Rivoli Bay Data Collection and Modelling

Summary Report

28 September 2021 | 13157.101.R1.Rev3

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Summary Report

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3	28 September 2021	Final	Revisions to Executive Summary	SJG	JC	

Executive Summary

Baird Australia Pty Ltd (Baird) were engaged by Wattle Range Council (WRC) to deliver the Rivoli Bay Data Collection and Modelling project. The contracted project scope included a metocean data collection campaign at the Beachport and Southend locations and the development of a numerical model of Rivoli Bay. The aim of the project was to improve the understanding of coastal processes in Rivoli Bay, and to inform future investment in infrastructure and maintenance options along the Councils coastal areas.

Rivoli Bay is located along the southeast coast of South Australia, approximately 400 km southeast of Adelaide. This project is focused on the township areas of Beachport, located at the northern end of Rivoli Bay, and Southend, located at the southern end. Both the town beaches of Beachport and Southend have been heavily modified by human influence. Rock groynes, seawalls and revetment works have been added along the coast over time, with the intent of stabilising the beaches and reducing erosion.

To develop and improve on the understanding of coastal processes within Rivoli Bay this study has leveraged off the existing knowledge of coastal processes, reported in previous studies, and is complemented by a targeted metocean data collection campaign and modelling investigations.

From the literature and existing data review and the general project requirements laid out in the study scope of work, the following key processes were identified as warranting specific assessment as part of this study:

- Improved definition of the hydrodynamics of Rivoli Bay and their potential to drive sediment transport
- Quantification of longshore sediment transport along the Beachport and Southend shorelines
- Definition of the longwave climate within Rivoli Bay and implications for coastal processes

As part of this scope, Baird engaged sub-consultant O2Marine to complete data collection of water levels, current, waves (sea and swell) and long waves at two locations; offshore of Beachport and Southend.

The following metocean data were collected and analysed as part of the campaign at both the Beachport and Southend ADCP locations:

- Water levels
- Waves
- Long waves
- Currents

A review of the measured data provides useful insights as to the metocean climate at Beachport and Southend. Both locations are relatively protected from the offshore wave climate, with inshore wave heights less than 1.5m (typically) arriving from within a ~25deg directional range, however remain subject to energetic wave conditions during winter storm events. Currents at both locations are relatively mild, generally remaining below 0.1m/s, flowing out of Rivoli Bay for a higher proportion of the time. This is a result of the tidal circulation within Rivoli Bay that establishes return eddies at either end of the embayment. At times, current speeds increase to ~0.2m/s and appear correlated with wind and wave conditions. An analysis of long wave energy indicated a high correlation with the swell conditions, with a long wave magnitude suggesting that there is a considerable amount of unbounded and/or reflected long wave energy present at the site. The measurement period was found to be representative of the longer term metocean climate within Rivoli Bay and well suited to be utilised for scenario modelling within this assessment.

A key deliverable of the study was to develop a base numerical model of Rivoli Bay that can be used to quantify coastal processes at the townships of Southend and Beachport and provide a basis for the

assessment of coastal infrastructure and management options. The range of processes that drive shoreline dynamics within Rivoli Bay are complex and no single numerical model is capable of replicating all relevant processes. For example, a limitation of 2D hydrodynamic models, is the ability to accurately replicate sediment processes at the shoreline. As such, a suite of numerical models was established including:

- A regional hydrodynamic and wave model was used to simulate shelf-scale and Rivoli Bay wide hydrodynamic processes. The model was validation over two seasonal one-month periods against measure data.
- The longshore transport model of Kamphuis (1991) was applied along the Beachport foreshore to assess whether there exists a differential in transport rates along the foreshore that may be contributing to the eroded beach width observed in some locations.
- A shoreline model COSMOS was applied along the Southend foreshore to investigate the cross-shore distribution of longshore transport and the potential for dominant cross-shore transport. COSMOS is a 2DV model of nearshore hydrodynamics, sediment transport and seabed evolution (morphodynamics).
- A local scale Delft3D model of the Beachport coast capable of modelling hydrodynamics, waves and long wave response via use of the Surfbeat module was applied to investigations of the Beachport Boat Ramp where long wave processes were deemed important.

Beachport Foreshore

The beach compartments along the Beachport foreshore are considered to be “full” and each groyne is actively bypassing sediment (Worley Parson, 2015). This observation is supported based on Baird’s site inspection (June 2019) and examination of aerial imagery and suggests an ample supply of sediment for alongshore transport across the length of the coastline. Further, from a historical analysis of shoreline positions, no clear long-term trends are observed, with beach width typically varying around a longer-term average. This observation suggests that the Beachport shoreline has an ample supply of sediment.

However, little to no beach width exists at the southwestern extent of the beach compartments located between the groynes to the north of the Beachport Jetty. This is a result of the groynes either being too short or the spacing too great for them to compartmentalise the beach effectively.

A set of shoreline profile models along the Beachport foreshore were established to identify if any discontinuity in longshore transport rate exists between groyne compartments that may be exacerbating the reduced beach widths that are observed at the southern end of the beach compartments. The results indicate that longshore transport is primarily driven by episodic storm conditions and it is unlikely that an alongshore differential in transport potential is significantly contributing to the shoreline position along this section of Rivoli Bay coast.

The primary issue identified along the Beachport Foreshore is the lack of beach width in beach compartment 8, in the vicinity of the vertical timber seawall. Proposed management options to address this have included:

- Placement of an Additional Groyne in Beach Compartment 8 (Option B1). The addition of a groyne north of the jetty would promote the retention of a beach volume in front of the vertical timber seawall.
- Modification to the Existing Groyne 8 (Option B2). The shoreline alignment within Beach Compartment 8 is at least in part a function of the size, length and orientation of Groyne 8.
- Extension of Groyne 9 (Option B3). Modification to the beach compartment was considered through the extension of Groyne 9. With ample sediment supply, it is anticipated that an extension of the groyne will result in a wider beach compartment and the optimal lengthening of the groyne will be assessed.

- Modification to the Existing Groyne Structures (Option B4). These included options to increase the effective permeability of the groyne structures can be considered, such as reducing crest elevation of the groynes and potentially removing the landside connection, to improve the continuity of the shoreline position between beach compartments.

To assess the relative merits of each, all options were either assessed using the numerical model systems developed for Beachport or engineering judgement based on the available data. The results from analysis of the options confirmed the thinking that the groynes that bound Beach Compartment 8 are spaced too far apart and therefore cannot maintain a suitable beach width.

From this a final optimised option, a resultant combination of Options B1 and B2, has been investigated. The optimised option has slightly extended and rotated Groyne 8 in combination with placement of a new groyne in the centre of Beach 8 (Groyne 8a). Groyne 8a was optimised in combination with the change to Groyne 8 to achieve acceptable stable beach widths and alignments. The layout of groynes and expected beach alignments are presented in Figure E.2. Groyne 8 is extended to 44m in length and rotated north by 20º, with the new Groyne 8a set at a length of 38m perpendicular to the shoreline in that location.

Figure E.2: Layout of the Recommended Option at Beachport foreshore including the extension and rotation of Groyne 8 and a new Groyne in the centre of Compartment 8

Southend Foreshore

The Southend foreshore has experienced significant changes over the past 40 years. Severe erosion in the early 1980's led to the construction of five groyne structures through the late 1980's and 1990's in an attempt to stabilise the shoreline. The groyne field has interrupted the natural eastward movement of sediment along the shoreline under littoral processes, with accretion on the western beach (west of the

Lake Frome outlet) and erosion on all beach compartments to the east of the Lake Frome outlet which continues to this day.

From a historical analysis of shoreline positions, using both satellite derived shoreline mapping and surveyed transect data, the following was concluded:

- the beach compartment to the west of the Lake Frome outlet appears stable with little change in the mean beach position. A rapid increase in beach volume was observed following construction of the Lake Frome outlet structures, which has reduced as the compartment neared capacity.
- the beach compartments to the east of the Lake Frome outlet between Groyne 2 and Groyne 5 (Leake St) show a clear recessionary trend. The change in mean shoreline position is estimated at approximately 10m to 15m over the last 15 years.
- Transects to the east of the Leake Street Groyne show an even higher rate of shoreline recession with a change in mean shoreline position of between 20m to 30m over the last 15 years.

The historical transect data was also used to derive an estimate of the longshore transport rate, being approximately 30,000m^3 annually along the western shoreline (to a depth of -2mMSL). The sediment transport rate increases moving eastward, under the relatively higher exposure to wave energy, to 33,000m^3.

A set of profile models along the Southend shoreline were established to specifically resolve the longshore sediment transport distribution across the surfzone. The profiles modelling also confirmed that potential transport rates increase towards the east, highlighting a sediment volume imbalance along this section of coast that contributes to the observed beach volume loss. The modelling was also used to assess the volume of sediment lost into the Lake Frome outlet, which was found to 15% to 20% of the east bound sediment that passes offshore of the western Groyne.

Options to reduce the rate of shoreline recession and restore beach widths along the Southend foreshore are aimed at reducing the trapping efficiency at the Lake Frome entrance, reducing the wave exposure of the shoreline (and hence transport potential) and maintaining an adequate beach width. To achieve these outcomes, the following options were assessed:

- Reducing the trapping potential of the Lake Frome Outlet (Option S1). The removal of both outlet groynes would allow greater movement of sediment to the eastern compartments. Their removal would effectively block the Lake Frome outlet promoting the easterly transport of sediment.
- Reducing the trapping potential of the Lake Frome Outlet (Option S2). Removal of the outlet groynes altogether would potentially have a major impact on the beach to the west, and hence an option to remove the eastern outlet groyne only was considered to balance dual objectives of maintaining beach width to the west of the Outlet while promoting further eastward transport.
- Offshore breakwater or Submerged Offshore Reef Fronting Caravan Park (Option S3). Options to reduce the exposure of the coast in front of the caravan park (between Groynes G2 and G3), thereby reducing longshore transport rates and cross-shore transport potential (under storm conditions) were considered. Two alternatives include an offshore detached breakwater (Option S3a) and a submerged reef structure (Option S3b).
- Modification to the Existing Groyne Field East of Lake Frome Entrance (Option S4), including:
    a) Lengthening and reprofiling the existing groynes.
    b) Modification of the distance between groynes.

Each of the options was assessed via consideration of the feasibility or through modelling of a representative one-month period for both winter and summer periods. The recommendation from the analysis is for Option S2 and Option S4a to be implemented concurrently. Figure E.2 summarises the expected sediment transport environment following implementation of the recommended option. The following is a summary of the actions and projected improvements from the current situation:

- Retention of Groyne 1 in its current location preserving the western beach shoreline amenity

- Removal of Groyne 2 with a view to reusing the rock where possible to extend the groynes further east
- Extension of Groyne 3, Groyne 4 and Groyne 5 would be undertaken to increase trapping efficiency.

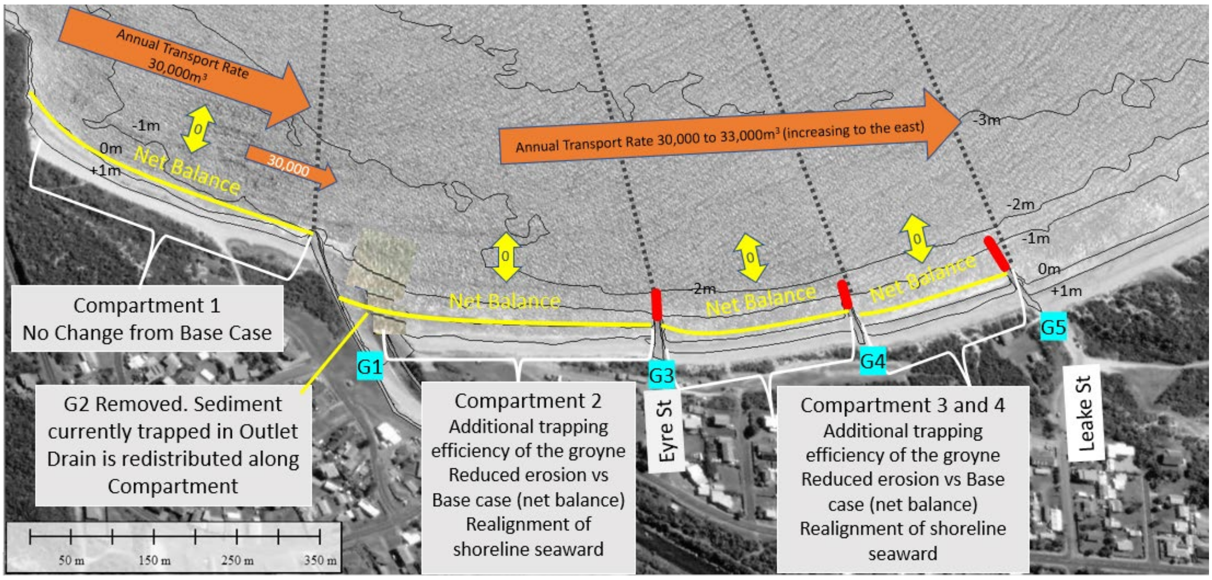

Figure E.2: Final recommended option for Southend shoreline including removal of Groyne 2 and extension of Groynes 3, 4 and 5

Beachport Boat Ramp

Since the construction of a breakwater in 2004 to protect the Beachport Boat ramp there has been sediment accumulation in the Beachport Boat ramp area. The extension of the breakwater in 2014 by approximately 100m in length to the north (parallel to the rock revetment armouring the shore) was constructed to form a larger protected basin to improve conditions for boat launching at the boat ramp. While allowing a significant amount of longshore transport to bypass the area, sediment in the form of fine sands manages to work its way into the basin area, creating a considerable ongoing burden in the maintenance of navigable depths.

The focus of this assessment is to develop an understanding of the longshore drift process along the boat ramp basin eastern breakwater and its influence as a source of sediment and driver for sedimentation in the entrance of the basin.

A number of transport mechanisms have been hypothesised as being contributors to the significant sedimentation observed within the boat ramp area, including wind and wave driven transport over and through the breakwater extension, the influence of an anti-clockwise shore current that may be driving sediment transport into the boat ramp area, or reflected long wave energy from the shorelines to the north.

Following site observations at the Beachport boat ramp, review of data received from the metocean data collection campaign and confirmation with coupled hydrodynamic and wave modelling, the primary mechanism for the siltation observed with the boat ramp area is as follows:

- Alongshore wave driven currents develop along the boat ramp breakwater to sufficient magnitude to mobilise sediment into suspension, resulting in a suspended sediment plume at the entrance to the boat ramp area.
- Incoming long wave energy and surfbeat (an oscillation of the mean water level in the nearshore as a result of wave grouping), generates long period oscillation of the water level in the boat ramp

area and an exchange of flows in and out of the area with a long period (2 to 3 minutes), allowing a portion of the suspended sediment generated along the outside of the breakwater to settle within the boat ramp area.

Options to reduce the accumulation of sediment within the protected, and hence tranquil, basin are limited given the location of the boat ramp adjacent to a prominent sediment transport pathway and the need to preserve protection to the boat ramp area.

Potential options were identified from concepts raised in community discussion, within previous studies and from Baird's assessment of key processes at the site. All options assume that the protected basin will be maintained, in some form, and the orientation and position of the ramp will not be moved. The range of potential options initially considered included:

- Modifying the entrance configuration to the boat ramp basin (Option BR1). Either narrowing the boat ramp basin or decreasing the entrance width to reduce the response of the basin to long wave energy and/or reduce the sediment pathway into the basin entrance.
- Trapping or deflecting the northbound sediment supply (Option BR2). Either the placement of a groyne, normal to the Boat Ramp breakwater, to intercept and trap northerly longshore transport or a breakwater extension that aims to deflect northbound sediment transport away from the Boat Ramp entrance.
- Reducing the magnitude of the wave generated current speed along the protective groyne (Option BR3). Enhancement of the submerged/low-crested offshore breakwater (currently made up of geotextile containers) that would induce wave breaking away from the structure and reduce alongshore current speeds at the structure. This aims to extinguish the suspended sediment transport pathway along the protective groyne structure.
- Improving the circulation in and through the basin area to breakdown the resonant response to long waves (Option BR4). Segmentation of the protective groyne structure to produce openings in the structure or reduction in the length of the breakwater structure, that aim to breakdown the resonant response to long wave energy and remove or reduce the sediment transport pathway through the boat ramp entrance.
- Changes to sand management practices along the Beachport coastline (Option BR5). The strategy for management of sand in Beach 5 could be reviewed in the context of potential sources of sedimentation to the boat ramp site.

The recommended option involved the construction of an extension to the existing boat ramp breakwater (Groyne 6), in the form a small deflection structure as shown in Figure E.3. Extending from the northern end of the existing breakwater and orientated to the NE, the deflection structure is effective in reducing sedimentation rates within the Boat Ramp basin. The deflection structure guides sediment laden currents away from the boat ramp entrance, thereby removing the principal source of sediment (suspended sediments at the breakwater end) that drives the existing sedimentation currently observed at the boat ramp.

Figure E.3: Recommended Option for the Beachport Boat Ramp involving a Breakwater Deflection Structure at the Northern End

Further assessment of the option is recommended, including detailed consideration of potential impacts to the Beachport beaches and a cost benefit analysis to compare the long-term maintenance costs of the proposed option against existing management approaches of the boat ramp.

Alternate Boat Ramp Location at Glenn Point

Given the management issues at the Beachport Boat Ramp, Council requested that Glenn Point be assessed as a potential alternative for a Boat Ramp location. Glenn Point is located at the southern end of the Beachport coastline and is in the lee of Penguin Island that affords the site protection from the offshore wave climate. However, following review of the modelled wave and hydrodynamics at the site the location is not considered appropriate for a boat launching facility due to:

- Wave conditions that are regularly above 0.5m (H_s) and at long wave periods, making the location less than ideal for boat launching (against the criteria of AS 3962).
- A structure to protect launching at the potential boat ramp location would need to be substantial, as a result of water depths at the site and exposure to storm wave conditions. Further, a structure would need to be shore parallel to not interrupt the longshore sediment transport in to Rivoli Bay. This in turn would create a navigation hazard with vessels experiencing beam on conditions as they transit out from behind the structure.
- The tidal hydrodynamics of the area generate an eddy flow feature in the lee of Penguin Island within the nearshore off Glenn Point. This would pose a concern for safe navigation in the area.

Future Work

A range of potential mitigation options have been addressed in this report with a select number being assessed based on detailed coastal process investigations. Outcomes from this options analysis demonstrate the feasibility of implementing selected options, with the recommended mitigation approaches worthy of more detailed analysis and engineering design. It is noted that the scope of this study was to assess options at a concept level. Before any options can be implemented a detailed process-based investigation, cost-benefit analysis and detailed engineering design would be recommended.

