Coastal Erosion at Patiti Point, Timaru

University of Canterbury

GEOG309: Research Methods

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Table of Contents

1. Executive Summary

Context:

- Patiti Point is located in Timaru, along the South Canterbury coast. It is a mixed sand and gravel shoreline, backed by a cliff face. There has been steady erosion over the past 30 years, however, the site is now experiencing accelerated erosion rates over the past 3-5 years. The Timaru District Council have raised concerns due to the area being of recreational significance to the community.

Research Question:

- What are the temporal coastal processes affecting the erosion rate of Patiti Point, Timaru?

Methods:

- A focus on secondary data analysis with some primary data
- Primary data collection:
    - UAV survey footage
- Secondary data analysis included:
    - 30 years of beach-profile data
    - 19 years of wave buoy data.
    - Historical aerial imagery

Key Findings:

- Rate of sediment movement calculated to be approximately 1012m per year.
- Estimations suspect the next pulse could reach Patiti Point in late 2020.
- It is clear that profiles north of Patiti Point are in a cycle of accretion. This is most likely the result of the breakwater introduced in early 1987. Since the implementation we can see the beaches in this area accreting over time.
- Beach volume profiles suggest that Patiti Point is in a period of accelerated erosion.
- Analysis of beach volume data identifies northward sediment transport.

Limitations:

- Limited by the frequency and length of secondary datasets.
- Depth of the reef was unknown when undertaking bathymetry analysis.
- Primary data collection conditions were not suitable.
- Wave buoy was located at Banks Peninsula, not Timaru.

Future Research Suggestions:

- Undertake a statistical significance test for coastal variables and their influence on erosion rates
- Identify the depth of the reef to help fully understand the impact of bathymetry on erosion.
- Investigate the potential impacts climate change may have on the South Canterbury coast.

2. Introduction

Patiti Point, located on Canterbury's East coast at the Southern end of the Timaru township is an area of mixed sand and gravel shoreline, backed by cliff face. The land directly adjacent to the shoreline holds recreational significance to the local and wider communities. Directly beyond the cliff lies a road and pedestrian walkway which have been closed due to certain areas being lost into the ocean and others posing significant danger to the public. Landward, beyond the road lies the Caledonian Sports Ground and pistol range, in the direct path of continued erosion. The sports club has already chosen to abandon its ground for a new site due to the erosion and safety concerns. Farther landward lies the Timaru Cemetery and beginning of the residential area. All areas directly beyond the shoreline hold great significance to the community and need to be considered in future decision making around the coastal management of Patiti Point.

The focus of this research aims to provide a better insight and understanding into the erosion rates and changes occurring at Patiti Point. An analysis of beach profile data has been undertaken in order to try and understand sediment movements through Patiti Point and the significance that sediment pulses have in relation to erosion rates. The framework also provides for further analysis using wave buoy data and historical images to develop an insight into what has occurred historically and why. The research will be used as an insight and guidance for Environment Canterbury (ECan) and potentially the Timaru District Council to inform their future decisions and actions in relation to cliff management, based on causes and rates of impact determined through the report.

Based on this, the following research question was proposed; What are the temporal coastal processes affecting the erosion rates at Paititi Point, Timaru? The two main objectives were determining what conditions were leading to accelerated erosion due to basaltic cliff face , and determining whether pulses of sediment in the coastal zone are influencing the rate of erosion. These were derived under the research question to help support the direction and focus of the research.

3. Literature Review

A literature review was undertaken in order to obtain a holistic understanding of coastal erosion, more specifically the erosion of mixed sand and gravel beach. Various coastal concepts were investigated to formulate the approach and focus for this research.

3.1 Mixed Sand and Gravel Beaches Dynamics and Processes

The morphology and transport processes of mixed sand and gravel (MSG) beaches is a complex and sophisticated area of research. MSG beaches consist of coarse grained material in addition to sand, presenting a more complex area of study with variable coastal processes (Neale, 1987).

The study area consisted of mixed sand and gravel beaches and when researching, we realised there is limited literature on their complex dynamics, due to their rare occurrence globally. However, it is known that they are steeper than their sand counterparts. The steep gradient allows waves to advance closer to the shore before breaking at higher energies. Therefore, the swash zone in MS&G systems tends to be very turbulent. This turbulence has the tendency to put fine sediment into suspension and transport it offshore. The process has been mentioned as being a “one-way” system as fine sediment cannot be easily transported back to the foreshore and thus it is usually lost permanently from the system. Kirk also noted the swash from strong southerly waves inundating the foreshore and is the main driver behind longshore transport of sand and gravel.

According to McLean (1970), all larger MSG beaches located on the east coast of the South Island have a common set of features and characteristics. They contain a large variation in sediment sizes (fine sand to boulders), the majority are derived from the same dominant rock type (greywacke), and are exposed to high-energy waves. Often MSG beaches along the South Island form the seaward margin of a large alluvial fan system. These features are very similar to those found at Patiti Point, Timaru.

Coastal retreat on MSG coastlines is widespread and rapid, resulting in huge amounts of sediments being cycled through the beach base volume and deposits (Kirk, 1980). New Zealand MSG beaches present a narrow high energy shore zone (Kirk, 1980). Generally MSG beaches are typically narrow, steep and broadly convex in shape (Kirk, 1980). A backshore zone is present landward of the highest runup point. At areas where cliffs are present, there is generally no storm berm and the foreshore is more planar. This is the case present at Patiti Point where the cliff is now primarily being eroded. The base of the cliff is likely to be either mantled in slump deposits or swept clear to reveal an abrasion ramp which dips seaward under the beach deposit (Kirk, 1980). The steep gradient of the foreshore allows waves to advance closer to land before breaking at higher energies (Dawe, 2006). Therefore, the swash zone in MSG systems tends to be very turbulent. This turbulence has the tendency to put fine sediment into suspension before transporting it offshore (Dawe, 2006; Kirk, 1980). The process has been mentioned as being a “one-way” system as fine sediment cannot be easily transported back to the foreshore and thus it is usually lost permanently from the system (Kirk, 1980). Kirk (1980), also noted the swash from strong southerly waves inundating the foreshore and is the main driver behind longshore transport of sand and gravel.

3.2 *Erosion due to storms*

Beach vulnerability to storm events is dependent on the difference between storm frequency and beach recovery, when storm frequency exceeds the beach recovery period, beach erosion is accentuated (Ferreira, 2005). The predominance of storm waves from the south (82 percent) is due to a virtually unlimited fetch in a south easterly direction. The greater the proportion of waves from a southerly direction the greater the net sediment movement in a northward direction occurs (Flatman, 1997).

