Open Coast Erosion and Flooding Assessment

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Open Coast Erosion and Flooding Assessment
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Executive summary

This study assessed how storm-driven erosion and future sea-level rise (SLR) will affect the Christchurch coastline, with a focus on dune system vulnerability and implications for coastal management. Most of the changes we will encounter on our coastline, particularly over the next 30 years, will be driven by large storms cutting into our protective dune system. Over the short term, the impacts of these storms will disrupt how we manage our dune system. The impacts of successive storms will mean that repairing the spinifex buffer becomes increasingly difficult with limited seed supply and resources.

Over the longer term, storms and SLR mean that eventually we will lose parts of our dune protection system - leading to lowered dune crest levels and a narrower dune buffer, and more frequent overtopping and flood hazards into the community behind the dunes.

The spatial analysis, which considers the overtopping and erosion hazards along the coast both in storms and with SLR, indicates that at present the key areas of concern along the open coast are:

- Brooklands Lagoon Spit (North of Heyders Road);
- North New Brighton Surf Club;
- Between the New Brighton Surf Club and the car park south of the Pier;
- Sumner; and
- Taylors Mistake.

With SLR, the foredunes that are limited in their landward extent by urban developments may progressively narrow, and crest elevations will lower, reducing the ability of the dune system to recover between storms, or protect against overtopping. With 0.2m SLR, there is no significant change from present day conditions where breaches may occur (from those noted above). By 0.6 m SLR, the coast from Waimairi Beach to the Pier becomes increasingly susceptible to erosion breaching and wave overtopping; by 1.2 m SLR, 21-35% the open coast is susceptible to breaching in 1-year Annual Return Interval (ARI) storm cut, and overtopping could affect more than half the shoreline. At 2.0 m SLR nearly half the open coast becomes susceptible to breaching from erosion in a 1-year storm, with severe erosion risk concentrated along Brooklands Spit, the Waimairi Beach - South New Brighton reach, and Southshore Spit. Although there are some areas along the open coast where the dune is projected to not be totally eroded, the dune crest may lower to a level where overtopping could become nearly continuous (97% of shoreline length). Sumner and Taylors Mistake remain persistently susceptible under all scenarios.

Given these findings, priority management areas include:

- North New Brighton - Requires rapid post storm recovery and ongoing spinifex maintenance; becomes susceptible to breaching and overtopping under relatively low SLR (0.6 m).
- New Brighton (Pier to New Brighton Surf Club; North New Brighton Community Centre to Surf Club) - Lower lying dunes backed by structures; prone to overtopping and scour during extreme events; dune widening and planting would reduce stress on walls.
- Sumner and Taylors Mistake - Narrow, low dunes; likely to experience significant storm driven dune loss; continuous planting and maintenance required to sustain protection, reduce impact on landward defences and support public access.
- Brooklands Lagoon / Spit - While fewer built assets are at risk, breaching could significantly alter lagoon hydrology and ecology. This area may be useful for trialing management interventions for narrow, marram dominated dunes.

It is recognised that many parts of the Open Coast dune system have prograded (built seawards) over recent decades and that the average shoreline position (in many locations) is likely to remain relatively stable or even prograde over the coming decades. That being said, this report focuses on an assessment of storms-in-

series to inform a risk-based and precautionary approach to dune management. It is important that we consider the variance in dune position that results from episodic storms, and where feasible, work to ensure that the dune system can serve as a buffer to overtopping, even when in an eroded state. This report helps to identify when and where the dune might not serve as an effective buffer to successive erosion events and overtopping, to inform a risk-based approach to dune management.

Spinifex planting has been an effective management approach for decades and remains suitable in the short to medium term, helping stabilise dune toes and improving post-storm recovery. However, with SLR the dry beach will become narrower, limiting sand supply to the dune and reducing the effectiveness of spinifex plantings, likely between 2060-2090. Over time, management will need to shift toward interventions that focus on the foredune itself (rather than embryo dune development) and supporting inland dune migration, including vegetation transition trials and dune-migration experiments.

Two triggers have been identified to guide when to shift from the current approach, which focuses on development of an embryo dune barrier (seaward of the primary foredune):

- Storm-driven trigger: Spinifex buffer width falls below the 1-in-10-year storm cut distance.
- Dry beach width trigger: Dry beach width falls below 10 m, limiting the dune’s ability to rebuild or migrate.

Overall, the study highlights the increasing stresses on Christchurch’s dune system and the need for timely, adaptive management to maintain coastal resilience under accelerating coastal hazard impacts.

Important note about this report

The sole purpose of this report and the associated services performed by Jacobs is to prepare an assessment of combined erosion and flood hazards on the open coast of Christchurch in accordance with the scope of services set out in the contract between Jacobs and Christchurch City Council ('the Client'). That scope of services, as described in this report, was developed with the Client.

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Appendices

1. Introduction

The Christchurch Open Coast in southern Pegasus Bay features fine-grained, dissipative sandy beaches backed by dunes along much of its length. This coastline is primarily nourished by greywacke sand from the Waimakariri River, resulting in a general sediment surplus under current sea levels.

Recent studies commissioned by Christchurch City Council - such as Tonkin & Taylor's *Coastal Hazard Assessment* (2021) and NIWA's *Coastal Sand Budget for Southern Pegasus Bay* (2018) - have focused on long-term shoreline responses to sea level rise (SLR) and climate-driven changes in sediment supply. These reports suggest the coast is currently in sediment surplus, but erosion is likely to occur as sea levels rise in the future.

However, this long-term focus overlooks potential present-day or short-term risks caused by storms. Coastal storms already pose a threat to the dune system, potentially breaching dunes, creating new flood pathways, and accelerating erosion. In some areas, narrow dune profiles may struggle to recover after storm damage, increasing vulnerability and potentially requiring ongoing intervention (e.g. planting, dune re-profiling).

The purpose of this study is to improve understanding of where the locations along the Christchurch coastline area are that are susceptible to coastal erosion and overtopping during storm events, and under future SLR. In this study, the term 'susceptibility' is used to describe the potential for overtopping or breaching to occur. This is measured through metrics of the dune - including the elevation of the crest, or the width of the dune. The dune is considered susceptible if its crest elevation is less than the wave runup elevation during a storm event; or if is dune width is not great enough to withstand a nominal storm cut.

Identifying these susceptible dune areas will support a more targeted and proactive approach to coastal management. The study also assesses the effectiveness of the current dune management approach - planting spinifex at the dune toe to build a storm buffer - and evaluates how effective this method may remain under future SLR. Based on these findings, the study suggests potential triggers for adapting future dune management practices.

1.1 Future dune responses to sea level rise and constraints

Dune systems develop over years to millennia through the gradual accumulation of sand, forming a natural buffer that protects coastlines from coastal erosion and flooding. Along the Christchurch coastline, however, the dune system is highly modified, with many sections repeatedly planted and restored in an effort to maintain this protective function. Urbanisation of the coastal margin - including residential development, commercial facilities, and community infrastructure such as roads, power, and three-waters services - has significantly altered natural dune forming processes. As a result, dune growth has been interrupted, and in many locations the system has been constrained to narrow strips along the coastline.

A healthy dune system typically requires:

- A wide, flat beach, that allows sand to dry and be transported landward. Importantly, the beach needs to have an area (ideally >10 m) that is permanently dry to enable wind blown transport - e.g. the area between everyday runup above high-tide, and the dune toe;
- Surplus sediment supply; and
- Onshore (including oblique-onshore) winds capable of moving sediment into the dune.

These conditions are currently present along the Christchurch coastline, supporting a relatively robust dune system that provides significant protection during storm events. However, the system's natural mobility in the upper and back-dune environment is reduced by:

1. Stabilising vegetation such as marram grass, which creates elevated dune crests, and

2. Landward constraints including roads, properties, and other infrastructure.

As a result, while the dunes act as an important barrier to overtopping and erosion today (Figure 1-1), their ability to adjust naturally is limited, and over time with storms and impacts from SLR they will inevitably become 'squeezed'.

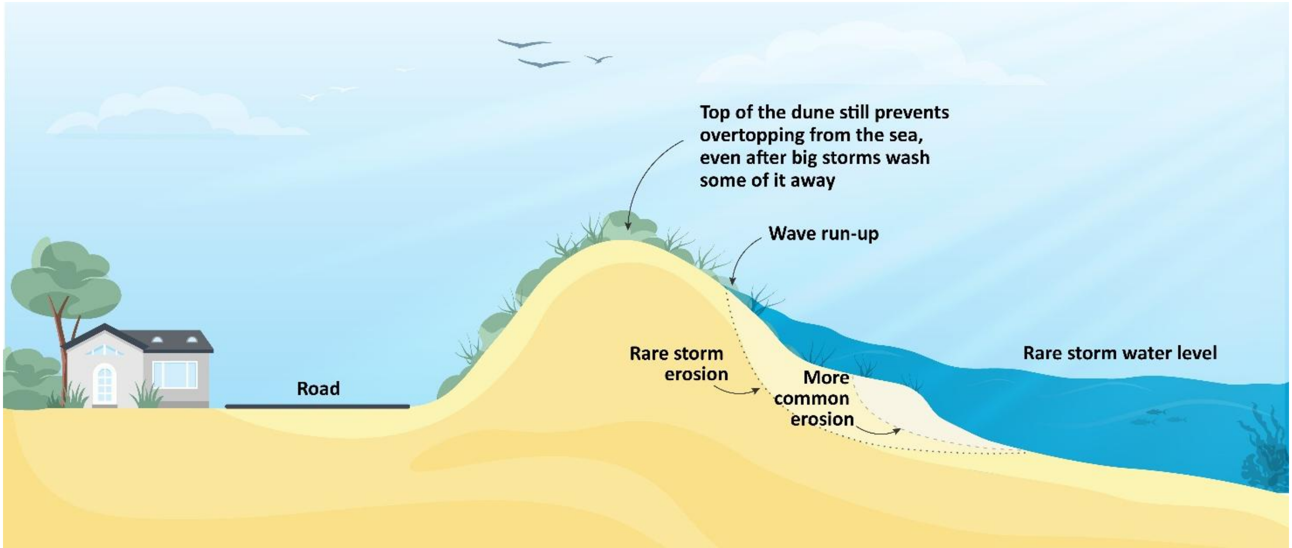


Figure 1-1: Schematic showing the current dune system that is present along some of the open coast environment, where there is a high (but often narrow) dune providing protection to landward assets during storm events.

Future dune response is inherently uncertain due to increasing pressures from SLR and climate change, combined with these existing landward constraints. According to coastal theory (e.g., Bruun, 1962), rising sea levels may cause sediment to be eroded from the dune and redistributed offshore to raise the seabed at the same rate as SLR occurs. Where sediment supply is insufficient, the foredune may narrow and lower over time (Figure 1-2). This conceptual model (Bruun, 1962), along with storm erosion and long-term shoreline trends, underpins the future shoreline positions used in Tonkin & Taylor (2021).

If sediment supply remains adequate and there is space for landward retreat, dunes can migrate inland as the shoreline recedes, maintaining the processes that build and sustain them. In Christchurch, however, landward migration is severely limited by infrastructure, and by the dominant vegetation species (marram grass) being unlikely to support landward migration, due to the dense vegetation cover and lack of sand transport through marram-dominated dunes. As shown in Figure 1-2, this constraint increases the likelihood of progressive dune narrowing, reduced crest height, and eventual loss of protective capacity. Over time, this may lead to overtopping or breaching during storms, creating new flood pathways into the coastal communities the dune currently protects.

If the dune continues to be managed within its current extent, and is constrained by landward infrastructure, sea level rise will progressively reduce the effectiveness of the processes that transport sand to the dune and allow it to accrete. Even with continued sediment input from the Waimakariri River, dry beach width will decrease as sea levels rise, reducing the area where sand can dry and be transported into the dune (effectively reducing the dune's sand supply). Sediment may still arrive at the beach, but the processes that move it into the dune will become increasingly ineffective if the dune is not allowed to migrate landward.

These factors highlight the need for careful dune management to understand when protective functions may diminish under current constraints, and where proactive intervention could help delay erosion-related impacts.

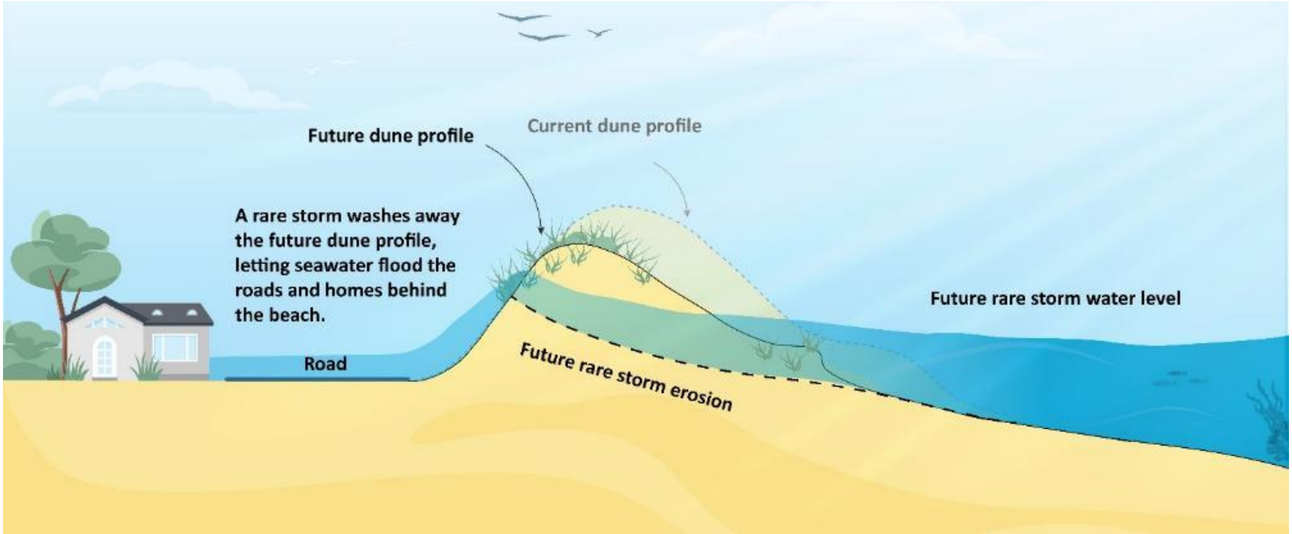


Figure 1-2: Schematic showing a potential future dune profile along the open coast environment, where the dune has narrowed and lowered due to future erosion with SLR, and the resulting dune profile is insufficient to cope with a rare storm, enabling overtopping of the dune crest.

1.2 Study Areas

This study considers three key areas:

1. Christchurch Open Coast dunes from the Waimakariri River south to the Southshore Spit;
2. Sumner Beach from Shag Rock to Cave Rock; and
3. Taylors Mistake beach.

The spatial location and coverage of these three areas is shown in Figure 1-3.

Throughout the study, ECan beach profiles are used to calculate statistics, and are used to represent a length of shoreline for potential changes that might be seen. The location of these profiles used within the study areas are shown in Appendix A.

Figure 1-3: Location of study areas.

1.3 Structure of this report

This study considers the future dune responses in two parts:

1. Identifying where constrained foredunes may be overtopped or breached under storm conditions and sea level rise, creating potential flood pathways into coastal communities; and
2. Reviewing current dune management practices (e.g., planting and storm response), evaluating their effectiveness, and identifying where future efforts should focus to reduce the risk or delay dune breaching under rising sea levels.

The structure of this report to address these points is as follows:

- **Section 2** sets out the approach used to identify locations where dunes may be susceptible to breaching from storm erosion, future longer-term erosion, and wave overtopping. This section first sets out the updated ARI values for storm cuts (based on the latest profile data) and wave runup levels (from Tonkin and Taylor, 2021) used in the assessment, followed by the spatial analysis method used to produce the results presented in Section 3. This section relates to point '1' above.
- **Section 3** presents the results of the spatial analysis identifying the areas along the dunes that are susceptible to breaching or overtopping. This section considers the vulnerability of:
  - The current dune system to breaching or overtopping during a large storm;
  - The current dune system to breaching or overtopping following successive storm events;
  - The future dune system under various SLR scenarios to breaching or overtopping in storm events under various future SLR scenarios; and
  - Sensitivity testing to changes in sediment supply in 2150.

  This section relates to point '1' above.
- **Section 4** describes the current dune management approach along the Christchurch coastline - primarily planting Spinifex at the dune toe to form a lower-dune storm buffer - and evaluates how effective this method is currently and how long it may remain effective under future SLR. The section also identifies priority areas for future management and proposes triggers to inform when changes to current dune management practices may be required. These triggers relate to storm buffer width relative to available seed supply for effective post-storm recovery, as well as the expected reduction in dry beach width under future SLR. This section relates to point '2' above.
- **Section 5** provides the key conclusions of the study.

2. Methods for assessing dune system vulnerability

The purpose of this section is to set out the approach used to identify locations where dunes may be susceptible to breaching from storm erosion, future longer-term erosion, and wave overtopping. Dune vulnerability in this assessment is related to **dune width** and **crest elevation** - representing its ability to withstand breaching from erosion events and to serve as a barrier to wave overtopping.

This section first sets out the updated ARI values for storm cuts and wave runup levels used in the assessment, followed by the spatial analysis method used to produce the results presented in Section 3.

2.1 Storm cut erosion ARI values

2.1.1 Summary of previous ARI analysis (Tonkin & Taylor, 2021)

Tonkin & Taylor (2021) produced a district-wide assessment of coastal erosion and flood hazards. For short-term storm-induced erosion, 100-year ARI storm cuts[1] were derived using ECan beach-profile data collected up to 2020. Profiles were grouped into geomorphically similar "cells," with further consolidation for statistical robustness, as shown in Figure 2-1. The Christchurch open coast was divided into four groups - Brooklands Spit, Northern Profiles, Southern Profiles, and Southshore Spit - with Sumner and Taylors Mistake analysed separately.

Tonkin & Taylor tested several statistical distributions, including Generalised Extreme Value (GEV Type 1 / Gumbel) and Peaks Over Threshold (POT). Gumbel was applied to most groups, while POT was used for Brooklands Spit and Southshore Spit due to smaller datasets (i.e. fewer profiles located within these smaller geomorphic areas). Resulting 100-year ARI storm cuts represent expected dune-toe erosion during a 100-year storm event and are summarised in Table 2-1.

Table 2-1: Summary of T&T (2021) 100 year ARI storm cuts.

Cells	Profiles	100 year ARI Storm Cut (m)
1	Brooklands spit (CCC2200)	-22
2 to 4	Northern Profiles (CCC2070 to CCC1273)	-22
5 to 13	Southern Profiles (CCC1130 to CCC0300)	-29
14	Southshore Spit (CCC0271)	-41
28	Sumner (CCC0190 to CCC0180)	-8
30	Taylors Mistake (BPN8010 to BPN7975)	-17

[1] Storm cut is the horizontal retreat distance of the dune toe or specified contour in a storm event or storms-in-series.

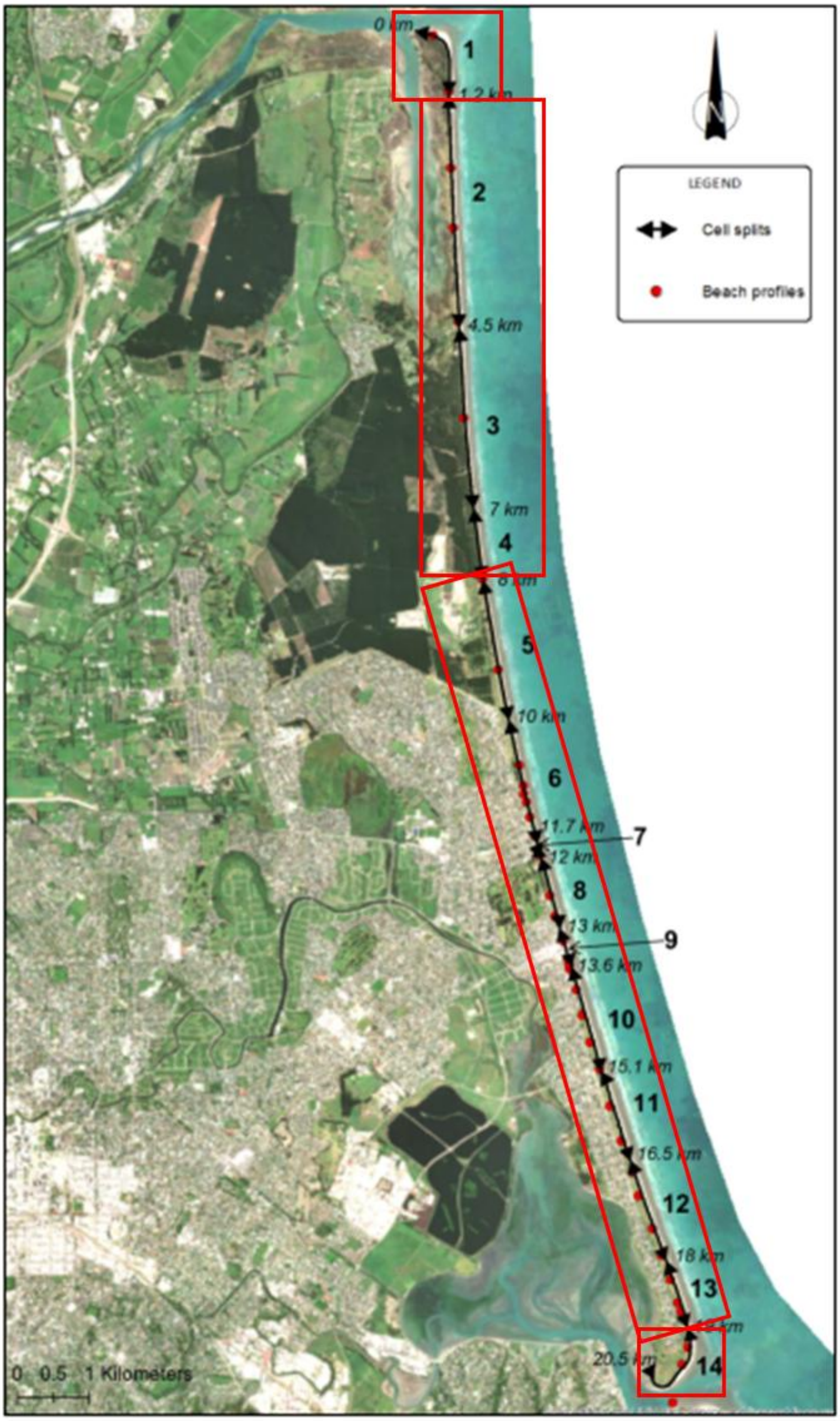


Figure 2-1: T&T (2021) Cell splits and beach profiles. Red boxes indicate the combined cells used to undertake the extreme value analysis for assessing 100 year ARI storm cuts.