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1. Introduction

Baird Australia Pty Ltd (Baird) and O2 Metocean Pty Ltd (O2M) were engaged by Wattle Range Council (WRC) to deliver the Rivoli Bay Data Collection and Modelling project. The project includes a metocean data collection campaign at the Beachport and Southend locations and the development of a numerical model of Rivoli Bay. The project aims to improve understanding of coastal processes in Rivoli Bay, and to inform future investment in infrastructure and maintenance options along the Councils coastal areas.

1.1 Scope of Work

The project is structured to deliver the following:

1. Literature review to inform an understanding of coastal processes within Rivoli Bay.
2. Collection of metocean, bathymetric and sediment data to calibrate the numerical model.
3. Development of a base numerical model including the townships of Southend and Beachport.
4. Analysis of outputs from the model for a range of scenarios including the addition, removal or alteration of coastal infrastructure and changes to coastal management practices.
5. A report summarising the outputs from the model and making recommendations about the next steps in determining the most appropriate actions to:
   - Reduce the impacts of coastal processes on the town beaches of Beachport;
   - Reduce the impacts of coastal processes on the town beaches of Southend;
   - Reduce siltation at the Beachport boat ramp; and
   - Consideration of Glenns Point as alternate location of the Beachport boat ramp.

In the delivery of the project to date a number of method statements have been submitted to Council including:

- Metocean Data Collection (Baird, 2019)
- Numerical Modelling (Baird, 2020)
- Scenario Modelling (Baird, 2020)

1.2 Site Locality

Rivoli Bay is located along the southeast coast of South Australia, approximately 400 km southeast of Adelaide. This project is focused on the township areas of Beachport, located at the northern end of Rivoli Bay, and Southend, located at the southern end, as shown in Figure 1.1.

The town beaches of Beachport have been heavily modified by human influence since the 1940’s. Rock groynes, seawalls and revetment works have been added along the coast since this time, with the intent of stabilising the beaches and reducing erosion (WRC, 2019). The structures have been modified, added to and extended over time to protect the beaches as well as nearby infrastructure.

Similarly, at Southend coastline recession has been a major issue since at least the early 1980s and groynes were constructed to reduce the movement of sand in response to a reduction in updrift transport as a result of the entrance structures at Lake Frome. These groynes are generally in poor condition and appear to be relatively ineffective (WRC, 2019).

A boat ramp has been servicing Beachport since 2004, and in 2014 an extension of the breakwater was completed to create a larger marina basin and an extra launching lane. Since that time, Council has been actively managing sedimentation of the boat ramp basin, using excavators, a drag flow pump suspended from a crane and a traditional cutter suction dredge. A number of modifications to the existing boat ramp have been suggested to reduce sedimentation (WRC, 2019).

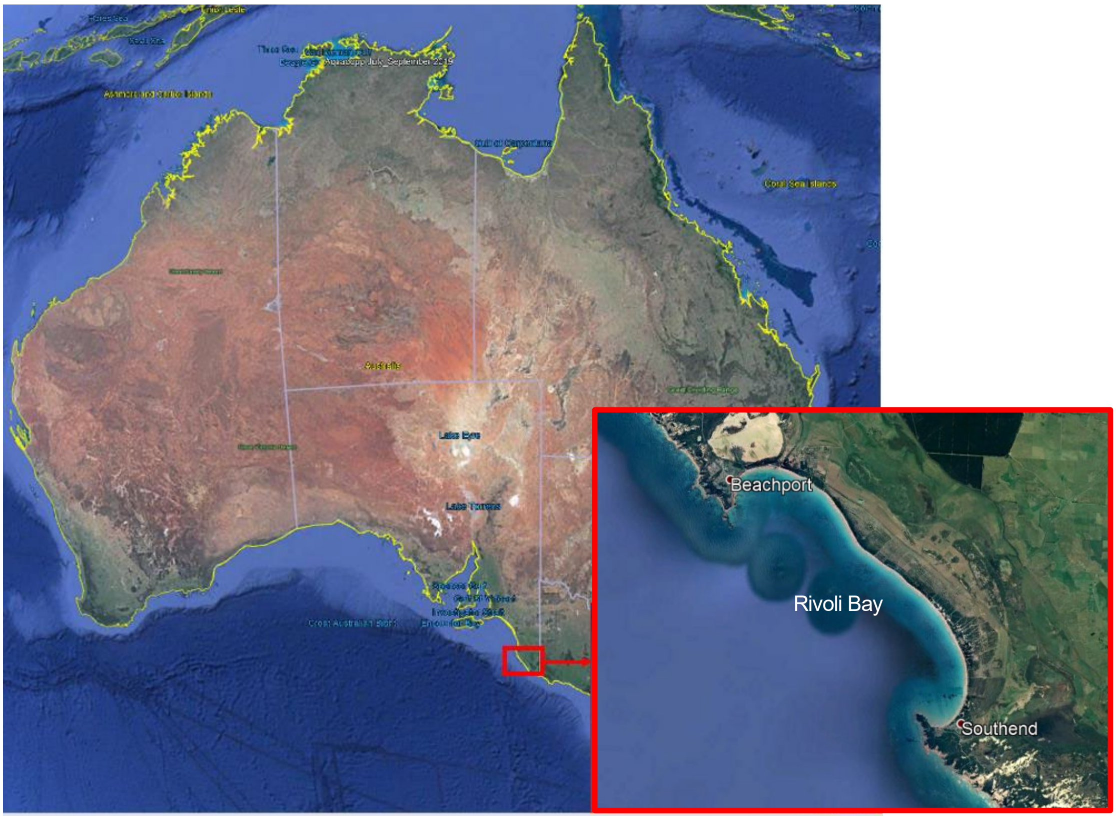


Figure 1.1: Locality Plan showing Rivoli Bay and the townships of Beachport and Southend

The offshore metocean climate is subject to predominantly southwest wave conditions off the Southern Ocean and a coastal current that sweeps eastward along southern Australia, a branch of the Leeuwin Current. The metocean climate displays some seasonality with the passage of low-pressure systems during the winter months causing increased wind and waves, while a reversal of the coastal current (westward) is observed during the Summer months (GABRP, 2018).

The embayment of Rivoli Bay, formed as a result of a breach in the Robe Range (Worley Parsons, 2018), is recessed back from the open coast. As such coastal hydrodynamics at the locations of Beachport and Southend are dominated by tidal circulation in deeper waters and littoral currents closer to the shorelines due to the oblique direction of incident waves at the shoreline that diffract around Glen Point (west) and Cape Buffon (east).

1.3 Key Processes to be Investigated

The following sections of this report outline the reviews and analyses that have been completed to develop a comprehensive understanding of the coastal processes within Rivoli Bay. This understanding leverages off the existing knowledge of coastal processes, reported in previous studies, and is complemented by a targeted metocean data collection campaign and modelling investigations.

From the literature and existing data review (see Section 2) and the general project requirements laid out in the study scope of work (WRC, 2019), the following key processes were identified as warranting specific assessment as part of this study:

- Improved definition of the hydrodynamics of Rivoli Bay and their potential to drive sediment transport (particularly anti-clockwise currents within the western region of the Bay and implications at the Beachport Boat ramp);
- Quantification of longshore sediment transport along the Beachport and Southend shorelines;
- Definition of the longwave climate within Rivoli Bay and implications for coastal processes;
- Nearshore transformation of waves, including the occurrence and potential for focussing at the Beachport shoreline.

Each of these issues are explored in this report.

1.4 Structure of Investigations

Given the disparate study locations and issues being investigated, this summary report has been structured as per the following sections. The initial focus of the study was to establish the primary sediment transport pathways within the study area such that the right numerical tools could be identified and applied to efficiently quantify these pathways with a view to informing potential options to improve beach stability and siltation issues.

1.4.1 Literature Review and Data Compilation

The literature review presented in Section 2 provides a comprehensive summary of the existing knowledge of coastal processes within Rivoli Bay. The literature review drew heavily off the Rivoli Bay study (Worley Parsons, 2015), Maintenance Options for the Beachport Boat Ramp (WGA, 2017) and the Southend Adaptation Strategy (Wavelength Consulting, 2018) and provides a basis for identifying data gaps and has guided the development of the targeted modelling scopes at each location.

A review of available data was then completed which provided specific definition of wind and wave climates, bathymetric and seabed condition (including sediment composition) and other observational data (such as aerial imagery).

1.4.2 Metocean Data Collection

As part of this scope, Baird engaged sub-consultant O2Marine to complete data collection of water levels, current, waves (sea and swell) and long waves at two locations; offshore of Beachport and Southend. Approximately 6 months of continuous data was collected covering portions of a winter and summer season. The data has been instrumental in providing validation of the numerical tools developed in this study and defining boundary conditions for local scale modelling. A summary of the data collection is provided in Section 3 with a detailed report included in Appendix A.

1.4.3 Base Hydrodynamic Modelling

A key deliverable of this study is the development of a Rivoli Bay Base Hydrodynamic model. The model provides a tool by which the key coastal processes can be identified and quantified to better interpret and understand the coastline responses at the three sites being investigated. The model setup, validation and interpretation is provided in Section 4.

1.4.4 Conceptual Sediment Transport Models

Prior to the development of site-specific modelling approaches, the primary drivers of sediment transport need to be identified and described within the context of the regional and local coastal system. For each location a brief summary of the key coastal processes has been summarised and a conceptual sediment transport model developed. This is outlined for Beachport foreshore, Southend shoreline and Beachport Boat Ramp in Sections 5, 6 and 7, respectively at the start of each report chapter.

1.4.5 Sediment Transport Modelling

Leveraging off the hydrodynamic modelling, sediment transport modelling has been established to allow investigation of the specific transport mechanisms with the view to being able to assess potential coastal works or management options. The purpose of the modelling has focused on quantifying specific sediment transport processes, including the longshore transport potential along the Beachport Foreshore (Section 5) and Southend shoreline (Section 6) and the transport mechanisms that lead to siltation at the Boat Ramp (Section 7).

1.4.6 Identification of Potential Mitigation Options

Having established the specific transport mechanisms through the interpretation of available data and numerical model outcomes at Beachport and Southend, the identification of a range of potential mitigation options was made for each location.

Prior to completing the options assessment in the sediment transport models, Baird sought review and feedback from Council as to the final set of options to be assessed. The options assessment and development of recommendations has been completed and is reported for the Beachport Foreshore (Section 5), the Southend shoreline (Section 6) and the Boat Ramp (Section 7) at the end of each respective chapter in the report.

2. Literature Review and Data Summary

Coastal processes within Rivoli Bay have been extensively assessed over the last 6-7 years, hence, to establish a baseline understanding of coastal processes at the site a review of available literature and data was completed.

2.1 Existing Literature

The following reports were reviewed and provide a summary of the current understanding of coastal processes within Rivoli Bay:

1. Rivoli Bay Study (Worley Parsons, 2015)
2. Beachport Boat Ramp Review of Maintenance Requirements (WGA, 2017)
3. Sand Management Plan for Beachport Town Beaches (WRC, 2017)
4. Southend Adaptation Strategy (Wavelength, 2018)

2.1.1 Rivoli Bay Study (Worley Parsons, 2015)

The Rivoli Bay study provides a comprehensive analysis of coastal processes in Rivoli Bay and assessment of the coastal structures in the shoreline areas along the Southend and Beachport coast. The report includes findings from coastal process models developed for the Beachport and Southend foreshores, which describe the dominant wave direction and pathways for sediment movement.

At the study locations of Beachport and Southend, the key coastal process is longshore drift due to diffracted wave action that drives sediment transport along the foreshore. For Beachport this is a net northward direction and for Southend on the shoreline east of the Lake Frome outlet the net littoral transport is northward and lower in magnitude compared to Beachport. This process is evident both in examination of the build-up of sand on the groyne structures in the coastal compartments from aerial imagery and confirmed from site inspections by Baird in 2019. Longshore drift is considered the primary driver of sediment transport along the coast of both Southend and Beachport.

The Rivoli Bay study provides a succinct conceptual model of the regional wave driven coastal processes within Rivoli Bay, as shown in Figure 2.1. The large-scale sediment transport overview presented in the model is considered to represent the general processes well for Rivoli Bay. The numerical modelling and sediment transport models will examine the wider scale processes in this conceptual model and look to refine the longshore transport processes along the Beachport and Southend shorelines. The volume of littoral transport annually and seasonally is a data gap that will be examined in the sediment transport modelling, which will inform potential modification of the groyne features and management options for sedimentation in the boat ramp basin. The numerical model and sediment transport modelling will be developed to determine the potential rates of sediment movement along the Beachport and Southend beaches.

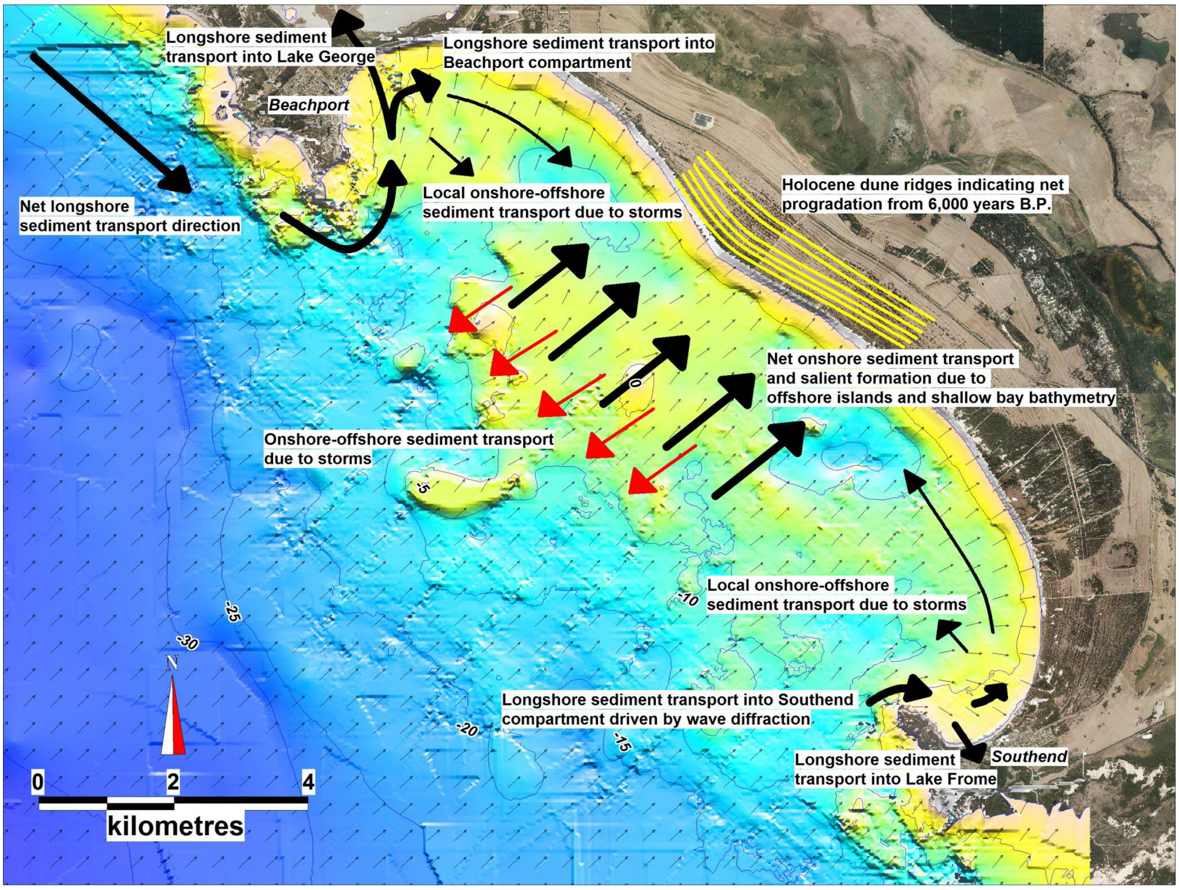


Figure 2.1: Conceptual model of the regional wave driven coastal processes within Rivoli Bay (reproduced from Worley Parsons, 2015)

For groynes along the Beachport foreshore it is noted beach compartments are all "full" and each groyne is actively bypassing sediment. This observation is supported based on Baird's recent site inspection (June 2019) and examination of aerial imagery.

For the Beachport boat ramp, it is stated that the breakwater constructed in 2014 on the ocean side of the basin has allowed longshore transport to bypass the area. However, it is then noted that since it's construction there has been significant sediment accumulation in the basin. This is a focus of this current study and cited as one of the key data gaps that will be examined with a focus on understanding the longshore drift process along the Boat ramp basin eastern breakwater and its influence as a source of sediment and driver for sedimentation in the entrance of the basin.

The report critically examines the groyne spacing versus groyne length and bathymetry at Beachport and Southend. It is noted that groynes south of the boat ramp in Beachport conform with general design practice (spacing between groynes should be 2-3 times the groyne length). North of the jetty it is noted the groynes are either too short or the spacing too great for them to compartmentalise the beach effectively. Similarly, at Southend for the groynes east of the Lake Frome outlet these are cited as being too short or too far apart. Recommendations for additional length to the existing groynes to work more effectively and/or shortening of the groynes at the Lake Frome outlet is presented a means of increasing sand supply and increasing stability of shorelines on the east. This will be examined using the sediment transport model developed in this study at Southend to examine means by which erosion currently being observed east of Lake Frome could be stabilised.

The Rivoli Bay study makes the following recommendations with respect to improving shoreline stability at Beachport and Southend:

- Provision of an additional groyne just north of the Beachport jetty or extension of the existing groyne north of the jetty that would encourage additional sand build-up around the jetty area,
- Provision of a rock revetment in front of the vertical timber seawall near the jetty with the aim of reducing the wave reflections from the existing seawall, reducing wave runup onto Beach Road and encouraging the buildup of sand in this area;
- Repair of and shortening of the groynes at the outlet to Lake Frome at Southend;
- Lengthening of the groynes east of the Lake Frome outlet at Southend.

2.1.2 Beachport Boat Ramp Review of Maintenance Requirements (WGA, 2017)

The Review of Maintenance Requirements at the Beachport Boat Ramp provides a detailed account of the history of the boat ramp site, the development of structures aimed at improving the location and the on-going sedimentation issues through the various reconfigurations of the facility. There is detailed discussion of coastal sediment movement processes affecting the boat ramp that provides additional insight into drivers of sedimentation at the Beachport boat ramp.