3.3 Headland Erosion

From literature readings it is understood that as Patiti Point is a headland, it is an erosive location in itself. Carter, Jennings and Orford (1990) suggest there is a significant opportunity for erosion to accelerate at the headlands. Reinforcing that it is within the nature of headlands to erode over time. Additionally, the longshore transport system was recognised to have has a vital role. The divergence of wave energy across the shore is important for longshore transport in regards to the erosion process and deposition of headland sediment (Masselink, Hughes & Knight, 2014).

4. Methodology

A mixed method approach was taken towards the research, using quantitative data with some qualitative data integrated (Creswell, 2014). Secondary data analysis was undertaken, this ensured different aspects and inputs were explored and recognised as potential contributors to the erosion.

4.1 Primary Data

4.1.1 UAV Survey

Primary data in the form of a UAV survey was collected during our site visit. A drone quadcopter (DJI Phantom 4) was flown to capture a video of the research site and surrounding area as well as collect data for a structure from motion analysis. However, this structure from motion data could not be used to form a point cloud as the high tide and crashing waves at the time of data collection made it not possible.

4.2 Secondary Data

Secondary data were obtained from ECan and used throughout the data analysis process to examine different aspects and features of the erosion at Patiti Point and the wider research area of the Canterbury coast.

4.2.1 Beach Profiles

Analysis of beach profile data is a useful method to examine the change in beach morphology over time and space (Emmanuel, Parisot, Michallet, Barthélemy, & Sénéchal, 2009; Larson & Kraus, 1994). A 30 year set of beach profile data was obtained from ECan in the form of excel documents showing the raw survey data obtained at different dates throughout the time period. The data set included 38 different sites stretching approximately 60km from the Waitaki River at the Southern end, to Timaru in the North.

The data was used to derive chainage and elevation values for each site which would then be used to return volume change data for each site using Matlab software. These results were standardized, as was done by Neale (1987), which allowed for different sites to be graphed and compared on the same scale. This graphing allowed us to visually track sediment pulses which were classified as periods in time when the volume appeared to be higher than surrounding years. These pulses were visually tracked to see if they moved from more southern sites, northwards. As this is not the most precise method, the standardised volume values for each site were also aligned next to each other and conditionally formatted which highlighted the values in a gradient of colour from green to red as the values decreased. These values and colours were analysed and compared to the dates pulses arrived, and left sites according to the previous method mentioned. The two methods overall produced equivalent estimates as to when which pulses would arrive and leave a specific site. When these methods produced varying estimations (1 to 2 years difference), the average was taken.

This time and the distance between sites was recorded for 34 different pulses over the 30 year time span along different regions of the coastline, the overall average speed of pulses along the whole coastline was then calculated using the equation below. The average speed for areas where the coastline was concave versus convex was also calculated and compared.

$$Speed = Distance/Time$$

4.2.2 Wave Buoy Data

A 19 year set of Banks Peninsula wave buoy data was obtained from ECan in an excel format. The sheets contained a number of wave parameters such as wave direction, maximum wave height and significant wave height that were used to explore the drivers behind the coastal erosion rates currently occurring at Patiti Point. In general, data was available for every half hour relatively consistently since July 2000. Data was averaged monthly to try and detect trends which may be leading to the accelerated erosion rates at Patiti Point.

4.2.3 Historical Imagery

Historical imagery of Patiti Point from 2010 and 2019 was obtained through Google Earth to carry out a qualitative analysis of change over time. This was done by comparing the images of the research site and adding a line along the cliff edge to determine the extent of shoreline movement over this period.

4.2.4 Bathymetry and Wave Direction

A bathymetry analysis was carried out to determine the extent of impact from a reef which lies under the water, East of Patiti Point. A satellite image of the Patiti Point coast was obtained through Google Earth and the imagery was then annotated to outline the reef area as shown in figures 9 and 10. This was done through studying bathymetry sketches from Rutledge (1992), and modern aerial images. It was noted that there is a clear pathway at approximately 100° where there is no reef present, and we wanted to investigate whether waves travelling through this channel had any increased effects on the accelerated erosion rates of the headland.

Five significant accretion and seven significant erosion events were identified from looking at Patiti Point beach profile data from 1999 to 2019. The wave approach angle was averaged for the 6 months prior to each of these events. This was because, as noted in previous studies, it is important to account for time lags as accretion and erosion events may not be immediate (Atkinson & Esteves, 2018). These findings were then plotted on the bathymetry map to provide an effective overview of potential effects which the reef presence and wave direction have on sediment movement at Patiti Point.

5. Results

5.1 Beach Profile and Volume Analysis

Using the existing profile data from ECan, beach volume profiles were generated. Figure 1 displays the beach volume of Patiti Point from 1990 through to 2019. From this profile it is evident that while Patiti Point has endured various fluctuations in volume since 1990, since 2015 the point has been in a substantial period of erosion.

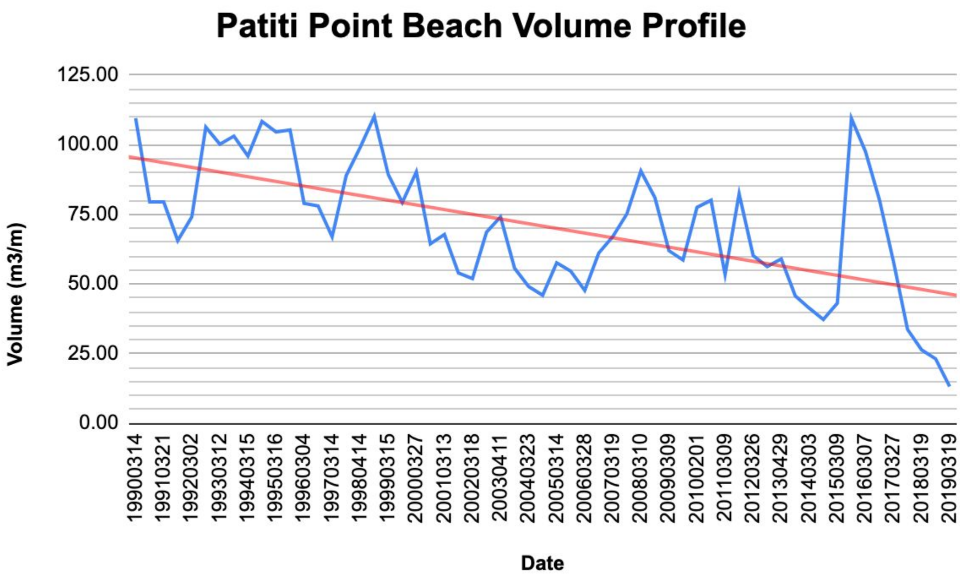


Figure 1: Line graph of Patiti Point Beach Volume changes over time (Site TCS1732).

