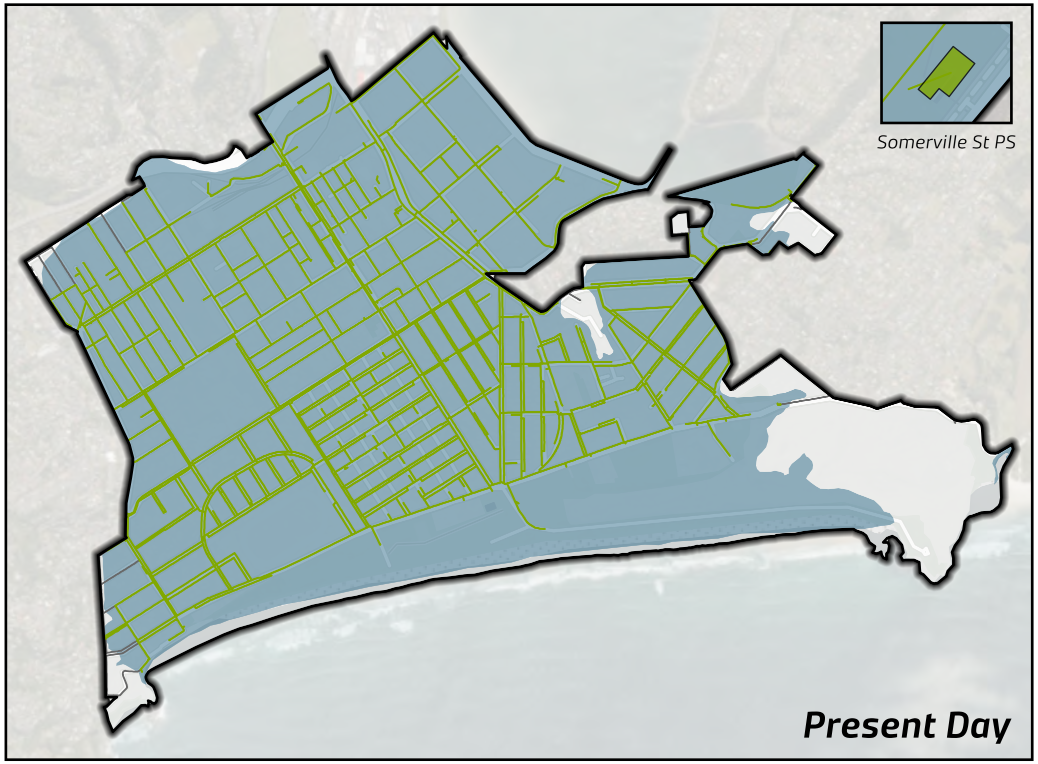


Figure 5.32 Water supply infrastructure risk due to landslide and liquefaction

Liquefaction



Explainer: These maps show the risk to water supply due to liquefaction. Risk ratings for individual pipe lengths are based on exposure of each asset to liquefaction potential, combined with their vulnerability rating (high). The maps illustrate liquefaction risk is low across South Dunedin at the present day. Liquefaction risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of sea level rise on liquefaction potential. If it were to occur, liquefaction can impact water infrastructure by deforming the pipe network. Ground settlement or stretching may damage or disconnect pipes and chambers and subsequent inflow of sediment can cause blockages. Buoyancy can cause uplift of buried structures, and disrupt drainage systems, while sediment discharge can reduce water quality and affect aquatic habitats.
Disclaimer: These maps are not intended to assess liquefaction risk at individual asset level, which requires consideration of site specific liquefaction risk as well as more detailed asset information. Liquefaction hazard information is based on a high level desktop review, where subsequent site specific assessment (Hornblow, 2020) has found that liquefaction potential is highly variable across sites analysed.
Hazard data source: Barrell, 2014

Landslide

Explainer: These maps show the risk to water supply due to landslide, where some pipes at the South Dunedin boundary are rated medium risk. Risk ratings for individual water supply pipes are based on exposure of each asset to landslides, combined with their vulnerability rating. Landslides can severely damage water supply resulting in sudden collapse or failure. The maps illustrate that landslide risk is confined to areas around the South Dunedin boundary. Landslide risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of climate change (groundwater level rising or increased rainfall intensity) on landslide.
Disclaimer: These maps are not intended to assess landslide risk at individual asset level, which requires consideration of a site specific landslide risk as well as more detailed asset information. The landslide extent is based on known landslide areas and does not account for other potential sources of landslide nor represent the extent of the area of deposition/runout.
Hazard data source: DCC Hazard database data provided for South Dunedin Future programme

South Dunedin Future Boundary

Land instability

Liquefaction (Domain C: moderate liquefaction potential)

Water Pipe (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

Water Pump Station (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

N

0 0.4 0.8 1.2 1.6 2 (km)

5.5.2 RISK TO STORMWATER INFRASTRUCTURE

There are 71 km of stormwater pipes in South Dunedin, key features within the stormwater network include:

- Tainui SW pump station (on same site as WW pump).
- Portobello stormwater pump station.
- Portobello Road Screens.
- All flap gates.
- High criticality pipes.

Figure 5.39 shows how the risk to stormwater infrastructure within South Dunedin changes over time with each hazard. Spatial representation of risk to stormwater infrastructure is shown in Figure 5.34, Figure 5.35, Figure 5.36, Figure 5.37, Figure 5.38, with high criticality pipes highlighted with grey shadow. Table 5-5 shows risk ratings for stormwater key features (structures only). Further detail regarding stormwater infrastructure vulnerability is contained in Appendix C.

The stormwater pipe network is at high risk due to groundwater, with 22% of pipes at high risk at present, which slightly increases over time to reach 28% of the pipe network at high risk by late century under a high-end climate scenario. These pipes are at high risk because they are at a level that is lower than the modelled groundwater table and are of an age and or material type that means they are extremely vulnerable to groundwater infiltration. Groundwater infiltration into the stormwater network will reduce the pipe capacity causing a reduction in level of service. The overall effect of this reduction in pipe capacity on the network is currently under investigation, but is likely to drive increased pluvial flooding.

The other notable risks to the stormwater pipe network are due to pluvial flooding and coastal inundation. At present day 60% of the network is at moderate risk due to pluvial flooding, which rises to 80% at late century. Risk due to coastal inundation jumps sharply from 2% to 86% of the network at moderate risk at late century under a high-end climate scenario. Similarly to the wastewater network, flooding can cause a reduction in level of service resulting in environmental contamination.

Risk to stormwater structures is shown in Table 5-5. This shows that Portobello Pump Station and Tainui Pump Station are both at high risk due to pluvial flooding (present day and mid-century respectively) and coastal inundation (late century). If flooded, these pump stations may fail due to switchboard damage. This could significantly worsen the impact of flooding on the community as this type of pump failure would occur during a flooding or coastal inundation event. The proximity of Wilkie Road pump station to the coast means it is at high risk due to coastal erosion[35] and coastal inundation under all timeframes and scenarios.

[35] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

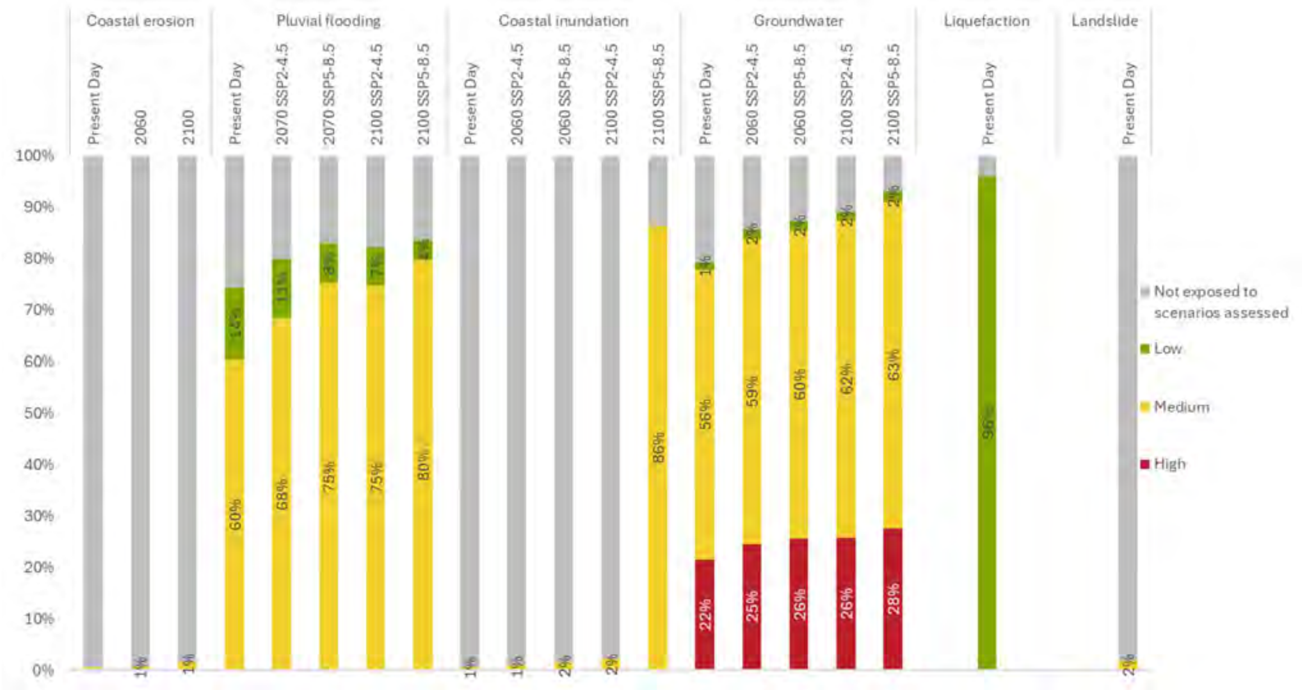


Figure 5.33 Risk to stormwater pipes presented as percentage of pipe length at each risk rating[35]

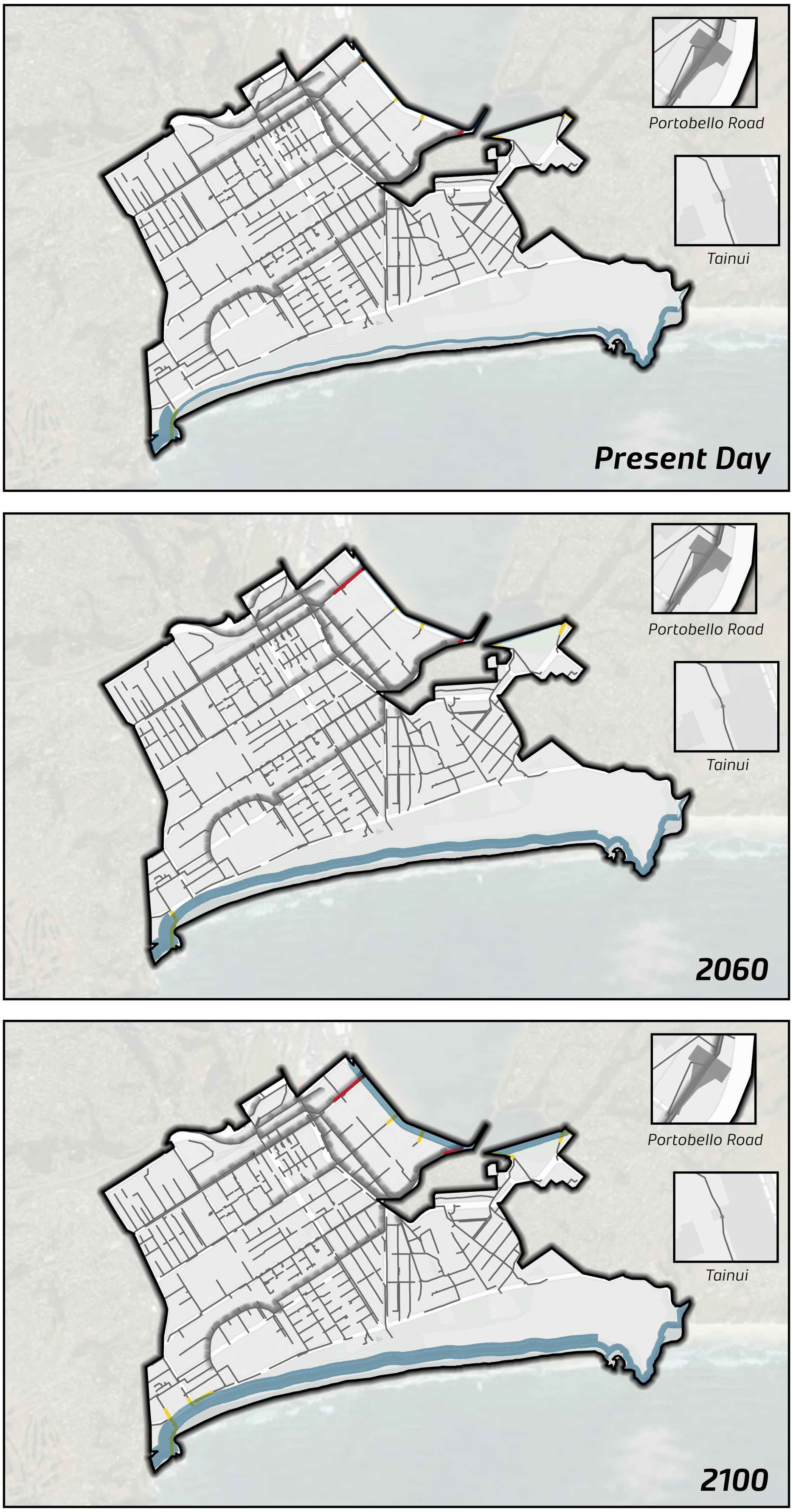
Table 5-5 Risk to stormwater structures[1]

	Coastal erosion			Coastal inundation					Groundwater					Pluvial flooding					Land-slide	Lique-faction
	Present Day	2060	2100	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2070 SSP2-4.5	2070 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Portobello pump station (SW)	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	High	High	Low	Low	Low	Low	Low	High	High	High	High	High	Not exposed	Low
Tainui Stormwater Pumping Station (SW)	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	High	Low	Low	Low	Low	Low	Medium	High	High	High	High	Not exposed	Low
Wilkie Road Stormwater Pump Station (SW)	High	High	High	High	High	High	High	High	Low	Low	Low	Low	Low	High	High	High	High	High	Not exposed	Low

Low | Medium | High | Not exposed to scenarios assessed

[1]There is a high level of uncertainty regarding coastal erosion risk in localised areas, particularly around engineered coastal erosion structures (e.g. sea walls) as a result of the scale of the district-wide screening assessment. More detailed coastal erosion hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed later in 2025.

Figure 5.34 Stormwater infrastructure risk due to coastal erosion



Explainer: These maps show the risk to stormwater infrastructure due to coastal erosion, noting that there is a high level of uncertainty regarding coastal erosion risk due to data limitations at present (e.g. scale of screening study and accounting for impact of engineered structures). The maps indicate that coastal erosion risk to stormwater is confined to the Otago Harbour coastline at present day, and increases to a small number of pipes along the St Clair-St Kilda Coastline at mid-century, with higher risk of erosion at the St Clair end of the beach.

Disclaimer: These maps are not intended to assess coastal erosion risk to specific assets, which requires more detailed hazard data and consideration of a range of building specific factors (e.g. foundation type). More detailed coastal hazard assessments are underway as part of the St Clair-St Kilda Coastal Plan, these will be completed in late-2025, after which coastal erosion risk ratings will be reviewed.

Hazard data source: WSP, 2024

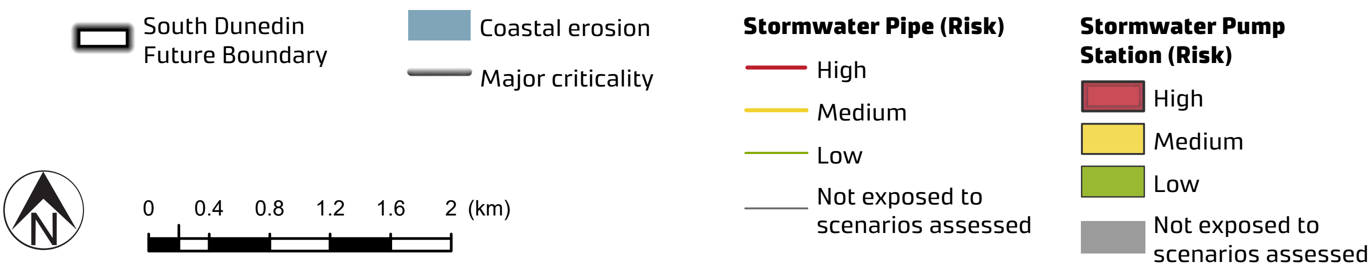
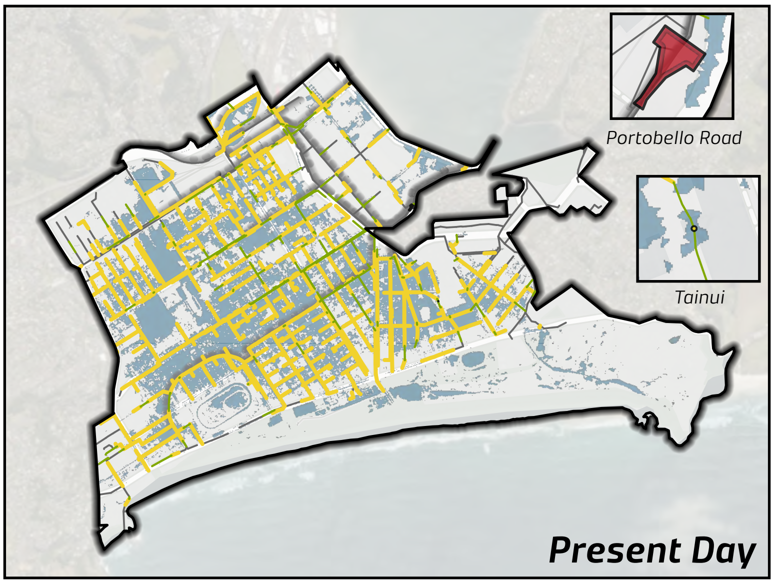


Figure 5.35 Stormwater infrastructure risk due to pluvial flooding

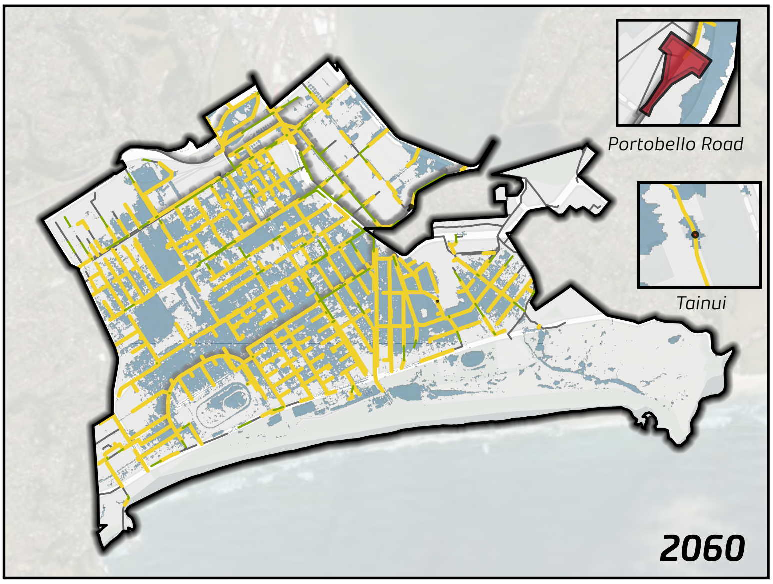


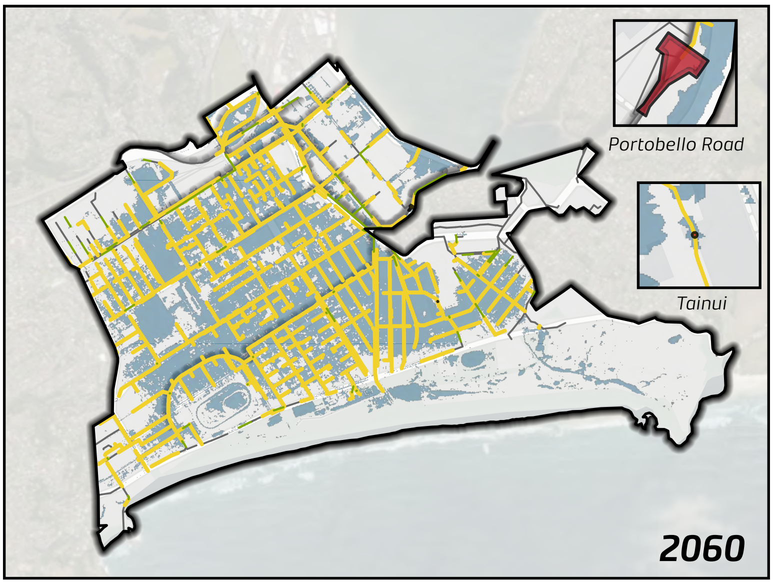
Explainer: These maps show the risk to stormwater infrastructure due to pluvial flooding (blue shading). Risk ratings for individual stormwater pipe sections are based on exposure of each asset to modelled pluvial flooding, combined with the vulnerability of the asset to flooding. While many stormwater pipes are extremely exposed to frequent severe flooding (>10% AEP), stormwater pipes are rated to have very low vulnerability to pluvial flooding as they do not tend to sustain damage during flooding. However, stormwater pump stations are highly vulnerable to flooding. The maps illustrate widespread medium risk at present day, which increases slightly in extent over time. Risk to pump stations is rated high under all timeframes.
Disclaimer: These maps are not intended to assess pluvial flooding risk at individual asset level, which requires consideration of site specific flooding risk as well as more detailed asset information.

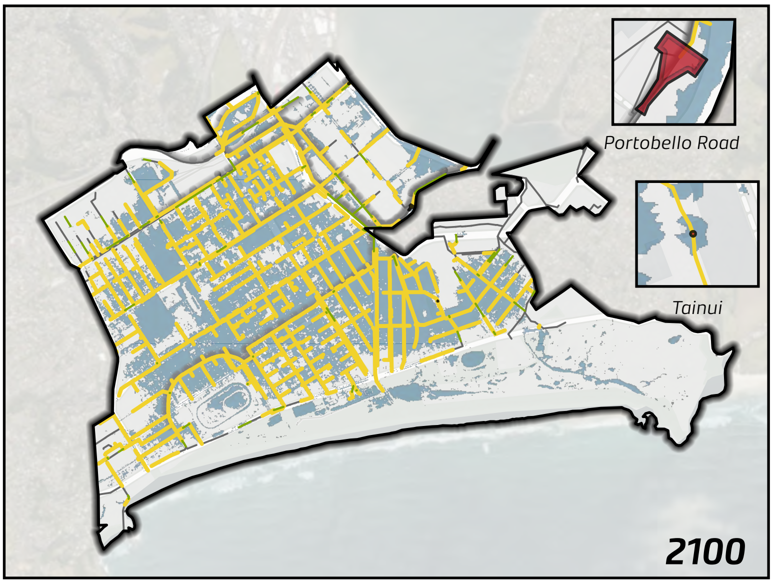
Hazard data source: DCC ICMP Flood Model (Beca, WSP, 2024)

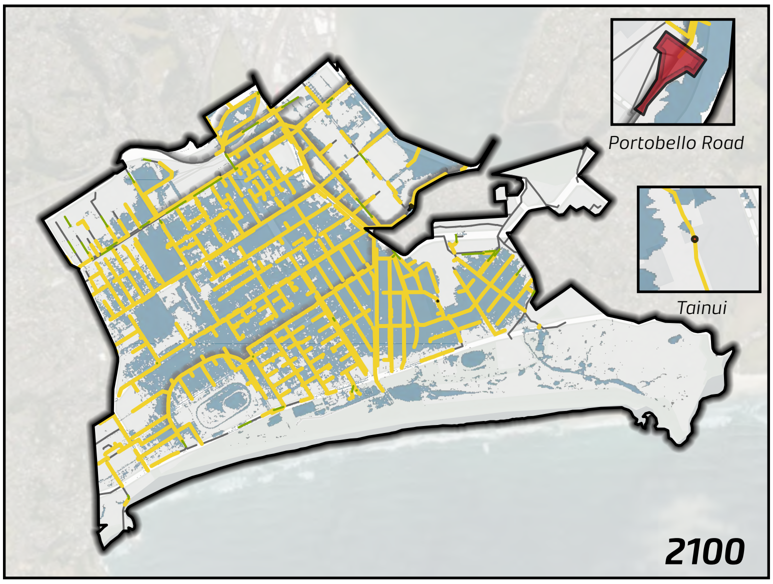
SSP2-4.5

SSP5-8.5









South Dunedin Future Boundary

1% AEP pluvial flood extent

Major criticality

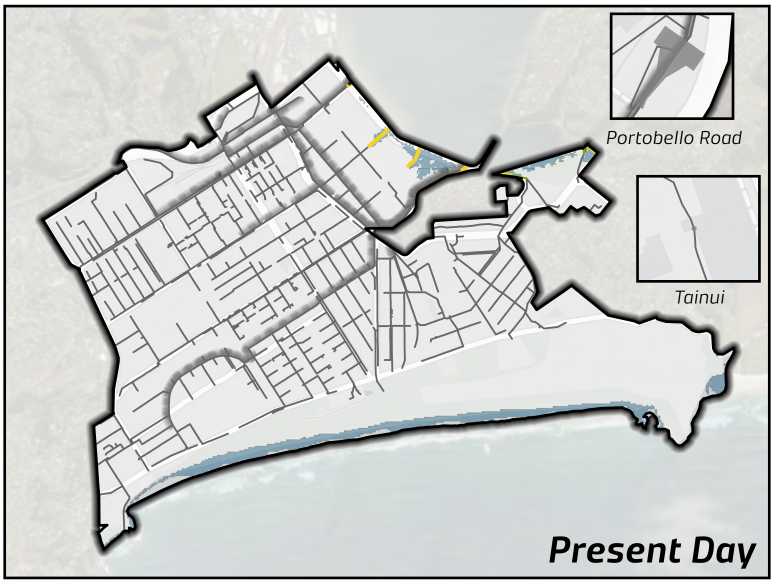
Stormwater Pipe (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

Stormwater Pump Station (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

N

0 0.4 0.8 1.2 1.6 2 (km)

Figure 5.36 Stormwater infrastructure risk due to coastal inundation



Explainer: These maps show the risk to stormwater infrastructure due to coastal inundation (blue shading). Risk ratings for individual stormwater pipe sections are based on exposure of each asset to modelled coastal inundation, combined with the vulnerability of the asset. While many stormwater pipes are extremely exposed at late century, due to relatively frequent severe flooding (>10% AEP), stormwater pipes are rated to have low vulnerability to coastal inundation as they do not tend to sustain damage during such events. The maps illustrate that at late century widespread low risk arises under a mid-range climate scenario, which increases to medium risk under a high end climate scenario. Risk to pump stations is rated high at late century.

Disclaimer: These maps are not intended to assess coastal inundation risk at individual asset level, which requires consideration of site specific flooding risk as well as more detailed asset information.

Hazard data source: Paulik, et al., 2023

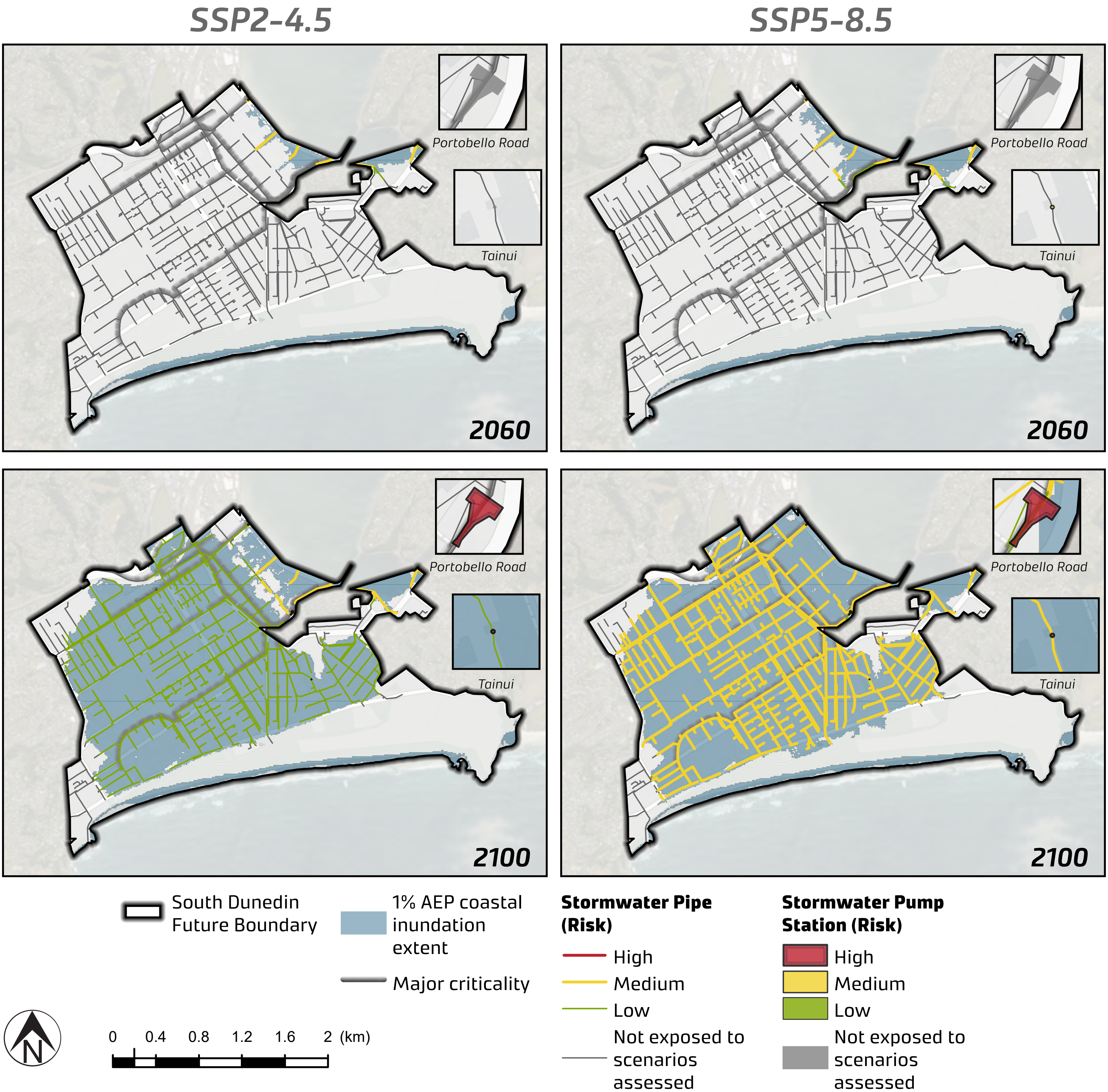
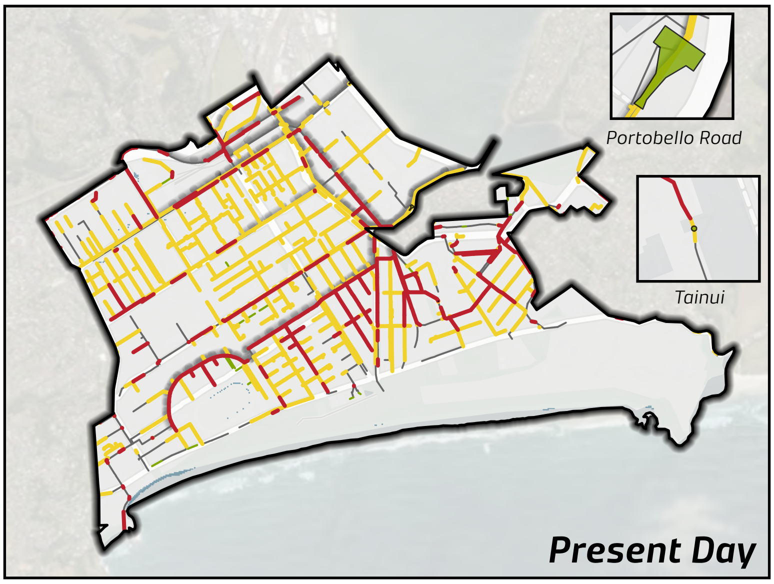


Figure 5.37 Stormwater infrastructure risk due to groundwater



Explainer: These maps show the risk to stormwater infrastructure due to groundwater hazard (blue shading). Risk ratings for stormwater pipe sections are based on exposure of each pipe to the modelled median groundwater level (using pipe invert level to test whether the pipe is exposed). Pipe vulnerability to groundwater is a function of the pipe material or age, where cracked pipes or leaky joints mean that groundwater will flow into the system and reduce the pipe capacity, ultimately causing a reduction in level of service. The maps illustrate groundwater risk is medium or high for most stormwater pipes within South Dunedin under the assessed scenarios. A number of high criticality pipes (grey shadow on pipe) are rated at high risk. The impact of groundwater infiltration at a network scale is under investigation.

Disclaimer: These maps are not intended to assess groundwater risk at individual asset level, which requires consideration of site specific groundwater risk as well as more detailed asset information.

Hazard data source: Cox, et al., 2023

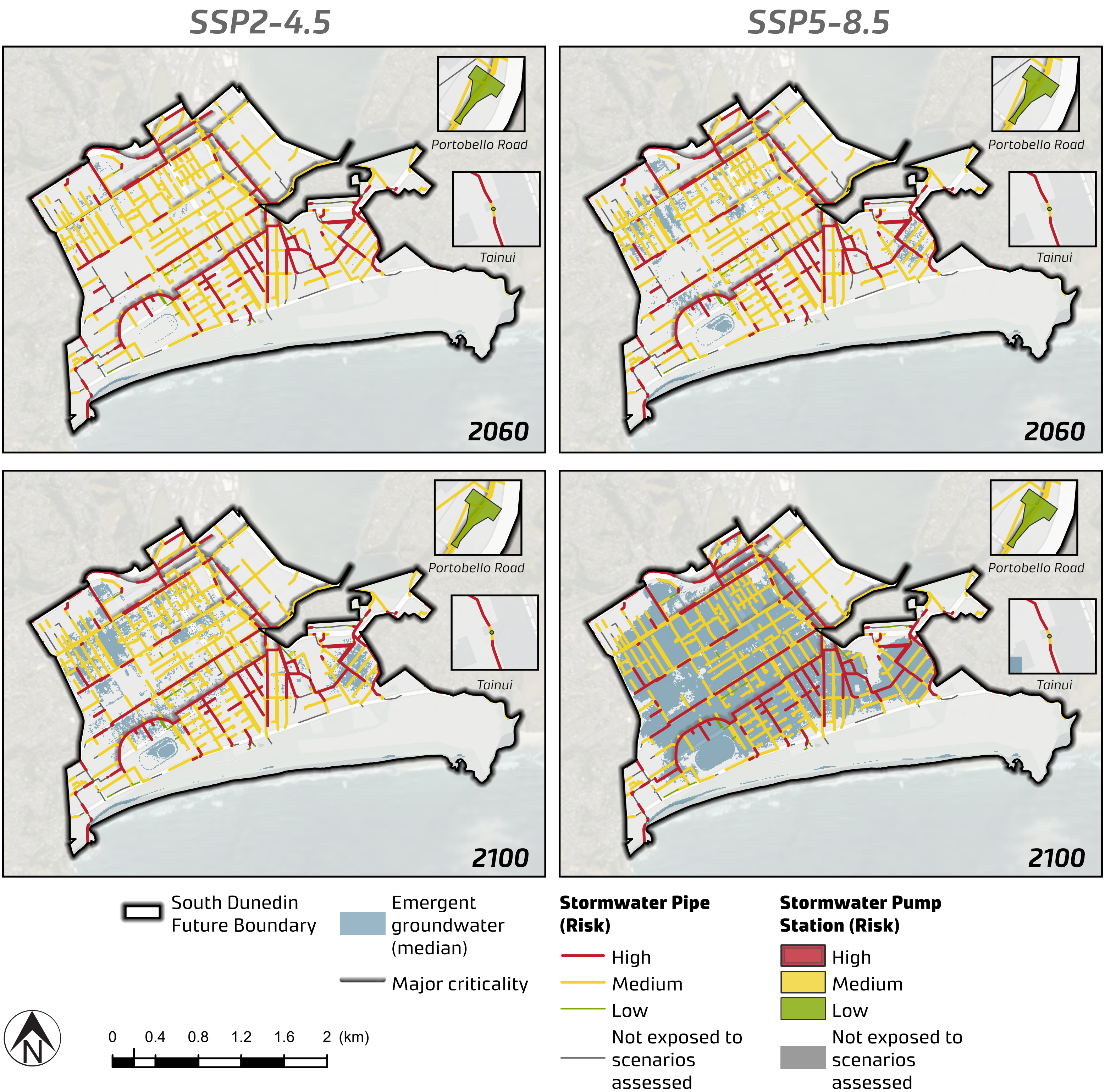
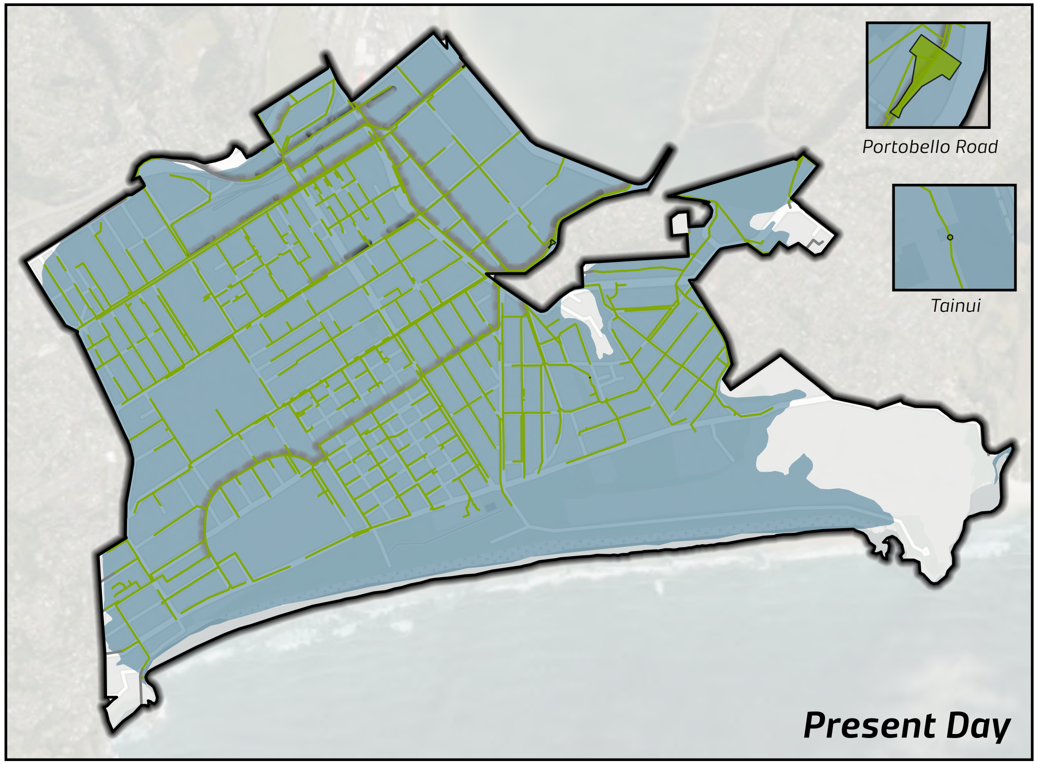


Figure 5.38 Stormwater infrastructure risk due to landslide and liquefaction

Liquefaction



Explainer: These maps show the risk to stormwater infrastructure due to liquefaction. Risk ratings for individual pipe lengths are based on exposure of each asset to liquefaction potential, combined with their vulnerability rating which is based on pipe material and age. The maps illustrate liquefaction risk is low across South Dunedin at the present day. Liquefaction risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of sea level rise on liquefaction potential. If it were to occur, liquefaction can impact water infrastructure by deforming the pipe network. Ground settlement or stretching may damage or disconnect pipes and chambers and subsequent inflow of sediment can cause blockages. Buoyancy can cause uplift of buried structures, and disrupt drainage systems, while sediment discharge can reduce water quality and affect aquatic habitats.
Disclaimer: These maps are not intended to assess liquefaction risk at individual asset level, which requires consideration of site specific liquefaction risk as well as more detailed asset information. Liquefaction hazard information is based on a high level desktop review, where subsequent site specific assessment (Hornblow, 2020) has found that liquefaction potential is highly variable across sites analysed.
Hazard data source: Barrell, 2014

Landslide

Explainer: These maps show the risk to stormwater infrastructure due to landslide, where some pipes at the South Dunedin boundary are rated medium risk. Risk ratings for individual stormwater pipes are based on exposure of each asset to landslides, combined with their vulnerability rating and adjusted for pipe criticality (grey shadow on pipe). Landslides can severely damage stormwater resulting in major repairs and reduction in level of service. The maps illustrate that landslide risk is confined to areas around the South Dunedin boundary. Landslide risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of climate change (groundwater level rising or increased rainfall intensity) on landslide.
Disclaimer: These maps are not intended to assess landslide risk at individual asset level, which requires consideration of a site specific landslide risk as well as more detailed asset information. The landslide extent is based on known landslide areas and does not account for other potential sources of landslide nor represent the extent of the area of deposition/runout.
Hazard data source: DCC Hazard database data provided for South Dunedin Future programme

South Dunedin Future Boundary
Land instability
Liquefaction (Domain C: moderate liquefaction potential)
Major criticality

Stormwater Pipe (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

Stormwater Pump Station (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

N

0 0.4 0.8 1.2 1.6 2 (km)

5.5.3 RISK TO WASTEWATER INFRASTRUCTURE

There are 79 km of wastewater pipes in South Dunedin, key features within the wastewater network include:

- Musselburgh WW pump station.
- Tahuna WWTP.
- All flap gates.
- WW Pump station - Marne St Pump station (overflow pump station which pumps to Musselburgh).
- High criticality pipes.