The prevailing action for sediment transport along the Beachport foreshore is identified as being from longshore drift due to wave action. However, longshore transport along the coast to the north is not the only coastal process that is identified as the cause of sedimentation, and of note for the current study, there are a number of other transport mechanisms that are hypothesised to contribute to the sedimentation of the boat ramp site including:

1. Wind driven – sand blowing over the groyne to the immediate south of the original outer breakwater shore connection, noting that in recent years this beach cell has typically been overfilled relative to historical levels;
2. Wave action pushing sand in over the top of the outer breakwater;
3. Waves pushing sand around the end of the breakwater after being refracted slightly south of west as they transform around the end of the outer submerged breakwater;
4. Sand carried in under suspension due to anti-clockwise currents that can form within Rivoli Bay;
5. Sand driven through the permeable breakwater extension.

The last 2 mechanisms are cited in the report as being particularly relevant during heavy swell conditions within Rivoli Bay, as the water turns from ‘blue’ to ‘green’ due to the suspended sediment.

The potential source of north - south sediment transport into the boat ramp marina basin by reflected long-period wave from the surf beaches across Rivoli Bay is a mechanism cited for further investigation. The WGA report notes observation at the site in June 2017 of the process of a slow rise and fall in the water levels within the basin, and potential for long period waves to cause high water velocities and sediment transmission from bed scour, as a mechanism to transfer the sand bar into the basin. This phenomenon is similar to observations made by Baird during a site visit in January 2020, where surges of current at the entrance to the basin were driving sediment plumes into the basin over the sandbar and sediment in suspension was then settled out in the calm of the basin.

The offshore geotextile breakwater is cited as being responsible for refocusing and concentrating wave energy toward the beach immediately north of the basin entrance and potentially contributing to increased levels of erosion to the north in front of the ‘Harbourmasters’ Residence’. The vertical seawall adjacent to the jetty is cited as an important feature of the overall system, particularly due to the increased wave energy with reflected waves forming at the seawall with increased force due to the greater water depths. WGA states this “reflected wave energy is particularly effective at mobilising sediment into the water column, which is potentially transported back towards the boat ramp area when anti-clockwise currents exist in the Beachport end of Rivoli Bay”.

2.1.3 Sand Management Plan for Beachport Town Beaches (WRC, 2017)

The management strategy for the Beachport beaches outlines councils commitment to protecting and restoring the beaches showing signs of or at risk of erosion such as the southern ends of Beaches 7, 8 and 9 by relocating sand from those beaches that store sand, such as Beach 4 and at times Beach 5 (refer Figure 2.2). The triggers for relocation of sand and suitable interventions have been determined in consultation with the Coastal Management Branch. It is stated that “Beach 4 has significant sand storage capacity, which can be utilised to top up other beaches as required. At times, there is also additional sand on the northern end of Beach 5 that could be used to address erosion in other areas”. A monitoring pole at Beach 4 is listed as one of the monitoring methods.

Figure 2.2: Beach and Groyne Numbers adopted in Revised Sand Management Plan (WRC, 2017)

2.1.4 Southend Adaptation Strategy (Wavelength, 2018)

The Southend Adaption Strategy report provides a detailed account of the historical issues with regard coastal processes (erosion and inundation) at Southend. It is noted that sea level rise and climate change are likely to exacerbate the issues currently faced.

The historical account of coastal recession cites the Lake Frome outlet as being chiefly responsible, initially contributing to loss of seagrass communities in the nearshore, removing the natural defence to wave exposure and increasing erosion potential along the shorelines of Southend. The construction of training walls either side of the outlet in the mid-1980's led to disruption of the natural sediment pathway from west to east. The sediment supply was reduced to the eastern beaches, meanwhile on the other side accretion led to the increased width and stability of Western Beach. There is evidence that sediment transported around the training wall from the Western Beach side has been trapped between the groynes in the outlet drain. To the east there were three groynes constructed between 1993 and 1995 on the beaches between Eyre and Leake Street to prevent the erosion that were noted as having slowed the process, however erosion of the shoreline has continued. The report states that recession of up to 14m in front of the Caravan Park was observed over the 29-year period (between 1988 and 2017). Key features along the Southend shoreline and summary of the coastal processes is presented in Figure 2.3.

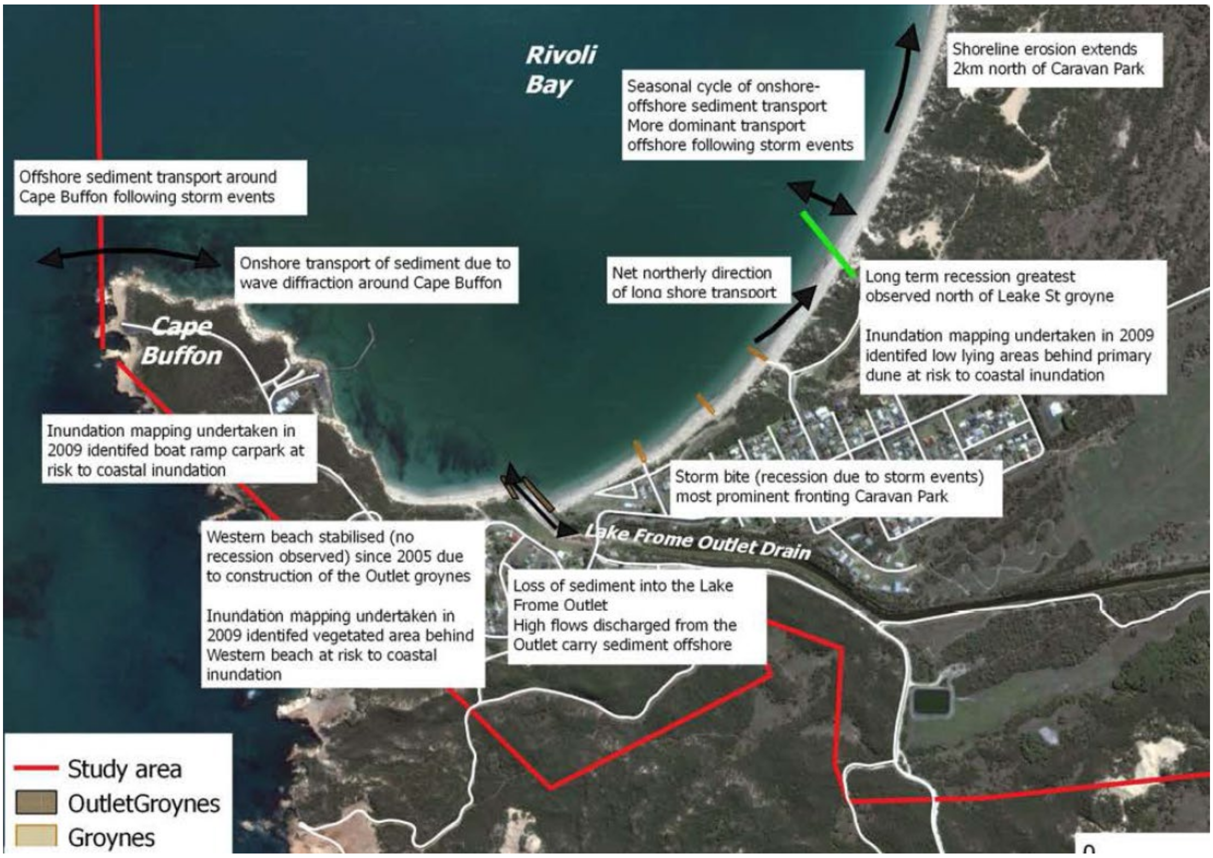


Figure 2.3: Southend – Summary of Coastal Processes and Coastal Management Issues (Wavelength, 2018)

Wavelength have completed setback lines and first pass coastal hazard lines to assess adaptation approaches for the Southend community. Based on observed rates of erosion, analysis has identified retreat as the likely 'best practice' approach for the long-term planning horizon (2100) for private property. Ongoing monitoring is required to support decision making and further build the understanding of the shoreline areas. There is a recommendation that measured metocean data including bathymetric surveys is undertaken to capture seasonal profiles of conditions in winter and summer months. The captured metocean data as part of this study will assist in filling this knowledge gap.

Wavelength cite reasons for the poor performance of the groynes is due to:

1. Being insufficient in length, with the littoral drift zone extending significantly beyond the end of the groynes; and/or

2. Cross-shore sediment transport being more dominant than alongshore processes.

It was noted in Worley (2015) the design of the groyne field is not adequate to compartmentalise the sand and groynes should either extend further seaward or additional groynes built.

The current study will examine the modification of the groyne field in the shoreline transport model to develop the understanding of coastal processes. This will support the assessment of the 'Defend' strategy in the Wavelength adaptation options assessment. The options assessment for the numerical model would include the scenarios outlined in Wavelength (2018) as follows:

- Reconfiguration of the groyne field between Eyre St and Leake St – groynes would require to be extended a significant distance offshore and their orientation reassessed in order to be effective. Review of the storm modelling results for the cross-shore profile located within the vicinity of the groynes showed that the groynes would need to be extended a minimum of 50m to effectively capture the cross-shore movement of sediment driven by storms.
- Redesign of the outlet groynes – shortening and possibly realignment of both groynes to allow the east – west sand transport from the Western Beach.

Three further adaptation measured put forward as part of the defend options included beach nourishment, re-establishment of seagrass communities and hard defences (offshore breakwater/onshore seawall) could be examined in the modelling. Based on discussions to date with the project team the reconfiguration / extension of the groynes between Eyre St and Leake St and redesign of the outlet groyne (shortening) are the key scenarios to be tested in the model.

2.2 Available Data

Existing data that was available for this study is summarised in Table 2.1.

Table 2.1: Summary of Available Data

Data Type	Source Data	Source
Metocean Data	Measured wave data from the Cape du Couedic buoy	BoM
	Bureau of Meteorology Wind Measurement Sites Closest to Rivoli Bay	BoM
	Hindcast Wind and Wave Conditions (ERA5)	ECMWF
	Tidal Planes at Beachport	Hydrographic Service
Aerial Imagery	High resolution Aerial Imagery 2018	DEWNR
	Historical Imagery from Google Earth	Google Earth
Elevation and Bathymetric Data	LiDAR Data 2018	DEW
	Bathymetry Data Beachport and Southend	DEW
	Beach Transects	DEW
	Bathy Survey from Pre and Post Dredge 2018, 2019	Farren Group
	Navigation Chart AUS127	Hydrographic Office
Sediment Data	Sediment Sampling Data	Worley Parsons / Baird

2.2.1 Measured Wave Data

Measured wave data from the Cape du Couedic buoy was sourced from the BoM. This data site records waves from approximately 350km northwest of the site (Located at 36.07ºS, 136.62ºE). The data will be used in conjunction with the measured data being collected currently at the Southend and Beachport locations. The long-term record at Cape du Couedic buoy can be used to characterise the offshore long-term wave climate for the summer and winter period and applied as boundary conditions to the regional scale numerical model. The data covers a period of approximately 20 years (2001 – 2020 inclusive).

Figure 2.4: Locations of Cape Du Couedic Wave Buoy and the Robe Airfield Anemometer from the Study Site

2.2.2 Measured Wind Data

The locality of wind data sites closest to Beachport is shown in Table 2.2. Wind roses for the Robe location are shown in Figure 2.5. The long-term wind data was sourced from the BoM and is used to characterise the metocean conditions for the Rivoli Bay project area in the winter and summer periods and will be applied in the numerical model to actively develop the wind-sea conditions in Rivoli Bay. It is noted that the local wind conditions in Rivoli Bay may differ from the Robe measured data, however in the absence of site-specific wind data the Robe dataset is considered generally representative of conditions in Rivoli Bay.

Table 2.2: Summary of BoM Wind Data sites adjacent Rivoli Bay.

Site	Dist. From Riv. Bay	Lon.	Lat.	Start	End
Robe Airfield	38km	139.8054 E	37.1776 S	2003	Present
Cape Jaffa	63km	139.7164 E	36.9655 S	1992	Present

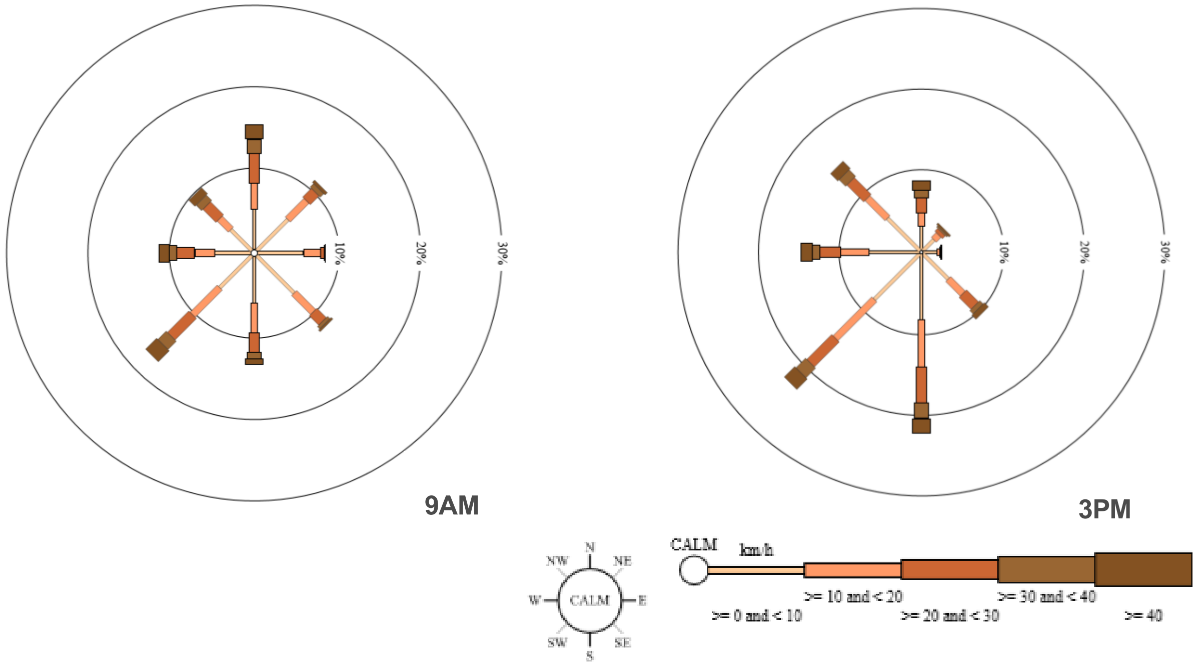


Figure 2.5: Annual Wind Roses from Robe (BoM station 26026) showing wind speed and direction at 9am (left) and 3pm (right). Source BoM online direction shown as 'Direction from).

2.2.3 Hindcast Wind and Wave Data

A long term (41 years between 1979 and 2020) numerical wind and wave hindcast is available at locations just offshore of Rivoli Bay. The ERA5 dataset, produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) is one of the most accurate numerical hindcasts datasets available with data archived on a 28km resolution grid. ERA5 combines vast amounts of historical observations into global estimates using advanced modelling and data assimilation systems. The performance of the ERA5 wave hindcast was assessed by comparison to measured wave data from Cape Du Couedic (see Section 2.2.1), as shown in Figure 2.6, and was found to replicate offshore wave conditions in the vicinity of Rivoli Bay very well. The data set can therefore be reliably used to inform spatially varying numerical model boundary conditions in this study.

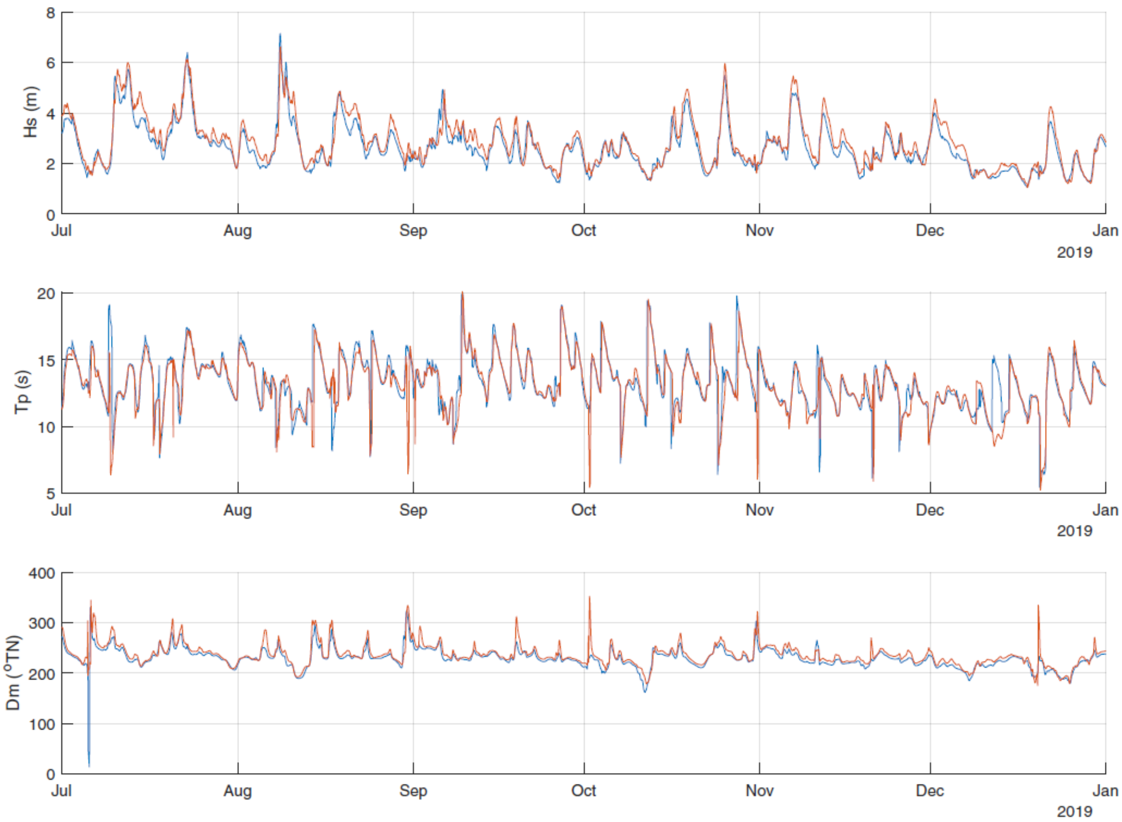


Figure 2.6: Comparison of Wave Conditions from the ERA5 wave hindcast (red) against measured data at Cape Du Couedic (blue)

2.2.4 Tidal Planes

Rivoli Bay experiences mixed-semidiurnal conditions which also exhibit diurnal characteristics. There are two high tides and two low tides on some days and only a single high and low tide on other days (Worley 2014). The tidal planes from the Australian Hydrographic Office are shown in Table 2.3.

