Clarence City Council Shoreline Monitoring Program

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Cover Image: Shoreline erosion at northern Roches Beach, June 2022.

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Executive Summary

The Clarence City Council Shoreline Monitoring Program is an annual coastal surveying project that documents contemporary and historical changes in shoreline structure and position on numerous beaches within the Clarence Municipality. The project was initiated after a large storm event on the 9th of July 2011 which resulted in substantial damage to both beaches and infrastructure along the south and south-east coasts of Tasmania. Significant erosion and shoreline retreat were observed at beaches stretching from as far west as Spain Bay in Port Davey, as far south as Prion Beach on the South Coast and east to Roaring Beach on the Tasman Peninsula.

The main study sites of Bellerive, Howrah, Seven Mile, Roches and Clifton Beaches along with Cremorne and the southern end of Pipe Clay Lagoon have been surveyed and analysed annually starting immediately after the 2011 event. A further eleven sites have also been surveyed at least once since the inception of the program.

Pre 1960 historical aerial photographs for 12 of the 16 sites have been rectified to provide an historical record of shoreline positions and to provide a geomorphic context for areas experiencing elevated shoreline erosion.

The 2021-2022 survey reveals that Seven Mile Beach is the only beach to show a significant recovery trend, as it has since the 2011 event. Bellerive and Howrah Beaches remain stable with very low rates of seaward shoreline growth. The remaining beaches at Cremorne, Clifton, Roches and the shorelines inside of Pipe Clay Lagoon at Bicheno Street and Pipe Clay Esplanade have seen their shorelines recede. These results are broadly in line with the shoreline trends seen since the program was initiated in 2011. Notably the northern part of Roches beach experienced additional considerable shoreline erosion in excess of 4 metres in places during a protracted swell event in June 2022.

The shorelines at Roches Beach and those surveyed on the inside of Pipe Clay Lagoon have all exhibited a long-term recession signal since the 1950's. As such they can be considered highly vulnerable to any elevation of current sea levels.

2022-2023 likely sees a third consecutive La Nina weather pattern develop, the first time this has occurred in over 50 years. Previous La Nina events have resulted in the temporary elevation of the sea level along the Eastern seaboard of Australia of around 10cm due to a change in the prevailing winds across the Pacific Ocean. These events generally result in a marked increase in coastal erosion, as seen throughout 2020-2022 on the east coasts of New South Wales, Victoria, Queensland and to a lesser extent Tasmania.

These temporality elevated sea levels and the changing weather patterns associated with the La Nina weather event may account for the significant increase in annual shoreline recession observed at the majority of the study areas during the 2021-2022 survey.

Introduction

Beginning on the 9th of July 2011 a large storm event pounded the west and south coasts of Tasmania with waves in excess of ten metres for approximately 54 hours. The long-period swell and associated surge resulted in a substantial storm bite with large quantities of sand removed from the beaches along much of the southern and south eastern Tasmanian coastline.

The beaches of Storm Bay and Frederick Henry Bay were hit particularly hard with wave heights exceeding three metres and storm bites of around ten metres measured at parts of both Seven Mile and Roches Beach (Figure 1).

Immediately after the storm event it was identified that there was a need to capture the resulting impacts using high resolution aerial photography for many of the beaches within the Derwent Estuary, Storm Bay and Frederick Henry Bay. The flights were flown on the 15th of July 2011. In total 1250 photographs were taken covering numerous beaches within the Clarence, Sorell and Kingborough Municipal areas.

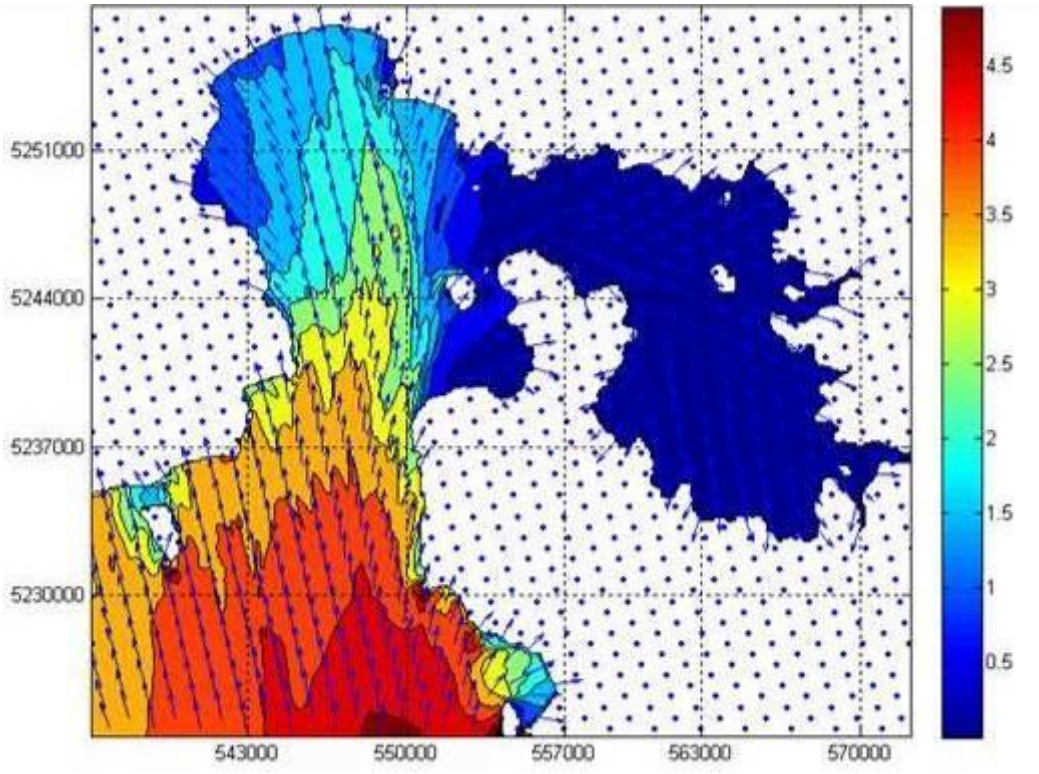

Figure 1 - Significant wave heights for Frederick Henry Bay 9 July 2011 (source: Water Research Laboratory, University of New South Wales, 2011).

The 10-15cm resolution orthophotography provided a quick quantifiable representation of the resulting shoreline position and clearly identified the areas hardest hit by the storm event.

The subsequent 2012 to 2021 surveys were more comprehensive surveys focussed primarily on the beaches of the Clarence Municipality. During these survey's the beaches were intensively photographed with three or more flight runs per beach so that an accurate three-dimensional representation of the beach profile information could be generated.

The data was processed in two stages. In the first stage, the seaward extent of the vegetation line was extracted from the orthophotography. The second stage was a computationally intensive analysis of the orthophotography which enabled the extraction of relative beach profile information for all the beaches surveyed.

The Clarence City Council Shoreline Monitoring Program is primarily a baseline monitoring project aiming to provide an objective set of accurate high-resolution data from which decisions on future planning requirements and adaptation measures can be based. The data will support and strengthen the effectiveness of existing projects such as the TASMARC shoreline monitoring program, the findings of the *Clarence City Council Coastal Vulnerability Assessment Report* and the *Tasmanian Coastal Adaptation Decision Pathways* project.

The Study Area

The 2021-22 survey (Figure 2) aimed to cover most of the densely populated sandy beaches that experience substantial wave action within the Clarence Municipality.

Figure 2 - Study area and 2021-2022 flight lines for the *Clarence City Council Shoreline Monitoring Program*. Photos were captured for all the blue flight lines.

These shorelines included:

- Seven Mile Beach
- Roches Beach
- Cremorne Beach
- Clifton Beach
- Bellerive Beach
- Howrah Beach

Wave Climate and Tide Regime

The southern coast of Tasmania is a high energy swell environment (Davies 1980). It is a very stormy region. Waves of less than two metres occur only 2% of the time and waves of greater than five metres occur 40% of the time (Chelton *et al.* 1981). Waves of greater than four metres regularly pound the coastline (Bureau of Meteorology 1995).

The study area has a micro-tidal regime with spring tides of greater than two metres. This tidal range is regularly amplified by high winds and large swells which cause areas of the beach and fore dunes that are normally beyond the reach of the tide and wave attack, to suffer significant erosion events. This effect is illustrated in Figure 3 below. The identified and labelled peaks correspond to a series of intense low-pressure systems which pushed observed sea levels over 50cm above predicted levels during the storms in July 2011.

During 2022 a tide gauge was installed in Pipeclay Lagoon for four months in conjunction with the University of New South Wales Water Research Laboratory. Data from this gauge showed a mean tide approximately 10cm cm lower than the Hobart tide gauge. This has implications for inundation modelling and will feed important information into further tide and wave regime monitoring,

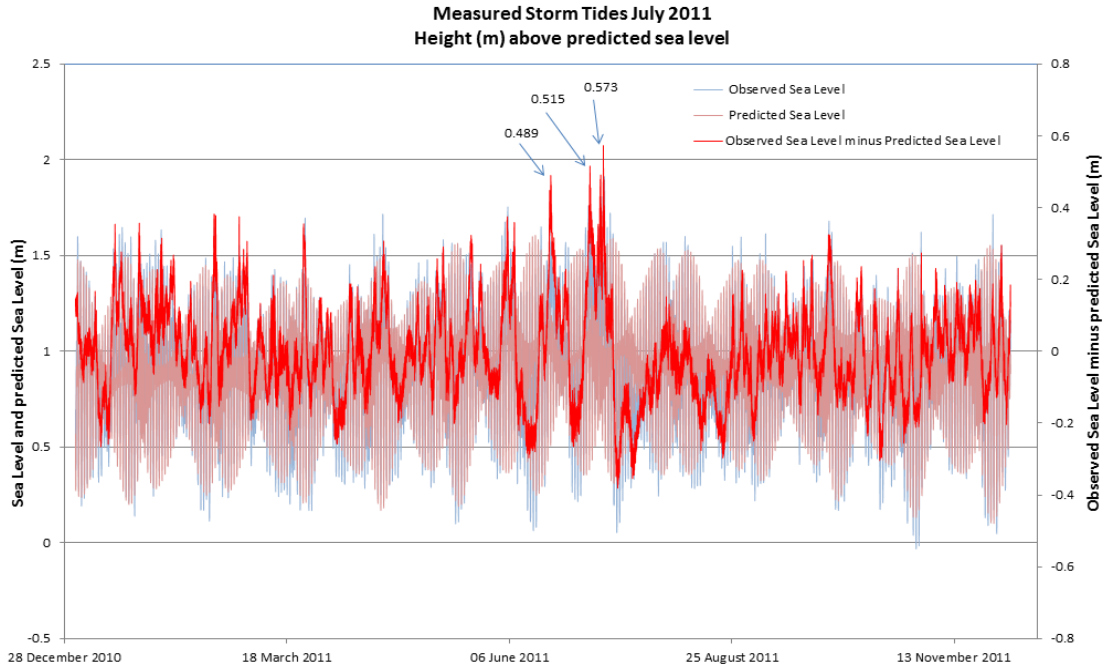

Figure 3 - Storm tide peaks visible in tide gauge data from the 2011 Hobart Ports tide gauge data (Data courtesy of the Bureau of Meteorology 2011).

Geology and Geomorphology

The bedrock geology of the study area is principally Permian siltstones, Triassic sandstones and Jurassic dolerite. These rocks have been subject to normal faulting which has resulted in them being variably tectonically uplifted and dropped forming the typical undulating horst and graben landscape. The Permian and Triassic sedimentary rocks have been intruded in places by igneous Jurassic dolerite. Overlying the hard bedrock are Tertiary and Quaternary sediments as poorly consolidated alluvium, colluvium and coastal sediments.

Previous studies (e.g. Davies 1980) have identified the dune and beach deposits within the study area as being of Holocene or Pleistocene (Quaternary) age.

