Changes in the Rakaia River mouth barrier dynamics.

In association with Bill Southward and the Rakaia Community.

Brennan A, Drummond L, Lu L, Ninnes J and Smith S, 2024, A study of the Rakaia Community.

1.0 Introduction

Bill Southward has requested research to investigate the everchanging environment at Rakaia Huts River mouth. This will allow Bill's years of data collection to be published into a useful document that should assist in flood management and community understanding.

The study site consists of a hapua formed at the mouth of the Rakaia River where the interaction between the river flow and coastal process creates an elongated water body parallel to the coast separated from the sea by a gravel barrier. On the terrestrial side of the hapua lies the infrastructure of the Rakaia Huts community, such as housing and a camping ground, both of which hold cultural significance to the Mana Whenua.

The Rakaia River and hapua are significant to the Rakaia Huts community, however flooding here occurs regularly. Extreme flooding events influenced by hydrology cause significant erosion and alteration to the river mouth and the barrier system (Browne, 2002; Horrell et al., 2012). Wave action further intensifies the challenges that face the community. The interaction between wave action and the dynamic river mouth can heighten the erosion rates and shift the sediment deposition patterns.

The dynamic nature of the barrier and subsequent flooding presents many challenges to the community of Rakaia huts, as the barrier is an important storm buffer for the local community and their infrastructure. Understanding long-term changes in its position is crucial to the longevity of the Rakaia community. Therefore, our project aims to:

1. Identify any significant change in the barrier and beach profile over the last 30 years.
2. Aid our findings using river flow and wave height and riverbed level data.
3. Understand how these changes have impacted on the local environment.

The effects of flooding at Rakaia Huts are becoming more prevalent, but there is a significant knowledge gap regarding how these patterns have evolved. This research aims to track changes in the barrier and 7 0 595.25 842 r.25 842 re

1.1 Background

The Rakaia River mouth is located south of Rakaia Huts in Canterbury, New Zealand (see Figure 1). The river mouth forms a hapua formed due to the interaction between the river flow and coastal processes creating an elongated water body parallel to the coast, separated from the ocean via a 3km long barrier (Kirk and Lauder, 2000) (see Figure 2). The Rakaia huts community holds residential housing, camping ground, boat ramp and is home to 85 permanent residents, plus 200 seasonal residents (Witter, 2008).

Figure 1. Map of Canterbury New Zealand, in relation to the study site.

Therefore, this causes barrier rollover and migration inland or the drowning of the barrier (Orford et al., 1991). The amount of sediment available affects the barrier's ability to migrate inland during over washing. Sediment must be transported from both behind and onto the barrier to promote migration and prevent the drowning of the barrier (Lorenzo-Trueba & Ashton, 2014). However, with globally increasing sea levels, more barriers are expected to drown in place as sediment supply cannot keep pace with the sea-level rise induced overwashing (Lorenzo-Trueba & Ashton, 2014).

Extreme flood events, such as the January 1994 flood and the December 2010 storm, have largely affected both the hydrology and ecology of the Rakaia River. The 2010 storm brought about 350mm of rain, causing one of the highest recorded river flows and expanded flood channels to about 400 meters wide. This led to increased erosion along gravel beaches (Horrell et al., 2012). The 1994 flood had a peak discharge of 5595 cubic meters per second that caused large amounts of coastal erosion, reshaped riverbanks, and reduced clast sizes downstream (Browne, 2002). These large flood events have damaged riparian vegetation, salmon migration routes and different aquatic habitats like fish spawning beds. This has also impacted groundwater recharge and wetland ecosystems (Unwin, 1997). As the increase in sediment deposition from these floods has changed ecosystems by reduced water quality, it has also buried aquatic habitats and shifted species distributions (Horrell et al., 2012; Hicks et al., 2020). Overall these extreme weather events have a large impact on the ecology and physical structure of the river.

2.0 Methods

The study analyses datasets collected over the last 30 years to investigate barrier position and migration at the Rakaia River hapua. The data included both beach and barrier profiles, riverbed cross-sections, river flow data, wave buoy information, and sediment dynamic. Much of the data was initially gathered by Bill Southward, with additional records like acquired from ECAN and National Institute of Water and Atmospheric Research (NIWA).