Table 2.3: Tidal Planes – Beachport (Australian Hydrographic Office, Chart AUS127)

Datum	Height in metres above Datum of Soundings
Highest Astronomical Tide	1.6
Mean High High Water	1.1
Mean Low High Water	0.9
Mean Sea Level	0.7
Mean High Low Water	0.5
Mean Low Low Water	0.3

The general spring tide range is 0.8 m and during neap tides the average tide range is approximately 0.4 m. Table 2.3: Tidal Planes – Beachport (Australian Hydrographic Office, Chart AUS127)

2.2.5 Aerial Imagery

The aerial imagery sourced for the study covering the coastline areas from Beachport to Southend are summarised in Table 2.4. In brief these are to inform the study as follows:

1. The Google Earth historical aerial data sets will be used as a reference for understanding the changes to the coastline areas over the recent historical record. In particular the imagery shows the alterations to the section of coast where the Beachport Boat ramp is located. Access to satellite imagery back to 1988 is available through the Google Earth Engine. Hence, imagery is available prior to the establishment of the basin and breakwaters. The temporal resolution of imagery from 2010 to 2020 increases from approximately yearly to weekly, which is adequate to visualise the modifications to the shoreline (geotextile breakwater, current breakwater structure).
2. The DEWNR aerial from 2018 provides a very high-resolution image that can be used in the presentation of figures for the reporting of the project.

Table 2.4: Summary of Aerial Imagery available for the study.

Description	Data Type	Date	Source
Google Earth historical Imagery	Satellite and aerial imagery covering all shoreline areas in Rivoli Bay	First Image 1988 to present	Google Earth
Rivoli Bay including Southend and Beachport Areas	Aerial Imagery covering all shoreline areas in Rivoli Bay	Acquisition date of image between 22/5/2018 – 24/8/2018	DEWNR
Historical Aerial Analysis	Aerial Imagery covering Beachport and Southend	Aerial photographs dating between 1946 and 2013	Worley Parsons (2015)

2.2.6 Elevation and Bathymetric Data

Table 2.5 summarises the survey and bathymetry data available for this study. Examples of the data sources are shown graphically in Figure 2.7 to Figure 2.12.

In summary there is a good description of the offshore and onshore areas to inform the development of the numerical model. The latest LiDAR data (2018) is used to define coastal foreshore areas and the coastal structures at Beachport and Southend. Offshore bathymetry for the numerical model is defined from marine swathe data in Rivoli Bay and nearshore seabed survey in Beachport and Southend, with gaps filled using the available hydrographic Chart data (AUS127). The recent pre and post-dredge surveys from the Beachport boat ramp (Farren Group 2018, 2019) provide a high-resolution description of this key area for the boat ramp basin.

Table 2.5: Summary of Bathymetry Data relevant to the study

Description	Type	Date	Comments	Reference
Bathymetry Data	Marine Swath Data of Rivoli Bay	21 May 2014	Swathes through Rivoli Bay offshore areas	DEH 2014

Description	Type	Date	Comments	Reference
Bathymetry Data	Marine Bathymetry survey Data	May 2002	Swathes through Beachport nearshore and Southend Nearshore areas	DEWNR 2012
LiDAR	LiDAR	22/5/2018 – 24/8/2018	Excellent description of the Beachport and Southend areas	DEWNR 2018
Bathy Survey from Pre- and Post-Dredge Boat Ramp Basin	Bathymetry as xyz data	Pre and Post Surveys 24 Sep – 7 Oct 2019 20 Mar- 3 Apr 2019	Key Dataset to describe levels in basin. High resolution surveys in the boat ramp area describing levels. Reported dredge volumes are: March 2019 = 6,624m^3 September 2019 = 5,883m^3	Farren group (2019)
Hydrographic Chart	Chart AUS127 with soundings and contours for all of Rivoli Bay	-	Describes all of Rivoli Bay Study area not described by bathy survey. Points digitised.	Australian Hydrographic Office

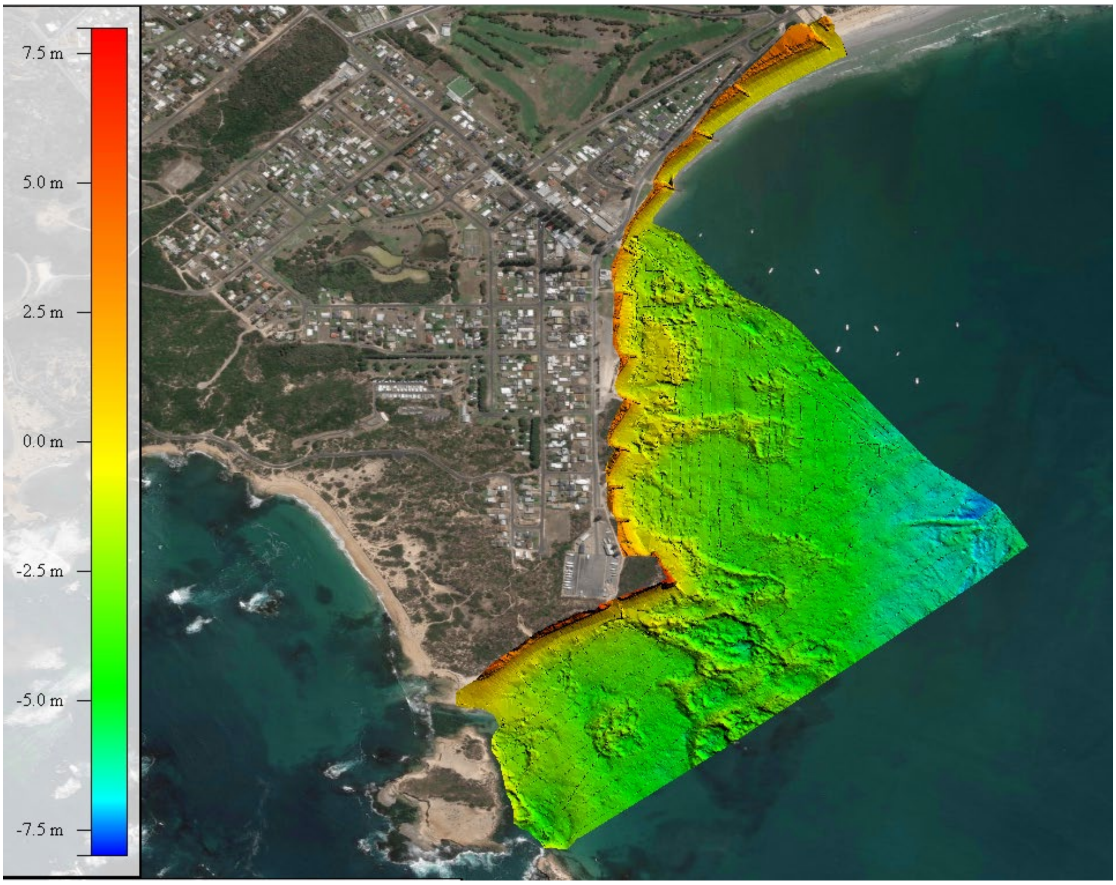


Figure 2.7: Multibeam Bathymetry 2012. Beachport

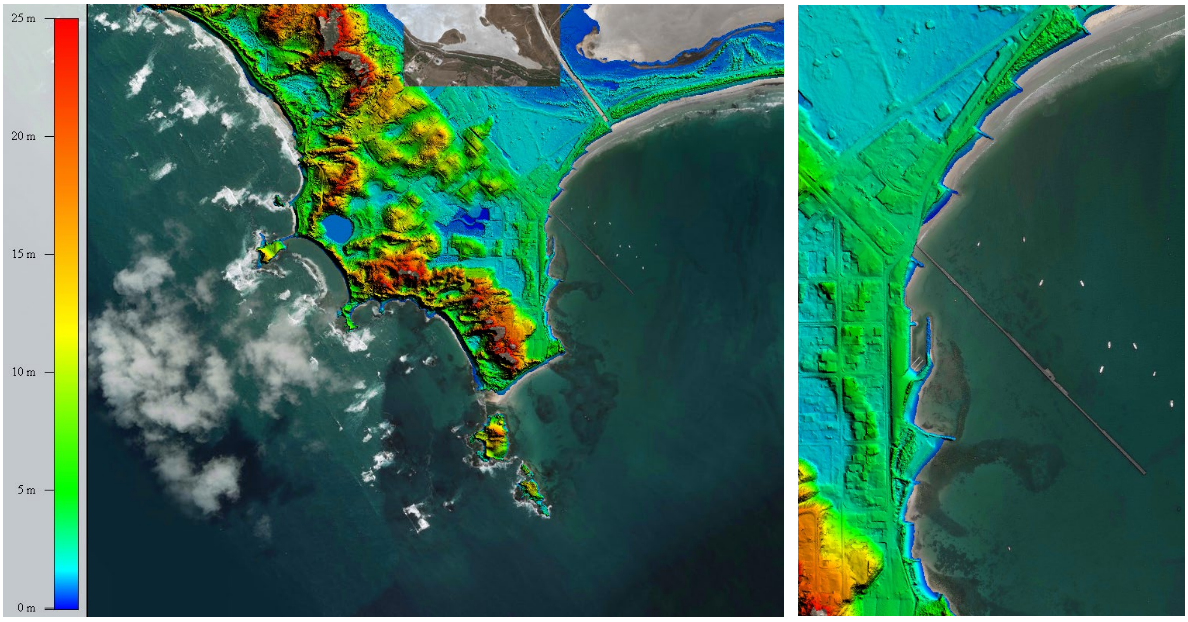


Figure 2.8: LiDAR Data 2018. Example of Coverage around western Rivoli Bay and Beachport

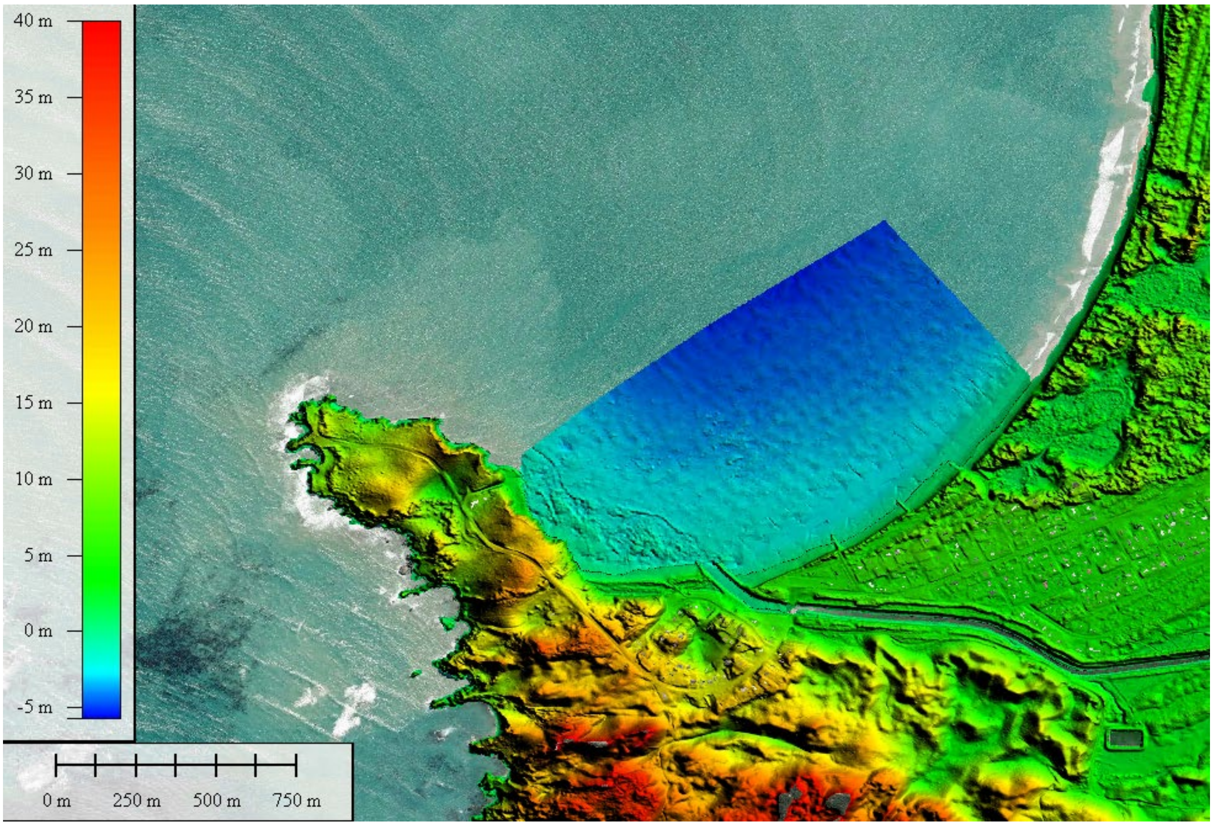


Figure 2.9: Southend Combined Survey LiDAR (2018) and offshore bathymetry survey data (2012).

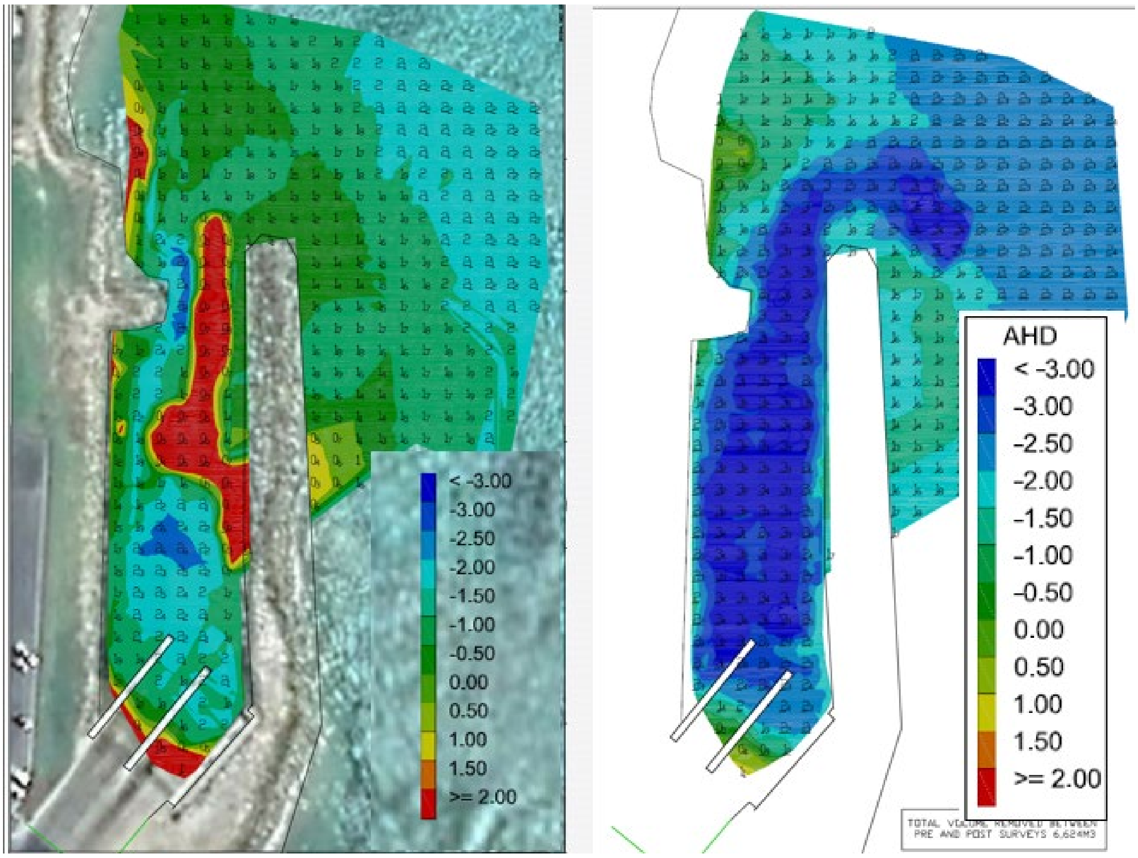


Figure 2.10: Pre-Dredge and Post Dredge Survey in Boat Ramp Basin (Farren Group). Level of seabed (left) pre-dredge 20 March 2019 and (right) post dredge taken 3 April 2019. Datum mAHD.