2.1.2 Updated storm cut ARI values

This study adopts the Tonkin & Taylor (2021) methodology, with the following key updates:

- Inclusion of 2020-2025 beach-profile data;
- Refinement of cell groupings to reflect more consistent geomorphic characteristics; and
- Calculation of smaller ARI frequencies (e.g., 1-, 5-, and 10-year ARI storm cuts).

Profile data from 2020-2025 were incorporated to determine whether larger storm cuts had occurred since the previous assessment and whether these aligned with the ECan storm register (based on the Steep Head wave buoy record). Consistent with T&T (2021), the 2.5 m contour was used as a proxy for the dune toe.

Of the 43 coastal profiles, 10 recorded their maximum storm cuts over their total record during 2020-2025 (Table 2-2). However, these maximum cuts did not consistently correspond to high-ranking storms in the ECan register. This inconsistency may relate to:

- Sheltering effects from Banks Peninsula, meaning offshore wave conditions at Steep Head may not represent nearshore conditions along the Christchurch coast. Smaller easterly and north-easterly events will have greater erosion impacts along the Christchurch Coast than larger southerly events due to the sheltering effect of Banks Peninsula.
- Antecedent beach states, where even moderate storms can produce significant erosion depending on pre-storm morphology.
- Time between the storm event and the survey being undertaken, where a survey immediately following a storm will display greater effects than a survey undertaken several months after the storm.
- Active dune-management effects, where dune building efforts may create more erodible volume, or where post-storm works alter measured storm cut magnitudes.

Two profiles (Sumner and Taylors Mistake) showed storm cuts >40 m. In both cases the values resulted from non-storm mechanisms (stream incision or low/hummocky dune morphology). These anomalous points were removed.

Table 2-2: ECan beach profiles where maximum storm cuts measured at the 2.5m contour were recorded between 2020-2025, and relevant storms from the ECan storm register that can be attributed to the survey period when the storm cut occurred.

Cell	Description	ECAN Profile	Max storm cut Jan 2020 - July 2025	Storms in survey period
1	Waimakariri River mouth	CCC2200	-20.8	• 29 - 30 Jan 2021 (lowest ranked storm - 99th); • 28 - 30 June 2021 (3rd ranking storm)
5	Bottle Lake	CCC1273	-13.0	• 3 - 6 July 2023 (57= ranking)
6	Waimairi Beach/North New Brighton	CCC1111	-11.6	• 3 - 6 July 2023 (57= ranking)
		CCC1100	-10.9	• 3 - 6 July 2023 (57= ranking)
		CCC1086	-12.9	• 3 - 6 July 2023 (57= ranking)
		CCC1065	-12.8	• 3 - 6 July 2023 (57= ranking)
		CCC1041	-13.9	• 3 - 6 July 2023 (57= ranking)
28	Sumner - Cave Rock	CCC0190	-43.7	• 30 April - 2 May 2025 (60th ranked)
		CCC0180	-18.2	• No storms on register
30	Taylors Mistake	BPN7985	-46.8	• 25 - 26 April 2022 (45th ranked); • 21 - 22 May 2022 (16th ranked); • 12 - 13 July 2022 (19= ranked)

Sensitivity testing across multiple distribution types and profile-grouping structures showed wide variation due to natural profile variability. Updated groupings were developed to:

- reflect geomorphic cohesion;
- maintain sufficient sample size for distribution fitting; and
- improve spatial representativeness compared to the broader T&T (2021) groupings.

Nine profile groups were adopted (compared with four in the 2021 analysis) including:

- Spit tips at the Waimakariri River and Southshore (A, G);
- Well-developed dune fields north and south of New Brighton (B, F);
- Newly constructed dunes around New Brighton Pier (E);
- Two individual profiles constrained by backshore structures (C, D); and
- Sumner (H) and Taylors Mistake (I), unchanged from T&T (2021).

These refined groups produced consistent storm-cut estimates across both Gumbel and POT distributions and aligned well with T&T (2021) results.

The resulting storm-cut annual Return Intervals (ARI) values, incorporating updated data, refined groupings, and additional ARI frequencies, are presented in Table 2-3.

Table 2-3: Updated Storm Cut ARI Analysis for this study.

New Group	Cells	Profiles	Annual Return Interval (ARI) Storm Cuts (m)					
			2-year ARI	5-year ARI	10-year ARI	20- year ARI	50-year ARI	100-year ARI
A	**1**	Brooklands spit (CCC2200)	NA	-17	-25	-28	-30	-30
B	**2 to 6, 8**	Northern Profiles (CCC2070 to CCC1041) & New Brighton dunes north of pier (CCC0952 to CCC0924)	-6	-10	-13	-16	-20	-23
C	**7**	North New Brighton Surf Club (CCC1011)	-3	-6	-8	-12	-19	-26
D	**9**	Backshore structures at New Brighton (CCC0889)	NA	-9	-14	-17	-20	-22
E	**9**	'New Dunes' around New Brighton Pier (CCC0863 to CCC0853)	-2	-4	-6	-8	-11	-14
F	**10 to 13**	Open Coast dunes south of Pier (CCC0848 to CCC0350)	-3	-6	-8	-11	-14	-18
G	**14**	Southshore Spit (CCC0300 to CCC0271)	-6	-10	-14	-19	-29	-40
H	**28**	Sumner (CCC0190 to CCC0180)	-3	-5	-9	-13	-19	-24

I	**30**	Taylors Mistake (BPN8010 to BPN7975)	-6	-8	-10	-12	-14	-16

Summary estimates for the open coast are as follows:

- **1-year ARI storm cut:** 3-6 m
- **10-year ARI storm cut:** 6-25 m
- **100-year ARI storm cut:** 14-40 m

These updated ARIs are applied in Section 3 to model dune erosion under various storm scenarios.

These storm-cut ARIs have been calculated using the available annual beach-profile record. In reality, actual storm cuts may be smaller or larger than the values presented here. The size of any storm cut will depend strongly on the antecedent condition of the beach (and on the timing of surveys relative to the storm cut, noting that some amount of recovery is likely to take place prior to surveying) - for example:

- whether earlier storms have already lowered the beach profile, allowing waves and water levels to run further up the beach; or
- whether nearshore rips or channels focus wave energy at particular points along the coast; or
- whether a well-developed embryo-dune buffer is present, helping to absorb wave energy before it reaches the main foredune

The storm-cut values used in this assessment reflect what has been observed to date. As monitoring continues and the dataset grows, our confidence in estimating likely storm cut magnitudes will improve. For now, these results provide a useful indication of the magnitude of erosion that may occur during storm events.

2.1.2.1 Comparison of calculated ARI storm cuts with known storm events

There is notable alongshore variation in storm event response, particularly between the beaches north and south of the pier, due to differences in exposure. Within the 40 year profile record, three storm periods stand out for producing the largest observed storm cuts:

- 1992 storms: A series of storms caused extensive dune damage, with profile data showing horizontal storm cuts greater than 10 m. Wave statistics are not available, but the magnitude of erosion makes these events memorable.
- 20-21 July 2001 storm: Although this event ranks relatively low on the ECan storm register (=32nd), it approached from the SE/E (116°) and produced 66 hours of significant wave heights above 4 m. It is widely recalled by park rangers and community members. Water levels were estimated to be around a 1-year ARI (NIWA, 2015), but due to the storm's south-easterly direction and its duration, coastal experts considered the storm-cut response more consistent with a 10-20-year ARI. Larger storm cuts along the open coast are typically associated with easterly to south-easterly storms than with higher ranked southerly storms, as south-easterly waves have a more direct onshore impact. In contrast, the open coast is relatively sheltered from larger southerly storms commonly recorded in the ECan storm register.
- 1 July 2008 storm: Ranked 21st on the storm register, this event was significant for the open coast because it approached almost directly from the east (87°). It produced 30 hours of significant wave heights above 4 m, including 9.5 hours above 6 m. Water levels were estimated to be around a 10-year ARI (NIWA, 2015), with storm-cut response likely of similar magnitude. The smaller storm cuts in most locations relative to the 2001 storm reflect the lower duration of the event (50% less), so the dune toe was exposed to half the high tide periods where run-up would reach the dune toe.

Storm-cut data from these events were extracted for six beach profiles: two northern profiles (CCC1755, CCC1400), two north of the pier (CCC0952, CCC0924), and two in South New Brighton (CCC0815, CCC0748). All profiles showed erosion, though the magnitude varied. Table 2-4 compares the observed storm cuts with the calculated ARIs from Section 2.1.2.

Table 2-4: Comparison of storm cuts (at 2.5m contour) from various storms in the profile record and calculated ARI's.

	Observed storm cut (m) from ECan profile record			Relevant Calculated Storm Cut ARI's from this report		
Profile	**1992 Storms**	**2001 Storm**	**2008 Storm**	**5-year ARI**	**10-year ARI**	**100-year ARI**
CCC1755	-15.8	-9.6	-9.0	-10 m	-13 m	-23 m
CCC1400	-13.8	-9.3	-6.0			
CCC0952	-10.6	-8.0	-6.8	-10 m	-13 m	-23 m
CCC0924	-5.3	-3.7	-6.5			
CCC0815	-13.5	-9.4	-5.6	-6 m	-8 m	-18 m
CCC0748	-10.2	-9.0	-5.9			

Overall, the calculated ARIs (from Table 2-3) fall within the expected range of observed storm cuts, consistent with the fact that the ARI calculations are derived from the same long-term profile record. Based on this comparison:

- The 1992 storms correspond to approximately a 10 - 20 year ARI.
- The 2001 storm corresponds to roughly a 5 - 10 year ARI.
- The 2008 storm corresponds to approximately a 1 - 5 year ARI.

These results align with expert interpretation and with erosion patterns observed across the full 40-year dataset.

2.1.2.2 Comparison of NIWA (2015) wave runup ARI levels with beach profile data

NIWA (2015) assessed extreme sea levels generated by storm tides and wave runup along the Canterbury coastline. The dataset underpins the Coastal Calculator, which estimates extreme water levels for a range of ARIs using site-specific beach-profile characteristics (from ECan monitoring) and wave modelling.

Appendix C of NIWA (2015) documents historical storm observations, linking individual storms to inferred runup water levels based on erosion scarps and debris lines. These events were assigned ARIs generally ranging between 1 and 10 years for locations relevant to this study.

Where NIWA's ARI-assigned runup levels correspond to profiles within the study area, beach-profile data were analysed to estimate the storm cuts occurring during those events. These results are summarised in Table 2-5.

Table 2-5: Storm cuts from relevant storms at ECan profiles relating to Extreme Water Level ARI's from NIWA (2015).

ECan Profile	Annual Return Interval Extreme Water Level (From NIWA, 2015)	Storm	Storm cut (2.5m RL) m
CCC1130 (Waimairi Beach)	**1**	12-13 July 2001, 20-21 July 2001	-6.8
	10	1/08/2008	-6.5
	20	3-4 March 2014	1.5
CCC0924 (New Brighton)	**1**	12-13 July 2001, 20-21 July 2001	-3.7
	5	20-23 June 2013	-3.6

ECan Profile	Annual Return Interval Extreme Water Level (From NIWA, 2015)	Storm	Storm cut (2.5m RL) m
	10	1/08/2008	-6.5
CCC0863 (New Brighton - Structure)	**1**	12-13 July 2001, 20-21 July 2001;	-6.7
	5	20-23 June 2013	-4.3
	10	25-30 May 2002	-5.5
	10	1/08/2008	-8.0
CCC0362 (Southshore)	**1**	12-13 July 2001; 20-21 July 2001	-6.8
	1	20-21 June 2014	-3.3
	10	25-30 May 2002	2.8
	10	1/08/2008	-4.5

This analysis shows no consistent correlation between extreme water-level ARIs and storm-cut magnitude. While elevated water levels contribute to erosion, storm cut size is more likely to be strongly influenced by:

- Antecedent profile conditions;
- Embyro dune development, which can absorb storm energy and result in larger relative storm cuts, as there is more embryo dune width available to be eroded in a storm;
- Beach slope and dune face morphology, which influence wave dissipation and overtopping; and
- The influence of wave conditions (e.g. height, period, direction, duration). Storm cuts will be influenced by the joint probability of water levels and wave runup.

For example, a well-developed embryo dune may produce a larger storm cut than a steep, eroded dune face under the same water-level conditions.

Across the events assessed, storm cuts associated with 10 year ARI water levels typically range from 3 - 8 m, supporting the updated ARI storm-cut values presented in Table 2-3. These comparisons provide further confidence that the updated ARIs are appropriate for modelling dune erosion in Section 3.

2.2 Dynamic (wave runup) water levels

To better understand potential wave runup elevations along open coast sites, a review was conducted using existing studies (Tonkin and Taylor, 2021; NIWA, 2015) and the Coastal Calculator (NIWA, 2015).

Tonkin and Taylor (2021)

Tonkin and Taylor (2021) developed dynamic water levels (wave runup levels), including wave setup, using empirical equations applied across a full hydrodynamic time series. Beach slopes were assessed separately for wave runup and wave setup: a 1:15 slope (0.06) was used for runup, and a 1:65 surf zone slope for setup. For wave setup, comparisons between XBeach model outputs and empirical estimates indicated that the USACE (2006) method provided the most reliable predictions across the slope gradients used. For wave runup, several empirical formulas were tested against post-storm debris lines, with Mase (1989) found to best match observed runup during the extreme 2001 event (20-21 July 2001). Results from this analysis are presented in **Table 2-6**, which include 'static' (i.e. Storm tide and wave setup), and 'dynamic' (storm tide and wave setup and wave runup) values.

Table 2-6: Static and dynamic water levels from Tonkin and Taylor (2021) in NZVD2016.

	1 year ARI		10 Year ARI		100 Year ARI	
	Static	Dynamic	Static	Dynamic	Static	Dynamic
Christchurch Open Coast	1.8	3.8	2	4.2	2.3	4.4

Sumner	1.8	4.5	2	4.9	2.3	5.3
Taylors Mistake	1.8	4.5	2	4.9	2.3	5.3

NIWA (2015)

The NIWA Coastal Calculator applies Stockdon et al. (2006) to estimate runup across various ARIs. It uses a single beach slope for both wave setup and runup calculations and calibrated their results against sites along the open coast. When applied to open coast sites using the storm gradients (approx. 1 in 10 to 1 in 12 slope), the tool appeared to calculate runup values significantly lower than the T&T (2021) assessment, as shown in Table 2-7. For example, at Waimairi Beach, a slope of 0.28 (1 in 3.6) would be required to match the T&T modelled runup. Such a steep face is unlikely during extreme water levels based on coastal observations (e.g. is greater than the max recorded up to 2020 in the calculator).

This indicates that the Stockdon method, when used with Christchurch storm-period slopes, underestimates runup relative to the T&T assessment.

Table 2-7: Calculated dynamic water levels from the NIWA (2015) Coastal Calculator in NZVD2016.

			1 year ARI		10 Year ARI		100 Year ARI	
Location	**Profile**	**Storm Gradient (slope)**	**Static (m)**	**Dynamic (m)**	**Static (m)**	**Dynamic (m)**	**Static (m)**	**Dynamic (m)**
Waimairi Beach	CCC1130	0.105	1.3	2.0	1.6	2.4	1.8	2.7
New Brighton (Dune)	CCC0924	0.105	1.4	2.2	1.7	2.7	1.9	3.1
New Brighton (No dune)	CCC0863	0.720	1.3	1.9	1.5	2.3	1.8	2.7
South New Brighton	CCC0362	0.078	1.4	2.1	1.7	2.6	1.9	3.0
Sumner	CCC0190	0.136	1.6	2.8	2.0	3.5	2.3	3.9
Taylors Mistake	BPN7985	0.109	1.5	2.5	1.9	3.1	2.1	3.5

It is noted that the Coastal Calculator is currently being updated, with a re-assessment of beach slopes and run-up formula; however this update is not yet available at the time of this report.

Adopted approach of wave overtopping levels

Based on these comparisons, the Tonkin & Taylor (2021) dynamic water levels have been adopted for assessing potential dune overtopping along the open coast. These values:

- incorporate locally validated empirical methods,
- were tested against observed storm debris lines, and
- provide a conservative, coastline-wide estimate suitable for screening-level vulnerability analysis.

While site-specific variability in slope, structures, and local morphology will influence true runup elevations, the T&T (2021) values provide an appropriately precautionary basis for this study. For dune segments identified as susceptible, more detailed site-specific analysis is recommended to refine runup predictions using local beach slopes, hydrodynamics, and morphological constraints.

2.3 Method for spatial analysis of combined erosion and flood hazard

A spatial analysis has been undertaken to identify where the dune system - and therefore landward areas - may become susceptible to storm-driven overtopping and erosion, both now and under future SLR scenarios. The assessment considers current dune width and crest elevation, as well as projected future dune width and crest levels under SLR.

The methodology used for this analysis is outlined below, and the results are presented in Section 3.

2.3.1 Breaching from reduced dune width in storms and with SLR

The purpose of this analysis is to assess dune-system vulnerability in relation to dune width, specifically how much dune remains after storm erosion or the effects of SLR. The remaining dune width indicates the system's ability to recover from a storm, as well as to continue providing protection. This analysis provides an indication of what parts of the coast the dune may become susceptible soonest, and with what amount of SLR. A schematic illustrating how dune width varies with storms and SLR is provided in Figure 2-2.

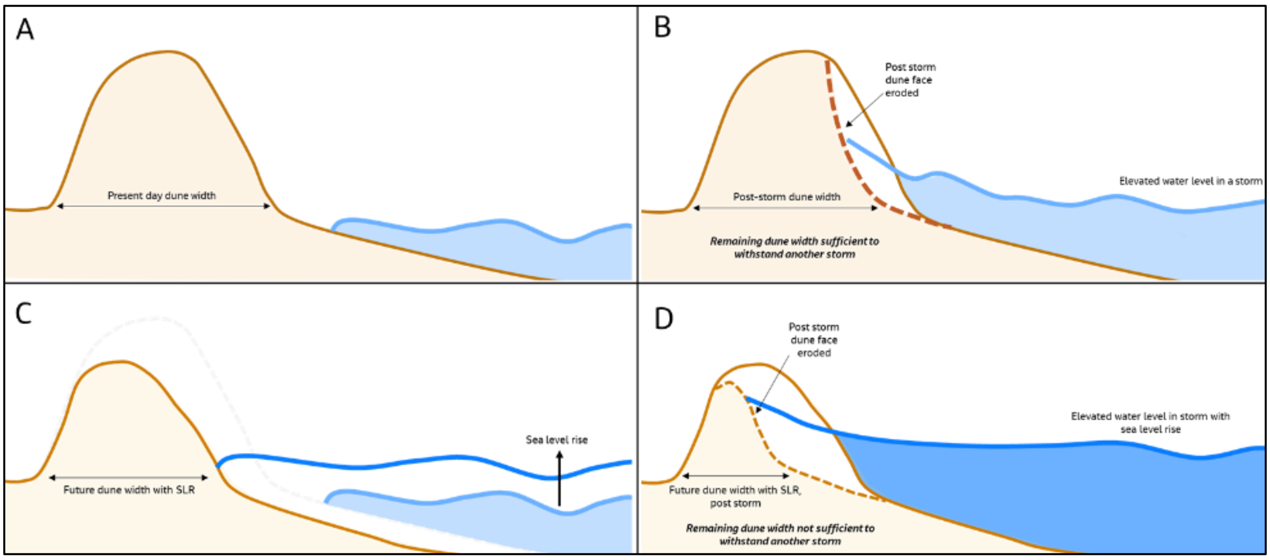


Figure 2-2: A schematic showing the various changes in dune width with (a) present day conditions; (b) elevated water levels in a storm under present day conditions; (c) erosion due to future SLR; and (d) a storm in the future with SLR.

The existing dune width was calculated by manually mapping the foredune extent from the 2025 LiDAR dataset. Widths were measured from the approximate 2.5 m contour to the back of the foredune at 10 m intervals along the coastline (Figure 2-2.A).

To assess how storms affect the present-day dune, storm cut values from Section 2.1.2 were subtracted from the existing dune width to determine the remaining width post-storm cut (Figure 2-2.B). For example, if a dune is 60 m wide and experiences 23 m of erosion during a 100-year ARI storm, the remaining width is 37 m.

The remaining dune width for each storm ARI was then mapped to evaluate whether it would:

a. breach due to the initial storm of various magnitudes (presented in Section 3.2.1.1), where for example, the current dune width is too narrow to withstand a 100-year ARI storm cut; and

b. be able to withstand a subsequent storm of similar magnitude (presented in Section 3.2.1.2). For example, a remaining dune width of 37 m is sufficient to withstand another 100-year ARI storm cut and is therefore not considered susceptible to breaching in the short-term after the storm.