Barrier and beach profiles from three locations (south of the Rakaia River mouth, at the barrier, and north of the Rakaia River mouth) (see Figure 3) were accessed through Environment Canterbury. They were imported into Excel, and a visual map of the locations the surveys were taken along the coastline was created. The data was then adjusted to the Lyttleton 1937 local vertical datum for consistency. Barrier/beach profiles were then plotted in Excel, and a graduated colour ramp was used to highlight the physical differences to the coastal envelope of change over time.

River flow data was collected from the Fighting Hill stream gauge by NIWA. The data was first imported into excel, where the mean daily flow was calculated, then plotted as a time series graph spanning from 1991 to 2023. Time stamps of the barrier surveys were added to the river flow graph to add a visual representation of the survey timing. Flow rates were then statistically analysed using R Studio and an ANOVA test was run the study period is from 1991 to 2023, which determined the significance in changes to the river flow.

Wave data used was accessed from the ECAN/NIWA wave buoy (located 17km east of Le Bons Bay, at a Latitude 43° 45’ South, Longitude 173° 20’ East), as well as the hindcast wave model (1993–2019) (Hanson et al., 2009) and both were processed using Excel. The mean daily wave heights and directions were then calculated and plotted into a wave directional rose and two time series graphs. A wave threshold was set at the 95th percentile to identify any critical events. The use of wave thresholds, as discussed in Mortlock and Goodwin (2015), was applied to help identify critical wave heights with a major geomorphic impact on coastal processes such as sediment transport and erosion. The time stamps of the barrier surveys were added to the wave time series graph to add a visual representation of the survey timing.

Riverbed elevation data from NIWA (1989, 2010, and 2023) was processed using Excel, along with LINZ LiDAR (2015) digital elevation model data which was imported into ArcGIS along with the existing riverbed profile transect. Data from the 2015 dataset was then extracted along the transect and converted to the LDV37 datum to match existing datasets. The riverbed levels of each of the four years were then plotted on one line graph using excel to easily visualise any changes occurring along the same cross-section.

Figure 3gure

has shown a number of different shapes with multiple crests, the most obvious example being the bimodal shape visible in 1991 and 1992.