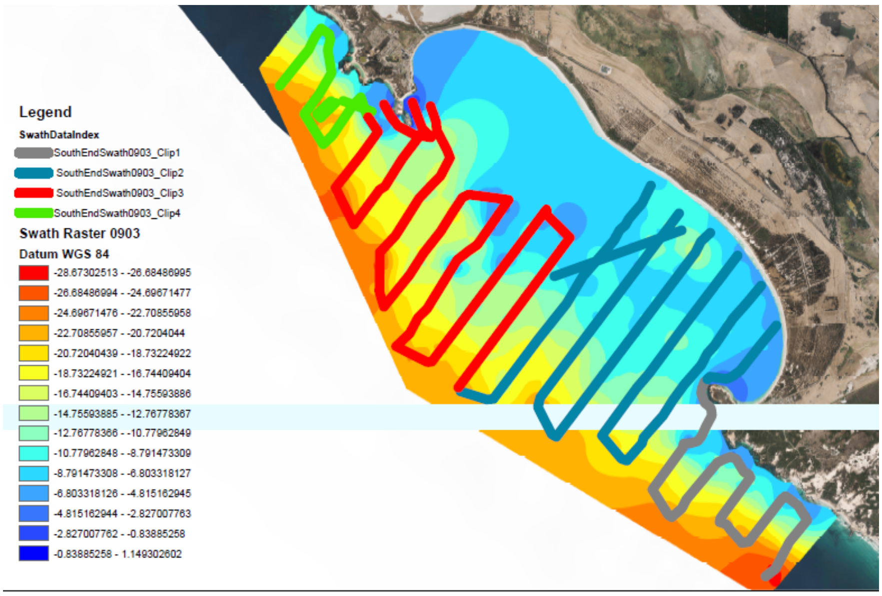


Figure 2.11: Marine Swathes – Offshore Bathy Capture 2014 (DEH)

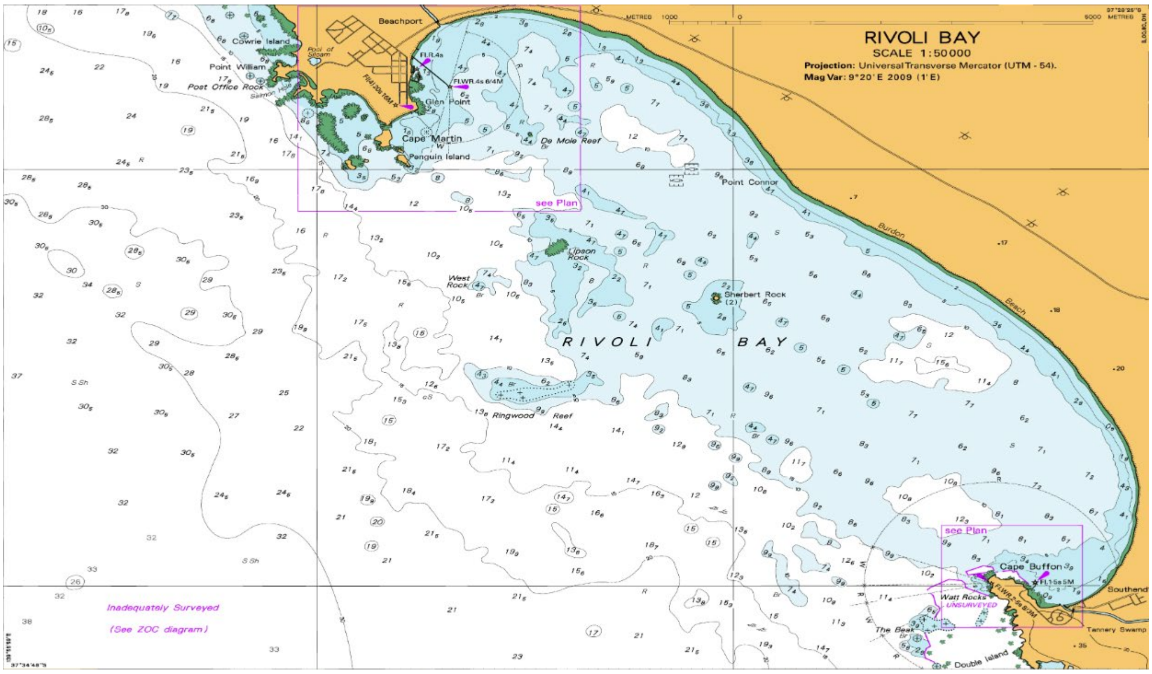


Figure 2.12: Hydrographic Chart of Rivoli Bay (AUS00127P2).

2.2.7 Sediment Sampling Data

The following sediment samples have been collected through the Beachport and Southend project:

- Detailed reporting from sediment samples collected as part of the Rivoli Bay Study (Worley Parsons 2015) was received providing the Particle Size Distribution (PSD) information for 8 locations in Beachport and 4 in Southend. The data is summarised in Table 2.6 and Figure 2.13.
- Sediment sampling completed in March 2014 with PSD information for one sample in the Beachport boat ramp basin area over the sandbar (Tonkin 2014).
- During the site visit in June 2019 Baird collected four sediment samples from locations along the Beachport town beaches to describe beaches that were not covered by the Worley data, with locations noted in Table 2.6 and Figure 2.13.
- During the site visit in January 2020 Baird collected 4 sediment samples from locations around the Beachport Boat ramp basin to describe the seabed composition. One sample was collected from the sandbar inside the basin to characterise the sediment size of the material that falls out of suspension and representative of the material that requires maintenance dredging. One sample was collected from Southend on the beach north of Leake St (S4).

The collated sediment samples have provided sufficient data for developing a spatial map of the seabed sediment grain size distributions. The full sediment sample PSD results were reported in Baird (2019) and the D50 values are summarised in Table 2.6.

Table 2.6: Summary of sediment sample data for use in the study.

Site	Lon.	Lat.	D50 (mm)	Date	Reference
Basin1	140.0153	-37.4839	0.14	Mar-14	Tonkin (2014)
B1	140.0202	-37.4769	0.15	Oct-15	Worley (2015)
B2	140.0184	-37.4780	0.40	Oct-15	Worley (2015)
B3	140.0155	-37.4812	0.40	Oct-15	Worley (2015)
B4	140.0150	-37.4852	0.40	Oct-15	Worley (2015)
B5	140.0152	-37.4890	0.22	Oct-15	Worley (2015)
B6	140.0006	-37.4864	0.55	Oct-15	Worley (2015)
L1	140.0188	-37.4761	0.30	Oct-15	Worley (2015)
L2	140.0166	-37.4738	0.15	Oct-15	Worley (2015)
S1	140.1222	-37.5690	0.37	Oct-15	Worley (2015)
S2	140.1210	-37.5709	0.20	Oct-15	Worley (2015)
S3	140.1182	-37.5697	0.22	Oct-15	Worley (2015)
S4	140.1261	-37.5665	0.21	Jan-20	Baird (2020)
BB1	140.0174	-37.4789	0.21	Jun-19	Baird (2019)
BB2	140.0164	-37.4800	0.30	Jun-19	Baird (2019)
BB3	140.0153	-37.4864	0.26	Jun-19	Baird (2019)
BB4	140.0149	-37.4878	0.19	Jun-19	Baird (2019)
BR0	140.0153	-37.4848	0.20	Jan-20	Baird (2020)
BR1	140.0154	-37.4837	0.20	Jan-20	Baird (2020)
BR3	140.0156	-37.4838	0.20	Jan-20	Baird (2020)
BR6	140.0150	-37.4828	0.17	Jan-20	Baird (2020)

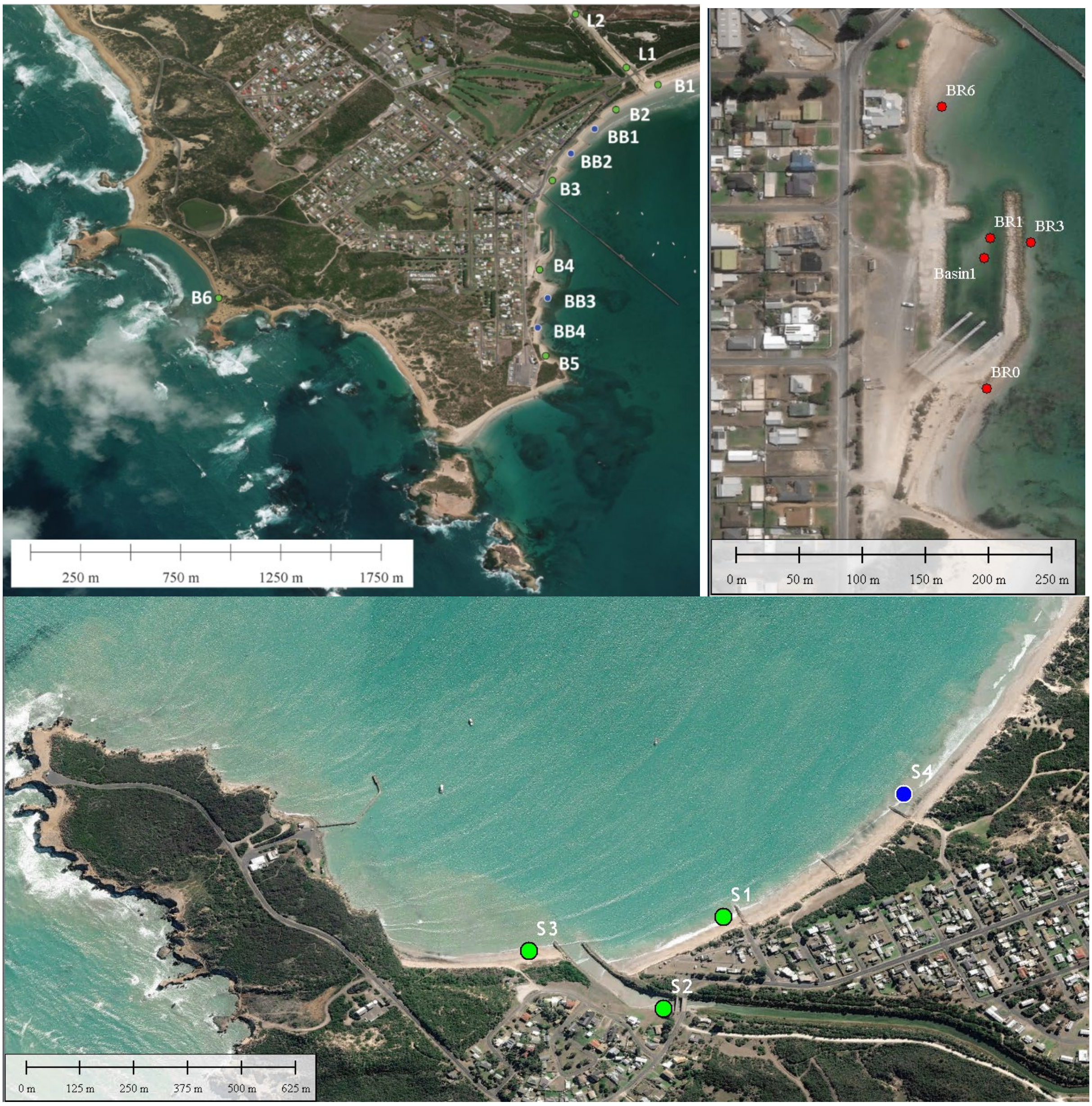


Figure 2.13: Sediment Sampling Locations with PSD data

3. Metocean Data Collection

As part of this scope, Baird engaged sub-consultant O2Marine to complete data collection of water levels, current, waves (sea and swell) and long waves at two locations; offshore of Beachport and Southend. This section provides a brief overview of the data collection campaign. For full details of the data collection campaign, including summaries of all field activities, instrumentation, deployment and retrieval methodology, data QA/QC procedures and presentation of the processed data, see the final report from O2Marine included in Appendix A.

3.1 Site Selection

The selection of locations for the placement of instruments to measure the waves and currents in Beachport and Southend was bound by consideration of the following:

- Water depth. Ideally the instruments require between 5m and 10m of water above them to reduce the forces on the seabed during periods of large waves (these could cause the instrument to break its moorings and be lost);
- For the Beachport deployment the distance from the boat ramp should be within reasonable proximity (ideally within 300m);
- Locations that avoid areas of high vessel traffic or locations where vessels may be anchoring (particularly relevant for Southend); and
- Locations where noted influence from bathymetric features (shallow reefs) or coastal structures is minimised.

All of the above factors were taken into consideration for the selection of the deployment locations. Local advice from a skipper familiar with the Beachport and Southend areas was sought to confirm the selected locations minimised risk from vessels interference (anchors and traffic).

The deployment locations are presented in Figure 3.1 with a summary in Table 3.1.

Table 3.1: Deployment Locations

Deployment Location	Geographic Co-ordinates	Depth
Beachport – approximately 100m southwest of the end of the jetty	-37.487216° S 140.019949° E	Approx. 5mCD
Southend – approximately 400m north of the Lake Frome structures	-37.563854° S 140.117722° E	Approx. 4mCD

Figure 3.1: Metocean Data Collection Locations at Beachport and Southend

3.2 Data Supply

The following metocean data were collected and analysed as part of the campaign at both the Beachport and Southend ADCP locations:

- Water levels, derived from bottom mounted pressure gauges and acoustic surface tracking data;
- Waves, including sea and swell, derived from bottom mounted surface tracking and velocity data;
- Long waves, derived from bottom mounted pressure gauge data;
- Currents, derived from bottom mounted acoustic current profiles

The data was processed, quality controlled and supplied in comma separated value (csv) and Network Common Data Form (NetCDF) formats. The complete and final set of data was provided to Council via Baird's Sharefile system on the 9th April 2020.

Full presentations of the data are provided in the final Data Collection report (see Appendix A).

3.3 Key Interpretations from the Measured Data

3.3.1 Wave Conditions

A review of the measured data provides some useful insights as to the metocean climate at Beachport and Southend. Both locations are relatively protected from the offshore wave climate, with wave heights rarely exceeding 1m at Beachport and 1.5m at Southend, some 15-20% of the offshore wave height. Waves are also essentially unidirectional for most of the time, arriving within a ~25deg directional range at both locations. Figure 3.2 presents the wave roses for Winter and Summer deployments at both Beachport and Southend locations.

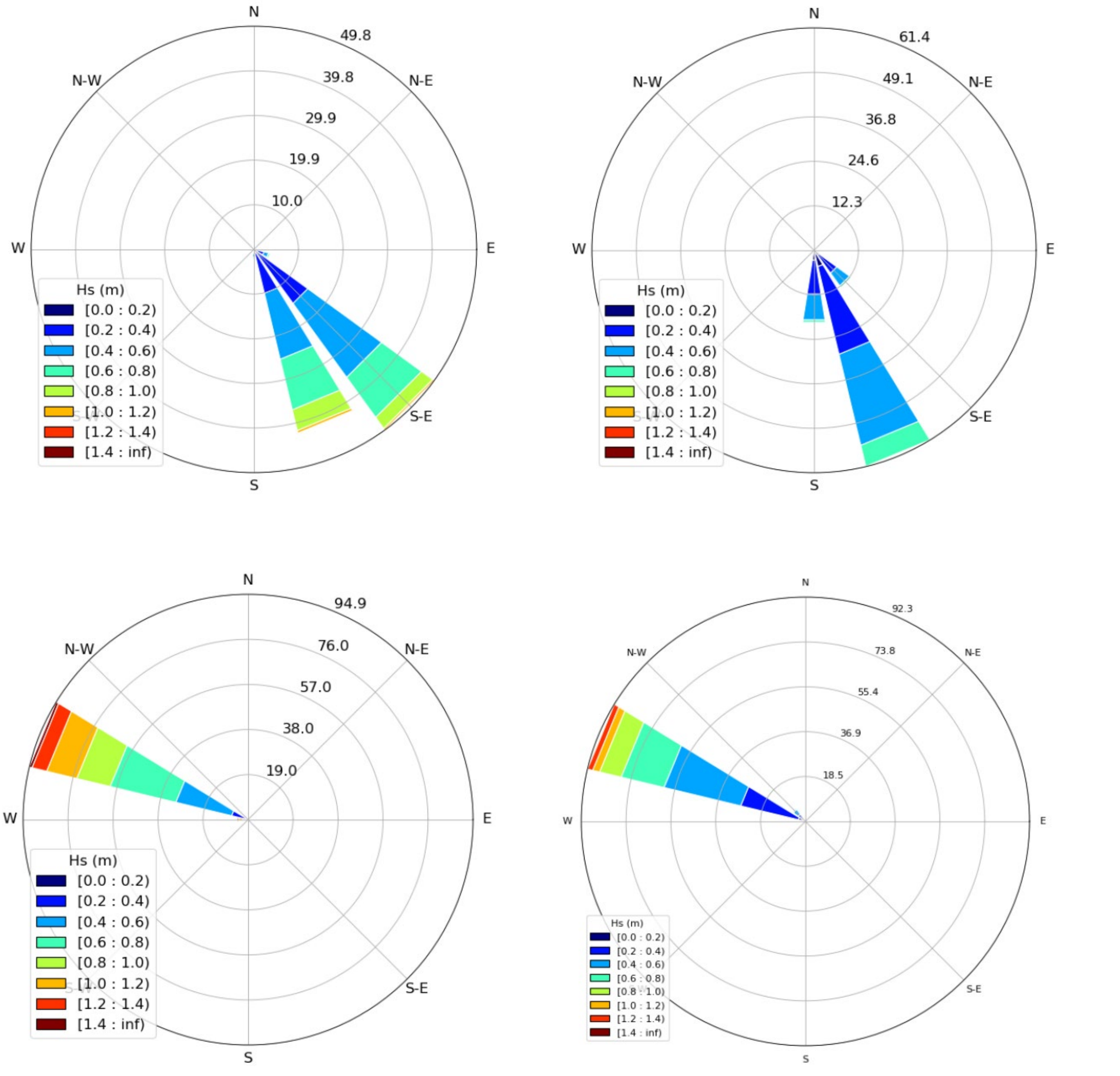


Figure 3.2: Wave Roses from the Winter (left) and Summer (right) deployments at the Beachport (top) and Southend (bottom) ADCP locations. Direction coming from.

3.3.2 Currents

Currents at both locations are relatively mild, generally remaining below 0.1m/s, flowing out of Rivoli Bay for a higher proportion of the time, as shown in Figure 3.3. This is a result of the tidal circulation within Rivoli Bay that establishes return eddies at either end of the embayment. At times, current speeds increase to ~0.2m/s and appear correlated with wind and wave conditions. It is noted that the current measurements are taken from offshore (approximately 400m) and the current magnitude in the nearshore area would be higher. Current transects measured from the shoreline to the offshore are presented in the Metocean Study Report (Appendix A, Section 6.4).

At Beachport, increased currents align with periods when winds are from the north-northeast or when wind and elevated waves approach Rivoli Bay from the southwest (see Figure 3.4). At Southend, increased current speeds align with periods when elevated winds are from the east or northwest (see Figure 3.5). The increase in the current magnitude is due to the alignment of the wind direction along the general axis of the current direction, enhancing the current flow for each respective location (refer Figure 3.3).