Dune vulnerability is mapped based on the remaining width after storm erosion. Dunes are considered to have lower vulnerability if the remaining width exceeds that required to withstand a 1 in 100-year storm cut. Vulnerability increases as the remaining width decreases, with dunes considered to have higher vulnerability if the remaining width is insufficient to withstand even a 1 in-1 year storm cut. In the mapping outputs, the following colouration is applied:

- Red = remaining dune width insufficient to withstand a 1-year ARI storm cut;

- Orange = remaining dune width insufficient to withstand a 10-year ARI storm cut;
- Yellow = remaining dune width insufficient to withstand a 100-year ARI storm cut;
- No colour = sufficient dune width remaining to withstand calculated storm cuts at least up to 100-year ARI.

For future conditions, dune widths were recalculated using the present day back of dune position and the projected dune toe positions from Tonkin & Taylor (2021) (Figure 2-2.C).

Future SLR increments used in this assessment are:

- 0.2 m by 2050;
- 0.6 m by 2080;
- 1.2 m by 2130;
- 2.0 m by 2150; and
- Sensitivity testing for sediment supply changes along the open coast for 1.5 m SLR by 2130

When consideration is had for local vertical land movement to understand the rates of relative sea level rise across the various study areas, the SLR increments adopted for 2050 (0.2m); 2080 (0.6m); and 2130 (1.2m) align most closely to the SSP3-7.0 scenario along the New Brighton open coast; and closer to the SSP5-8.5 scenario in the Sumner and Taylors Mistake areas (as a result of lower rates of projected subsidence compared to the open coast). The increment used of 2.0 m SLR by 2150 is aligned to a higher SSP5-8.5H+ scenario.

These future dune widths were then compared with the storm cut values for each transect to assess how the remaining width might respond to a significant storm at that time (Figure 2-2.D). It is important to note that the Tonkin & Taylor (2021) projections already incorporate the effects of a storm event; therefore, this analysis evaluates the vulnerability of the dune system to an additional storm, and therefore serves to provide an assessment of the risk to storms-in-series. This analysis also assumes that current estimated ARI storm cuts will be the same in the future as they are estimated to be at present, which could potentially under-estimate the future storm cuts if wave climate and foreshore slopes change in the future with SLR.

Mapping outputs for each SLR scenario (0.2 m, 0.6 m, 1.2 m, 2 m) identifies where the remaining dune width is susceptible to breaching under 1-year, 10-year, and 100-year ARI storm cuts. Dunes are considered less susceptible where the remaining width can withstand a 100-year ARI storm cut, and most susceptible where the remaining width is less than that required to withstand a 1-year ARI storm cut. The same colouration described above used for present day mapping was also applied for the future dune analysis.

2.3.2 Overtopping of dune crest during storm events and with SLR

The purpose of this analysis is to determine where and when flood pathways from storm driven overtopping could form as dune crest elevations lower through a combination of post storm erosion and progressive erosion associated with SLR. The analysis assumes that the inland extent of dunes remains fixed to its current position, and that erosion of the foredune leads to a gradual lowering of the crest (Figure 5D), reducing its ability to prevent overtopping during storm events.

For present day conditions, the dune crest position was extracted from the 2025 LiDAR dataset by manually identifying the highest point alongshore on the foredune. Crest elevations were then sampled at the same 10 m intervals used in Section 2.3.1. These elevations were compared with runup water levels to assess whether overtopping could occur and potentially create a flood pathway. A potential limitation of this approach is that throughout the dune profile there are variable slopes that will influence the runup level - for example the slope gets steeper higher up the dune face; and hence will impact the runup level. In theory, a steeper slope would increase the runup level higher up the profile, though the porous nature of the sand profile will reduce runup energy as the wave travels across the sand surface.

Mapping outputs identify locations where the dune crest is lower than the calculated runup levels for 1-year, 10-year, and 100-year ARI events. Vulnerability increases where overtopping occurs under more frequent events (e.g., 1-year ARI) and decreases where overtopping only occurs under more extreme events (e.g., 100-year). The outputs of this analysis include maps of overtopping locations for each event (Section 3), and the total length of shoreline overtopped (Section 3).

To assess how overtopping vulnerability may change in the future with SLR, an estimated future crest position was developed using the Tonkin & Taylor (2021) projected shoreline positions together with the present-day crest location. For each SLR scenario, a new dune crest position and elevation was determined under the assumption that the dune system remains constrained and does not migrate landward (i.e., the backshore position is fixed by vegetation and infrastructure). The future dune crest was taken as either the present-day crest elevation (where future accretion is projected, or where erosion of the toe has not progressed further landward than the current crest) or the dune elevation at the retreated shoreline position from Tonkin and Taylor (2021) (where future erosion is projected). Once the projected shoreline moves landward of the current crest, the new crest elevation becomes lower than the present-day crest, as dune height decreases in the landward direction. An alongshore profile of these future crest positions was created for each scenario, and water levels were overlaid to identify where new overtopping or flooding pathways could emerge under dynamic or static water levels.

Figure 6 provides an example of this process. The black profile shows the current dune morphology (2025 LiDAR). The blue profile represents a truncated dune under the 0.6 m SLR scenario, where erosion has shifted the dune toe landward of the present-day crest; in this case, the remaining crest elevation is still high enough to prevent overtopping (blue dotted line). By contrast, under the 1.2 m SLR scenario (pink), erosion removes the entire dune, placing the crest at the back of the present-day dune. At this point, wave runup could overtop the dune entirely, creating a new flooding pathway.

A key limitation of this study is that the analysis identifies only where overtopping could occur - i.e., where a hydraulic pathway across the dune is possible. It does not quantify the volume, duration, or inland extent of overtopping flows. As a result, some areas identified as overtopped may experience only small overtopping volumes, while others - particularly where dune crest elevations are significantly lower - may be exposed to much larger overtopping flows.

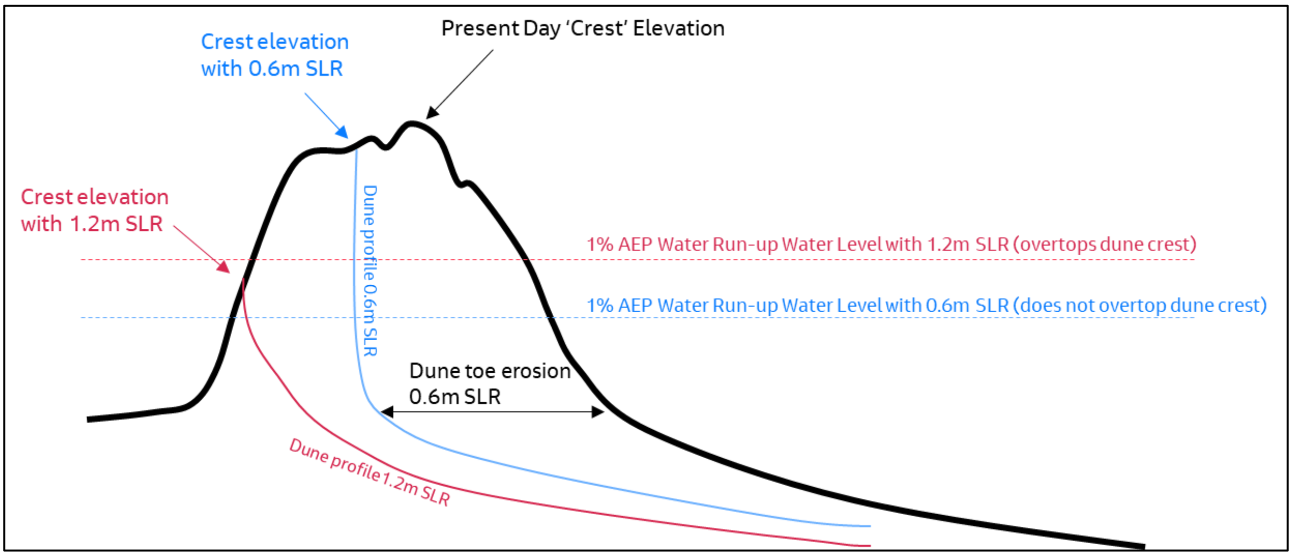


Figure 2-3: Example schematic of dune topping overtopping calculation process, showing how erosion with SLR in a constrained dune will reduce the crest elevation, and result in overtopping.

3. Susceptibility to coastal erosion and overtopping hazards

This section presents an analysis of the current (2025) dune system along the open coast, identifying areas that may be susceptible to overtopping during extreme water level events or breached due to reduced dune width in successive large storms. This section first discusses the existing constraints and land uses along different sections of the coast behind the dune, followed by an analysis of dune breaching under present day conditions (Section 3.2), and in the future with SLR (Section 3.3).

3.1 Current dune system

3.1.1 Dune state and vegetation

The dune system along most of the coastline is highly modified, with extensive historical planting of marram grass to maintain high dune elevations. The condition of the dune varies alongshore, ranging from recently planted areas to eroded sections and lower, man-made dunes constructed in front of infrastructure.

Over the past 25 years, Christchurch City Council Park Rangers have progressively planted spinifex along accessways and the seaward face of the dune to act as a buffer, particularly in areas where infrastructure is located behind the dune (Figure 3-1). Spinifex has been favoured along the open coast because it traps sediment on the lower beach due to its sprawling stolons and flexible, wind-permeable leaves that break wind movement and cause sand to drop and accumulate around the plant. Spinifex provides a sacrificial buffer during storms, and can self-seed, allowing it to migrate both landward and seaward over time.

Figure 3-1: Spinifex embryo dune in front of higher marram grass dominated dune at Sandra Street, South New Brighton.

Spatially, less planting and maintenance have occurred in areas with a naturally wider dune system and limited infrastructure behind it. These dunes have largely been left in their ‘natural’ state, dominated by marram grass. While marram contributes to dune elevation, it is slow to recover once damaged by storms. This limited recovery is evident along the Bottle Lake and Spencer Park sections of the open coast, where dunes have not successfully re-established themselves following storm events (Figure 3-1). Continued erosion has removed the seaward buffer, leaving steep scarps with exposed marram roots that die off over time. In some locations, marram has not re-established at all, and the dune is now retreating into the backshore scrub and pine forest behind it. Although the dune system remains wide, the vegetation required to maintain dune stability is progressively declining.

Figure 3-2: Scarped marram dominated dune at Spencer Park, eroding into back-dune vegetation.

In addition to these natural and modified dune types, some sections of the coastline contain hard coastal protection structures (e.g., seawalls, gabion baskets). In several of these locations, low, man-made dunes have been constructed and planted in front of the infrastructure - for example, at the New Brighton Hot Pools complex (He Puna Taimoana). These low spinifex dunes provide a modest erosion buffer and act as a supplementary layer of protection to the 'backstop' protection structures during storm events.

3.1.2 Dune constraints and existing land use

The dune system along the open coast is constrained in various locations by existing infrastructure, land use, and geomorphology. These constraints, shown spatially in Figure 1-3, can be described as follows:

A. **Brooklands spit/Lagoon -** The dune system is narrow and constrained landward by the lagoon. Any landward migration of the dune into the lagoon would likely lower the dune crest, reducing its ability to prevent future overwashing into the lagoon and neighbouring communities.

B. **Bottle Lake -** The dune system is generally unconstrained. Land behind the dunes is mostly zoned as open space, with a small area of 'specific purpose' zoning associated with the former Burwood Landfill site, now used primarily for recreation.

C. **Waimairi Beach -** The dunes are located within open-space zoning, with approximately 60 m between the current back of dune and the residential zone. There is generally sufficient space for landward dune migration.

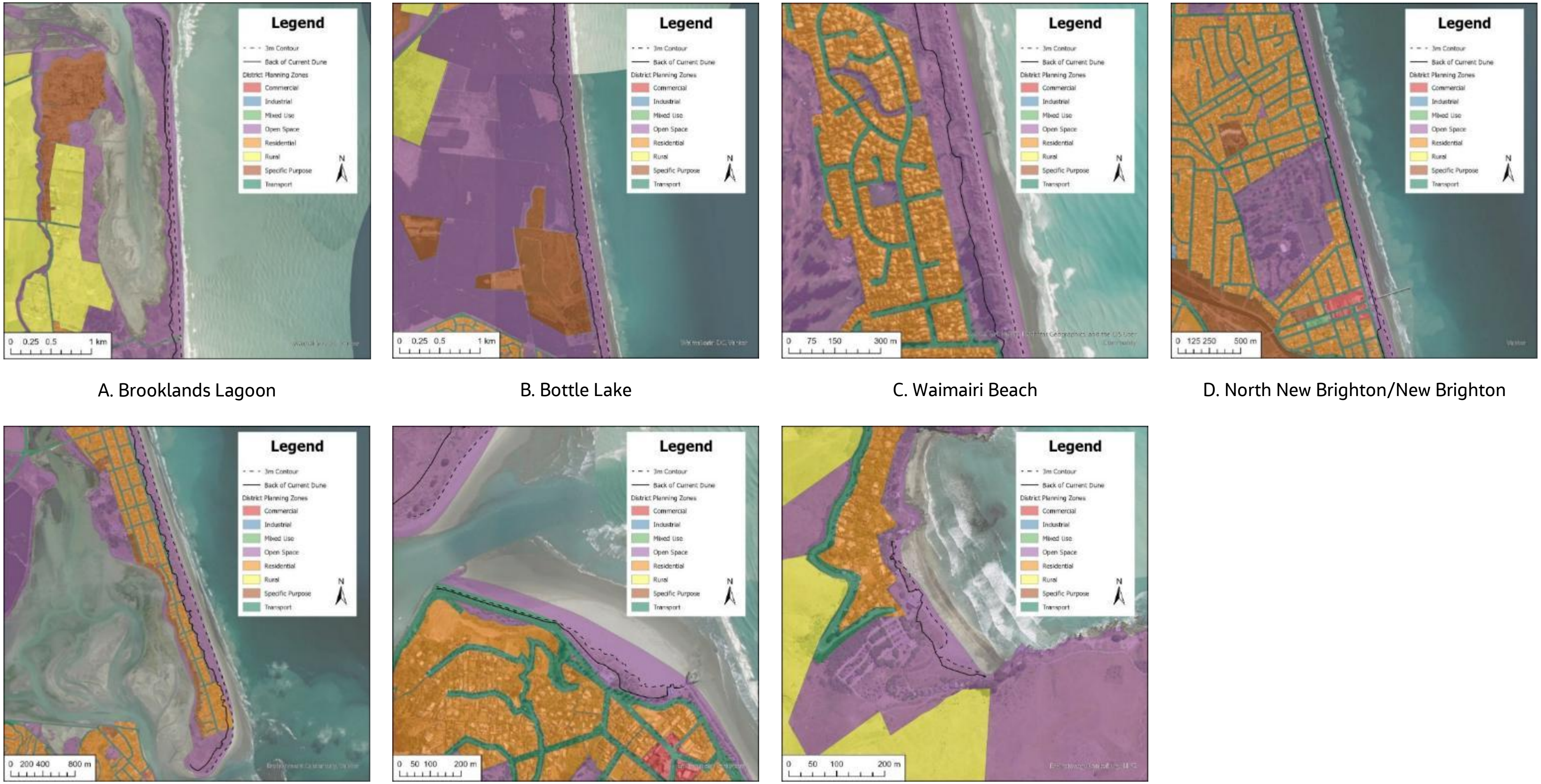
D. **North Beach and New Brighton -** The dune system is narrow and zoned as open space but is immediately constrained landward by transport corridors (Marine Parade) and residential and commercial land. Council three-waters infrastructure (wastewater and water supply pipes) is also located within these corridors, further limiting landward migration.

E. **South New Brighton and Southshore -** The wider dune system is constrained landward by Marine Parade and residential zoning. At the southern end of Southshore Spit, the residential zone lies within the dune system. While the wider dunes have some internal space for limited landward migration, they will ultimately become constrained by existing residential development and infrastructure, similar to Waimairi Beach.

F. **Sumner -** The dune is immediately constrained landward by transport corridor zoning (Main Road). Under current land use, there is no available space for the low-lying dune to migrate inland. Additional local constraints include the surf club, coastal pathway, and a beachfront restaurant.

G. **Taylors Mistake -** The dune is located within open-space zoning. Land behind the dune is mostly open space, with some residential zoning at the north-western end of the bay. Local constraints include the surf club building and carpark, though there is some space - particularly at the south-eastern end - for potential landward migration.

The analysis of future dune width reduction under storms and SLR, as well as overtopping during storm events, is undertaken under the assumption that existing land use remains unchanged and the dune does not migrate landwards (even in open spaces). For example, the dune is assumed not to migrate landward across Marine Parade, and the road remains in place and functional. Under this scenario, erosion continues to occur seaward, progressively reducing dune width and the level of protection the dunes provide. Section 4 discusses dune management options and the potential to delay or avoid complete dune loss over time.



A. Brooklands Lagoon

B. Bottle Lake

C. Waimairi Beach

D. North New Brighton/New Brighton

E. South New Brighton/Southshore

F. Sumner

G. Taylors Mistake

Figure 3-3: Current dune extent and district plan zoning.

3.2 Present day dune breaching from coastal erosion in storms

The following sections present the analysis of dune erosion and overtopping during storm events, using the methodology outlined in Section 2.3.2. Section 3.2.1 examines the relationship between dune width and storm-induced erosion (storm cuts), while Section 3.2.2 assesses how dune crest elevation compares with projected wave runup water levels during different sized storms.

3.2.1 Present day dune width

Dune widths along the open coast, Sumner, and Taylors Mistake are shown spatially in Figure 3-4 and summarised in width bands in **Table 3-1**, with a further breakdown attributed to longshore profile groupings along the Open Coast in Table 3-2.

Along the open coast, dune widths are predominantly greater than 30 m, with 95% of the shoreline exceeding this threshold. Only 5% (approximately 1 km) of the open coast shoreline has dunes narrower than 30 m. These narrower sections occur primarily along Brooklands Spit, where the dune is currently narrowing, and in locations where the dune has been highly modified or removed to accommodate infrastructure and accessways - such as at Waimairi Surf Club, North New Brighton Surf Club and Community Centre, the New Brighton Surf Club to Pier section, and South New Brighton Surf Club. A substantial proportion of the open coast (44%) has dune widths greater than 90 m, particularly around Bottle Lake and Southshore.

In contrast, dunes at Sumner and Taylors Mistake are generally much narrower. At Sumner, 69% of the dune system is less than 30 m wide, and at Taylors Mistake this increases to 83%. These narrow dune widths indicate a higher vulnerability to storm-driven erosion and breaching during significant events.

Overall, the dune width distribution indicates clear contrasts in vulnerability along the coastline. Wider dune systems on the open coast - particularly around Bottle Lake and Southshore - provide a substantial buffer for storm erosion, whereas the narrow dune systems at Sumner and Taylors Mistake are inherently more exposed and likely to become susceptible earliest under future SLR scenarios. The narrowest sections along the open coast coincide with highly modified or infrastructure constrained areas, indicating locations where adaptation options may be limited and where earlier management intervention may be required. These patterns provide important context for interpreting future dune width reductions and overtopping risk under SLR.

Table 3-1: Summary of shoreline length with attributed dune widths in bands.

	Length of shorelines with attributed dune width		
Present Day Dune width	**Open Coast**	**Sumner**	**Taylors Mistake**
<30 m	1,020 m (5%)	630 m (69%)	300 m (83%)
30-60 m	4,120 m (21%)	260 m (29%)	60 m (17%)
60-90 m	5,620 m (29%)	20 m (2%)	0 (0%)
>90 m	8,450 m (44%)	0 (0%)	0 (0%)

Table 3-2: Further breakdown of dune width along open coast groups.