Methods

The project methodology used a combination of traditional photogrammetric techniques and modern computer vision techniques. The orthophotos and digital elevation models were generated through complex mathematical analysis of on ground features within the overlapping areas of vertical digital aerial photographs. A detailed flight plan was developed to ensure all beaches were completely surveyed and to ensure a minimum of three photographs contained any one point on the ground within the area of interest. Vertical digital aerial photographs of the selected beaches were collected at 7.5 cm resolution using a Phase

One DSLR camera and 90mm Lens. These photos were then orthorectified using differential GPS (DGPS) located control points resulting in planar positional accuracy of +/- 10cm.

To better understand the long-term trends in shoreline position historical orthophotos were scanned and orthorectified and their shoreline positions examined and digitised. It was not always possible to generate the orthophotos to the same accuracy as the modern equivalents and in some cases the photography was of such poor quality it was not suitable for use at all. For example, the pre-1960 orthophotos have a positional accuracy of +/- 1 to 2 metres depending on the scanning quality.

The shoreline position was defined in this study by the most seaward position of continuous vegetation on the beach. The shoreline was hand digitised on the orthophotos at a scale of 1:50. The shoreline position for each time step and beach profile measurements, where available, were recorded along a series of 100 metre spaced transects located along the length of each beach.

It should be noted that Quickbird satellite data was used to delineate the 2005 and 2007 shorelines as part of this project. Quickbird imagery has a relatively coarse resolution of 40 cm when compared to a resolution of 5-15 cm for the digitally acquired images and the positional accuracy of the Quickbird imagery is generally +/- 0.5 to 2 metres. Further historical orthophoto generation would need to be developed before more spatially and temporally accurate long-term shoreline behaviour recession trend based around these shorelines could be determined.

The deliverable products for this project are orthophotos and shoreline position for all time intervals, and beach profile information for each study area at each discrete time interval for the annual 2011 to 2022 flights where sufficient photographic coverage and comprehensive ground control network exists.

The project expands on the work of the *Shorewave Project* by Sharples *et al.* (2012 in prep). The *Shorewave Project* used scanned analogue aerial photographs that were orthorectified using the Climate Futures LiDAR Data as a base. This method was not a full photogrammetric reconstruction as all photos including the 1950's images were forced to fit over the 2005 LiDAR topography and as a result have a higher margin of error (+/- 1 metre) than results of this project. However, the *Shorewave Project* covered beaches throughout Australia at more regular time intervals and provided a more in-depth analysis of the drivers of the observed changes in the shoreline with an analysis of long-term climatic and oceanographic datasets.

The use of the 100 metre spaced points and transects for analysing was developed as part of the *Shorewave Project*. This technique allows for the semi-automated consistent sampling of data along the beach.

Results

During 2021-2022 the shorelines of Pipeclay Lagoon along Bicheno Street, Roches, Cremorne and Clifton beaches all showed a general recession trend. Seven Mile, Bellerive and Howrah Beaches all showed a recovery in seaward shoreline position, with Seven Mile beach continuing to show a strong recovery since the 2011 event. The recession observed at Roaches beach continues despite an ongoing beach replenishment program. Some ongoing shoreline erosion and vegetation degradation was observed around uncontrolled beach access points at most beaches, as was the reactivation of the 2011 storm bite at select locations at beaches throughout the study area.

The ongoing La Nina weather event that started in 2019 has resulted in increased swell activity up and down the Eastern seaboard of Australia. In June 2022 a series of long duration, large swell events impacted the shorelines of Frederick Henry Bay over a period of two weeks. Average wave heights recorded on the Cape Sorell Wave buoy were up to seven metres with significant wave heights in excess of 12 metres (Figure 4). This event reactivated the 2011 storm bite along many of the beaches and resulted in additional shoreline retreat of over two metres above what was already recorded during summer monitoring.

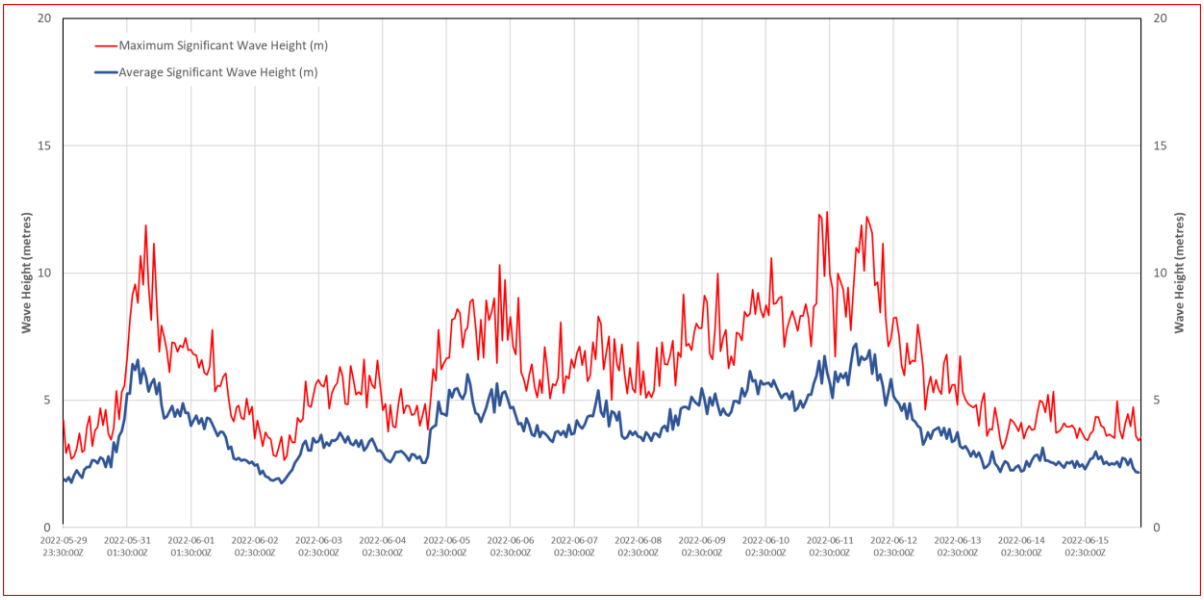

Figure 4. Wave records from the Cape Sorell Wave rider Buoy 29th May to the 15th of June 2022.

Cremorne Beach

Cremorne Beach exhibited a minor recession in shoreline position, averaging 12 centimetres of shoreline retreat between the 2021 and 2022 surveys. This is at odds with the long-term trend which averages 11 centimetres of shoreline recovery per year since the first recorded shoreline in 1958. Shoreline position changes from 2021 to 2022 at the survey points ranged from a recession of 1.27 metres to a growth of 1.17 metres. Nine of the fourteen sites exhibited a seaward growing shoreline (Figure 5).

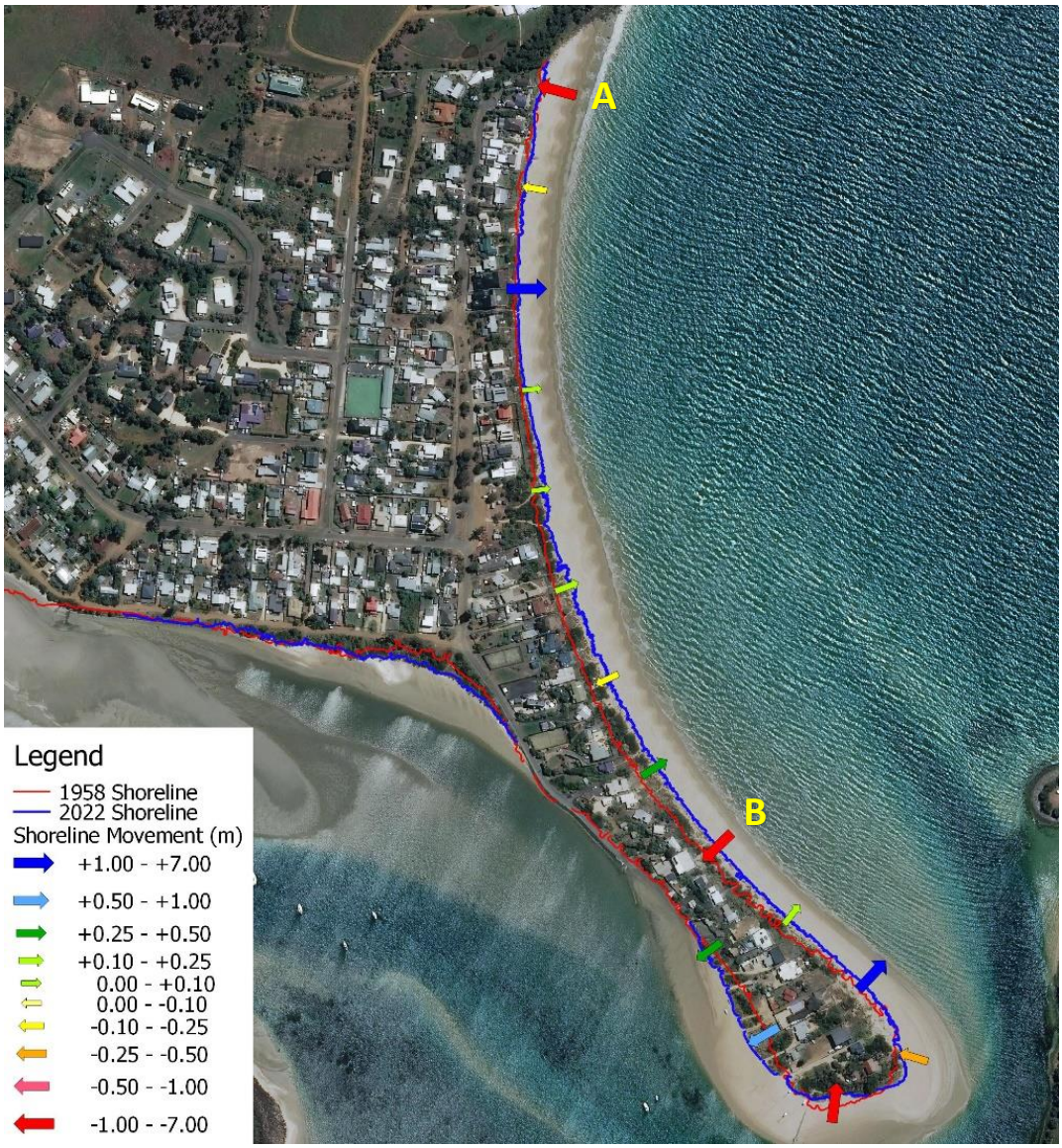

Figure 5 - Shoreline movement at Cremorne Beach, 2021-2022.

Significant erosion continues to be experienced on the end of the spit after an extended period of stability prior to the 2020-21 survey. Erosion in excess of one metre was also observed at two other sites on the ocean facing beach, shown as sites A and B on Figure 5.

During the June 2022 swell event the beach to the north of the Lagoon Channel sustained an additional moderate level of erosion due to the swell angle and the astronomical high tides. The most active erosion was centered around Site B on Figure 5, compounding the shoreline recession that was recorded during the previous twelve months. Figure 6 shows the waves actively eroding the primary dune on the evening of the 22nd of June 2022.

Figure 6. Wave action at Cremorne beach 10th of June 2022.

Historical orthophoto generation for the full shoreline of Pipeclay Lagoon is currently in progress with an aim to provide a timeseries of all the vulnerable soft sediment shorelines.

Roches Beach

The shoreline at Roches Beach showed an increased recession trend since the 2020-21 survey with an average shoreline recession of around 70 centimetres. This rate of recession is significantly larger than the long-term erosion trend of 12.2 cm per year observed at the beach over the last 70 years (Figure 7). During the 2021-2022 survey period shoreline retreat ranging from 0.14 to 2.6 metres was observed at 15 of the 20 surveyed transects. Seaward growth of the shoreline was observed in the remaining five transects ranging from 0.01 to 0.71 metres. Shoreline retreat of over four metres was observed between the monitoring points at several location in the northern third of the beach.

Unlike the previous ten years, shoreline recession was observed at sites along the full length of the beach, with the replenished shoreline retreating due to the consistent large to moderate swell events. Notably the two northern most survey sites adjacent to the hardened shoreline near Bambra reef have remained relatively stable since the 2021 survey.

Over the last 11 years the shoreline position immediately north from the Canal has been less susceptible to recession thanks to the ongoing sand replenishment program and lower exposure to

erosive swell events. However, during the past year this part of the beach has been impacted by shoreline recession.