As seen in Figure 1, the beach volume has reached the lowest volume recorded record within the ECan dataset. Interestingly, before this extreme erosion, we can see a peak in volume from 2014 to 2015 reaching 109 m^3/m. Figure 2 is a standardised volume profile of not only Patiti Point but the the site above and below. These three sites can be seen on the survey location maps within Appendix A, TCS1672 (North of Patiti), TCS1732 (Patiti Point) and TCS1887 (South of Patiti).

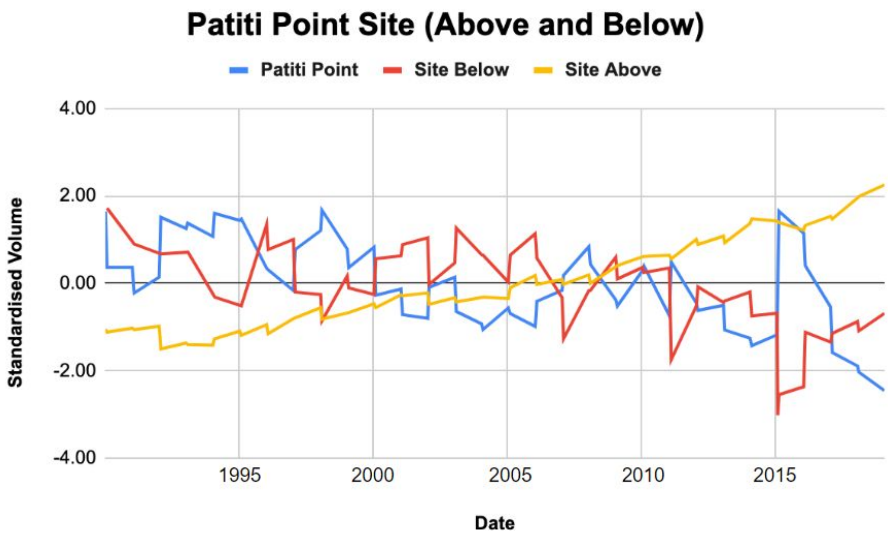


Figure 2: Standardised Volume Profile. Displaying the survey Site of Patiti point (TC1732, Blue), the site above (TCS1672, Orange) and the site below (TCS1887, Red).

From viewing figure 2, we can observe a long term trend of accretion in the site North of Patiti Point from 1990 to 2019. This is a strong contrast to Patiti Point and the Southern site. Looking more specifically at the site below the point, we can see that there is again noticeable variation in volume over time. Comparing this site closely to Patiti Point, we can see an almost inverse relationship. There are periods where TCS1887 (red) has a loss of volume while Patiti Point (blue) has a rise in volume.

Figure 3, seen below, is another standardised beach volume profile, however in this case only the sites North of Patiti Point are displayed. Overall, the plot heavily reflects the trend of accretion we observed from the first site north of Patiti Point. This pattern however should be expected, given the literature mentioned earlier, which provided insight into the formation and impacts of the Timaru Port breakwater.

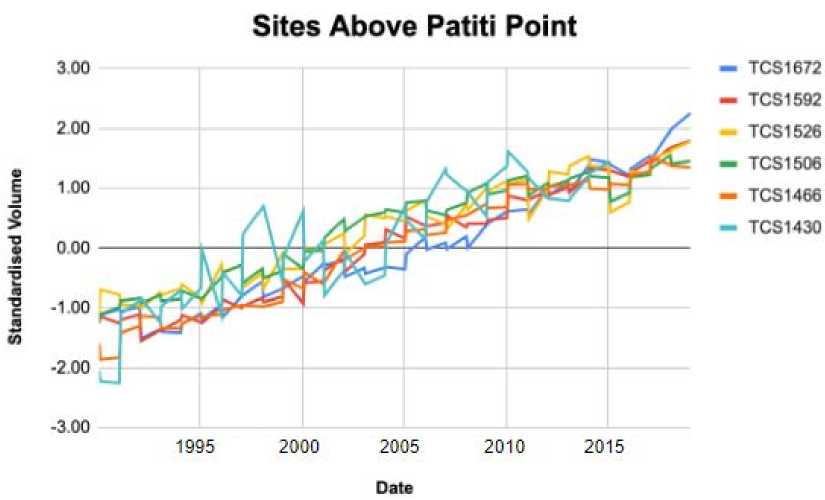


Figure 3: Standardised Volume Profiles displaying the survey sites of North of Patiti Point.

5.2 Wave Buoy Data

The average wave direction and significant wave height was calculated for the 6 months prior to 5 significant accretion events, seen in figure 4 where the volume plot (blue) goes above the mean zero line, and 7 significant erosion events where the volume plot is below the mean zero line. As seen in table 1 below, six months prior to accretion events, the average wave approach angle is more southerly than the overall average and the average significant wave height is slightly higher than the overall average. Six months prior to erosion events, the average wave approach angle is more easterly than the overall average and the average significant wave height is the same as the overall average.

Table 1. *Overall averages for wave direction and significant wave height along with averages prior to accretion and erosion events.*

	Wave Direction	**Significant Wave Height**
Overall Average	146º	2.0 m
6 months prior to Accretion	154º	2.2 m
6 months prior to Erosion	138º	2.0 m

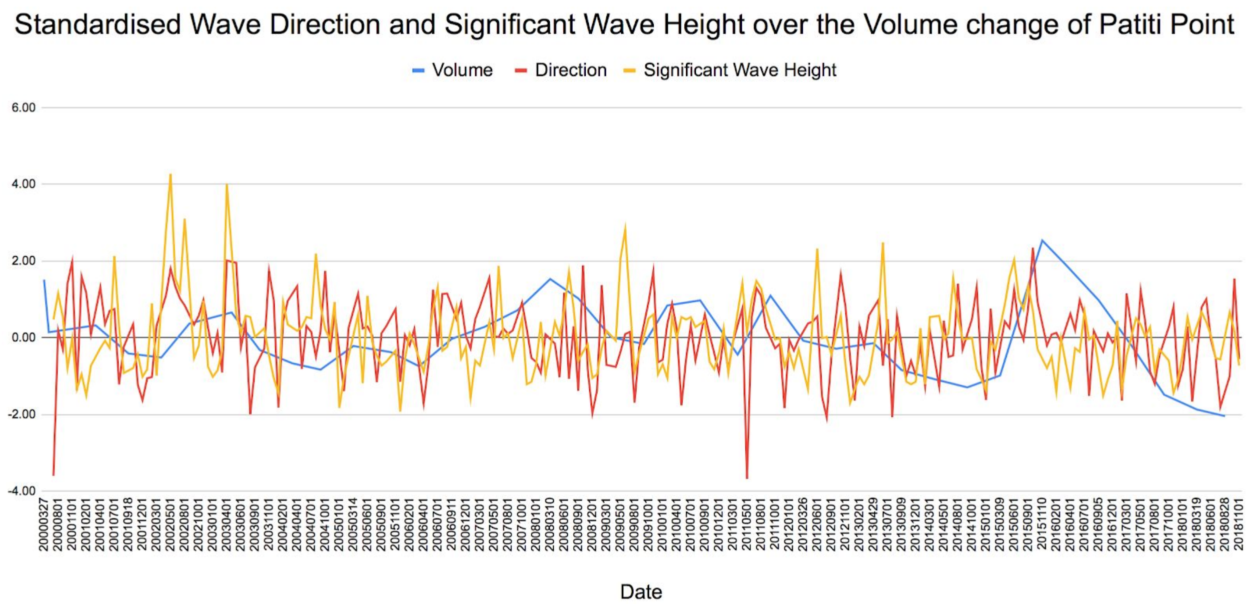


Figure 4: Graph showing the average wave direction, average significant wave height and volume plot for Patiti Point all standardised.