Group	Profiles	Length of shorelines within attributed Dune width (m)			
		0-30m	30-60m	60-90m	>90m
A	Brooklands spit	0 m	260 m (35%)	480 m (65%)	0 m
B	Northern Open Coast Dune Profiles	370 m (3%)	3420 m (30%)	2000 m (17%)	5700 m (50%)
C	North New Brighton Surf Club	170 m (85%)	30 m (15%)	0 m	0 m
D	New Brighton Surf Club/Hot pools	190 m (100%)	0 m	0 m	0 m
E	New Brighton Pier	260 m (67%)	130 m (33%)	0 m	0 m
F	Open Coast dunes profiles south of Pier	30 m (1%)	180 m (3%)	2440 m (46%)	2620 m (50%)
G	Southshore Spit	0 m	100 m (11%)	700 m (75%)	130 m (14%)

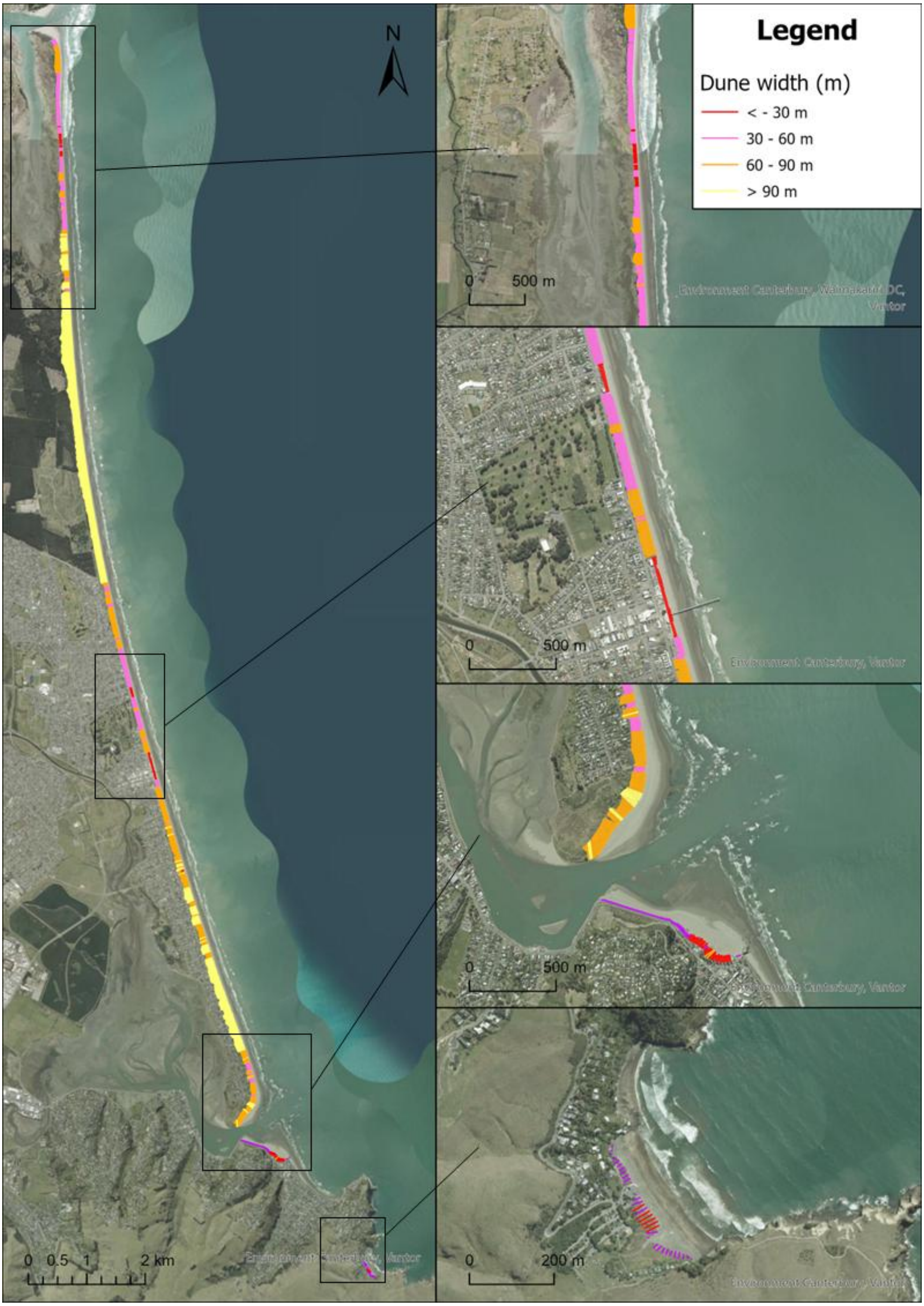


Figure 3-4: Present day dune width along the open coast, Sumner and Taylors Mistake.

3.2.1.1 Current dune width in relation to storms

An analysis has been completed to assess how the current dune widths may respond to storm events of varying magnitudes (1-year ARI, 10-year ARI, and 100-year ARI). Table 3-3 summarises the lengths of shoreline where the existing dune morphology could be breached under each storm cut scenario, with the spatial distribution shown in Figure 3-5.

Table 3-3: Summary of length of shoreline along the present dune that could be breached by various ARI storm cuts.

	Length of shorelines with attributed dune width		
Present Day Dune width	**Open Coast**	**Sumner**	**Taylors Mistake**
1 Year - ARI	0m	40 m (4%)	110 m (31%)
10 Year - ARI	0m	510 m (56%)	130 m (36%)
100 Year - ARI	550 m (3%)	610 m (67%)	250 m (69%)

Along the open coast, the current dune widths are sufficient to withstand both the 1-year and 10-year ARI storm cuts. Under a 100-year ARI event, however, approximately 550 m of the open coast is susceptible to full erosion and potential breaching. These areas include:

- Approximately 140 m through the central section of Brooklands Lagoon Spit.
- Approximately 160 m in front of the North New Brighton Surf Club, where erosion could undermine the existing seawall.
- Approximately 250 m between the New Brighton Surf Club and the car park south of the Pier, where low man-made dunes backed by built structures could be undermined.

At Sumner, dune widths are limited, and the analysis indicates that breaching could occur along substantial portions of the shoreline under both 10-year and 100-year ARI storm cuts. Along most of the ‘breached’ system there are structures that may be undermined.

At Taylors Mistake, the narrow and discontinuous dune system is similarly susceptible, with up to 69% of the frontage susceptible to breaching during a 100-year ARI event.

Figure 3-5: Mapping results of the dune width analysis, showing where the present dune could potentially breach from various ARI events - 100-year ARI (yellow), 10-year ARI (orange), 1-year ARI (red).

3.2.1.2 Remaining dune widths post-storm

An analysis has been undertaken to assess the remaining width of the present-day dune following a large storm event, and to determine whether this residual width would be sufficient to withstand a subsequent storm or allow the dune to recover between events. The method subtracts the projected storm cuts (Section 2.1.2) from the current dune width, then compares the remaining width with the storm cut expected from a storm of the same magnitude. In other words, the analysis evaluates whether the post-storm dune width is adequate to resist another event of similar size.

Mapping outputs highlight areas where the remaining dune width is insufficient under current conditions: red indicates locations where the dune would not have enough width after a 1-year ARI storm to withstand another 1-year ARI event; orange indicates the same for a 10-year ARI storm; and yellow indicates insufficient width following a 100-year ARI storm. These areas represent sections of dune that may be susceptible to repeated storm impacts.

The mapping results of this analysis are shown in Figure 3-6. From north to south, the key susceptible areas under present day conditions are:

- **Brooklands Lagoon/Spencer Park** - Most of the Brooklands Lagoon Spit is susceptible to erosion from sequential storm events. The majority of the spit would not withstand two consecutive 100-year ARI storms (yellow on the map), and several narrower sections could be breached by sequential 10-year ARI storms.
- **North New Brighton Surf Club - Community Centre** - There is generally no dune in front of this section of coast. Sand accumulates intermittently but is regularly cleared to prevent windblown sand affecting the car park and nearby properties. The small mound that forms in front of the backstop seawall is insufficient to withstand two significant storm events and could lead to undermining of the seawall in an erosion event. Narrower areas toward the southern end would not withstand sequential 10-year ARI storms.
- **New Brighton Surf Club - Pier -** This area contains small, low, man-made dunes in front of a seawall, providing a limited buffer. As with North New Brighton, the area is susceptible to erosion from sequential 100-year ARI storms, with smaller sections also susceptible to sequential 10-year ARI events.
- **Southshore Spit -** The southern end of the spit is susceptible to erosion from sequential 1-in-100-year storm events.
- **Sumner -** The very narrow, low dune in front of the seawall along Main Road is not sufficient to withstand sequential 1-year ARI storms. However, this coastline is highly dynamic, and beach width and volume vary considerably, which may provide differing levels of protection depending on antecedent conditions. The wider, low dunes from the surf club through to Cave Rock are susceptible to sequential 1-in-100-year ARI storms.
- **Taylors Mistake -** Dune width varies along this section of coast. North of the surf club, the dunes are narrow and would not withstand sequential 1- to 10-year ARI events. Immediately south of the surf club, the dune is wider but still contains areas susceptible to sequential 1-in-100-year storms. South of the creek, the low dunes in front of the baches would not withstand sequential 1- to 10-year ARI events.

Figure 3-6: Mapping results of the dune width analysis, showing areas susceptible to dune breaching from storm cut erosion.

3.2.2 Overtopping of present-day dune crest in storms

A similar analysis to that described in the previous section has been undertaken to identify locations along the coastline where the present-day dune crest could be overtopped by wave-runup levels during 1-, 10-, and 100-year ARI storm events. This assessment compares the current alongshore dune-crest elevation with the calculated wave-runup levels (Section 2.2). The lengths of shoreline overtopped under each ARI scenario are summarised in **Table 3-4** and mapped spatially in **Figure 3-7**. A further breakdown of where dune crest along the open coast is overtopped in the same conditions is presented in **Table 3-5**.

Table 3-4: Length of current dune crest overtopped by static and dynamic (wave runup) water levels in a 1 in 1-, 10-, and 100-year ARI event.

		Length of shoreline susceptible to being overtopped (m)					
		1 year ARI		10 Year ARI		100 Year ARI	
Area	Total Shoreline length (m)	Static	Dynamic	Static	Dynamic	Static	Dynamic
Open Coast	19,210	0	820	0	1,080	30	1,290
Sumner	910	10	890	30	900	80	910
Taylors Mistake	360	10	350	10	360	20	360
Yellow = 10-30% of shoreline overtopped; Orange cells = 30-50% of shoreline overtopped; Red Cells = >50% of shoreline overtopped.							

Table 3-5: Further breakdown of length of dune crest overtopped on the open coast by static and dynamic (wave runup) water levels in a 1-, 10-, and 100-year ARI event.

		Length of shoreline susceptible to being overtopped (m)					
		1 year ARI		10 year ARI		100 year ARI	
Group	Profiles	Static	Dynamic	Static	Dynamic	Static	Dynamic
A	Brooklands spit	0m	50m (7%)	0m	50m (7%)	0m	80m (11%)
B	Northern Open Coast Dune Profiles	0m	30m (<1%)	0m	70m (1%)	0m	70m (1%)
C	North New Brighton Surf Club	0m	160m (80%)	0m	160m (80%)	0m	170m (85%)
D	New Brighton Surf Club/Hot pools	0m	140m (74%)	0m	160m (84%)	20m (11%)	180m (95%)
E	New Brighton Pier	0m	260m (67%)	0m	270m (69%)	10m (3%)	270m (69%)
F	Open Coast dunes profiles south of Pier	0m	10m (<1%)	0m	20m (<1%)	0m	30m (1%)
G	Southshore Spit	0m	170m (18%)	0m	350m (38%)	0m	490m (53%)
Yellow = 10-30% of shoreline overtopped; Orange cells = 30-50% of shoreline overtopped; Red Cells = >50% of shoreline overtopped.							

Table 3-4 shows that the present dune crest would be completely overtopped during significant dynamic water-level events at both Sumner and Taylors Mistake. Along the open coast, approximately 0.8-1.2 km of dune crest is currently susceptible to dynamic overtopping. These results are consistent with the dune-width analysis in Section 3.2.1, with the following areas identified as susceptible to dynamic overtopping during high water-level events:

- Brooklands Lagoon.
- North New Brighton Surf Club to Community Centre.
- New Brighton Surf Club to the Pier.
- Southshore Spit.

- Sumner.
- Taylors Mistake.

There are very small areas that could be overtopped by static water levels in a 1-year ARI under present conditions (Sumner and Taylors Mistake). In a 100-year ARI, these lengths of shorelines are potentially overtopped by static water level increase in Taylors Mistake and Sumner, which will also occur along a short distance of shoreline (30m) around the New Brighton Surf Club/Pier area.

Figure 3-7: Locations along the shoreline where the current dune crest could be overtopped by runup water levels (e.g. dynamic overtopping) in a 1-year ARI (red), 10-year ARI (orange), or 100-year ARI (yellow).

3.2.2.1 Overtopping of eroded dune crest from storm erosion

Additional analysis was undertaken to assess whether additional locations could be overtopped following storm events that erode the dune and potentially lower the crest (i.e., where the storm cut intersects the crest position). This scenario represents a sequence in which a storm erodes the dune, followed by a subsequent extreme water level event with elevated wave runup conditions.

The lengths of shoreline that could be susceptible to being overtopped under different combinations of storm cuts and water-level scenarios are presented in Table 3-6, and shown spatially for the open coast area in Figure 3-8. A further breakdown of this analysis on the open coast is presented in Table 3-7.

Table 3-6: Storm cuts from varying storms combined with overtopping from varying storms.

			Length of shoreline susceptible to being overtopped (m) in subsequent extreme water level event					
			1-Year ARI		10-Year ARI		100-Year ARI	
	Dune Crest Position	Total Shoreline Length (m)	Static	Dynamic	Static	Dynamic	Static	Dynamic
Open coast	2025 Dune Crest (No Storm)	19,210	0	820	0	1,080	30	1,290
Open coast	2025 Dune Crest (1-year ARI Storm cut)	19,210	0	850	0	1,110	40	1,320
Open coast	2025 Dune Crest (10-year ARI Storm cut)	19,210	20	1,370	20	1,700	70	1,850
Open coast	2025 Dune Crest (100-year ARI Storm cut)	19,210	230	1,980	340	2,460	510	2,700
Sumner	2025 Dune Crest (No Storm)	910	10	890	30	900	80	910
Sumner	2025 Dune Crest (1-year ARI Storm cut)	910	10	890	30	900	80	910
Sumner	2025 Dune Crest (10-year ARI Storm cut)	910	10	890	30	910	80	910
Sumner	2025 Dune Crest (100-year ARI Storm cut)	910	10	910	40	910	80	910
Taylors Mistake	2025 Dune Crest (No Storm)	360	10	350	10	360	20	360
Taylors Mistake	2025 Dune Crest (1-year ARI Storm cut)	360	10	350	10	360	20	360
Taylors Mistake	2025 Dune Crest (10-year ARI Storm cut)	360	10	350	10	360	20	360
Taylors Mistake	2025 Dune Crest (100-year ARI Storm cut)	360	10	350	10	360	40	360
Yellow = 10-30% of shoreline overtopped; Orange cells = 30-50% of shoreline overtopped; Red Cells = >50% of shoreline overtopped.								

This analysis shows that the length of shoreline susceptible to dynamic overtopping during extreme water-level events increases along the open coast as storm cuts extend landward, particularly for the 10-year and 100-year ARI storm-cut scenarios. A 1-in-100-year storm cut effectively doubles the length of shoreline that could be overtopped during an extreme water-level event - for example, under present conditions, approximately 820 m of dune crest would be overtopped in a 1-year ARI event, whereas following a 100-year ARI storm cut, this increases to around 1,770 m susceptible to being overtopped by the same water level.

Spatially, few new areas become susceptible to dynamic overtopping; however, the areas already identified as susceptible (Section 3.2.2) extend in length and become susceptible under more frequent ARI events. This effect is particularly pronounced along Brooklands Spit, where the narrow dune system could be breached during a storm and subsequently overtopped.

Along Sumner and Taylors Mistake, the low nature of the shoreline means the length of overtopped shoreline does not change significantly with additional storm cuts. However, the depth of overtopping during high water-level events will continue to increase.

Although it is not as significant as dynamic water level overtopping; small lengths of shoreline are susceptible to overtopping from static water level, which increases under the lower frequency event storm cuts (100-year ARI). Along the open coast, the 100-year ARI storm cut creates up to 510 m of shoreline that could become susceptible to overtopping with a 100-year ARI static water level. Along Taylors Mistake and Sumner beaches, due to the lower lying nature of the dunes, overtopping from static water level does not significantly increase under various storm cut scenarios.

Table 3-7: Breakdown of length of shoreline overtopped following various storm events along the open coast.

			Length of shoreline susceptible to being overtopped (m) in subsequent extreme water level events					
			1-year ARI		10-Year ARI		100-Year ARI	
Group	Dune Crest Position	Total Shoreline Length (m)	Static	Dynamic	Static	Dynamic	Static	Dynamic
A	2025 Dune Crest (No Storm)	740	0	50	0	50	0	80
A	2025 Dune Crest (1-year ARI Storm cut)	740	0	70	0	80	0	90
A	2025 Dune Crest (10-year ARI Storm cut)	740	0	90	0	140	0	150
A	2025 Dune Crest (100-year ARI Storm cut)	740	0	110	0	180	10	210
B	2025 Dune Crest (No Storm)	11,490	0	30	0	70	0	70
B	2025 Dune Crest (1-year ARI Storm cut)	11,490	0	50	0	70	0	90
B	2025 Dune Crest (10-year ARI Storm cut)	11,490	0	120	0	240	0	300
B	2025 Dune Crest (100-year ARI Storm cut)	11,490	140	670	200	880	290	930
C	2025 Dune Crest (No Storm)	200	0	160	0	160	0	170
C	2025 Dune Crest (1-year ARI Storm cut)	200	0	160	0	160	0	170
C	2025 Dune Crest (10-year ARI Storm cut)	200	0	160	0	160	0	170
C	2025 Dune Crest (100-year ARI Storm cut)	200	0	170	0	170	0	170
D	2025 Dune Crest (No Storm)	190	0	140	0	160	20	180
D	2025 Dune Crest (1-year ARI Storm cut)	190	0	140	0	160	20	180
D	2025 Dune Crest (10-year ARI Storm cut)	190	0	140	0	160	20	180
D	2025 Dune Crest (100-year ARI Storm cut)	190	0	140	0	160	20	190
E	2025 Dune Crest (No Storm)	390	0	260	0	270	10	270
E	2025 Dune Crest (1-year ARI Storm cut)	390	0	260	0	270	10	270
E	2025 Dune Crest (10-year ARI Storm cut)	390	0	260	0	270	10	270
E	2025 Dune Crest (100-year ARI Storm cut)	390	0	260	0	270	20	270
F	2025 Dune Crest (No Storm)	5,270	0	10	0	20	0	30

	2025 Dune Crest (1 year-ARI Storm cut)	5,270	0	10	0	20	0	30
	2025 Dune Crest (10-year ARI Storm cut)	5,270	0	10	0	20	0	30
	2025 Dune Crest (100-year ARI Storm cut)	5,270	0	40	0	90	0	180
G	**2025 Dune Crest (No Storm)**	930	0	170	0	350	0	490
	2025 Dune Crest (1-year ARI Storm cut)	930	0	160	0	350	10	490
	2025 Dune Crest (10-year ARI Storm cut)	930	20	590	20	710	40	750
	2025 Dune Crest (100-year ARI Storm cut)	930	90	590	140	710	190	750
Yellow = 10-30% of shoreline overtopped; Orange cells = 30-50% of shoreline overtopped; Red Cells = >50% of shoreline overtopped.								

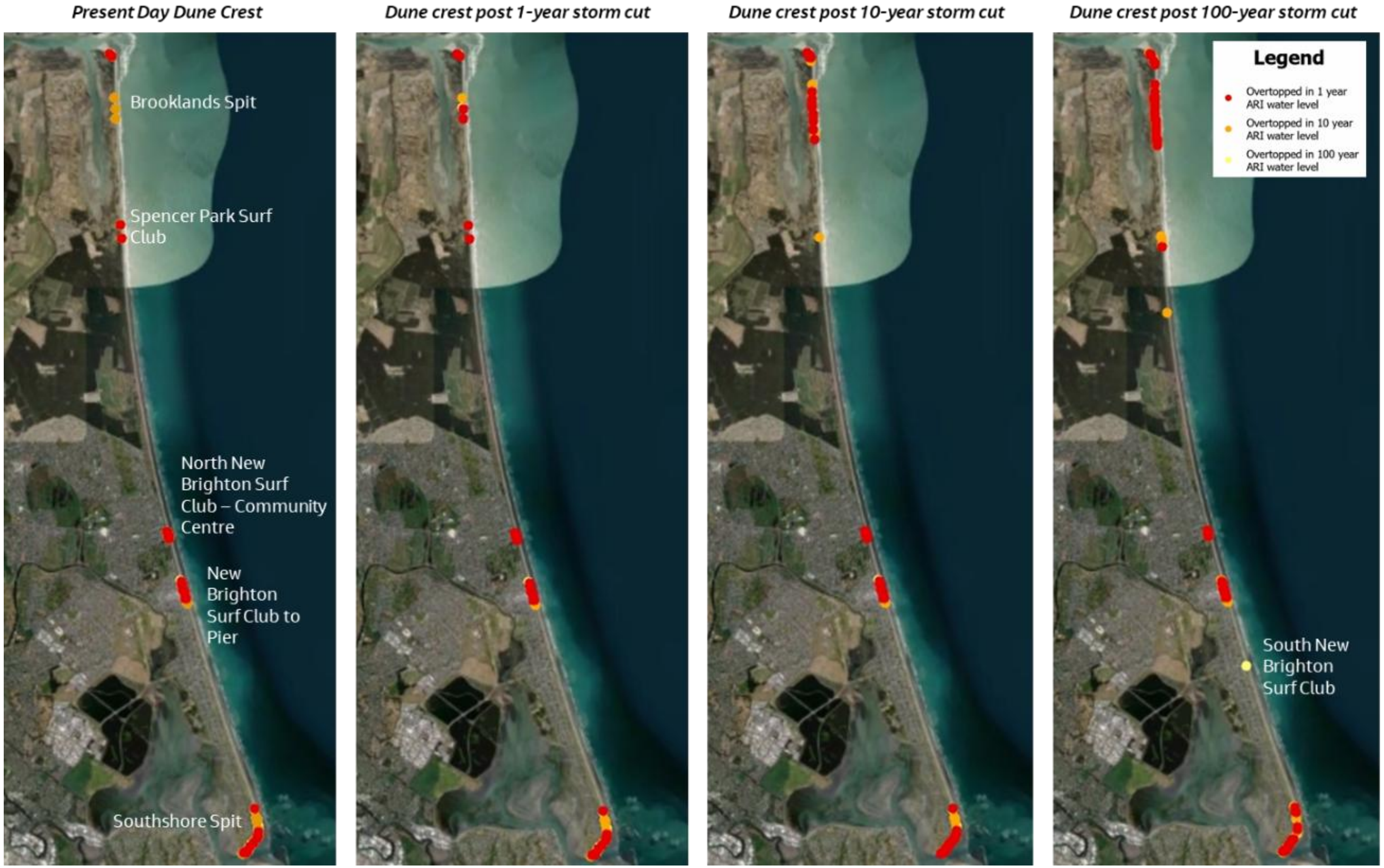


Figure 3-8: Locations of dynamic overtopping along the open coast present day dune crest (left), compared to potential dynamic overtopping of the dune crest following storm cut events (from 1 in 1 year, 1 in 10 year, and 1 in 100 year storm cut) that have eroded the dune. Variations in extreme run-up levels that may over top the dune are shown in yellow (overtopped in a 1 in 100 year water level); orange (overtopped in a 1 in 10 years water level); or red (overtopped in a 1 in 1 year water level).