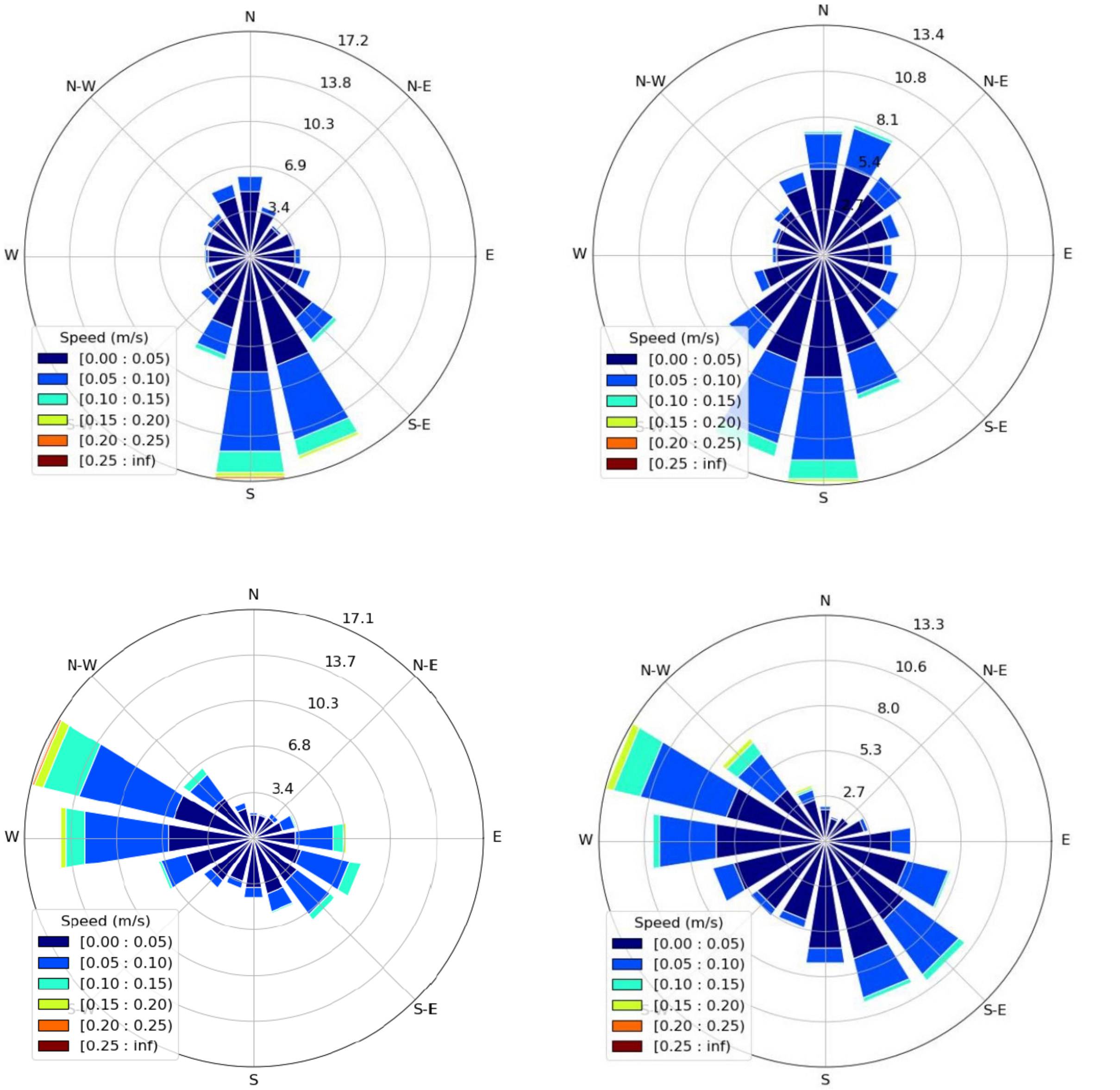


Figure 3.3: Current Roses from the Winter (left) and Summer (right) deployments at the Beachport (top) and Southend (bottom) ADCP locations. Directions going to.

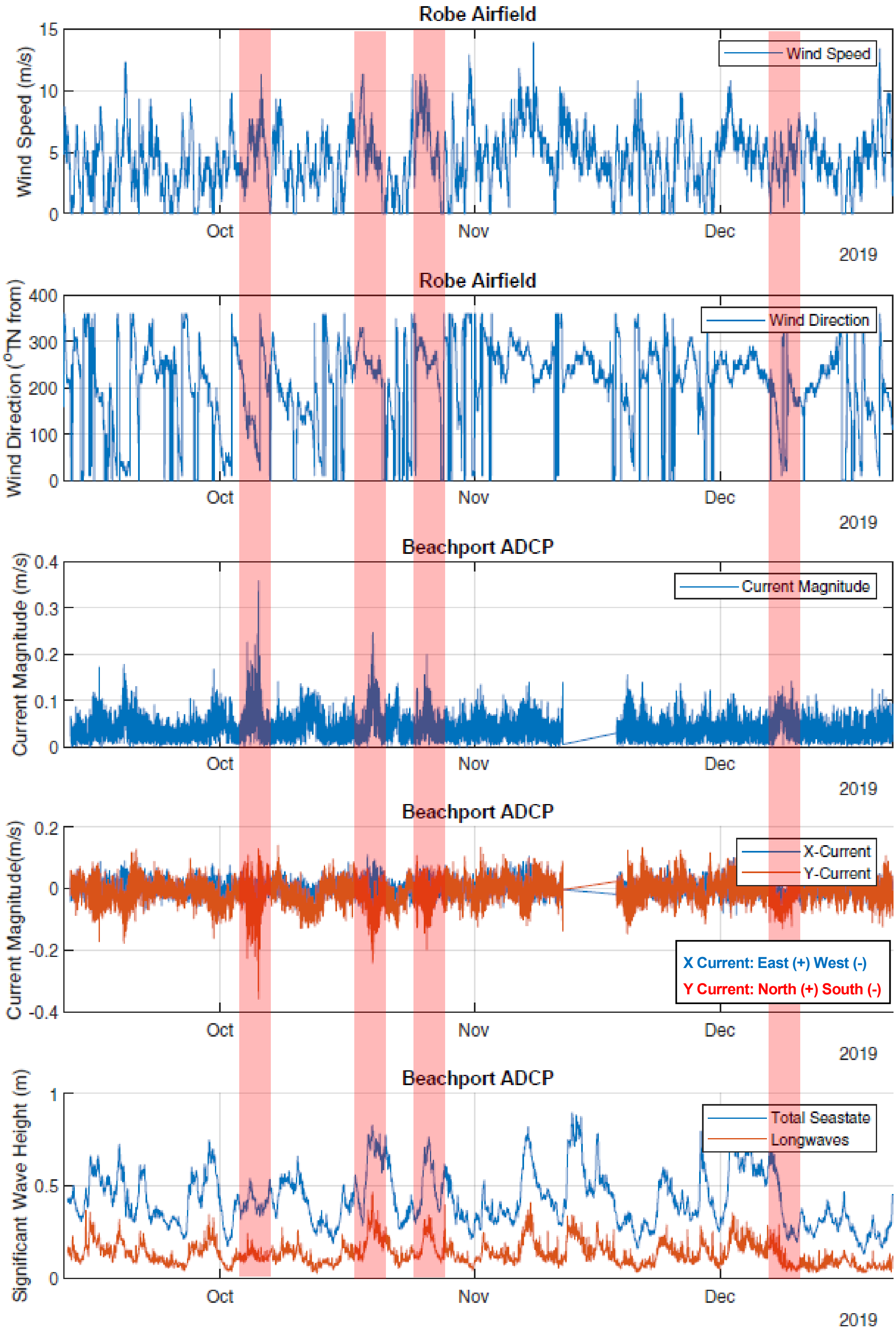


Figure 3.4: Coincident wind, current and wave data for the Beachport ADCP location. Periods of elevated current speeds identified in red shaded areas.

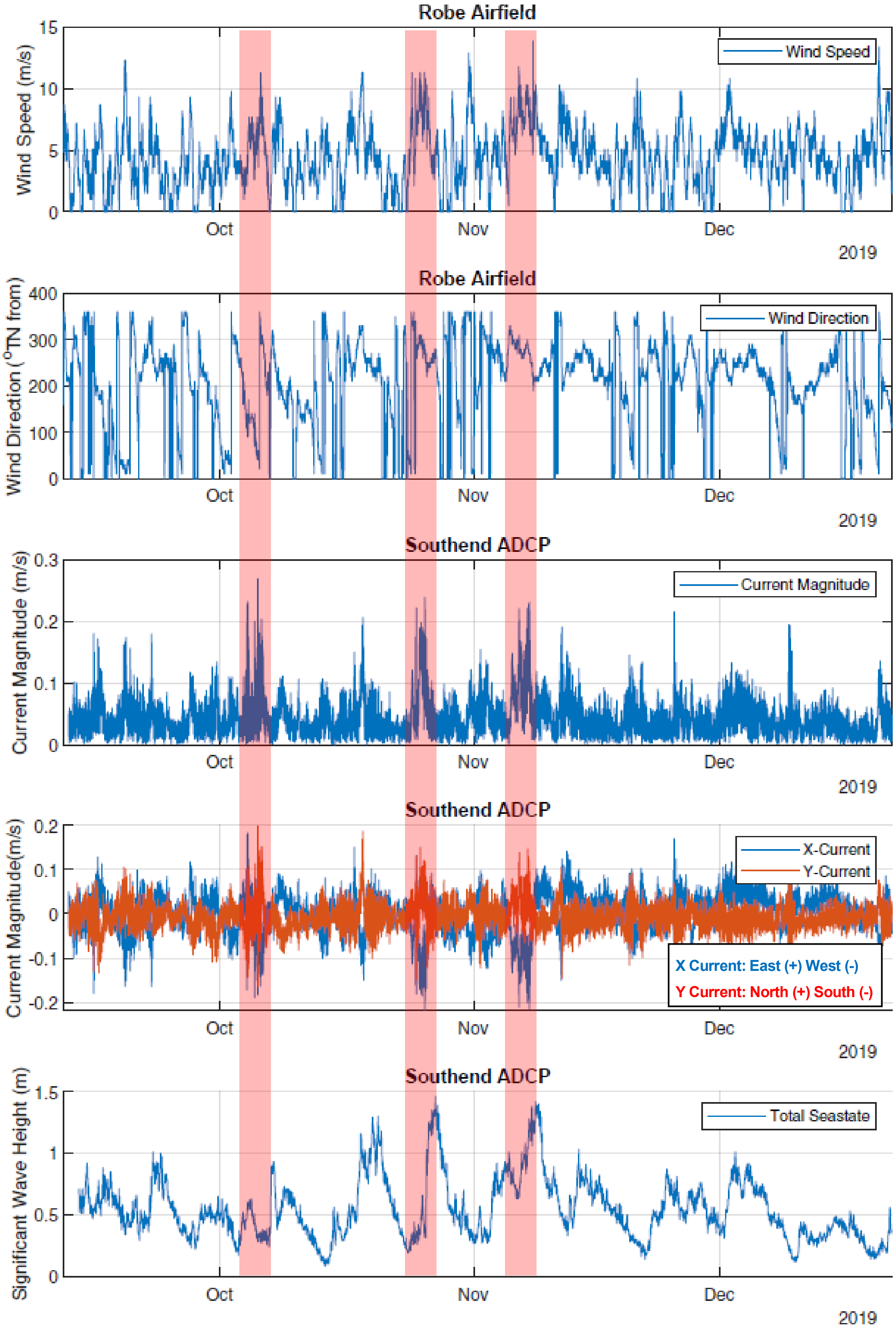
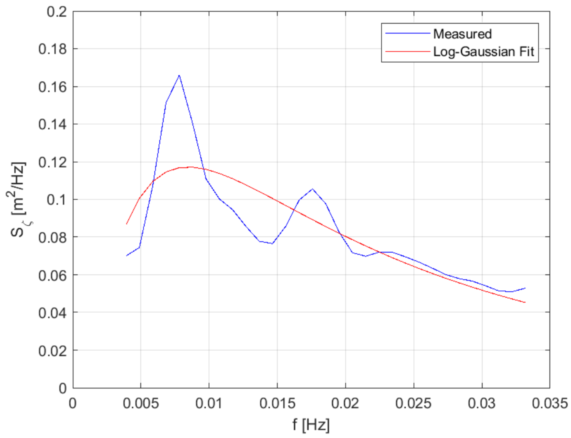


Figure 3.5: Coincident wind, current and wave data for the Southend ADCP location. Periods of elevated current speeds identified in red shaded areas.

3.3.3 Long Waves

At the Beachport location, pressure measurements were analysed to estimate the long wave energy present at the site. The timeseries of total wave height (combined sea, swell and long wave energy) and long wave height is presented in Figure 3.4. The two signals are highly correlated, with long wave heights approximately 40% of the total seastate. This is a high ratio, much larger than would be expected as a result of bounded long wave energy associated with swell wave grouping, suggesting that there is a considerable amount of unbounded and/or reflected long wave energy present at the site. The same observation can be made when reviewing the long wave measurements from the Southend deployment as presented in Appendix A.

Baird undertook an analysis of the raw logged pressure data (at 1Hz frequency) to investigate the long wave spectrum. Examples of the resulting long wave spectra are presented in Figure 3.6. These are very wide spectra, however two distinct peaks of energy are found near wave periods of 140 s and 60 s. These are considered a result of surfbeat-type effect from reflected long waves from the shore (60 second peak), and a pattern of freeing of long waves in the shallow refraction zone around the main headland that protects the bay (140 second peak).



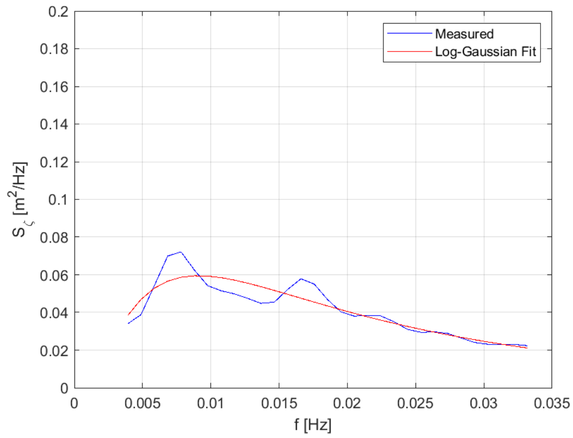


Figure 3.6: Measured and fitted long wave spectra for the selected periods during the winter (left) and summer (right) deployments

3.3.4 Characterisation of the Measurement Period

To understand how representative conditions during the measurement period were of the longer-term climatic averages, statistics for the key parameters of wind speed and wave height were analysed. Probability distributions were developed for all available data, winter months (April to September) and summer months (October to March) using measured wind data from the Robe Airfield (see Section 2.2.2) and the 41-year offshore wave hindcast from ERA5 (see Section 2.2.3). The longer-term averages were then compared to the subset of data covering the metocean data collection period (July 2019 to December 2019) and are presented in Figure 3.7.

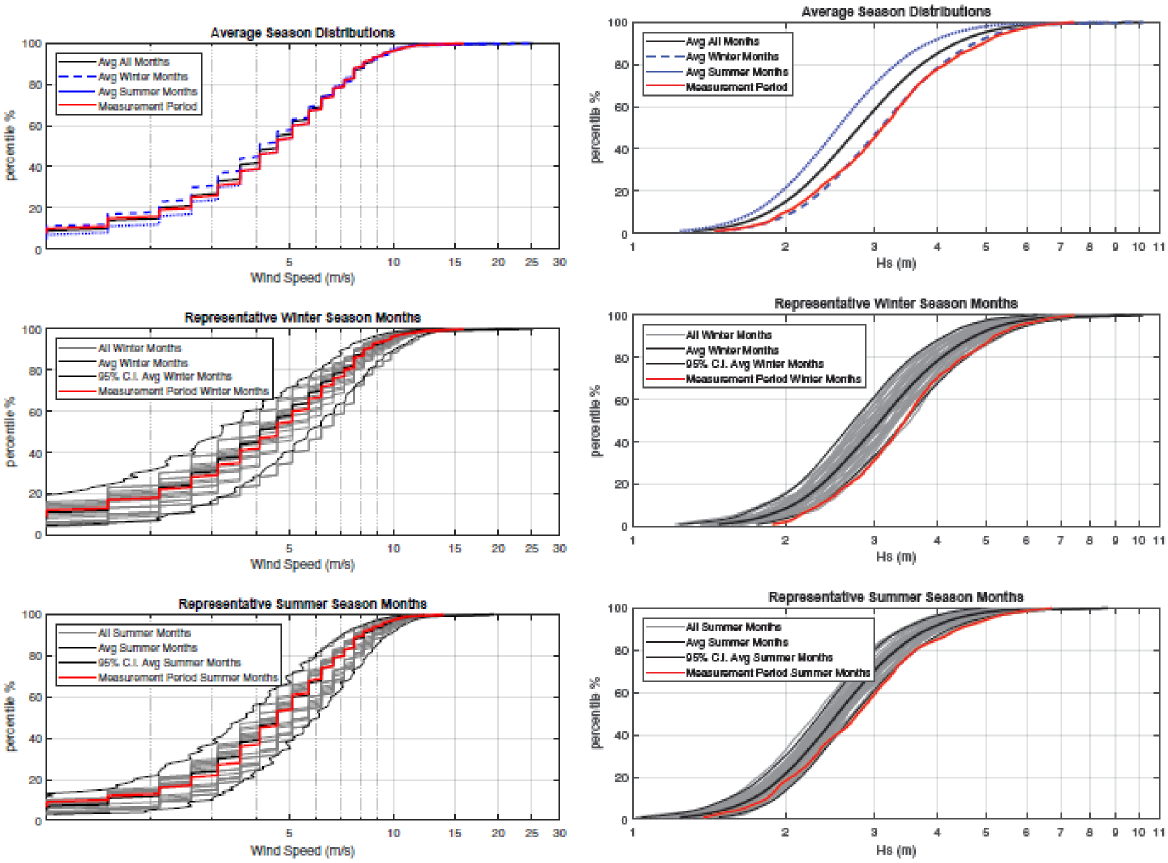


Figure 3.7: Comparison of the Statistics for Wind Speed (left) and Wave Height (right) of the metocean measurement period to the longer-term climates.

This analysis identifies that the meteocean data collection period was a reasonably representative period of the average wind climate, while at the upper limit of the long-term wave climate. The measurement period is well suited to be utilised for scenario modelling within this assessment, as it will reasonably replicate typical ambient conditions within Rivoli Bay and present a conservative (worst case) period of wave activity and associated estimates of sediment transport.

4. Hydrodynamic, Wave and Sediment Transport Models

A key deliverable of the study is to develop a base numerical model of Rivoli Bay that can be used to quantify coastal processes at the townships of Southend and Beachport and provide a basis for the assessment of coastal infrastructure and management options.

The range of processes that drive shoreline dynamics within Rivoli Bay are complex and no single numerical model is capable of replicating all relevant processes. As such, a suite of numerical models has been established. This section describes the development and calibration of regional and local scale hydrodynamic and wave models, targeted on reproducing the regional circulation and nearshore processes, and provides an introduction to the shoreline process model system.

4.1 Modelling Approach

The modelling scope has adopted a scenario-based approach. Such a modelling approach is selected to optimise the model run times, as continuous modelling of environmental conditions over the full or multiple years would be impractical due to the long run times of the complex process-based model systems. The outcomes from short model simulation periods can be scaled to infer longer-term impacts. Both seasonal and extreme modelling cases were established based on the long-term climate statistics, presented in Section 3.

4.2 Modelling Software

To model hydrodynamics and waves within Rivoli Bay, coupled Hydrodynamic (Delft3D) and Spectral Wave (SWAN) models have been established. Delft3D (Deltares, 2019) is an industry standard integrated modelling suite developed at Delft University of Technology in the Netherlands. The model system simulates two-dimensional (in either the horizontal or a vertical plane) and three-dimensional flow, sediment transport and morphology, waves, water quality, and ecology and can handle the interactions between these processes.