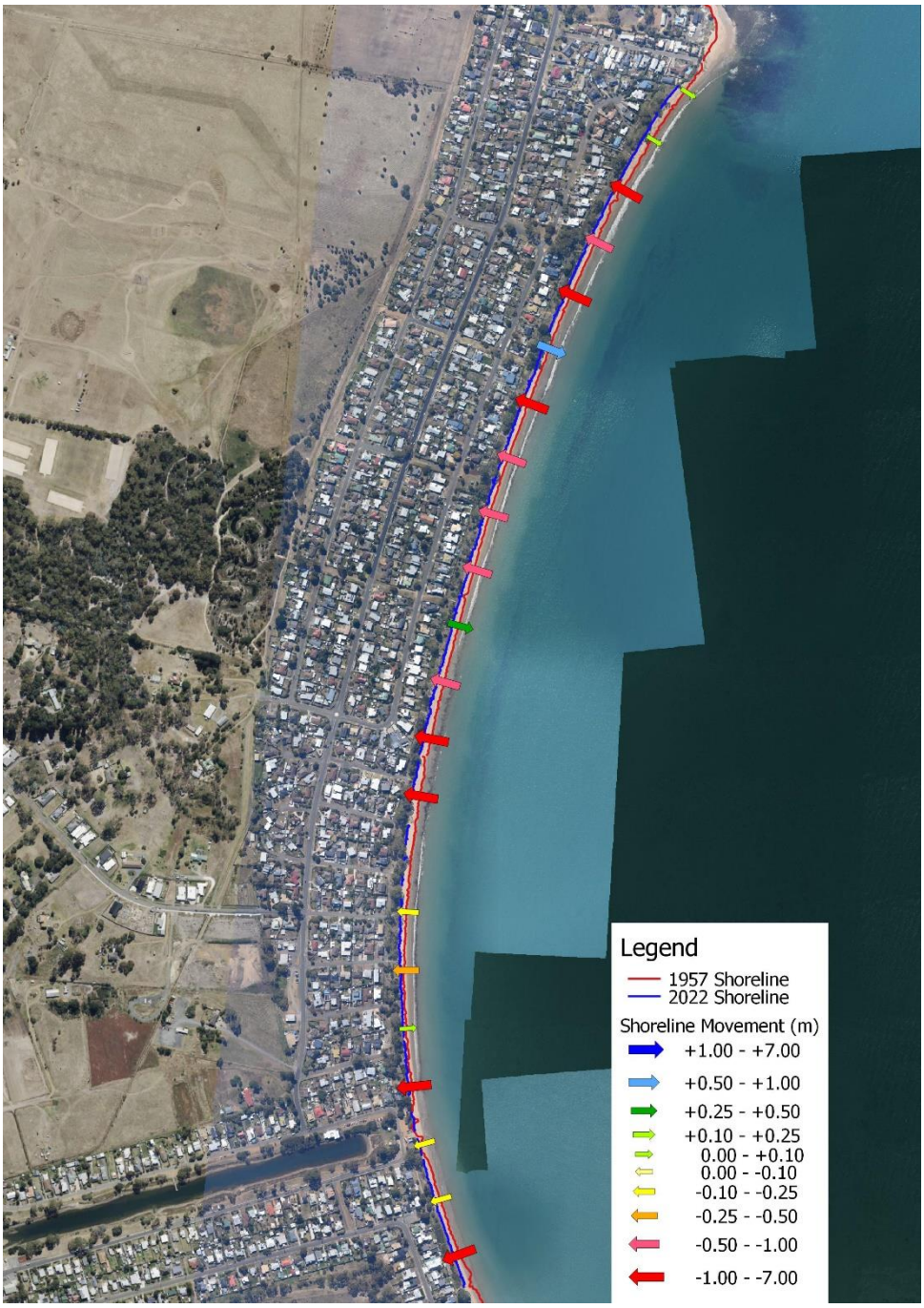

Figure 7 – Shoreline movement at Roches Beach, 2021-2022.

Detailed analysis of the net shoreline position at Roches Beach observed between 2011 and 2022 shows a slight net gain in seaward shoreline position in 16 of the 20 sites surveyed (Figure 8). This is in a large part due to ongoing beach replenishment program and dune stabilisation program. The recovery is in line with the stabilisation of the storm bite observed at the other surveyed beaches in the aftermath of the large erosion event in 2011.

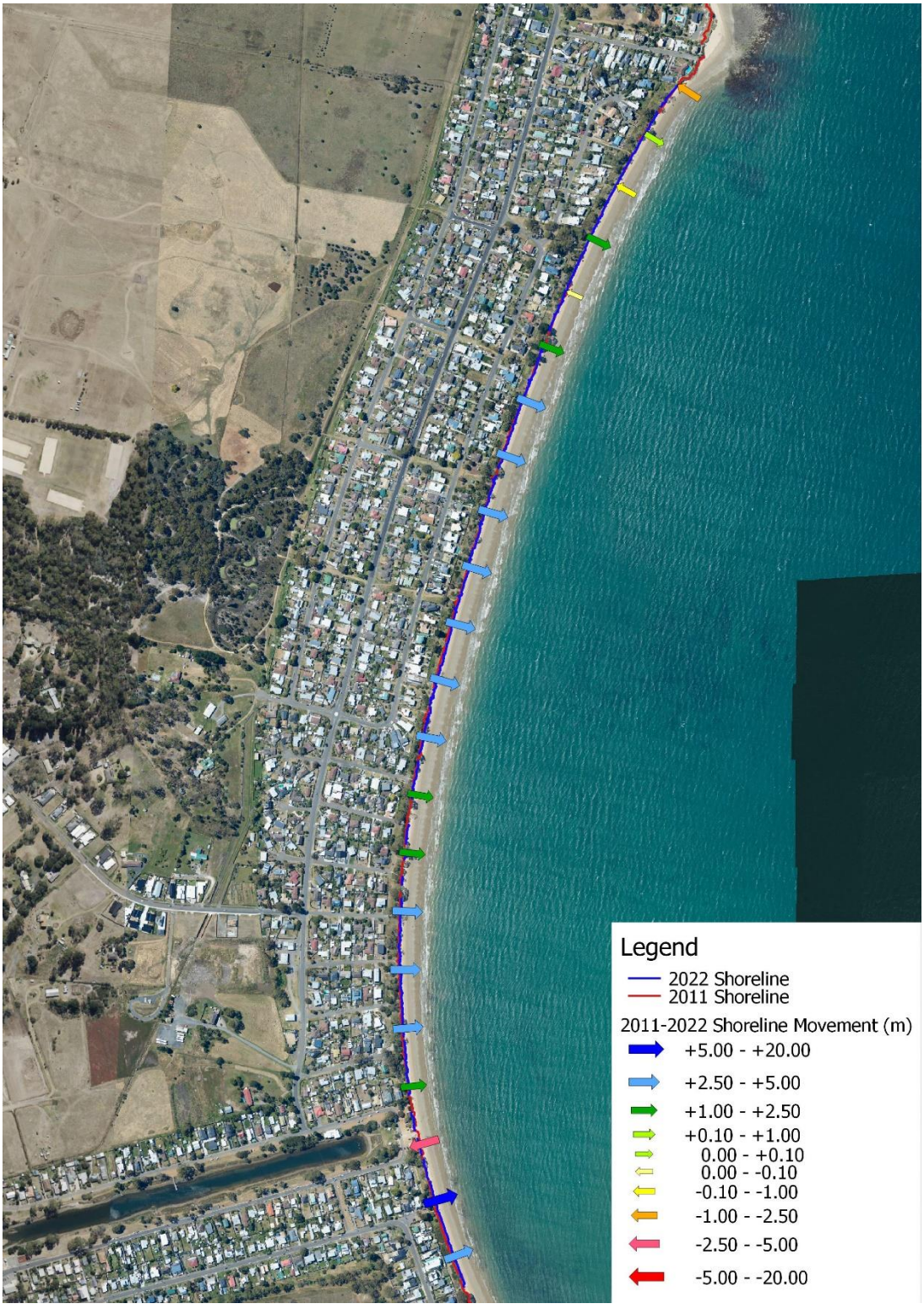

Figure 8 – Shoreline movement at Roches Beach, 2011-2022.

Analysis of the Net shoreline position since 1957 reveals a very strong recession signal with an average net recession of 8.4 metres ranging from 4.4 to 13.5 metres (Figure 9). This clear ongoing recession

trend was exacerbated by the very strong erosion event immediately prior to the 2011 survey from which the beach has shown very little to no natural recovery.

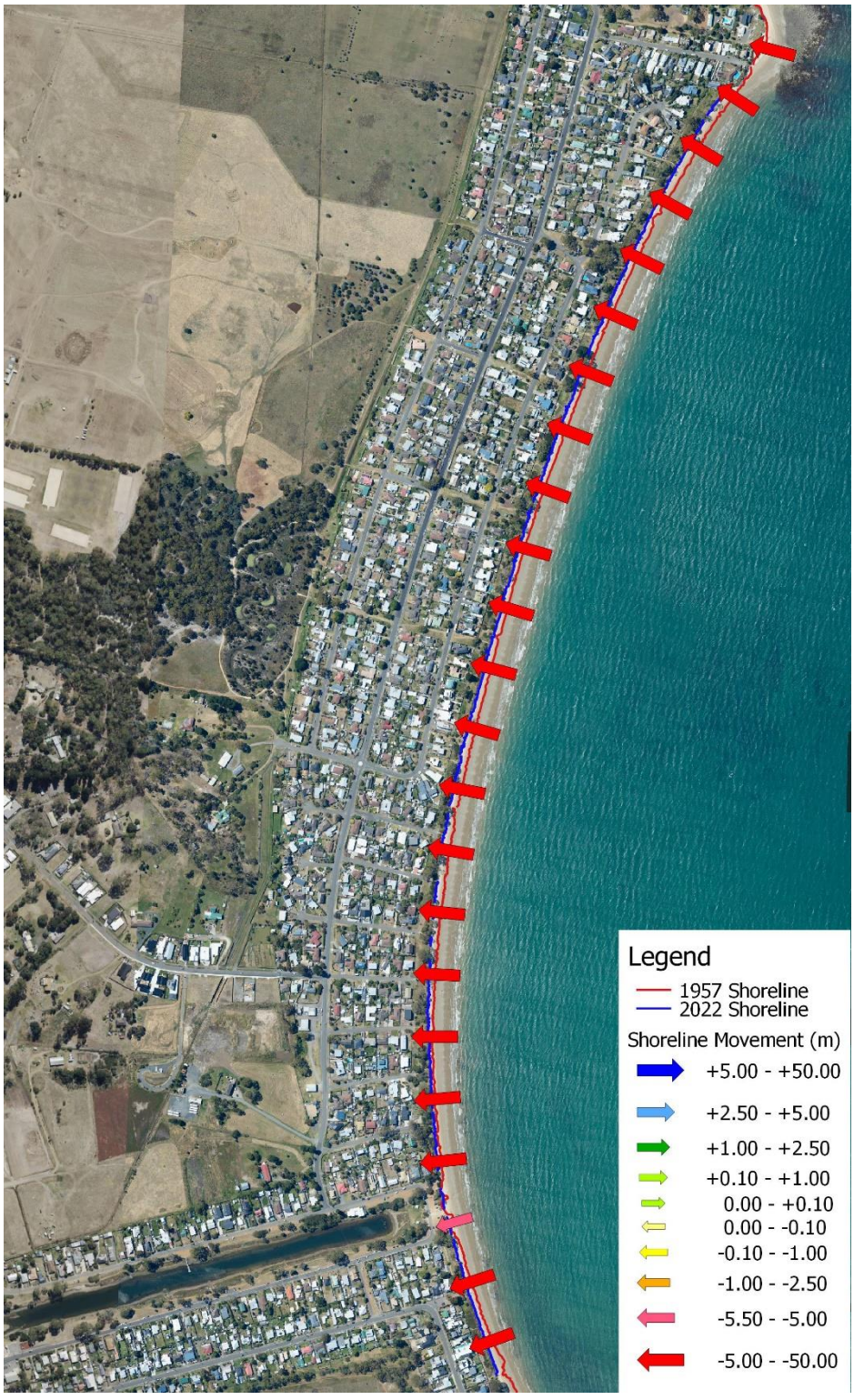

Figure 9. Net Shoreline Movement 1957-2022.