The graph shown in Figure 5.39 identifies how the risk to wastewater infrastructure within South Dunedin changes over time with each hazard. Spatial representation of risk to wastewater infrastructure is shown in Figure 5.40, Figure 5.42, Figure 5.43 and Figure 5.44, with high criticality pipes (criticality rating greater than >4) identified. Table 5-6 shows risk ratings for key wastewater structures. Further detail regarding wastewater infrastructure vulnerability is contained in Appendix C.

The wastewater pipe network is at high risk due to pluvial flooding, coastal inundation, groundwater and coastal erosion (Figure 5.39). Present day risk is highest due to pluvial flooding and groundwater, with 39 km (51% and 50% respectively) of pipes rated at high risk which increases to 57 km (72%) at late century for pluvial flooding, and 46 km (58%) at late century. These pipes are at high risk because they are at a level that is lower than the modelled groundwater table and are of an age and or material type that means they are extremely vulnerable to groundwater infiltration. Groundwater infiltration into the wastewater network presents a chronic issue that will reduce the pipe capacity causing a reduction in level of service. The overall effect of this reduction in pipe capacity on the network is currently under investigation.

At late century, coastal inundation poses a high risk to the greatest proportion of the network with 63 km (80%) of the pipe network rated at high risk. Pipe network vulnerability to flooding and groundwater is related to impacts on the pipe level of service. Pipe surcharging due to inflow and infiltration results in widespread reduction in level of service. Flooding can result in widespread environmental contamination. It is important to note that pipe infiltration draws down groundwater level.

Risk to wastewater structures is shown in Table 5-6. This shows Tahuna WWTP and Musselburgh Pump Station are at high risk from pluvial flooding at present day, with Musselburgh also at high risk from coastal inundation at mid-century under a high end climate scenario. Flooding of wastewater Pump Stations may flood the dry well, resulting in failure of the pump station. Unless a bypass is used, this would mean flows could not be pumped to sea, resulting in high environmental and public health consequences. The proximity of Marne Street to the coast means it is at high risk due to coastal erosion at present day[36].

[36] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

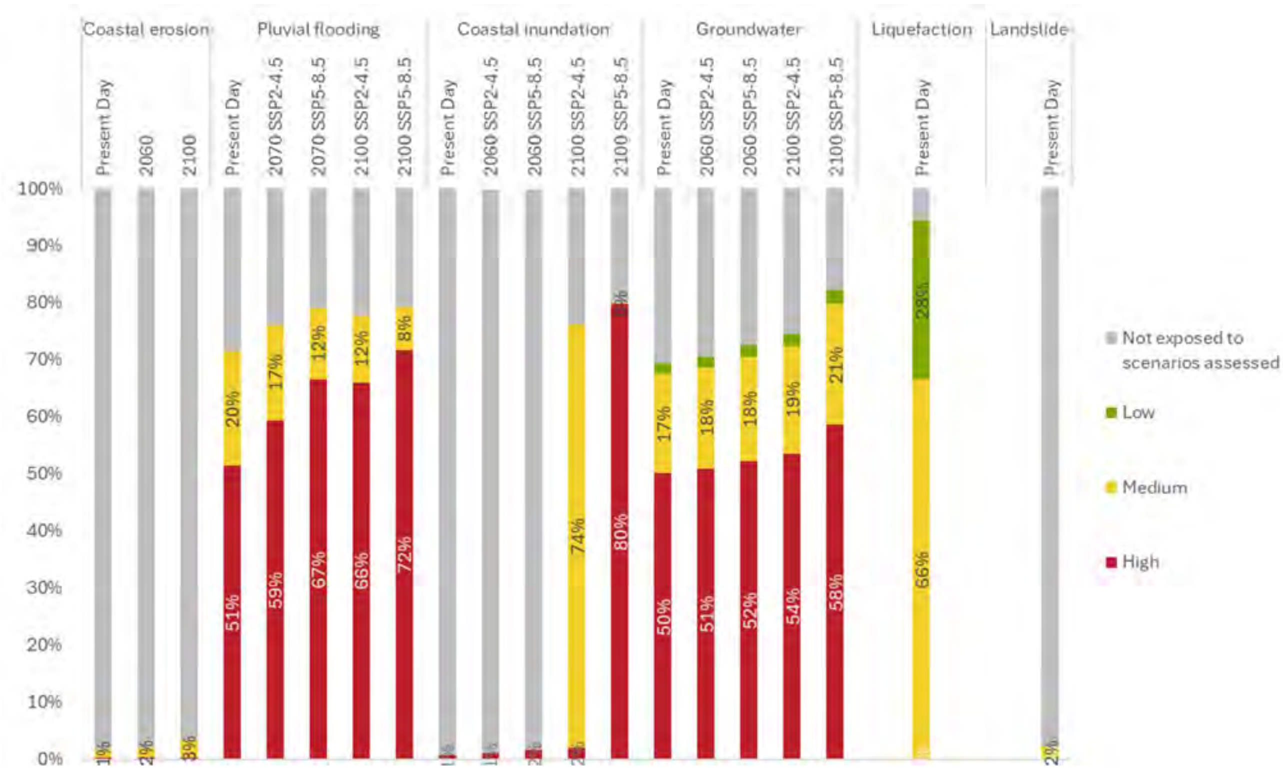


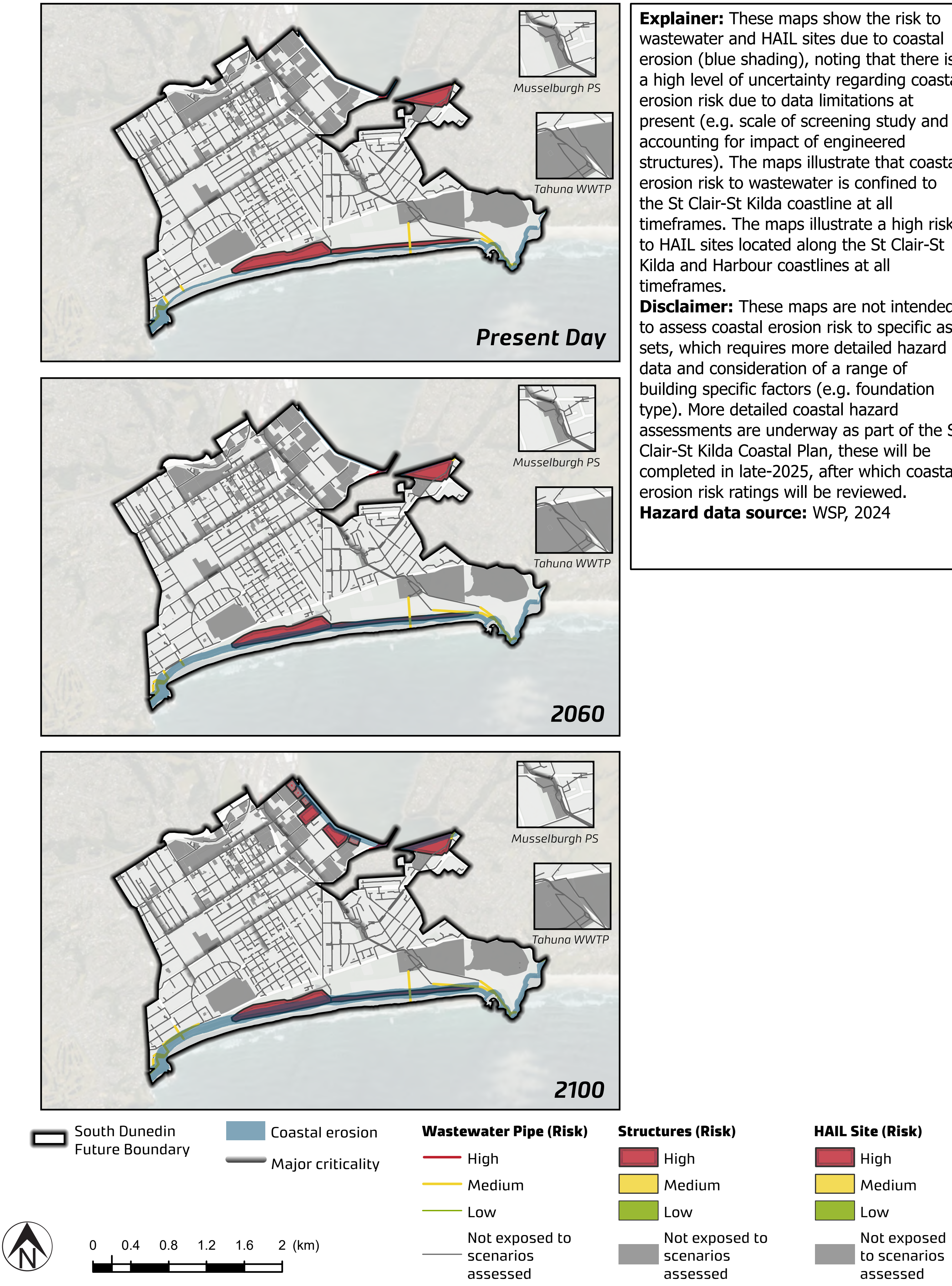
Figure 5.39 Risk to wastewater pipes presented as percentage of pipe length at each risk rating[36]

Table 5-6 Risk to wastewater structures[36]

	Coastal erosion			Coastal inundation					Groundwater					Pluvial flooding					Land-slide	Lique-faction
	Present Day	2060	2100	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2070 SSP2-4.5	2070 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Tahuna WWTP Building	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	Medium	Medium	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
Tahuna WWTP Outfall & Trickling Filter Pump Station	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low	Low	Low	Low	Low	High	High	High	High	High	Not exposed	Low
Musselburgh Pumping Station (FS)	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	High	High	High	Low	Low	Low	Low	Low	High	High	High	High	High	Not exposed	Low
Marne Street Pump Station (FS)	High	High	High	Medium	Medium	Medium	Medium	Medium	Low	Low	Low	Low	Low	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Low

Low | Medium | High | Not exposed to scenarios assessed

Figure 5.40 Wastewater infrastructure and contaminated land (HAIL sites) risk due to coastal erosion

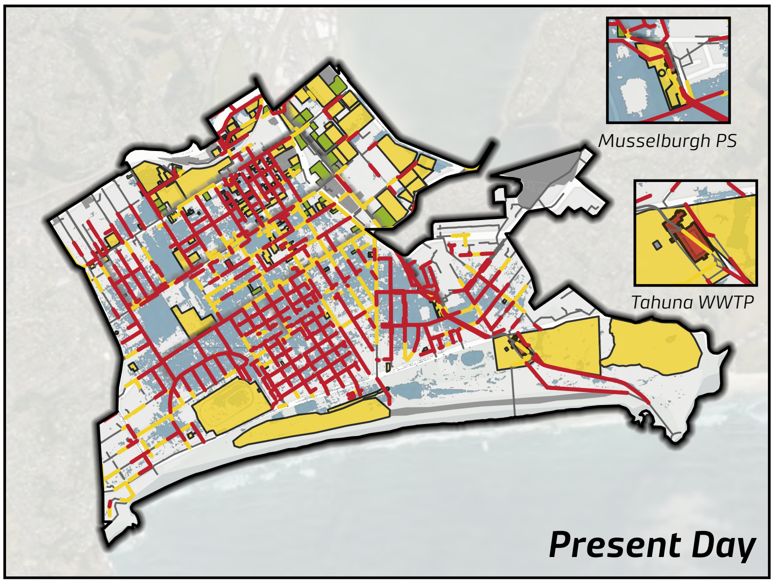


Explainer: These maps show the risk to wastewater and HAIL sites due to coastal erosion (blue shading), noting that there is a high level of uncertainty regarding coastal erosion risk due to data limitations at present (e.g. scale of screening study and accounting for impact of engineered structures). The maps illustrate that coastal erosion risk to wastewater is confined to the St Clair-St Kilda coastline at all timeframes. The maps illustrate a high risk to HAIL sites located along the St Clair-St Kilda and Harbour coastlines at all timeframes.

Disclaimer: These maps are not intended to assess coastal erosion risk to specific assets, which requires more detailed hazard data and consideration of a range of building specific factors (e.g. foundation type). More detailed coastal hazard assessments are underway as part of the St Clair-St Kilda Coastal Plan, these will be completed in late-2025, after which coastal erosion risk ratings will be reviewed.

Hazard data source: WSP, 2024

Figure 5.41 Wastewater infrastructure and contaminated land (HAIL sites) risk due to pluvial flooding



Explainer: These maps show the risk to wastewater infrastructure and HAIL sites due to pluvial flooding (blue shading). Risk ratings for individual wastewater pipe sections and HAIL sites are based on exposure of each asset or site to modelled pluvial flooding, combined with the vulnerability of the asset to flooding. Many wastewater pipes and HAIL sites are extremely exposed, due to frequent severe flooding (>10% AEP). Wastewater pipes are rated to have high vulnerability to pluvial flooding due to the potential for a reduction in level of service, which results in environmental contamination and associated breaches of consent conditions. Wastewater pump stations are extremely vulnerable to flooding. HAIL sites are rated to have low vulnerability to pluvial flooding. The maps illustrate pluvial flood risk is medium or high across most of the pipe network at present day, with the extent of high risk increasing in future timeframes. Risk to Musselburgh Pump Station is rated medium and Tahuna Wastewater Treatment Plant is rated high under all timeframes. Risk to many HAIL sites is medium at all timeframes.

Disclaimer: These maps are not intended to assess pluvial flooding risk at individual asset level, which requires consideration of site specific flooding risk as well as more detailed asset information.

Hazard data source: DCC ICMP Flood Model (Beca, WSP, 2024)

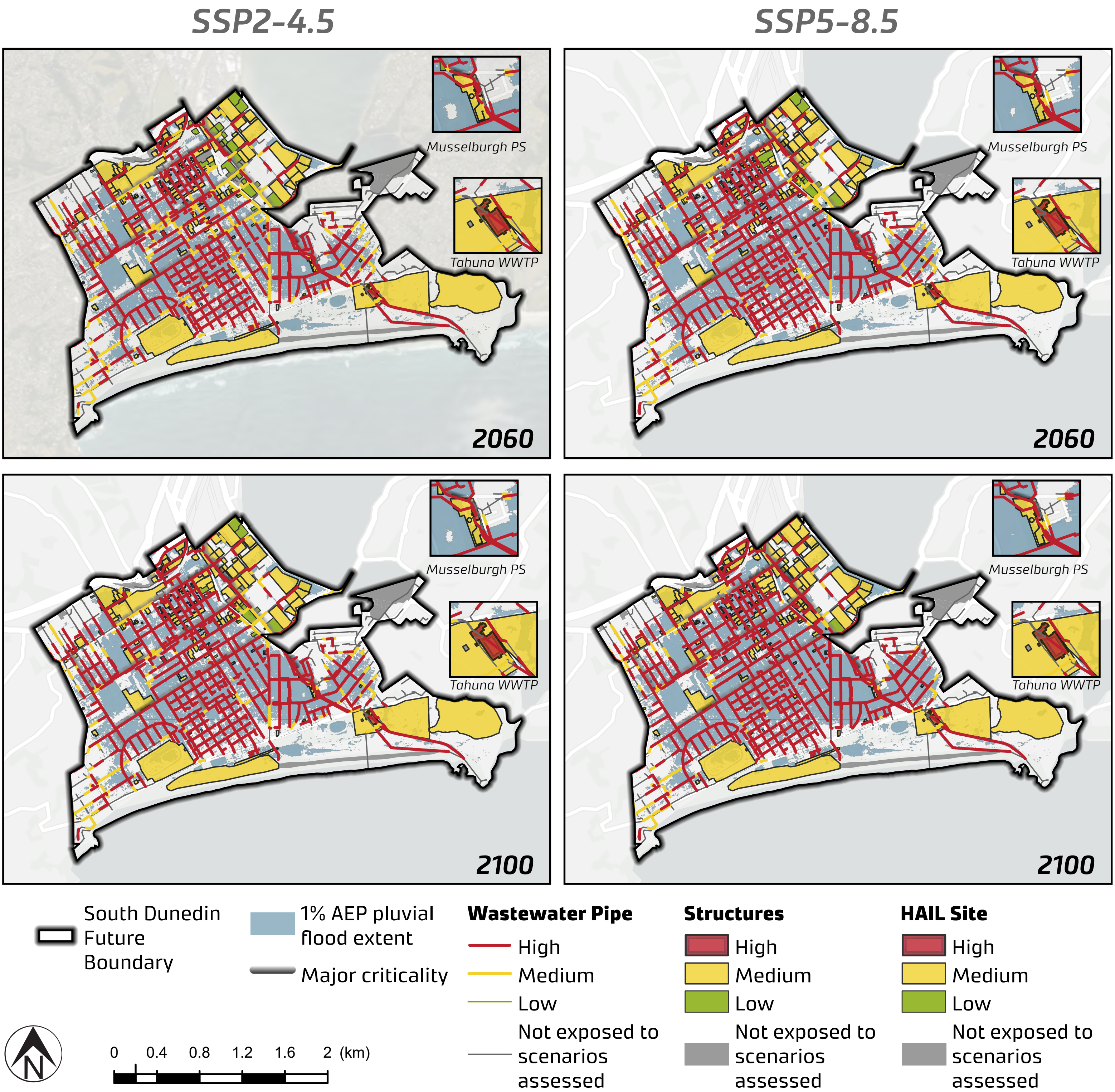
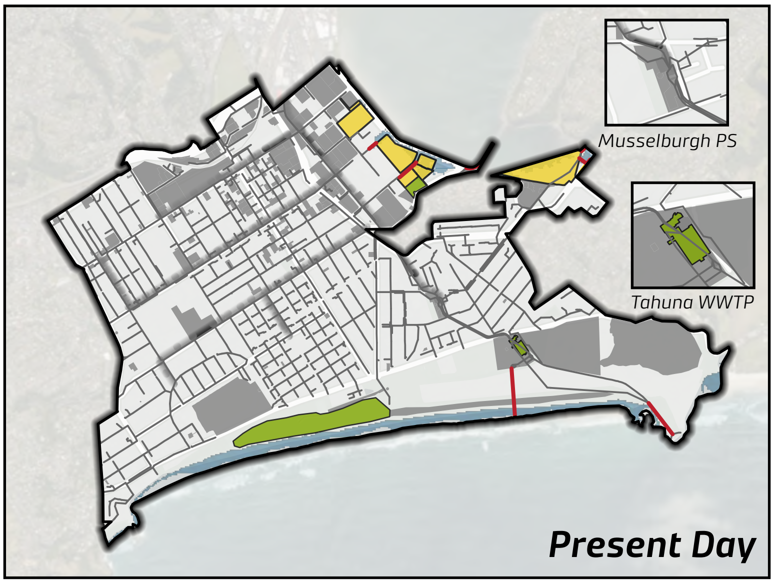


Figure 5.42 Wastewater infrastructure and contaminated land (HAIL sites) risk due to coastal inundation



Explainer: These maps show the risk to wastewater infrastructure and HAIL sites due to coastal inundation (blue shading). Risk ratings for individual wastewater pipe sections and HAIL sites are based on exposure of each asset to modelled coastal inundation, combined with the vulnerability of the asset to inundation. While many wastewater pipes and HAIL sites are extremely exposed to frequent severe flooding (>10% AEP), HAIL sites are rated to have low vulnerability to coastal inundation as they do not tend to sustain damage during such events. Wastewater pipes are rated to have high vulnerability to coastal inundation due to the potential reduction in level of service, which results in environmental contamination and associated breaches of consent conditions. The maps illustrate that at late century coastal inundation risk becomes medium under a mid-range climate scenario, and high under a high end climate scenario for most wastewater pipes within South Dunedin. Risk to pump stations is rated low at mid century , and increases to medium at late century.

Disclaimer: These maps are not intended to assess coastal inundation risk at individual asset level, which requires consideration of site specific flooding risk as well as more detailed asset information.

Hazard data source: Paulik, et al., 2023

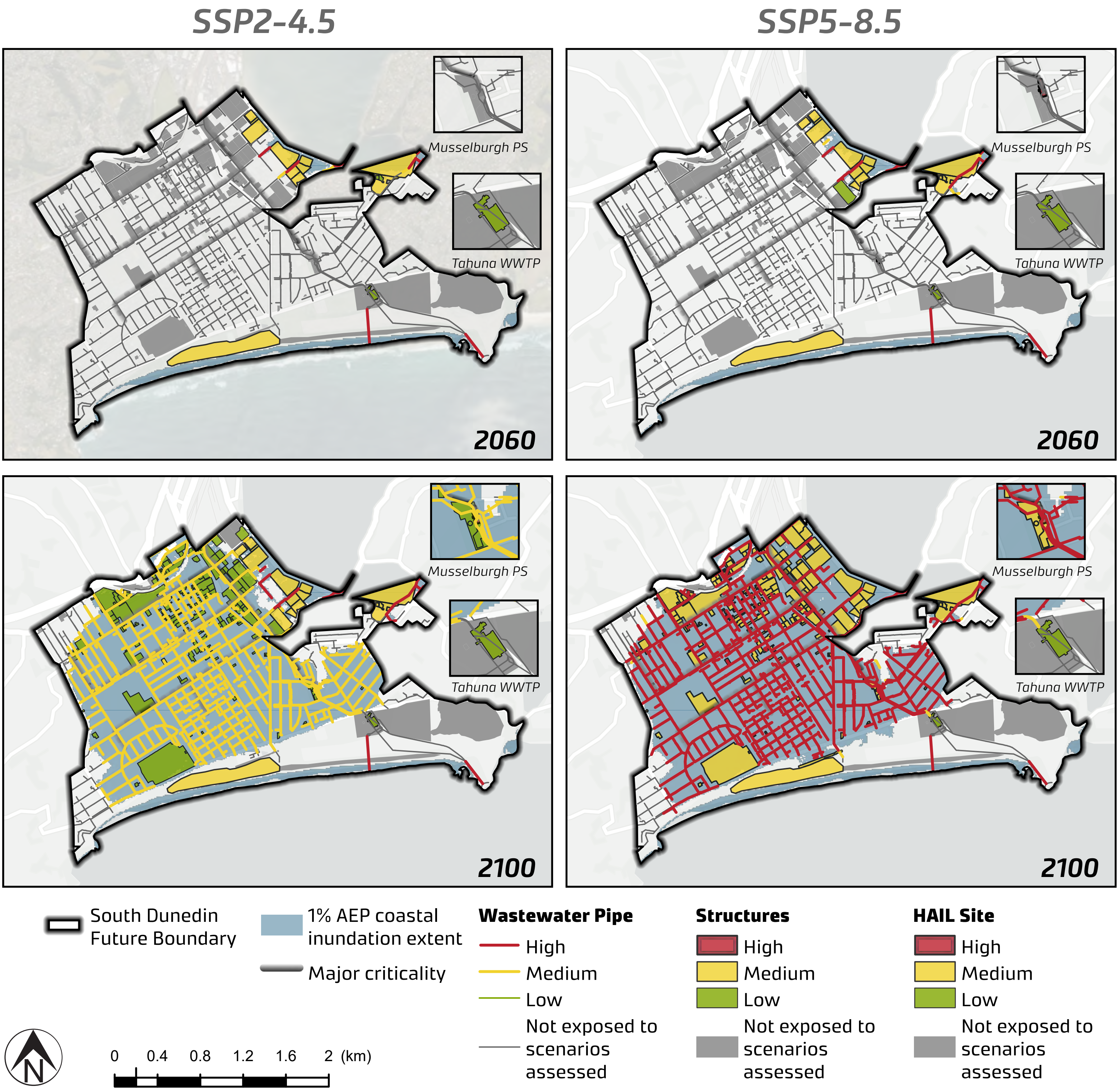
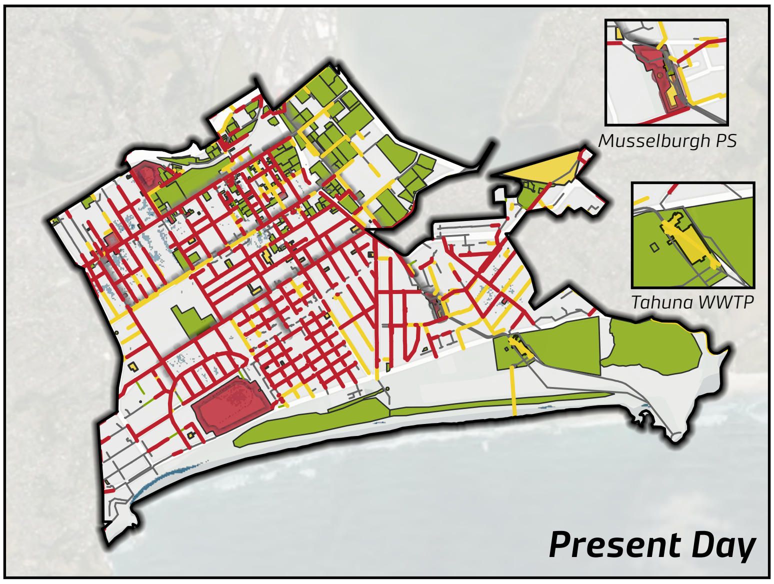


Figure 5.43 Wastewater infrastructure and contaminated land (HAIL sites) risk due to groundwater



Explainer: These maps show the risk to wastewater infrastructure and HAIL sites due to groundwater (blue shading). Risk ratings for individual wastewater pipe sections are based on exposure of each asset to the modelled median groundwater level (using pipe invert level to test whether the pipe is exposed). Pipe vulnerability to groundwater is a function of the pipe material or age, where cracked pipes or leaky joints mean that groundwater will flow into the system and reduce the pipe capacity, ultimately causing a reduction in level of service. The maps illustrate groundwater risk is medium or high for most wastewater pipes within South Dunedin under the assessed timeframes. A number of high criticality pipes (grey shading) are rated at high risk. The impact of groundwater infiltration at a network scale is under investigation. Risk ratings for HAIL sites are based on exposure of each asset to the modelled median groundwater level, where residential sites are assessed to be highly vulnerable to groundwater if the median groundwater level rises to within 0.3 m of the ground surface (light blue shading) and industrial sites are highly vulnerable if the median groundwater level is emergent (dark blue shading).

Disclaimer: These maps are not intended to assess groundwater risk at individual asset level, which requires consideration of site specific groundwater risk as well as more detailed asset information.

Hazard data source: Cox, et al., 2023

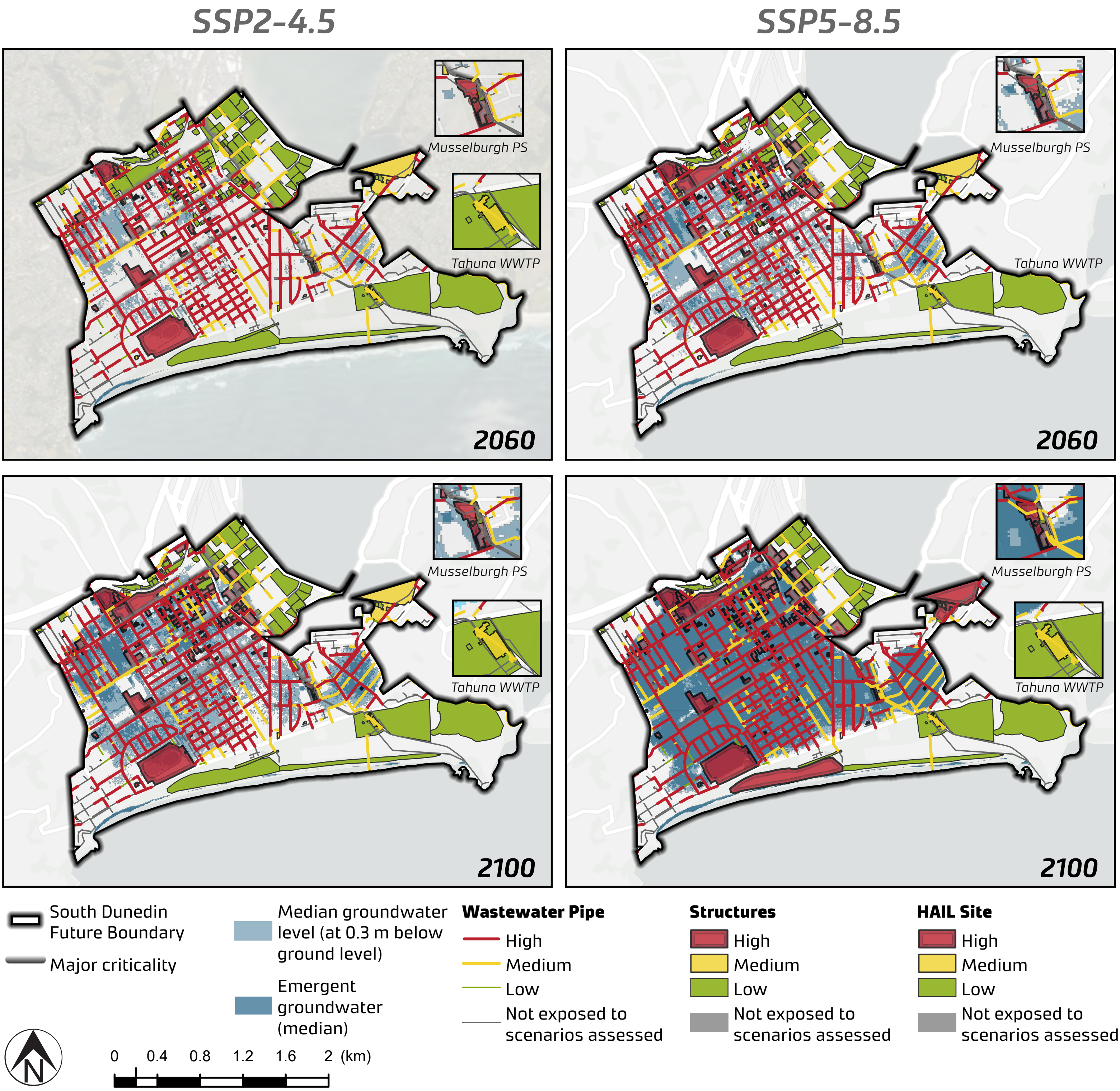
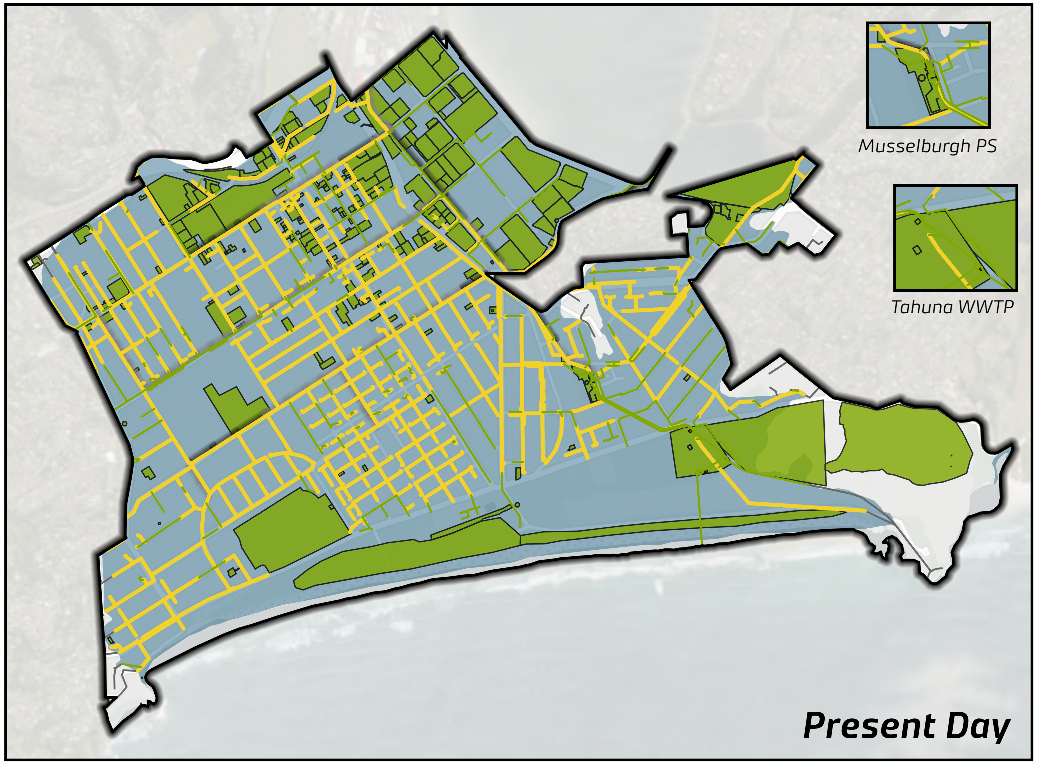


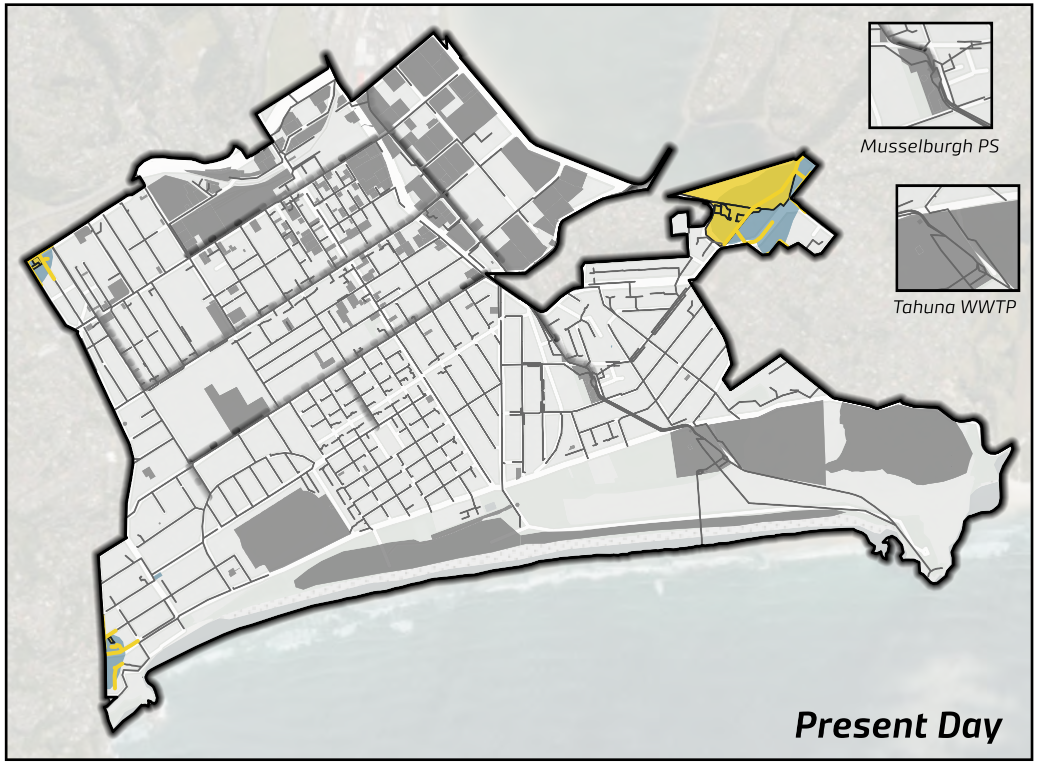
Figure 5.44 Wastewater infrastructure and contaminated land (HAIL sites) risk due to landslide and liquefaction

Liquefaction



Explainer: These maps show the risk to wastewater infrastructure and HAIL sites due to liquefaction. Risk ratings are based on exposure of each asset or site to liquefaction potential, combined with their vulnerability rating. The maps illustrate liquefaction risk is low across South Dunedin at the present day. Liquefaction risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of sea level rise on liquefaction potential. If it were to occur, liquefaction can impact water infrastructure by deforming the pipe network. ground settlement or stretching may damage or disconnect pipes and chambers and subsequent inflow of sediment can cause blockages. Buoyancy can cause uplift of buried structures, and disrupt drainage systems, while sediment discharge can reduce water quality and affect aquatic habitats.
Disclaimer: These maps are not intended to assess liquefaction risk at individual asset level, which requires consideration of site specific liquefaction risk as well as more detailed asset information. Liquefaction hazard information is based on a high level desktop review, where subsequent site specific assessment (Hornblow, 2020) has found that liquefaction potential is highly variable across sites analysed.
Hazard data source: Barrell, 2014

Landslide



Explainer: These maps show the risk to wastewater infrastructure and HAIL sites due to landslide. Risk ratings for individual wastewater pipes are based on exposure of each asset to landslides, combined with their vulnerability rating and adjusted for pipe criticality (grey shadow on pipe). Landslides can severely damage wastewater resulting in sudden collapse or failure and posing a potential risk to life in critical assets. The maps illustrate that some pipes and HAIL sites at the South Dunedin boundary are rated medium risk. Landslide risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of climate change (groundwater level rising or increased rainfall intensity) on landslide.
Disclaimer: These maps are not intended to assess landslide risk at individual asset level, which requires consideration of a site specific landslide risk as well as more detailed asset information. The landslide extent is based on known landslide areas and does not account for other potential sources of landslide nor represent the extent of the area of deposition/runout.
Hazard data source: DCC Hazard database data provided for South Dunedin Future programme

South Dunedin Future Boundary

Land instability

Liquefaction (Domain C: moderate liquefaction potential)

Major criticality

Wastewater Pipe (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

Structures (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

HAIL Site (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

N

0 0.4 0.8 1.2 1.6 2 (km)

5.6 CONTAMINATED LAND RISK

Potentially contaminated sites have been identified in the HAIL register[37]. This register has limitations with data relating to both completeness, (i.e. not all sites have been identified) and some sites are unable to be identified (e.g. lead paint on buildings).

There are 236 contaminated sites in South Dunedin with a combined area of approximately 1.5 km^2. Key features are:

- Sites within industrial areas.
- Sites residential areas.
- Kettle Park (Ocean Beach Domain Landfills).
- Gas Works.