The Delft3D-FLOW module is used to simulate hydrodynamics under general tidal and meteorological forcing within the model domain. Delft3D-FLOW is a multi-dimensional (2D or 3D) hydrodynamic (and transport) simulation program which calculates non-steady flow and transport phenomena that result from tidal and meteorological forcing on a rectilinear or a curvilinear, boundary fitted grid.

Review of available metocean data suggests that at times, offshore wave conditions will influence circulations within Rivoli Bay and as such, wave conditions will be added to the simulations using the Delft3D-WAVE module. This allows direct coupling of the forces that are imparted on the currents by the wave conditions and vice-versa. The WAVE module utilises the SWAN wave model, a third-generation spectral wave model developed at Delft University of Technology, that computes random, short-crested wind-generated waves in coastal regions and inland waters (Deltares, 2019). SWAN accounts for the following physics:

- Wave propagation in time and space, shoaling, refraction due to current and depth, frequency shifting due to currents and non-stationary depth;
- Wave generation by wind;
- Wave interaction;
- Whitecapping, bottom friction and depth-induced breaking;
- Dissipation due to aquatic vegetation and turbulent flow;
- Wave-induced set-up;

- Transmission through and reflection (specular and diffuse) against obstacles; and
- Diffraction

The Delft3D models allow for dynamic coupling of the wave conditions and hydrodynamics through the full duration of a simulation. The modelling approach is termed 'FLOW-WAVE-FLOW' (FWF) with the water levels in the model evaluated in the hydrodynamic model (FLOW) and the wave conditions separately evaluated in the waves module (WAVE). The key processes affecting water level including radiation stresses are passed across and updated in the hydrodynamic model during the simulation. The FWF process runs continuously through the simulation to update and interchange wave and water level information. The effect of waves on current (via forcing, enhanced turbulence and enhanced bed shear stress) and the effect of flow on waves (via set-up, current refraction and enhanced bottom friction) are accounted for within this coupled modelling approach (Deltares, 2015).

Wind and pressure fields active over the model domains influence the wind growth of waves and wind/pressure setup of the water level in the hydrodynamics. Baird's approach is to update spatial wind and pressure fields every 30 to 60 minutes for ambient and swell dominated conditions, and to align coupling intervals of hydrodynamics and waves with the input forcing.

The following model setups have been established for the Rivoli Bay modelling study:

- Regional scale Coupled Hydrodynamic and Spectral Wave model (Delft3D FWF); and
- Local scale Coupled Hydrodynamic and Spectral Wave model (Delft3D FWF).

The various modelling components are routinely applied by Baird for coastal processes and hazard definition studies at coastal locations. The model setups are presented in the sections below.

4.3 Regional-scale Hydrodynamic and Wave Models

A regional hydrodynamic model was used to simulate shelf-scale hydrodynamic processes and derive boundary conditions for local scale hydrodynamic and shoreline modelling of the Beachport and Southend areas.

The primary function of the regional scale hydrodynamic and wave models is to transfer deepwater tide and offshore wave conditions into Rivoli Bay in order to generate boundary conditions for local scale models. The layout of the regional Delft3D model is shown in Figure 4.1 and summarised as follows:

- The hydrodynamic model setup is established as a Domain Decomposition Delft3D-FLOW model, which allows dynamic two way coupling of structured domains, to maximise the efficiency of the model simulations, with three hydrodynamic grids that increase in resolution from offshore and into Rivoli Bay:
  - 5km Outer Grid - extending 350km offshore and approx. 750km in the along coast direction;
  - 1km Shelf Grid – extending to the 150km offshore and approx. 400km in the along coast direction;
  - 200m Regional Grid – covering the entirety of Rivoli Bay and adjacent offshore areas. Total grid area 70km x 15km.
  - 40m Rivoli Bay Grid – covering Rivoli Bay at high resolution. Total grid area 6km x 17km.
- Tidal boundary conditions at the outer boundary are driven by 14 tidal constituents derived from TOPEX8 (http://volkov.oce.orst.edu/tides/tpxo8_atlas.html, http://volkov.oce.orst.edu/tides/region.html). The tidal constituents are A0, M2, S2, N2, K2, K1, O1, P1, Q1, M4, MS4, MN4, MM and MF.
- The environmental forcing from winds and atmospheric pressure is sourced from measured data at nearby BoM locations;
- A model timestep of 0.25 minutes (15 seconds) is applied.

- The wave model setup adopts a nested grid approach with the model grid layout and resolution replicating the Delft3D-FLOW model, however excluding the 5km Outer Grid.
- Wave conditions applied to the offshore model boundary (1km Shelf Grid) were developed from the available measured wave data sources offshore, notably Cape du Couedic Waverider buoy (Located at 36.07S, 136.62E, 4nm west of Cape du Couedic Light House, Kangaroo Island). Wave conditions are spatially corrected along the offshore boundary from correlation analysis of conditions extracted from the ECMWF ERA 5 wave hindcast.

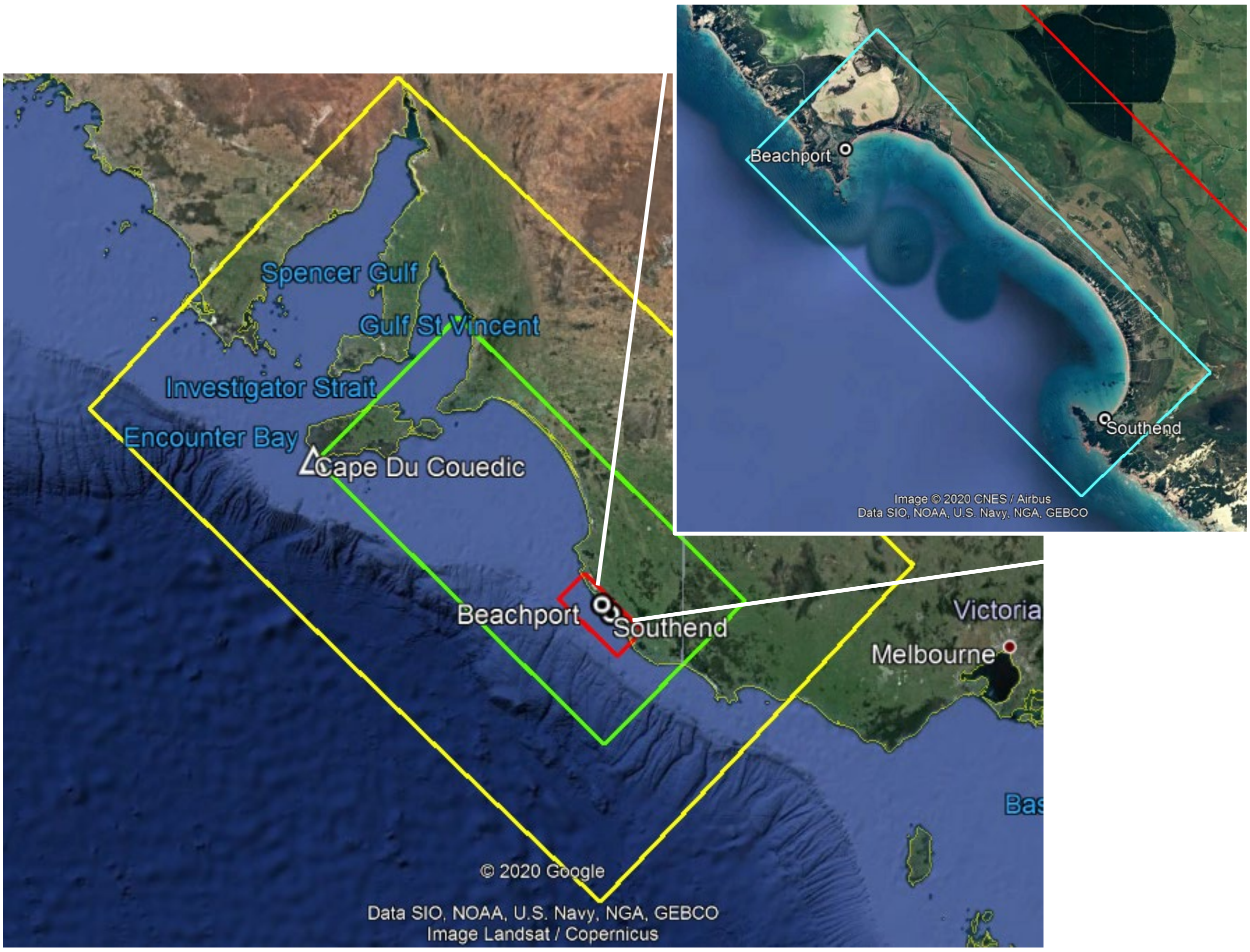


Figure 4.1: Regional Hydrodynamic and Wave Model Grid Setup. 5km Outer Grid (Yellow – Flow Only), 1km Shelf Grid (Green – Flow and Waves), 200m Regional Grid (Red – Flow and Waves) and 40m Rivoli Bay Grid (Blue – Flow and Waves).

4.3.1 Model Validation

Validation of the tidal hydrodynamics and waves was completed for two one-month periods covering the months of August 2019 (Winter) and November\December 2019 (Summer). Comparisons of the modelled water level, currents and waves at the Beachport and Southend ADCP locations for a Winter month are presented in Figure 4.2 to Figure 4.5. The same presentations are provided for a Summer period month, in Figure 4.6 to Figure 4.9.

Water level calibration is good at both sites with high model skill, and low bias and error statistics. Depth averaged currents from the model were adjusted to reflect the 0.6m blanking distance between the seabed and the lowest recorded depth from the ADCP. The resulting comparisons show good agreement for current speed and direction, with the trends and magnitudes reasonably replicated by the model. It is noted that the model does not replicate the high amount of scatter in the measured current speeds which is considered an artefact of the ADCP signal noise at such low current speeds.

Wave conditions are also well replicated by the model, with any discrepancies between measured and modelled timeseries attributable to wave boundary conditions used to force the model.

In summary, the model calibration over the 1-month summer and winter periods show the model provides a good representation of the water level, current and wave conditions for application in the study. It is noted that the 1-month periods selected are generally representative of the longer-term model comparison to measured data over the full term of measured data.

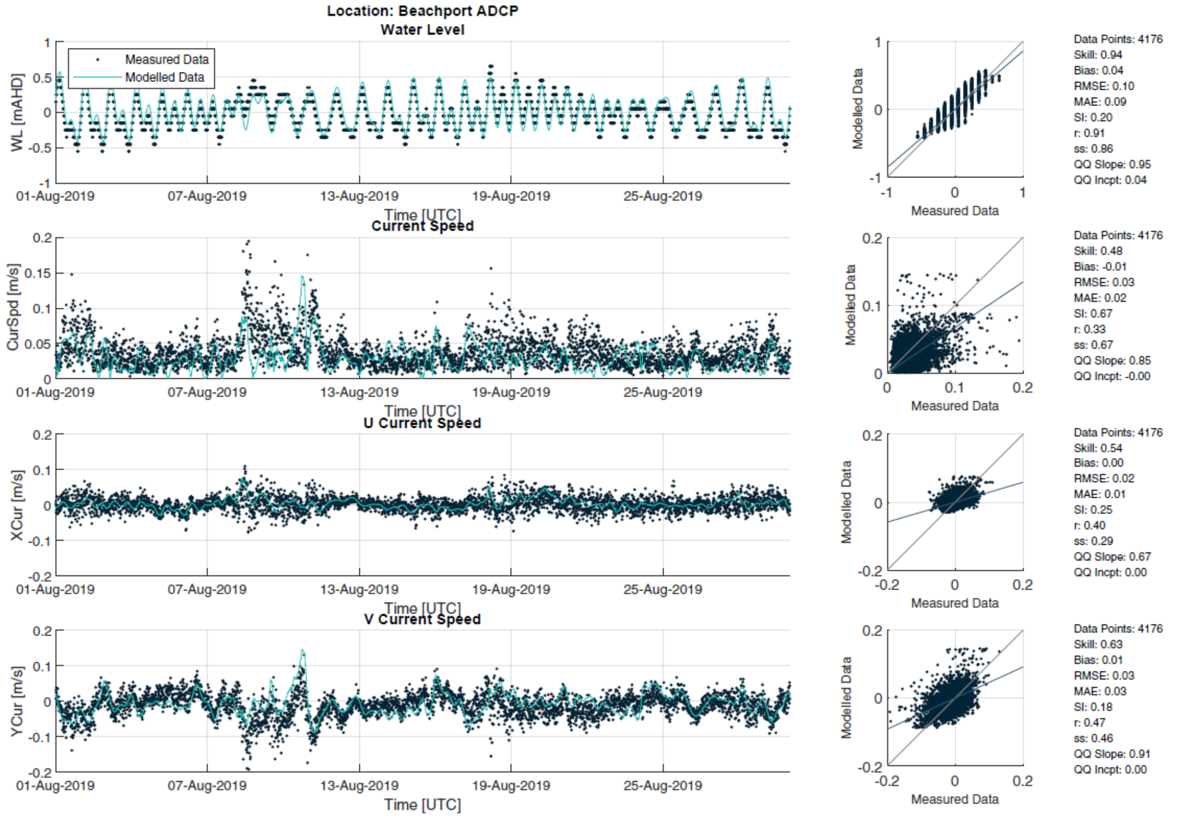


Figure 4.2: Model Validation of Tidal Hydrodynamics at Beachport ADCP. Winter Period (August 2019)

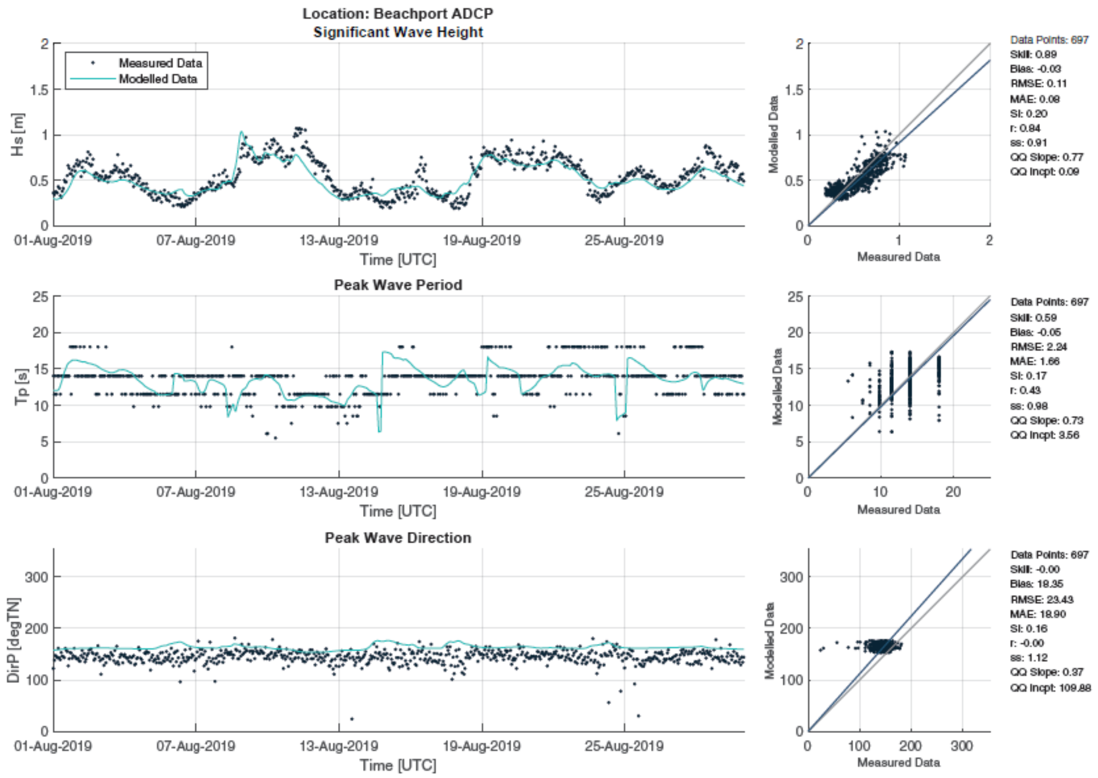


Figure 4.3: Model Validation of Wave Conditions at Beachport ADCP. Winter Period (August 2019)

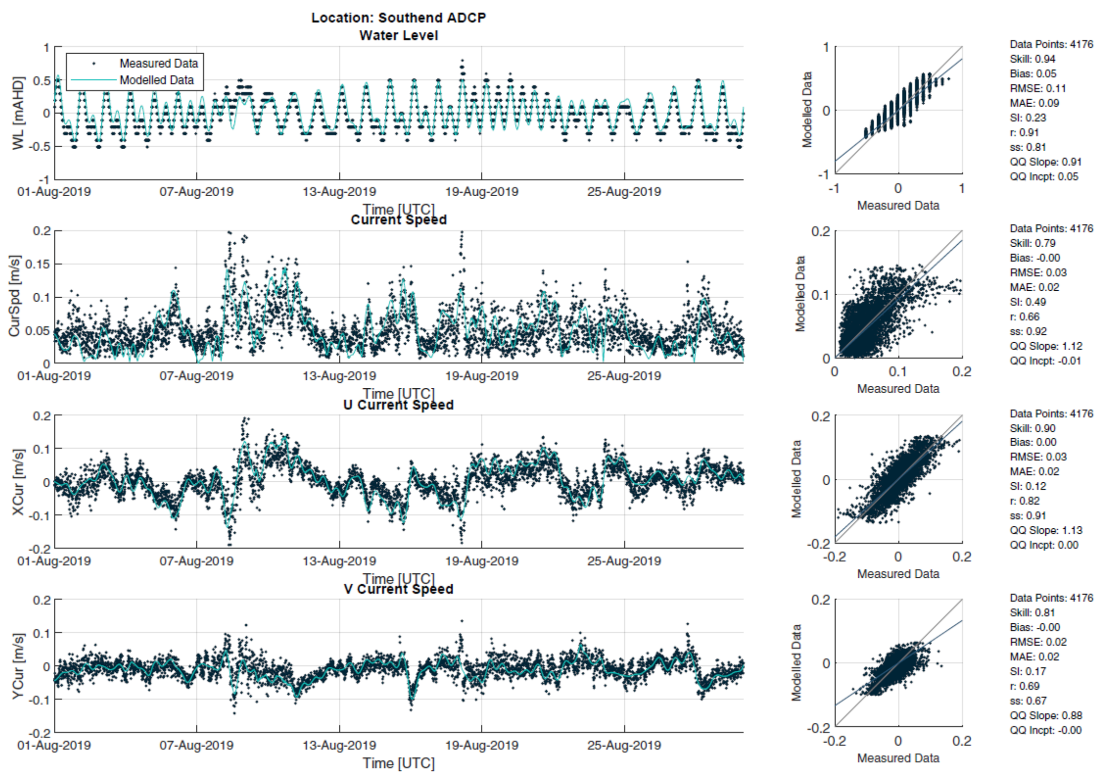


Figure 4.4: Model Validation of Tidal Hydrodynamics at Southend ADCP. Winter Period (August 2019)