3.3 Future combined dune erosion and flood hazards with SLR

The following sections present the analysis of dune erosion and overtopping under future SLR driven erosion, applying the methodology described in Section 2.3. Section 3.3.1 explores how dune width relates to future erosion influenced by SLR, storm impacts, and long-term shoreline trends. Section 3.3.2 evaluates dune crest elevations relative to projected wave-runup water levels after accounting for long-term erosion and the effects of sea-level rise on crest height.

3.3.1 Dune width reduction with SLR

An analysis was undertaken to assess the future remaining dune width under SLR scenarios of 0.2 m (2050), 0.6 m (2080), 1.2 m (2130), and 2.0 m (2150). The purpose is to determine whether the residual dune width (at various future time steps) would be sufficient to withstand a large storm or enable recovery between storm events. The method (Section 2.1.2) compares the projected future dune width - derived from Tonkin & Taylor's (2021) erosion estimates - with the expected storm cut from a large storm event (from Section 2.1.2). In essence, the analysis identifies locations where future dune width is unlikely to be adequate to withstand major storm impacts. This analysis assumes that the landward extent remains in its current location and does not migrate inland.

Table 3-8 summarises the length of shoreline where dune width is insufficient to withstand storm cuts associated with 1-, 10-, and 100-year ARI events. A further breakdown of how these lengths vary within the Open Coast, separated by Groups A-G (Table 2-3), is presented in Table 3-9.

Mapping outputs (Figure 3-9) for the open coast and Sumner illustrate these areas: red indicates locations where the remaining dune width would not withstand a 1-year ARI event; orange indicates insufficient width for a 10-year ARI event; and yellow indicates insufficient width for a 100-year ARI event. These areas represent dune sections that may be susceptible under future conditions with SLR.

Table 3-8: Length of shoreline which is narrower than ARI storm cut values, when taking into account longer term erosion with SLR.

		Length of shoreline with remaining dune width less than ARI storm cut values											
	SLR	0.2m SLR 2050			0.6m SLR 2080			1.2m SLR 2130			2.0 m SLR 2150		
Area	Total Shoreline Length (m)	1 ARI	10 ARI	100 ARI	1 ARI	10 ARI	100 ARI	1 ARI	10 ARI	100 ARI	1 ARI	10 ARI	100 ARI
Open Coast	19,210	800	980	1,620	1,000	1,770	3,740	3,980	5,230	6,780	9,060	9,420	11,460
Sumner	910	590	610	740	590	680	860	810	880	910	880	910	910
Taylor's mistake	360	300	320	330	360	360	360	360	360	360	360	360	360
Yellow = 10-30% of shoreline width < storm cut width; Orange cells = 30-50% of shoreline width < storm cut width; Red Cells = >50% of shoreline width < storm cut width.													

Table 3-9: Further breakdown of remaining dune width relative to ARI storm cut values along the Open Coast.

		Length of shoreline with remaining dune width less than ARI storm cut values											
	SLR	0.2m SLR 2050			0.6m SLR 2080			1.2m SLR 2130			2.0 m SLR 2150		
Group	Total Shoreline Length (m)	1 ARI	10 ARI	100 ARI	1 ARI	10 ARI	100 ARI	1 ARI	10 ARI	100 ARI	1 ARI	10 ARI	100 ARI
A	740	100	120	130	130	150	160	670	740	740	740	740	740
B	11,490	60	200	640	180	840	2,520	2,480	3,540	4,470	5,200	5,220	6,430

		Length of shoreline with remaining dune width less than ARI storm cut values											
	SLR	0.2m SLR 2050			0.6m SLR 2080			1.2m SLR 2130			2.0 m SLR 2150		
Group	Total Shoreline Length (m)	1 ARI	10 ARI	100 ARI	1 ARI	10 ARI	100 ARI	1 ARI	10 ARI	100 ARI	1 ARI	10 ARI	100 ARI
C	200	160	170	190	170	180	190	190	190	190	190	190	190
D	190	190	190	190	190	190	190	190	190	190	190	190	190
E	390	250	260	340	290	370	380	380	380	390	390	390	390
F	5,270	40	40	40	40	40	40	40	40	170	1,700	1,930	2,590
G	930	0	0	90	0	0	260	30	150	630	650	760	930
Yellow = 10-30% of shoreline width < storm cut width; Orange cells = 30-50% of shoreline width < storm cut width; Red Cells = >50% of shoreline width < storm cut width.													

Under 0.2 m SLR, the pattern of vulnerability is broadly consistent with the dune-width “hotspots” identified in Section 3.2.1. Key locations where dunes become too narrow to withstand storm induced erosion include Brooklands Spit, the North New Brighton Surf Club and Community Centre frontage, the section from New Brighton Surf Club to the Pier, and the dunes at Sumner and Taylors Mistake. These areas already exhibit limited dune width under present conditions, and the small increase in sea level does not substantially alter their susceptibility.

With 0.6 m SLR, the extent of the coastline susceptible to breaching increases noticeably. The shoreline between Waimairi Beach and New Brighton Pier becomes particularly susceptible, with dune widths projected to be insufficient to withstand a 1-in-100-year storm cut. Several sections within this reach will also be susceptible to 1-in-1-year and 1-in-10-year storm cuts, indicating reduced capacity for storm buffering and post-event recovery. Overall, the length of shoreline classified as susceptible more than doubles between the 0.2 m and 0.6 m SLR scenarios for each ARI event. For example, the length of coastline unable to withstand a 1-in-100-year storm cut increases from 1.6 km under 0.2 m SLR to 3.7 km under 0.6 m SLR.

At 1.2 m SLR, no significant new areas become susceptible; however, the severity and spatial extent of vulnerability increase substantially in locations already identified as being susceptible. In many of these areas, future dune widths fall below the threshold required to withstand even a 1-in-1-year storm cut, indicating extremely limited resilience. The shoreline between Waimairi Beach and New Brighton Pier becomes highly susceptible, as does Brooklands Lagoon Spit. Under this scenario, an estimated 21% (1-year ARI) to 35% (100-year ARI) of the open-coast shoreline could be susceptible to breaching. Vulnerability is even more pronounced along the at Sumner and Taylors Mistake: 89% (1-year ARI) to 100% (100-year ARI) of the Sumner shoreline, and 100% of the Taylors Mistake shoreline, may be unable to withstand storm-induced erosion.

Under 2.0 m SLR, nearly half of the open coast (47%) is projected to be susceptible to breaching from a 1-in-1-year storm cut. Key areas susceptible to breaching include Brooklands Lagoon Spit, the continuous shoreline from Waimairi Beach through to South New Brighton, and Southshore Spit. For a 1-in-100-year ARI event, approximately 60% of the open-coast shoreline is projected to be unable to withstand storm-cut erosion, indicating a substantial reduction in natural coastal buffering capacity under high SLR conditions.

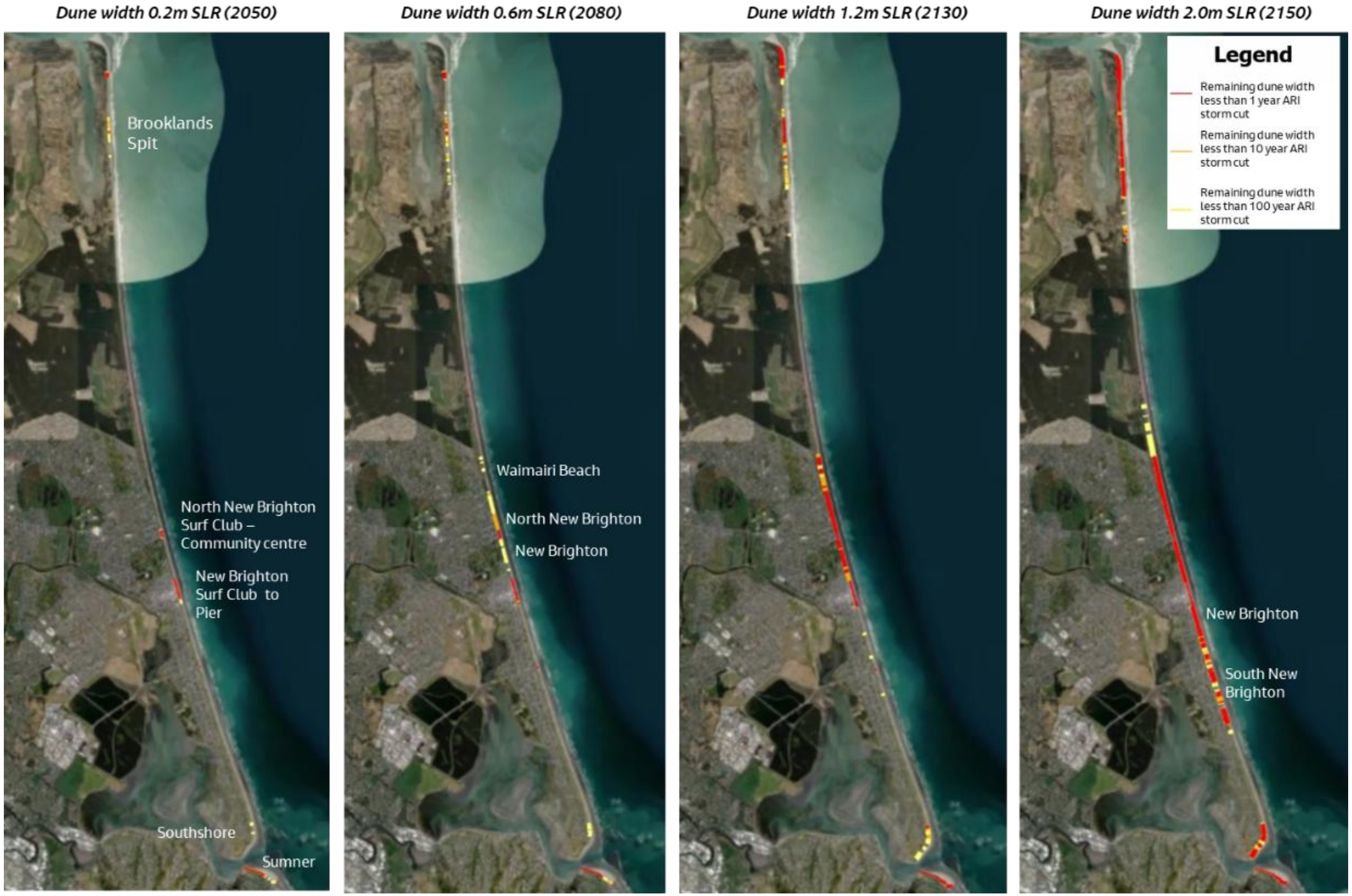


Figure 3-9: Series of maps of the open coast and Sumner with increasing SLR which show how the remaining dune width over time with erosion projections with SLR compare to calculated ARI storm cut values. Yellow lines indicate where the remaining dune width is less than 100-year ARI storm cut; orange lines indicate where the remaining dune width is less than 10-year ARI storm cut; and red lines indicate where the remaining dune width is less than a 1-year ARI storm cut.

3.3.1.1 Sensitivity testing - changes to sediment supply

Sensitivity testing was undertaken using available dune erosion mapping from Tonkin and Taylor (2021) to assess how changes in sediment supply from the Waimakariri River influence coastal erosion vulnerability. The three sediment supply scenarios from Tonkin and Taylor (2021) were considered: status quo supply, a -11% supply scenario and a +28% supply scenario[2], all assessed under 1.5 m SLR by 2130. This represents a high SLR scenario for 2130, meaning that even with no change in sediment supply, widespread erosion along much of the coastline would be expected.

The resulting length of shoreline where the remaining dune width (under 1.5 m SLR by 2130) is less than the projected storm cut ARIs under each sediment supply scenario is summarised in Table 3-10 and mapped in Figure 3-10. This analysis focuses on the open coast section only, as this area is directly influenced by sediment supply from the Waimakariri River.

The sensitivity results show that even with an increase in sediment supply, 4.4-7.5 km of shoreline could remain susceptible to storm cut breaching. This reflects the dominance of the high SLR scenario, where the impacts of SLR have a greater influence on dune vulnerability than sediment supply in some locations - particularly between New Brighton and Waimairi Beach, and along the Brooklands Lagoon Spit.

Under a decrease in sediment supply scenario, the same areas remain susceptible, with the extent of potential impact increasing southward to South New Brighton and further along the Southshore Spit.

Overall, the sensitivity testing indicates that even with a positive increase in sediment supply, the coastline from New Brighton to Waimairi Beach and the Brooklands Spit remains susceptible to breaching from storm cut erosion over this timeframe.

Table 3-10: Sensitivity testing results for length of shoreline where the remaining dune width is less that calculated storm cuts.

		Length of shoreline with remaining dune width less than ARI storm cut values								
	Sediment Supply & SLR Scenario	+28% Sediment Supply 1.5m SLR 2130			1.5m SLR 2130 (no sediment supply change)			-11% Sediment Supply 1.5m SLR 2130		
Area	Total Shoreline Length (m)	1-year ARI	10-year ARI	100-year ARI	1-year ARI	10-year ARI	100-year ARI	1-year ARI	10-year ARI	100-year ARI
Open Coast	19,360	4,420	5,520	7,460	5,980	6,900	9,200	6,640	8,240	9,820
Yellow = 10-30% of shoreline width < storm cut width; Orange cells = 30-50% of shoreline width < storm cut width; Red Cells = >50% of shoreline width < storm cut width.										

[2] These scenarios were derived by NIWA (2018) *Coastal Sand Budget for Southern Pegasus Bay stage B: Future sand budget;* which cover the maximum range of possible variation from present day in supply from the Waimakariri River to the coastal sediment budget associated with a 1.

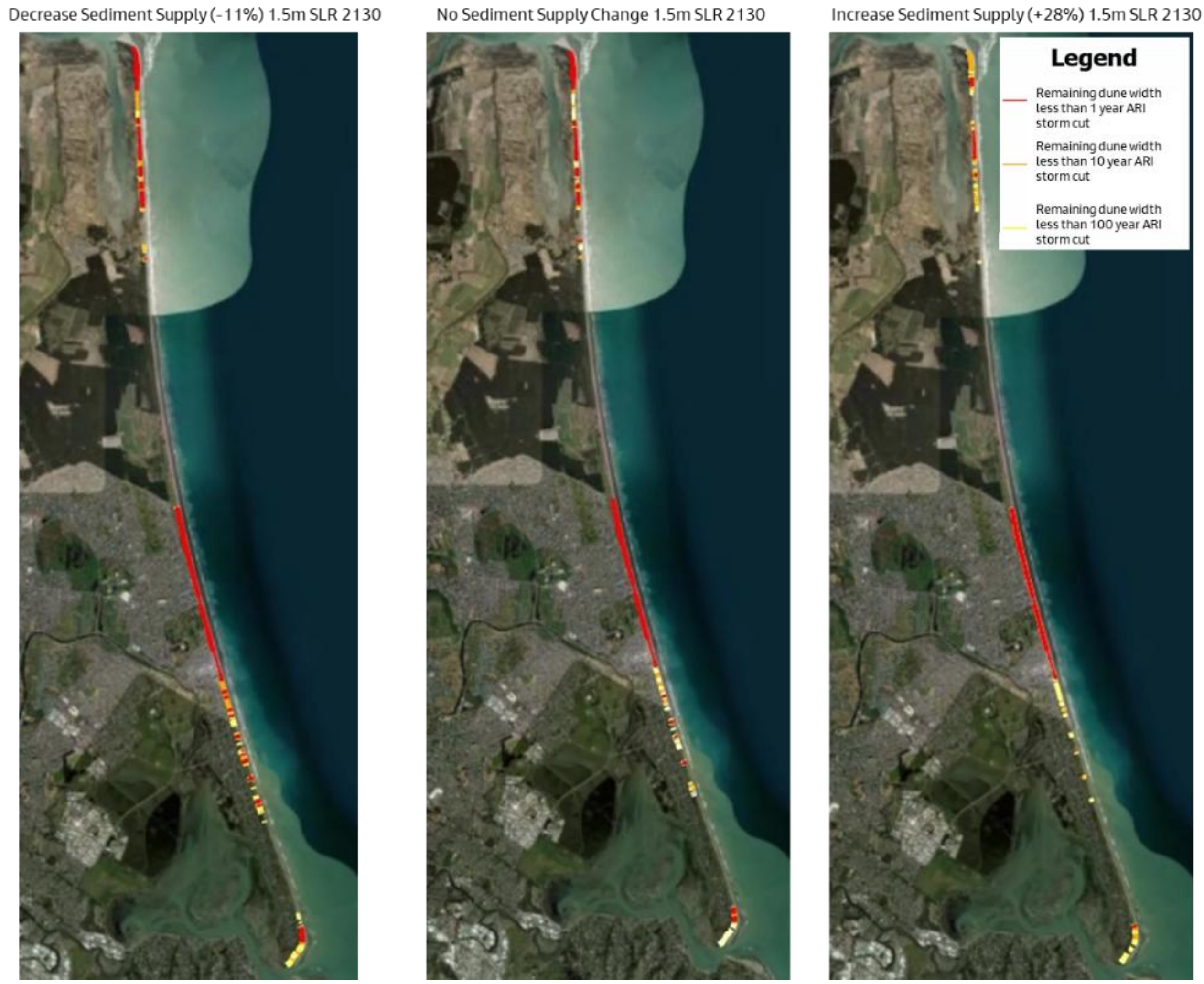


Figure 3-10: Sensitivity testing of sediment supply scenarios for remaining dune width and its ability to withstand storm cuts with 1.5m SLR by 2130.

3.3.2 Dune crest overtopping with SLR

A corresponding analysis was carried out to identify locations along the coastline where dune crests may be overtopped by wave-runup levels during future 1-, 10-, and 100-year ARI storm events under projected dune erosion and SLR. This assessment compares alongshore dune-crest elevations with calculated wave-runup levels (Section 2.2). The lengths of shoreline projected to be overtopped under each ARI event, based on future dune crest elevations (method described in Section 2.3.2), are summarised in Table 3-11 and shown spatially in Figure 3-11. Further breakdown of how these lengths vary within the Open Coast, separated into Groups A-G (from Table 2-3), is presented in Table 3-12.

Table 3-11: Length of Shoreline overtopped by various water levels with changing dune crest elevation under SLR scenarios.

			Length of shoreline susceptible to be overtopped by extreme water levels (m)					
			1 year ARI		10 Year ARI		100 Year ARI	
			Static	Dynamic	Static	Dynamic	Static	Dynamic
	Crest Position under SLR scenario	*Water level (present day) (mNZVD)** Total shoreline length (m)	*1.8*	*3.8*	*2*	*4.2*	*2.3*	*4.4*
Open Coast	0.2m Crest	19,360	0	1,820	20	2,410	40	3190
Open Coast	0.6m Crest	19,360	310	4,030	400	4,840	670	5,960
Open Coast	1.2m Crest	19,360	2,560	10,730	2,990	11,650	3,660	12,660
Open Coast	2.0m Crest	19,360	12,120	17,940	13,110	18,450	14,070	18,800
Sumner	0.2m Crest	910	10	900	20	910	80	910
Sumner	0.6m Crest	910	100	880	150	880	270	880
Sumner	1.2m Crest	910	310	850	340	850	700	850
Sumner	2.0m Crest	910	660	770	690	780	740	780
Taylors Mistake	0.2m Crest	360	10	280	10	320	60	330
Taylors Mistake	0.6m Crest	360	70	220	80	220	100	220
Taylors Mistake	1.2m Crest	360	20	190	60	190	140	200
Taylors Mistake	2.0m Crest	360	120	160	120	160	120	160

*Water levels have had corresponding SLR increment applied to assess overtopping hazard
Yellow = 10-30% of shoreline overtopped; Orange cells = 30-50% of shoreline overtopped; Red Cells = >50% of shoreline overtopped.

Table 3-12: Further breakdown Length of Shoreline overtopped along the open coast by various water levels with changing dune crest elevation under SLR scenarios.

			Length of shoreline overtopped by dynamic water (m)					
			1 year ARI		10 Year ARI		100 Year ARI	
			Static	Dynamic	Static	Dynamic	Static	Dynamic
Group	SLR Scenario	*Water level (present day) (mNZVD)** Total shoreline length (m)	***1.8***	***4.5***	***2***	***4.9***	***2.3***	***5.3***
A	0.2m Crest	740	0	70	0	170	0	270
A	0.6m Crest	740	90	560	140	620	150	730
A	1.2m Crest	740	380	740	420	740	530	740
A	2.0m Crest	740	740	740	740	740	740	740
B	0.2m Crest	11,490	0	200	0	360	0	840
B	0.6m Crest	11,490	110	1,600	110	2,140	130	2,950
B	1.2m Crest	11,490	1,550	7,590	1,800	8,300	2,240	9,030
B	2.0m Crest	11,490	7,820	10,920	8,560	11,140	9,170	11,230
C	0.2m Crest	200	0	170	0	170	0	180
C	0.6m Crest	200	0	180	0	180	140	190
C	1.2m Crest	200	180	190	190	190	190	190
C	2.0m Crest	200	200	200	200	200	200	200
D	0.2m Crest	190	0	170	0	180	0	190

			Length of shoreline overtopped by dynamic water (m)					
			1 year ARI		10 Year ARI		100 Year ARI	
			Static	Dynamic	Static	Dynamic	Static	Dynamic
Group	SLR Scenario	*Water level (present day) (mNZVD)** **Total shoreline length (m)**	***1.8***	***4.5***	***2***	***4.9***	***2.3***	***5.3***
	0.6m Crest	**190**	0	180	0	190	0	190
	1.2m Crest	**190**	0	180	50	180	60	180
	2.0m Crest	**190**	190	190	190	190	190	190
E	**0.2m Crest**	**390**	0	340	10	370	20	380
	0.6m Crest	**390**	0	370	0	380	50	380
	1.2m Crest	**390**	90	380	140	380	170	380
	2.0m Crest	**390**	390	390	390	390	390	390
F	**0.2m Crest**	**5,270**	0	80	0	230	0	400
	0.6m Crest	**5,270**	0	210	0	400	0	560
	1.2m Crest	**5,270**	0	720	0	930	0	1,210
	2.0m Crest	**5,270**	2,020	4,570	2,190	4,860	2,450	5,120
G	**0.2m Crest**	**930**	0	790	10	930	20	930
	0.6m Crest	**930**	110	930	150	930	200	930
	1.2m Crest	**930**	360	930	390	930	470	930
	2.0m Crest	**930**	760	930	840	930	930	930

*Water levels have had corresponding SLR increment applied to assess overtopping hazard
Yellow = 10-30% of shoreline overtopped; Orange cells = 30-50% of shoreline overtopped; Red Cells = >50% of shoreline overtopped.