5.3 Sediment Pulses

The rate of 34 different sediment pulses was calculated as they travelled northwards by recording the distance between sites and the time it took the pulses to move this distance. The overall rate of pulses was calculated to be 1012m/yr.

To investigate how the dynamic coastline shape may affect this rate, we also calculated the rate specifically for concave regions of the coast line versus convex areas. Approximately, in the area between Patiti Point and the Waitaki River, the top half has a concave shape while the bottom half is a convex shape leading to the subtle ‘S’ shape of the coastline. The overall average rate for the concave region was calculated to be 952m/yr while the average rate in the convex region was seen to be 1056m/yr which is approximately 100m/yr faster. It is also interesting to note that the 11km just North of the Waitaki River mouth has an average rate of 1349m/yr which is faster still, this may be due to this area being the furthest eastward that the coastline protrudes in this region. Therefore, it may be more exposed to the northward longshore currents compared to the sheltered concave areas.

Figure 5 is a plot displaying standardised volume over time across SCS survey sites. The number 1 on the y-axis represents the most northward SCS site (SCS2183) and as the numbers increase, the sites go further southward so that the number 30 represents the site just above the Waitaki River (SCS7620). Through this figure we see some movement of sediment up the coast, transported up from sites near the Waitaki river mouth through to the sites closer to the Point. The yellow colour indicates dates where the standardised volume is higher than the mean, and therefore there is a large amount of sediment present. Dark blue areas show standardised volume valued that are well below the mean and represent a lack of sediment present. Sediment pulse movement can be seen through the movement of some lighter areas moving from left to right as you move down the plot.

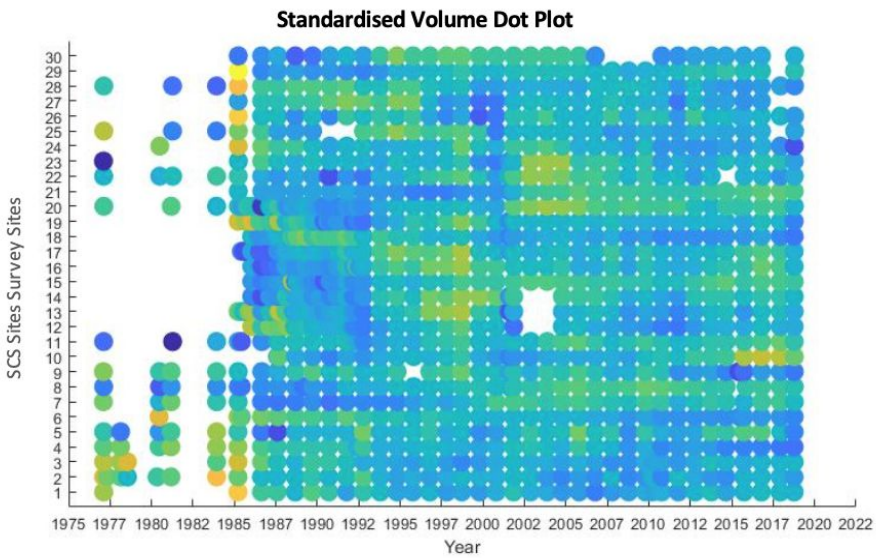


Figure 5: Standardised Volume Dot Plot of survey sites south of Paiti Point. The y-axis represents the SCS sites, 1 being closest to Paiti Point and 30 being closest to the Waitaki River. The X-axis displaying the years from 1975-2022.

5.4 Historical Imagery Analysis

The qualitative historical satellite imagery seen in figure 6 demonstrates the temporal changes that have occured at Patiti Point, between 2010 and 2019. From the 9 years between the two images it is clear that overall the cliff has retreated. At the lower end of the images the point more prevalent in the first image has retreated to form a flatter curve. The dip in the middle of the two annotated lines has retreated with the area between the cliff and sports ground being smaller.

Figure 6: A comparison of historical satellite images at Patiti Point between 2010 (left) and 2019 (right). The red line shows the relative position of the cliff edge in the given year. Source: Google Earth Pro (2019).

6. Discussion

6.1 Coastal Processes

From the results previously analysed, there are some evident trends and patterns. While we can not directly link these coastal processes to the causation of erosional/accretional events, it is important to take into account their involvement.

6.1.1 Beach Profiles and Volume Change

After researching further into this pattern between Patiti Point and the first site South, two large storm events were identified with wave buoy data as shown in table 2. These storms both approached from a southerly direction. The first event was highlighted in 2011 and the other in 2015. These two storm periods also line up to the peaks and troughs in volume displayed in figure 6. What we suspect from this observation is that material from site below may have been transported northwards by these southerly waves and deposited at Patiti Point. This pattern would seem to be the result of different beach response to storm events, potentially due to sites being in different sediment phases (Neale, 1980).

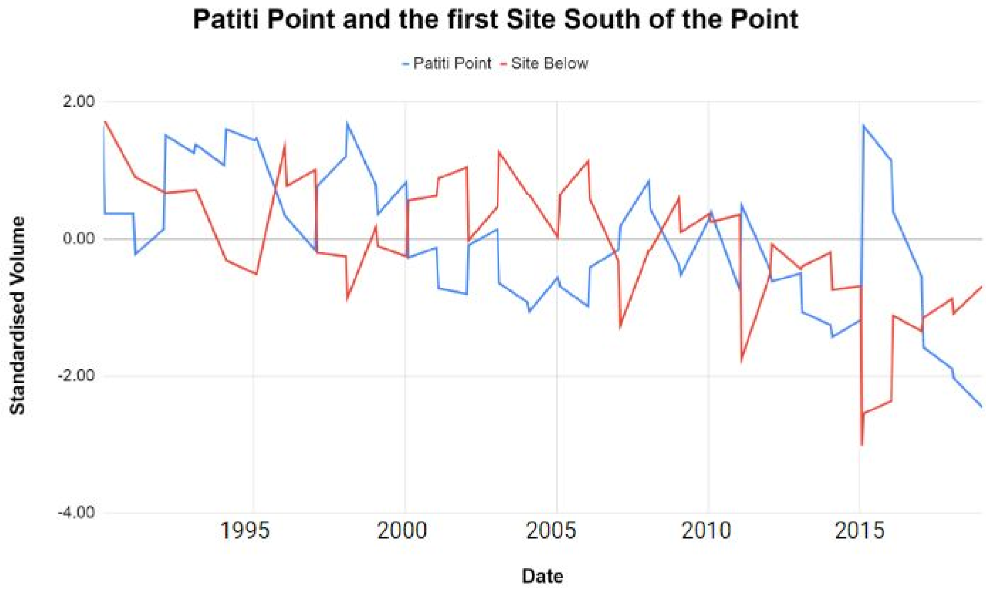


Figure 7: Standardised Volume Profile. Displaying the first site south of Patiti Point (TCS1887) alongside the Patiti Point itself (TCS1732).