The graph shown in Figure 5.45 identifies how the contaminated land risk within South Dunedin changes over time with each hazard. Spatial representation of risk to contaminated land is shown in Figure 5.40, Figure 5.42, Figure 5.43, and Figure 5.44. Further detail regarding contaminated land vulnerability is contained in Appendix C.

As shown in Figure 5.45, groundwater poses the greatest risk to contaminated sites both at present day and into the future. The number of sites rated high risk due to groundwater increases significantly with time, from 7% at present day, rising to 80% of sites at late century under a high end climate change scenario. Sites within industrial zoning that are rated high risk are those that are exposed to emergent groundwater. Sites within residential zones that are rated high risk are those that are exposed to groundwater above 0.3 m below ground level. Sites that are rated moderate risk are located within residential areas that are exposed to groundwater shallower than 1 m below ground level.

Where near surface contamination is exposed to emergent groundwater there is potential for contamination to be transported, resulting in spread of contamination. Contaminated sites within industrial areas tend to have higher contamination loading and are extremely vulnerable to emergent groundwater due to the potential for transport and exposure of contaminants. These sites have the potential for exposing workers and public. Widespread hardstand in these areas mean there is a greater tolerance for high (but not emergent) groundwater due to the presence of barriers between contamination and the surface.

The nature of contamination in residential areas tends to be less severe, however activities carried out in residential areas tend to have a higher likelihood of interacting with the ground (for example vegetable gardens, sportsgrounds). Consequences relating to residential contamination may impact the health of residents e.g. ingested via residential vegetable gardens. At a catchment scale, changing groundwater levels may result in increased infiltration of contaminants into stormwater or wastewater network.

Contaminated sites are also rated at high risk due to coastal erosion at present day, where the number of sites rated at high rises from 1% at present day to 7% at late century.

A large number of sites are rated at medium risk due to pluvial flooding and coastal inundation. Exposure to these hazards may drive some increase in contaminant transport, resulting in environmental or health risks.

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[37] https://environment.govt.nz/publications/hazardous-activities-and-industries-list-hail/

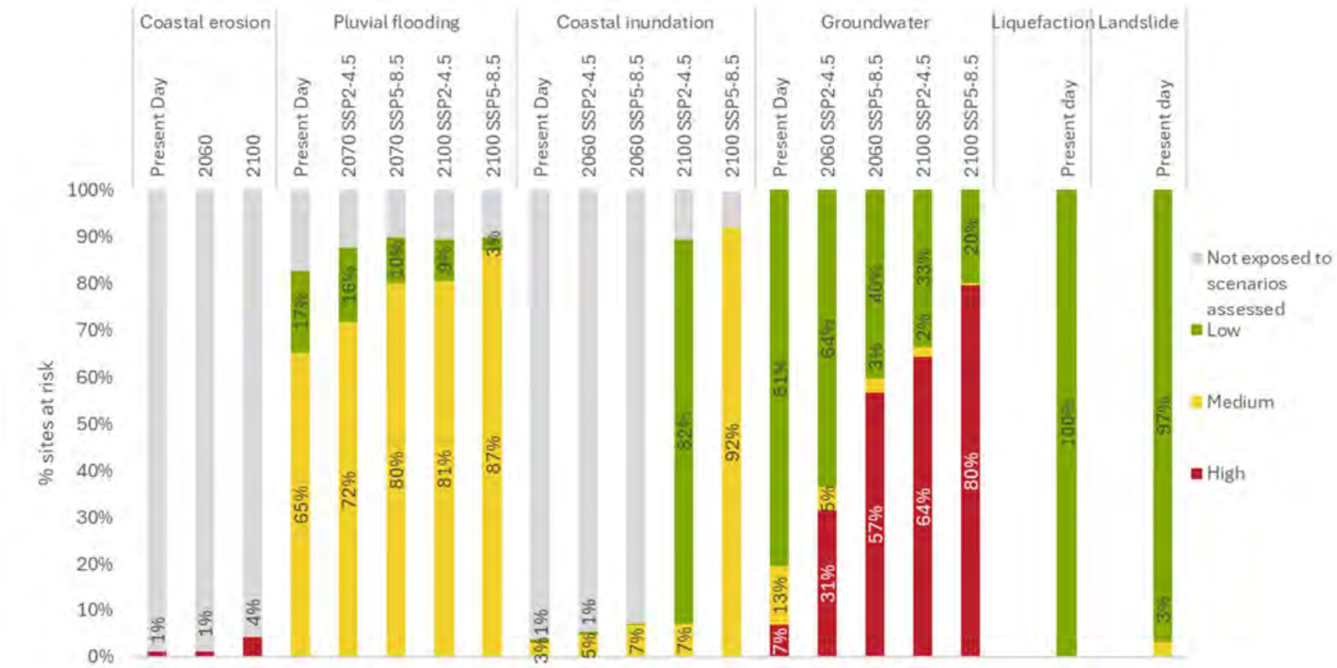


Figure 5.45 Risk to contaminated land presented as percentage of HAIL sites (by number) at each risk rating[38].

Risk to identified contaminated sites is shown in Table 5-7. This shows the Ocean Beach Domain landfills and Andersons Bay Closed Landfill are at high risk from coastal erosion at present day and into the future due to their proximity to the coast[38]. These sites are rated to be at high risk due to groundwater at late century under a high end climate change scenario. These sites are at medium risk due to coastal inundation, groundwater and landslide at all timeframes and climate change scenarios.

The Gasworks sites are rated to be at high risk due to groundwater at later timeframes, with some sites rated at high risk at mid-century under a high end climate change scenario. This risk is driven primarily by the extent of emergent groundwater encroaching on the Gasworks sites.

[38] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

Table 5-7 Risk to contaminated land: identified key features[38]

	Coastal erosion			Coastal inundation					Groundwater					Pluvial flooding					Land-slide	Lique-faction
	Present Day	2060	2100	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2070 SSP2-4.5	2070 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Andersons Bay Closed Landfill	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Low
Ocean Beach Domain Landfill 1 & 2	High	High	High	Low	Medium	Medium	Medium	Medium	Low	Low	Low	Low	High	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
Ocean Beach Domain Landfill 3	High	High	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low	Low	Low	Low	Low	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
Chisholm Park Landfill	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low	Low	Low	Low	Low	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
DCC Gasworks, Shell Site	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low	Medium	Low	Low	High	High	High	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
DCC Gasworks, Countdown Site	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low	Medium	Low	Low	Low	Low	High	Not exposed	Not exposed	Low	Medium	Medium	Not exposed	Low
DCC Gasworks, Museum Site	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low	Medium	Low	Low	High	High	High	Not exposed	Low	Low	Low	Medium	Not exposed	Low
DCC Gasworks, Tar Well Site	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low	Medium	Low	Low	Low	Low	High	Low	Medium	Medium	Medium	Medium	Not exposed	Low
DCC Gasworks, Honda Site	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low	Medium	Low	Low	Low	High	High	Medium	Medium	Medium	Medium	Medium	Not exposed	Low
DCC Gasworks, Nova Energy Site	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low	Medium	Low	Low	Low	High	High	Medium	Medium	Medium	Medium	Medium	Not exposed	Low

Low | Medium | High | Not exposed to scenarios assessed

5.7 RISK TO TELECOMMUNICATIONS INFRASTRUCTURE

The telecommunications network within south Dunedin comprises the lines and South Dunedin Exchange site (Melbourne St). Identified key features are:

- Telecommunication lines.
- South Dunedin Exchange.

Risk ratings for the South Dunedin Exchange are shown in Table 5-8, these ratings are based on the building vulnerability ratings established for the building stock of South Dunedin. This shows that at present day the site is rated medium risk due to groundwater, which increases to high risk at mid-century under a high end climate scenario when the median groundwater level is modelled to rise above 0.3 m below ground level. Coastal inundation risk is rated medium and high at late century under mid-range and high end climate scenarios respectively on account of the location of the exchange within the 1% AEP and 10% AEP coastal inundation floodplain respectively.

Chorus is in the process of improving site resilience across the network and has recently retrofitted the South Dunedin Exchange with flood protection measures (these measures were not factored into the risk assessment). Spatial representation of risk to the South Dunedin Exchange is shown in Figure 5.48, Figure 5.50, Figure 5.51, and Figure 5.52. Further detail regarding telecommunications infrastructure vulnerability is contained in Appendix C.

A site specific risk assessment of telecommunication lines has not been assessed, however the following points are provided to support adaptation planning:

- Location of lines are not available as part of this assessment, although we understand that they generally follow roads.

- Parts of the telecommunication network are vulnerable to hazards (particularly coastal erosion, landslide, and liquefaction) however a key vulnerability of telecommunications infrastructure relates to their dependency on road access and power supply.
- Some copper connections remain in South Dunedin. This may decrease as the copper network is phased out in areas where fibre is available.
- Groundwater ingress is an issue for copper lines.
- Many network faults can be remedied (including reconnections) relatively quickly, giving the network a high adaptive capacity. Chorus has also built redundancy into their network such that connections between exchanges may not impact on service delivery. In addition, two containerised exchange sites ('MEOW's) have been set up which could be commissioned if damage occurred to the South Dunedin Exchange.

Table 5-8 Risk to the Chorus exchange site[39]

	Coastal erosion			Coastal inundation					Groundwater					Pluvial flooding					Land-slide	Lique-faction
	Present Day	2060	2100	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2070 SSP2-4.5	2070 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Chorus exchange	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Medium	Medium	High	High	High	Medium	Medium	Medium	Medium	Medium	Not exposed	Low

Low | Medium | High | Not exposed to scenarios assessed

[39] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

5.8 RISK TO ENERGY INFRASTRUCTURE

The South Dunedin electricity network is managed by Transpower (national grid) and Aurora (local grid). The network comprises the following key features, where risk was assessed to each asset within the features:

- Transpower South Dunedin Substation.
- Transpower: Transmission line.
- Aurora Substations: Carisbrook, St Kilda.
- Aurora 33kV Buried lines.
- Aurora Overhead lines.
- Genesis bulk LPG Facility.

Electricity is supplied into Dunedin City from two Transpower substations, one of which is within South Dunedin. From these substations, two adjacent power lines feeds into one of the Aurora zone substations to form the local distribution network.

The Transpower South Dunedin Substation and a small section of the Halfway Bush - South Dunedin A transmission line (7 structures) are located within South Dunedin. Transpower considers South Dunedin substation to be nationally significant based on to it being part of the South Island 'black start' plan, regionally significant based on the number of power connections (~21,000 ICPs - Installation Control Points).

The Dunedin reticulated LPG network crosses South Dunedin. The Genesis bulk LPG Facility is located at Hillside Road and operates at 55kPa. It powers approximately 350 homes and business with LPG and was commissioned in 2001. Specific risks to gas reticulation are not assessed as part of this assessment, however risks to buildings at the Genesis LPG facility are assessed as part of the building stock of South Dunedin, with risk ratings included Table 5-9.

Figure 5.46 and Figure 5.47 show how the risk to overhead lines and underground lines within South Dunedin changes over time with each hazard. Spatial representation of risk to energy infrastructure is shown in Figure 5.48, Figure 5.50, Figure 5.51, and Figure 5.52. Further detail regarding energy infrastructure vulnerability is contained in Appendix C.

Risk to the Transpower transmission line and substation (Transpower South Dunedin Substation) and Aurora substations (St Kilda and Carisbrook) are shown in Table 5-9. At mid-century, under a high end climate change scenario, the Transpower South Dunedin Substation site is rated high risk to coastal inundation. The St Kilda substation is rated at medium risk to coastal inundation at present day, increasing to high risk at mid-century under a mid-range scenario, and Carisbrook substation is rated at medium risk to groundwater under all scenarios and timeframes.

Table 5-9 Risk to energy key features[40]

	Coastal erosion			Coastal inundation					Groundwater					Pluvial flooding					Land-slide	Lique-faction
	Present Day	2060	2100	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Transpower Transmission line Halfway Bush - South Dunedin A	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	Low	Low	Medium	Medium	Medium	Low	Low	Low	Low	Low	Not exposed	Low
Transpower South Dunedin Substation	Not exposed	Not exposed	Not exposed	Not exposed	Low	High	High	High	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Not exposed	Low
Carisbrook Zone Substation	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	Medium	Medium	Medium	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
St Kilda Zone Substation	Not exposed	Not exposed	Medium	Medium	High	High	High	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low	Not exposed	Low
Genesis bulk LPG Facility *Ratings show building risk to all buildings at 61-65 Hillside Road Risk ratings were assessed under building risk assessment criteria and are not specific to gas reticulation services.*	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Medium	Medium	High	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Low	Low	Low	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Low	Low	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Low	Low	Medium	High	High	High	High	High	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Low	Low	Medium	Medium	High	High	High	High	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Medium	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Medium	Medium	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Low	Low	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low
	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Medium	High	Low	Low	Low	Low	Medium	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed	Low

Low | Medium | High | Not exposed to scenarios assessed

There are 20 km of overhead high voltage and sub transmission lines within the South Dunedin energy distribution network. Figure 5.46 shows the risk to overhead lines (and associated poles) presented as a percentage of line length at risk for each risk rating. This shows that groundwater poses the highest rated risk at present day and into the future for overhead lines. Poles may be sensitive to waterlogged soils as a result of rising groundwater, which can cause instability depending on foundation type (no data available to inform the assessment). Asset managers have indicated that this slow onset chronic risk is likely to have impacts that can be managed over time and therefore ongoing service delivery is unlikely to be impacted.

There are 59 km of underground high voltage and sub transmission lines. Figure 5.47 shows the risk to underground lines, which is relatively low compared to overhead lines, and most other

[40] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

elements at risk within South Dunedin. Coastal erosion poses the only high rated hazard, with 1% of lines rated at high risk at present day, which rises to 6.7% of lines at late century.

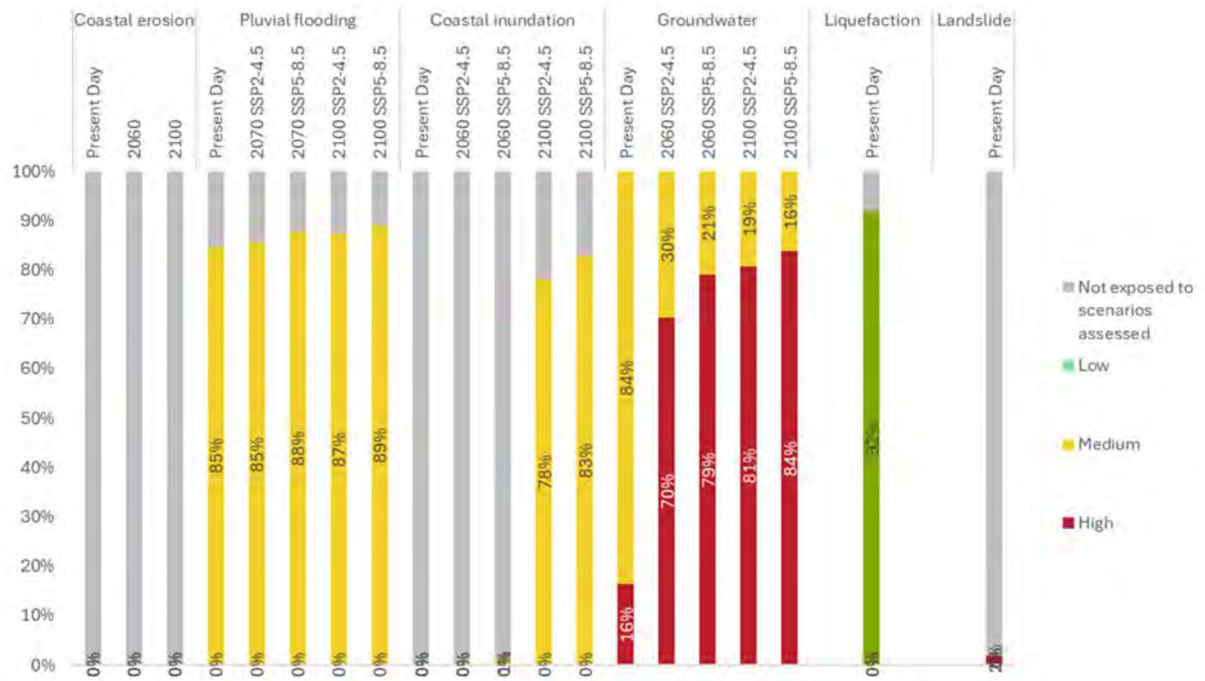


Figure 5.46 Risk to overhead lines (and associated poles) presented as percentage of line length at risk for each risk rating[41]

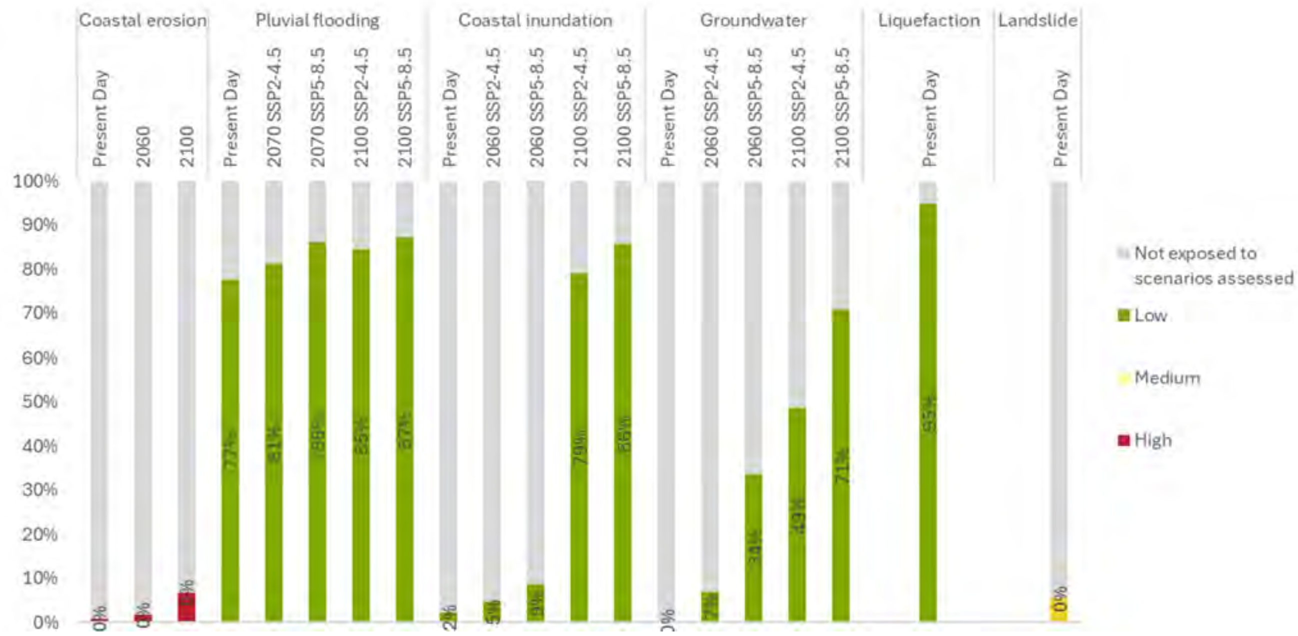
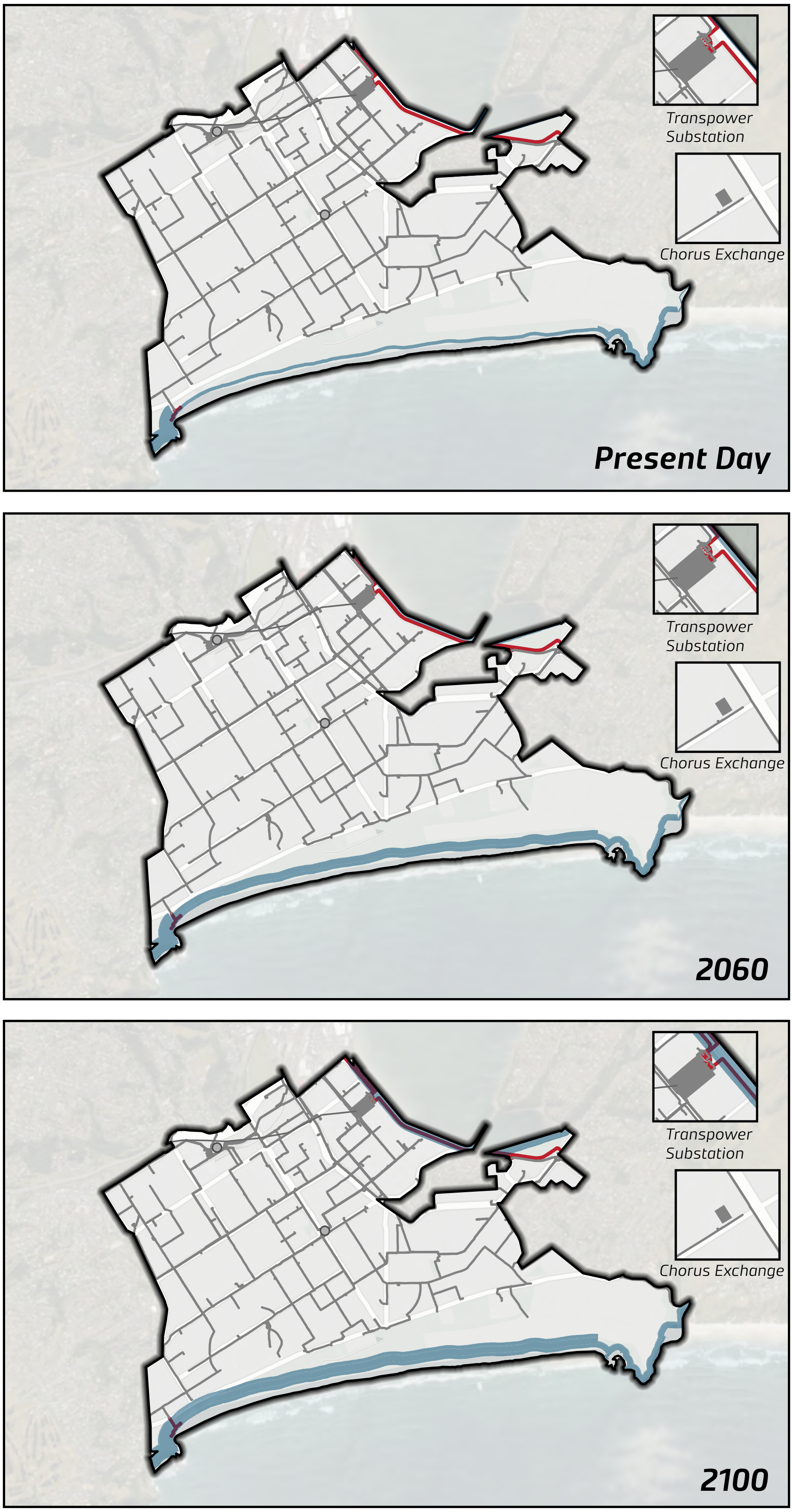


Figure 5.47 Risk to underground lines presented as percentage of line length at risk for each risk rating[42]

[41] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.
[42] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

Figure 5.48 Energy and telecommunications infrastructure risk due to coastal erosion

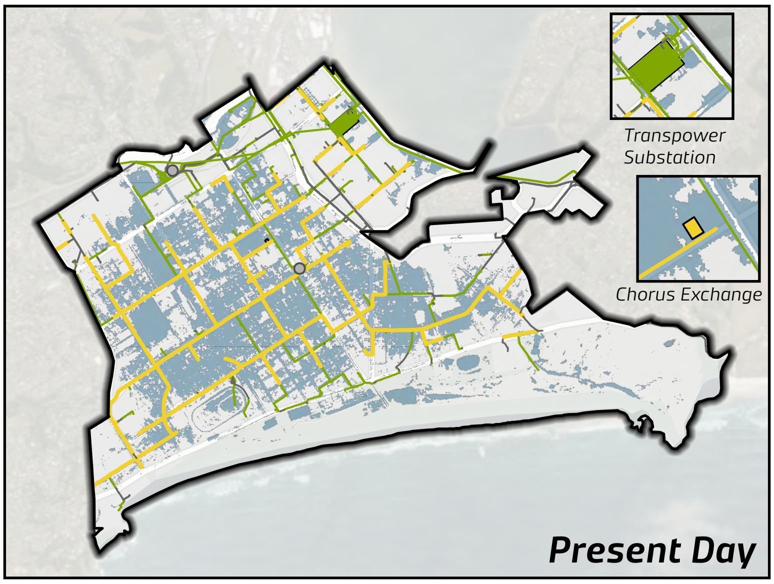


Explainer: These maps show the risk to energy and telecommunications infrastructure due to coastal erosion (blue shading), noting that there is a high level of uncertainty regarding coastal erosion risk due to data limitations at present (e.g. scale of screening study and accounting for impact of engineered structures). The maps indicate that coastal erosion risk to telecommunications lines is confined to areas directly adjacent to the Otago Harbour, and a small number of lines along the St Clair-St Kilda coastline at the St Clair end of the beach. More detailed coastal hazard assessments are underway as part of the St Clair-St Kilda Coastal Plan, these will be completed in late-2025, after which coastal erosion risk ratings will be reviewed.

Disclaimer: These maps are not intended to assess coastal erosion risk to specific assets, which requires more detailed hazard data and consideration of a range of building specific factors (e.g. foundation type).

Hazard data source: WSP, 2024

Figure 5.49 Energy and telecommunications infrastructure risk due to pluvial flooding

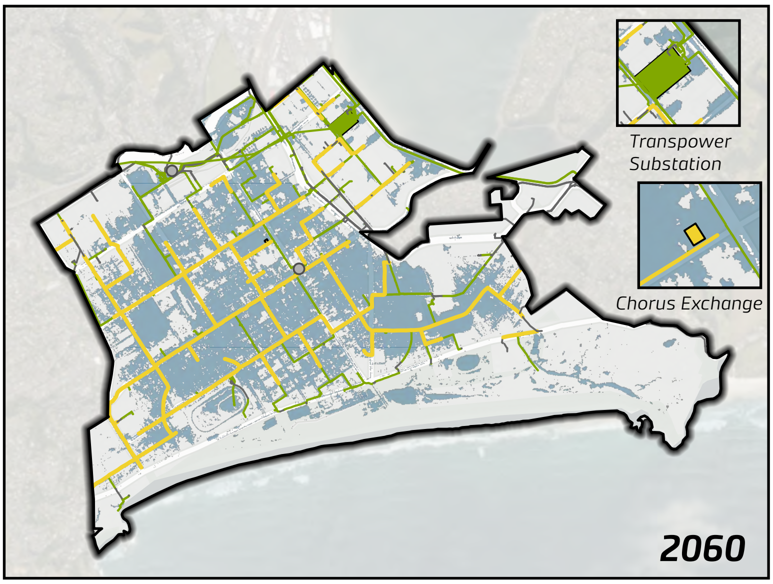


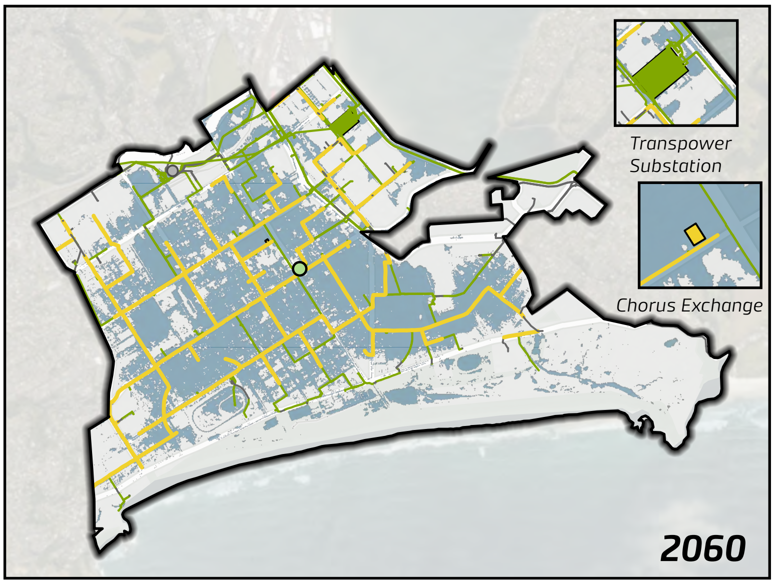
Explainer: These maps show the risk to energy and telecommunications infrastructure due to pluvial flooding (blue shading). Risk ratings for individual lines, substations and exchange sites are based on exposure of each asset or site to modelled pluvial flood at a range of return intervals, combined with the vulnerability of the asset to flooding. The maps illustrate pluvial flood risk is medium across the transmission line network across all timeframes and scenarios assessed. Risk to the Transpower substation is low across all scenarios and timeframes assessed, while the Chorus exchange site is at medium risk across all timeframes and scenarios.
Disclaimer: These maps are not intended to assess pluvial flood risk at the individual asset level, which requires considera-tion of site specific flooding risk as well as more detailed asset information.

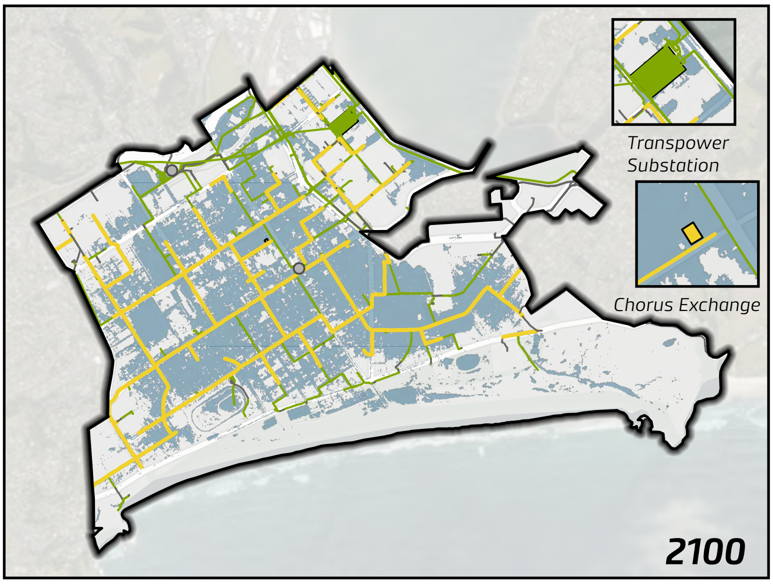
Hazard data source: DCC ICMP Flood Model (Beca, WSP, 2024)

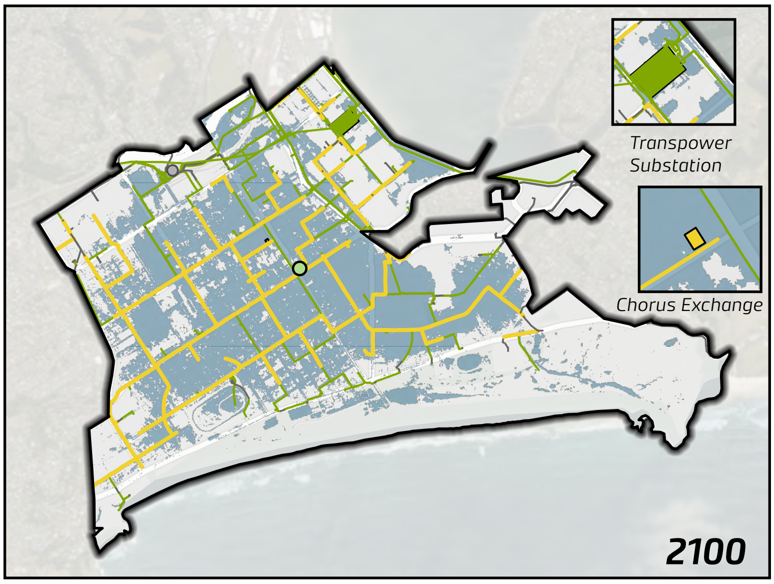
SSP2-4.5

SSP5-8.5









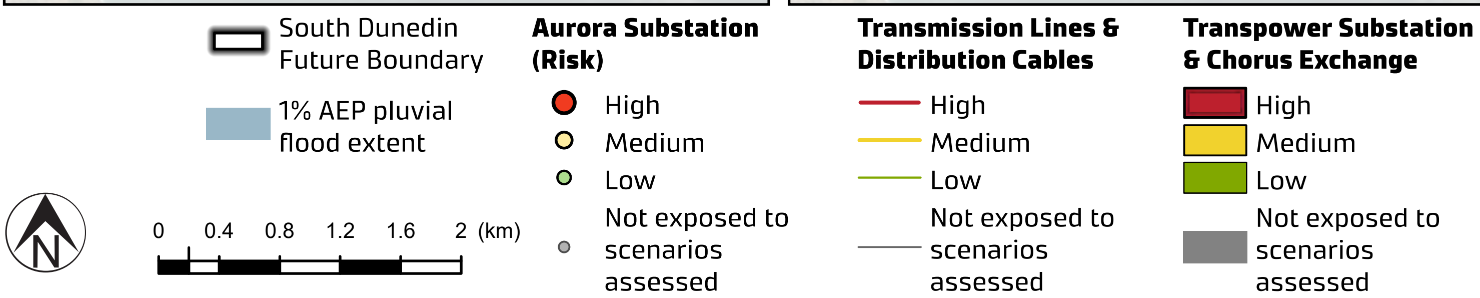
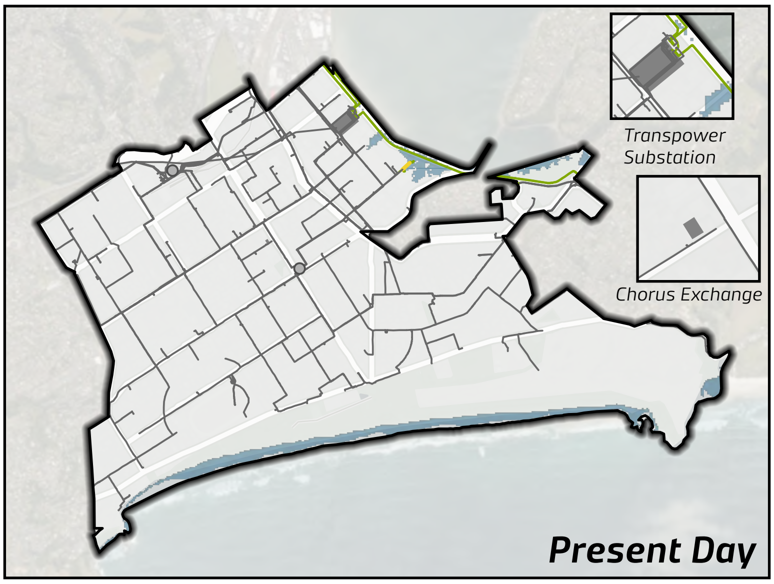


Figure 5.50 Energy and telecommunications infrastructure risk due to coastal inundation

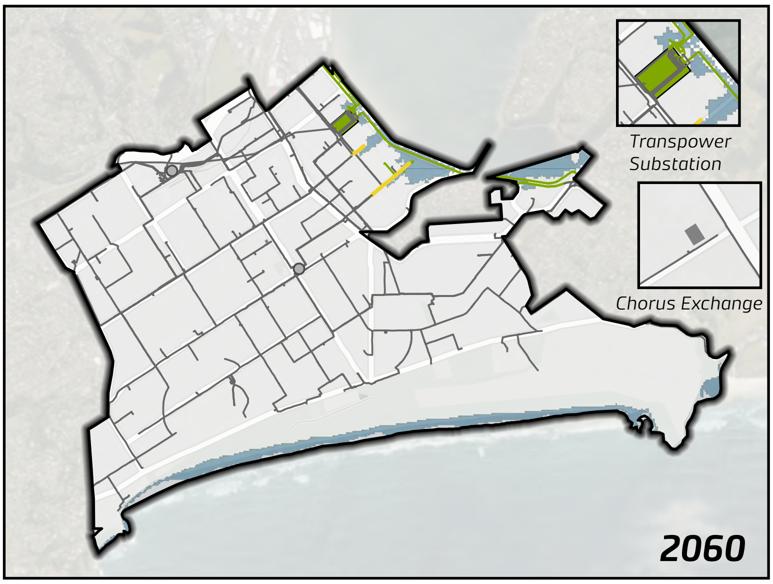


Explainer: These maps show the risk to energy and telecommunications infrastructure due to coastal inundation (blue shading). Risk ratings for individual lines, substations and exchange sites are based on exposure of each asset to modelled coastal inundation at a range of return intervals, combined with the vulnerability of the asset to inundation. Underground cables are rated to have very low vulnerability to pluvial flooding due to their location, while substations are rated high vulnerability where flood depths are greater than 0.2 m. Site specific review of Transpower South Dunedin substation found that sensitive transmission assets are located in minimally affected areas of the site, resulting in a very low service vulnerability for the scenarios assessed. The maps illustrate very little coastal inundation risk for most lines and substations until late century. Under a high end climate scenario, both the Transpower South Dunedin substation and the Chorus exchange are at high risk at late century. Risk to underground cables is low across all timeframes, while overhead cables and associated poles have a medium risk at late century.

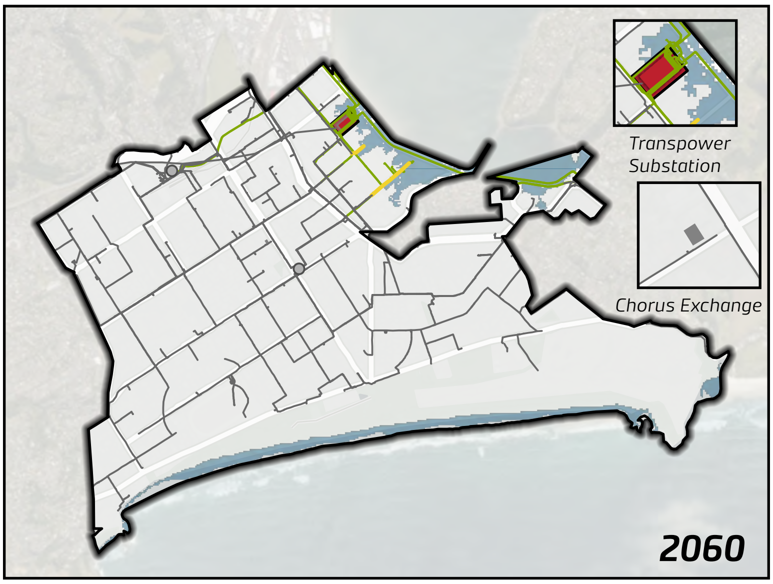
Disclaimer: These maps are not intended to assess coastal inundation risk at the individual asset level, which requires consideration of site specific flooding risk as well as more detailed asset information.