With 0.2 m of SLR, several locations along the coast are projected to be overtopped by extreme dynamic water levels even during a 1-year ARI event. These locations are broadly consistent with those identified under present-day conditions and include Brooklands Spit, the Spencer Park Surf Club frontage, the section from North New Brighton Surf Club to the Community Centre, the reach from New Brighton Surf Club to the Pier, and an extended area around Southshore Spit. Short lengths of shoreline win each of the three study areas are susceptible to overtopping from static water level, however this is a negligible increase from present day.

With 0.6 m of sea-level rise, the extent of shoreline susceptible to dynamic overtopping increases. The overtopping area along Brooklands Lagoon extends further south, and the area around the Spencer Park Surf Club also expands. Consistent with the erosion-based breaching assessment, the North New Brighton shoreline becomes increasingly susceptible to overtopping under this scenario. The length of shoreline potentially overtopped by static water levels under various ARI events increases considerably, with up to 670 m of shoreline along the open coast potentially overtopped with a 100-year ARI static water level.

With 1.2 m of sea-level rise, approximately 55% of the open coast shoreline is projected to be susceptible to dynamic overtopping during a 1-year ARI water-level event. The total length of the reach from New Brighton to Brooklands Spit is projected to be overtopped, as is Southshore Spit. Smaller overtopped sections are also projected around the South New Brighton Surf Club and the adjacent northern dune. Overtopping from static water levels increases along the shoreline, with 2.5 km to 3.6 km of shoreline projected to be overtopped in 1 to 100 year ARI water levels.

Under 2.0 m of sea-level rise, overtopping becomes more widespread, with an estimated 93% of the shoreline overtopped during a 1-year ARI event. Overtopping from static water level also impacts 62% (12.1 km) of the shoreline in a 1-year ARI water level.

At Sumner and Taylors Mistake, the dune system is already projected to be almost entirely overtopped under present day extreme dynamic water levels, and this condition is expected to persist under future erosion and SLR scenarios. The slight reduction in overtopped shoreline lengths shown in Table 12 over time reflects the inland migration of the erosion line into higher ground. Although this indicates a loss of beach area, the higher land elevations behind the eroded shoreline may provide some additional protection from extreme water levels.

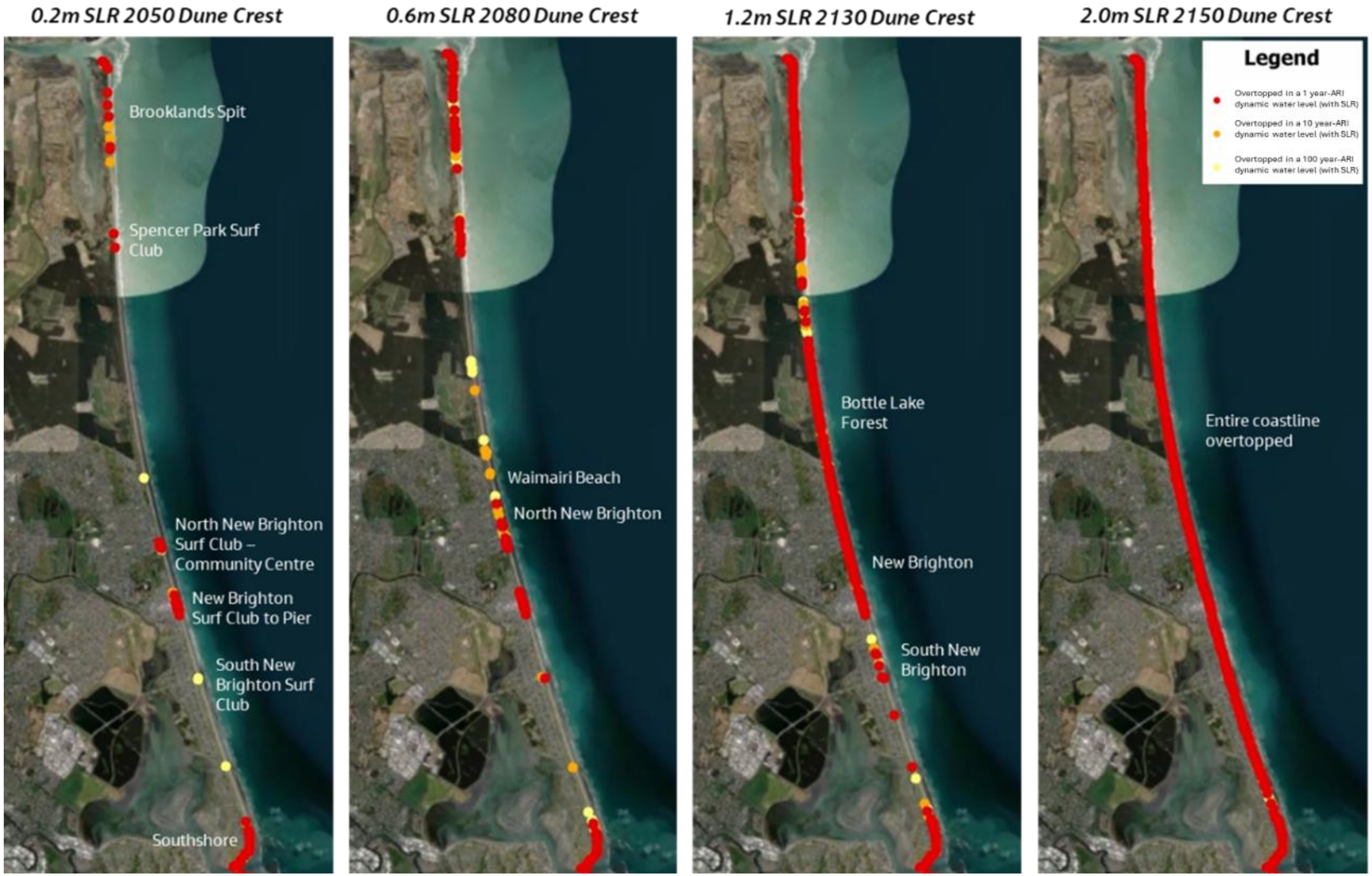


Figure 3-11: Locations of potential overtopping along the open coast present day dune crest (left), compared to overtopping of the dune crest with future erosion from SLR (0.2m SLR through to 2.0m SLR). Variations in extreme dynamic water levels that may over top the dune are shown in yellow (overtopped in a 100 year ARI dynamic water level); orange (overtopped in a 10 year ARI dynamic water level); or red (overtopped in a 1 year ARI dynamic water level).

3.3.2.1 Sensitivity testing - changes to sediment supply

Sensitivity testing was undertaken using dune-erosion mapping from Tonkin and Taylor (2021) to assess how changes in sediment supply from the Waimakariri River influence future susceptibility to dune crest overtopping as coastal erosion progresses. Three sediment-supply scenarios were evaluated: status quo supply, a -11% supply scenario, and a +28% sediment supply scenario, all assessed under 1.5 m of sea-level rise (SLR) by 2130. This represents a high SLR scenario for 2130, meaning that even without changes in sediment supply, widespread erosion and reduced dune crest elevations would be expected along much of the open coast.

The resulting length of shoreline where the dune crest elevation (under 1.5 m SLR) is lower than the projected extreme water levels under each sediment supply scenario - and therefore potentially overtopped - is summarised in Table 3-13, and mapped spatially in Figure 3-9. The analysis is limited to the open coast section, as this area is directly influenced by sediment supply from the Waimakariri River.

Table 3-13: Length of Shoreline potentially overtopped along the open coast by various extreme water levels due to changing dune crest elevation with 1.5m SLR by 2130, and changes to sediment supply.

		Length of shoreline overtopped by extreme water level (m)					
		1 year ARI		10 Year ARI		100 Year ARI	
		Static	Dynamic	Static	Dynamic	Static	Dynamic
Crest Position	*Water level (present day) (mNZVD)** **Total shoreline length (m)**	*1.8*	*3.8*	*2*	*4.2*	*2.3*	*4.4*
+28% Sediment Supply 1.5m SLR	**19,360**	4,160	10,340	4,930	11,420	5,850	11,840
1.5m SLR (no sediment supply change)	**19,360**	6,460	13,200	7,300	14,260	8,300	14,710
-11% Sediment Supply 1.5m SLR	**19,360**	8,010	14,570	8,760	15,500	9,760	16,030
*Water levels have had corresponding SLR increment applied to assess overtopping hazard ***Yellow = 10-30% of shoreline overtopped; Orange cells = 30-50% of shoreline overtopped; Red Cells = >50% of shoreline overtopped.***							

Under all sediment supply scenarios, potential overtopping is projected across a substantial proportion of the total shoreline length, with the extent increasing as sediment supply decreases. The sensitivity testing shows patterns consistent with those described in Section 3.3.1.1, where overtopping from wave runup is projected to affect more than half of the coastline during a 1-year ARI event, even when sediment supply increases. Figure 3-12 illustrates that potential overtopping is widespread along the open coast under all scenarios, with the most extensive impacts occurring in association with decreased sediment supply. Even with increased sediment supply, overtopping remains common, with only modest reductions in overtopping length - mainly along the Southshore coastline.

Overall, the results indicate that under a 1.5 m SLR scenario, sediment supply changes have a secondary influence compared with the dominant effect of SLR. Even with a positive sediment supply increase, most of the coastline remains susceptible to overtopping during extreme water level events, especially under dynamic conditions that incorporate wave runup.

Figure 3-12: Sensitivity testing of sediment supply scenarios for dune crest overtopped with 1.5m SLR by 2130.

4. Dune management and restoration

The purpose of this section is to determine where there are opportunities for 'no-regret' short term dune management interventions that will help the coast be more resilient to coastal erosion and overtopping in storms. This section describes the current dune management approach undertaken along the Christchurch coastline, determining its effectiveness with a comparison of relevant profile data, and identifies potential constraints for future dune management along the coast. This is followed by an assessment of initial triggers that could be used to help inform future management and adaptation planning.

4.1 Current dune management approach

A workshop was held on 9 December 2025 with Christchurch City Council Park Rangers (Jason Roberts, Robbie Hewson, and Pieter Borcherds), followed by an on-site meeting with Jason Roberts on 21 January 2026, to discuss the current operational approach to dune management and identify potential constraints for future management.

The current approach focuses on proactively planting in areas where the foredune is narrow and located seaward of infrastructure (e.g., roads and facilities) and communities. Rangers also respond to dune cuts following extreme events by repairing blowouts and restoring accessways - typically by pushing up sand to help restore natural dune form and speed up vegetation regeneration. Overall, the dunes are managed primarily for their natural hazard protection function, recognising that dune failure could have significant consequences for coastal communities.

Planting spinifex (Figure 4-1) is currently the primary and most effective tool available to coastal rangers for managing the dune system. Since the early 2000s, rangers have steadily increased their supply of spinifex seed to establish a native buffer in front of the marram-dominated dune. Small patches have been planted each year since 2001 as seed has become available, resulting in a near-continuous buffer along the embryo dune from approximately Sandra Street in South New Brighton through to Waimairi Beach Surf Club, and Sumner and Taylors Mistake (Figure 4-2).

Figure 4-1: Spinifex planting at dune toe near Beatty Street, South New Brighton, planted at the end of July 2025.

Spinifex plays a formative role in dune building. The species produces long, flexible runners that trap and hold wind-blown sand, initially forming small mounds or embryo dunes that gradually merge into a stronger, more resilient and more continuous lower foredunes. In favourable years (e.g., dry and windy conditions), spinifex can self-seed and spread rapidly through wind-dispersed seed heads, increasing vegetation density on the lower foredune with minimal maintenance.

Areas where spinifex has been planted are currently reducing storm impacts, generally preventing storm cuts from encroaching into the marram-dominated primary foredune. When only part of a planted area is eroded, natural recovery can occur as remaining runners extend down the dune and rebuild the lower dune toe. However, if all spinifex is lost back to the marram edge, recovery planting is required, often alongside reprofiling to create suitable conditions for regeneration. This is because the marram-dominated dune does not have the same ability to recover as evidenced by the steep scarp (which has not recovered for many years) in the foredune adjacent to Brooklands Lagoon. Park Rangers estimate that complete loss of a spinifex buffer from storm erosion would take approximately four years, with intervention, to return to a state where the embryo dune and vegetation could withstand storms, depending on seed availability.

In addition to spinifex planting, rangers use several other methods for ongoing dune maintenance:

- **Sand fences -** Low, permeable barriers that slow wind and trap moving sediment, helping to build and stabilise the dune toe. They are installed along much of the urban coastline, particularly where low, man-made dunes exist. At North New Brighton Surf Club, sand fences are cleared regularly (3-4 times per year) to prevent excess sand from blowing over the low seawall into the neighbouring carpark and road.
- **Reprofiling** - After storm events that create large vertical scarps, CCC can undertake dune-recovery activities under an existing resource consent (CRC951255), which allows for artificial adjustments to the beach profile, for foreshore regrade within the area from Waimairi Beach to Southshore, and to carry out full dune recontouring within the area between Heyders Road, Spencerville, and Caspian Street, South New Brighton.
- This reshaping supports faster re-formation of the lower dune toe by creating a more stable surface for vegetation to trap sediment and rebuild the dune.
- **Weeding and spraying -** As part of the ongoing planting programme, rangers carry out regular weeding and spraying to reduce invasive and pest species on the dune. This is particularly important for controlling lupin, which can shade out and kill spinifex higher up the dune system.
- **Maintenance of accessways -** Rangers regularly monitor and undertake maintenance of access ways to promote their use and to discourage pedestrians from trampling dune plants. This also includes signage, bringing awareness to people of the value of the dunes, and the importance of staying off the dunes.
- **Backshore planting** - Rangers have previously undertaken backshore planting to link with the wider dune network and improve stability in the backshore environment. This is now done less frequently, with current efforts focused primarily on planting the embryo dune.
- **Community awareness -** Rangers run community engagement and education sessions with local groups (e.g., planting initiatives during Sea-week and support local 'Dune Days') and through school programmes such as *Saving the Sand Dunes*. These activities help build understanding of the protective value of the dune system and promote appropriate behaviour, including using designated accessways and avoiding trampling of dune vegetation.

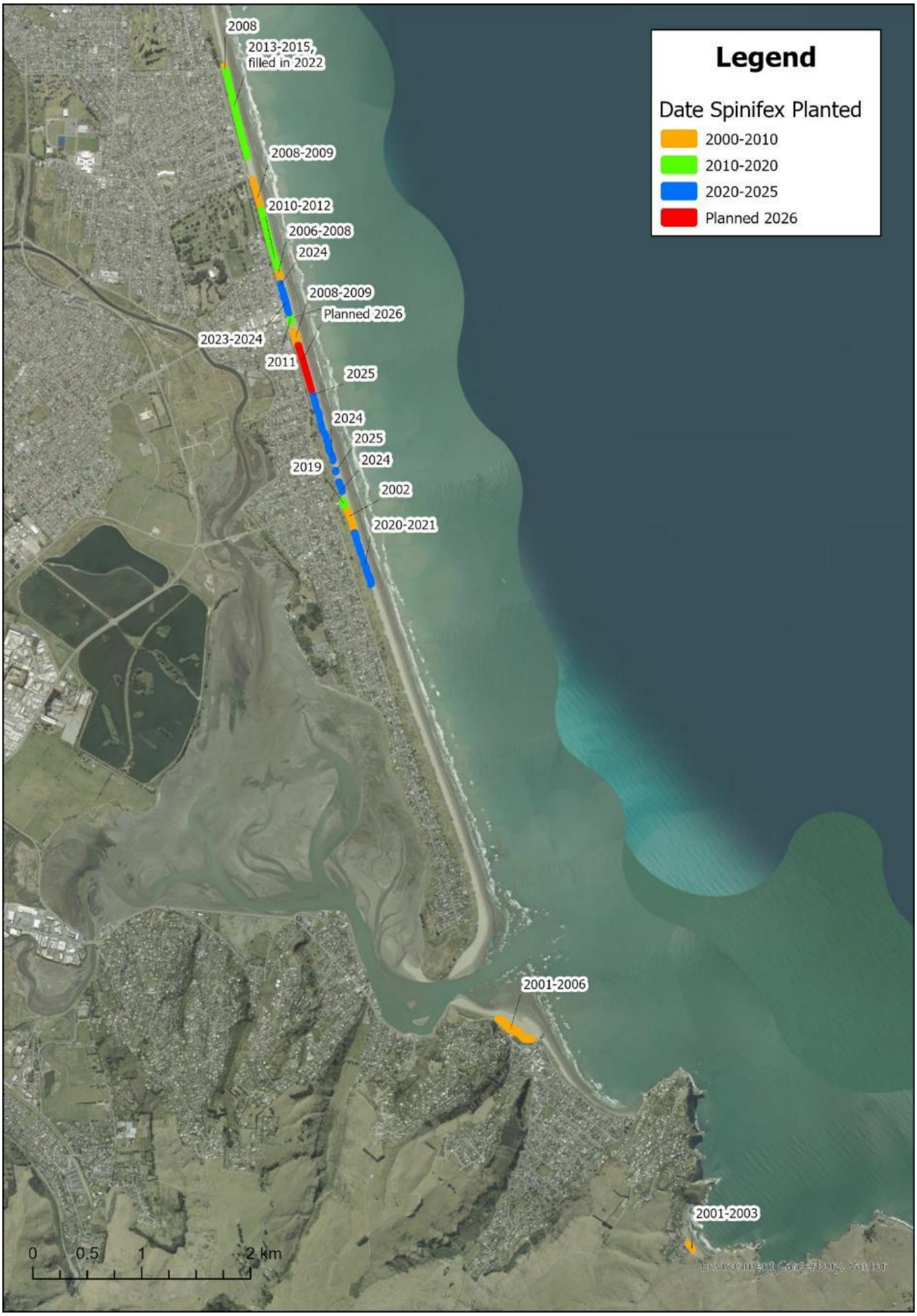


Figure 4-2: Areas of spinifex planting along the open coast, Sumner and Taylors Mistake. Dates informed by CCC Park Ranger Jason Roberts (pers comms, 2026). Note that there are some smaller scale plantings around accessways and by residents along Southshore that are not shown on this map.

4.1.1 Effectiveness of spinifex planting

Analysis of available data and information has been undertaken to assess how effective the spinifex planting approach has been in protecting the dune system. While several external factors influence dune dynamics (e.g., fluctuations in sediment supply, seasonal variability), this assessment provides a simplified evaluation of the role of spinifex in:

1. Promoting increased rates of embryo dune accretion and growth, and
2. Reducing the likelihood that storm erosion impacts the primary (marram-dominated) foredune.

Bergin (2008) documents spinifex planting undertaken along the open coast, including Sumner and Taylors Mistake, since the 1990s. Where possible, the sites described by Bergin have been aligned with Environment Canterbury beach profile records (Appendix A), enabling planting dates to be compared against profile-derived accretion and erosion trends over time. Four sites from Bergin (2008) were suitable for this analysis:

- **CCC1111 (planted July 2008) -** Open-coast dune south of the Waimairi Beach Surf Club. Cumulative dune-toe position fluctuates during the first ~10 years post-planting (LRR +0.88 m/yr), followed by a noticeable increase in accretion rates from ~2018 onwards (LRR +1.42 m/yr). During the large 2023 storm - which generated >10 m of erosion at the dune toe (estimate 10-year ARI) - the dune toe did not retreat back to the 2008 position (the presumed extent of the marram-dominated primary foredune at that time). This suggests that sediment accumulated since planting provided an effective buffer against storm impacts.
- **CCC0856 (planted 2008) -** Man-made dune on the south side of New Brighton Pier. Cumulative dune-toe position shows a similar pattern to CCC1111, with fluctuations over the first ~10 years post-planting (LRR +1.06 m/yr), followed by accelerating accretion from ~2018 (LRR +1.39 m/yr). Although minor fluctuations occur over the full record, dune-toe cuts have generally been smaller than those at CCC1111. A buffer of approximately 15 m has now developed, providing improved storm protection.
- **CCC0180 (planted 2003) -** Low, landscaped dune at Sumner Beach, west of Cave Rock. Cumulative dune-toe position shifts steadily seaward over the first 10 years (LRR +1.31 m/yr), with further acceleration from around 2013 (LRR +1.64 m/yr). Variability in dune-toe position has remained small due to how sheltered the site is; and, since 2012 the dune toe has not retreated back to its pre-planting position.
- **BP7985 (planted ~1996) -** Low dune system at Taylors Mistake. The profile record spans 1993-2025; however, the site was cut through by a stream around 2014, so profiles after this date are not appropriate for comparison. The site shows an initial phase of accelerated dune-toe accretion between 1996-2003 (LRR +1.13 m/yr), followed by a more stable, slower accretion rate between 2003-2014 (LRR +0.22 m/yr). After the 2014 stream breakthrough, dune-toe interpretation is no longer possible.