As seen in figure 8 below, the last sediment pulse seen in the SCS sites just south of Patiti Point occurred in 2016. These sites are approximately 4km south of Patiti Point so assuming that the average sediment pulse rate of 1012m/yr is accurate, this pulse of sediment should arrive at Patiti Point in late 2020 and may help with beach nourishment.

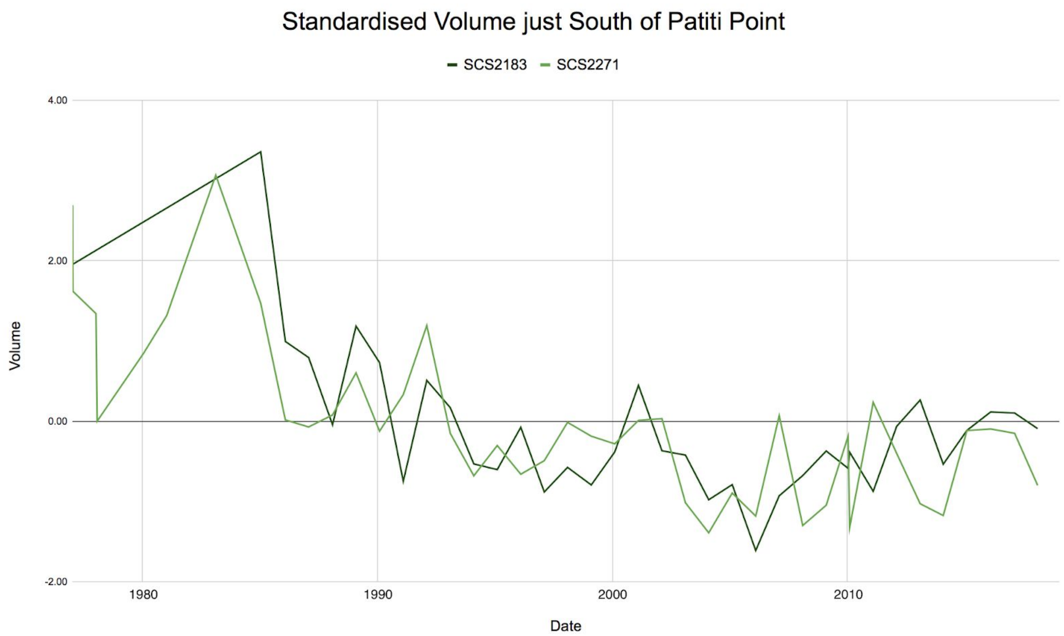


Figure 8: Standardised volume plots for the two SCS sites just south of Patiti Point.

Table 2. *Average significant wave height and direction for April 2011 and May 2015 storm events. The April storm was from 7/4/11 to 9/4/11 and the May storm was from 25/5/15 to 27/5/15.*

	Average Significant Wave Height	**Average Wave Direction**
April 2011 Storm	4.71m	190°
May 2015 Storm	5.95m	176°

6.1.2 Bathymetry

Bathymetry data was produced to explore the potential role reefs have on influencing the rate of erosion at Patiti Point. It is generally accepted that reefs provide an effective protection measure against wave assaults (Martins, Pedro de Souza Pereira, Esteves, & Williams, 2019; Roger, Dudon, Krien, & Zahibo, 2014; Clark, 1996). However, figure 9 shows the reefs are located at both the southern and northern end of the point, leaving a gap in the middle where easterly waves could potentially increase erosion rates. Figure 9 identifies that, before significant erosion events, the previous 6 month averaged wave direction is south easterly, or between 134° and 148°. Therefore, waves approaching from a more easterly direction tend to lead to stronger erosion events at Patiti Point as they may be travelling through the channel.

Figure 9: Map of Patiti Point reef and erosion events. Arrows show averaged 6 month wave direction before erosion events. The length of these arrows displays the averaged significant height 6 months before erosion events. The colour gradient goes from green to red with red corresponding to more severe erosion events.

Contrast to this, figure 10 depicts that before significant accretionary events at Patiti Point, the average wave direction is more southerly (between 145° and 165°). This is likely due to the southerly wave direction moving sediment northwards along the coastline before depositing this sediment at Patiti Point.