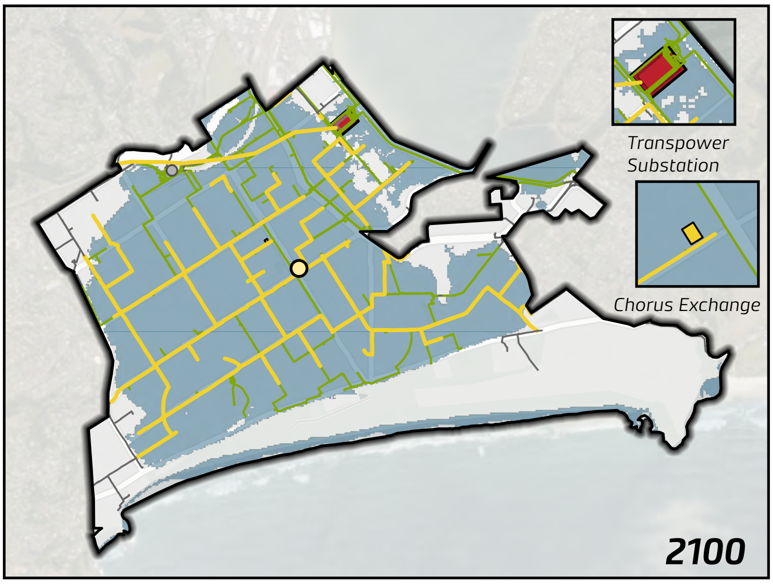
Hazard data source: Paulik, et al., 2023

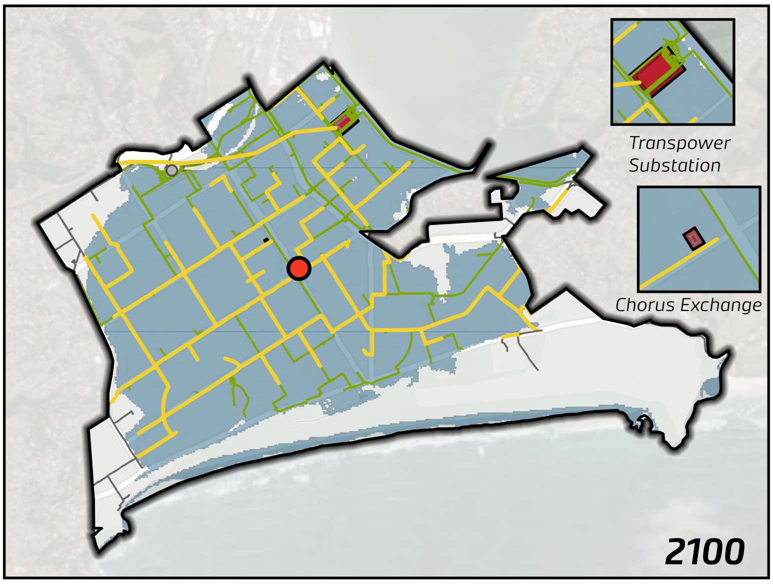
SSP2-4.5



SSP5-8.5







South Dunedin Future Boundary

1% AEP coastal inundation extent

0 0.4 0.8 1.2 1.6 2 (km)

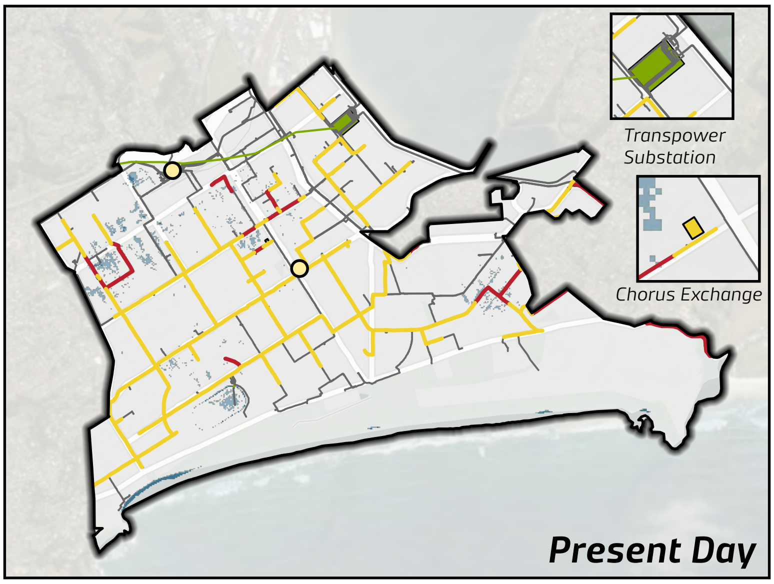
N

Aurora Substation (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

Transmission Lines & Distribution Cables
- High
- Medium
- Low
- Not exposed to scenarios assessed

Transpower Substation & Chorus Exchange
- High
- Medium
- Low
- Not exposed to scenarios assessed

Figure 5.51 Energy and telecommunications infrastructure risk due to groundwater



Explainer: These maps show the risk to energy and telecommunications infrastructure due to groundwater (blue shading). Risk ratings for individual lines, substations and exchanges are based on exposure of each asset to the modelled median groundwater level. Distribution lines and associated poles are vulnerable to a groundwater level that is within 0.3 m of the ground surface (light blue shading), however transmission infrastructure and substations have a lower vulnerability. The maps illustrate groundwater risk is medium across the distribution line network in the present day which increases to high for most of the network at mid-century. Risk to the Transpower South Dunedin substation is low across all scenarios and timeframes assessed, while the Chorus exchange site is at medium risk in the present day, which increases to high in future timeframes.
Disclaimer: These maps are not intended to assess groundwater risk at the individual asset level, which requires consideration of site specific groundwater risk as well as more detailed asset information.
Hazard data source: Cox, et al., 2023

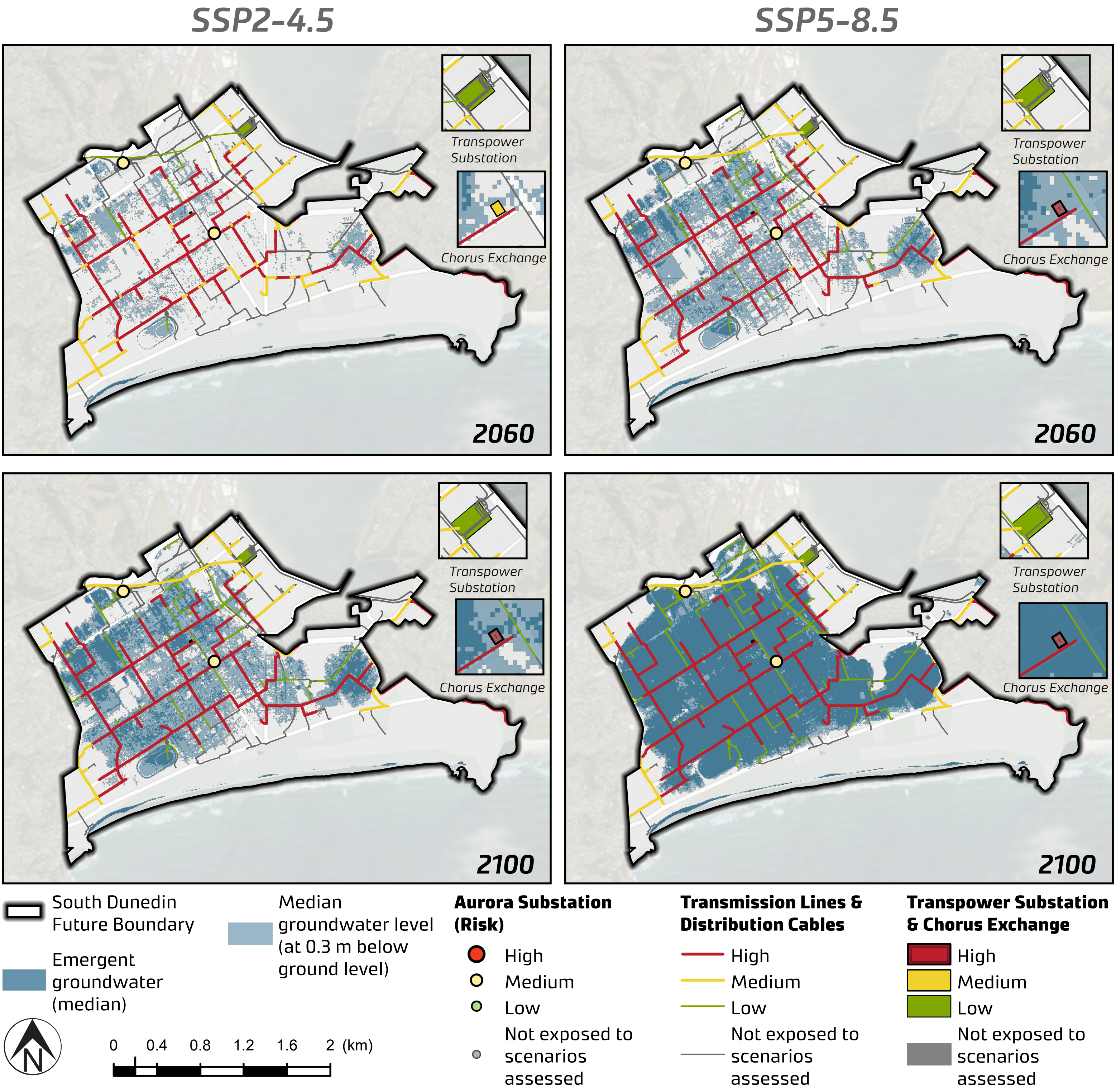
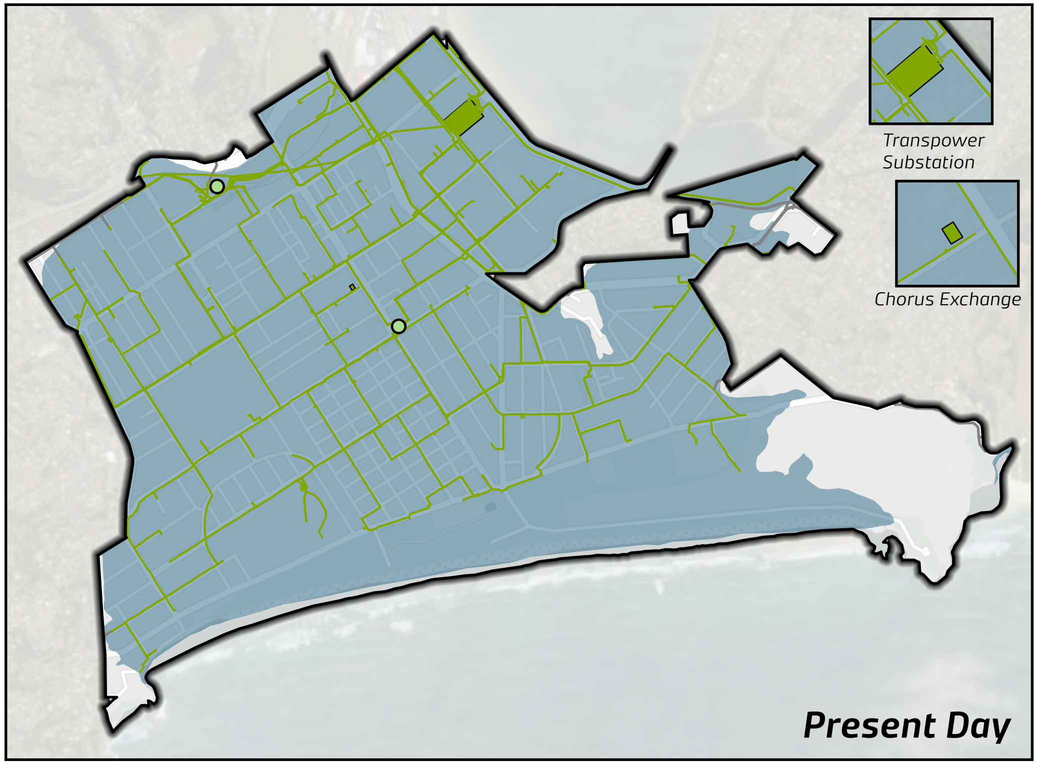
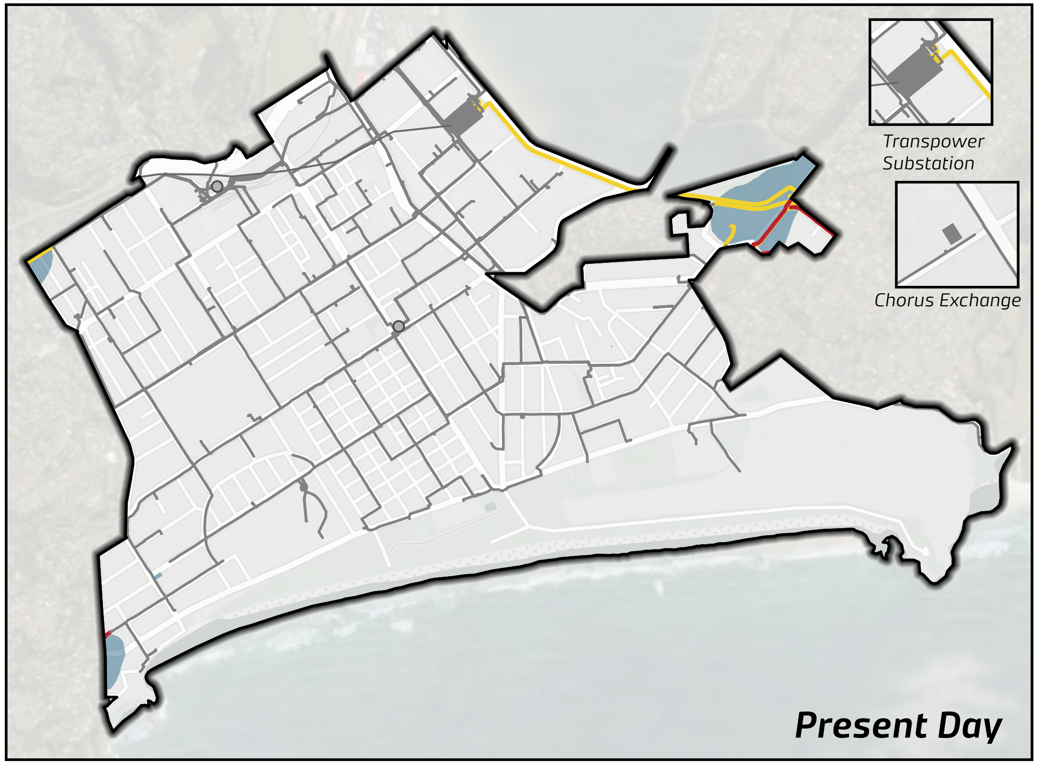


Figure 5.52 Energy and telecommunications infrastructure risk due to landslide and liquefaction

Liquefaction



Landslide



Explainer: These maps show the risk to energy and telecommunications infrastructure due to liquefaction. Risk ratings for individual lines, substations and exchanges are based on exposure of each asset or site to liquefaction potential, combined with their vulnerability rating. Distribution and transmission poles have a moderate vulnerability rating, while underground cables are have high vulnerability rating. The maps illustrate liquefaction risk is low across South Dunedin at the present day. Liquefaction risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of sea level rise on liquefaction potential. If it were to occur, liquefaction can cause differential settlement and lateral spreading that distorts structures, reduces foundation-bearing capacity, and damages pile supports and service connections.
Disclaimer: These maps are not intended to assess liquefaction risk at individual asset level, which requires consideration of site specific liquefaction risk as well as more detailed asset information. Liquefaction hazard information is based on a high level desktop review, where subsequent site specific assessment (Hornblow, 2020) has found that liquefaction potential is highly variable across sites analysed.
Hazard data source: Barrell, 2014

Explainer: These maps show the risk to energy and telecommunications infrastructure due to landslide (blue shading). Risk ratings for individual lines, substations and exchanges are based on exposure of each asset to landslides, combined with their vulnerability rating. Landslides can severely damage infrastructure through sudden collapse or failure. The maps illustrate some cables at the South Dunedin boundary are rated medium and high risk, with very little other exposure across South Dunedin. Landslide risk is not assessed at future timeframes due to the absence of spatial data that incorporates the influence of climate change (groundwater level rising or increased rainfall intensity) on landslide.
Disclaimer: These maps are not intended to assess landslide risk at individual asset level, which requires consideration of a site specific landslide risk as well as more detailed asset information. The landslide extent is based on known landslide areas and does not account for other potential sources of landslide nor represent the extent of the area of deposition/runout.
Hazard data source: DCC Hazard database data provided for South Dunedin Future programme

South Dunedin Future Boundary

Land instability

Liquefaction (Domain C: moderate liquefaction potential)

0 0.4 0.8 1.2 1.6 2 (km)

Aurora Substation (Risk)
- High
- Medium
- Low
- Not exposed to scenarios assessed

Transmission Lines & Distribution Cables
- High
- Medium
- Low
- Not exposed to scenarios assessed

Transpower Substation & Chorus Exchange
- High
- Medium
- Low
- Not exposed to scenarios assessed

5.9 DIRECT PHYSICAL RISK ASSESSMENT RESULTS SUMMARY

This section provides a summary of findings of the direct physical risk assessment. Table 5-10 identifies the percentage of places or assets across South Dunedin rated high risk from the natural hazards. In general, high rated risks correspond to places or assets that are exposed and extremely vulnerable, or those that are extremely exposed (i.e. to a 10% AEP event) and with high vulnerability. Many of these risks correspond to complete loss of functionality of the element at risk.

Table 5-11 provides similar results, for both medium and high risk elements, these risks encompass a broader set of risks that represent places or assets that have functionality compromised.

Spatial summaries of risk have been developed to show risk 'hot spots' at present day, mid-century and late century. These maps show where medium or high rated risk are located, with colouring indicating the number of hazards from which a risk is identified. Risk to buildings, roads and parks are shown in Figure 5.53 because these three elements at risk provide complete spatial coverage of South Dunedin, while also representing important components of the physical landscape of South Dunedin.

The summaries in Table 5-10 and Table 5-11 show that groundwater is the dominant hazard for most elements at risk, both at present and into the future. When seen spatially (in Figure 5.53), the coastal edge experiences risks arising from multiple hazards earliest in time. Areas within the inland low lying area of South Dunedin show widespread risk from a single hazard at present (predominantly groundwater) with patches of risk arising from a second hazard (predominantly pluvial flooding). This pattern of risk becomes more severe with time, where at late century the majority of South Dunedin is at risk from at least 3 hazards.

At present, all roads, sports fields and parks and significant proportions of most other elements are at high or medium risk to groundwater hazard. Of these, roads and wastewater assets have the highest proportion of assets rated at high risk. Pluvial flooding poses a high risk to a significant proportion of buildings and wastewater assets under present day conditions (23% and 53% respectively) as well as a medium or high risk to significant proportions assets within many of the other elements. Coastal erosion and coastal inundation pose high risk to very small proportions of assets within most elements and pose medium to high risk to some sports fields (11% coastal inundation) and parks (13% coastal inundation, 21% coastal erosion[43]). Liquefaction poses a medium risk to a significant proportion of wastewater pipes (66%) but high risk to none, and landslide poses medium risk to a notable proportion of sports fields (13%) but high risk to a very small proportion of a few elements.

At mid-century, many of the risks identified at present day increase incrementally. Additionally significant increases in medium to high risk arise in sports fields due to coastal erosion (increase from 0% at present day to 20% at mid-century), buildings due to groundwater (increase from 23% at present day to 71%-78% at mid-century) and contaminated land due to groundwater (19% at present day to 36%-60% at mid-century).

[43] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

At late century, a large proportion of most elements are at medium to high risk due to groundwater under medium and high-end climate scenarios (buildings (80-84%), stormwater (87-91%), contaminated land (67-80%), energy distribution (100%) and telecommunications infrastructure (100%)). Risk due to coastal inundation rises to become extremely widespread under a high end climate scenario for many elements (buildings, sports fields, roads, wastewater, stormwater, contaminated land, telecommunications, and energy distribution).

Risks to each element at risk are summarised:

- Buildings: The buildings within South Dunedin generally face high and widespread risk from a range of existing hazards. Notably, 23% of buildings are rated as high risk to pluvial flooding at present day, and 84% of buildings are rated as high risk from groundwater by late-century. These risks, if realised, would negatively impact building performance and functionality, making some buildings uninhabitable. This would have a range of adverse impacts on residents, including to physical health and wellbeing and wider economic and societal impacts.
- Parks: The 56 parks in South Dunedin generally face medium risk from various existing hazards, with only 5% at high risk, mainly those with playgrounds vulnerable to waterlogging due to groundwater. Currently, 95% of parks are at medium risk from groundwater and 57% from pluvial flooding. By late century, medium risk due to coastal inundation and erosion will rise to 29% and 30%, respectively.
- Sports fields: Many of the sports fields within South Dunedin currently face medium risk due to a range of hazards. Groundwater and coastal erosion are the two main drivers of high risk to Sports fields. Groundwater impacts the sports fields due to chronic saturation of the playing turf and grass root zones which causes die-off, and coastal erosion causes a loss of sport field area. At present 17% of fields are at high risk due to groundwater, which increases at mid century to 46%. Coastal erosion[44] poses a high risk to parks at mid-(20%) and late century (29%) timeframes, and typically those fields that are at lower risk from groundwater are more impacted by coastal erosion. Consequentially 75% of all fields are at high risk by late century due to either coastal erosion or high groundwater. Loss of sports fields would have widespread impacts on the wide city, as South Dunedin provides for 45% of the Dunedin City playing field area.
- Roads: South Dunedin's 90 km of roads are increasingly at risk due to high groundwater levels and coastal erosion. Currently, 35% of roads are at high risk from groundwater, rising to 76% by 2100, while coastal erosion threatens 2% of roads, increasing to 9% by the end of the century. These conditions will lead to severe road damage, challenging maintenance efforts, and potential road collapses, impacting local and regional transport routes, especially the 3 km of critical routes.
- 3 Waters: Of the 71 km of stormwater pipes in South Dunedin, 22% are currently at high risk from groundwater, increasing to 28% by late century. Medium risk from pluvial flooding affects 28% of pipes today, rising to 38% by mid-century, while coastal inundation will impact 76% by late century. These risks, if realised, will erode the level of service of the stormwater system, resulting in increased flooding.

[44] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

Of the 79 km of wastewater pipes in South Dunedin, 50% are currently at high risk from groundwater, increasing to 58% by the end of the century. Pluvial flooding poses a high risk to 51% of pipes today, rising to 72% by century's end. Coastal inundation risks are lower except in the late-century high-range scenario, where 80% of the network is at high risk. These risks threaten the wastewater system's service, potentially causing widespread contamination and public health issues.

In general, natural hazard risks to the water supply network in South Dunedin is low.

- Contaminated sites: The 236 contaminated sites in South Dunedin are primarily at risk from groundwater, with 7% currently at high risk, rising to 80% by late century. These high-risk sites have the potential for contaminants to be transported, resulting in spread of contamination. Additionally, coastal erosion poses a high risk to 1% of sites, which increases to 4% at late century with further potential for increased spread of contamination.
- Telecommunications: The telecommunications exchange site in South Dunedin is currently at medium risk from groundwater, increasing to high risk by late century. It also faces medium to high risk from coastal erosion by late century. Risks to the wider network haven't been fully assessed, although their dependency on road access and power supply is identified.
- Energy: Risk to energy assets in South Dunedin varies by type. The energy distribution network, with more assets than the transmission network, faces higher risks. Currently, 16% of overhead distribution lines are at high risk from groundwater, increasing to 84% by late century. Pluvial flooding and coastal inundation pose medium risk to most lines by late century (89% and 83%, respectively). The Transpower South Dunedin Substation and St Kilda Zone Substations both become high risk at mid-century[45].

[45] Risk to specific key features (e.g. Wastewater Treatment Plant, Pump stations, Substations, and other features) is shown in Section 5.

Table 5-10 Percentage of elements at risk across South Dunedin rated high risk[1,2,3].

	Coastal erosion			Pluvial flooding					Coastal inundation					Groundwater					Lique-faction	Land-slide
	Present Day	2060	2100	Present Day	2070 SSP2-4.5	2070 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Buildings	1%	1%	2%	23%	31%	39%	37%	47%	0%	0%	0%	1%	83%	3%	9%	32%	49%	78%	0%	2%
Sports fields	0%	20%	29%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	17%	46%	47%	47%	48%	0%	0%
Parks	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	5%	5%	5%	5%	0%	0%
Roads	2%	5%	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	35%	63%	68%	70%	76%	0%	2%
Water supply	1%	1%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Wastewater	0%	0%	0%	51%	59%	67%	66%	72%	1%	1%	2%	2%	80%	50%	51%	52%	54%	58%	0%	0%
Stormwater	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	22%	25%	26%	26%	28%	0%	0%
Contaminated land	1%	1%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	31%	57%	64%	80%	0%	0%
Telecommunications	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	100%	100%	100%	0%	0%
Energy distribution	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	16%	70%	79%	81%	84%	0%	2%

Table 5-11 Percentage of places or assets across South Dunedin rated medium or high risk[1,2,3].

	Coastal erosion			Pluvial flooding					Coastal inundation					Groundwater					Lique-faction	Land-slide
	Present Day	2060	2100	Present Day	2070 SSP2-4.5	2070 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	2060 SSP2-4.5	2060 SSP5-8.5	2100 SSP2-4.5	2100 SSP5-8.5	Present Day	Present Day
Buildings	1%	1%	2%	49%	57%	63%	61%	69%	0%	0%	1%	81%	84%	32%	71%	78%	80%	84%	0%	2%
Sports fields	0%	20%	29%	76%	76%	77%	76%	77%	11%	13%	13%	69%	75%	100%	100%	100%	100%	100%	0%	13%
Parks	21%	25%	30%	57%	61%	63%	63%	66%	13%	14%	14%	16%	29%	100%	100%	100%	100%	100%	0%	7%
Roads	2%	5%	9%	43%	47%	52%	50%	55%	2%	4%	4%	5%	72%	100%	100%	100%	100%	100%	0%	2%
Water supply	1%	1%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%
Wastewater	2%	2%	3%	71%	76%	79%	78%	79%	1%	1%	2%	76%	80%	67%	69%	70%	72%	80%	66%	2%
Stormwater	1%	1%	2%	60%	68%	75%	75%	80%	1%	1%	2%	2%	86%	78%	84%	85%	87%	91%	0%	2%
Contaminated land	1%	1%	4%	65%	72%	80%	81%	87%	3%	5%	7%	7%	92%	19%	36%	60%	67%	80%	0%	3%
Telecommunications	0%	0%	0%	100%	100%	100%	100%	100%	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	0%	0%
Energy distribution	0%	0%	0%	85%	85%	88%	87%	89%	0%	0%	1%	78%	83%	100%	100%	100%	100%	100%	0%	2%

[1] Percentages for each element at risk show: buildings: % number of building footprints; sports fields, parks, contaminated land: % number of sites; roads, 3 waters assets and energy: % length of road. Colour coding is based on Table 3-12.

[2] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

[3] Risk to specific key features (e.g. Wastewater Treatment Plant, Pump stations, Substations, and other features) is shown in Section 5.

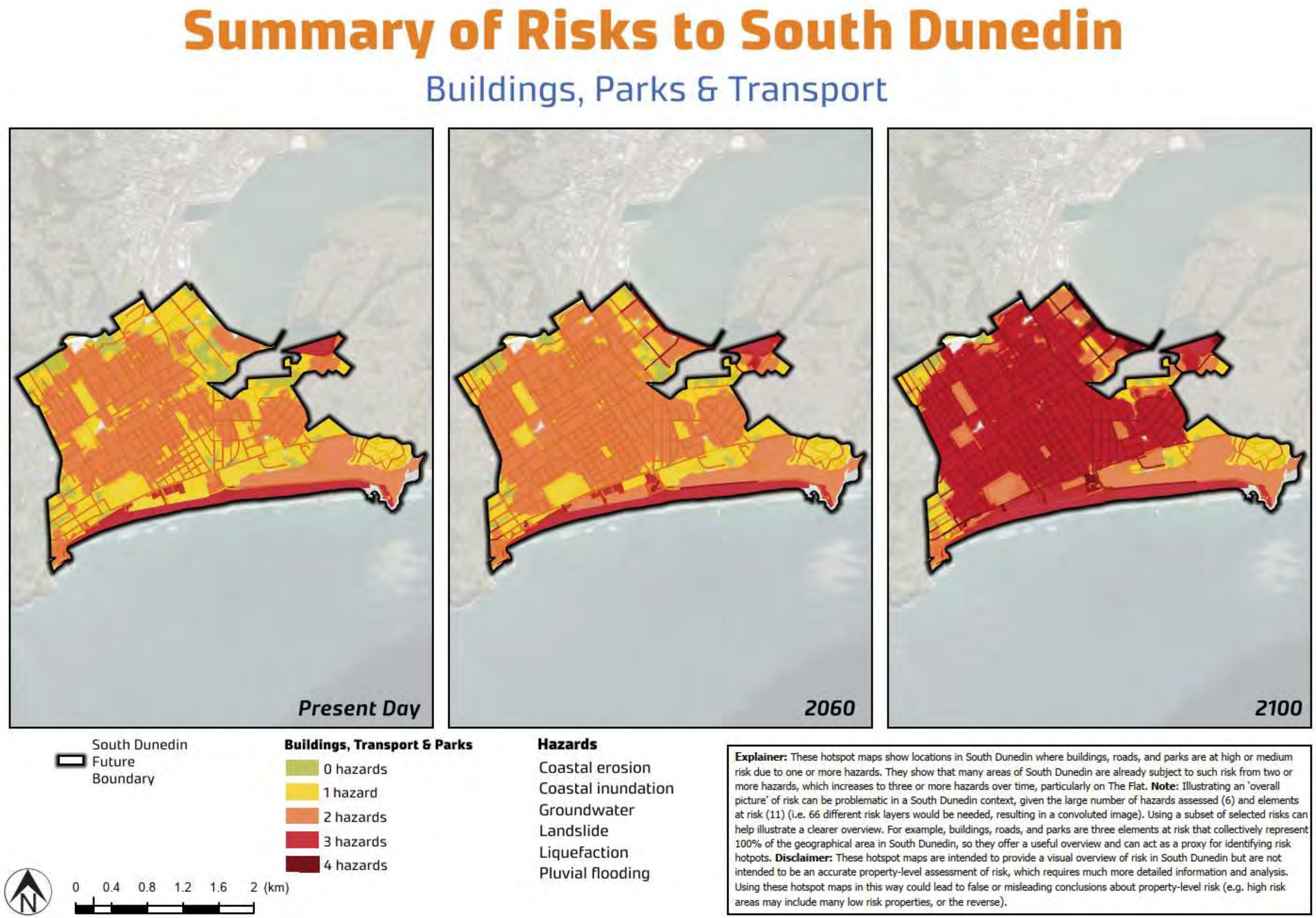


Figure 5.53 Hotspot summary of risks to South Dunedin: Buildings, parks and transport

6 IMPACTS FROM THE PHYSICAL RISKS TO SOUTH DUNEDIN

This section presents the findings relating to impacts arising from the physical risks to South Dunedin. Impacts presented in this section are those that may occur in the absence of risk mitigation. This risk assessment is designed to support the adaptation planning for South Dunedin, which is intended to minimise these impacts.

6.1 OVERVIEW OF CASCADING IMPACTS IN SOUTH DUNEDIN

The interconnectedness of physical elements (places and assets) with their users within South Dunedin means that realised risks or impact on one part of the system can trigger complex interrelated and cascading consequences to other parts (referred to as impacts). While the physical risk assessment relates to clearly defined spatial extents, the spatial extents of impacts are much more complex to define. Impacts will be felt not only in South Dunedin, but also the broader Dunedin City and wider region. This is due to the interactions of businesses and people across spatial boundaries.

A high-level summary of the relationships between impacts identified through this assessment (and which draws on the work of Harrison, et al. (2022)) are presented in Figure 6.1. The diagram shows that physical risk, when realised, can cause impact pathways that extend across social, environmental, and economic domains. Major themes within this diagram are discussed further in subsequent sections and incorporate some of the more detailed insights gathered through previous research into the impacts of climate change on South Dunedin (Harrison, et al., 2022). Some of these discussions have supplementary diagrams designed to capture additional complexity within the system. These major themes are:

- Social impacts including health and wellbeing, accessibility, and residential housing.
- Economic impacts including insurance, property values, and impacts on business.
- Environmental impacts.

Specific Mana Whenua consideration has not been included in this analysis of cascading risk but is covered in the mana whenua risk assessment.

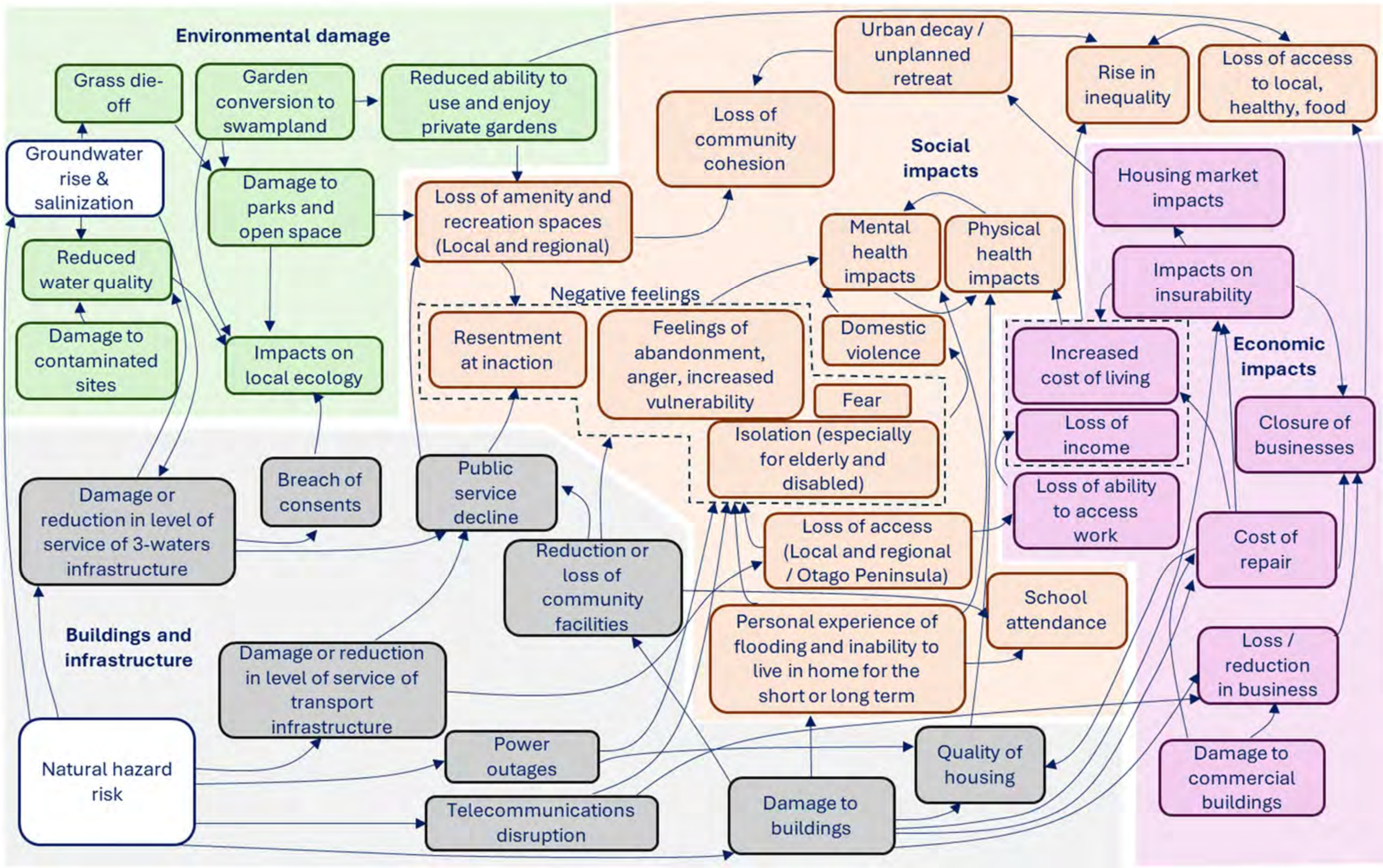


Figure 6.1 Overview of cascading impacts arising from natural hazard and climate change risk to South Dunedin (colour scheme: grey = buildings and infrastructure damage and impacts, orange = social impacts, purple = economic impacts, green=environmental damage)

6.2 SOCIAL IMPACTS

6.2.1 COMMUNITY AND SOCIAL HEALTH AND WELLBEING

Impacts on mental health and physical health are likely to arise from a range of cascading pathways. At a national scale, risks to people and communities are identified as being extreme by mid-century (Ministry for the Environment, 2020), with their relevance to the Otago region highlighted in the Otago Regional Climate Change Risk Assessment (Tonkin and Taylor, 2021):

- Risks to social cohesion and community wellbeing from displacement of individuals, families and communities due to climate change.
- Risks of exacerbating inequities and creating new and additional inequities due to differential distribution of climate change impacts.

The additional national risks are rated to be 'major' by late century (Ministry for the Environment, 2020), and are highlighted as being relevant to the Otago Region in the Regional Assessment (Tonkin and Taylor, 2021):

- Risks to physical health from exposure to extreme weather events.
- Risk of conflict, disruption and loss of trust in government from changing patterns in the value of assets and competition for access to scarce resources primarily due to extreme weather events and ongoing sea level rise.

Ultimately, all impacts tend to influence mental health, and the interrelationship between mental and physical health is very close and can often become a feedback loop. For example, when physical health impacts mental health, or when mental health presents as physical ailments. Some of the main drivers identified include:

- Loss or potential loss of access resulting in feelings of isolation or anxiety.
- Reduced ability to access goods, services and amenities resulting in physical or mental health.
- Reduced ability to access place of work or education, resulting in loss of personal wealth and reduced wellbeing.
- Loss of insurability and access to property finance resulting in loss of personal wealth and reduced wellbeing.
- Increased financial burden (e.g. cost of repairs and insurance) resulting in increased stress and mental health impacts.
- Decline of vibrancy of the area and loss of wider community wellbeing.
- Decline in the quality of housing from both acute and chronic risks resulting in physical health impacts (e.g. due to living in damp, cold housing) with associated impacts on mental health.

Disabled people or the elderly are likely to be disproportionally affected, examples include an inability to reside in standard emergency shelter accommodation due to specialised health requirements and specific housing needs driving a heightened sensitivity to reduction in housing availability (for example if all bottom floors are flooded there would be no accessible options available).

Event related anxiety is identified as a major issue, where some community members reported feeling stressed during heavy rainfall since experiencing previous flooding, and feeling anxious until the rainfall stops. Additionally, high stress associated with uncertainty of the future was raised, where community members reported fear that severe flooding may occur again. There is also stress relating to potential increases in the costs associated with damaging events, including access to affordable insurance and increased administrative burdens and landlord management, as well as other additional costs (e.g. relocation or disruption costs, vehicle costs, cleaning). These issues are likely to impact homeowners, renters, and landlords in different ways.

Impacts on the disabled community were identified as being most acute earliest in time. Some people within this group have heightened sensitivity to physical risks and may be more vulnerable to physical harm during an event. Many are also highly sensitive to increased mental stress, and may find increasing risk, damage, or disruption to the local area difficult to manage. For example, small changes in local surroundings such as a changed bus route can be highly stressful for someone with vision impairment, closure of an important local business can be highly disruptive for someone who is reliant on those services, or increased anxiety relating to a flood event may be overwhelming for some. Social impacts are likely to become increasingly relevant for the wider population over time.

The sense of community may be undermined with significant impacts on the vibrancy and appeal of South Dunedin. One major cause of this is likely due the voluntary withdrawal of community members in response to increasing damage and/or risk. This mechanism is likely to be taken up earliest by those who have means to relocate, leaving more vulnerable members of the community in place. Some of these people are likely to hold positions as community advocates, further compounding the impact on community wellbeing associated with this voluntary relocation. Resultant vacancies are likely to be filled by increasingly transient or temporary inhabitants, who only stay until they find the risk intolerable themselves. This emptying of the area could exacerbate existing social vulnerabilities and urban decay.

In a discussion regarding a future hazard scenario for South Dunedin one SDF Community Expo participant and resident said:

“I wouldn’t wait for this, but not everyone has the ability to get out”

While it is possible that services and amenities could relocate to form a new community, the following considerations were identified to be important:

- Retain access to local amenities (flat, short distances).
- Any new housing should be accessible and dry (with ramp and be safe from hazards).
- Relocating support service providers is highly disruptive to disabled communities, particularly those with learning disabilities.
- Change to the housing stock may increase cost, thereby reduce affordability.

6.2.2 ACCESSIBILITY

South Dunedin provides a significant source of accessible housing for the city as it provides the largest area of flat land across Dunedin city. Because of this, South Dunedin is identified as an important location of housing for the disabled and aged care communities. In the 2018 Census, 18% of respondents in the area reported having at least some difficulty walking, which is significantly higher than that of the wider Dunedin population (7.2%). The geographic distribution of people with mobility difficulties is shown in Figure 3.11.

South Dunedin provides a wide range of basic services (e.g. supermarkets, healthcare, vet, gym). It is also where most of Dunedin’s disability service providers, rest homes and respite /funded care are located. Relative to wider Dunedin, there is high availability of low cost rental accommodation, supporting low income individuals and families (including many who may be on social benefit schemes).