The cumulative dune-toe movements for these sites post-planting are shown in Figure 4-3. On average, across all four profiles, in the 10 years post-planting the dune toe accretes in the order of +0.9 m/yr; and accelerates once well established to around +1.4 m/yr. It is unknown how long the accelerated rate may continue in the future, or whether there will be a point in time at which it stabilises, particularly as the beach fetch reduces under rising sea levels. There is limited information around the timing of plantings at adjacent sites, however much of the open coast from South New Brighton to Waimairi, Sumner and Taylors Mistake is now planted with Spinifex. These four sites have allowed for analysis of how spinifex plantings have contributed to accretion rates over a long (nearly 20 year) record. In the future, further analysis will be able to be undertaken at additional sites to continue to test the effectiveness of the planting, particularly if further details are captured as to scale, location and time of plantings (improved record keeping).

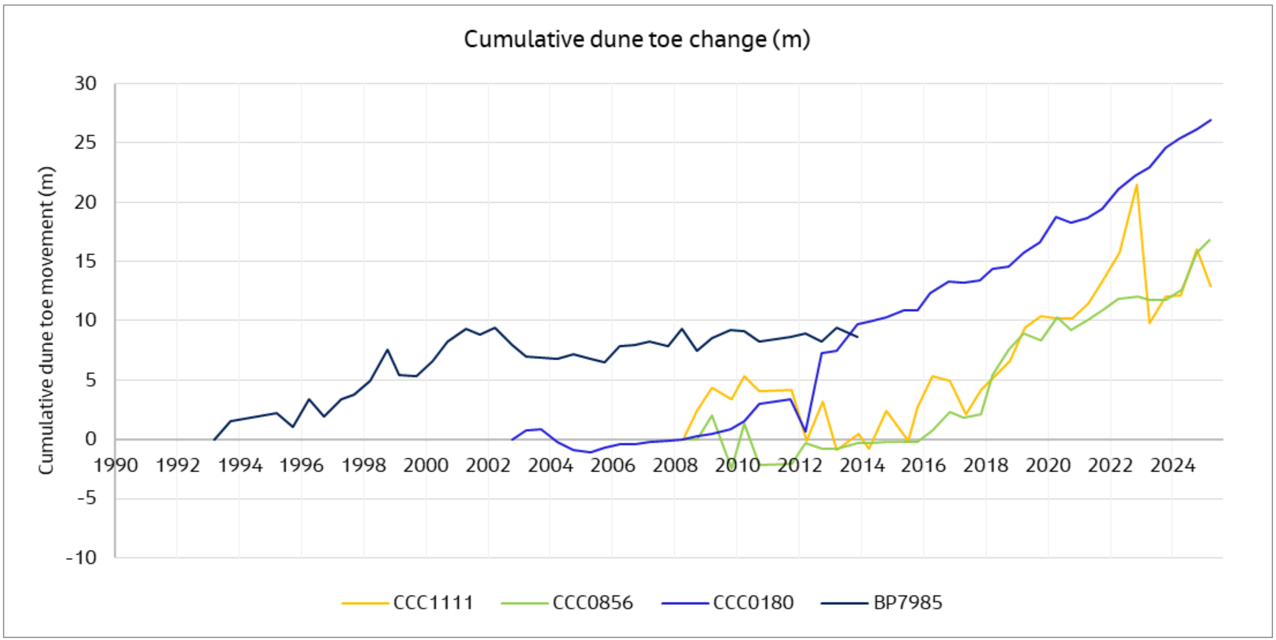


Figure 4-3: Cumulative dune toe position change (m) at planted sites.

This analysis suggests that spinifex planting is effective in enhancing dune resilience. The age at which spinifex plants can withstand (and recover from the effects of) storms along the Christchurch coastline is around 5 years (Thompson, 2021). At three of the four sites reviewed, dune toe accretion appears to accelerate approximately 10 years after planting, which likely corresponds to the point at which spinifex becomes mature, well-established, and densely distributed across the foredune's seaward face. This increased vegetation density enhances sand trapping efficiency, resulting in improved dune building and storm buffering capacity. This analysis also indicates that because of the effective dune toe accumulation, the spinifex planting creates an effective buffer to reduce storm cuts into the primary foredune, with the post-storm dune toe not receding back to pre-planting positions.

It is noted also that accumulation rates taken from the profile data are much higher than the generalised accretion rates reported by cell in the CHA (2021) report, which suggest lower accumulation rates (over a longer period, taken from aerial imagery) of +0.1 m/yr. This may be due to the plantings in many locations being very recent, so it is likely that the higher accumulation rates may only be captured in the more recent profile record, as opposed to the longer term aerial imagery record.

Although it is difficult to separate completely the general accretionary trend of the open coast shoreline with the effects of the spinifex planting, it can be concluded from the above analysis that the spinifex planting does not show any negative impacts on the dune toe accumulation rates, and is an effective management action in reducing storm cut effects on the primary foredune. It is highly unlikely that a marram-dominated system would have achieved the same degree of progradation, given marram's lower salt tolerance and its limited capacity for natural recovery following storm cuts. Planting spinifex on the embryo dune has therefore supported the progradation of the dune system by enabling it to make use of the current surplus of sediment reaching the coast.

4.1.2 How long might spinifex planting be effective for with SLR?

The analysis above indicates that spinifex planting is facilitating the development of an embryo dune in front of the primary foredune, thereby providing an additional protective buffer from storms. It is currently unknown how long this accretion trend will continue following planting; however, based on the analysis to date, it is assumed that dune-toe accretion may occur at rates between +0.9 m/yr and +1.4 m/yr. These values include the impacts of extreme storms (up to 10-year ARI storm cuts), but over the longer term do not account for the influence of relative sea level rise (RSLR) on the dune system.

As sea levels rise and the dune continues to accrete, a future 'pinch point' is likely to develop where the dry-beach width becomes too narrow to effectively dry and transport sand into the dune (fetch limited system). Figure 4-4 shows conceptually that while ongoing accretion provides storm-protection benefits, this same accretion may progressively reduce the dry-beach area, limiting the aeolian transport potential required for continued dune building.

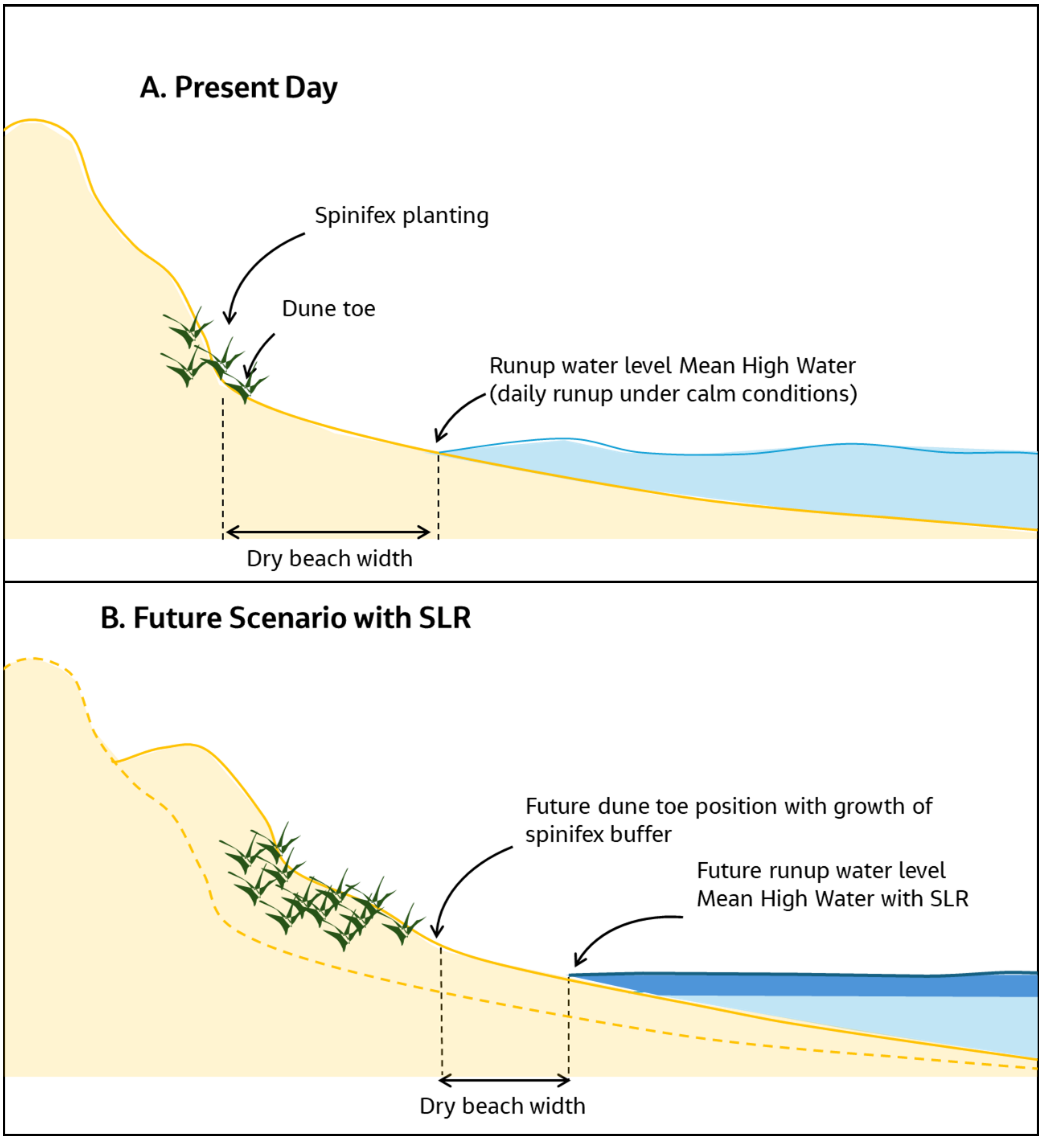


Figure 4-4: Conceptual diagram of how dry beach width could reduce with continued dune toe accretion from spinifex planting, and sea level rise - effectively limiting the supply of dry sand available to support in dune building.

For this analysis, the 'dry beach' is defined as the area between Mean High Water (Jacobs, 2025) plus a representative runup elevation[3] for everyday/calm conditions, and the dune toe (2.5 m contour) from CCC1111 profile data. Under these conditions, current dry-beach width is approximately 20 m (ranging

[3] Runup water levels were calculated using Mase (1989) and sensitivity-tested against Stockdon et al. (2008). Runup elevation was estimated using a beach slope of 0.05 (measured between the 0.5 m and 3 m contours), a significant wave height (Hs) of 1.25 m (representing the 'slight' wave condition from Environment Canterbury wave data), a wave period of 8 seconds, and Mean High Water level. Under these parameters, Mase (1989) produced an estimated runup elevation of 1.3 m NZVD2016, while Stockdon et al. (2008) produced a higher estimate of 1.6 m NZVD2016. These values were adopted as lower and upper bounds respectively for testing the timing of potential 'pinch points' associated with continued spinifex-driven dune growth.

between 16-22 m depending on the wave-runup elevation applied). Although limited research exists on the minimum dry-beach width required to sustain effective aeolian transport into a foredune (and we note this depends on a number of site specific factors), it is recognised that the present width is sufficient. However, if the dry beach narrows to below ~10 m, aeolian sediment transport processes are likely to become heavily disrupted.

Dry beach width was recalculated by translating the foredune seaward at the observed accretion rates from Section 4.1.1 (+0.9 to +1.4 m/yr) and comparing these trajectories with increasing wave runup water levels under an SSP58.5 RSLR scenario[4]. To evaluate the range of potential pinch point timings, the lower accretion rate (+0.9 m/yr) was paired with the lower wave runup elevation (1.3 m), and the higher accretion rate (+1.4 m/yr) was paired with the higher runup elevation (1.6 m). Table 4-1 presents the recalculated dry beach width over time under spinifex driven accretion, with highlighted values indicating instances where the beach width falls below the 10 m threshold.

Table 4-1: Dry beach width analysis with RSLR. Cells highlighted in red indicate where the dry beach width reduces below the 10 m threshold.

Timeframe	RSLR estimate (m) (SSP5-8.5)	Dry beach width +0.9m/yr dune toe accumulation & lower wave runup (1.3m)	Dry beach width +1.4m/yr dune toe accumulation & high wave runup (1.6m)
2020	0.00	22.3	16.8
2030	0.10	20.8	14.5
2040	0.21	19.1	13.1
2050	0.34	16.4	11.1
2060	0.43	14.4	9.7
2070	0.54	12.9	8.1
2080	0.66	11.1	6.3
2090	0.80	9.0	5.0
2100	0.94	7.3	3.8

This analysis indicates that if spinifex continues to enhance foredune growth, the dry-beach width is likely to narrow below the 10 m threshold sometime between 2060 and 2090. Once this threshold is crossed, dune-building processes could become constrained. As a sensitivity test, wave runup levels under a lower SSP2-4.5 RSLR scenario were tested, which indicated that with lower dune accumulation rates the dry beach width would not reduce to less than 10 m prior to 2100; and with higher dune toe accumulation rates the dry beach would reduce to less than 10 m around 2070. It is noted that these results reflect the impact on dry beach width at one location along the open coast beach; in some instances, this pinch point could be realised sooner or later than projected, depending on the local conditions.

These results suggests that continued dune management through spinifex planting remains an effective short to medium term strategy; however, over the longer term, a 'pinch point' could be reached at which this approach is no longer sufficient. At this point, if not before, measures should be put in place to allow for landward dune mobility. If measures are not in place to allow for this, there is a risk that the dune becomes starved of sediment and begins to erode more consistently, meaning greater chances of breaching and overtopping.

Although spinifex-driven accretion could theoretically continue until 2060 - 2090 without disrupting sediment-transport processes (or beyond this under a less precautionary SSP scenario), it is likely that other coastal drivers will have a greater influence on shoreline position before it reaches that point. These include shoreline retreat associated with sea level rise, and more frequent interaction of water levels (and wave

[4] Relative Sea Level Rise - which accounts with local estimates of post-seismic and inter-seismic vertical land movement (subsidence) into the future.

runup) with the dune toe as sea levels rise. These factors are expected to limit or halt continued seaward growth of the spinifex-dominated foredune prior to the anticipated pinch-point window.

Overall, this analysis suggests that the growth of spinifex at the dune toe is not expected to reach a critical 'pinch point' in the short term, and that spinifex planting should continue to be used as the predominant dune management method. In the near term, the key determinant of dune toe position will likely be the system's ability to recover after storm events (the time between successive events and the conditions being favourable for plant growth), rather than any constraint related to the dry beach width.

For longer term management, however, the findings indicate that the focus of intervention will need to shift from the dune toe to higher elevations within (and landward of) the dune system, as over time the effectiveness of the spinifex planting at the dune toe may decline as the vegetation interacts more frequently with elevated water levels. Longer term management is discussed in Section 4.2.4.

4.2 Priorities for dune management going forward

Dune management along the Christchurch coastline will need to balance short-term protection requirements with longer-term adaptation to changing coastal conditions. The analysis shows that spinifex planting remains an effective tool for building and maintaining a permanent embryo dune buffer in the near term; however, its long-term effectiveness is likely to diminish as the dune system interacts more frequently with elevated water levels and increased storm activity.

In the coming decades, dune management will need to shift from reinforcing seaward growth to supporting adaptive, resilient dune systems capable of recovering under rising sea levels and increasingly frequent storms. Spinifex planting remains a crucial near-term strategy, but proactive preparation for alternative long-term approaches will be essential for maintaining coastal protection along the Christchurch open coast.

The following priorities are recommended to guide future dune-management implementation.

4.2.1 Short term priorities

In the short term, dune management should continue to focus on the establishment and maintenance of the spinifex storm buffer. Key actions include:

- Maintaining and expanding the spinifex buffer along the open coast to ensure continued storm-protection benefits, and ensuring quality record keeping on the scale, location time (date) of plantings
- Preserving high-quality seed stock to support recovery following major storm events and ensure planting efforts remain viable.
- Prioritising post-storm recovery in locations where the spinifex buffer is significantly reduced and natural re-formation is unlikely without intervention.
- Supporting dune reformation through proactive management, such as targeted re-profiling where necessary to facilitate rapid re-establishment of vegetation.

4.2.2 Priority locations for short term management

Not all sections of the coastline face equal levels of exposure or urgency. The following areas should be prioritised based on the most noticeable changes in hazard exposure to erosion and flood hazards, and the role of the dune in protecting adjacent land:

- **North New Brighton -** Already well planted and known to be at risk with 0.6 m SLR. Maintaining rapid recovery after storm events will be critical due to increasing exposure pressures.
- **Lower lying dunes backed by walls in North New Brighton Surf Club to Community Centre -** While not a major focus of this study, water levels in extreme events are projected to overtop existing wall structures,

and also potentially scour under their foundations leading to failure. Planting a dune buffer in front of these wall structures will help dissipate wave energy reaching the structures, and provide a buffer to reduce scour impacts on the structure foundation. This is particularly important along the section of coastal wall between the North New Brighton Community Centre to the North New Brighton Surf Club, which is not currently planted and is regularly cleared of sand build up.

- **Lower lying dunes backed by walls in New Brighton (Pier to New Brighton) -** Similar to the point above, the lower lying dunes in front of walls between the New Brighton Pier and Surf Club are also susceptible to erosion and overtopping. Noting that some areas along here are already planted, continued work should be undertaken to provide a sufficient buffer to reduce wave energy reaching the walls, and therefore reduce the risk of scouring beneath the walls.
- **Lower lying dunes at Sumner and Taylors Mistake** - Continue building and strengthening dunes. Both sites are highly exposed and likely to experience significant storm-driven dune loss in the future, potentially removing much of the existing spinifex.
- **Brooklands Lagoon / Spit** - While direct risk to infrastructure is lower than other areas, any breaching of the spit could create noticeable changes in the hazard exposure resulting from the increased hydrological connection to the sea, with potential ecological impacts for the lagoon system. This area also provides an opportunity to trial management approaches for narrow, marram-dominated dunes.

4.2.3 Constraints and limiting factors for implementing short-medium term priorities

While several priorities have been identified to guide dune management efforts over the short to medium term, there are also a number of constraints and limiting factors that should be acknowledged. Addressing these constraints will be important to ensure the effectiveness and longevity of dune management actions:

- **Seed supply limitations -** Widespread erosion of the spinifex buffer would create a significant challenge for replanting, as seed supply would be insufficient to replace large areas simultaneously. While seed availability has improved over the past two decades, it remains limited in the event of large-scale loss, as well as with the increased maintenance and recovery required in the future with SLR. Although this constraint cannot be fully eliminated, the risk can be reduced by continuing to widen and strengthen the existing spinifex buffer, increasing the volume of locally available seed over time.
- **Dune maintenance and invasive vegetation -** Lupin remains a significant constraint on spinifex expansion. Its dense canopy introduces excessive shading, suppressing spinifex growth and preventing it from establishing higher on the dune profile. Effective removal or long-term control of lupin will be necessary to allow the spinifex buffer to continue migrating landward and upward as required.
- **Development proposals and private land ownership -** In some areas, CCC has limited mandate over development proposals located within or adjacent to the dune system due to land ownership. This can result in developments being progressed without CCC's awareness or ability to influence them, potentially undermining dune resilience or interrupting sediment and vegetation processes. Improved communication, and purchase or transfer of landownership may be required to mitigate these risks. The council could use Proposed Plan Change 12 (Coastal Plan Change) as a mechanism to gain greater control over development in these areas.
- **Financial constraints -** A key issue raised by CCC rangers during the workshop was the tight funding constraints that limit the ability to manage dunes at the scale required to maintain ongoing effective coastal protection. The long-term benefits of dune management, and the value of investing early in dune resilience, need to be better communicated and recognised to ensure that sufficient resources are available into the future. Adequate resourcing is particularly important given the likely need to accelerate management efforts to mitigate future erosion hazards associated with SLR, as well as to support trials aimed at developing alternative and more effective planting approaches. Insufficient maintenance and reduced investment in dune systems will increase the need for reactive works after storm events and heighten the risk of damage to landward infrastructure. Conversely, consistent maintenance and

proactive investment - including ongoing trials - will reduce the extent of post-storm recovery required and lower the risk to infrastructure that relies on dunes for protection over the longer term.

4.2.4 Preparing for long-term adaptation

Spinifex-based dune management is unlikely to remain effective over the long term due to:

- the anticipated emergence of a 'pinch point' where accretion processes are constrained by narrowing dry-beach width, and
- increasing erosion pressure due to the higher frequency of water levels (operating on higher levels due to SLR) interacting with the dune toe.

Future management of the dune system will require approaches that support landward migration and improve recovery following storms. Potential future management options could include changes to planting strategies and enabling dune retreat:

- **Adjusting the planting strategy:** Over the longer term, the current planting approach will become less effective as spinifex loses suitability under retreating dune conditions. Trials will be required along the open coast to understand:
  - whether spinifex can be used further up the dune face as the dune retreats;
  - how other dune plant species may support landward migration; and
  - whether selective vegetation removal is needed to facilitate dune movement.
- **Enabling dune retreat:** This study has identified that due to existing landward constraints, some sections of the open coast do not have sufficient space for the dune to migrate. A longer-term strategy will need to consider how additional space could be created - this may include removing infrastructure or protection structures, or changing land uses. Further work is required to determine how much land would need to be released, how this could be staged over time, and what on-the-ground actions (e.g., removal of backshore or marram vegetation) would be needed to support dune migration.

Short-term efforts should prioritise future-proofing trials, including:

- **Dune migration trials**, exploring how excavation, marram removal, native planting, and fencing interact to facilitate landward movement of the dune system.
- **Vegetation-transition trials higher on the dune**, assessing how planting spinifex or other native species higher in the profile affects dune crest height, vegetation stability, and post-storm recovery. This may include removal of lupin and other invasive species to help promote this growth and establishment. The working hypothesis is that establishing spinifex higher in the dune system may retain on-site seed sources after lower-dune erosion, improving resilience and reducing reliance on external seed supply.