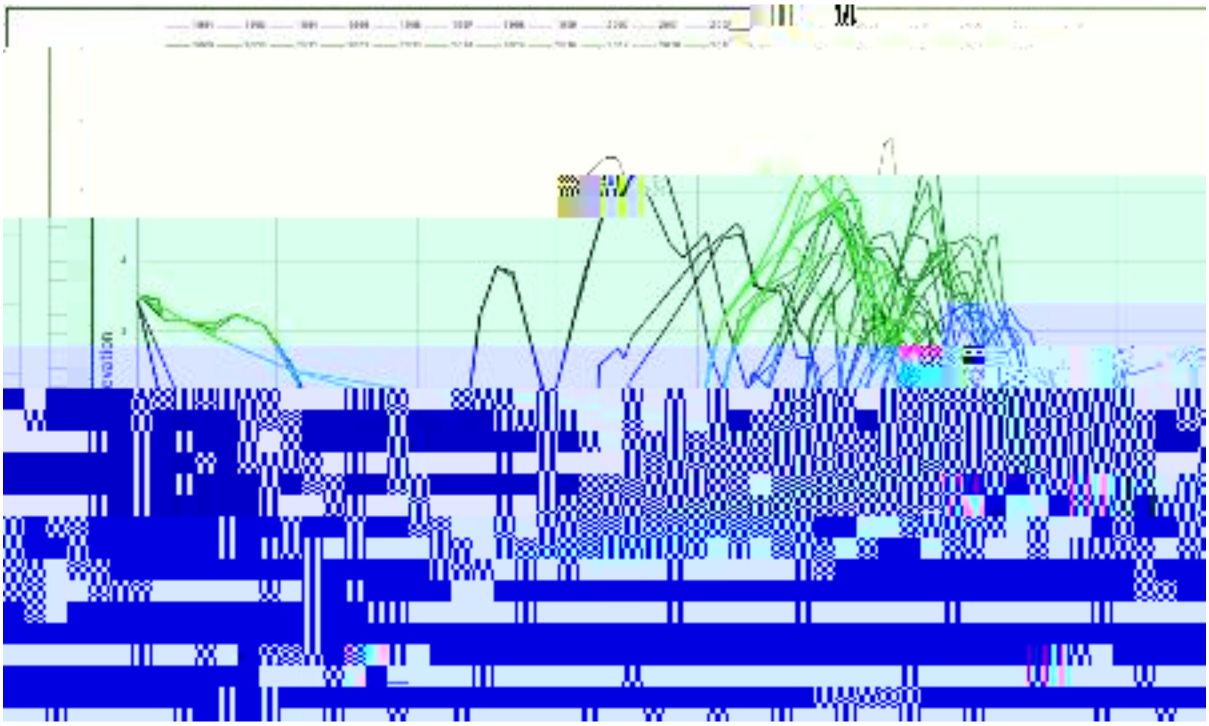

Figure 4. Movement of the barrier from 1991-2024

3.2 Results - Beaches

Both beaches north and south of the barrier have shown gradual progradation since the first profiles were recorded in 1991. The beach profiles recorded to the south of the river mouth have stayed roughly parallel to one another, and the slope of the beach has undergone little change (see Figure 5). At an elevation of 3m above sea level (roughly halfway up the profile), the beach has experienced a net accretion of roughly 11m, however the difference between its most landward point (in 2000) and its most seaward point (in 2014) is 34m. The beach has been gradually receding since 2014 and has receded 5m. The beach to the north of the river mouth has experienced a net accretion of roughly 23m (at the same elevation of 3m asl) (see Figure 6). The beach face is highly dynamic, and the data shows the development and disintegration of many berms and other temporary changes in the beach slope and profile such as a berm in 2022 which extended seaward an additional 10m compared to the rest of the profile, however the beach face was completely reformed by the 2023 survey.