During early June 2022 a long duration moderate to large swell event impacted many of the shores of the Clarence Municipality. Wave heights exceeded seven metres on and off for a period of over

two weeks. This increased wave action combined with astronomical high tides resulted in considerable erosion particularly on the northern end of Roches Beach. Shoreline recession in excess of 4.5 metres was observed at several places along the beach (Figure 10).

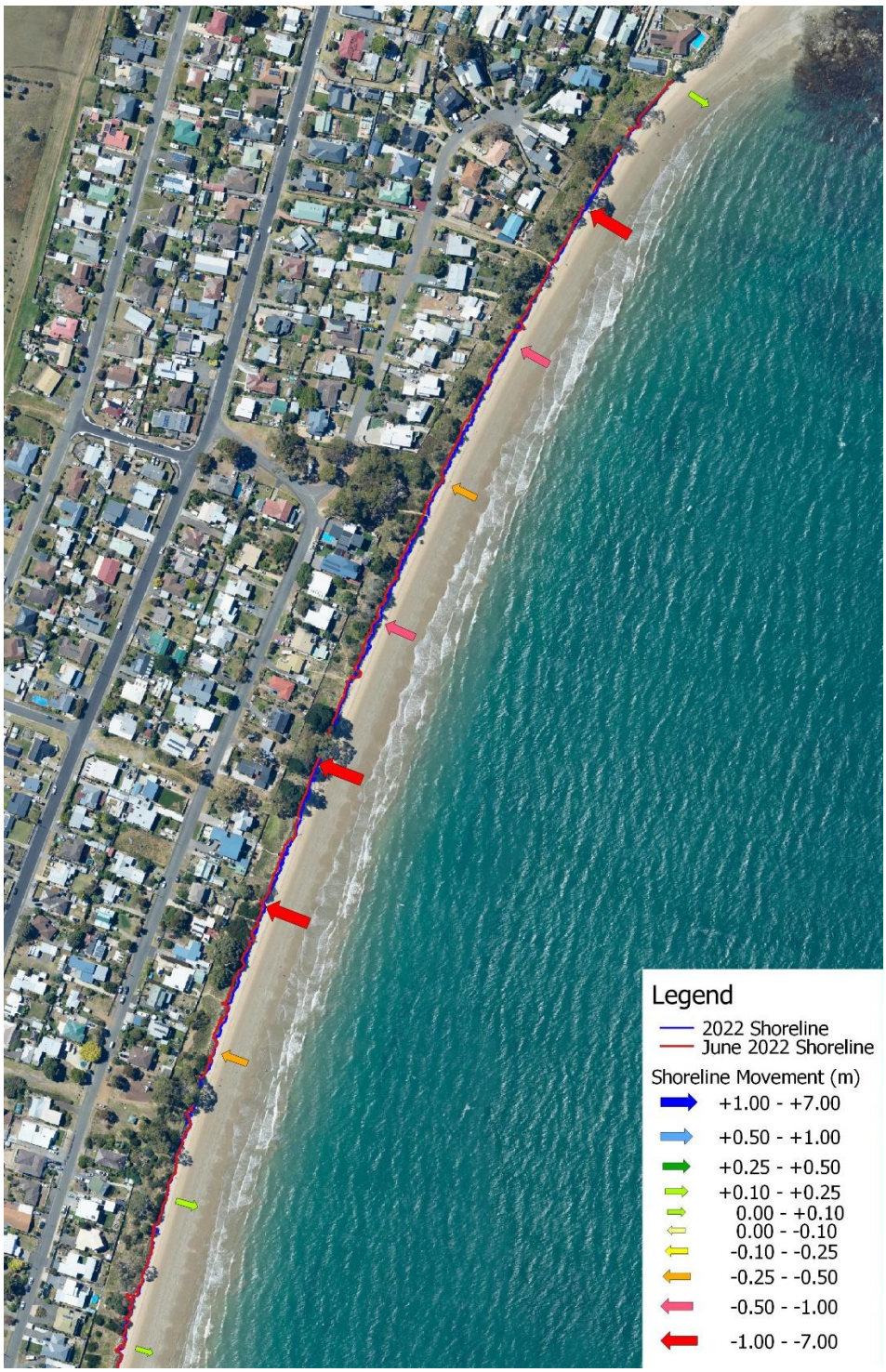

Figure 10 – Shoreline recession at northern Roches Beach after June 2022 swell event.

The observed impacts of this swell event were greatest at the Northern end of Roches Beach extending 800 metres South from Bambra Street. Erosion scarps from one to three metres high were created

and for the most part its position was well behind the scarp created during the 2011 Swell event. Examples of the damage to the beach can be seen in Figures 11 and 12.

Figure 11. Erosion at northern Roches Beach, June 2022.

Figure 12. Erosion and infrastructure impacts at Roches Beach, June 2022.

Western Seven Mile Beach

At the Seven Mile Beach survey site an average seaward growth of the shoreline averaging 0.81 meters was recorded, ranging from 1.07 metres recession to seaward shoreline growth up to 4.2 metres (Figure 13). Shoreline recession was limited to areas adjacent to the Acton Creek at the southern end of the beach and two sites of marram grass leader truncation at the northern end of the study area. Ongoing strong seaward growth of the shoreline ranging from 5 cm to 1.57 metres is observed at the remaining seventeen survey points.

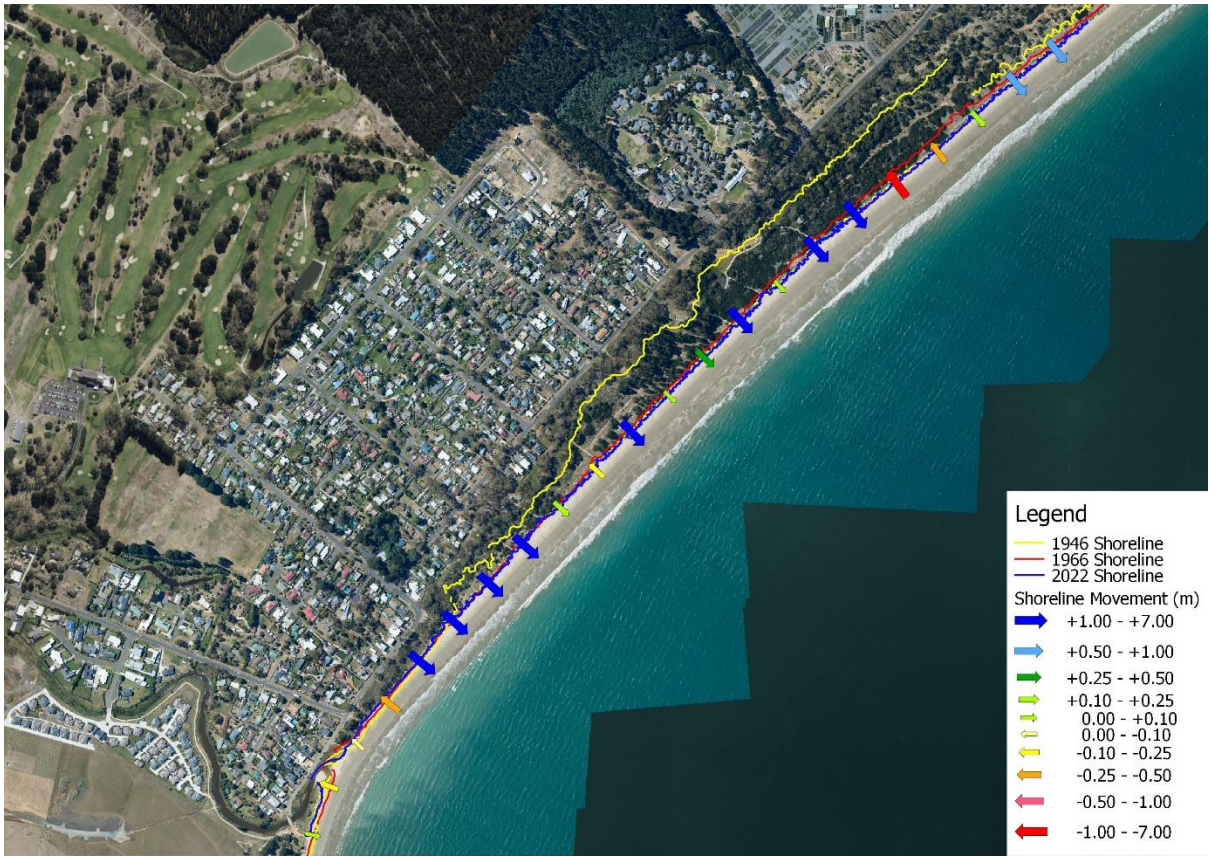

Figure 13 – Shoreline movement at Western Seven Mile Beach, 2021-2022.

In keeping with the trend since 2011, marram grass and recently emergent coastal saltbush is consolidating and growing the dune vegetation seaward. The observed erosion generally only occurs around the Acton Creek mouth at the southern end of the beach where variability is expected (Figure 14) or close to well used beach access points.

The otherwise stable nature of the beach is well illustrated in Figure 15, with site photos capturing the shoreline at the northern end of the study site, looking south and taken a year apart in December 2020 and 2021. The photos show the low foredune stabilised by the marram grass, which sits in front of the 2011 storm bite scarp. The photo also illustrates the ongoing removal of the Radiata pine trees along the beach continues to have no effect on beach recovery.

Figure 14 – Shoreline position at the mouth of Acton Creek Seven Mile beach 1966-2022.

Figure 15. Stable low beach profile and emergent Marram Grass at Northern Seven Mile Beach Study Site at 2021 above and 2022 below.

An analysis of the Shoreline behavior from 2011-2022 illustrated in Figure 16, shows a strong seaward growth in shoreline position at all of the survey points along the beach, the exception is minor shoreline retreat a mouth of Acton Creek. This recovery has been aided by the consolidation of main beach access points, the removal of the radiata pines from the coastal zone, the resilient nature of the marram grass and emerging coastal saltbush.

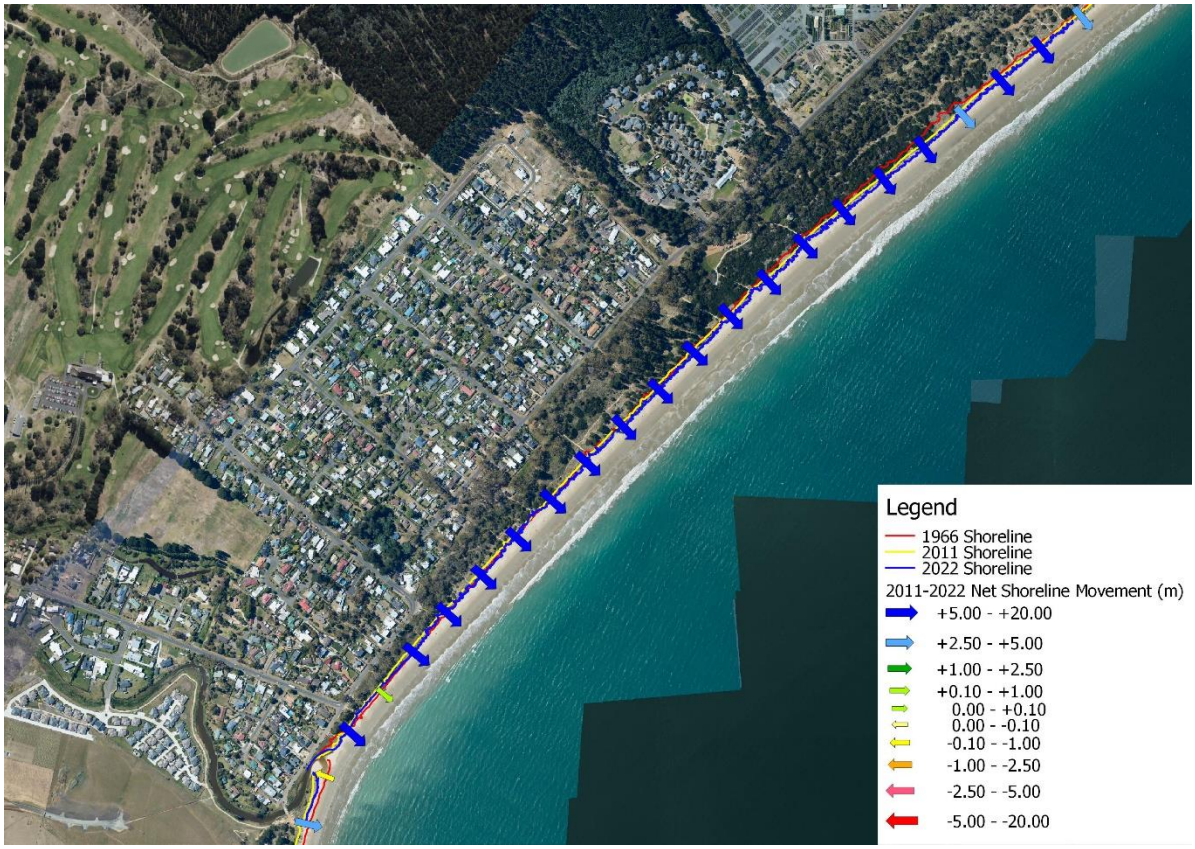

Figure 16– Shoreline movement 2011-2022 at western Seven Mile Beach.