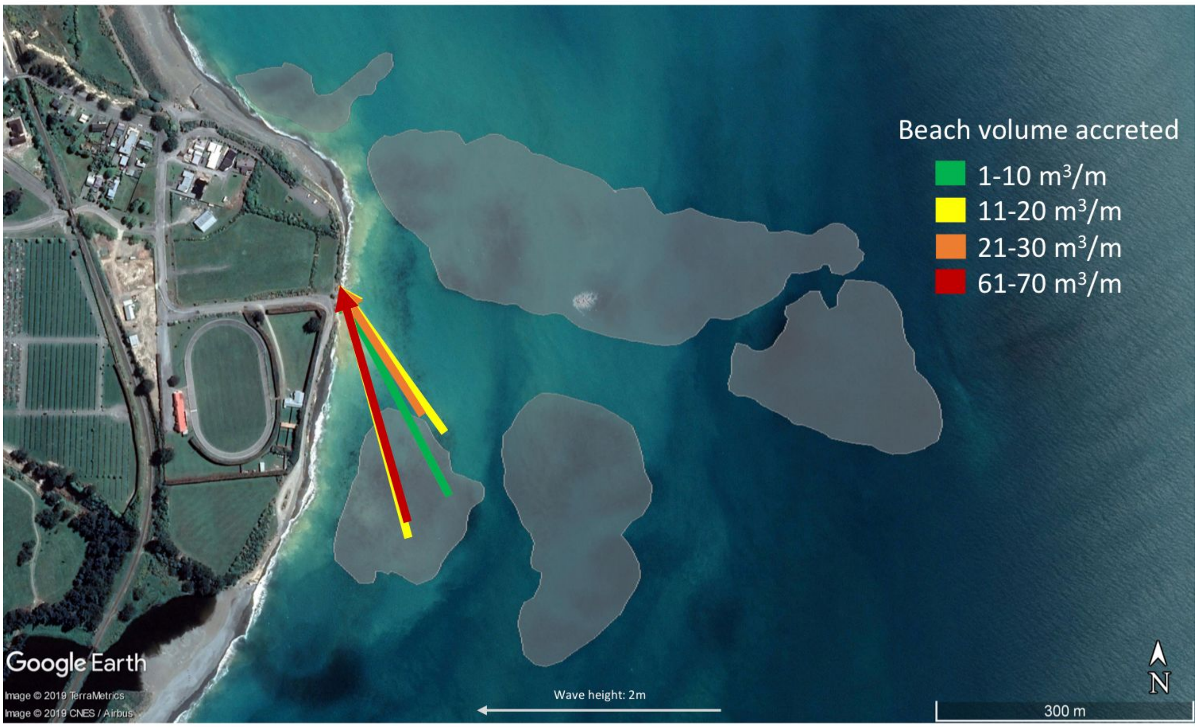


Figure 10: Map of Patiti Point reef and accretion events. Arrows show averaged 6 month wave direction before accretion events. The length of the arrows display the averaged significant height over the 6 months before accretion events. The colour gradient goes from green to red with red corresponding to larger accretion events.

In figure 9, it is also seen that the events which have a lower average significant wave height, cause more erosion than those with a larger average significant wave height. This is thought to occur as larger waves break on the reef as it becomes too shallow for a wave of this height to be stable, thus protecting the shoreline. However, smaller waves can travel over the reef and break directly onto the beach causing a larger amount of energy to be dispersed and therefore, a larger impact on sediment being lost.

6.2 General Discussion

6.2.1 Limitations

While the coastal data obtained from ECan was an adequate baseline for our research, we believe it would be beneficial to have continued frequent monitoring, increasing accuracy, reliability and specific knowledge about the effects of storms.

A study by Péquignet, Becker, Merrifield, and Boc (2011) found that “wave energy is strongly depth-limited and controlled by the reef submergence level.” The bathymetry analysis was limited to a qualitative approach due to the lack of local bathymetry data such as exact size and depth of the reef. Therefore, the extent of the bathymetry and its role within coastal erosion can only be assumed. Perhaps a more quantitative approach could build upon the findings of this report and strengthen the evaluation of Bathymetry involvement.

The Banks Peninsula wave buoy data utilised for analysis is situated at a reasonable distance away from the study area of Patiti Point which may lead to slight differences in conditions. However, after consulting with ECan it was ensured that there would be minimal differences in the overall trends. Conducting research with data in closer proximity to Timaru could enhance the results of the research.

While a UAV survey was conducted, this data was not sufficient for the formation of a 3D model due to the conditions under which the survey was taken.

6.2.2 Future Research

Moving into the future, further research is necessary around the significance of individual coastal variables on erosion. Development of a statistical significance test would help understand the extent of the contribution from particular variables towards the erosion rates in coastal environments.

A quantitative investigation into the involvement of the bathymetry along the Timaru coastline would help quantify its impact in a more robust manner. The current qualitative analysis is helpful, however a statistical analysis on the impact will bring clarity and confidence of its involvement in erosion along the coastline.

Further research is needed with the ever growing concern of climate change. The presence of climate changes and its future influences on erosion rates of the South Canterbury Coast is a particularly limited area of study due to its uncertainty. Hannah and Bell (2012) estimated a future sea level rise of 1.7 +/- 0.1 mm per year. Local trends show that, from climate change, storm clusters in New Zealand are including a higher number of storms, increasing in duration (Godoi, Bryan, & Gorman, 2017), and increasing in frequency and magnitude (Tonkin & Taylor, 2015). Further investigation of the future impacts of sea level rise and increased storminess would compliment other research and provide clarity around the potential overall impact climate change may have in this area.

7. Conclusion

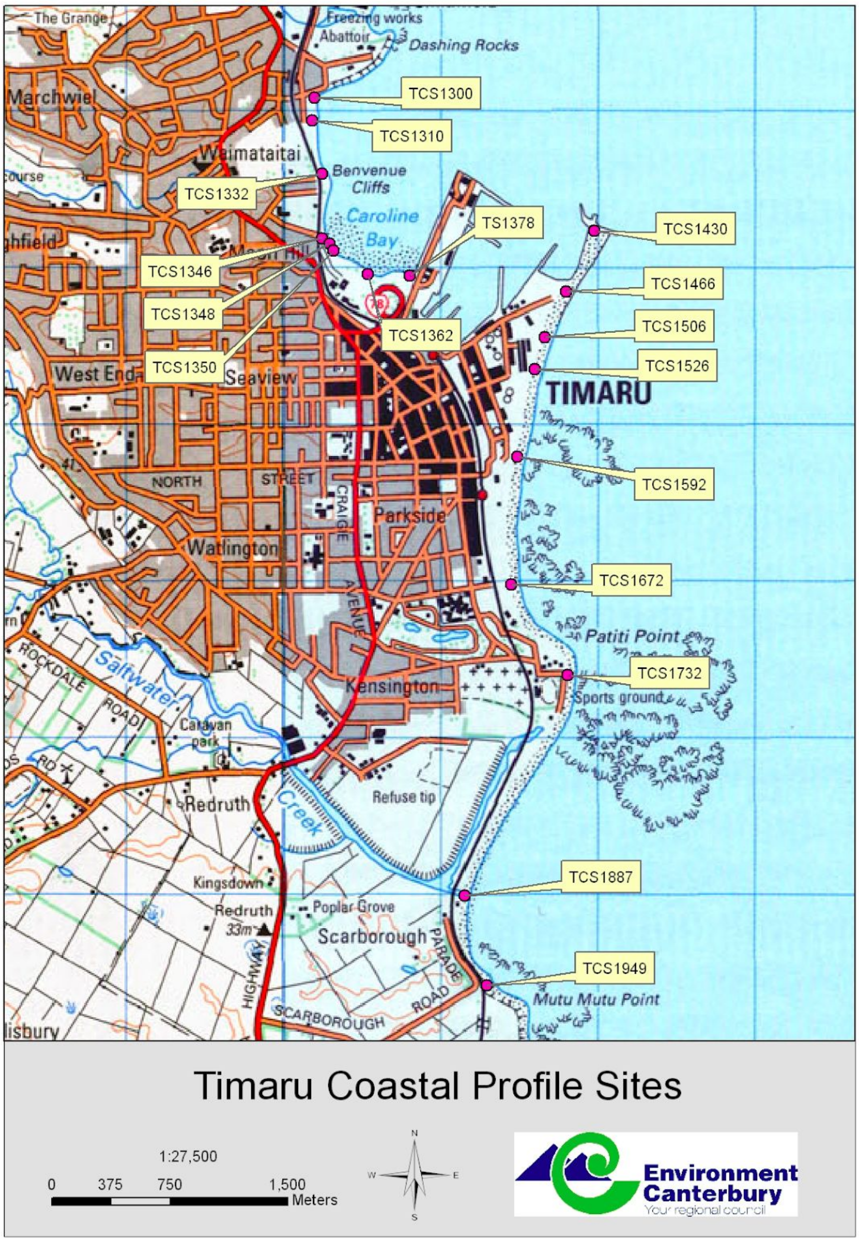
Overall, there are a range of key findings in which this research report has produced. Firstly, the conditions which lead to erosion of Patiti Point were found to be south easterly wave direction and slightly higher than average significant wave heights. Sites located North of Timaru have seen substantial beach volume increases while the majority of the Southern sites have encountered similar conditions to Patiti Point. Additionally, sediment has been tracked across the coast originating from the Waitaki, moving Northward in pulses alongshore. This rate of movement was calculated to be approximately 1012 metres per year, which is within a similar range of previous South Canterbury coast research conducted. Through applying this rate this report suspects that the next pulse of sediment to move north to Patiti Point will arrive in late 2020. However, it is important to account that this report has not attempted to form predictions nor solutions, rather provide an analysis and insight into the temporal coastal processes. It is hoped that this report can be of use for coastal management moving forward.