It would be appropriate to first trial these in areas with limited landward infrastructure that are still representative of potential future states of the open coast dune if spinifex buffer is lost. This is likely to be away from communities and houses in the first instances. Appropriate places for trials may include Brooklands Spit, Bottle Lake, and the southern end of Southshore Spit.

4.2.5 Monitoring

CCC should continue to prioritise dune monitoring in addition to existing datasets (ECan beach profile monitoring, and CCC's more recently established event-based monitoring). New systems do not need to be complex or duplicate existing ECan beach-profile or storm-monitoring datasets. The highest value would come from:

- Developing a simple interface for CCC rangers to record operational activities (e.g. planting dates, locations, maintenance actions) and reactive works following storms.

- Creating a centralised record of dune condition (e.g. vegetation type and coverage (%), storm scarps/scour, dune elevation, width, foredune slopes), management interventions to support analysis of dune recovery, tracking the width of the spinifex buffer, and identifying areas requiring future resourcing.

Such an information system will support evidence-based decision-making and assist in prioritising management efforts over time.

4.2.6 Enhancing Community Knowledge

Community engagement remains an essential component of effective dune management along the Christchurch coastline. It is recommended that CCC continues to invest in:

- Public education on dune protection, including why dunes are critical for coastal resilience and how recreational behaviours can impact dune health.
- Promotion of appropriate access, reinforcing the use of designated pathways and discouraging trampling of dune vegetation.
- Ongoing ranger-led outreach, including school and community workshops, signage explaining the role of spinifex, and opportunities for community planting events.

These initiatives help build local understanding and support and will be important precursors to wider adaptation planning discussions in eastern Christchurch.

4.3 Potential triggers or limits to the current spinifex planting approach

As established in the previous sections, spinifex planting remains an effective approach for building and maintaining a foredune buffer by reducing storm-erosion impacts on the dune toe. This method is expected to continue providing protection until other factors - such as increased frequency of high water levels interacting with the dune toe as a result of SLR, causing erosion - begin to dominate. In the absence of these drivers, spinifex planting may remain effective until approximately 2060 - 2090 under RSLR scenarios. However, it is likely that storm-driven erosion and SLR-related impacts will affect some areas earlier, particularly in North New Brighton, where significant changes are expected around 0.6 m SLR (approx. 2070 - 2080).

To support long-term adaptation planning, a series of triggers should be defined to indicate when spinifex planting on the lower foredune is no longer effective and a shift in dune-management approach is required. Prior to these triggers being reached, trials should be undertaken to explore alternative dune-management options (e.g., modified planting strategies, marram removal, renourishment methods).

Two primary triggers are recommended.

4.3.1 Trigger 1: Storm-Driven - Spinifex dune buffer width reduces below the 1-in-10 Year storm cut

This trigger is a ‘soft’ trigger, or decision point, which would help identify when to undertake dune profile adjustments to help facilitate the natural recovery and reestablishment of the remaining spinifex planting to restore the lost embryo dune. This trigger could also signal the need for a change to planting strategy (to change from foredune spinifex planting), as the planted buffer continuously reduces in width.

This trigger is reached when the width of the spinifex dune buffer (embryo dune) becomes narrower than the 1 in 10 year ARI storm cut distance (e.g. 6 m to 25 m depending on location - from Table 2-3). Spinifex typically requires around four to five years to develop storm resistance and recover effectively after erosion. If a storm were to remove the entire spinifex buffer (along a significant distance of shoreline), managed reestablishment could be unlikely due to insufficient onsite seed supply, hence before this point is reached, dune profile adjustments and planning for a change in planting strategy should be undertaken.

Maintaining a buffer wider than the 1 in 10 year storm cut ensures that even if a more frequent 1 in 5 year storm occurs, some spinifex survives and can facilitate natural recovery, reducing reliance on external seed sources.

Once buffer width falls below the 1 in 10 year threshold - with limited ability to reestablish due to management constraints (seed supply limitations) - a change in dune management approach should be initiated. Timing of this trigger will vary across the coastline depending on local exposure, storm frequency, and post storm recovery potential.

Monitoring this Trigger

Monitoring can be undertaken by CCC park rangers using one or both of the following approaches:

- Visual assessments, comparing observed dune-buffer width with the estimated 1 in10 storm cut distance for each location (from Table 4).
- Spatial mapping, where the landward spinifex extent and dune toe is mapped and overlain with a 1 in 10 year storm cut buffer in GIS. Aerial photography or survey data can be reviewed every 1-2 years to determine whether buffer width has fallen below the threshold.

4.3.2 Trigger 2: Dry beach width reduces to <10 m

A second, longer-term trigger relates to the reduction of dry-beach width due to combined lower foredune growth and rising sea levels. Progressive narrowing of the dry beach reduces the area available for aeolian processes, eventually limiting the supply of sand to the foredune. Once the dry-beach width declines below approximately 10 m, sediment transport is likely to become increasingly constrained, and the spinifex-driven lower foredune is unlikely to continue developing effectively.

Reaching this threshold does not mean that spinifex becomes ineffective immediately; rather, it indicates that a transition to longer term management options will soon be required to ensure sustainable dune growth and maintenance of storm protection functions.

Monitoring this Trigger

Monitoring of dry-beach width should involve:

- Annual visual inspections by CCC park rangers during calm or everyday conditions to assess approximate dry-beach width.
- Five-yearly technical assessments using ECan beach-profile data, updated water-level datasets (e.g. updated Coastal Calculator), and best available information on RSLR projections to calculate dry-beach width with higher accuracy.

Given the longer-term nature of this trigger, consistent recording and trend assessment will be important for anticipating when management changes are needed.

5. Conclusions

The purpose of this study was to understand the impacts of storm erosion on the Christchurch coastline, both in how it may impact how we currently manage our coastline, and how it may impact the coastline in the future with SLR. Most of the changes we will encounter on our coastline, particularly over the next 30 years, will be driven by large storms cutting into the protective dune system. Over the short term, the impacts of these storms will disrupt how we currently manage our dune system, which is by planting spinifex to form more permanent and resilient lower foredunes. The impacts of successive storms will mean that repairing the spinifex buffer becomes increasingly difficult with limited seed supply and resources. Over the longer term, storms and SLR mean that eventually we will lose parts of our dune protection system, leading to lowered dune crest levels, and more frequent overtopping and flood hazards into the community behind the dunes.

5.1 Summary of spatial analysis

The spatial analysis, which considers the overtopping and erosion hazards along the coast both in storms and with SLR, indicates that at present, the key areas of concern along the open coast are:

- Brooklands Lagoon Spit;
- North New Brighton Surf Club;
- Between the New Brighton Surf Club and the car park south of the Pier;
- Sumner; and
- Taylors Mistake.

These areas exhibit dunes that are generally narrower than a 1-100 year storm cut, and may be susceptible to total dune loss (or at least crest lowering) following an extreme storm event of this magnitude. These dunes are also, in most cases, very low, and hence are susceptible to overtopping during storm events, increasing the inundation hazard to the land behind it. In several of these locations, there are walls behind the low-lying dunes. While this may form a final line of defence, erosion and profile lowering in an extreme storm may result in the undermining of the walls (including edge-effects on neighbouring areas of dune), resulting in failure.

With SLR, the foredunes that are width-restricted by urban developments will progressively narrow and crest elevations will lower as they are squeezed against landward constraints, reducing the ability of the dune system to recover between storms, or protect against overtopping. In addition to the key spots identified as being susceptible under present day conditions, these additional areas may become impacted with SLR, either from overtopping hazards (increasing flood risk to land behind the dune), or total loss of the dune due to erosion:

- **0.2m SLR:** No new areas, beyond what is already identified as susceptible - Brooklands Spit, North New Brighton, New Brighton (Club-Pier), Sumner, and Taylors Mistake
- **0.6m SLR:** The shoreline from Waimairi Beach to New Brighton Pier becomes particularly susceptible, with dune widths insufficient to withstand a 1-year ARI storm cut. Areas susceptible to overtopping increase, particularly across Brooklands Spit, Spencer Park, and North New Brighton.
- **1.2 m SLR:** Vulnerability intensifies markedly in already-exposed areas. Between 21-35% of the open coast is projected to be unable to withstand storm cuts in a 1-year ARI event, and ~55% of the open coast could be overtopped in this magnitude event.
- **2.0 m SLR:** Nearly half the open coast becomes susceptible to breaching from erosion in a 1-year storm. Major exposed areas include Brooklands Spit, the continuous reach from Waimairi to South New Brighton, and Southshore Spit. Although there are some areas along the open coast where the dune is projected to not be totally eroded, the dune crest has lowered to a level where overtopping could become nearly continuous (97% of shoreline length).

- At Sumner and Taylors Mistake, the potential for overtopping is already widespread and remains so under all future scenarios due to low crest elevations and limited space for landward migration.

5.1.1 Priority areas

Although much of the coastline will eventually be impacted under future SLR, the following areas should be prioritised due to their current vulnerability, exposure to early impacts, and the critical role of the dune system in protecting adjacent land:

- **North New Brighton -** Requires rapid post-storm recovery and ongoing spinifex maintenance; becomes susceptible under relatively low SLR (0.6 m).
- **New Brighton (Pier to New Brighton Surf Club; North New Brighton Community Centre to Surf Club) -** Lower-lying dunes backed by structures; prone to overtopping and scour during extreme events; dune widening would reduce structural stress.
- **Sumner and Taylors Mistake -** Narrow, low dunes; likely to experience significant storm-driven dune loss; continuous planting and maintenance required to sustain protection.
- **Brooklands Lagoon / Spit -** While fewer built assets are at risk, breaching could significantly alter lagoon hydrology and ecology. This area may be useful for trialing management interventions for narrow, marram-dominated dunes.

5.2 Summary of dune management and restoration

Spinifex planting on the foredune has been the primary form of dune management along the open coast for the last 2-3 decades. Spinifex planting is likely to remain effective in the short to medium term, enhancing dune resilience by promoting dune-toe accretion and improving storm recovery. Mature spinifex stands (10+ years) trap sand efficiently and in storm events have maintained dune toe positions seaward of pre-planting levels. This analysis has shown that this approach is an effective use of resources to reduce the impacts of erosion hazards. In the short term, management should continue to focus on sustaining this buffer through planting, seed preservation, post-storm repair, and targeted dune reprofiling where required after storms to help re-establish any lost spinifex.

Over the longer term, SLR and narrowing dry-beach width will limit how long spinifex can continue accumulating sand at the dune toe. It is anticipated that, in absence of very extreme storms, this could happen between 2060-2090. Management will need to transition toward upper-dune interventions, such as planting higher on the dune face to improve post-storm recovery, removing invasive species, and trialing methods that support landward dune migration. Proposed future-proofing trials include dune-migration experiments and vegetation-transition trials.

Two triggers have been developed to guide when current spinifex-focused management should shift to alternative approaches:

1. **Storm-driven trigger -** When the spinifex buffer width drops below the 1-in-10-year storm-cut distance, indicating insufficient vegetation to recover naturally after moderate events. This should trigger the need for profile modification to enable faster natural recovery of remaining spinifex, as well as act as a signal to start planning for a change in planting strategy.
2. **Dry beach width trigger-** When dry-beach width falls below 10 m, limiting aeolian sand supply and reducing the ability of the foredune to rebuild or migrate. This should act as a trigger for the shift in planting strategy and approach.

6. References

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Appendix A. ECan Beach Profile Locations

Figure 6-1: ECan Profiles from Waimakariri River Mouth to Bottle Lake Forest

Figure 6-2: ECan Profiles from Waimairi Beach to New Brighton.

Figure 6-3: ECan profiles from New Brighton to South New Brighton.

Figure 6-4: ECan profiles from South New Brighton to Southshore.

Figure 6-5: ECan Profiles at Sumner Study Area.

Figure 6-6: ECan Profiles at Taylors Mistake study area.

Appendix B. Community Summary

Purpose of this study

Christchurch's dune system provides an important natural buffer between the sea and the communities that live behind it, noting that flooding can also occur from the estuary and Avon River. Many people think of coastal erosion as something that will mainly affect us in the future, as sea levels rise. While long-term erosion will almost certainly happen, this study shows that storm-driven erosion is already affecting parts of the coastline today, and these impacts will increase as sea level continues to rise.

This assessment looks at how erosion and storm-driven flooding (overtopping) could affect the Christchurch coastline now and in the future, and what this means for how we manage the dunes.

Storms are a present-day hazard - not just a future one

Large storms can erode the front of the dune very quickly (known as storm-cut), sometimes by several metres in a single event. For example, the July 2001 storm eroded the beach up to 10 m along the New Brighton coast, and the 1992 storms eroded the beach up to 16 m in some areas.

While much of the open coast still has wide dunes that can absorb this storm erosion, in several places the dune is either narrow, low, or already modified by structures such that these areas are already susceptible to damaging erosion or overtopping in an extreme storm event. These areas include:

- Brooklands Lagoon / Spit
- North New Brighton Surf Club - Community Centre
- New Brighton Surf Club to New Brighton Pier
- Southshore Spit
- Sumner
- Taylors Mistake

Sea level rise will increase the combined impacts of erosion and coastal flooding

As sea level rises, the Christchurch coastline will be exposed to higher water levels and more frequent wave impacts on the dunes. Over time this means:

- The dune toe will be eroded more often, as there will be less time between successive storms for the dune to recover
- The protective width of the dune will shrink
- Crest elevations (the top of the dune) could be lowered if erosion extends landward of the current dune crest
- Overtopping could happen during smaller, more frequent storms

Eventually, in some locations, the dune will no longer be able to perform its protective function - allowing water to reach landward areas more often and more easily.

By the time sea level rises 0.6 m (expected around 2080 under current projections), the length of coast considered susceptible (to storm-induced erosion and overtopping) more than doubles. With 1.2 - 2.0 m of sea level rise, large parts of the open coast, and almost all of Sumner and Taylors Mistake, become susceptible to breaching or overtopping.

How we currently manage dune erosion

At present, Christchurch City Council manages dune erosion mainly through planting spinifex (a native sand-binding grass) along the lower dune (along with monitoring the coast, noting that this is primarily done by Environment Canterbury). Spinifex is effective because:

- It traps sand and builds a “buffer” in front of the main dune
- It recovers well after storms
- It can spread naturally when conditions are favourable
- It reduces the occurrence at which storms reach and erode the higher marram-dominated dune

The spinifex buffer now extends along much of the open coast, Sumner and Taylors Mistake and has proven successful in reducing storm cut erosion into the primary dune. However, this approach is likely to have limitations as conditions change.

Why spinifex planting will come under increasing pressure

Sea level rise will gradually narrow the dry beach - the area of beach that dries between tides and supplies sand to build dunes. Once the dry beach becomes less than about 10 metres wide, there won’t be enough space for wind to move sand into the dune, and spinifex can no longer build or maintain a strong buffer.

Based on current trends:

- The dry beach is expected to narrow below the 10 m threshold sometime between 2060 and 2090.
- This means spinifex planting will remain effective in the near to mid-term, but its ability to protect the dune will decline over time as sea level rise accelerates.
- More frequent storm erosion under rising sea levels will also increase the pressure on spinifex recovery, and seed supply may not meet future replanting needs after repeated storms.

Priority areas for management in the short-term

Some parts of Christchurch’s coastline are already showing signs of vulnerability. Without ongoing care, these dunes will be the first to lose their ability to protect nearby homes, roads, and public spaces. The key areas to focus on are:

- **North New Brighton (North of surf club) -** This area is planted and well looked after, but it still becomes highly susceptible to breaching and overtopping as sea level rises. After big storms, the dunes here need fast recovery work to ensure they can continue to protect the community.
- **Lower lying dunes backed by walls in North New Brighton Surf Club to Community Centre -** the sand dunes in front of the sea walls in this area are low, and often cleared. During very large storms, waves could wash over the top of the walls, and over time this can also wash sand out from underneath them, increasing the risk of failure of the wall. Adding a planted sand dune in front of the walls would help absorb wave energy before it reaches the wall and provide extra protection at the base.
- **Lower lying dunes backed by walls in New Brighton (Pier to New Brighton) -** Similar to the point above, the lower lying dunes in front of walls between the New Brighton Pier and Surf Club are also susceptible to erosion and overtopping. Noting that some areas along here are already planted, continued work should be undertaken to provide a sufficient buffer to reduce wave energy reaching the walls, and to reduce the risk of scouring beneath the walls.
- **Lower lying dunes at Sumner and Taylors Mistake -** These beaches have naturally low, narrow dunes. They are exposed to strong waves and are likely to lose sand quickly during future storms. Strengthening and rebuilding these dunes now will help delay damage later.
- **Brooklands Lagoon / Spit -** Although there are fewer public and private assets at risk here, a breach of the spit could change how the lagoon floods and functions.

Work in these areas now can help reduce future impacts and prolong the life of the existing dune system.

Planning ahead: why we need to trial new approaches now

Because spinifex planting will eventually become less effective on a narrowing and increasingly constrained dune system, this report recommends starting to test alternative or complementary dune-management methods now. This could include:

- Trialing spinifex planting higher up the seaward face of the dune.
- Testing different species or mixed plantings.
- Supporting landward dune migration where space allows, and through adaptation planning considering where land-use changes might be required to support future dune system functioning.
- Developing methods to accelerate post-storm dune recovery.
- Planning for where dunes may not be able to provide long-term protection.

Early trials will help identify which approaches work best in Christchurch's unique coastal environment before the need becomes urgent.

Summary of key messages:

- Erosion is not just a future issue - storms already impact the dunes today, and this will worsen with sea level rise.
- The effects of erosion will progressively reduce the protective function of Christchurch's dunes against coastal flooding over coming decades with SLR.
- Spinifex planting is effective now, but its long-term performance will be limited by sea level rise, storm frequency, and seed availability.
- Some areas need intervention now to help delay impacts and maintain protection for coastal communities over the long term.
- New dune-management strategies should be trialed in the coming years and decades, so Christchurch is prepared for a future where the current approach is no longer sufficient

Appendix C. Comparison of T&T (2021) Storm Cuts and Updated Storm Cuts from this report

Description	ECAN Profile	T&T 100 year ARI Storm Cut (m)	Recalculated Storm Cut ARI used in this study (m)					
			2-year ARI	5-year ARI	10-year ARI	20-year ARI	50-year ARI	100-year ARI
Waimakariri River mouth	CCC2200	-22	NaN	-17	-25	-28	-30	-30
Brooklands	CCC2070	-22	-6	-10	-13	-16	-20	-23
	CCC1972	-22	-6	-10	-13	-16	-20	-23
	CCC1891	-22	-6	-10	-13	-16	-20	-23
	CCC1755	-22	-6	-10	-13	-16	-20	-23
Bottlelake	CCC1565	-22	-6	-10	-13	-16	-20	-23
	CCC1400	-22	-6	-10	-13	-16	-20	-23
	CCC1273	-29	-6	-10	-13	-16	-20	-23
Waimairi Beach/North New Brighton	CCC1130	-29	-6	-10	-13	-16	-20	-23
	CCC1111	-29	-6	-10	-13	-16	-20	-23
	CCC1100	-29	-6	-10	-13	-16	-20	-23
	CCC1086	-29	-6	-10	-13	-16	-20	-23
	CCC1065	-29	-6	-10	-13	-16	-20	-23
	CCC1041	-29	-6	-10	-13	-16	-20	-23
North New Brighton Surf Club*	CCC1011	-29	-3	-6	-8	-12	-19	-26
New Brighton/Rawhiti Domain	CCC0952	-29	-6	-10	-13	-16	-20	-23
	CCC0924	-29	-6	-10	-13	-16	-20	-23
New Brighton Pier	CCC0889	-29	NaN	-9	-14	-17	-20	-22
	CCC0863	-29	-2	-4	-6	-8	-11	-14
	CCC0856	-29	-2	-4	-6	-8	-11	-14
	CCC0853	-29	-2	-4	-6	-8	-11	-14
New Brighton	CCC0848	-29	-3	-6	-8	-11	-14	-18
	CCC0815	-29	-3	-6	-8	-11	-14	-18
	CCC0781	-29	-3	-6	-8	-11	-14	-18
	CCC0748	-29	-3	-6	-8	-11	-14	-18
	CCC0703	-29	-3	-6	-8	-11	-14	-18
South New Brighton	CCC0650	-29	-3	-6	-8	-11	-14	-18
	CCC0600	-29	-3	-6	-8	-11	-14	-18
South New Brighton	CCC0531	-29	-3	-6	-8	-11	-14	-18
	CCC0513	-29	-3	-6	-8	-11	-14	-18
	CCC0471	-29	-3	-6	-8	-11	-14	-18
	CCC0431	-29	-3	-6	-8	-11	-14	-18
Southshore	CCC0396	-29	-3	-6	-8	-11	-14	-18
	CCC0362	-29	-3	-6	-8	-11	-14	-18
	CCC0350	-29	-3	-6	-8	-11	-14	-18
	CCC0300	-41	-6	-10	-14	-19	-29	-40
	CCC0271	-41	-6	-10	-14	-19	-29	-40
	CCC0190	-8	NaN	-5	-9	-13	-19	-24

Description	ECAN Profile	T&T 100 year ARI Storm Cut (m)	Recalculated Storm Cut ARI used in this study (m)					
			2-year ARI	5-year ARI	10-year ARI	20-year ARI	50-year ARI	100-year ARI
Sumner - Cave Rock	CCC0180	-8	NaN	-5	-9	-13	-19	-24
Taylors Mistake	BPN8010	-17	-6	-8	-10	-12	-14	-16
	BPN7998	-17	-6	-8	-10	-12	-14	-16
	BPN7985	-17	-6	-8	-10	-12	-14	-16
	BPN7975	-17	-6	-8	-10	-12	-14	-16