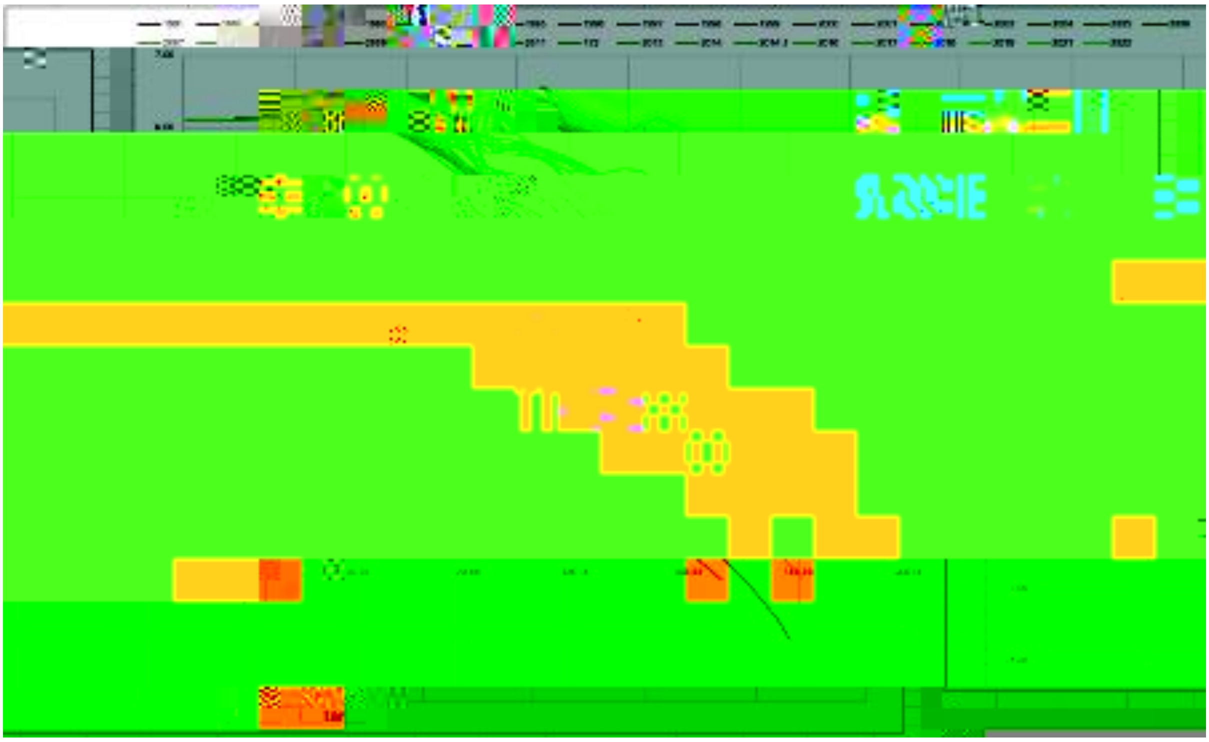

Figure 5. Beach profile from south of the Rakaia River mouth

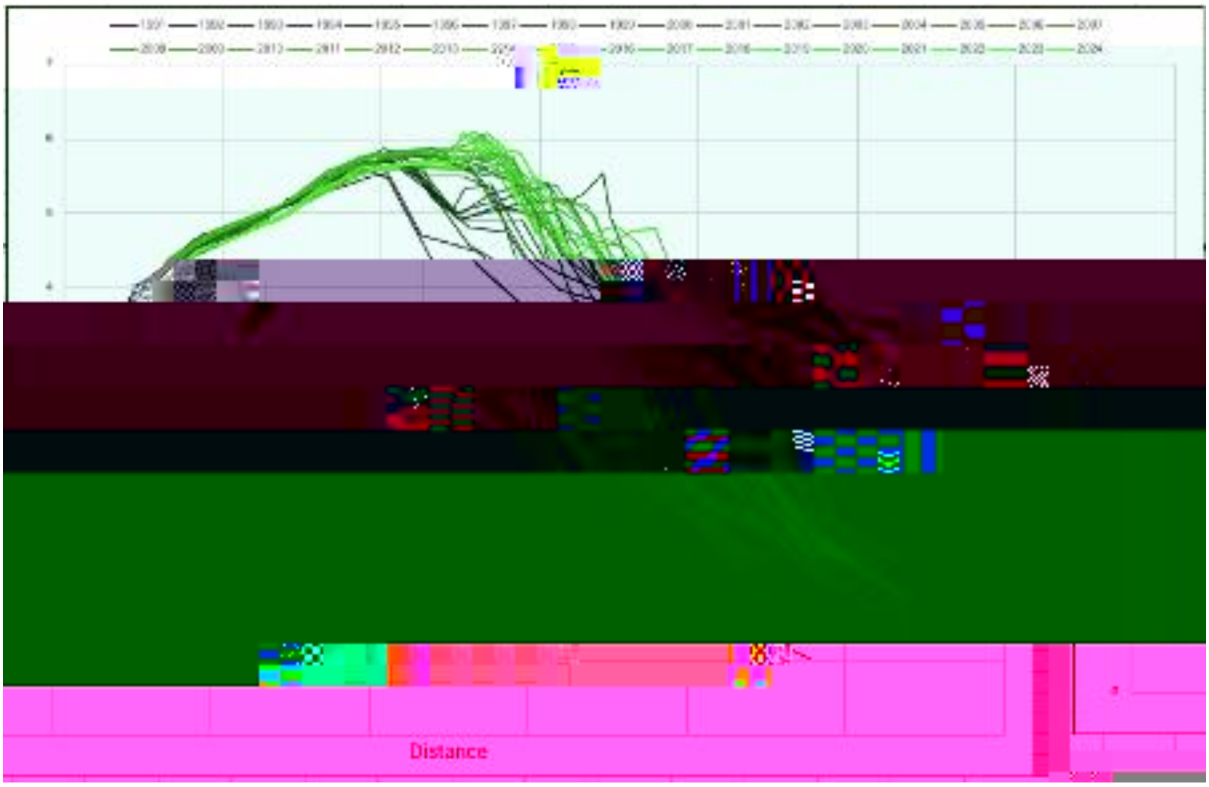

Figure 6. Beach profile from north of the Rakaia River mouth

3.3 Results - River bed

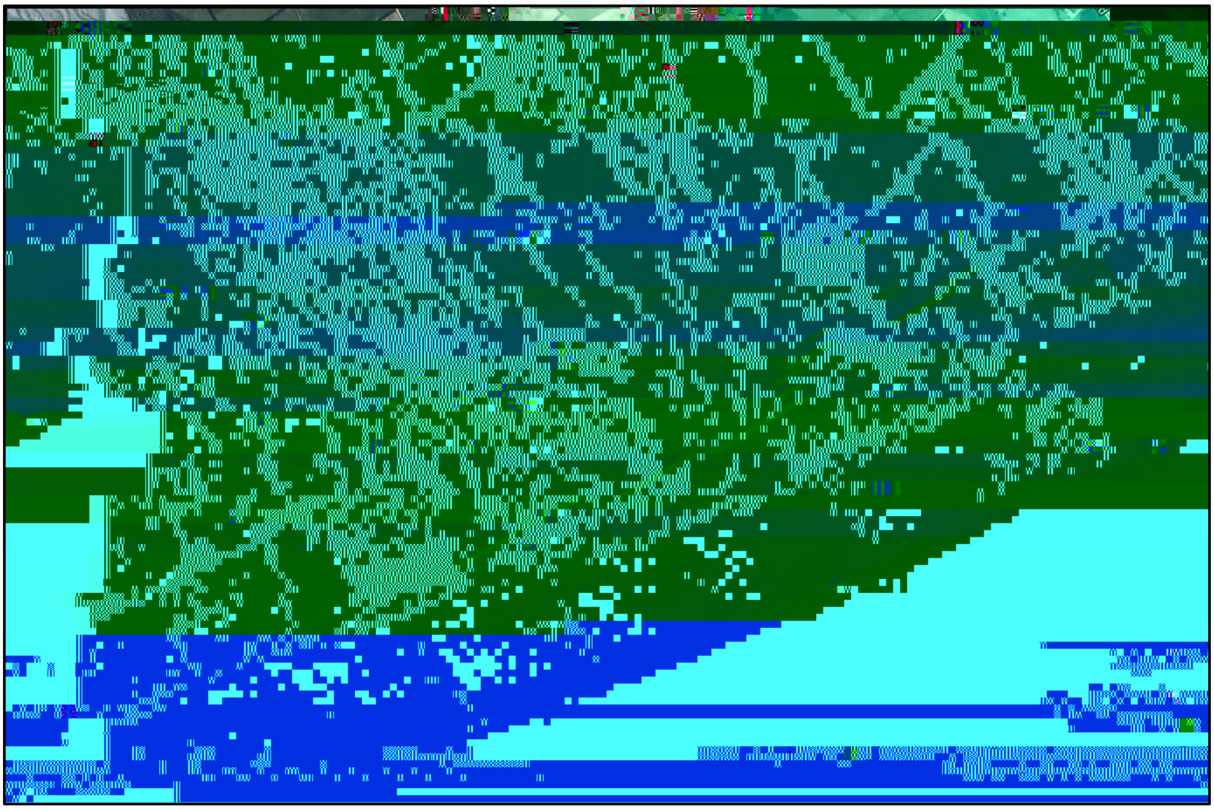

Figure 8; The cross section of the bed level change displayed in ArcGIS

3.4 Results Waves

Directional data from the ECan wave buoy shows that the predominant wave direction is east, consistent with the typical coastal conditions at Rakaia (see Figures 9 and 10). A significant wave height of greater than 2.7m is from the south direction represents high wave energy events (see Figure 10).

There is a high variability in the significant height of waves recorded. This variability is likely driven by seasonal fluctuations, where winter months experience more frequent storm activity due to intensified wind. Most of the data fluctuates between 1 and 3 metres in height with the with the highest peaking at 6.71 m. The peak wave height was recorded in Feb 2002 and there was a barrier profile recorded in Jun the same year. These higher waves than the threshold (percentile line) is the wave energy occurring during storms or big swell events, influencing sediment transport.

The significant wave height data from the hindcast data shows similar fluctuations as the wave buoy data, with typical height ranging between 1-4m and the peaks exceeding 6m (see Figure 12). These peaks as stated above are representative of the higher wave energy events. Additionally, the percentile line (grey) is a threshold for wave heights that are critical for coastal processes such as erosion (see Figures 11 and 12).

Figure 10. Mean wave direction and wave height displayed on Python wave rose.

Figure 11. ECan wave buoy

Figure 12. Mean daily significant wave height displayed from the Hindcast model in comparison with barrier profile surveys.

3.5 Results - River flow

The river flow at Rakaia has shown significant variability over the period from 1991 to 2023, with several high-flow events exceeding 3000 m^3/s, extreme conditions which normally happen in the spring and early summer. Flow events above 2000 m^3/s occurred sporadically, with the majority of river flow values generally remaining below 1000 m^3/s. Barrier surveys (indicated