8. Acknowledgements

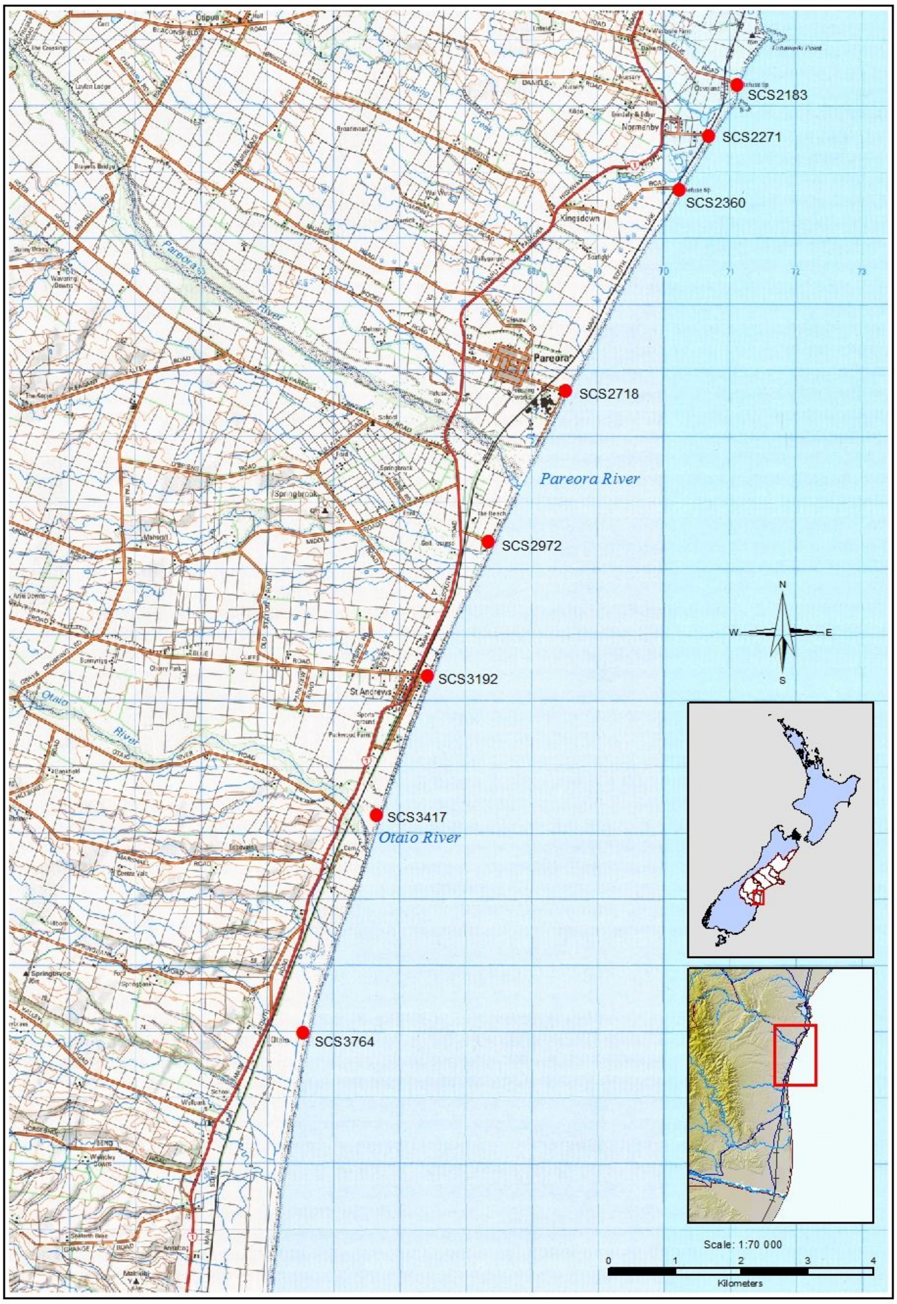
We would like to thank Dr Sebastian Pitman for his professional guidance and encouragement throughout the entire research process. Our group would also like to acknowledge the technical assistance from Paul Bealing. We would like to thank Environment Canterbury in particular, Justin Cope and Bruce Gabites for providing this project and the data required to conduct our research. Additionally, we would like to extend our thanks to the Timaru District Council for their backing of the Patiti Point research. Lastly, we would like to thank the GEOG309 staff for their direction, advice and assistance while undertaking the project.