The Net shoreline position movement since 1996 (Figure 17) shows moderate to high levels of overall shoreline recession at the southwestern end of the beach. As illustrated previously in Figure 14 the three bottom survey points are strongly affected by the variable nature of the mouth and associated vegetation change of Acton Creek. The remaining three sites exhibiting recession north of the creek mouth experienced substantial recession in excess of six metres during the 2011 event. These sites have a high density of beach access points and receive most of the foot traffic and sunbathing crowds during the summer months. As seen in Figure 16 all but one of these sites have exhibited a net seaward growth in shorelines since 2011. The northern two thirds of the beach have experienced a strong shoreline recovery from the exposed mobile sands observed in the 1946 and 1966 photography.

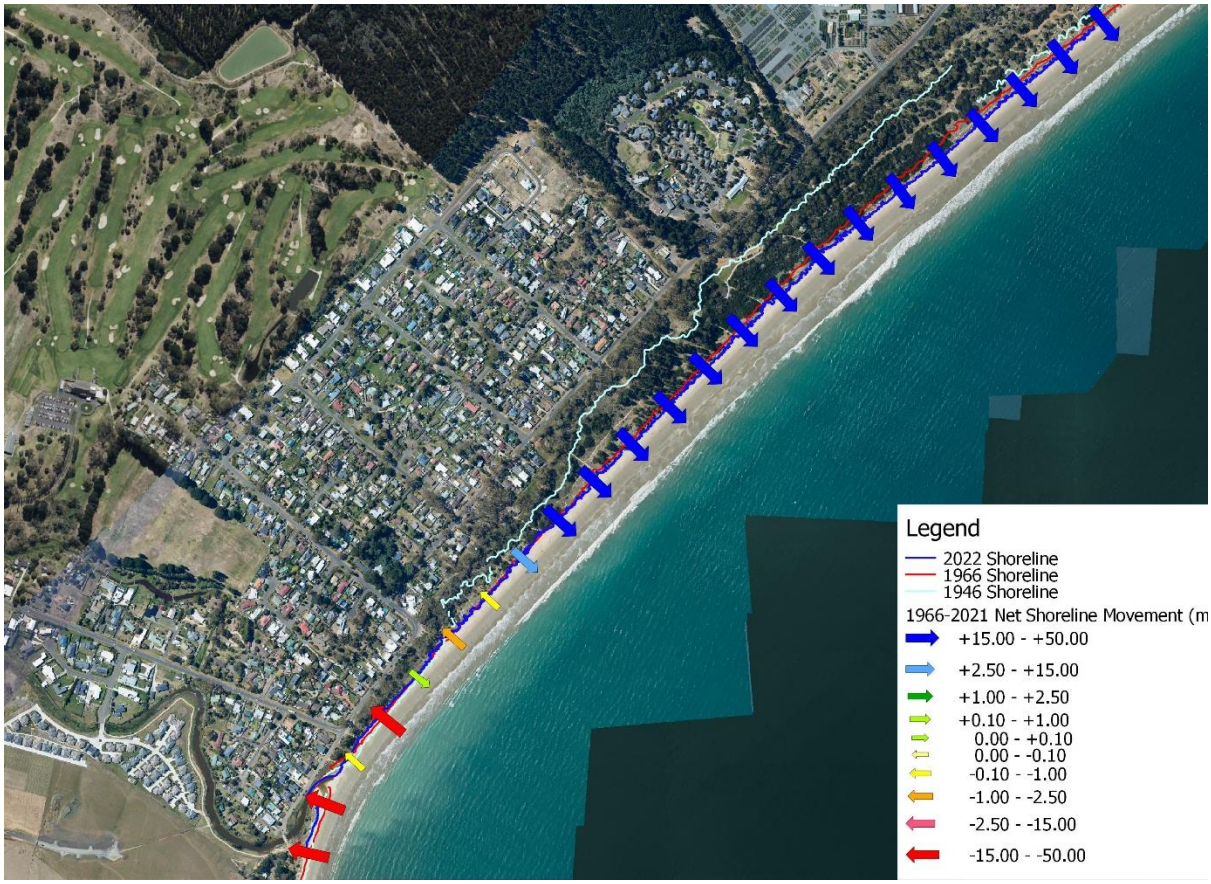

Figure 17 – Shoreline movement 1966-2021 at western Seven Mile Beach.

Bellerive

Bellerive Beach remained relatively stable between the 2021 and 2022 surveys. The shoreline moved seaward by an average of 4cm during 2021-2022 survey period, which is slightly lower than the long-term annual average of 12cm growth since 1957. Shoreline movement ranged from 76cm recession through the centre of the beach to 32 cm growth. Recession was observed in five of the nine transects, ranging from five to 38 centimetres (Figure 18). The highest recorded areas of recession were adjacent to two well used beach access points.

The measured net shoreline movement at Bellerive Beach between 2011 and 2022 show a small but consistent average 3cm recession trend of with eight out of ten sites showing a recession of between 5 centimetres and 5.3 metres (Figure 19). The main recession point is an outlier caused through the clearing of vegetation associated with a new path and stormwater outlet on the beach. Seaward shoreline movement is restricted to two sites on the eastern end of the beach exhibiting seaward growth of 0.11-1.6 metres. This area of the beach has been partially stabilised through fencing and shoreline vegetation has recovered strongly.

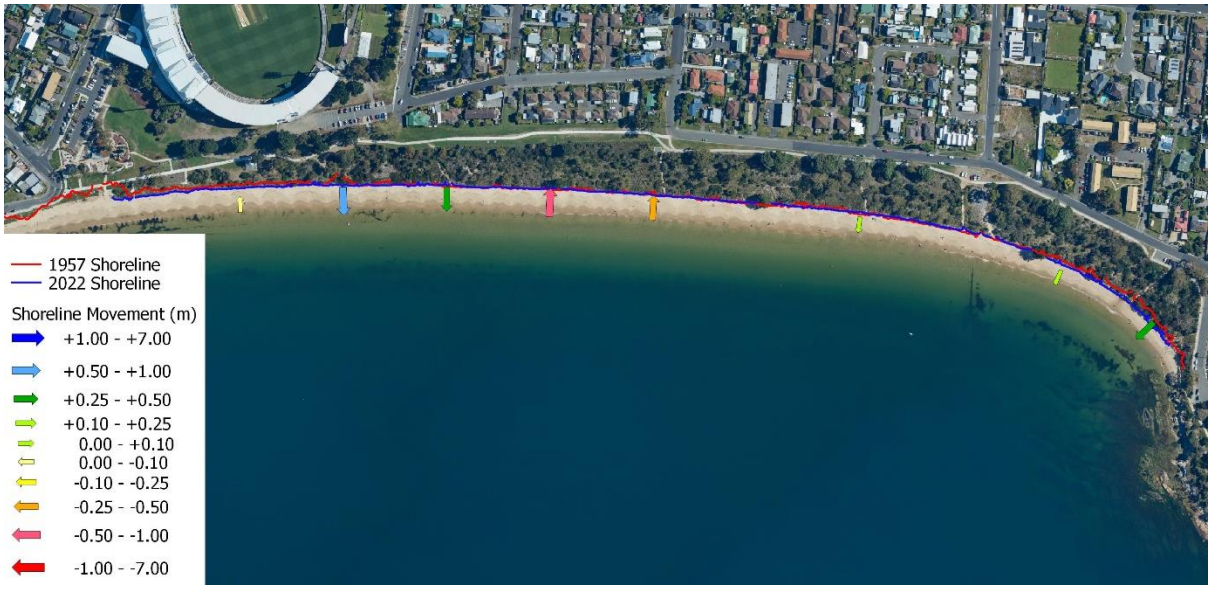

Figure 18 – 2021-2022 Shoreline movement at Bellerive Beach.

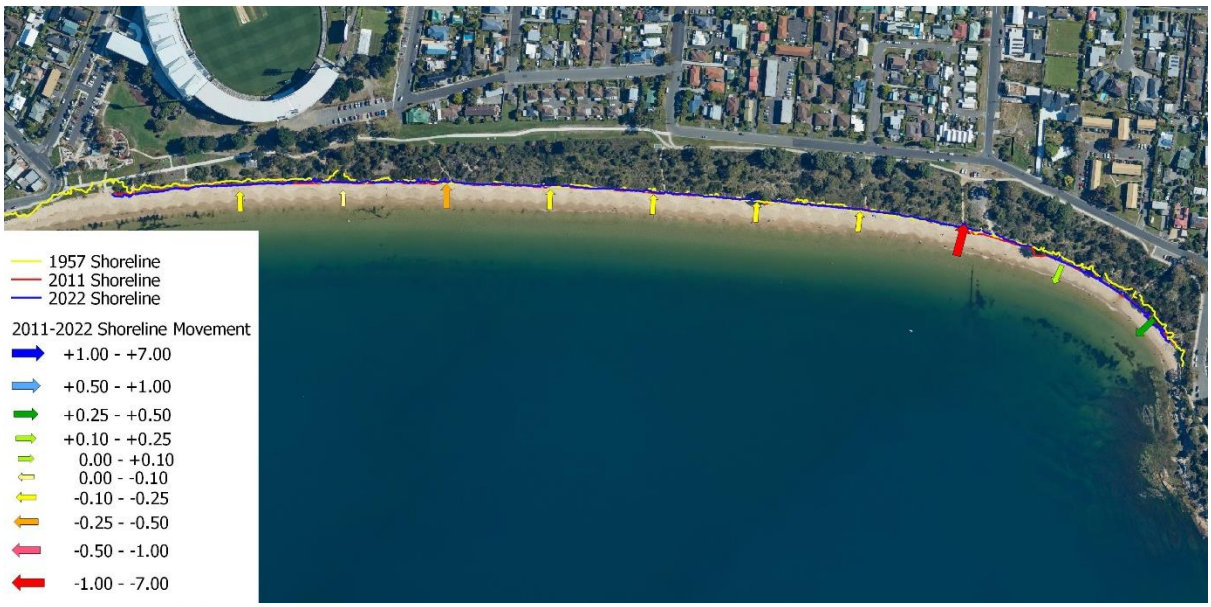

Figure 19 – 2011-2022 Net shoreline movement at Bellerive Beach.

The net shoreline movement recorded at Bellerive beach since 1957 shows a broad area of recession through the middle of the beach with six out of the seven recession sites experiencing net recession in excess of 1.5 metres. (Figure 20).

The fencing of the coastal vegetation at the eastern end of the beach and hardening at the western end have partially stabilised the beach.