Increasing natural hazard damage is likely to cause a range of impacts, the main themes and causal relationships relating to loss of access within South Dunedin are shown in Figure 6.2. Damage to infrastructure or lowered level of service may undermine people's ability to access the goods and services of South Dunedin. Disabled people or those with mobility issues tend to be disproportionally affected; examples based on experience in the 2015 flood events include difficulty using wheelchairs in floodwater or over soggy ground, concern for the welfare of Guide Dogs (e.g. due to broken glass or debris following an event), and heightened or complete dependence on family or care providers to evacuate during an event. Additionally, those who do not drive or are dependent on public transport, cycleways and footpaths may be further disadvantaged should that infrastructure be damaged during an event.

Disruption of access (either due to loss of physical access (e.g. road damage preventing access to an area), or due to relocation of individuals or businesses) has a strong influence on the local economy. Loss of access may disrupt people's ability to access their place of work, impacting personal wealth and the ability of businesses to attract and retain staff. Reduced ability to access local businesses can reduce the amount of money spent in the local economy, and in turn may impact the viability of local businesses. Any decline in the number of businesses operating in the area would further reduce residents' access to goods and services, especially if travelling to other parts of the city is difficult or not possible for them.

Over time, declining confidence in the South Dunedin area could influence decisions about investing the area, including mitigation measures to reduce hazard. This may impact the economic stability of South Dunedin as discussed in Section 6.3.3.

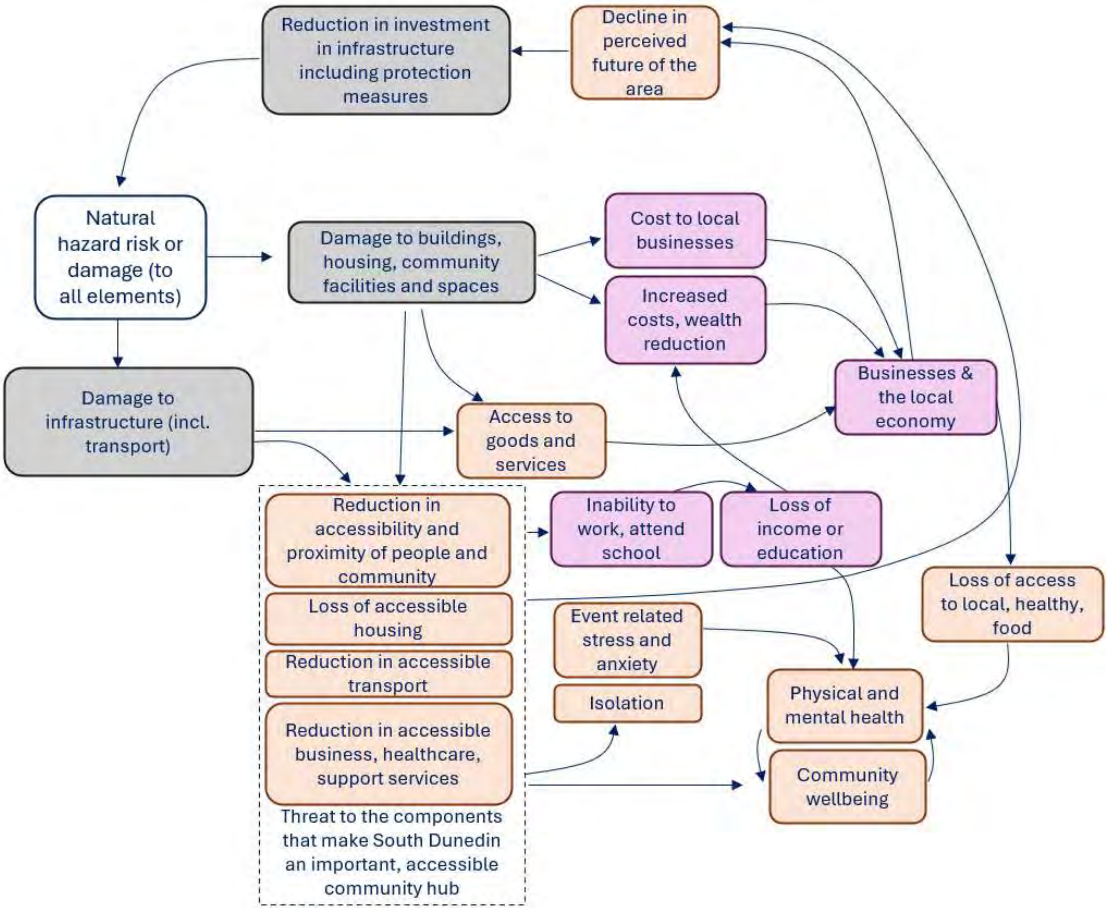


Figure 6.2 Cascading risk related to accessibility within South Dunedin (colour scheme: grey = buildings and infrastructure damage and impacts, orange = social impacts, purple = economic impacts)

6.2.3 *QUALITY OF HOUSING*

The quality of housing is likely to be impacted by increasing natural hazards, which is likely to cause a range of impacts. Main themes and causal relationships relating to the quality of housing are shown in Figure 6.3. Flooding and groundwater rise can contribute to cold, damp living conditions, with negative effects for resident health. Damp homes typically increase an occupant's desire for heating (if affordable) although deteriorating housing condition are also likely to reduce the house's ability to retain heat. Persistent dampness can lead to rot and the growth of mould, further reducing housing quality and conditions over time. This causes wide ranging implications for people's physical, mental, and social wellbeing.

The negative health outcomes that arise from living in poor quality housing have the potential to adversely affect people's life prospects by undermining their educational achievement or employment. This could exacerbate the potential for declining quality of housing by reducing income or earning potential, potentially compromising people's ability to afford to heat their homes or to live in quality, energy-efficient homes that are cheaper to heat. This can then form a reinforcing cycle of intergenerational fuel poverty and health inequities (Harrison, et al., 2022).

Housing, affordability, and investment are interconnected, where damage and decline in housing may lower house values, which may reduce people's willingness to spend money on upkeep or renovations. This has the potential, ultimately to reinforce a negative spiral further, adversely impacting residents and community alike.

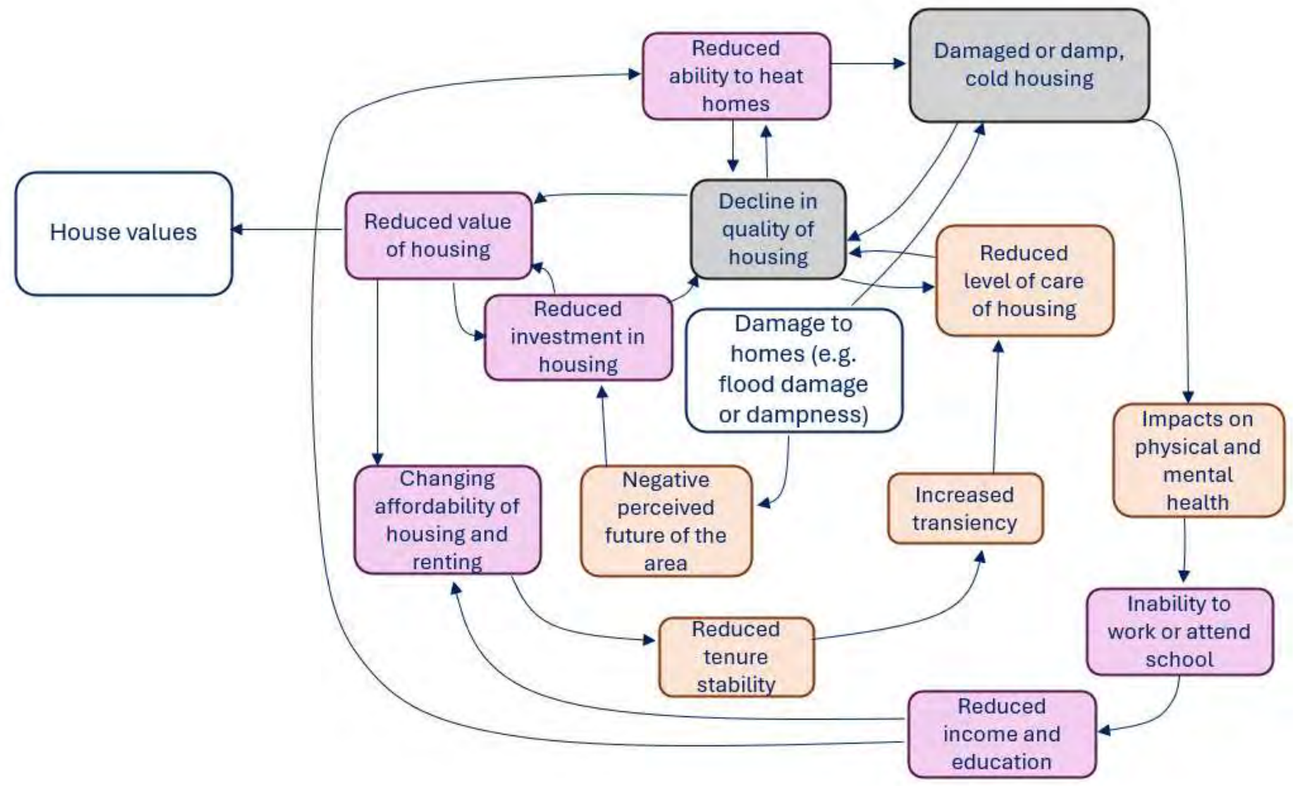


Figure 6.3 Cascading risk relating to the quality of housing in South Dunedin (colour scheme: grey = buildings and infrastructure damage and impacts, orange = social impacts, purple = economic impacts, green=environmental damage)

6.3 ECONOMIC IMPACTS

6.3.1 BACKGROUND

Dunedin City serves as the economic hub of the Otago region, accounting for approximately 54% of the region's total GDP (Statistics NZ, 2018).

South Dunedin (SA3 area[46]) accounts for 9.8% of Dunedin's GDP ($764m), 10.9% of Dunedin City's employment, and houses 4.7% of Dunedin City's business units[47]. Most businesses in South Dunedin fall within the small to medium enterprise (SME) category, encompassing a diverse range of establishments, including health care and social assistance, retail, wholesale, construction, commercial services, restaurants, and light industrial operations. The South Dunedin area also includes the large format and vehicle retail hub centred along Hillside Road, located between Anderson Bay and Portsmouth Drive. A summary of the industries within South Dunedin Statistical area 3 (SA3) is shown in Table 6-1.

[46] Statistical Area 3 is a new output geography developed by Stats NZ. The SA3 geography aims to approximate suburbs in major, large, and medium urban areas, and to allow comparisons between geographical areas that are larger in area and population size than SA2s but smaller than territorial authorities.
[47] Infometrics economic data supplied by DCC (May 2024).

Table 6-1 Summary of major employing industries of South Dunedin SA3 area[48]

Major employing industries and contribution to GDP		
Industry	Jobs	GDP
Health care and social assistance	1,367	$ 107,500,000
Other store-based retailing and non-store retailing	926	$ 66,800,000
Wholesale trade	723	$ 79,000,000
Construction services	700	$ 56,000,000
Supermarket, grocery stores and specialised food retailing	658	$ 43,100,000

South Dunedin has extensive infrastructure network including critical assets that service the wider Dunedin area including the Tahuna Wastewater Treatment Plant, State Highway 1 (SH1), South Island Main Trunk Line, and major Chorus and Transpower assets.

6.3.2 ECONOMIC IMPACTS OF NATURAL HAZARD AND CLIMATE DAMAGE

Natural hazards and climate change present significant potential financial and economic impacts to South Dunedin[49]. Economic implications stemming from the impact of climate change on systems are generally grouped into the following four main types of costs (Tonkin and Taylor, 2019):

- Loss or stranding of property and assets (including land), cost of repairing, rebuilding or replacing assets, and cost of preventative measures.
- Foregone production or lower efficiency of production.
- Medical and related costs.
- Higher insurance (only the component of the premium that represents the price for the service of insurance is an economic cost).

These costs can be both direct costs and indirect costs, where direct costs comprise the directly consequential effects on businesses, residents, or home owners caused by event. Indirect costs comprise the flow-on effects on supplying industries e.g. business interruption and reduction in production of goods and services. They can also be categorised as either financial or economic damages, where financial damages relate to the full replacement value directly incurred by individuals or entities, whereas economic damages consider the resource costs to the whole economy by considering the flow of money, e.g. the flow of insurance claim money into a regional economy following an event.

Climate change is widely acknowledged to pose significant financial and economic risks at the local, regional, and national scale. The National Climate Change Risk Assessment (Ministry for the Environment, 2020) identifies priority risks to the economic domain as:

- Risks to governments from economic costs associated with lost productivity, disaster relief, expenditure and unfunded contingent liabilities due to extreme events and ongoing gradual changes. This is rated as an 'extreme' risk at late century.

[48] Infometrics economic data supplied by DCC (May 2024).
[49] Financial damages relate to the full replacement value directly incurred by individuals or entities. Economic damages reflect the depreciated values of goods at the time flooding occurs, considering that one person's loss may be another's gain, thus implying a view from the community or regional/national economy's perspective. For example, a damaged house (loss) will be repaired by a construction business (gain).

- Risks to the financial system from instability due to extreme weather events and ongoing gradual changes. This is rated as a 'major' risk at late century.

Other economic risks were rated to pose a 'major' risk at a national scale by late century

- Risks to insurability of assets due to ongoing sea level rise and extreme weather events.
- Risks to business and public organisations from supply chain and distribution network disruptions, due to extreme weather events and ongoing gradual changes.

Regionally, many of the national scale risks are acknowledged to contribute to an 'extreme' risk[50] to the cost of doing business due to climate change hazards as part of the Regional Climate Change Risk Assessment (Tonkin and Taylor, 2021).

At a national scale, the cost of natural hazards can be seen to be rising through a review of privately insured damages from weather-related events (Figure 6.4). While much of the increase in total insured losses is likely to reflect the rising number of insured assets and the increasing costs of reconstruction, there has been a marked decline in the frequency of years with little or no significant adverse weather events over the last 50 years (The Treasury, 2023). The influence of climate change on insured costs is estimated to be growing, with 10%-40% of risk attributable to climate change across events analysed between 2007 and 2017 (Frame, et al., 2018). The last five years have all seen near record levels of insured losses. Costs in 2023 vastly exceed all previous years due to the Auckland Anniversary Weekend (approx. $2,000 m) flooding and Cyclone Gabrielle (approx. $1,900 m).

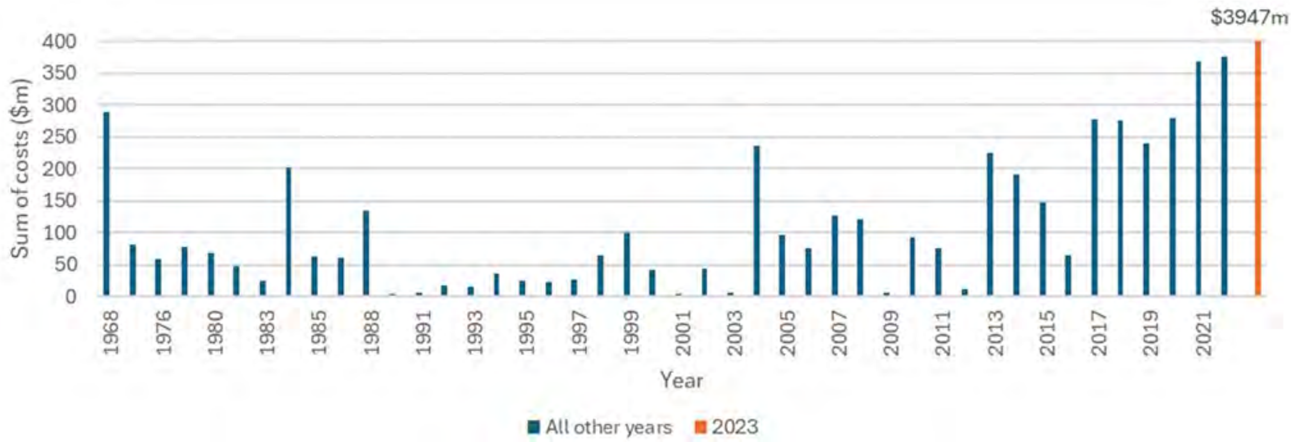


Figure 6.4 National insured weather-related losses from 1968 to 2023 (in 2023 dollars) (ICNZ, 2024)[51]

Weather related disasters are already resulting in significant costs for the Otago Region including but not limited to the following major recent events:

- October 2024 South Dunedin flooding will have incurred costs however details of the event and associated costs are not yet available at the time of writing this report.
- 2015 South Dunedin flooding (63 year ARI) incurred $28 million insurance costs[52] (ICNZ, 2024). However, the floods were estimated by insurer IAG to have social and economic costs of up to $138 million (Otago Regional Council, 2016; Otago Regional Council, 2015).

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[50] Note that the method used to evaluate risk in the Regional Climate Change Risk Assessment differs to the method used in this assessment.
[51] Figure shows the cost to the insurance industry in paying claims for damage resulting from natural disasters excluding fire and earthquake. This table has been updated with inflation-adjusted costs, as at 30 June 2023. The costs are exclusive of GST.
[52] ICNZ costs reported for event '2-4 June 2015: Flooding and Storm – Otago'. Costs are unadjusted and therefore do not account for inflation.

- 2017 Central Otago flood repairs cost nearly $1 million for central Otago District. This event also affected most of the entire region with a state of emergency declared. The total cost of the South Island floods was estimated at $31.2 million (ICNZ, 2024).
- 2017 Dunedin flooding cost insurers approximately $1.7 million (ICNZ, 2024).
- 2019 December and 2020 February flood events resulted in an estimated cost for the Regional Council of $3.9M (Otago Regional Council, 2020). This includes Priority 1 and Priority 2 repairs, but excludes Priority 3 repairs and is therefore an underestimate of costs[53].

The identified physical risks to South Dunedin coupled with an understanding of rising costs associated with weather events, and wider national economic context indicate that South Dunedin will continue to see economic shocks that increase in cost following acute events. Additionally, increasing risk due to chronic, slow onset of groundwater rise may incur further costs to manage the declining condition or level of service of places and assets.

In addition to wider economic costs associated with damage and recovery, increasing damage to public infrastructure is likely to increase cost and resourcing demands on Council. It may also have legal implications, for example as a result of increased breach in consent conditions associated with wastewater discharges to the harbour.

If unmanaged, there is a potential for unplanned relocation which can isolate services, or reduce the availability of service options density of services resulting in relatively high cost within an area. This may result in infrastructure that is too expensive to service. This is an issue for council, private, and state owned services and assets.

Damage caused by climate-related natural hazards and the associated large investments required to redesign, reposition and futureproof public infrastructure (such as transport networks and later services) will significantly increase the financial burden on citizens, businesses and public authorities (Boston & Lawrence, 2018). The Insurance Council of New Zealand forecasts that at present (based on historical data), New Zealand can expect on average for natural disasters to cost this country just under 1% of its GDP in any year or about NZ$1.6 billion (ICNZ, 2014). The long term financial impact of increasing drought and storm frequency has been modelled by Treasury. This resulted in a forecast 0.7% decrease in national GDP compared to the assumed trend in 2061 (The Treasury, 2023).

Increasing risks are anticipated to bring additional cost, however adaptation to mitigate this risk is expected to reduce the long-term costs faced by government, businesses, communities and households (The Treasury, 2023). Adaptation to the physical impacts of climate change in a timely way will drive a more efficient climate response, with benefits for broader wellbeing, economic growth and resilience, and reduced impacts on GDP. Conversely, continued investment in South Dunedin without appropriate climate adaptation measures increases the potential for economic loss.

6.3.3 BUSINESS CONFIDENCE

Cascading impacts relating to risk and damage from natural hazards is likely to impact business confidence. Major themes and causal relationships relating to business confidence are mapped in Figure 6.5.

[53] Priority 1 damage ($0.65M) includes immediate response and high priority repairs that could be implemented before the end of June 2020. Priority 2 damage ($3.25M) required investigation and design with work to be undertaken during the 2020/21 financial year. Priority 3 repairs require longer investigation or repairs and undertaken over a longer period

Discussion of natural hazard and climate risk with a range of representatives within the South Dunedin business community identified a range of concerns[54]:

- They were concerned about short term flood risk (more so than long term issues) and would like the council to make more substantive investments in flood protection infrastructure sooner.
- They were concerned about repeated flood events, the negative commentary about South Dunedin's flood risk, and the dampening effect on business confidence and economic activity in the area.
- They are experiencing varying tolerance to flood risk, with some large-scale property developers excluding South Dunedin due to flood risk, and others seeing ongoing opportunities for investment returns.
- They felt that ongoing uncertainty regarding plans for addressing the hazards of South Dunedin is not helpful.

When considering the adaptive capacity area, the business community identified the following considerations:

- They were encouraged by more positive framing that has been generated by South Dunedin Future, which focuses on the opportunities that could come with change and urban regeneration, rather than the negatives.
- Property investors in particular view themselves as 'part of the solution', bringing capital and investment to the area, which could be deployed to support urban regeneration if appropriately incentivised by council.
- They felt that opportunities were associated with potential upzoning and value uplift in areas that are lower risk or where risk can be meaningfully mitigated.
- They felt that tangible plan or proposal for adaptation will enable them to assess and make informed decisions about the future of their businesses.

Harrison, et al., (2022) discusses how a sense of future prosperity is an important factor in maintaining business activity within South Dunedin. A sense of future prosperity provides businesses with the certainty and confidence that keeps them operating locally. It may also give new businesses the confidence to establish themselves in the area. Declining confidence is likely to arise if recurring damage were to cause sustained financial losses or businesses closures, or if it prevents new businesses from establishing themselves in the area.

A strong economy supports the area's appeal and increases the level of vibrancy (i.e. sense of 'life' and 'energy') by attracting people to live or visit the area, which reinforces the economic wellbeing of the area. In a well-functioning economy, businesses that are doing well may hire more employees. These employees are likely to be local to the area which provides increased employment and household income which can flow back into the local economy.

Conversely, adverse impacts to workers and residents impact businesses both in terms of workforce supply and customer demand (e.g. though decreased personal wealth, or decreased physical or mental health, or transport damage). Increasing cost of repairs is increasingly likely over time. Without confidence in future risk mitigation plans, there will likely be a reduction in the ability to distribute risk (e.g. through insurance risk transfer). An inability to distribute risk will likely

[54] Discussion led by DCC SDF team, refer Stakeholder engagement schedule in Appendix B7

reduce business confidence.

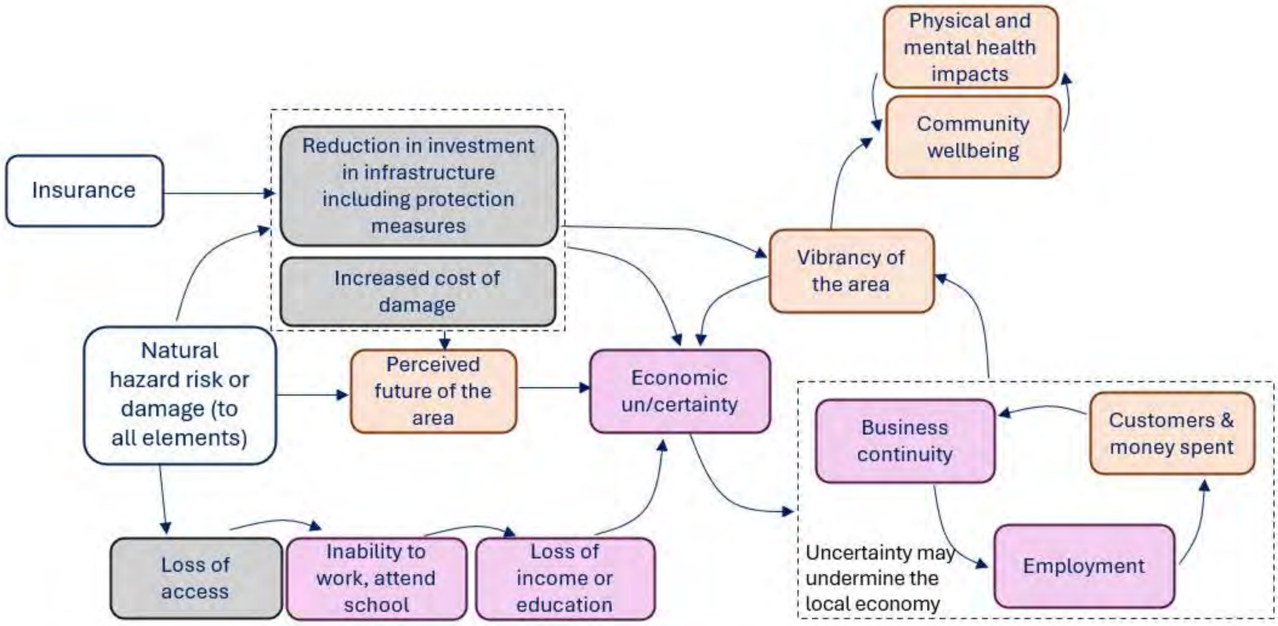

Figure 6.5 Cascading risk relating to confidence in doing business in South Dunedin (colour scheme: grey = buildings and infrastructure damage and impacts, orange = social impacts, purple = economic impacts, green=environmental damage)

6.3.4 HOUSING MARKET

There is a complex relationship between natural hazard damage, housing affordability and the appeal of South Dunedin. Major themes and causal relationships relating to housing market confidence are mapped in Figure 6.6.

Increasing damage or risk from natural hazards is likely to reduce the residential appeal of the South Dunedin area, without risk mitigation. Reduced demand is also likely to lower the relative value of housing, particularly when compounded with reduced investment and building quality. This can have major negative implications for people’s financial and mental wellbeing. Review of impacts of the 2015 floods on the South Dunedin housing market found that prior to the floods, houses in the pluvial floodplain sold for a 5% discount relative to the wider area. Following the floods, this discount tripled to become a 15% discount. Over time, this effect reduced and after 15 months there was no long term impact on house prices (Nguyen, et al., 2022).

Harrison, et al. (2022) discusses how the affordability of housing can influence the appeal of the area, and can influence the socioeconomic status and wellbeing of residents. New, high-quality housing developments may increase the appeal of the area, conversely, declining quality of housing may decrease appeal and result in a higher proportion of people living in the area who are renting, experiencing poverty, or unable to afford to upgrade or maintain their properties.

Increasing damage and risk could result in voluntary withdrawal of community members who have the means to relocate. Resultant vacancies would be filled by increasingly vulnerable people. Participants in Harrison, et al., (2022) believed it was highly unlikely people would move out of the area en-masse unless there was a major immediate threat or significant incentives and support to leave. They felt that other aspects of what makes the area appealing to live in would supersede flooding concerns, including the relative affordability of housing, cultural ties, a sense of place, access to natural amenities, and the “appeal of the flat” topography. Instead, they believed that most people would only leave the area because of insurance retreat, or if it was imposed from above by government. If a mass exodus were to occur, there would be significant negative wellbeing implications, including for those who would effectively be 'stuck' in the area due to financial, physical, or social constraints. Alongside more frequent flood events, this would further reduce the appeal of the area for those who can avoid living there, creating inequities in experience of risk.

Investment in flood resilience and amenity through blue-green infrastructure such as wetlands, may reduce the area's level of flood risk while increasing the appeal of the area, driving up demand for housing in the area.

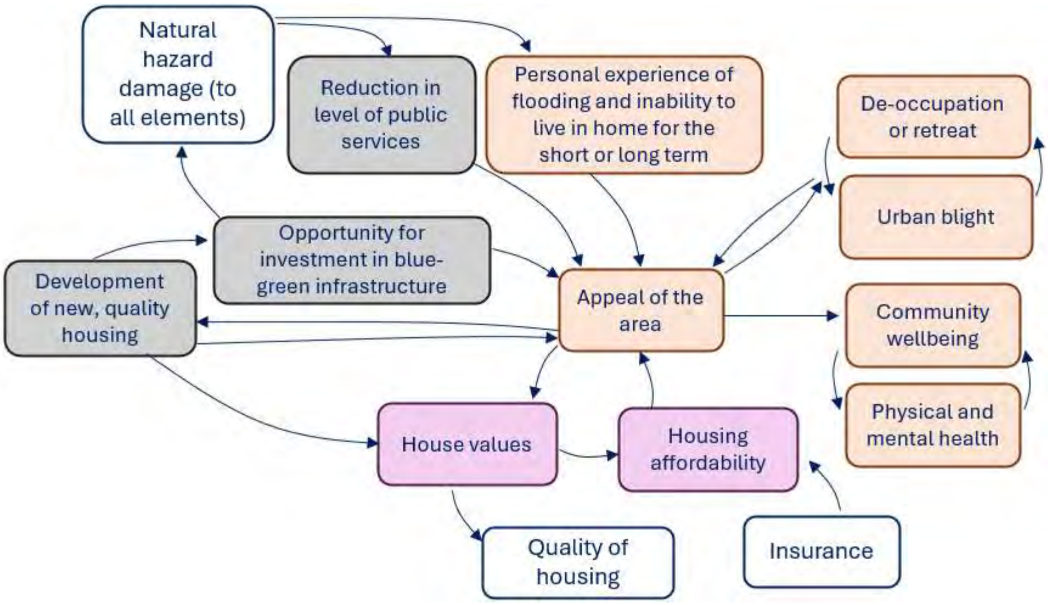

Figure 6.6 Cascading risk relating to the housing market in South Dunedin (colour scheme: grey = buildings and infrastructure damage and impacts, orange = social impacts, purple = economic impacts, green=environmental damage)

6.3.5 *INSURANCE*

The Treasury highlights that households in areas more exposed to physical risks (such as those near coasts and flood plains) will be disproportionately affected by climate change and face worsening insurance affordability and availability rise (The Treasury, 2023). At a national scale, 'insurance retreat' is an increasing problem, where insurance retreat occurs when a private or public insurer declines an application for insurance coverage or stops offering renewal of existing coverage, based on the property's exposure and vulnerability to an escalating hazard. A review of the insurability of Dunedin homes identifies that those which currently have a 1% probability of coastal inundation are expected to face a partial insurance retreat from around 2030, with full insurance retreat by 2050 (Storey, et al., 2020). This is based on anecdotal evidence from the insurance industry that suggests that partial insurance retreat begins to occur when the likelihood of an event reaches the 2% AEP threshold, and full retreat will have occurred by the time this reaches 5% AEP (Storey, et al., 2020). On this basis, within South Dunedin, most buildings that are rated to be 'high' risk due to either pluvial flooding or coastal inundation would be subject to insurance retreat. This equates to 83% of buildings at late century under a high-end climate scenario.

Availability of insurance has a complex relationship with increasing natural hazard damage and the social and economic landscape of South Dunedin. Major themes and causal relationships relating to insurance are shown in Figure 6.7. Increasing natural hazard damage will expose insurance companies to higher financial risk, who are then likely to raise insurance premiums or withdraw cover altogether. As insurance cover is generally a requirement for a mortgage or lending, the withdrawal of insurance would have serious implications for the housing market. It would also result in immense stress for home owners who would be personally liable for any flood-rated financial losses they incur (Harrison, et al., 2022).

There is an increasing awareness from the financial markets (including insurance) regarding their exposure of existing and future climate-related risks. This increased awareness results from both mandatory requirements (e.g. through the climate-related disclosure reporting) and non-mandatory drivers (e.g. shareholder expectations) and the trend is likely to continue. The likely response from the financial markets to the increased awareness is an evaluation of their risk profile across their portfolio and a subsequent reduction in their commercial exposure from high-risk areas. These high-risk areas could include South Dunedin, and would likely result in a combination of risk-based pricing (where insurance is priced higher in high risk areas) and/or insurance retreat (where insurance is either no longer available or is limited to a small number of suppliers who price accordingly).

Given the importance of insurance in obtaining finance (e.g. through a mortgage) and the likely reduction in property owners ability to transfer risk to insurers, there is significant potential for asset values to reduce. This also has major implications for people’s financial and mental wellbeing.

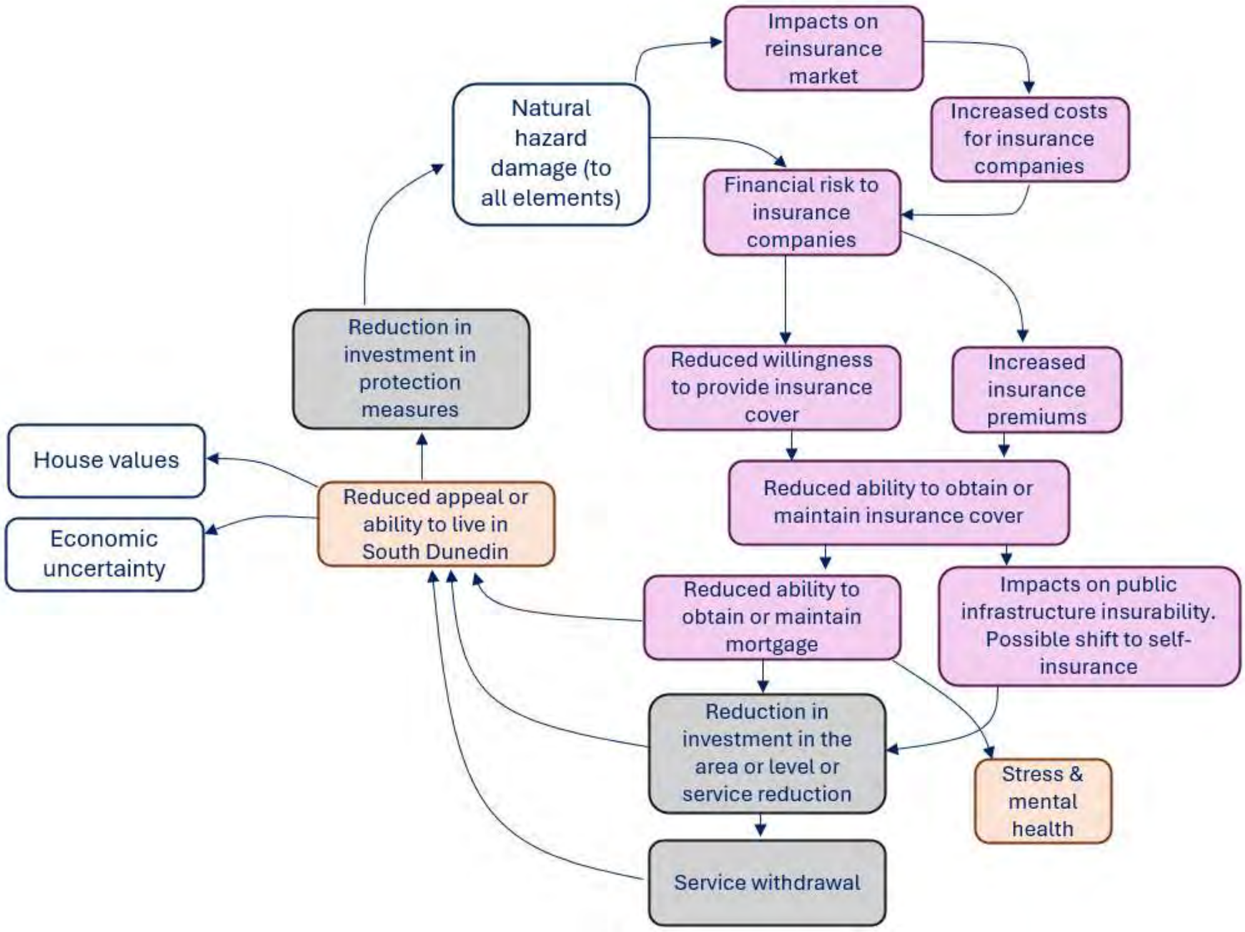

Figure 6.7 Cascading risk relating to insurance availability in South Dunedin (colour scheme: grey = buildings and infrastructure damage and impacts, orange = social impacts, purple = economic impacts, green=environmental damage)

6.4 ENVIRONMENTAL IMPACTS

At a national scale, climate change is identified to pose a range of risks, including the two following priority risks that were rated 'major' by late century:

- Risk to coastal ecosystems, including the intertidal zone, estuaries, due to ongoing sea-level rise and extreme weather events.
- Risks to indigenous ecosystems and species from the enhanced spread, survival and establishment of invasive species due to climate change.
- Additionally, environmental impacts will arise from many of the direct risks within South Dunedin. Increasing groundwater levels and saline intrusion may cause die-off of grass and vegetation. Extremely high groundwater levels will mean ground is soft, and may become unusable. This will impact many aspects of South Dunedin, including loss of the use of personal residential gardens, preventing urban gardening, with potential impacts on nutrition and the cost of food. This risk may be exacerbated by the presence of contaminated sites within residential South Dunedin, where soft ground may be more likely to transport contaminants, making use of some areas unsafe.
- Loss of amenity of public spaces may reduce enjoyment of parks and local open space. These impacts on sports fields would diminish the ability of South Dunedin to host sport to

the extent that it presently does. This would have impacts on the economic wellbeing of South Dunedin as well as the sense of community. It would also have wider impacts on users of playing fields from the wider Dunedin area.

- Increasing flooding, damage, and reduced level of service in stormwater and wastewater networks may cause increasing wastewater overflows. Wastewater overflows cause reduced water quality in both freshwater and marine waterbodies, causing impacts on local ecology, and can pose serious health risks.
- Risks to contaminated land may result in increasing environmental contamination from contaminated sites, most notably from the Kettle Park site which is at high risk due to coastal erosion[55].
- Damage to homes and infrastructure can also generate large volumes of contaminated runoff or debris, and generate large volumes of building waste.

Changing land-use, emphasis on blue green infrastructure and groundwater rise all may present opportunities to expand green space within South Dunedin. This may have a range of social and ecological benefits to South Dunedin and the wider area (also discussed in Section 5.3). Opportunities to restore some of the historical wetlands or salt marshes within South Dunedin may also carry cultural benefits.

[55] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

7 CONCLUSION

The purpose of this r*isk assessment* is to "*assess the potential for elements at risk (people, places, assets) to be negatively affected by pluvial flooding, coastal inundation, coastal erosion, groundwater, landslide and liquefaction natural hazards in South Dunedin*"

This document presents the findings of the SDF Risk Assessment at the present day, mid-century (2060-2070) and long term (2100) timeframes under mid-range climate change scenarios (SSP2-4.5) and high end climate change scenarios (SSP5-8.5), where data is available. This assessment was based on the principle of making the best use of available information, despite a range of limitations to the available data being identified. Importantly, the risk assessment provides a baseline assessment that assumes that risk is not mitigated, which is part of a separate piece of work. In this sense, the report represents a 'status quo' or 'do nothing' option.

The risk assessment is guided by two aims:

1. Outline the "case for change" in response to current and increasing natural hazard risks.
2. Support spatial adaptation planning

Importantly, the risk assessment is intended to support suburb-level adaptation planning, including dialogue with affected stakeholders about the options for mitigating and adapting to identified risks. The risk assessment is not intended to provide a detailed property-level assessment of risk and using the report in this way could lead to false or misleading conclusions (e.g. high risk areas may include low risk properties, or the reverse).

The risk assessment seeks to identify, classify, and prioritise risks across South Dunedin by assessing exposure to hazards, vulnerability of elements, and assigning corresponding risk scores. The associated impacts of these risks, should they be realised, are also described. The risk assessment does not however seek to prioritise areas for adaptation, which could be influenced by a range factors, including planning, budget, asset management, and other considerations. These factors could be unique to each of the potential futures explored for South Dunedin and will be considered as part of a separate but related workstream on adaptation options.

7.1 SUMMARY OF FINDINGS TO SUPPORT SPATIAL ADAPTATION PLANNING

The risk assessment supports spatial adaptation planning by providing a spatial representation of risk for a range of timeframes to the 12 'Elements at Risk', and their 'key features'.

7.1.1 WHERE ADAPTATION MAY BE NEEDED TO REDUCE RISK

Spatial risk quantification (as shown in Section 5 mapped risks and the accompanying Geospatial database) helps identify locations *where* adaptation measures are most needed to reduce risk.