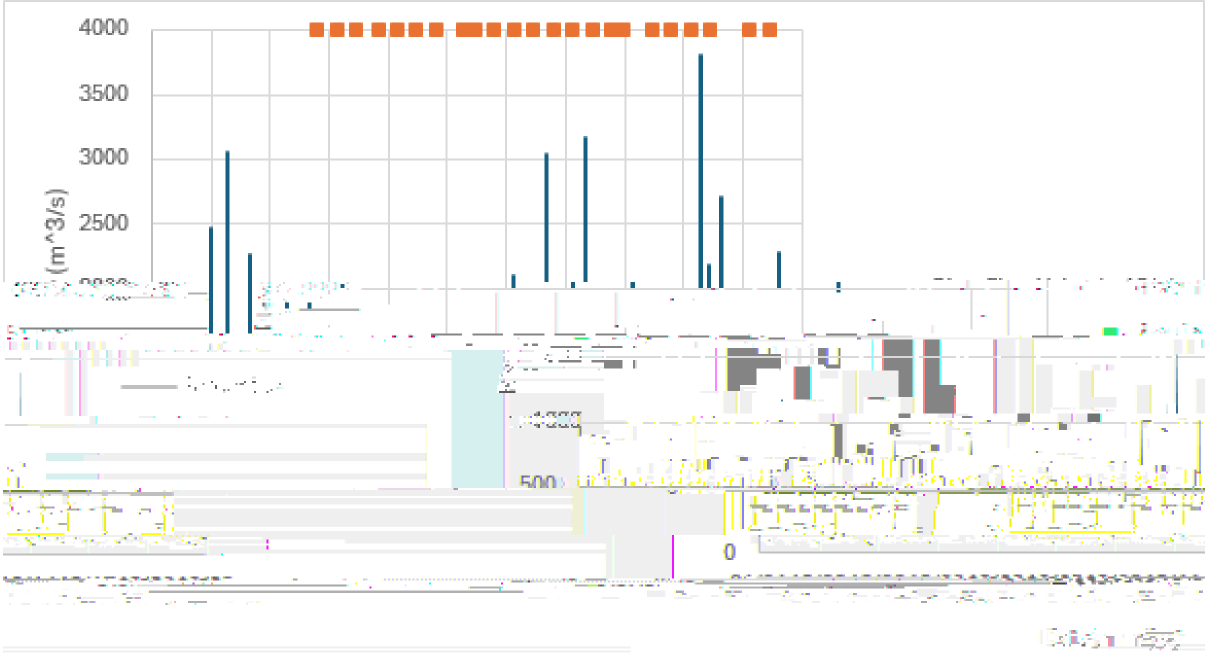

Figure 13. Mean river flow (m3/s) per day at Fighting Hill, Rakaia River, Canterbury containing 95 percentile threshold.

5.0 Discussion

5.1 Discussion General

Our research reveals that the Rakaia hapua mouth barrier experienced a shift from progradation (1991 to 2006) to erosion around 2006. However, there are no notable changes to the beach profiles around this time. This may indicate that the change in the barrier position is not solely due to changes in the wave regime or other marine processes, or a change at the beach profiles would also have been observed.

The changes in both barrier crest elevation and barrier shape (i.e. whether the barrier is unimodal or has multiple crests, and the width and slope of the barrier) are due to the balance between sediment transported onto the seaward side of the barrier via marine processes (wave action and overtopping), and the sediment transported to the back barrier via fluvial activity (Matias et al., 2011). If both processes deposit sediment but it does not reach the center of the barrier, the barrier will no longer exhibit a unimodal shape.

The beach to the north of the river mouth is notably more dynamic than the beach to the south, transport and coastal erosion at the study site. This data collected could be used as an insight into flood management or erosion rate knowledge.

These higher energy waves create erosional patterns over extended periods of time. Looking at wave height alone we can understand that the erosion processes of the shoreline will occur as the higher waves overwash the beach and barrier (Flores et al., 2016). Although within a dynamic environment natural processes are interlinked effecting each other constantly. In combination with the high energy events discussed above affecting the barrier and the beach it is influenced heavily by the direction of these big events. Sediment transported from these high energy events will alter and reshape the river mouth and barrier this could then affect the flow dynamics creating feedback loops (Mortlock & Goodwin, 2015). By having the beach profiles on the graph, it highlights the potential profiles that could show changes due to wave action (Figure 11 and 12). Important to note that the surveys are not aligned exactly with the high energy events. This could indicate limitations to the ability to capture the data of their influence. As the data was collected from a site further up the east coast there are other factors that could affect these results. The climate change and antarctic oscillation has impacted the wave action in southern hemisphere significantly the wave power has been increased 2.6 times above the world average level (Liu et al., 2024).

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series analysis, and regression modelling, strengthening the conclusions drawn from the research.

The time constraints

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