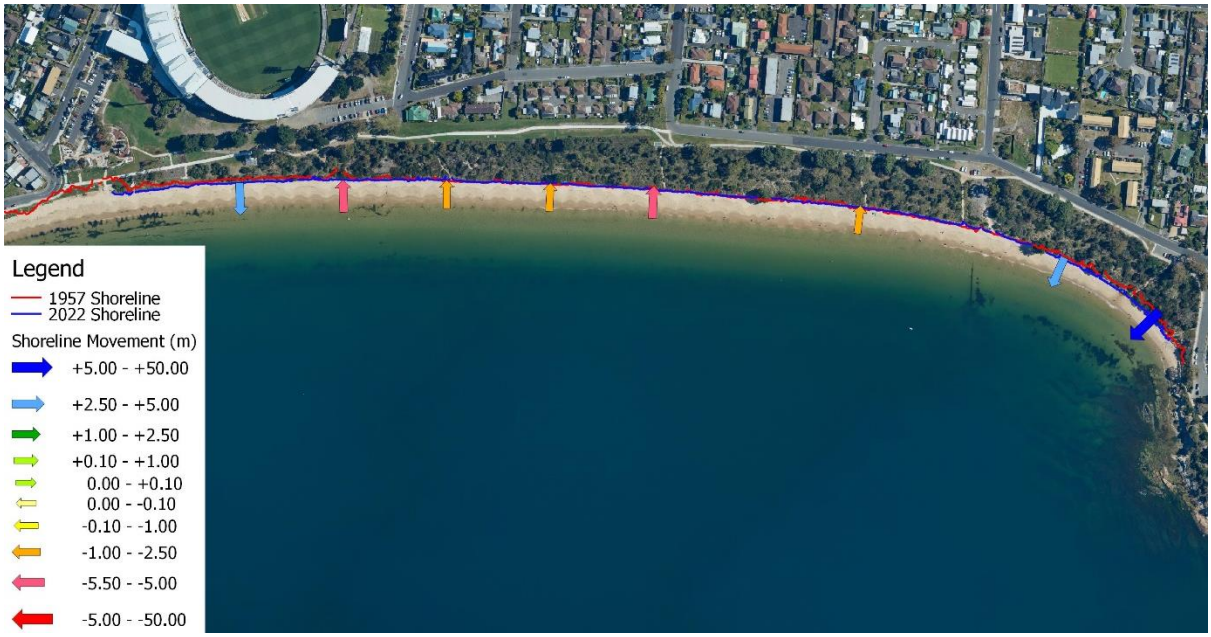

Figure 20 – 1957-2022 Net Shoreline movement at Bellerive Beach.

Howrah

The shoreline at Howrah beach recovered between the 2021 and 2022 surveys recording an average net shoreline growth across the survey sites of thirteen centimetres. Six of the eleven transect points measured along the beach showed a net shoreline recession since the 2021 survey ranging from seven to 42 centimetres. The remaining five transects recorded shoreline growth ranging from 0.03 to 1.4 metres (Figure 21).

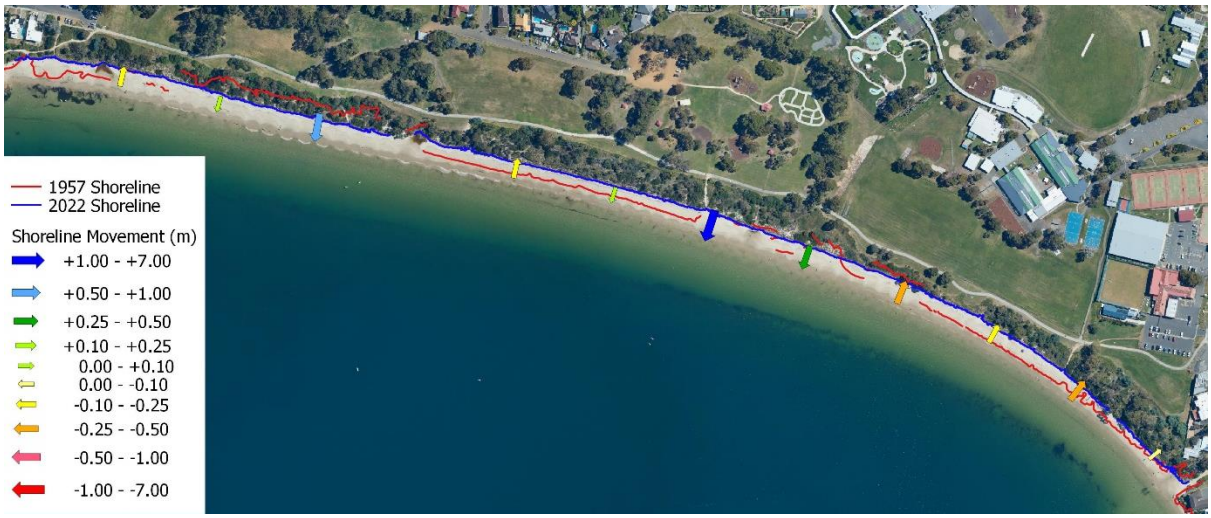

Figure 21 – Shoreline movement at Howrah Beach, 2021-2022.

Since the initial survey in 2011 Howrah beach has shown an average net shoreline growth of 1.12 metres. Nine of the eleven survey points have exhibited a net shoreline growth ranging from one centimetre to 3.15 metres, the remaining points showed low rates of recession ranging from 17 to 34

centimetres. Figure 22 below shows the net shoreline behavior between 2011 and 2022, with the two identified net recession points at the western end of the beach within very close proximity to uncontrolled beach/dune access points. The shoreline recovery through the central part of the beach continues to be aided by the fence line that restricts access.

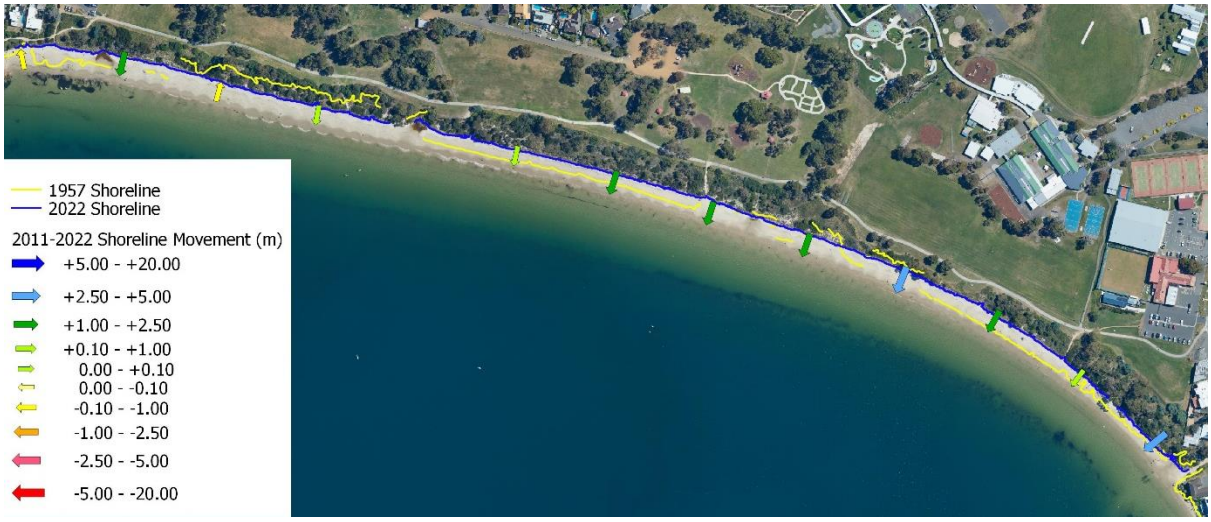

Figure 22 – Net shoreline movement at Howrah Beach, 2011-2022.

The net shoreline movement for Howrah beach between 1957 and 2022 shows a variable pattern, with a strong recovery in the old sand mining areas that are visible in the 1957 photography but a strong recession of the overall 'original' shoreline (Figure 23). This is particularly so through the middle of the beach behind the fenced off areas where the coastal dunes have been heavily impacted but are slowly recovering.

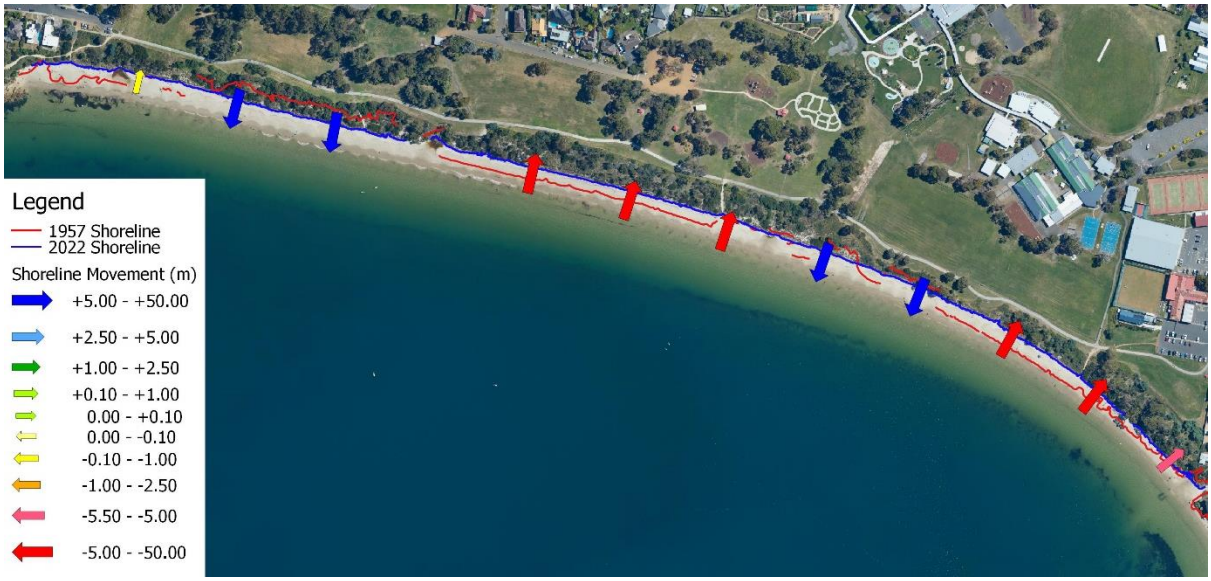

Figure 23 – Net shoreline movement at Howrah Beach, 1957-2022.

Clifton Beach – Bicheno Street

The shoreline at Clifton beach receded an average of 1.34 metres between the 2021 and 2022 surveys. Recession of the shoreline was observed at 17 of the 21 survey points along the beach, ranging from 5.8 metres of recession to 1.5 metres of seaward shoreline growth (Figure 24). This is the first time since 2011 that an overall recession of the shoreline position has been recorded at Clifton Beach. While erosion was present along almost the full length of the beach, an erosion scarp up to 2 metres high was present through the middle portion of the beach (Figure 25), between point A and B on Figure 24. Seaward shoreline growth was limited to either end of the beach where the beach profile is generally lower facilitating more effective marram grass establishment.

The shoreline along Bicheno Street showed an average recession since the 2021 survey of around 42 cm, ranging from a recession of 1.8 metres to a growth of 20 centimetres. This recession rate is roughly four times that of the observed long-term average of 11 centimetres per year since 2011. Recession was observed at 11 of the 14 survey points ranging from 14 centimetres to 1.8 metres. Shoreline recovery at the three recoded sites along Bicheno Street was less than 20cm.