South Dunedin has many locations that are identified as being of high importance to the community and which are important influences in adaptation planning. These key features are distributed across South Dunedin, with clusters of essential or important places located near St Clair, King Edward Street, Forbury Corner, and Portsmouth Drive (Figure 5.5). Due to the extensive spatial coverage of risk across South Dunedin, the majority of these are at high risk due to multiple hazards by late century.

7.1.2 WHEN ADAPTATION MAY BE NECESSARY

The changing risk profiles over time helps inform *when* adaptation may be necessary:

- Present: The risk to many elements within South Dunedin is due groundwater and pluvial flooding.
- Mid-century: Current risks intensify and expand due to climate change-driven increases in hazards. Consequently, at least half of all sports fields, roads, wastewater pipes, contaminated land, and overhead electricity distribution lines will be at high risk from groundwater under a high-end climate scenario.
- Late century: Groundwater-related risks continue to escalate in scale and severity across most elements. Additionally, there is a significant rise in risks associated with coastal inundation. This increase is driven by the inundation of inland South Dunedin during the 1% AEP event (mid-range climate scenario) and the 10% AEP event (high-end climate scenario). This frequency of inundation introduces medium and high risks across most elements.

When driven by the chronic, slow onset of groundwater rise, the identified high risks are associated with a decline or potential complete loss in functionality of the elements t risk unless mitigation measures are taken. When driven by acute, periodic events (such as flooding), the identified high risks are associated with increasingly frequent and severe damage. This will require lengthy repairs and, in some cases, may cause sudden failure resulting in threat to life. The scale of high groundwater and pluvial flood risk across most elements by mid century is associated with a range of negative impacts on the liveability and functionality of South Dunedin including:

- Widespread reduction in level of service of stormwater and wastewater systems.
- Loss of functionality of many playing fields.
- Decline in condition across the roading network.
- Increasingly damp living conditions in homes.
- Ponded surface water in parks and open spaces due to permanent emergent groundwater.
- The transport of contaminants across outdoor space and parkland.

These issues will become more widespread by late century, and will be compounded by the increasing frequency of damage from coastal inundation. Approximately 10% of South Dunedin buildings are rated medium or high risk arising from a single hazard, 60% from two hazards, and 20% arising from at least three hazards. This risk progression over time suggests that increasingly large scale mitigating actions will be required to manage risks.

Some of the identified present day risks are currently being managed, for example through existing roading and three waters maintenance schedules. However, this assessment indicates that these maintenance measures will become increasingly inadequate in managing the escalating risks in future scenarios. By late century, significant risk mitigation will likely be necessary for most assessed elements to manage the risks from multiple hazards across large areas of South Dunedin.

7.2 SUMMARY OF FINDINGS TO BUILD THE CASE FOR CHANGE

The interconnectedness of physical elements (places and assets) with their users within South Dunedin means that any disruption or impact on one part of the system can trigger complex interrelated and cascading consequences to other parts (referred to as impacts). These impacts relate strongly to the Strategic Objectives of South Dunedin, particularly posing risks to social and economic resilience, and environmental restoration. The following impacts build the case for change by highlighting some of the issues likely to occur without adaptation:

- Increasing physical risks to the elements of South Dunedin are likely to lead to increased physical harm to people living, working, and visiting the buildings of South Dunedin. These will arise through:
  - Risks to buildings associated with high groundwater which cause damp indoor living and working environments. This can cause higher incidence of respiratory diseases such as asthma, hypersensitivity pneumonitis, rhinosinusitis, bronchitis, and respiratory infections.
  - High groundwater causing mobilised contaminants from numerous contaminated land sites across Dunedin resulting in exposure to unsafe and contaminated water.
  - Increasing risk associated with acute, event based hazards such as pluvial flooding, coastal inundation, landslide, coastal erosion[56], and liquefaction. These risks introduce the potential for loss of life or injury due to structural failure of buildings, drowning, electrocution, or injury.
- Declining community and social health and well-being are likely to arise from
  - Increasing physical risk of harm to people.
  - Increasing feelings of anxiety or loss following an event.
  - Reduced ability to access goods, services, amenities, and places of work or education due to worsening road condition and event based disruption.
  - Stress related to increased financial burden of repairs and insurance.
  - General declining vibrancy of the area associated with increased natural hazard damage.
- Disproportionate impacts on more vulnerable populations. Many of Dunedin's most vulnerable people live in South Dunedin due to factors such as flat land, affordable housing, and proximity to social services. These groups are considered to be those with disabilities, in rental accommodation, over 65 years old, or classified higher on the Social Deprivation Index. Review of social demographic information and risk indicates that many vulnerable community members are likely to be directly affected by the natural hazard risks of South Dunedin. Vulnerable people are the least resilient to increased stresses caused by climate-related hazards. They are also likely to be the least able to adapt to changes caused by climate-related hazards.

[56] There is a high level of uncertainty regarding coastal erosion risk due to data limitations (scale of screening study and accounting for impact of engineered structures). More detailed coastal hazard assessment is underway as part of the St Clair-St Kilda Coastal Plan and will be completed in 2025.

- Increased environmental contamination may cause reduced water quality in both freshwater and marine waterbodies, cause impacts on local ecology, and pose serious health risks. These impacts may arise through:
  - Increasing groundwater and coastal erosion risk to contaminated sites.
  - Risks to stormwater and wastewater network due to multiple hazards will drive increased overflows leading to environmental contamination.
- Increasing costs and wider economic impacts are likely to arise due to increasing frequency and severity of natural hazards associate with climate change. The identified physical risks to South Dunedin coupled with an understanding of rising costs associated with weather events, and wider national economic context indicate that South Dunedin will:
  - Experience increasing costs resulting from property damage, foregone production or reduced efficiency of production, and increasing medical costs.
  - Experience increasing cost of insurance
  - incur further costs to manage the declining condition or level of service of places and assets associated with increasing risk due to chronic, slow onset of groundwater rise.
  - Continue to see increasing economic shocks following acute events.
  - Experience cascading impacts that influence consumer and business confidence, the housing market and insurance.
- Declining service delivery across South Dunedin driven by risks to the stormwater and wastewater networks due to multiple hazards. This is likely to:
  - Have adverse impacts on local residents as well as the wider Dunedin City and region including increasing negative feelings of residents and reduced access and mobility.
  - Increase environmental damage.
  - Increase costs and resourcing demands on Council.

  There is also potential for unplanned relocation. This has the potential to isolate services, resulting in infrastructure that is too expensive to service. Additionally, unmanaged relocation has the potential to generate negative community dynamics. The sense of community may be undermined with significant impacts on the vibrancy and appeal of South Dunedin. Unplanned relocation could exacerbate existing social vulnerabilities and urban decay.

Risks identified within this report and accompanying geospatial database[57] shows that South Dunedin has high exposure to natural hazards and a correspondingly high baseline risk profile. Anticipated changes in climate and associated increases in exposure to key natural hazards are expected to materially increase risk across all elements assessed in the risk assessment. If realised, these may result in complex interrelated and cascading consequences.

Consistent with the broader risk assessment findings, the mana whenua risk assessment has shown that, from a Kāi Tahu perspective, there is substantial risk resulting from a 'keep doing what we are doing' scenario, where there are no additional interventions to address the issues facing South Dunedin. Risk to the key Te Taki Haruru values is generally significant, ranging from high

[57] The results of the spatial risk assessment have been compiled into a geospatial database which has been provided to DCC alongside this report. The database holds spatial files relating to each element at risk with metadata holding risk ratings and some supporting information (e.g. identification of key features).

(mana, whakapapa, tapu & noa) to extreme (mauri) levels of risk. These results support the case for change in response to the modelled natural hazards and climate risks.

The findings of this assessment are being used to inform the SDF adaptation workstream, which will focus on developing a suite of preferred mitigation options (including timeframes, thresholds and triggers) that enable South Dunedin to prepare for and adapt to the impacts of climate change.

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APPENDIX A: RISK ASSESSMENT STAGES AND PURPOSE

A1 STAGES OF THE RISK ASSESSMENT PROCESS

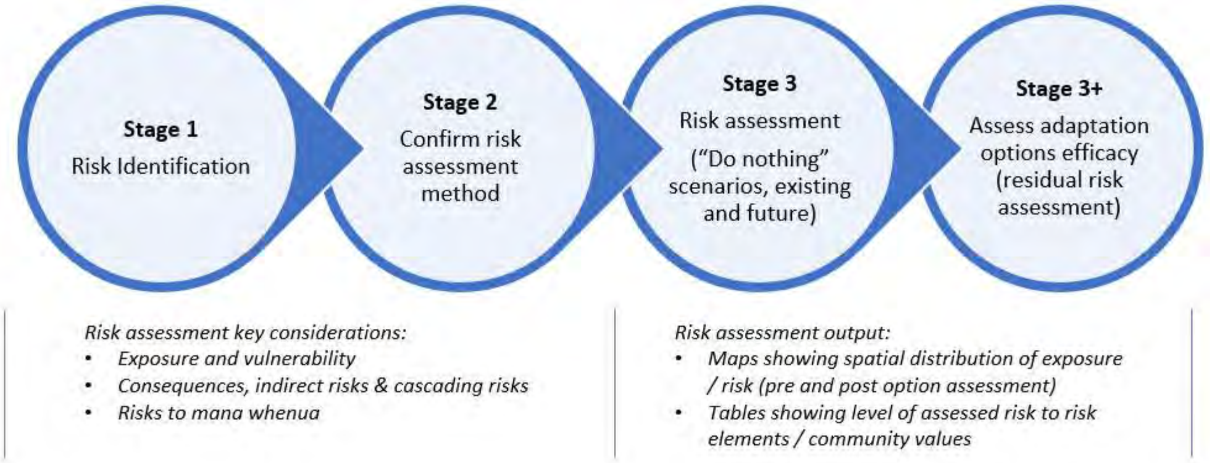

Figure A-1 Risk assessment stages, considerations and high level outputs

Stage 1 - Risk Identification: The Risk Identification Report (Kia Ropine, 2023) was the first stage of work, with the objectives:

- Collate available existing information regarding:
- Hazard awareness in relation to rainfall induced, coastal, groundwater and seismic natural hazards and climate change.
- People, places and asset information to support the exposure and vulnerability component of a risk assessment within South Dunedin.
- Provide a foundational understanding of natural hazard and climate change risk to South Dunedin that was to be built upon in the subsequent stages of the risk assessment.

Stage 2 – Risk Assessment Methodology: The draft risk assessment methodology (February 2024) was developed with input from Workstream 4 (Adaptation), DCC, and ORC. The approach adopted was reliant on input from engagement, particularly regarding the assessment of vulnerability and impacts on the community. This engagement was caried out between March and June 2024. Findings from this engagement was used to inform the risk assessment.

Stage 3 – Risk Assessment: This report documents the findings of the risk assessment as based on the information gathered through Stage 1 and Stage 2 of the risk assessment process. The main steps in the risk assessment are:

- Carry out the geospatial risk assessment.
- Identify key features.
- Assess exposure of elements at risk to hazards.
- Assess vulnerability of elements at risk to hazards.
- Assess risk based on exposure and vulnerability assessment.

- Present spatial mapping of risk, where outputs are presented by hazard and by element.
- Document supporting spatial metadata relating to impacts arising from risks to key features.
- Describe impacts and present relevant supporting spatial data where available.

Stage 3+: The Risk Assessment is designed to be applied to evaluate residual risk relating to the adaptation options. This process is to be implemented under the Efficacy Assessment component of Workstream 4: Adaptation Options.

A2 RISK ASSESSMENT PURPOSE DETAIL

Within the wider programme purpose, the purpose of *Workstream 3: Risk Assessment* is to "*assess the potential for elements at risk (people, places, assets) to be negatively affected by rainfall, coastal, groundwater and seismic natural hazards in South Dunedin*".[58] This is an important component for achieving the SDF Strategic Operational Objectives because it identifies what may happen if nothing is done. It also provides a framework for assessing efficacy of adaptation options.

Specifically, the risk assessment methodology aims to provide natural-hazard exposure and vulnerability information for "key features" within the twelve "elements at risk". This is required to support two aims:

1. Support spatial adaptation planning
2. Outline the case for change in response to current and increasing natural hazard risk.

For both of these aims, there are key stakeholders that inform the outputs needed from the risk assessment, and the level of confidence and reporting detail needed. The two aims and stakeholders are discussed further in Sections A2.1 and A2.2 respectively.

A2.1 (AIM 2) OUTLINING THE CASE FOR CHANGE WILL BE ACHIEVED BY:

- Providing an overview of risks to South Dunedin with relevant supporting information. This will draw together the results and conclusions from the spatial risk assessment designed to meet Aim 1.
- Identification and discussion of non-spatial risks and their potential impacts. Many of these will be cascading risks (also termed indirect or compounding risks) that arise when an element is damaged. These impacts relate strongly to the Strategic Objectives of South Dunedin, particularly posing risks to social and economic resilience, and environmental and cultural restoration. This will identify what may occur if South Dunedin does not adapt, which is a critical component of the case for change.

The case for change has a relatively wide range of stakeholders, these include the community, Councillors, and business case decision makers. A range of stakeholders may draw on the results generated by the risk assessment for general adaptation and development decision-making purposes, including Council, ministries (Education, Health, Justice) and Kāinga Ora. These stakeholders are considered secondary, and their needs will not directly inform the risk assessment methodology.

[58] This purpose is stated in the RFP and has been adopted in the Risk Identification Report, noting that the terminology 'things of value' is changed to 'elements at risk'.

A2.2 (AIM 1) THE RISK ASSESSMENT SUPPORTS SPATIAL ADAPTATION PLANNING BY:

- Providing a spatial representation of risk for a range of timeframes[59] to the 11 'Elements at Risk' as identified in the *Risk Identification Report,* and their 'key features'.
  - Spatial risk quantification of these key elements will inform *where* adaptation is required to reduce risk.
  - Evaluation of risk at differing time horizons will show how risk profiles change over time, which will help inform *when* adaptation may be required.
  - The key features help characterise the elements at risk (e.g. residential buildings are a key feature that characterises the "buildings and open space" element at risk).
  - The inclusion of spatial risks is considered in line with the Principles of the risk assessment (refer Section 3).
- Providing a spatial representation of risk to key features. This will help guide decision making on what *type* of adaptation options are most appropriate for different areas.
- Informing efficacy of adaptation options. Evaluation of the efficacy of adaptation options to reduce risk to South Dunedin will draw on the risk assessment process.

The primary stakeholder in spatial adaptation planning is Workstream 4. Therefore, when planning to inform spatial adaptation planning, the Workstream 3 methodology is guided by the needs of Workstream 4 (which will be influenced by their stakeholders). The needs of Workstream 4 are identified below.

A2.2.1 WORKSTREAM 4: ADAPTATION OBJECTIVES AND RISK DATA REQUIREMENTS.

To ensure the risk assessment meets Purpose 1, it must provide required outputs to Workstream 4: Adaptation. The objectives of the adaptation workstream and corresponding data requirements from the risk assessment are outlined in Table A-1 These requirements and supporting discussion with Workstream 4 have helped to shape the risk assessment methodology.

Table A-1. Adaptation data needs from risk workstream

Adaptation Workstream objectives (Workstream 4)	Outputs needed from the Risk Assessment (Workstream 3) to assist Adaptation Workstream
(1) Inform drawing of cell/zone/adaptation-area boundaries	Geospatial identification of *Key Feature* risk within each *Risk Element.* e.g. either high/medium/low or scored mapped key features.
(2) Inform type of adaptation option e.g. is high risk due to high vulnerability (and therefore building modification or social initiatives may reduce risk sufficiently) or high exposure (and therefore requiring changes to hazard extents)	Supporting geospatial information (or metadata) that provides the rationale for each *Key Feature* risk within each *Risk Element*. e.g. industrial buildings at X location are high risk due to the high frequency flooding which is likely to exceed the floor level.

[59] 'Scenarios and time horizons' are discussed in Section 3.1.6.

(3) Inform how adaptation options are scoped / scaled / described e.g. if vulnerability data suggests inequities, how could blue green corridors or retreat be designed or conceptualized to reduce inequities; if rugby club is central to community cohesion, reshaping of communities must include a rugby club	Supporting geospatial information (or metadata) that provides the rationale for each *Key Feature* risk within each *Risk Element*. e.g. the rugby club has been identified as high risk because of the impacts associated with loss of playing surface due to groundwater inundation and the large number of local people that are either members or supporters of the club.
(4) Inform when adaptive actions are required e.g. when risk is above an acceptable threshold, action is required, and potential action lead time will guide development of signals and triggers Note: risk thresholds or intolerable risk is defined by WS1 but will be informed by information provided by WS2 and WS3	Supporting geospatial information (or metadata) that provides the rationale for each *Key Feature* risk within each *Risk Element* for different future timeframes. e.g. the wastewater underground assets at X location are predicted to shift from medium risk to high risk between 2080 and 2110 as a result of saline intrusion in the rising groundwater.

APPENDIX B: RISK ASSESSMENT APPROACH

B1 HAZARD DATA

The physical risk assessment draws on spatially mapped hazard data to evaluate exposure of elements to hazards. The key hazards facing South Dunedin (included in this risk assessment) are listed in Table B1. The inclusion of these hazards has been determined by the SDF programme scope, and subsequent considerations evaluated through the methodology development process.

Table B--1 Spatial hazard data availability and materiality

Hazard	Data availability	Materiality / assumptions	Data gaps / known updates (as of April 2024) (not included in assessment)
Pluvial flooding	ICMP Hydrodynamic model results (WSP, 2011): 'Current' state (circa 2011) 10%, 2% & 1% AEP Future state (2060) 10%, 2% & 1% AEP Rev 1 addition: Updated ICMP Hydrodynamic model results (Beca, WSP, 2024) at: 1%, 2%, 10% AEP Present day, 2070 SSP2 4.5, 2100 SSP2 4.5, 2070 SSP5 8.5, 2100 SSP5 8.5	Rev 1 addition: Include 2024 results in assessment	Rev 1 edition includes updated model results available August 2024 Model updates to the previous model (WSP, 2011) as part of ICMP. These include incorporation of groundwater influences associated with sea level rise.
SLR and coastal inundation	NIWA 1%, 2%, 10% AEP at 0.1 m RSLR increments to 2 m showing inundation of South Dunedin from Harbour	Include in assessment. Limitation: Coastal inundation modelling is based on a 'bathtub' approach that assumes inundation of all areas lower than the calculated extreme sea level (while also assuming no connectivity/permeability of the raised land/dune systems within the	Known gaps but no known plans underway Inundation from a breach of the St Clair/St Kilda dunes is not available. Modelling is not currently procured but may be material to the adaptation plan. The coastal inundation extent associated with

Hazard	Data availability	Materiality / assumptions	Data gaps / known updates (as of April 2024) (not included in assessment)
		proximity of the coast). This may be conservative (i.e. result in higher risk) as it does not account for the time varying nature of a storm event (i.e. when modelled to represent the time limited nature of a storm event, the level may be lower). It also does not account for any potential influence of permeability of the dunes or connectivity of the raised land around Andersons Bay Road area and therefore may underestimate the inundation potential.	tidal influences under SLR is not available but may be material to the adaptation plan.
Coastal erosion	WSP district coastal hazards data is available as of April 2024. Potential coastal erosion zone: Current day, 0.3, 0.6, 1.5 m SLR Kettle Park Coastal Erosion Exposure and Remediation (T+T 2023) is available, this assessment provides Areas Susceptible to Coastal Erosion (ASCE) along the Kettle Park shoreline. These results are not available for the full length of the coastline.	WSP district coastal hazards data has been used in the absence of any better dataset. Fewer SLR increments are available than are required for risk assessment. Substitution of available data has been done to fill gaps. The coastal erosion assessment is based on district scale analysis and therefore may not be fully reflective of the coastal environment. The coastal erosion analysis used to inform this study is of a high-level nature and has a number of limitations associated with it, notably it should not be used for the assessment of the erosion hazard for individual properties and infrastructure. Accordingly, the Coastal Erosion risk assessment at this stage	St Clair/St Kilda Coastal Erosion modelling underway as part of the St Clair – St Kilda Coastal Plan. Updated model results available: in 2025

Hazard	Data availability	Materiality / assumptions	Data gaps / known updates (as of April 2024) (not included in assessment)
		the South Dunedin Future Programme is not being used to inform adaptation planning along St Clair-St Kilda.	
Groundwater	GNS 2023 SR2023-43 Dunedin Groundwater Monitoring and Spatial Observations. Groundwater levels & emergent groundwater: at 0.1 m SLR increments to 1 m. Median, MHWS, p95, Extreme sea level: ESL10%, ESL1%, ESL0.1% Loss of subsurface storage for 12hr rainfall at 10%, 1%, 0.1% with SLR	Include: Median scenario groundwater level is applied for exposure assessment of all elements assessed (this is the equivalent of a 63% AEP) Vulnerability thresholds for some elements are tied to depth to groundwater (for example, buildings are vulnerable to groundwater within 0.5 m of the ground surface). These thresholds are included in element vulnerability tables (Appendix C).	No known updates, possible additional scenario testing the 2130 or 2150 groundwater extent may be required.
Tsunami	Not included on the grounds that available tsunami extents (NIWA, 2012) are smaller than those from 1% AEP storm event coastal inundation. Therefore, no further benefit is expected from assessing Tsunami separately. (Status – agreed exclusion with ORC)		
Landslide	DCC Landslide database (single timeframe, no inclusion for climate change)	Landslide exposure classification is Moderate (2 – 1% AEP) based on the following: Likelihood is based on the 'Risk status' classification in the DCC Hazard database data provided for South Dunedin Future programme	Future work could improve this dataset by incorporating the impact of climate change.
Earthquake	Not included on the grounds that Earthquake risk is unlikely to drive adaptation options as the level of risk is similar across the wider Dunedin area. Risk mitigation measures to be included in all adaptation options where appropriate. (Status – agreed exclusion with ORC)		
Liquefaction	Barrell 2014 dataset provides a coarse, conservative spatial liquefaction potential across South Dunedin. Hornblow, 2020 has provided an updated	Include: Barrell 2014 spatial data. Domain C exposure classification is 'Low' (1 –	

Hazard	Data availability	Materiality / assumptions	Data gaps / known updates (as of April 2024) (not included in assessment)
	assessment however data is not in a useable spatial format to inform the analysis. This update states South Dunedin is 'not very liquefiable'. High spatial variability in liquefaction potential (with no defined spatial pattern). Tonkin & Taylor (2025 publication pending). South Dunedin Liquefaction Hazard Groundwater Sensitivity Assessment The influence of rising groundwater (associated with climate change induced sea level rise) on liquefaction potential has been assessed. The assessment showed that generally across the South Dunedin area an increase in groundwater level does not translate to a material increase in liquefaction risk. More significant sensitivity may exist at specific sites due to localised near-surface soil conditions (e.g. local surface fill or infilled channels), however it is not possible to delineate these zones to a satisfactory level of accuracy with the currently available dataset.	0.04% AEP) based on the following: Liquefaction likelihood is based on the findings of Tonkin & Taylor (2025 publication pending): The 250-year and 1000-year levels of shaking provide lower and upper seismic cases. The 1 in 100-year levels of shaking are insufficient to cause any significant levels of liquefaction. Liquefaction susceptibility: • Domain C liquefaction susceptibility (Barrell, et al., 2014): Moderate to high likelihood of liquefaction-susceptible materials being present in some areas.	

Hazard data available at the time of developing the methodology is presented in Figure B-2. This figure shows climate hazard data available at 10 year increments, with corresponding climate scenario and increment of sea level rise.

Data that is currently under development and near completion is also presented, with the dataset title shaded orange.

Table B-2. Hazard data availability

Climate related hazards																							
	Timeframe	Present day	2050			2060			2070			2080			2100			2130			2150		
	Scenario	Best estimat	SSP1-2.6 50th percenti	SSP5-8.5 83rd percenti	SSP2-4.5 50th percenti	SSP1-2.6 50th percenti	SSP5-8.5 83rd percenti	SSP2-4.5 50th percenti	SSP1-2.6 50th percenti	SSP5-8.5 83rd percenti	SSP2-4.5 50th percenti	SSP1-2.6 50th percenti	SSP5-8.5 83rd percenti	SSP2-4.5 50th percenti	SSP1-2.6 50th percenti	SSP5-8.5 83rd percenti	SSP2-4.5 50th percenti	SSP1-2.6 50th percenti	SSP5-8.5 83rd percenti	SSP2-4.5 50th percenti	SSP1-2.6 50th percenti	SSP5-8.5 83rd percenti	SSP2-4.5 50th percentile
Relative sea level rise (m) (NZ SeaRise, 2022)		0 m SLR	0.2 m SLR	0.4 m SLR	0.2 m SLR	0.3m SLR	0.5m SLR	0.3m SLR	0.3m SLR	0.6 m SLR	0.4 m SLR	0.4 m SLR	0.8 m SLR	0.5m SLR	0.5m SLR	1.1 m SLR	0.6 m SLR	0.6 m SLR	1.7 m SLR	0.9 m SLR	0.79 SLR	2.31 SLR	1.06 SLR
Coastal inundation (NIWA, 2023)	**1% (AEP)**																						
	2%																						
	10%																						
	20%																						
Coastal inundation (WSP, 2024)	**1%**																						
	2%																						
	10%																						
	20%																						
Pluvial flooding (WSP 2012/13 data)	**1%**																						
	2%																						
	10%																						
	20%																						
Pluvial flooding (Beca & WSP, 2024)	**1%**																						
	2%																						
	10%																						
	20%																						
Groundwater & episodic extreme sea level (GNS, 2023)	**ESL 1%**																						
	ESL 2%																						
	ESL 10%																						
	ESL 20% (substitute 63% (1 yr ARI))																						
Groundwater (subsurface infiltration exceedance) (GNS, 2023)	**1%**																						
	2%																						
	10%																						
	20%																						
Coastal erosion (WSP, 2024)																							

** Sea level taken off the Kitchener Street data point from SeaRise. This is the more conservative data point in the area (in terms of subsidence), noting that local variations are not accounted for within SeaRise.*

Key:	
	Available and fits the scenario + probability
	No data available
	Superseded data (was used in Rev 0 and updated for Rev 1)
	Exact scenario does not exist, alternative proposed

Geohazards	
Tsunami	1 in 100 year ARI 1 in 500 year ARI
Liquefaction	No geospatial data
Landslide	Historical GNS landslide data

B3 ASSET DATA

Spatial files assessed or analysed to provide supporting metadata are listed in Table B-3.

Table B-3 Elements at risk characterisation and assessment component

Elements at risk	Spatial files assessed or used to inform metadata	Data source
Buildings	Archaeological sites	1
	Buildings	1
	Heritage sites	1
	Heritage character sites	1
	Property	1
	Census data (2018)	1
Parks and sports fields	Park locations	1
	Sports field	1
Ecological areas	No spatial data	
Roads and associated infrastructure	Road criticality	3
	Roads (line dataset buffered to make road 8 m wide)	1
	Cycle lanes	1
Rail	Rail corridor	1
	Rail transport buildings	1
Water	Tank	1
	Plant	1
	Node	1
	Pipe	1
	Criticality	2
Wastewater	Node	1
	Pipe	1
	Drain pipe	1
	Criticality	2
Stormwater	Node	1
	Pipe	1
	Retention pond	1
	Criticality	2
Contaminated land	HAIL register	1
Telecommunications infrastructure	Exchange site	1
Energy	Transpower assets	4
	Aurora assets	5
	LPG gas facility	1
Mana whenua	Assessed separately	

Source 1: DCC Rest Server (2023)

Source 2: DCC Three Waters Team (May 2024)

Source 3: DCC Roading team May (2024)

Source 4: Transpower website (2023)

Source 5: Aurora (June 2024)

Spatial risk outputs were assessed and presented separately by risk element (in some cases key feature), geometry, and hazard, allowing adaptation options to be developed in response to risks arising from specific hazards to specific elements. The spatial definition and exposure criteria for which each risk element will be assessed and results presented is shown in Table B-4:

Table B-4 Asset spatial definition and exposure criteria

Element / asset	Spatial definition	Exposure criteria[1]		
		Coastal & Pluvial	Coastal erosion, landslide, liquefaction	Groundwater (emergent and ground water level (GWL))
Buildings and open space	Asset feature class: Building footprint or land parcel.	Binary in/out (Proportion exposed)	Binary in/out (Proportion of polygon exposed)	Emergent and minimum GWL level under the building / parcel (Emergent proportion exposed, GWL average level under the building / parcel)
Roads and rail	Road block to block lengths (buffered to 8 m width)	Binary in/out & proportion exposed	Proportion of road area exposed	Emergent (binary in/out, proportion), GWL (average and minimum level under the road area)
3 waters and energy	Points	Binary (in/out)	Binary (in/out)	Manholes: invert level is below the GWL, not exposed = invert level is above GWL Treatment plant/ pump station: (Emergent GW: binary in/out, GWL, average and minimum depth at node)
	Line	Binary in/out & proportion exposed	Proportion of pipe exposed (retain original geometry, no splitting of lines)	Emergent GW: (not assessed), GWL (average and minimum groundwater level across the pipe)
	Polygon	Binary (in/out), proportion of polygon exposed	Binary (in/out), proportion of polygon exposed	Emergent (binary in/out), GWL (average and minimum level under poly)
Contaminated sites (HAIL)	Polygon	Binary in/out (Proportion exposed)	Binary in/out (Proportion of polygon exposed)	Emergent and minimum GWL level under the site (Emergent proportion exposed, GWL average level under the site)
Tele-communications	Exchange site assessed as part of buildings. No other data provided.			

[1]No minimum area or proportion threshold applied.

B4 EXPOSURE

Hazard exposure is categorised in accordance with the likelihood of its occurrence. The proposed relationship between timeframes, hazard scenarios and likelihood rating is based on the generic relationships shown in Table B-5, with hazard specific relationships shown in Section 3.3.2.

Table B-5: Exposure (adapted from pORPS Hazard likelihood[60])

Exposure	Present day	Medium-term	Long-term
Extreme	Up to once every 10 years (99%-10% AEP)	Up to once every 10 years (99%-10% AEP)	Up to once every 10 years (99%-10% AEP)
High	Once every 11-50 years (10%-2% AEP)	Once every 11-50 years (10%-2% AEP)	Once every 11-50 years (10%-2% AEP)
Moderate	Once every 51 – 100 years (2 – 1% AEP)	Once every 51 – 100 years (2 – 1% AEP)	Once every 51 – 100 years (2 – 1% AEP)
Low	Once every 100 – 2,500 years (1 – 0.04% AEP)	Once every 100 – 2,500 years (1 – 0.04% AEP)	Once every 100 – 2,500 years (1 – 0.04% AEP)
Very low	2,501 years plus (<0.04%AEP)	2,501 years plus (<0.04%AEP)	2,501 years plus (<0.04%AEP)

B5 VULNERABILITY

Vulnerability ratings have been developed to evaluate physical risk to key features.

B5.1 KEY FEATURES

Key features have been identified through:

- Stage 1 Risk identification Report
- Discussion with Workstream 4
- Engagement with owners, managers and those responsible for the elements at risk and key features
- Engagement with the community.

Identification of specific "Important or essential" features represents features that are of high value to the community (e.g. school, sports clubs, church, mosque, civil defence facility, emergency facility etc), or provide essential services to the area or wider Dunedin- (e.g. critical transport routes). These key features provide an indication of high consequence community features within South Dunedin. Supporting information for high consequence key features is provided in an accompanying database where this was able to be obtained. The following information was sought:

- Who is it of value to?
- Why is it of value?
- What are the impacts of damage to the feature?
- Whether the value the feature provides is intrinsically tied to its location. I.e. Could the feature / service be provided from elsewhere?

[60] ORC (2021) Proposed Regional Policy Statement APP6 Methodology for natural hazard risk assessment. Hazard likelihood table has been adapted by adding a new class 'up to once every 10 years', and combining the 100-1000 and 1000-2500 year classes.

- Whether it is locally or regionally important?

B5.2 VULNERABILITY - PHYSICAL RISK ASSESSMENT

The physical risk assessment considers asset specific vulnerability information, such as design, condition, and age. The availability and materiality of this information was tested with owners, managers and those responsible for the elements at risk. Physical vulnerability ratings were gathered through consultation with owners, managers and those responsible for the elements at risk and through community engagement (refer to engagement schedule outlined in Section B7.

Vulnerability was rated using a scale, where example guidance for the vulnerability rating is shown in Table B-5-1. This guidance has been developed to reflect damage arising from acute hazards. Specific vulnerability scale was developed for assets using the example as a guide, and incorporating considerations for chronic hazards if these were necessary.

Table B-5-1. Example vulnerability attributes by hazard

Vulnerability	Description
Extreme	Sudden collapse or failure likely, causing potential risk to life. For example house/culvert collapse putting people's lives at risk.
High	High damage likely. Loss of service with lengthy time to restore to operation (months).
Moderate	Moderate damage likely or possible. Short to medium time to restore to operation (less than one month).
Low	Minor damage sustained although it does not impact the operation of the asset.
Very low	No damage or loss of service

B6 IMPACT ASSESSMENT

Impacts (consequences, indirect risks, and cascading risks) are considered separately to physical risk and include social, cultural, economic and environmental impacts. In general, they are not rated or scored.

Cascading impacts arising from risks to South Dunedin have been identified through community engagement and discussion with SMEs. Many of the issues identified align with the findings of previous in-depth research into the cascading impacts of flooding on the South Dunedin community. Findings of this previous study have been incorporated into this discussion of cascading impacts of climate risk on South Dunedin.

These findings are presented through a description of impacts, casual maps, and where available, relevant supporting data is presented spatially.

Refer to Appendix B7 for details regarding stakeholder engagement. Refer to the South Dunedin Future Engagement Report: Risk and Long List of Adaptation Approaches for details of the public engagement activities.

B7 STAKEHOLDER ENGAGEMENT SCHEDULE

outlines the planned engagement sessions to inform the risk assessment.

Table B-7 Risk assessment stakeholder engagement schedule

Engagement	Purpose	Stakeholder group	Date	Status
Public engagement South Dunedin	Dunedin Future Expo 29 February – 3 March	Community	Expo 29 February – 3 March	Complete
	Street festival	Community		Complete
	Moana Nui	Community/Pasifika		Complete
	Online survey	Community	29 Feb - 28 March 2024	Complete
Engagement with community / social agencies	SD Risk & social impact	Community Network	March/April 2024	Complete
	SD Risk & social impact	Disability	18 March 2024	Complete
	SD Risk & social impact	Youth -Queens High -Bayfield High -Dunedin Youth council -Rangitahi workshop	March 2024 20 March	Complete (Note: not as much risk data from these sessions)
	Potential impacts arising from damage to education facilities & Key feature vulnerability	Ministry of Education (MoE)	June 2024	Complete
Engagement with economic sector representatives	SD Risk & economic impact	The DCC SDF team have carried out engagement with the business community through a range of activities over 2023-24. These activities have included: town hall meetings, presentations with community groups, one-to-one meetings. Groups spoken to include (but are not limited to): • South Dunedin Business Association • Otago Property Investors Association • Property Council of New Zealand (Otago Sub-Committee) • Infrastructure New Zealand • Business South		
	Initial call: Economic profile of	Sarah Gell, DCC	21 March 2024	Complete

Engagement	Purpose	Stakeholder group	Date	Status
	Dunedin / South Dunedin			
Emergency Management	Identification of key features and impacts	CDEM	May 2024	Complete
Risk to buildings and open spaces	Initial call: Data availability & materiality regarding: Residential buildings Non-residential buildings Built heritage Parks and open spaces	Pete Hebden, DCC*	19 March 2024	Complete
		Mark Mawdsley Katie Eglesfield Parks and Recreation Paul Freeland Principal Policy Advisor, City Development, DCC*.	21 March 2024	Complete
		Neil McLeod Principal Advisor Building Solutions, Building Services, DCC*.	22 March 2024	Complete
	Risk Workshop: • Agree key features • Potential impacts arising from damage to key features • Key feature vulnerability	Residential buildings Neil McLeod	19 April 2024	Complete
		Non-residential buildings Neil McLeod Pete Hebden Katie Eglesfield	19 April 2024	Complete
		Parks and open spaces Katie Eglesfield Aidan Battrick	18 April 2024	Complete
Risk to Marae, and other culturally significant sites	Carried out by Aukaha – refer Appendix D			
Risk to roads	Initial call: Data availability & materiality	Simon Smith, DCC	19 March 2024	Complete
	Risk Workshop: • Agree key features • Potential impacts arising from damage to key features	DCC Roading team: Simon Smith Peter Tomlinson Cynthia Wilson	19 April 2024	Complete

Engagement	Purpose	Stakeholder group	Date	Status
	• Key feature vulnerability			
Risk to seawalls	Risk discussion	Simon Smith Raphael Krier-Mariani. DCC	10 May 2024	Complete
UpRisk to areas of ecological significance	Initial call: Data availability & materiality	DCC parks and ecology: Zoe Lunniss Luke McKinlay Katie Eglesfield	22 March 2024	Complete
Risk to rail	Risk discussion:	KiwiRail	13 May 2024	Complete
Risk to telecommunications infrastructure	Risk discussion: • Data availability • Key features • Potential impacts • Key feature vulnerability	Chorus	6 May 2024	Complete
Risk to energy infrastructure	Risk discussion: • Data availability • Key features • Potential impacts • Key feature vulnerability	Aurora, Transpower	2 May 2024 & December 2024	Complete
Risk to water supply, stormwater, and wastewater infrastructure	Initial call: Data availability & materiality	DCC 3 Waters team: Jared Oliver, Heinz Jacobs, Sarah Stewart	18 March 2024	Complete
	Risk Workshop: • Agree key features • Potential impacts arising from damage to key features • Key feature vulnerability	DCC 3 Waters team: Jared Oliver, Heinz Jacobs, Sarah Stewart, Darrin Lane, David Dewhirst	18 April 2024 & 23 April 2024	Complete
Risk to solid waste and contaminated sites		Lincoln Coe, DCC	19 March 2024	Complete

Engagement	Purpose	Stakeholder group	Date	Status
	Initial call: Data availability & materiality	Raphael Krier-Mariani. DCC		
		Joon van der Linde, ORC Jean-Luc Payan, ORC	22 March 2024	Complete
	Risk Workshop: • Agree key features • Potential impacts arising from damage to key features • Key feature vulnerability	Lincoln Coe, DCC Simon Beardmore E3 Scientific, on behalf of ORC Contaminated Land team	15 April 2024	Complete

APPENDIX C: RISK ASSESSMENT VULNERABILITY DATA, LIMITATIONS, AND ASSESSMENT METHOD

This section outlines the data availability and method used to assess risks to each element. The level of detail to inform vulnerability and the corresponding data requirements has been determined based on the assessment principles (i.e. making the best use of available information and, ensuring effort is proportional to outcomes) and it also follows a series of workshops between Kia Rōpine, DCC and ORC during January and February 2024.

People and communities are a fundamental consideration in the risk assessment. Risks to people have been considered in relation to the elements identified below, where the physical risk of harm to people living, working and using South Dunedin's features has been considered, as well as the impacts arising from damage or loss to the other elements. These potential impacts will be reported in the findings of the risk assessment, where the cascading social, cultural, economic and environmental risks will be identified.

The following sub-sections present each of the 12 elements at risk and identifies the approach to the vulnerability assessment regarding how it will support the risk assessment. The fields in the tables are described below:

- Risk – identifies the physical risk consideration within each element at risk.
- Supports – this indicates whether the key feature is included to support Aim 1 and/or Aim 2.
- Key features – The components of importance to characterise the element at risk.
- Vulnerability criteria data availability – this is a list of considerations that were potential factors in the assessment of vulnerability. This informed our data requests and helped to inform conversations with owners, managers and those responsible for the elements at risk, as well as community engagement.
- Method – this is an indication of the type of method to assess risk to the element/key feature.
- Output – an indication of the outputs from the risk assessment.
- Limitations / uncertainties / assumptions – Important information relating to confidence levels in the risk assessment. These will be recorded in the risk assessment report for transparency.