9. Appendices

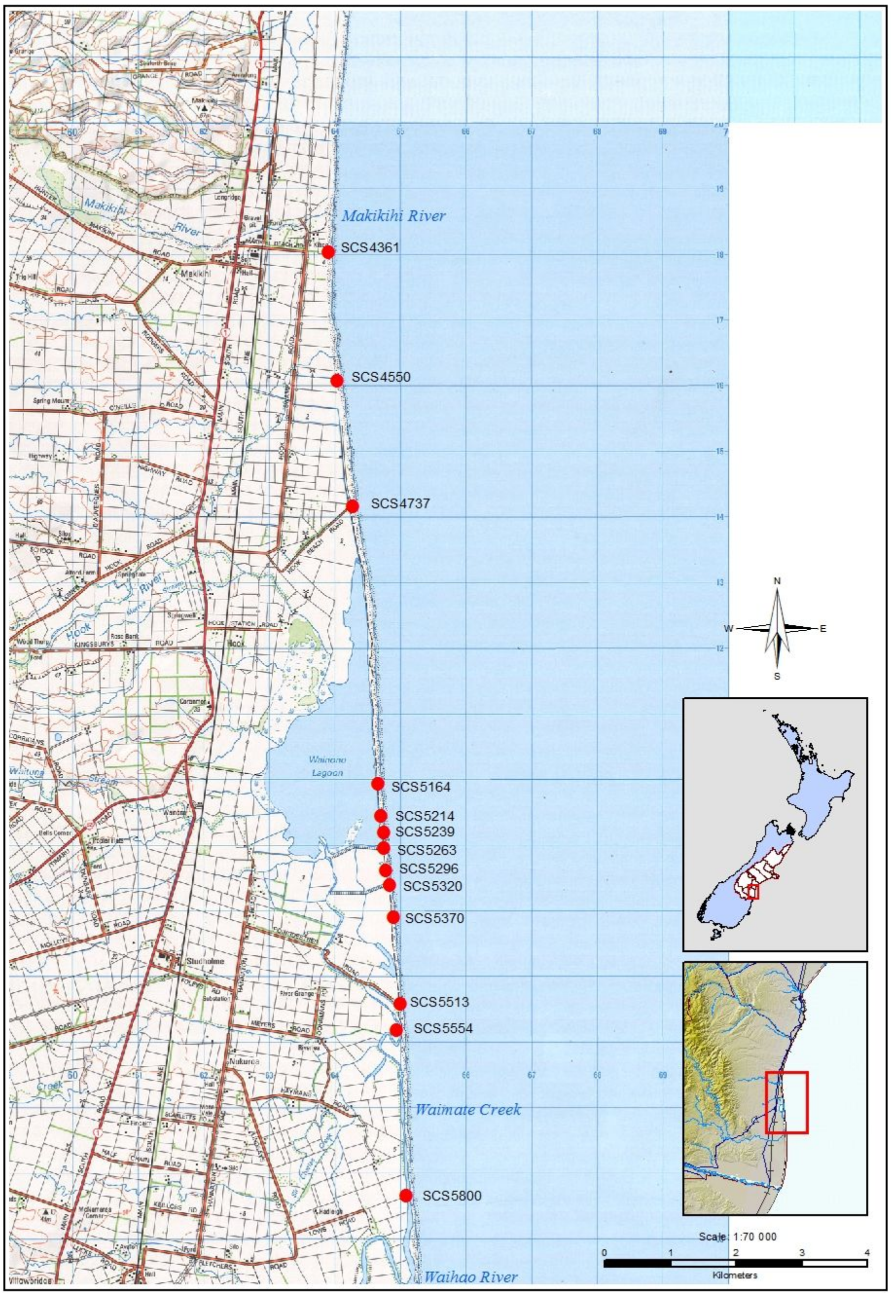
Appendix A. TCS site locations around the wider Timaru area.



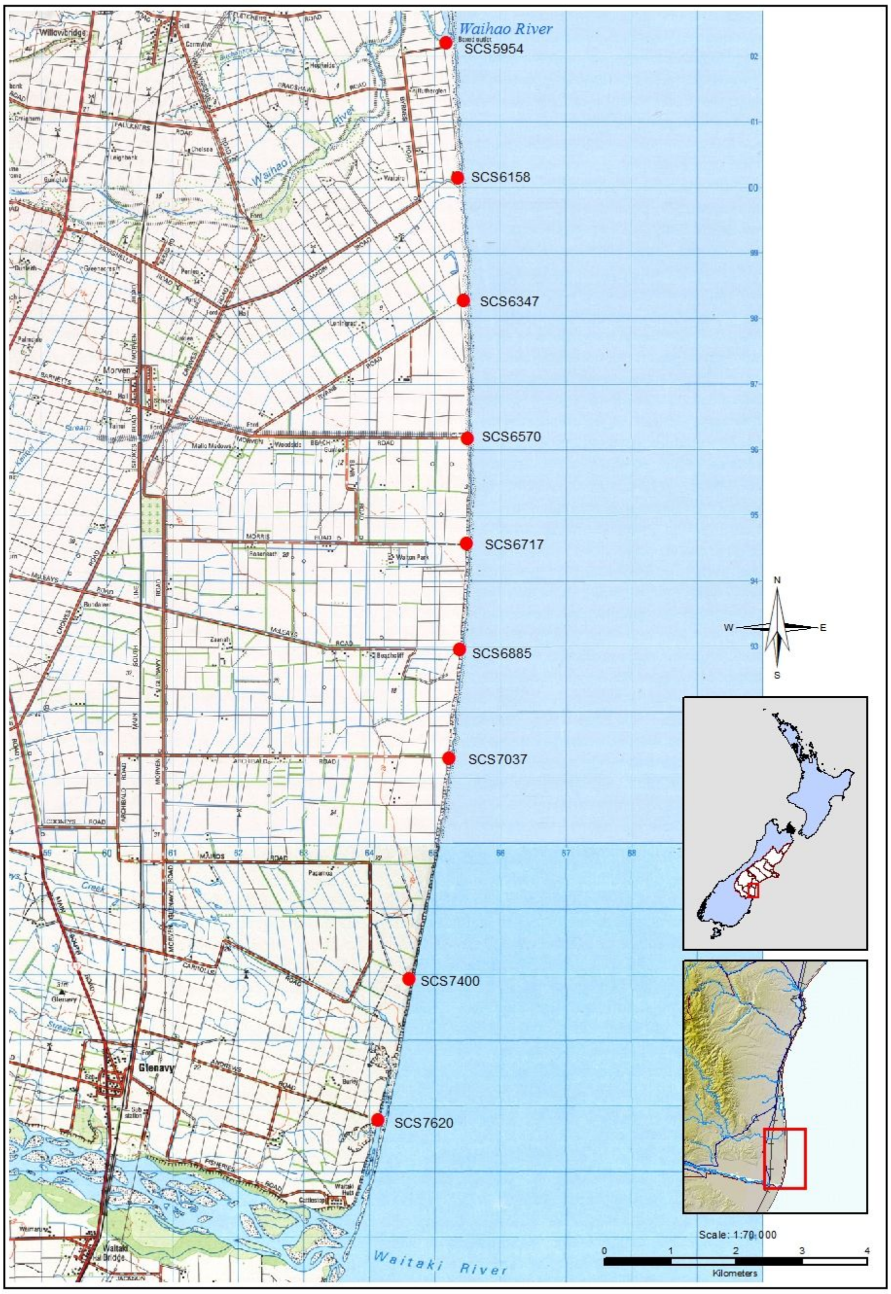
Appendix B. Eight most northward SCS sites below Timaru.



Appendix C. Next 13 SCS sites further South of Timaru.



Appendix D. 9 most southern SCS sites close to the Waitaki River.



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