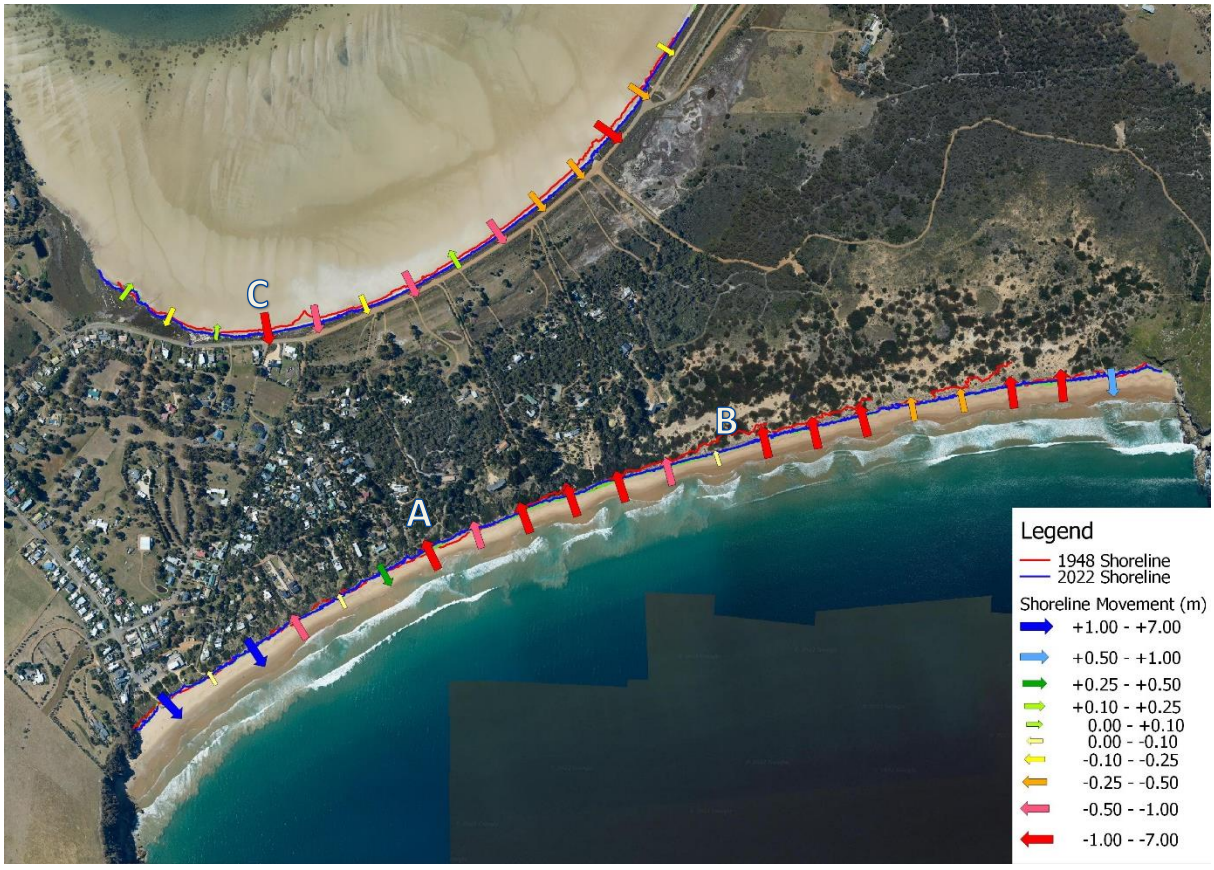

Figure 24 – Shoreline movement at Clifton Beach, 2021-2022.

The net shoreline movement at Clifton Beach between 2011 and 2022 shows a very consistent recovery trend with shoreline growth in excess of five metres observed at nine of the 21 surveyed

sites (Figure 26). This equates to an average annual shoreline recovery of 28 cm per year. This recovery is focussed on the North-eastern end of the beach where pedestrian foot traffic is generally well constrained and foredune and inland sand stabilisation by vegetation has been substantial since the 1950's, particularly during the last seven years.

Figure 25. Erosion scarp at Clifton Beach looking south from Point B on Figure 24.

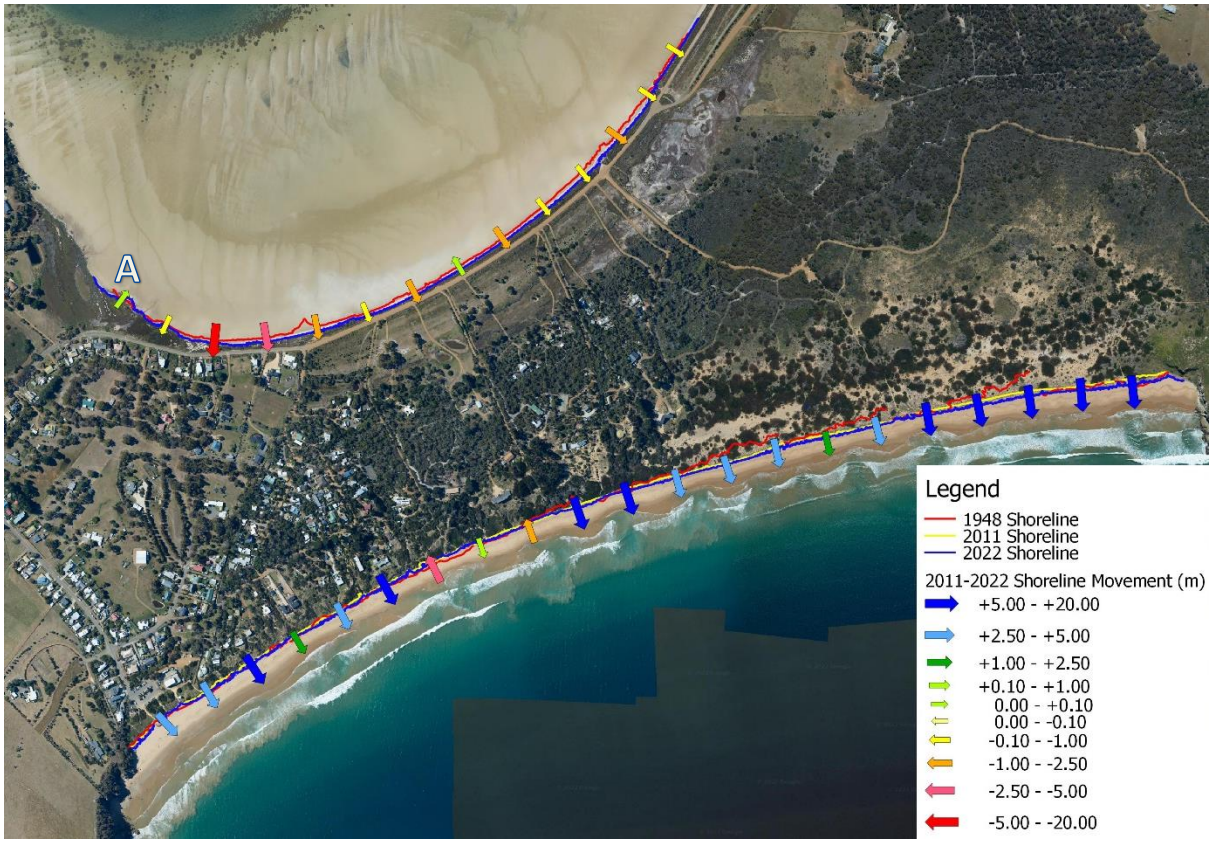

Figure 26 – Net shoreline movement at Clifton Beach, 2011-2022.

The shorelines of Pipe Clay Lagoon have shown an average annual recession rate of 13 cm since 2012, with net recession ranging between 30cm and 6.8 metres. Only two of the survey sites have shown evidence of seaward shoreline movement since 2012, the largest of these a recovery of 90cm is due to the establishment of coastal saltbush adjacent to the small ephemeral lagoons present in the southwest corner of the Lagoon, shown as site A on Figure 26 and in Figure 27.

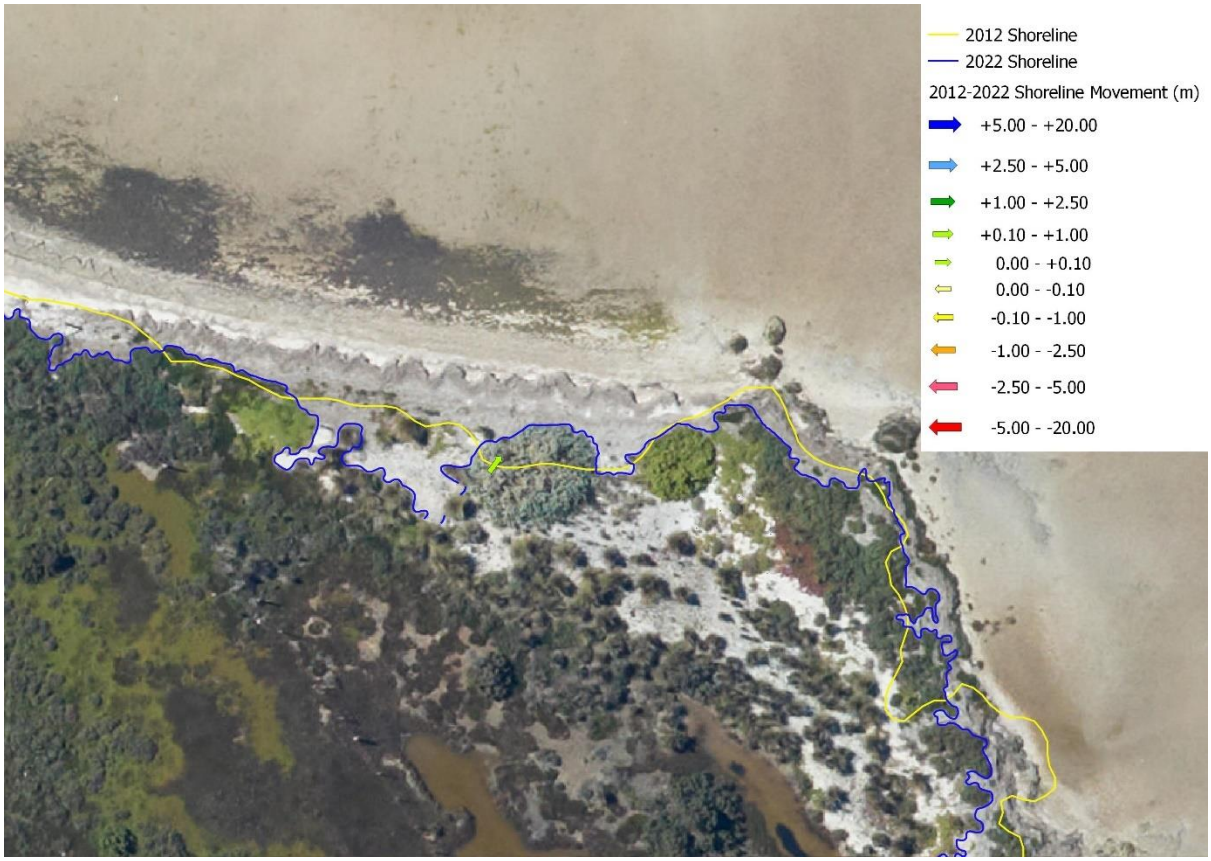

Figure 27. Shoreline recovery Observed at Pipeclay Lagoon 2012-2022. This site is located a site A on Figure 26

Since 1948 there has been an average net growth in the shoreline at Clifton Beach of 8.9 metres or 13cm per year (Figure 28). This recovery is largely due to the ongoing stabilisation of the large mobile sand blows present at the north-eastern end of the beach in the visible in 1948 photography (Figure 28). Shoreline position has recovered in excess of 20 metres at five sites including a recovery of 45 metres in front of these previously mobile sand systems at the eastern end of the beach. The two sites showing long term recession in excess of five metres on Clifton Beach are associated with a large offshore rip that has been present in some form or another since 2011. These points also coincide with numerous uncontrolled pedestrian access points, a generally steeper beach profile and the sites of ongoing scarp retreat behind the incipient dune.

In contrast the shoreline along Bicheno Street, at Pipe Clay Lagoon, has shown a substantial recession trend since 1948. Every transect point has shown a net recession with the average net recession of over six metres, and an average yearly recession rate of around nine centimetres. This shoreline is very susceptible and it seems responsive to the ongoing effects of sea level rise.