C1 BUILDINGS AND OPEN SPACES

Risks to buildings and open spaces were assessed using the methods and outputs identified in Table C-1-1.

Table C-1-1. Buildings and open spaces data availability, method, outputs and limitations

Risk	Supports	Key features	Vulnerability criteria data availability	Proposed method	Output	Limitations / uncertainties / assumptions
Physical risk to residential buildings Physical risk to non-residential buildings Physical risk to important or essential buildings Physical risk to heritage buildings	Aim 1, Aim 2	People	Population Physical risk to people from inundation hazard information. Refer also "Social impacts arising from damage to buildings"	**Physical risk to people:** Estimate number of people at risk using SA1 mesh-block population data (residential).	**Map:** Spatial distribution of population at risk **Table:** Quantification of population exposed to high risk residential buildings (or other buildings if information is available) (e.g. X people residing in SA1 areas with X% buildings rated at high risk)	Employee/patronage data is not available at time of assessment (June 2024), so cannot be used to estimate number of people at risk in non-residential buildings.
	Aim 1, Aim 2	Residential buildings, Non-residential buildings, Important or essential buildings	1. Location 2. Usage - assume based on land use zoning 3. Floor level – developed by proxy. 4. Building properties (foundation type. no. of storeys, age, build material) - see assumptions. 5. Property value – RV available 6. Fragility curves - see assumptions.	**Physical risk to buildings:** Assess exposure to a) property (i.e. land) b) above floor level (i.e. building). Vulnerability rating was developed and agreed through workshop with property / planning team at DCC. Key features were identified through community engagement and SME workshop. **Risk to contents**: Reported in relation to Aim 2 only. Indicate likely content damage range based on number of buildings with flooding above floor level, based off generic research.	**Map:** Risk to buildings arising from hazards showing identified key features **Table:** Quantification of risk assessment results at a property scale (may include building information – TBC following engagement) **Report section:** Description of risks and impacts	No information available for: 3. Floor level - Assume proxy 4. Building vulnerability properties – Where data is not available, propose qualitative generic ratings through workshop with City Development and Building Services team at DCC. 6. Fragility curves-propose not to use fragility curves, this level of detail is not required for spatial adaptation planning. Assumption: Exclude separate non-residential outbuildings buildings in residential areas (e.g. garages, sheds, outbuildings) - assume buildings less than 40m^2 are non-residential based on some high level assumptions from MBIE exemptions for building consents. Assume no allowance for warning time or experience (which both reduce damage).
Social impacts arising from damage to buildings	Aim 1, Aim 2	Residential buildings, Non-residential buildings, Important or essential buildings Contents	2018 Census data (available): Age, Ethnicity, Mobility issues Difficulty communicating Income Home ownership / renting Social deprivation Index Employment/ worker number need to confirm availability of information. Patronage / customer numbers - need to confirm availability of information.	**Social vulnerability:** Spatial data overlay upon hazard. Accompanied by a descriptive narrative in report including findings from community engagement.	**Map:** Spatial distribution of: Age Mobility issues Disability (Difficulty hearing or difficulty communicating) Social deprivation Index **Table:** Quantification of social indicators (e.g. X people have mobility issues that are in an area with high exposure to flooding) **Report section:** Description of impacts including cascading risks	Employment/ worker numbers were not available at time of assessment (June 2024). Patronage / customer numbers were not available at time of assessment (June 2024)..
Economic impacts arising from damage to buildings	Aim 1, Aim 2	Residential buildings, Non-residential buildings, Important or	Property value (RV available) Industry classification - need to confirm availability of information. Employment/ worker number - need to confirm availability of information.	Limited data is available at present, therefore limited economic assessment is possible. Where data is available, this will be used to produce: Spatial data overlay upon hazard.	Limited data is available at present, therefore limited economic assessment is possible. **Map:** Spatial distribution of economic data **Report section:** Description of impacts including cascading risks	Limited data is available at present, therefore limited economic assessment is possible.

Risk	Supports	Key features	Vulnerability criteria data availability	Proposed method	Output	Limitations / uncertainties / assumptions
		essential buildings Contents	Detailed GDP data - need to confirm availability of information. Patronage / customer numbers - need to confirm availability of information.	Accompanied by a descriptive narrative in report.		
Physical risk to open spaces	Aim 1, Aim 2	Parks	1. Land use 2. Surface - Need to confirm availability of information, see assumptions. 3. Condition - Need to confirm availability of information, see assumptions.	Physical risk: Assess exposure to a) property (i.e. land) Vulnerability rating to be developed through workshop with property / planning / parks team at DCC. Key features to be identified through community engagement and SME workshop	**Map:** Risk to open space arising from hazards showing identified key features **Table:** Quantification of areas at risk **Report section:** Description of risk and impacts	No information currently available for: 2. Surface, 3. Condition – information established through a qualitative generic ratings through workshop with Parks & Recreation team at DCC.
Impacts arising from damage to open spaces	Aim 2	Parks	High level assessment	Gather information from community engagement and managers of Open Space	**Report section:** Description of impacts including cascading risks	

BUILDING FLOOR LEVEL

Floor level is an important factor in building vulnerability. At the time of writing this report DCC had recently carried out a street-based observational assessment of floor levels in South Dunedin (Figure C1-1). These floor levels were incorporated into the analysis. A professional survey has been conducted on a sample of houses with the intention of confirming the accuracy of the observational assessment. The findings of this assessment are not available at the time of writing.

Floor levels gathered through the observational assessment were assigned to property parcels and were based on the floor height above ground of the assumed ‘primary dwelling’.

When applying the floor level assumptions to the buildings assessed for the purpose of the risk assessment, the following assumptions were applied:

- Where multiple buildings are located on a land parcel, the analysis assumes the floor level of primary dwelling is applied to all buildings on the property parcel.
- Where the parcel has ‘no data’, this parcel is excluded in the analysis.

Building floor levels were estimated to fall within the categories in Table C-1-2, which also shows the floor level applied in the risk assessment.

Table C-1-2. Building floor level categories applied through observational assessment by DCC (July-September 2024)

Range	Height used in risk assessment
Less than 15 cm	0 cm
Between 15 and 30 cm	15 cm
Between 30 and 45 cm	30 cm
Above 45 cm	45 cm
No data	No data (buildings were not assessed)

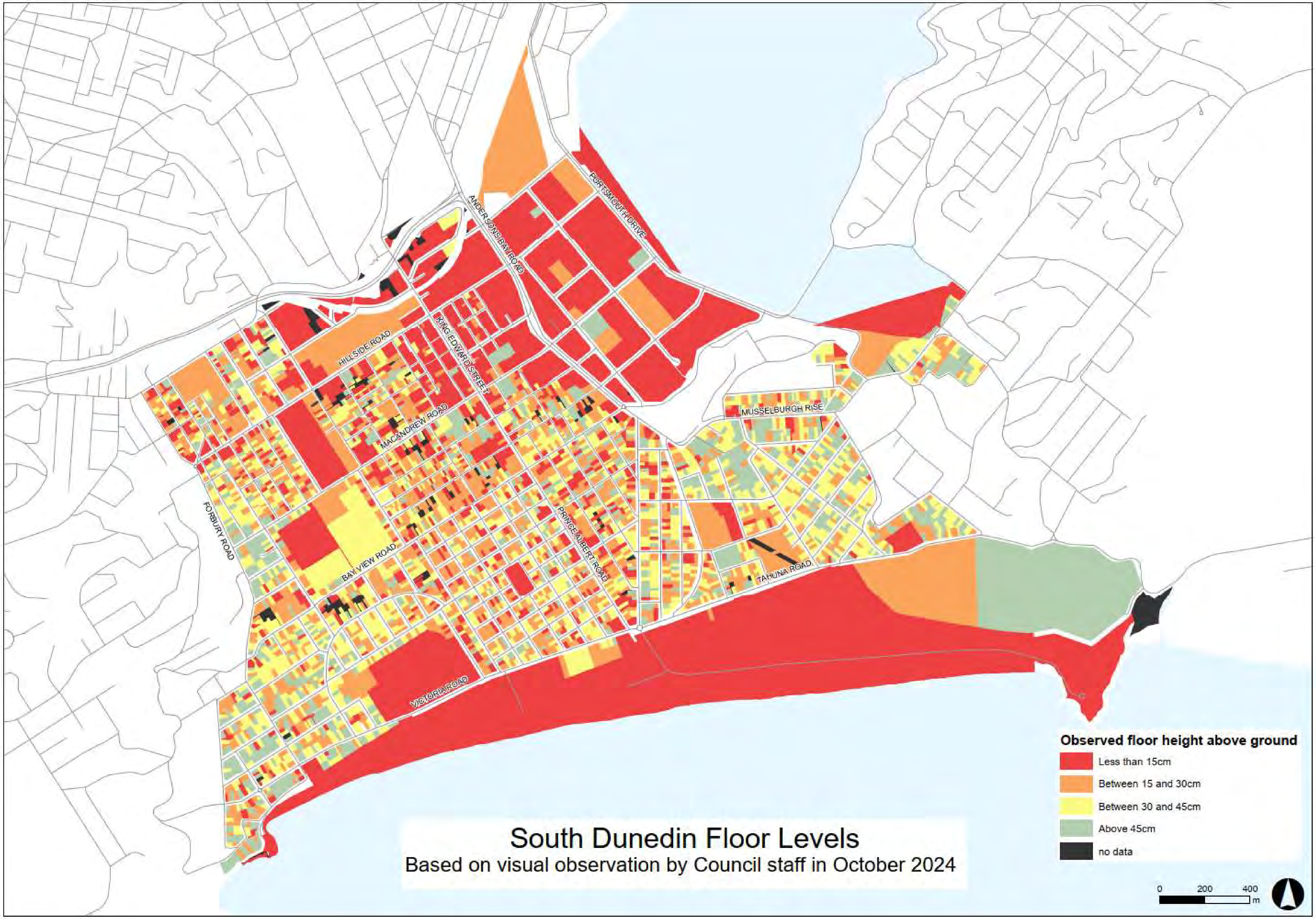

Figure C1-1 South Dunedin observed floor height above ground (Source: DCC)

SUMMARY OF WORKSHOP: BUILDINGS

KEY FEATURES

Key features were agreed through workshop with DCC staff:

- Residential, residential institution.
- Non-residential buildings:
  - Commercial.
  - School.
  - Church.
  - Built Heritage (heritage zoning).
  - Important or essential buildings (as identified by the community).
  - National significance.
  - International significance.
  - Local significance.
  - Rugby clubs (members tend to be very attached to home turf, could move fields but could not relocate clubs).
  - Sport facilities.

BUILDING VULNERABILITY TO PLUVIAL FLOODING AND COASTAL INUNDATION

Flooding can cause complete loss or damage to buildings and can lead to the need for extensive repairs . Building vulnerability to flooding is related to floor level, construction material, and building age. These characteristics are variable between building type and use. South Dunedin has a high proportion of ageing and poor condition buildings, which are particularly sensitive to flood damage.

Building resilience to flooding tends to vary with the age of the building where additional resilience measures (typically increase in minimum floor level) tend to be adopted following major floods. Updated controls in response to 2015 came into effect circa 2017.

New buildings tend to use Gib board in internal wall linings to provide seismic and wind strength. Gib board loses structural strength when wet or following an earthquake with resultant reduction in bottom plate strength. This requires complete re-lining following a floor or seismic event. Older buildings are more resilient to flooding due to the use of flood resilient building materials.

BUILDING VULNERABILITY TO GROUNDWATER

Emergent groundwater can cause instability in building foundations, lead to issues of dampness and mould in housing, and may cause various environmental problems such as pollution and salinity stress in properties. Where groundwater is high but not yet emergent, groundwater is unlikely to damage building condition, but will impact the liveability of homes. This may be less of an issue in non-residential settings due to extensive paving.
Reduction in level of service of roads, stormwater and wastewater may severely limit the function of buildings.

BUILDING VULNERABILITY TO COASTAL EROSION AND LANDSLIDE

Buildings and building foundations are highly vulnerable to erosion, landslide, or other ground instability, which can cause complete loss or damage to buildings, and can lead to the need for extensive repairs. Landslides may smother buildings.

BUILDING VULNERABILITY TO LIQUEFACTION

Liquefaction can cause differential settlement and lateral spreading that distorts structures, reduce foundation-bearing capacity, and damage pile supports and service connections.

BUILDING VULNERABILITY RATING

The below vulnerability rating table was informed by discussions through the workshop with property / planning team at DCC. In order to ensure that the vulnerability could be more widely applied and compared with other key elements some adjustments to agreed ratings have been made. Therefore, it may not completely align to outcomes from the discussion. All key features are to be assessed using the same vulnerability rating criteria.

Table C-1-3: Building vulnerability criteria*

Vulnerability		Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
	Vulnerability considerations relating to hazard and rating category	Floor level is the primary vulnerability consideration. Any flooding above the minimum floor level is assumed to possibly enter the building.		Emergent groundwater is likely to cause dampness and mould in buildings, which would render them uninhabitable over the long term. Near-surface groundwater would impact functionality of buildings, potentially disrupting access and posing a threat to health).	All assets are highly vulnerable	All assets are highly vulnerable	All assets are highly vulnerable
Extreme	Sudden collapse/failure causing potential risk to life.				All buildings are extremely sensitive to damage	All buildings are extremely sensitive to damage	n/a**
High	Acute hazards: Damage sustained resulting in the building being uninhabitable for > 1 month . Chronic hazards: No moisture barrier and inefficient drainage for the removal of stormwater (residential and non-residential buildings.).	All buildings when exposed to flood level > 0 mm above floor level	All buildings when exposed to flood level > 0 mm above floor level	No information regarding private drainage or moisture barrier. Therefore all buildings included in this category when exposed to emergent groundwater	n/a**	n/a**	All buildings are highly sensitive to damage
Moderate	Acute hazards: Damage sustained resulting in the building being uninhabitable for < 1 month. Chronic hazards: No moisture barrier but good drainage for stormwater (residential buildings).	n/a**	n/a**	No information regarding private drainage or moisture barrier. Therefore all residential buildings when exposed to groundwater 0-0.5 mbgl (access & health related)	n/a**	n/a**	n/a**
Low	Chronic hazards: No moisture barrier but good drainage for stormwater (non-residential buildings).	Building exposed to flooding with depth below floor level.	Building exposed to flooding with depth below floor level.	No information regarding private drainage or moisture barrier. Therefore all Non-Residential buildings when exposed GWL 0-0.5 mbgl	n/a**	n/a**	n/a**
Very low	No loss of service or repairs	n/a**	n/a**	n/a**	n/a**	n/a**	n/a**

* Spatial vulnerability indicators were not available. Therefore, vulnerability ratings have been developed based on subject matter expert judgement (refer to Appendix A for details of engagement)

** n/a assigned due to insufficient information to differentiate vulnerability between ratings

SUMMARY OF WORKSHOP: PARKS AND OPEN SPACES

KEY FEATURES

Key features were agreed with DCC staff and through community engagement:

- St Clair/St Kilda beach.
- Sports grounds.
- Marlow Park.
- Other parks & playgrounds.
- Tahuna Park.
- Caledonian gym and sporting facilities.

ADAPTIVE CAPACITY

Considerations regarding the development of adaptation options:

- Options to improve park performance under increasing flooding and groundwater rise are to change parks to turf or re-lay fields to improve drainage. These measures are a limit to their effectiveness which means their overall vulnerability should not change.
- When considering adaptation of playing fields, parks that are also HAIL sites should be preferentially removed because these need higher maintenance due to re-levelling (land subsidence).
- Playgrounds have 30 year renewal lifespan, and many are comprised of equipment that can be relocated, making theme very adaptable. Playgrounds can also adapt to reflect their changing environment, for example creating water features where groundwater is high.

Note on buildings associated with parks – many of these are community led, which means they have less funding. These buildings are likely to have lower adaptive capacity compared to private commercial. Loss of facilities would be a major community loss.

PARKS AND OPEN SPACES VULNERABILITY TO PLUVIAL FLOODING AND COASTAL INUNDATION

Flooding of open spaces is likely to prevent use where regular flooding would result in complete loss of field use. Associated buildings and playing fields may be damaged and grounds may become waterlogged.

PARKS AND OPEN SPACES VULNERABILITY TO GROUNDWATER

Rising groundwater is expected to compound the impact of rainfall by making fields more susceptible to waterlogging. The extent of this effect is currently unknown however any increase in groundwater is expected to be damaging to fields. The impact of waterlogging on fields is also related to recent rainfall and the frequency of use, where fields can be closed to reduce damage from playing. All fields are expected to become unusable when the root zone becomes waterlogged.

PARKS AND OPEN SPACES VULNERABILITY TO COASTAL EROSION

Direct damage from erosion would be highly damaging to parks. The Ocean Beach Reserve acts as a buffer for the dune system. This area is vulnerable to being buried by shifting dunes and sand is excavated from these areas at present.

PARKS AND OPEN SPACES VULNERABILITY TO LIQUEFACTION

Liquefaction may induce ground settlement and undulation in parks and sports fields, resulting in uneven surfaces. Sand boils can occur, posing hazards and necessitating cleanup, while lateral spreading near free faces may lead to ground cracking.

PARKS AND OPEN SPACES VULNERABILITY RATING

The below vulnerability rating table was developed and agreed through workshop with the roading team at DCC. Some of the agreed ratings have been adjusted to achieve standardisation across all elements.

Table C-1-4: Playing field vulnerability criteria

	Hazard	Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
Vulnerability Rating	Vulnerability considerations	Fields cannot be used when flooded, with increasing frequency of flooding posing a threat to the useability of fields.	Fields cannot be used when flooded. However coastal inundation events occur less frequently than pluvial flooding, meaning fields can recover between events.	Fields are highly vulnerable to groundwater, in many locations they would be vulnerable to any increase in groundwater level. The impact of waterlogging on fields is also related to recent rainfall and the frequency of use, where fields can be closed to reduce damage from playing. All fields are expected to become unusable when the root zone becomes waterlogged (the top approx. 0.3 m below the surface).	Direct damage from erosion would be highly damaging. Ocean Beach Reserve fields are not exposed directly to coastal erosion, but are vulnerable to being buried by shifting dunes.	All assets are highly vulnerable	All assets are highly vulnerable
Extreme	Permanent complete loss of field function	~~All sites~~	n/a	GWL 0-0.3 mbgl (or emergent)	All exposed areas and Ocean Beach reserve[1]		
High	Acute: Loss of field function during and following flood requiring a lengthy	All sites for increasing seasonality and annual rainfall (Not assessed as no hazard	~~All sites~~		n/a	All sites	All sites

	Hazard	Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
	time to restore functionality. Chronic: Permanent reduction in level of service	information is available regarding frequent storm events (this is out of scope))					
Moderate	Acute: Loss of field function during and following flood requiring a lengthy time to restore functionality. Chronic: Permanent reduction in level of service	All sites	All sites	All other sites are vulnerable to any increase in groundwater	n/a	n/a	n/a
Low	Minimal damage managed through routine maintenance.	All astroturf sites (not factored into assessment due to no data)	All astroturf sites (not factored into assessment due to no data)			n/a	n/a
Very low	No damage or change in function	n/a	n/a		All other sites (assume protection from seawall)	n/a	n/a

[1] Risk to Ocean Beach Reserve is exacerbated due to dune migration for which there is no hazard data (this is out of scope)

Table C-1-5: Playground vulnerability criteria

	Hazard	Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
Vulnerability rating	Vulnerability considerations	Flooding or inundation and associated storm damage may damage playgrounds. Permanent inundation is possible at Andersons Bay, which would be a major issue and result in complete loss of park function.		Emergent groundwater would mean playground should be removed. This is done relatively easily, however some facilities may have a higher cost to replace, e.g. soft fall	All assets are highly sensitive to damage. However, playgrounds have high adaptive capacity (multi dimensional play purposes and high frequency of renewal). Playgrounds can be redesigned to respond to changing conditions, and can incorporate resilient materials (e.g. less corrosion / rust susceptibility)	All assets are highly vulnerable	All assets are highly vulnerable
Extreme	Permanent complete loss of park function	n/a	MHWS inundation (Andersons Bay) not assessed	Playground GWL emergent or <0.3 mbgl	n/a	n/a	n/a
High	Acute: Severe damage likely Chronic: Reduction in park function	n/a	n/a	Playgrounds – all other sites Cemeteries GWL >2 mbgl	n/a	n/a	n/a
Moderate	Moderate damage may occur resulting in short term closure. No expected change in park functionality.				n/a	All sites	All sites
Low	Minimal damage managed through routine maintenance.	All sites	All sites		All sites	n/a	n/a

Very low	No damage or change in function	n/a	n/a	All other parkland	n/a	n/a	n/a

C2 MARAE, AND OTHER CULTURALLY SIGNIFICANT SITES

The approach to assessing risk to Marae, and other culturally significant sites is covered in the Mana Whenua Risk Assessment.

C3 ROADS

Risks to roads were be assessed using the methods and outputs identified in Table C-3-1.

Table C-3-1. Roads data availability, method, outputs and limitations

Risk	Supports	Key features	Vulnerability criteria data availability	Proposed method	Output	Limitations / uncertainties / assumptions
Physical risk to roads	Aim 1, Aim 2	Road criticality Associated infrastructure (e.g. footpaths, cycleways)	1. Road criticality 2. Road condition – not available. 3. Road material – not available. , see assumptions. 4. Road vulnerability information in relation to the hazards – need to confirm availability of information., see assumptions. 5. Flood depth 6. Flood velocity – not available.	Physical risk: Assess exposure to road length. Workshop with transport team at DCC to agree: Key feature classification Vulnerability rating.	Map: Risk to roads arising from hazards showing identified key features Table: Quantification of road length at risk Report section: Description of risk and impacts	Need to confirm availability of information for: 2. Condition, 3. Material, 4. Vulnerability Propose follow up workshop with roading team at DCC to gather any available material data or undertake qualitative generic vulnerability ratings.
Impacts arising from loss or damage to roads	Aim 1, Aim 2		2018 Census data: Mobility issues	Spatial data overlay upon hazard. Accompanied by a descriptive narrative in report.	Map: Spatial distribution of mobility Report section: Description of impacts including cascading risks	

SUMMARY OF WORKSHOP: ROADS AND ASSOCIATED INFRASTRUCTURE

KEY FEATURES

Key features were agreed through workshop with DCC staff:

- Electrical assets (street lights, signals).
- Stormwater infrastructure (Kerb, Catch pits, Lateral, culverts).
- Structures (retaining wall, sea wall, causeway).
- Bus routes.
- Cycle paths.
- Foot paths.
- Criticality - a layer has been developed also AF8 priority routes (not yet available).

Criticality scores used by the DCC roading team, provided May 2024
Table C-3-2 Summary of critical transport routes within South Dunedin

Criticality scale[1]	Description	Length of DCC roads within South Dunedin (km)
Criticality 1 (Vital)	A vital route or section of road whose failure would have a nationally significant economic or social impact, or is a nationally significant lifeline, ensuring access or continuity of supply of essential services during an unforeseen event.	SH1 No DCC roads in South Dunedin
Criticality 2 (Major)	A major route or section of road whose failure would have a significant economic or social impact to more than one region, or is a regionally significant lifeline, ensuring access or continuity of supply of essential services during an unforeseen event.	3
Criticality 3 (Significant)	An important route or section of road whose failure would have a significant economic or social impact to a region, or is a significant lifeline, ensuring access or continuity of supply of essential services during an unforeseen event.	17
Criticality 4 (local)	A local route or section of road whose failure would have a serious local economic or social impact, or is a locally important lifeline, ensuring access or continuity of supply of essential services during an unforeseen event.	64
Criticality 0		5,952*

1

*Includes 4km of null values that are assumed to be 0

ADAPTIVE CAPACITY

Roading infrastructure has interdependencies that may influence adaptation planning:

- Raising of roads as a measure to adapt to high groundwater is limited due to the potential that this may prevent overland flow paths and increase pluvial flood risk.
- The 3 Waters network as roading drainage provides stormwater management and connects to the wider stormwater network.
- Parks as these influence stormwater generation, where greater parkland coverage results in lower stormwater runoff generation.

ROADS AND ASSOCIATED INFRASTRUCTURE VULNERABILITY TO PLUVIAL FLOODING AND COASTAL INUNDATION

Much of the flooding within South Dunedin occurs within the local road network. Although flooding of roads prevents access, this provides important flood storage volume to minimise the flooding of private properties and buildings.

Pavements may be damaged through repeated / regular wetting causing faster deterioration rates driving increased roading maintenance needs.. Roads and associated infrastructure have low vulnerability to flooding in South Dunedin. The generally flat terrain means scour and erosion are uncommon.

Streetlight and signal poles may start to rust if exposed to salinity through coastal inundation.

ROADS AND ASSOCIATED INFRASTRUCTURE VULNERABILITY TO GROUNDWATER

High groundwater is already impacting road strength, resulting in maintenance issues. Damage to roads is dependent on vehicle loading, where high volume and heavy loading result in increased deterioration of the road. As median groundwater levels approach the roading sub-base at around 300-400 mm below ground level, increased maintenance is expected. If groundwater is at or near the ground surface, it is unlikely that roads will be able to be maintained.

ROADS AND ASSOCIATED INFRASTRUCTURE VULNERABILITY TO COASTAL EROSION AND LANDSLIDE

Sections of roading adjacent to the St Clair – St Kilda coastline may be exposed to coastal erosion. This may cause direct damage or complete loss of roads and associated infrastructure.

ROADS AND ASSOCIATED INFRASTRUCTURE VULNERABILITY TO LIQUEFACTION

Liquefaction can compromise roads and related infrastructure by causing settlement, cracking, and sinkholes, as well as by ejecting soil onto the surface. These processes may deform embankments and bridge abutments, reducing the stability of road surfaces and bridge foundations, and may also disrupt nearby underground services.

ROADS AND ASSOCIATED INFRASTRUCTURE VULNERABILITY RATING

The below vulnerability rating table was developed and agreed through workshop with the roading team at DCC.

Unless otherwise noted, all key features are to be assessed using the same vulnerability rating criteria apart from the following exceptions:

- Infer rating of SW assets from associated main.
- Seawalls to be assessed separately.

- Retaining walls are not currently included, DCC to send retaining wall locations (not assessed).

Table C-3-3: Roads and associated infrastructure vulnerability criteria

	Hazard	Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
Vulnerability rating	Vulnerability considerations	Roads and associated infrastructure have low vulnerability to flooding in South Dunedin. The generally flat terrain means the main mechanisms for damage; scour and erosion are uncommon. Streetlight and signal poles may be damaged by flooding or rust due to exposure to seawater.		Groundwater level applies to all roads and includes damage and loss of all utilities.	All assets are highly vulnerable	All assets are highly vulnerable	Risk Assessment team to discuss with liquefaction specialist.
Extreme	Sudden collapse/failure causing potential risk to life.	n/a	n/a		All roads are highly sensitive to damage	All roads are extremely sensitive to damage	
High	Damage sustained so that asset is not functional until repairs are made.	n/a	~~Streetlight and signal poles~~	GWL above 0.6 mbgl for heavily trafficked roads GWL above 0.4 mbgl for all other roads,	~~All roads are highly sensitive to damage~~	n/a	All roads are highly sensitive to damage
Moderate	Damage sustained that can be repaired without any loss of functionality.	n/a	Streetlight and signal poles	Default value for all other roads. This is based on the present road condition related to widespread high groundwater.	n/a	n/a	
Low	Minor damage sustained that can be repaired through regular maintenance.	All road assets	All roads	n/a	n/a	n/a	
Very low	No loss of service or repairs	n/a	n/a	Streetlight and signal poles	n/a	n/a	

C4 AREAS OF ECOLOGICAL SIGNIFICANCE

Risks to areas of ecological significance will be assessed using the methods and outputs identified in Table C-4-1

Table C-4-1. Areas of ecological significance data availability, method, outputs and limitations

Risk	Supports	Key features	Vulnerability criteria data availability	Proposed method	Output	Limitations / uncertainties / assumptions
Physical risk to areas of ecological significance	Aim 1, Aim 2	Important habitats, species or ecosystems	1. Location of ecological sites within South Dunedin - need to confirm availability of information. 2. Ecological assessment of South Dunedin - need to confirm availability of information.	Should data be available, this will be used to produce a physical risk assessment: Physical risk: Assess exposure to ecological areas. Vulnerability rating to be developed through workshop with environment team at DCC/ORC.	**Map:** Risk areas of ecological significance arising from hazards showing identified key features **Table:** Quantification of areas at risk **Report section:** Description of risk and impacts	Need to confirm availability of information regarding areas of ecological significance. Propose qualitative generic ratings through workshop with environment team at DCC/ORC.
Impacts arising from damage to areas of ecological assessment	Aim 2		High level assessment	Gather information from community engagement	**Report section:** Description of impacts including cascading risks	

SUMMARY OF ECOLOGY FOCUSSED DISCUSSION WITH DCC PARKS TEAM

South Dunedin has a lack of biodiversity, however there are pockets of ecological value in and around the area. The primary feature of ecological significance within South Dunedin is the coastal beaches. These are frequently visited by sea lions and marine birds and provide habitat for native reptiles. Common plant and bird species are likely to be present in the gardens of residential properties.

Within the local area are nature parks within the Caversham Area, this includes the Caversham Peripatus Reserve, Caversham Valley Bush Reserve, Sidney Park and Caversham Station Reserve. The Dunedin Town Belt, wider dune system, and Otago Peninsula are also relevant ecological areas to South Dunedin. South Dunedin provides the land-link to the Otago Peninsula which has several breeding grounds/ habitats for local/ regional/ nationally important species. Preventing possums entering the soon-to-be possum free Peninsula is top priority for Predator Free Dunedin (DCC coordinated conservation collective comprising 22 member organisations). While the vast urban and industrial areas of South Dunedin largely stop possum movement, a corridor of vegetation along the coast creates another pathway.

C5 RAIL INFRASTRUCTURE

Risks to rail will be assessed using the methods and outputs identified in Table C-5-1

Table C-5-1 Rail infrastructure data availability, method, outputs and limitations

Risk	Supports	Key features	Vulnerability criteria data availability	Proposed method	Output	Limitations / uncertainties / assumptions
Physical risk to rail infrastructure	Aim 1 in part (exposure only) Aim 2	Railway line Other (e.g. buildings, structures, equipment, land, yards to support the rail lines)	1. Rail locations 2. Rail vulnerability information in relation to the hazards	Physical exposure: Rail exposure to hazards The risk assessment will be informed by exposure only.	**Map:** Rail exposure	
Impacts arising from loss or damage to rail	Aim 2		High level assessment	High level description of impacts arising from loss of rail services.	**Report section:** Description of impacts including cascading risks	If risks to rail and associated services become too high, it is presumed that KiwiRail will develop their own adaptation management plans.

Rail exposure ratings are based on tables in Section, with the exception of Groundwater exposure. The following exposure thresholds have been used:

Extreme	Emergent groundwater (median)
High	Groundwater level higher than 0.6 mbgl
Moderate	
Low	Groundwater level lower than 0.6 mbgl
Very low	

C6 WATER SUPPLY INFRASTRUCTURE

Risks to water supply infrastructure will be assessed using the methods and outputs identified in Table C-6-1.

Table C-6-1 Water supply infrastructure data availability, method, outputs and limitations

Risk	Supports	Key features	Vulnerability criteria data availability	Proposed method	Output	Limitations / uncertainties / assumptions
Physical risk to water supply infrastructure	Aim 1, Aim 2	Feature classification to be based on DCC criticality rating (e.g. Above and below ground water supply infrastructure: Regionally significant, locally significant, Local)	1. Level of service - need to confirm availability of information, see assumptions. 2. Condition - need to confirm availability of information, see assumptions. 3. Material and age	Physical risk: Assess exposure Workshop with 3 waters team at DCC to agree: Key feature classification: Regionally significant, locally significant, local Vulnerability rating.	Map: Risk to water supply arising from hazards showing identified key features Table: Quantification of areas at risk Report section: Description of risk and impacts	Need to confirm availability of information: 1. – 2. Propose follow up workshop with three waters team at DCC to gather any available material data or undertake qualitative generic vulnerability ratings.
Impacts arising from damage to water supply infrastructure	Aim 2		High level assessment	Gather information from community engagement	Report section: Description of impacts including cascading risks	

SUMMARY OF WORKSHOP: WATER SUPPLY

KEY FEATURES

Key features were agreed through workshop with DCC staff:

- Criticality rating (from ISP).
- Somerville Street Water Pumping Station.
- Somerville Distribution mains (from treatment plant that feeds Somerville).

WATER SUPPLY INFRASTRUCTURE VULNERABILITY TO FLOODING

Pluvial and coastal flooding: LoS damage may occur if buried air valves are damaged and result in floodwater entering system due to negative pressure (this is a rare event and requires multiple issues to occur). Pump station: Flooding may interrupt site access, meaning if a problem were to occur it could not be fixed.

VULNERABILITY RATINGS WATER SUPPLY

Table C-6-2 Vulnerability ratings for all Water Supply Assets

Vulnerability		Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
	Vulnerability considerations	Network unlikely to be vulnerable to flooding.	Network unlikely to be vulnerable to flooding.	Network unlikely to be vulnerable to groundwater rise.	All assets are highly vulnerable	All assets are highly vulnerable	All assets are highly vulnerable Or Material Age (experience from the 2011 Christchurch Earthquake sequence found that ageing pipes of asbestos cement (AC) or Cast Iron (CI) were the most susceptible to damage).
Extreme	Sudden collapse/failure causing potential risk to life.				Criticality 5	Criticality 5	

Vulnerability		Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
	For example house/culvert collapse putting people's lives at risk.						
High	High damage likely and loss of service with lengthy time to restore to operation (months).				Criticality 3-4	Criticality 3-4	Highly sensitive to damage unless foundations are specifically designed
Moderate	Moderate damage likely or possible although only short to medium time to restore to operation (less than one month).				Criticality 1-2	Criticality 1-2	
Low	Minor damage sustained although it does not impact the operation of the asset.						
Very low	No damage or loss of service	All parts of network	All parts of network	All parts of network			

C7 STORMWATER AND WASTEWATER INFRASTRUCTURE

Risks to wastewater will be assessed using the methods and outputs identified in Table C-7-1Table C-7-1.

Table C-7-1. Wastewater infrastructure data availability, method, outputs and limitations

Risk	Supports	Key features	Vulnerability criteria data availability	Proposed method	Output	Limitations / uncertainties / assumptions
Physical risk to wastewater infrastructure	Aim 1, Aim 2	Above and below ground water supply infrastructure: Regionally significant, locally significant, Local	1. Level of service -, see assumptions. 2. Condition - see assumptions. 3. Material and age.	Physical risk: Assess exposure Workshop with 3 waters team at DCC to agree: Key feature classification: Regionally significant, locally significant, local Vulnerability rating	**Map:** Risk to waste water arising from hazards showing identified key features **Table:** Quantification of areas at risk **Report section:** Description of risk and impacts	Need to confirm availability of information: 1. – 2. Propose follow up workshop with three waters team at DCC to gather any available material data or undertake qualitative generic vulnerability ratings.
Impacts arising from damage to wastewater infrastructure	Aim 2		High level assessment	Gather information from community engagement	**Report section:** Description of impacts including cascading risks	

Risks to stormwater will be assessed using the methods and outputs identified in Table C-7-2.

Table C-7-2. Stormwater infrastructure data availability, method, outputs and limitations

Risk	Supports	Key features	Vulnerability criteria data availability	Proposed method	Output	Limitations / uncertainties / assumptions
Physical risk to stormwater infrastructure	Aim 1, Aim 2	Above and below ground water supply infrastructure: Regionally significant, locally significant, Local	1. Level of service - see assumptions. 2. Condition - see assumptions. 3. Material and age	Physical risk: Assess exposure Workshop with 3 waters team at DCC to agree: Key feature classification: Regionally significant, locally significant, local Vulnerability rating	**Map:** Risk to stormwater arising from hazards showing identified key features **Table:** Quantification of areas at risk **Report section:** Description of risk and impacts	Need to confirm availability of information: 1. – 2 Propose follow up workshop with three waters team at DCC to gather any available material data or undertake qualitative generic vulnerability ratings.
Impacts arising from damage to stormwater infrastructure	Aim 2		High level assessment	Gather information from community engagement	**Report section:** Description of impacts including cascading risks	

SUMMARY OF WORKSHOP: STORMWATER AND WASTEWATER

KEY FEATURES

Key features were agreed through workshop with DCC staff:

- Criticality rating (from ISP).
- Musselburgh WW pump station.
- Tahuna WWTP.
- Tainui SW pump station (on same site as WW pump).
- Portobello sw pump station.
- Portobello Road Screens.
- All flap gates.
- WW Pump station - Marne St Pump station (overflow pump station which pumps to Musselburgh).

8.1.1.1 VULNERABILITY RATINGS WW & SW

Vulnerability ratings WW & SW Pipes & Manholes/nodes (all criticality ratings).

Liquefaction can impact water infrastructure by deforming underground systems, such as water supply, wastewater, and stormwater networks. Ground settlement or stretching may damage or disconnect pipes and chambers and subsequent inflow of sediment can cause blockages. Buoyancy can cause uplift of buried structures, and disrupt drainage systems, while sediment discharge can reduce water quality and affect aquatic habitats.

Table C-7-3. WW & SW Pipes & Manholes/nodes (all criticality ratings)

Vulnerability		Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
	Failure mode	LoS failure mode & damage	LoS failure mode	LoS failure mode NB: MH have same rating as adjacent pipe	Damage failure mode	Damage failure mode	Damage failure mode
	Vulnerability considerations	Pipe surcharging results in widespread reduction in LoS which results in environmental contamination and associated breaches of consent conditions.	Pipe surcharging results in widespread reduction in LoS which results in environmental contamination	Material and/or age are the main factors determining pipe vulnerability. Cracks and leaky joints mean groundwater inflows will enter system and reduce pipe capacity. The extent of this reduction in pipe	All assets are highly vulnerable	All assets are highly vulnerable	All assets are highly vulnerable Or Material Age (experience from the 2011 Christchurch Earthquake sequence found that ageing pipes of asbestos cement (AC) or Cast Iron (CI) were the most susceptible to damage).

Vulnerability		Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
		Increase in the severity of scour damage to surrounding areas in steep zones.		capacity is currently under investigation. Pipe infiltration also draws down groundwater level.			
Extreme	Damage failure mode: WW Physical damage to level 5 Criticality asset, Level of service failure mode: Sustained level of service reduction resulting in a failure to meet minimum standards (e.g. capacity reduction to the limit of functionality)			WW - All non-plastic based pipes that have past their useful life	WW -Criticality 5	WW -Criticality 5	WW All non-plastic based pipes that have past their useful life
High	WW Physical damage to level 3 & 4 Criticality asset, Level of service failure mode: Event based level of service reduction resulting in a failure to meet minimum standards (e.g. consent condition breach)	WW-All wastewater pipes: Level of service	WW - All pipes: Level of service	SW, WW - All plastic based pipes that have past their useful life	WW - Criticality 3-4 SW – Criticality 3-5	WW – Criticality 3-4 SW – Criticality 3-5	WW All plastic based pipes that have past their useful life SW All pipes past their useful life
Moderate	Damage sustained that can be repaired within short timeframes (days / weeks).	SW-Damage to pipe & nodes: Steep zone Sandringham St and Forbury Rd	n/a	SW, WW – Pipes within their useful life that were installed before 1960 Non-plastic based pipes that are within the last 1/3 of useful life	WW – Criticality 1-2 SW - Criticality 1-2	WW - Criticality 1-2 SW - Criticality 1-2	Pipes within their useful life that were installed before 1960 Non-plastic based pipes that are within the last 1/3 of useful life
Low	Level of service failure mode: Minor damage sustained that can be repaired through regular maintenance.	n/a SW All pipes: Level of service	SW - All pipes	SW, WW - Non-plastic based pipes within first 2/3 of useful life	n/a	n/a	Non-plastic based pipes within first 2/3 of useful life
Very low	No loss of service or repairs	Damage to pipe & nodes: all other areas	n/a	SW, WW - Plastic based pipes within their useful life that were installed after 1960 Non-plastic based pipes within first 1/3 of useful life	n/a	n/a	Plastic based pipes within their useful life that were installed after 1960 Non-plastic based pipes within first 1/3 of useful life

WW & SW Pump stations (Musselburgh WW, Portobello SW, Tainui SW)

Table C-7-4. WW & SW Pump stations

Vulnerability		Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
	Vulnerability considerations	Flooding of SW pump stations may damage the switchboard, resulting in pump station failure. Flooding of Musselburgh Pump Station may flood the dry well, resulting in failure of the pump station. This would mean flows could not be pumped to sea, resulting in very high consequence.		The main issue relates to groundwater infiltration into the drywell, however as this is a slow process leaks will be detected and fixed with no risk to the function.	All assets are highly vulnerable	All assets are highly vulnerable	Extremely sensitive to damage unless foundations are specifically designed
Failure mode		Damage failure mode	Damage failure mode	LoS failure mode	Damage failure mode	Damage failure mode	Damage failure mode

Vulnerability		Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
Extreme	Sudden collapse/failure causing potential risk to life. e.g. wastewater pump station failure causing extensive flooding and contamination.	Musselburgh Pump Station: depth >0 (including criticality +1)	Musselburgh Pump Station: depth >0 (including criticality +1)				
High	High damage likely and loss of service with lengthy time to restore to operation (months).	SW pump stations: depth >0 (including criticality +1)	SW pump stations: depth >0 (including criticality +1)		All assets	All assets	All assets
Moderate	Moderate damage likely or possible although only short to medium time to restore to operation (less than one month).				n/a	n/a	n/a
Low	Minor damage sustained although it does not impact the operation of the asset.	All other pump stations	All other pump stations		n/a	n/a	n/a
Very low	No damage or loss of service			All pump stations	n/a	n/a	n/a

Table C-7-5.Tahuna WWTP

Vulnerability		Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
	Vulnerability considerations	Flood water may cause damage and prevent operation. Flooding is likely to trigger the emergency bypass, which would reduce consequence of failure.	Salinity and debris may cause damage or blockages. High salinity loading may wash out treatment plant.	Loss of level of service and increasing salinity entering WWTP resulting from damage to the network.	All assets are highly vulnerable	All assets are highly vulnerable	Extremely sensitive to damage unless foundations are specifically designed
Extreme	Sudden collapse/failure causing potential risk to life. For example house/culvert collapse putting people's lives at risk.						~~Extremely sensitive to damage unless foundations are specifically designed (tbc with SDF Liquefaction specialist)~~
High	High damage likely and loss of service with lengthy time to restore to operation (months).	Flood depth > 0 (including criticality +1)	Flood depth > 0 (including criticality +1)		All assets	All assets	All assets
Moderate	Moderate damage likely or possible although only short to medium time to restore to operation (less than one month). Repair works would reinstate to original design only (i.e. no betterment) at the existing location.			Moderate sensitivity to increasing salinity in inflows. (including criticality +1)	n/a	n/a	n/a
Low	Minor damage sustained although it does not impact the operation of the asset.				n/a	n/a	n/a
Very low	No damage or loss of service				n/a	n/a	n/a

Table C-7-6. Flap gates and outlet

Vulnerability	Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
Vulnerability considerations	Not specifically assessed	Not specifically assessed	Not specifically assessed	Flap gates and outlets are located at the coastal edge within the seawall. If the seawall is performing as designed there is unlikely to be any change in vulnerability of the flap gates and outlets. Same vulnerability as seawall (low / very low on harbourside).	Not specifically assessed	Not specifically assessed
Extreme	n/a	n/a	n/a		n/a	n/a
High	n/a	n/a	n/a		n/a	n/a
Moderate	n/a	n/a	n/a		n/a	n/a
Low	n/a	n/a	n/a		n/a	n/a
Very low	n/a	n/a	n/a	All harbourside outlets	n/a	n/a

C8 CONTAMINATED LAND

Risks to contaminated land will be assessed using the methods and outputs identified in Table C-8-1.

Table C-8-1. Solid waste and contaminated sites data availability, method, outputs and limitations

Risk	Supports	Key features	Vulnerability criteria data availability	Proposed method	Output	Limitations / uncertainties / assumptions
Physical risk to contaminated land	Aim 1, Aim 2	Closed landfills Contaminated sites	1. HAIL register 2. Cap thickness - see assumptions. 3. Cap material - see assumptions. 4. Waste material type - see assumptions. 5. Closure dates - see assumptions. 6. Size of landfill - see assumptions. 7. Volume of landfill - see assumptions.	**Physical risk:** Assess exposure to site. Vulnerability rating to be developed through workshop with property / planning team at DCC.	**Map:** Risk to solid waste and contaminated sites arising from hazards showing identified key features **Table:** Quantification of areas at risk **Report section:** Description of risk and impacts	Need to confirm availability of information for: 2. – 7. Propose follow up workshop with contaminated land team at DCC to gather any available material data or undertake qualitative generic vulnerability ratings.
Impacts arising from damage to contaminated sites	Aim 2		High level assessment	Gather information from community engagement	**Report section:** Description of impacts including cascading risks	

SUMMARY OF WORKSHOP: SOLID WASTE AND CONTAMINATED SITES

DATA AVAILABILITY

Potentially contaminated sites are those identified in the Hail register. This register has limitations with data relating to both completeness, (i.e. not all sites have been identified) and some sites are unable to be identified (due to other contaminates are not identified e.g. lead paint on buildings). Data records show which sites have been investigated (some have been tested to not be contaminated)

KEY FEATURES

Key features were agreed through workshop with DCC staff:

- Kettle Park.
- Gas Works.
- Industrial area.
- Residential area.

CONTAMINATED SITES VULNERABILITY TO PLUVIAL FLOODING AND COASTAL INUNDATION

Saturation of contaminated sites may result in discharge of contaminated water. However, most events will be short infrequent events that are unlikely to drive contamination transport. If contaminant transport were to occur, it is expected that floodwater will also be contaminated by other contaminants of potentially larger magnitude e.g. wastewater overflows.

Transport of contaminants may also occur via erosion. The potential for eroding is considered low due to an assumed low velocity of flood water.

CONTAMINATED SITES VULNERABILITY TO GROUNDWATER

Contaminated sites are likely to be increasingly exposed to higher groundwater levels. Where near surface contamination is exposed to emergent groundwater there is potential for contamination to be transported, resulting in spread of contamination.

Contaminated sites within industrial areas tend to have higher contamination loading and are extremely vulnerable to emergent groundwater due to the potential for transport and exposure of contaminants. These sites have the potential for exposing workers and public. Widespread hardstand in these areas mean there is a greater tolerance for high (but not emergent) groundwater due to the presence of barriers between contamination and the surface.

The nature of contamination in residential areas is less severe, however activities carried out in residential areas tend to have a higher likelihood of interacting with the ground (vegetable gardens, sportsground (mud),… Consequences relating to residential contamination potentially may impact the health of residents e.g. vegetable gardens.

At a catchment scale, changing groundwater levels may result in increased infiltration of contaminants into SW/WW network.

CONTAMINATED SITES VULNERABILITY TO COASTAL EROSION

Coastal erosion is likely to increase over time and will exacerbate existing erosion issues at the Kettle Park Landfill. Erosion of these sites may result in contaminated material entering the receiving environment and may cause issues with land stability and integrity.

Contaminated sites are located adjacent to Andersons Bay Road however the presence of the seawall is expected to provide protection from coastal erosion.

CONTAMINATED SITES VULNERABILITY TO LANDSLIDE

Contaminated sites are vulnerable to landslide as this would cause damage and require clean up of the site. The damage is likely to be relatively limited, however the nature of the site contaminant would determine the consequences of the damage.

CONTAMINATED SITES VULNERABILITY TO LIQUEFACTION

IN AREAS WITH PRE-EXISTING CONTAMINATION, LIQUEFACTION CAN MOBILISE AND SPREAD HAZARDOUS SUBSTANCES BY EJECTING CONTAMINATED SOIL OVER A WIDER AREA. THIS INCREASES ENVIRONMENTAL AND PUBLIC HEALTH RISKS AND COMPLICATES SUBSEQUENT REMEDIATION EFFORTS. CONTAMINATED SITES VULNERABILITY RATING

The below vulnerability rating table was developed and agreed through workshop with the roading team at DCC.

Unless otherwise noted, all key features are to be assessed using the same vulnerability rating criteria.

Table C-8-2: Contaminated sites vulnerability criteria

Vulnerability		Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
	Vulnerability considerations	Contaminated sites have low vulnerability to flooding in South Dunedin. Mobilisation of contaminants is likely to be lower or a similar level of contamination to contamination from other sources. The generally flat terrain means scour and erosion are uncommon.		Potential for transport and exposure of contaminants under emergent groundwater. Industrial contaminated sites have higher contaminant loading, but widespread paving provides a barrier to below surface groundwater.	All assets are highly vulnerable	All assets are highly vulnerable	All assets are highly vulnerable
Extreme	Permanent damage and/or widespread mobilisation of severe contaminants through new pathways.	n/a	n/a			n/a	n/a
High	Remediable damage and/or widespread permanent mobilisation of less severe contaminants through new pathways.	n/a	n/a	Industrial sites: GWL emergent Residential sites: GWL 0-0.3 mbgl	All sites	All sites	
Moderate	Temporary mobilisation of moderate contaminants / mobilisation through existing pathways	n/a	n/a	Residential sites: GWL 0.3-1 mbgl	n/a	n/a	All sites
Low	Temporary mobilisation of contaminants through existing pathways	All sites	All sites	n/a		n/a	n/a
Very low	No damage	n/a	n/a	Industrial sites GWL < 0mbgl Residential sites: GWL < 1mbgl	n/a	n/a	n/a

C9 TELECOMMUNICATION INFRASTRUCTURE

Risks to telecommunication infrastructure will be assessed using the methods and outputs identified in Table C-9-1.

Table C-9-1. Telecommunication infrastructure data availability, method, outputs and limitations

Risk	Supports	Key features	Vulnerability criteria data availability	Proposed method	Output	Limitations / uncertainties / assumptions
Physical risk to Tele-communication infrastructure	Aim 2	Critical assets	Geospatial telecommunication data to be provided by Chorus – see limitations	Physical risk: Assess exposure to site. Vulnerability rating to be developed through workshop with Chorus.	**Map:** Critical assets **Report section:** Description of risk and impacts	Location of exchange site provided by Chorus. Lines information not shared.

The telecommunications network within south Dunedin comprises the lines and South Dunedin Exchange site (Melbourne St).

Key features:

- Lines.
- South Dunedin Exchange (1 site within South Dunedin, corner Melbourne St & King Edward St).

RISK TO THE TELECOMMUNICATIONS NETWORK

As a network, telecommunications is relatively resilient due to redundancy that is built into the system. Telecommunications have high adaptive capacity due to regular renewal and ease of reinstatement. Risk to the provision of telecommunications is primarily dependent on the availability of power and roads.

Risk to specific assets has not been assessed due to the following points:

- Site specific risk to the South Dunedin Exchange is assessed alongside other buildings and identified as a key feature in the risk to buildings assessment.
- Location of lines are not available, but follow roads.

VULNERABILITY OF THE TELECOMMUNICATIONS NETWORK

Lines are not sensitive to flooding as they are buried and not exposed. Floodwater ingress could be a major issue for exchange sites. However, sites are easy to retrofit (status of South Dunedin site is unconfirmed but Chorus is in the process of improving site resilience across the network). The South Dunedin exchange is an Access exchange. That means if the site was flooded (if our remedial measures proved insufficient) it would result in a loss of service to South Dunedin customers: the Access function in exchanges is not duplicated elsewhere and so is vulnerable to loss of the site.

Groundwater ingress is an issue for copper lines. The copper network is being phased out in areas where fibre is available.

The network is vulnerable to destructive hazards (coastal erosion, landslide, and liquefaction), but no more so than other services. The primary vulnerability relates to the dependency on road access and power supply. Telecommunications equipment requires power to operate. For most modern telecommunications services, power is needed at the exchange and the end-users' premises, whilst copper connections require power to the exchange, to cabinets in the street, and to powered devices in the end-users' premises. . Some copper connections remain in South Dunedin. This may decrease as the copper network is phased out in areas where fibre is available. .

The network is easy to rebuild, giving it a high adaptive capacity. Chorus seek to build redundancy into their network, The Dunedin area operates as a network where damage or loss of a single exchange would be compensated for through the wider network. In addition, two containerised exchange sites ('Meow') have been set up which could be commissioned if damage occurred to the South Dunedin Exchange.

There is a potential for retreat creating isolated services, or reduced density of services resulting in relatively high cost within an area. This may result in infrastructure that is too expensive to service.

C10 ENERGY

Risks to telecommunication infrastructure will be assessed using the methods and outputs identified in Table C-10-1Table C-10-1.

Table C-10-1. Electricity transmission and distribution data availability, method, outputs and limitations

Risk	Supports	Key features	Vulnerability criteria data availability	Proposed method	Output	Limitations / uncertainties / assumptions
Physical risk to energy	Aim 2	Critical assets	Geospatial transmission and distribution data to be provided by Transpower and Aurora – see limitations	Physical risk: Assess exposure to site. Vulnerability rating to be developed through workshop with Aurora and Transpower.	Map: Critical assets Report section: Description of risk and impacts	Locations of critical assets provided by Aurora and Transpower

KEY FEATURES:

- Transpower GXP: South Dunedin.
- Transpower: Transmission lines.
- Aurora Substations: Andersons Bay, Carisbrook, St Kilda.
- Aurora 33kV Buried.
- Aurora Overhead lines.

CONSEQUENCE / CRITICALITY

Transpower considers South Dunedin substation to be nationally significant based on to it being part of the South Island 'black start' plan, regionally significant based on the number of power connections (~21,000 ICPs - Installation Control Points)

No additional comments have been provided by Aurora or Gas facilities.

ADAPTIVE CAPACITY

Considerations that may be relevant to adaptation planning:

- Transpower applied to the Commerce Commission for resilience funding for 2025-2030, including some potential funding for South Dunedin. The Commerce Commission approved some funding to mitigate substation flooding in their final determination, with options for Transpower to request additional funding later.
- Transpower published a Transpower Adaptation Plan in September 2024, which sets out action areas and high-level actions to both deliver climate resilience and adaptive capacity, and further develop their organisational adaptation planning.
- Transpower is planning to apply dynamic adaptive pathways planning for transmission infrastructure in South Dunedin. This will consider replacement, upgrade, or resilience work planned or forecast, and should provide sufficient adaptive capacity. Transpower would look to integrate it's planning with Aurora and South Dunedin Future adaptation planning later in that process.

VULNERABILITY

Table C-10-2: Overhead transmission lines (Transpower)

Vulnerability	Pluvial flooding	Coastal inundation	Groundwater level (GWL)	Coastal erosion	Landslide	Liquefaction
Vulnerability considerations	Poles & towers in South Dunedin have very low sensitivity to pluvial flooding.	Poles & towers may be sensitive to coastal inundation and associated potential wave action and salinity.	Poles & towers may be sensitive to waterlogged soils as a result of rising groundwater, which can cause instability. Unlikely to be vulnerable from a service perspective, as this is a chronic risk with impacts that can be managed over time	Poles may be damaged if impacted severely and directly. However, lines are not exposed and therefore not a credible risk for Transmission assets in South Dunedin	Landslide may damage or cause failure of tower or pole. Qualitatively indicating slightly higher vulnerability for poles due to smaller foundation footprint.	Liquefaction may cause pole or tower instability. The transmission network has performed well during past seismic events. Even if damage does occur, this may not result in interruption to service, and may only require repairs. Qualitatively indicating slightly higher vulnerability for poles due to smaller foundation footprint.
Extreme	n/a	n/a	n/a	n/a	Poles sensitive to damage if impacted severely and directly (or n/a)	n/a
High	n/a	n/a	n/a	n/a	Towers are sensitive to damage if impacted severely and directly (or n/a)	n/a
Moderate	n/a	All poles and towers	n/a	n/a	n/a	Poles
Low	n/a	n/a	GWL >= 0. mbgl (groundwater level is emergent), and the poles/towers foundations are sufficient to withstand permanently high groundwater.		n/a	Towers
Very low	All poles and towers	n/a	All other poles and towers (when groundwater is not emergent).	n/a	n/a	n/a

Table C-10-3: Overhead distribution lines (Aurora) - towers / poles vulnerability criteria

Vulnerability	Pluvial flooding	Coastal inundation	Groundwater level (GWL)	Coastal erosion	Landslide	Liquefaction
Vulnerability considerations	Poles & towers may be sensitive to waterlogged soils as a result of flooding, which can cause failure.	Poles & towers may be sensitive to waterlogged soils as a result of flooding, which can cause failure.	Poles & towers may be sensitive to waterlogged soils as a result of rising groundwater, which can cause instability. Unlikely to be vulnerable from a service perspective, as this is a chronic risk with impacts that can be managed over time	Poles may be damaged if impacted severely and directly.	Landslide may damage or cause failure of tower or pole. Qualitatively indicating slightly higher vulnerability for poles due to smaller foundation footprint.	Liquefaction may cause pole or tower instability. The transmission network has performed well during past seismic events. Even if damage does occur, this may not result in interruption to service, and may only require repairs. Qualitatively indicating slightly higher vulnerability for poles due to smaller foundation footprint.
Extreme	n/a	n/a	n/a	Poles sensitive to damage if impacted severely and directly (or n/a)	Poles sensitive to damage if impacted severely and directly (or n/a)	n/a
High	n/a	n/a	GWL > 0.3 mbgl (groundwater level is higher than 300 mm below ground level), and the poles/towers foundations are not sufficient.	n/a	Towers are sensitive to damage if impacted severely and directly (or n/a)	n/a
Moderate	All poles and towers	All poles and towers	n/a	n/a	n/a	Poles
Low	n/a	n/a	All other poles and towers	n/a	n/a	Towers
Very low	n/a	n/a	n/a	n/a	n/a	n/a

Table C10-4: Underground cables (Aurora)

Vulnerability	Pluvial flooding	Coastal inundation	Groundwater level (GWL)	Coastal erosion	Landslide	Liquefaction
Vulnerability considerations	Cables are not affected by surface flooding unless located in steeply sloping locations where erosion may occur.	Cables are not affected by surface flooding but terminations in Substations may be susceptible.	Buried cables are designed to resist moisture - vulnerability low	Coastal erosion may expose and damage buried cables	Landslide may damage or cause failure of buried cables.	Liquefaction may cause damage to buried cables
Extreme	n/a	n/a	n/a	n/a	n/a	n/a
High	n/a	n/a	n/a	All cables	All cables	All cables
Moderate	n/a	n/a	n/a	n/a	n/a	n/a
Low	n/a	n/a	n/a	~~All cables~~	~~All cables~~	~~All cables~~
Very low	All cables	All cables	All cables	n/a	n/a	n/a

Table C10-5: Transmission (Transpower) substation

Vulnerability	Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
Vulnerability considerations	Flooding can potentially damage electrical equipment located on the ground surface such as control and comms equipment and cable terminations, leading to power outages. Power transformers are relatively robust to low-level flooding	Flooding can potentially damage electrical equipment located on the ground surface such as control and comms equipment and cable terminations, leading to power outages. Power transformers are relatively robust to low-level flooding	Unlikely to be vulnerable from a service perspective, as this is a chronic risk with impacts that can be managed over time. The substation is on reclaimed land, and we already see some subsidence at this site, which does not interrupt service.	If exposed, coastal erosion can cause extensive damage to assets on the exposed parts of sites. However, this is not a material risk for the South Dunedin substation due to site layout. Qualitatively less vulnerable as low % of assets on site may be impacted at once.	If exposed, landslides can cause extensive damage to assets on the exposed parts of sites. However, this is not a credible risk for the transmission network in South Dunedin.	The transmission network has performed well during past seismic events. Even if damage does occur, this may not result in interruption to service, and may only require repairs.
Extreme	n/a	n/a	n/a	n/a	n/a	n/a
High	If the site is exposed at flood depth >0.2m, this could start to affect some, but not all substation assets.	If the site is exposed at flood depth >0.2m this could start to affect some, but not all substation assets.	n/a	n/a	n/a	n/a
Moderate	n/a	n/a	n/a	n/a	n/a	n/a
Low	All other sites if exposed to flood depth <0.2 m.	All other sites if exposed to flood depth <0.2 m.	If ground water is near the surface, some assets could be affected, to differing degrees over time. Most likely to be managed proactively, limiting impacts.	Vulnerability of site is low because while some assets could be affected, assets are spread out over a larger site and most assets are located outside erosion extent. Individual assets exposed may have higher vulnerability than the site-level vulnerability. Or n/a if no exposure.	n/a	Liquefaction may cause damage to some assets at a site. This may be to different degrees and may not result in interruptions to service.
Very low	Based on a site-specific review of exposure extent and intensity at South Dunedin substation, sensitive transmission assets are located in minimally affected areas of the site, resulting in a very low service vulnerability for the scenarios assessed.	n/a	n/a	n/a	n/a	n/a

Table C10-5: Distribution (Aurora) substations

Vulnerability	Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
Vulnerability considerations	Flooding can potentially damage electrical equipment located on the ground surface such as control and comms equipment and cable terminations, leading to power outages. Power transformers are relatively robust to low-level flooding	Flooding can potentially damage electrical equipment located on the ground surface such as control and comms equipment and cable terminations, leading to power outages. Power transformers are relatively robust to low-level flooding	Unlikely to be vulnerable from a service perspective, as this is a chronic risk with impacts that can be managed over time. The substation is on reclaimed land, and we already see some subsidence at this site, which does not interrupt service.	If exposed, coastal erosion can cause extensive damage to assets on the exposed parts of sites. However, this is not a material risk for the South Dunedin substation due to site layout. Qualitatively less vulnerable as low % of assets on site may be impacted at once.	If exposed, landslides can cause extensive damage to assets on the exposed parts of sites. However, this is not a credible risk for the transmission network in South Dunedin.	The transmission network has performed well during past seismic events. Even if damage does occur, this may not result in interruption to service, and may only require repairs.
Extreme	n/a	n/a	n/a	n/a	n/a	n/a
High	Aurora zone substations 33/6.6 kV if the site is exposed at flood depth >0.2m. This could start to affect some, but not all substation assets. Types of assets more likely to be negatively affected include local power supply for the substation itself and secondary assets that are used to control the substation and lines. Potential for minor damage to other assets like switchgear and buildings. Primary assets like transformers not likely to be affected. This could interrupt service, however restoration times could be expected to be lower as only some assets affected.	Aurora zone substations 33/6.6 kV if the site is exposed at flood depth >0.2m. As per Pluvial flooding.	n/a	Aurora zone substations 33/6.6 kV.	Aurora zone substations 33/6.6 kV.	n/a
Moderate	Aurora zone substations 6.6/0.4 kV if the site is exposed at flood depth >0.2m	Aurora zone substations 6.6/0.4 kV if the site is exposed at flood depth >0.2m	n/a	Aurora zone substations 6.6/0.4 kV (small localised outages if exposed)	Aurora zone substations 6.6/0.4 kV (small localised outages if exposed)	All Aurora zone substations. Asset foundation movement may cause outages

Vulnerability	Pluvial flooding	Coastal inundation	Groundwater	Coastal erosion	Landslide	Liquefaction
Low	All other sites if exposed to flood depth <0.2 m.	All other sites if exposed to flood depth <0.2 m.	If ground water is near the surface, some assets could be affected, to differing degrees over time. Most likely to be managed proactively, limiting impacts.	n/a	n/a	n/a
Very low	n/a	n/a	n/a	n/a	n/a	n/a

APPENDIX D: MANA WHENUA RISK ASSESSMENT SUMMARY (DRAFT)

The following information has been provided by Aukaha to Kia Rōpine (February, 2025). Final reporting will be available in early-mid 2025:

A mana whenua risk assessment has been undertaken for the South Dunedin Future programme, which has identified and rated risks through a Kāi Tahu lens. Based on an analysis of cultural values, it takes a broad approach to risk. As well as risks to specific places and features important for the cultural associations to mana whenua, it considers risks to Kāi Tahu perspectives and values relating to wider environmental, social and economic factors in South Dunedin. This mahi was facilitated by Aukaha with guidance and validation from a panel of Kāi Tahu mana whenua representatives.

The risk assessment was conducted on a 'keep doing what we are doing' scenario, where no additional interventions are made to address the climate and hazard issues facing South Dunedin. The methodology has been aligned as far as possible with the wider Workstream 3 risk assessment, including an approach based on identifying risk elements, then assessing the level of vulnerability and exposure to those risks. Aukaka will be providing further detail regarding their methodology in a separate report. ical approach will follow in a separate and more detailed report on the mana whenua risk assessment.

MANA WHENUA VALUES

The starting point for identifying mana whenua risk was to examine mana whenua values relating to South Dunedin. A series of wānaka involving the mana whenua panel was used to formulate a cultural values framework for South Dunedin Future. This framework was built on the foundations laid by Te Taki Haruru, the Māori Strategic Framework developed to operationalise the Dunedin City Council Treaty of Waitangi partnership with mana whenua.

The key principles and key values of Te Taki Haruru are set out in Table D1, along with an articulation of these in the South Dunedin context.

Several related mana whenua values and cultural practices were also identified for the South Dunedin Future programme, associated with the four key Te Taki Haruru principles/values. These related values and practices also helped with the development of mana whenua risk factors. More detail on these will be provided in the separate mana whenua risk assessment report to follow.

Table D1: Te Taki Haruru Values in South Dunedin

Key Principle	Key Value	South Dunedin Context
Autūroa	Mana (Rakatirataka, authority, responsibility)	Mana whenua are decision-makers in relation to te taiao, including how wai is managed, in adaptation responses to climate change and in management approaches to Three Waters. Mana whenua are leaders able to influence decisions affecting the social and economic wellbeing of South Dunedin, with a focus on building empowered, connected and resilient communities. Use of Kāi Tahu knowledge and reflections of Kāi Tahu identity are led and approved by Mana Whenua according to tikaka.
Auora	Mauri (Life force, vital essence)	The restoration and enhancement of the mauri of te taiao is an integral part in the South Dunedin programme. The restoration and regeneration of South Dunedin is guided by Kāi Tahu kaitiakitaka. Socio-economic and cultural well-being are at the heart of a just transition for the South Dunedin community. The hauora of the people and communities of South Dunedin are enhanced.
Autakata	Whakapapa (Genealogy, history, layers, connections)	Kāi Tahu traditions and connections, including to wai, whenua and moana, are recognised in the South Dunedin programme. Contemporary mana whenua relationships guide the journey to a just and equitable transition Mana whenua names and places are used and celebrated, along with Kāi Tahu design elements, to enhance sense of place and identity. Kāi Tahu mātauraka and tikaka inform planning and decision-making approaches.
Autaketake	Tapu and Noa (Safety, restoration of balance, restriction)	Human activities, including those relating to stormwater and wastewater, are managed to protect te taiao. Community safety and well-being are protected through responsible regulatory measures and other processes. Mana whenua will identify and lead the appropriate tikaka regarding tapu and noa.

MANA WHENUA RISK FACTORS & RATINGS

The South Dunedin Future Cultural Values Framework was used to identify mana whenua risk factors, set out in Table D3 below. Some of the risk factors are of a quantitative nature and draw on Workstream 3 data relating to the impact of modelled natural hazards on physical assets and socio-economic factors. Other risks are of a qualitative nature, including those relating to the Kāi Tahu mana whenua lived experience – such as perceptions of the Treaty partnership experience, ability to exercise rakatirataka or impacts on whakapapa associations to the South Dunedin area.

A risk assessment was undertaken for each risk factor set out in Table D3 below. The outcome of this exercise is set out in Figure D1 below, showing both vulnerability and exposure ratings for each risk factor. These risk ratings were aggregated up to the level of the four key Te Taki Haruru principles / values to give an overarching picture of risk. More detail on the methodology underpinning this will follow in the separate mana whenua risk report.

In describing the level of risk, Aukaha developed a vulnerability rating scale for each Te Taki Haruru principle. This aligns with the vulnerability ratings used across the wider Workstream 3 risk assessment, allowing the risks to mana whenua values to be meaningfully viewed alongside the other risks. The vulnerability ratings are set out in Table D2 below. The descriptors for these risk ratings also include representations in te reo Māori which, rather than necessarily being a direct translation, articulate the level of risk using te ao Māori concepts.

Risk exposure ratings were evaluated using both the geospatial data provided by as part of the wider Workstream 3 risk assessment; allowing distribution and likelihood of hazards to be inferred, and qualitative inputs from the mana whenua panel which captured their perceptions of the risk to values that are not tied to physical features or assets.

Table D2. Vulnerability Ratings for Te Taki Haruru Principles & Values

Autūroa - Mana		
Extreme	Rakatirataka lost, community disempowered	*He pokorehu, he whare puehu*
High	Rakatirataka compromised, community fragmented	*He ahi teretere, he whare tīwekaweka*
Moderate	Rakatirataka understood, community cohesion observed	*He ahi tāwhiri, he whare pūmahana*
Low	Rakatirataka asserted, community strengthened	*He ahi muramura, he whare ruruhau*
Very Low	Rakatirataka fully realised, community empowered and resilient	*He ahi kā roa, he whare taurikura, he āhuru mōwai*
Auora - Mauri		
Extreme	Mauri is depleted	*He mauri e mate ana*
High	Mauri is damaged	*He mauri e pakoki ana*
Moderate	Mauri is unchanged	*He mauri e noho ana*
Low	Mauri improves	*He mauri e tū ana*
Very Low	Mauri flourishes	*He mauri e puāwai ana*
Autakata - Whakapapa		
Extreme	Past/future connections to place broken	*Kua motu ngā aho o te taura takata ki inamata, ki anamata hoki*
High	Past/future connections to place diminished	*Kua tāwekoweko haere te taura takata*
Moderate	Past/future connections to place acknowledged	*Kua kitea te taura takata*
Low	Past/future connections to place improved	*Kua purutia te taura takata*
Very Low	Past/future connections to place strengthened & celebrated	*Kua whiria aukahatia te taura tangata, ā, kua whakanuia hoki ia*
Autaketake – Tapu & Noa		
Extreme	Tikaka & Kawa are trampled on	*Kua takahia a Tikaka rāua ko Kawa*
High	Tikaka & Kawa are ignored	*Kua waiho(tia) a Tikaka rāua ko Kawa*
Moderate	Tikaka & Kawa are known about but not actively utilised	*Kua mōhiotia noatia a Tikaka rāua ko Kawa*
Low	Tikaka & Kawa are utilised to maintain balance	*Kua whakamahia a Tikaka rāua ko Kawa hei whakanonoi i te taurite*
Very Low	Tikaka & Kawa are embedded into social structure and used to restore and maintain balance	*Kua whakatōria a Tikaka rāua ko Kawa ki ngā pūnaha maha, mā rāua kē te taurite e whakarauora*

MANA WHENUA RISK FINDINGS

The mana whenua risks identified are shown in Table D3. These were evaluated using the above methodology to clarify the risk ratings. The findings are summarised to a high level in Figure D1.

Table D3: Risks to mana whenua values in South Dunedin

Autūroa Mana	01. Risk that te tiriti partnership is not upheld 02. Risk of further disadvantaging communities that are currently disadvantaged and / or struggling 03. Risk to ahi kā / Rakatirataka and subsequent manaakitaka and kaitiakitaka responsibilities 04. Risk to Te Taki Haruru not being honoured or upheld 05. Risk to social and cultural connections of whānau and hapori
Auora Mauri	06. Risk to the protection of whenua, awa, moana, wāhi tapu, marae access, ara tawhito, archaeological sites, mahika kai, hauora 07. Risk to te mana o te wai 08. Risk to the ki uta ki tai perspective
Autakata Whakapapa	09. Risk to mātauraka-ā-hapū, mātauraka-ā-iwi, tikaka-ā-iwi, tikaka-ā-hapū 10. Risk to economic capacity to adapt and thrive in an equitable manner 11. Risk to upholding the traditions, pūrākau and relations that weave mana whenua to te taiao 12. Risk to cultural landscapes 13. Risk of ongoing social isolation, social marginalisation to communities 14. Risk of overlooking intergenerational impacts (both past and potential future) of inequitable transitions
Autaketake Tapu & Noa	15. Risk to using / practicing of tikaka and kawa to restore and maintain balance

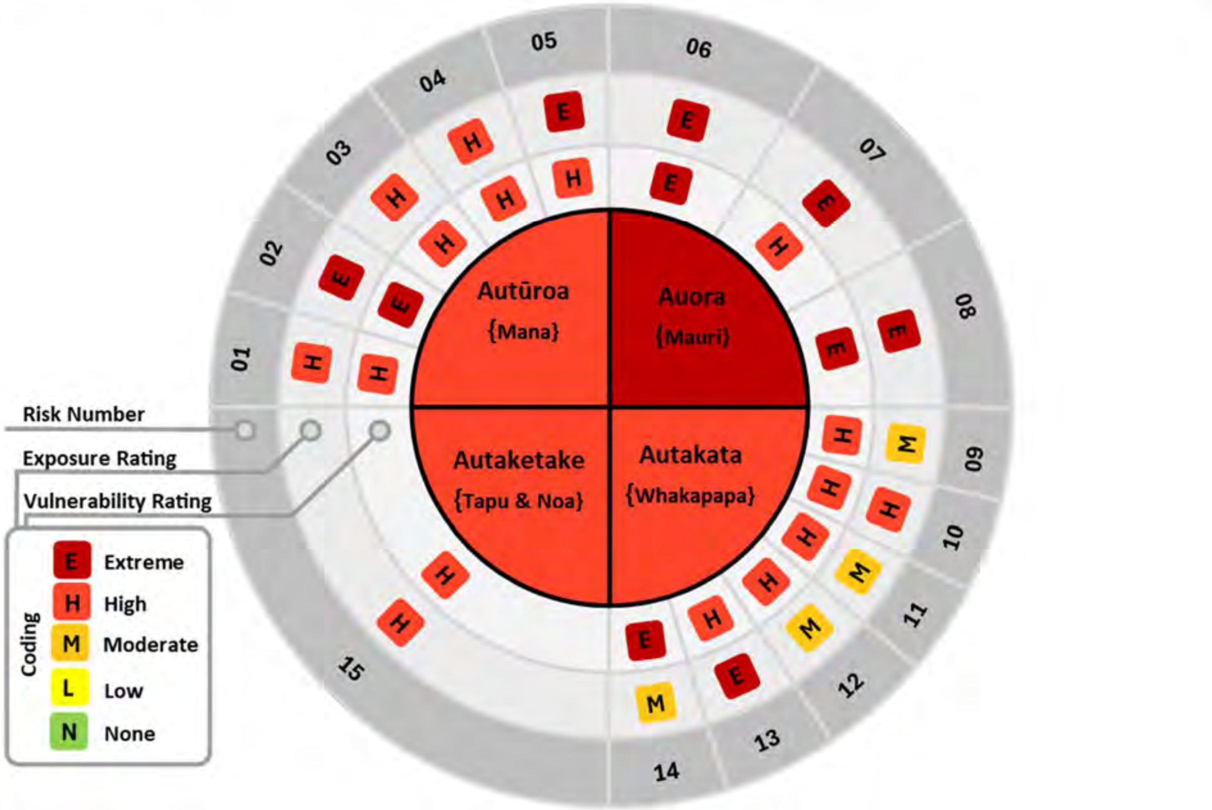

Figure D1: Combined risk to each Te Taki Haruru Principle / Value

The mana whenua risk assessment has shown that, from a Kāi Tahu perspective, there is substantial risk resulting from a ‘keep doing what we are doing’ scenario, where there are no additional interventions to address the issues facing South Dunedin. The level of risk to all four Te Taki Harura values is significant, ranging from high (mana, whakapapa, tapu & noa) to extreme (mauri). The results from the mana whenua risk analysis support the case for change in response to the modelled natural hazards and climate risks.

APPENDIX E: GEOSPATIAL OUTPUTS

The geospatial files listed in Table E-1 accompany this report. Geospatial files should be viewed alongside the 'Readme' explanatory information in Table E-2.

Table E-1: Geospatial files that accompany the risk assessment

Element	File name	Source of base file	Date	Joined data	File description
Energy	Aurora_Substation_Risk	Aurora	Jun-24		Base file with spatial join data and risk assessment attributes added: Binary exposure assessment (refer Readme file) Exposure rating (refer Readme file) Vulnerability rating (refer Readme file) Risk rating (refer Readme file)
Energy	Aurora_Subtransmission_HV_OHConductor_Risk	Aurora	Jun-24		
Energy	Aurora_Subtransmission_HV_UGCable_Risk	Aurora	Jun-24		
Buildings	Buildings_Risk	DCC Rest server	Oct-23	Property, rate assessment property, key features	
Telecommunications	ChorusExchangeRisk	DCC Rest server	Oct-23		
Roads	CycleLanes_Risk	DCC Rest server	Oct-23		
Contaminated land	HAILSites_Risk	DCC Rest server	Oct-23	Land use	
Energy	NationalGridTransmissionLine_Risk	Transpower	Oct-23		
Parks	ParkLocations_Risk	DCC Rest server	Oct-23	Key features	
Railways	Railway_Exposure	DCC Rest server	Oct-23		
Roads	Roads_Risk	DCC Rest server	Oct-23	Criticality	
Sports fields	SportField_Risk	DCC Rest server	Oct-23		
Stormwater	StormwaterPipes_Risk	DCC Rest server	Oct-23	Criticality	
Three waters	ThreeWaters_PumpStations_Risk	DCC Rest server	Oct-23		
Three waters	ThreeWatersFacilities_TahunaWWTPOnly_Risk	DCC Rest server	Oct-23		
Energy	Transpower_Substation_Risk	Transpower	Oct-23		
Waste water	WastewaterPipes_Risk	DCC Rest server	Oct-23	Criticality	
Water supply	WaterPipes_Risk	DCC Rest server	Oct-23	Criticality	
Social demographics	SA1_BuildingRisk	Statistics New Zealand (via DCC Rest server)	Oct-23	Aggregated building risk	

Table E-2: Readme files that accompany the geospatial files

READ ME	
Acronym	Description
CE	Coastal erosion
CF	Coastal flooding
GW	Groundwater
LS	Landslide
PF	Pluvial flooding
OD	One dataset
PD	Present day
LQ	Liquefaction
Vuln	Vulnerability
Exp	Exposure
Risk	Risk
Med	Median
dep	depth
min	Minimum
SSP2_4_5	SSP2-4.5
SSP5_8_5	SSP5-8.5
Numbers (e.g. CF_20_2060_SSP2_4_5)	_20_ Represents 20% AEP
Note the following scenarios relate to SLR increments	
Coastal Flooding Present Day (0 cm)	
Coastal Flooding 2060 SSP2 (30 cm)	
Coastal Flooding 2060 SSP5 (50 cm)	
Coastal Flooding 2100 SSP2 (60 cm)	
Coastal Flooding 2100 SSP5 (110 cm)	
Ground Water Level Present Day (0 cm)	
Ground Water Level 2060 SSP2 (30 cm)	
Ground Water Level 2060 SSP5 (50 cm)	
Ground Water Level 2100 SSP2 (60 cm)	
Ground Water Level 2100 SSP5 (100 cm)	
Coastal Erosion Present Day (0 cm)	
Coastal Erosion 2060 (30 cm)	
Coastal Erosion 2100 (150 cm)	

For some layers the exposure values represent a binary (0= not exposed, 1= exposed) value, and for others the value represents the proportion of the asset exposed (0= no exposure, 1= entire asset exposed). *Note: proportion of exposure for polygon layers can be supplied if desired.*	
Layer	Exposure result type: Binary/Proportion
Building footprint	Binary
Cycle lanes	Proportion
Park Locations	Binary
Roads	Proportion
Sport Fields	Binary
Stormwater Pipes	Proportion
Three Waters Facilities	Binary
Three Waters Pump Stations	Binary
Water Supply Pipes	Proportion
Wastewater Pipes	Proportion