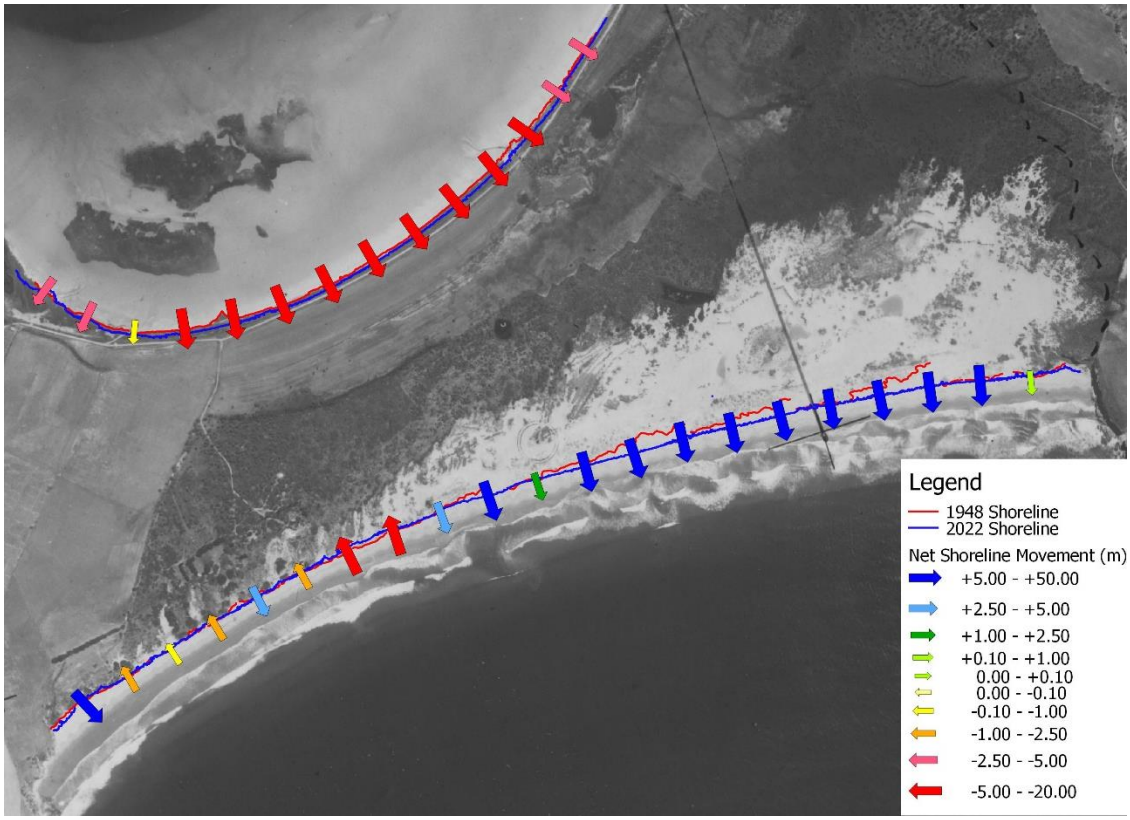

Figure 28 – Net shoreline movement at Clifton Beach, 1948-2022.

General Discussion

Of the six sites surveyed only Seven Mile beach showed a significant shoreline recovery averaging 81 centimetres since the 2020-2021 survey, while slight a recovery was observed at both Bellerive and Howrah beaches. Strong shoreline recession was observed at Clifton, Roches and the Bicheno Street shoreline in southern Pipeclay Lagoon. Cremorne Beach exhibited minor shoreline recession averaging 12 centimetres for the first time since to 2011 event.

Bellerive and Howrah Beaches have remained relatively stable since the 2020-2021 survey with recession limited to nine sites between the two beaches. The shoreline recovery at these beaches has been aided by the hardening and protective fencing of high use or vulnerable areas. Shoreline recession where present is generally associated with uncontrolled access points into the dune system. Saltbush establishment is becoming more prevalent at both beaches.

The shorelines at both Bicheno Street in Pipe Clay Lagoon and Clifton Beaches experienced moderate to high levels of shoreline recession since the 2020-2021 survey. The low energy shoreline along Bicheno Street receded an average of 48 cm well above the long-term average recession of 8 cm per year. While the high energy shoreline at Clifton receded an average of 1.34 metres along the length of the beach with a maximum recession of 5.8 metres recorded. Seaward shoreline recovery was minor and was limited to seven of 35 survey sites between the two beaches.

Roches Beach continues to exhibit a long-term recession trend despite the comprehensive beach replenishment program, and is becoming increasing vulnerable to moderate to large swell events. This is evidenced by the dramatic erosion observed after the June 2022 swell event. Total shoreline recession at the northern end of Roches Beach from the 2021 survey through to June 2022 exceeded five metres at several locations. An example of this recession can be seen in Figure 29.

Beach access points, particularly those initiated outside of established and/or stabilised accesses, still pose an issue due to the susceptibility of these sites when large swell events occur, and during periods of intensive use where the effect of foot traffic depresses the sand level immediately around the access point. Most of the major erosion sites observed on semi protected beaches during the 2011 storm event were centred on foot or vehicular access points onto the beach. This effect was also observed at some sites on the exposed high energy beaches like Clifton Beach, where recession of the shoreline in excess of four metres was observed at various access points along the beach.

The majority of the observed natural stabilization of the beaches has been facilitated by the expansion of a mix of native and introduced coastal vegetation such as Marram Grass, Coastal Salt Bush, Pig Face and most recently at Cremorne an introduced Daisy species. Marram Grass stabilization is observed at most of the open ocean beaches and usually starts after the stabilization and vertical growth of the incipient dunes in front of the most recent storm bite. My yearly surveys have shown that second stage of stabilization involves the thickening of the Marram Grass and development of the downslope shoots. This results in more sand capture and further dune stabilisation. Once these leaders have been established, the Marram grass thickens again and then expands laterally along the beach.

Figure 29. Significant shoreline recession at northern Roches Beach showing shoreline from the 2020-21, 2021-22 and June 2022 Surveys. Inset is photo of the stairs taken on the 22nd of June 2022.

Coastal Saltbush continues to spread naturally throughout most of the surveyed beaches, and has appeared most recently at several locations along Seven Mile Beach as well as Roches, Cremorne, Pipeclay Lagoon, Bellerive and Howrah beaches. The deep root system and robust branches and foliage appear to offer an affective armoring during heightened tides and storm erosion events, as evidenced by the stability of the shoreline adjacent to Bambra reef during the June 2022 swell event.

2023 sees a continuation of the La Nina weather conditions which in past occurrences have related to significantly increased rates of shoreline erosion particularly on the eastern seaboard of Australia and Tasmania. Autumn and early winter 2023 are likely times for major shoreline erosion events.

Future Work and Recommendations

While there has been a stabilisation of recession at some of the study sites, a number of beach sections surveyed as part of this study are still exhibiting, or starting to exhibit a clear ongoing long-term recession trend. It is recommended that where this recession is occurring close to dense residential areas or within areas containing valuable infrastructure that ongoing annual aerial surveying be undertaken. These beaches include Roche's, Bellerive, Pipeclay Lagoon, Rokeby and Seven Mile. This will help develop an accurate picture of the shoreline movement and will identify beaches exhibiting similar characteristics to Roche's Beach which has shown an ongoing recession trend since 1977.

Within the municipality there are still a number of shorelines that are either very low lying and are at risk of recession or are already exhibiting signs of shoreline recession. These include the shorelines of Halfmoon Bay, Hope and Calvert's Beach, Barilla Bay, Mile Beach, Richardson's Beach and a number of other beaches and saltmarshes inside of Ralph's Bay. Where a significant shoreline recession signal is detected, consideration should be given to the establishment of monitored transects using a combination of photogrammetric data and the TASMARC methodology.

Where possible, ongoing annual aerial surveying should occur during summer months, ideally around the summer solstice where it is possible to eliminate the shadows cast by the dune scarps or coastal vegetation. This shadowing can affect the clarity of the aerial photography which in turn affects the clarity of the vegetation line and accuracy of the derived three-dimensional models. For rapid response flights before or after major events it is recommended that shorter flights throughout the day be used to minimise shadowing on east, west and south facing beaches.

Recent advances in drone imagery capture and the development of compact drone LiDAR also provide a means for rapid response, accurate beach monitoring for both pre and post significant storm events such as the June 2022 swell event.

Now a comprehensive set of contemporary orthophotographs have been developed for all the current primary study sites some effort needs be made in the generation of historical sequences of photos to establish a record of beach behaviour and rate of beach oscillation. The work of Sharples *et al*. (in prep.) 2012 produced detailed comprehensive time series datasets at intervals of around ten years for Roches Beach, Clifton Beach and part of Barilla Bay which gave a valuable insight into beach behaviour.

The ground control network is still a work in progress which will need to be maintained and expanded upon if the project is to continue into the future. There are currently over 450 control points that have been used during the course of the project and each one must be revisited to check on their status if they fall within the yearly survey area. Many of the beaches in the municipality are sparsely developed and do not contain the infrastructure needed to establish permanent and comprehensive ground control network. Such a process would need to involve placing markers on privately owned land, fence posts or buildings to assist in the accurate generation of orthorectified imagery. This work could be incorporated into future surveys of coastal council infrastructure. The development of a permanent set of ground control across the study area would enable remotely sensed data collected by the State Government to be more readily incorporated into this study.

Table 1 provides a summary of data collection and completeness of all the beaches surveyed since the initial survey in 2011.

Table 2 provides the estimated pricing breakdown of the $7,250 estimated for the 2022-2023 Clarence Municipality Coastal Survey.

Table 1 – Clarence City Council Shoreline Monitoring Program summary data and data completeness.

Study Site	Year first	Year last	Average m	Record	TASMARC	Historical	Future
Bellerive	2011	2022	-2	13 to 65	3	4	
Howrah	2011	2022	-1	65	3	4	
Clifton	2011	2022	9	74	3	4	
Bicheno Street	2013	2022	-1	74	3	4	
Cremorne	2011	2022	2	12 to 64	3	1	
Roches	2011	2022	-7	64	4	6	
Seven Mile	2011	2022	6	56 to 76	2	4	
Rokeby	2012	2019	-10	25		1	
Barilla	2013	2013	-10	24 to 68		3	
Halfmoon	2012	2022	2	10	3		
Fort	2013	2022					
Fivemile	2013	2016					
Hope	2011	2011			3	1	
Calvert's	2011	2011					
Richardson's	2014	2014				1	
Mile	2013	2019	-2	44		1	

KEY:

Comprehensive	Urgent/ongoing
Preliminary	High/ongoing
No Data	Moderate/intermittent

Table 2 – Indicative pricing for a 2022-2023 coastal survey.

Beach	Survey Ground Control ($)	Beach Length (m)	Total Flightlines (m)	Photos	Photo Processing ($)
Howrah	100	1200	3650	91	NA
Bellerive	100	1200	3650	91	NA
Roches	200	4800	29000	363	NA
Western Seven Mile Beach	300	2000	12600	158	NA
Cremorne	100	3200	15500	194	NA
Clifton	100	4200	16000	200	NA

	$1000
Plane Hire	**$4250**
Ongoing Reporting	**$2000**
Total Cost	**$7250**

Table 3 – Ongoing Clarence Shoreline Monitoring Program activity plan and estimated costings – 2022 to 2025.

Job	Details	Who	2022-2023	2023-24	2024-25
Shoreline monitoring flights and data processing	Ongoing shoreline monitoring flights. Flying of all beaches and processing of selected beaches as needed. Biannual rotation of less active beaches. Ancillary collection of other shorelines or areas such as new developments, inundation, fire scars.	Matt Dell, UTAS	Howrah* Bellerive* Roches* Cremorne* Seven Mile* Clifton* Halfmoon*	Howrah Bellerive Roches Cremorne Seven Mile Clifton	Howrah Bellerive Roches Cremorne Seven Mile Clifton
			$4000	**$22000**	**$22000**
Historical orthophoto generation	Orthophotos generated as funds allow. Priority given to beaches identified as problem areas or where other events are identified through the Coastal History Project.	Matt Dell, UTAS	-	-	-
Ground Control Network	Continual establishment and maintenance of ground control network and rotating calibration of beaches. Cost reductions achieved through integration into Council surveying program.	Matt Dell, CCC	**$1000**	**$1000**	**$1000**
Ongoing reporting, analysis and other works as scope increases and budget allows	Compilation of reports. Use of new technologies/sensors. Integration of Shorewave Project results and datasets, preliminary sand budget investigations and scoping of bathymetric lidar surveys.	Matt Dell, CCC	**$2000**	**$2000**	**$2000**

*Indicates acquired but not processed

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