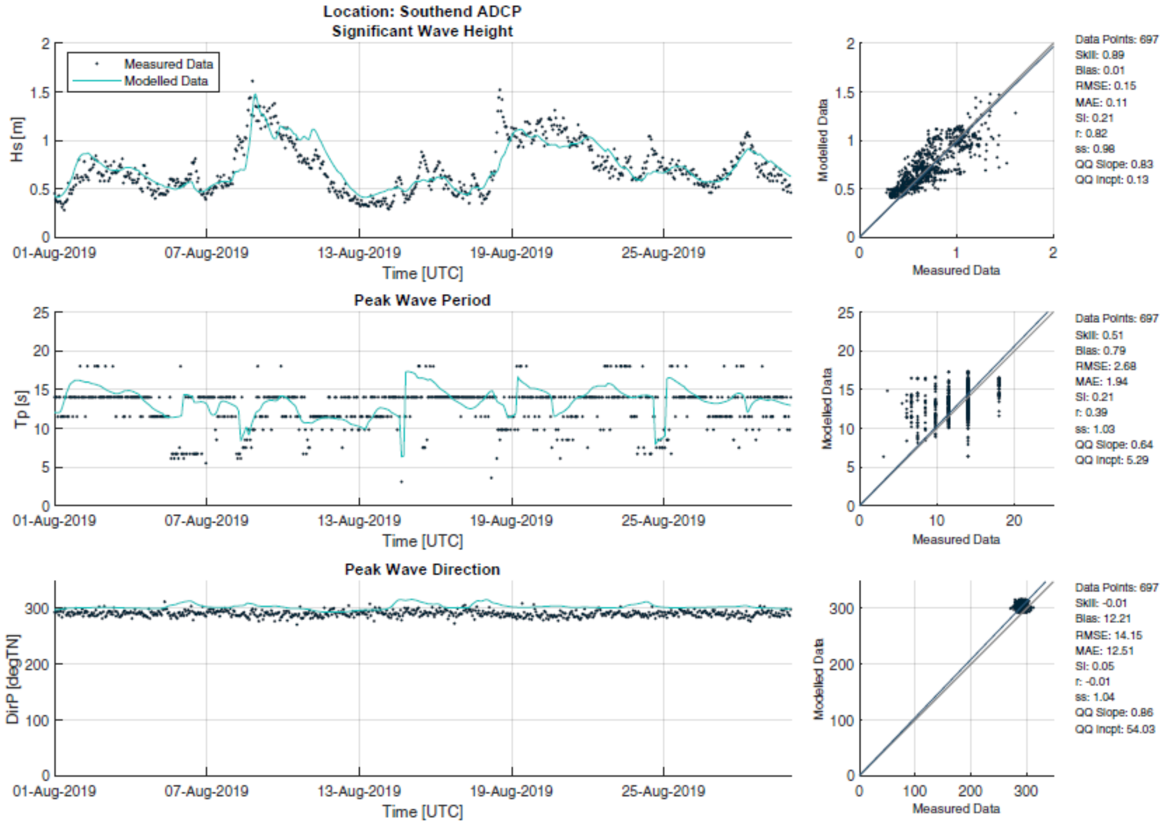


Figure 4.5: Model Validation of Wave Conditions at Southend ADCP. Winter Period (August 2019)

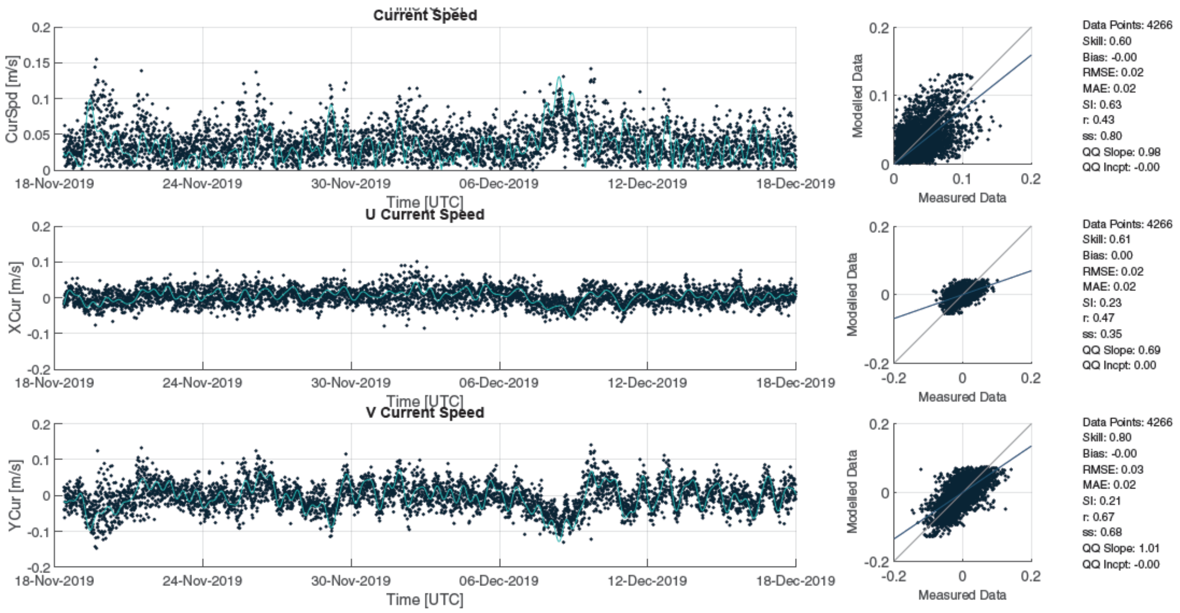


Figure 4.6: Model Validation of Tidal Hydrodynamics at Beachport ADCP. Summer Period (Nov-Dec 2019)

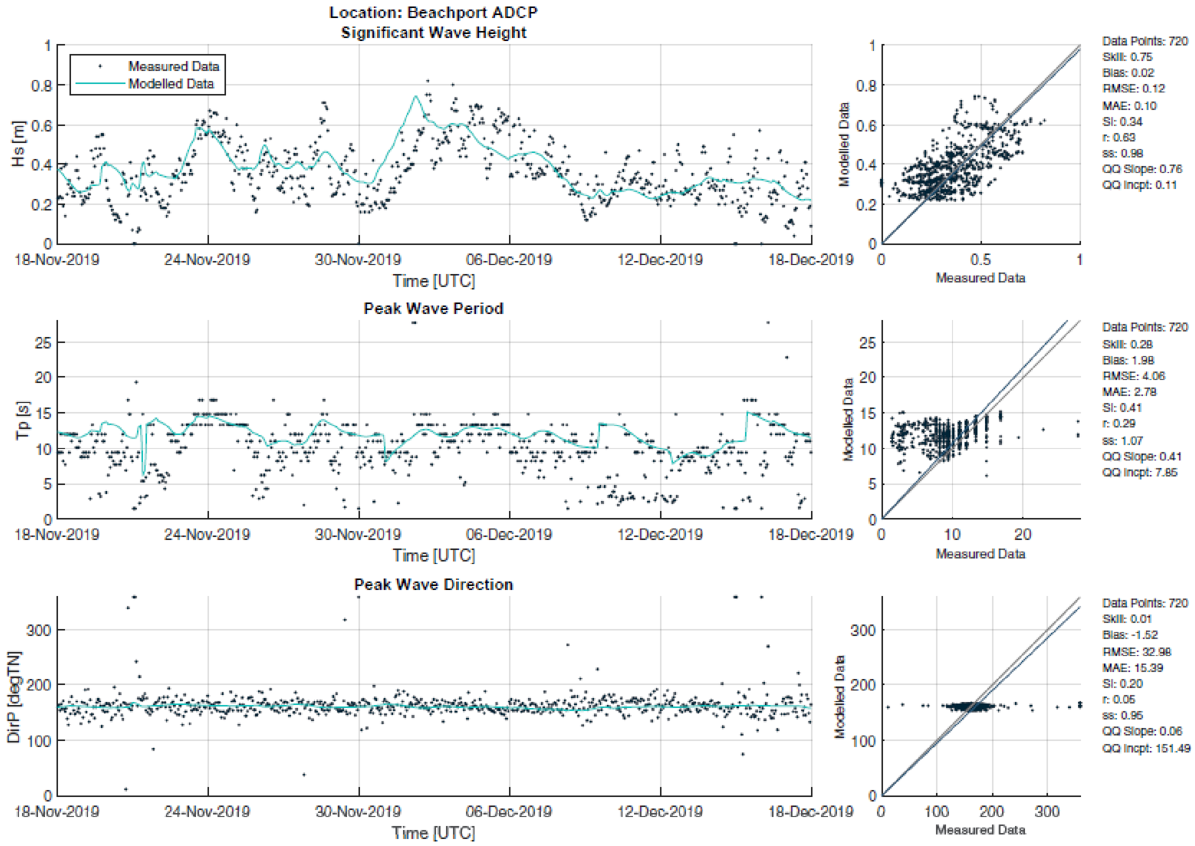


Figure 4.7: Model Validation of Wave Conditions at Beachport ADCP. Summer Period (Nov-Dec 2019)

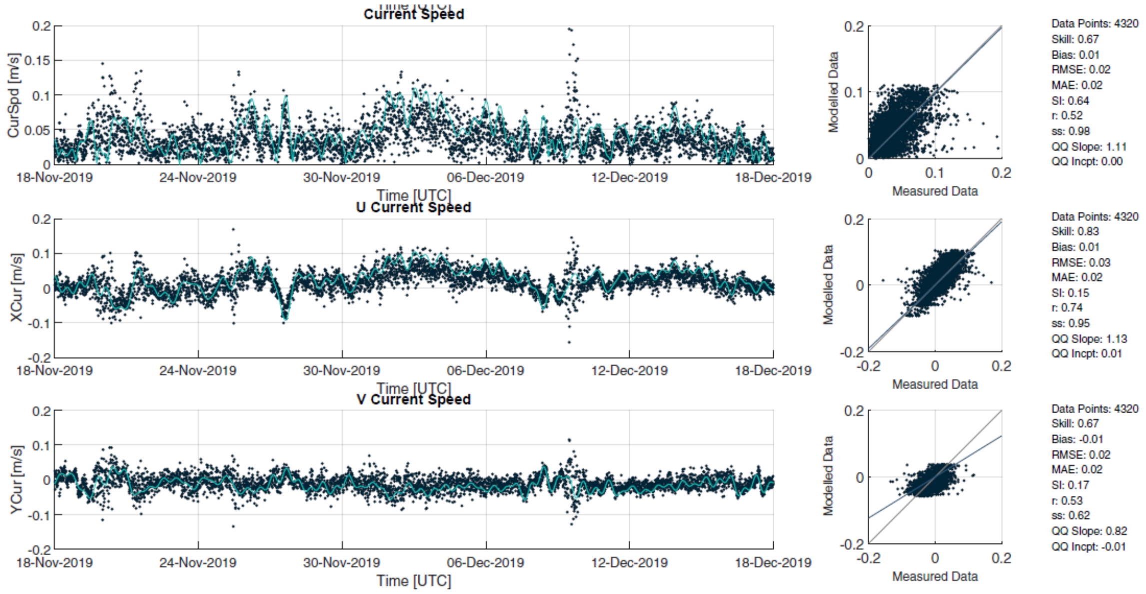


Figure 4.8: Model Validation of Tidal Hydrodynamics at Southend ADCP. Summer Period (Nov-Dec 2019)

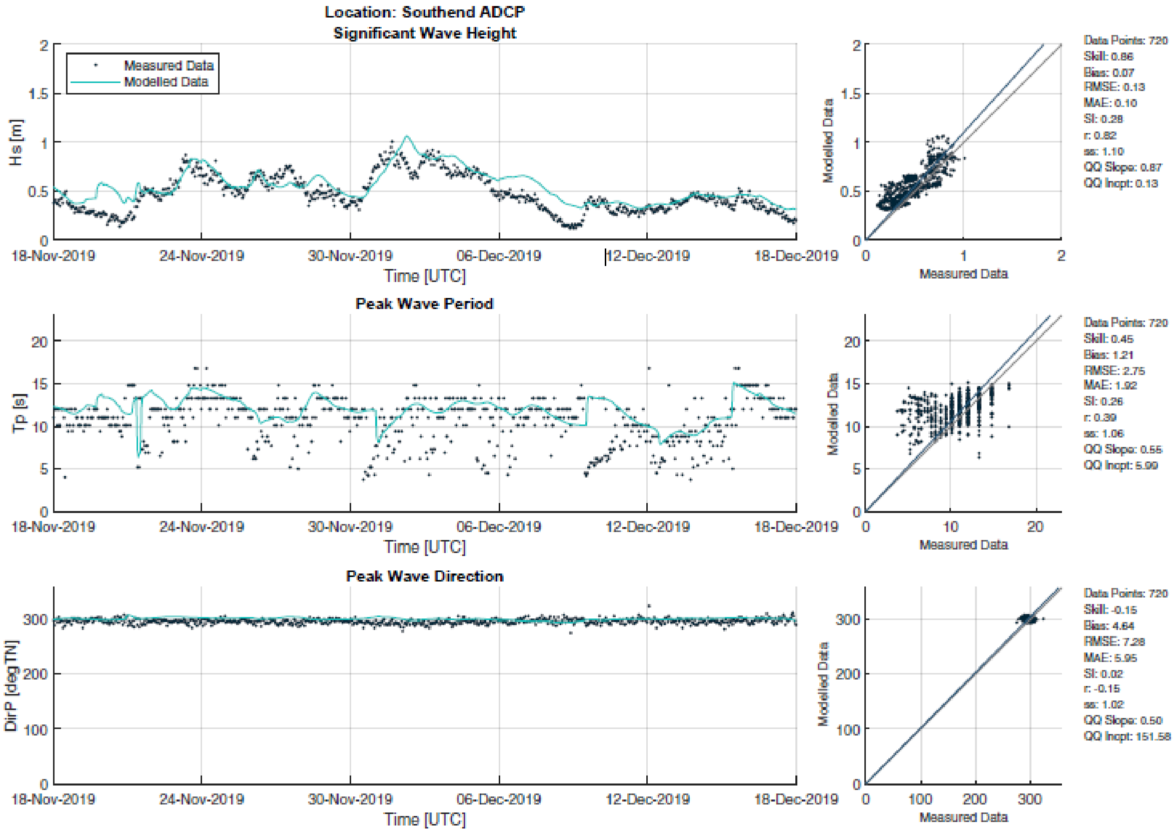


Figure 4.9: Model Validation of Wave Conditions at Southend ADCP. Summer Period (Nov-Dec 2019)

4.4 Local Scale Hydrodynamic and Wave Model

The regional scale model provides adequate resolution within Rivoli Bay to derive boundary conditions for shoreline modelling, however, is too coarse for consideration of dynamics in and around the Beachport boat ramp. To accurately model the joint occurrence and interaction of water levels and waves in the vicinity of the boat ramp, a separate local scale Delft3D model of the Beachport coast has been established. The local scale model is forced with offshore boundary conditions derived from the regional scale hydrodynamic and wave models presented above.

A key addition to the model setup described for the regional models is the use of the wave surface roller model in Delft3D, which has been demonstrated to provide an improved description of surf zone currents (Luijendijk et. al., 2017), critical for the description of sediment transport processes in the vicinity of the Beachport and southern groyne fields and the Beachport boat ramp. The Roller model incorporates the effect of breaker delay due to the presence of the surface roller, which is a phenomenon that occurs when waves break in the nearshore. The presence of the roller results in a non-zero fraction of broken waves farther into the surf zone than without the roller which acts to enhance onshore sediment transport and shifts the peak of the cross-shore distribution of the longshore current. Further the Roller model allows for the explicit hydrodynamic simulation of long waves associated with surface wave grouping.

The layout used in the local scale Delft3D models for Beachport is shown in Figure 4.10. The domain has been established with sufficient resolution to define the key transport processes along the foreshore and Beachport boat ramp areas, with the following settings:

- Spatial grid resolution of 5m;

- Model depths based on available bathymetric and topographic datasets with priority given to the more recent and high-resolution data, most notably the Multibeam Bathymetry datasets collected in 2012;
- Hydrodynamic boundary conditions derived from the regional models;
- The environmental forcing from winds and atmospheric pressure sourced from measured data at nearby BoM locations;
- A model timestep of 0.05 minutes (3 seconds).

Figure 4.10: Extent of the Local Beachport Delft3D domain

4.4.1 Hydrodynamic Validation

There is limited available data for validation of the local scale Delft3D model, given the Beachport ADCP location is close to the applied boundary conditions. Of particular interest is the ability of the local scale model to replicate the littoral current that has been observed to run along the boat ramp breakwater. Following retrieval of the ADCP instruments, roving ADCP measurements transects were taken along transects roughly perpendicular to the beach at Beachport and Southend shorelines. The ADCP transects, collected on the 8 Jan 2020 provide a snapshot of the nearshore current structures present at that time (see Appendix A, Section 6.4).

The local scale Delft3D model was applied to simulate the 8 January 2020 conditions and compare the current structures along the same ADCP transects from the models. A longwave equal to 35% of the surface short waves, consistent with the data interpretation in Section 3.2.1, was applied to the offshore boundary via the Roller model to replicate the bounded and unbounded long wave energy present at the site.

Figure 4.11 provides a snapshot of the steady longshore current that is established in the model. This replicates the observations from site of a current running along the boat ramp breakwater. The alongshore current is relatively localised and dissipates once past the breakwater head, and the current magnitudes are sufficient to both initiate and maintain sediment transport along the extent of the breakwater.

To benchmark the model outcome, comparison against the ADCP transect data was made. Data from Transect 0 (see Appendix A, Figure 6.20) extends across a 600m long profile starting in the vicinity of the boat ramp entrance and is overplotted in Figure 4.11. Of note on that transect is the relatively strong northerly current (0.2m/s) that is measured towards the start of the transect and then a reversal of the flow over the rest of the Transect with current speeds <= 0.1m/s in the southerly direction. The numerical model replicates these features reasonably well and is considered suitably reliable for the options assessment.

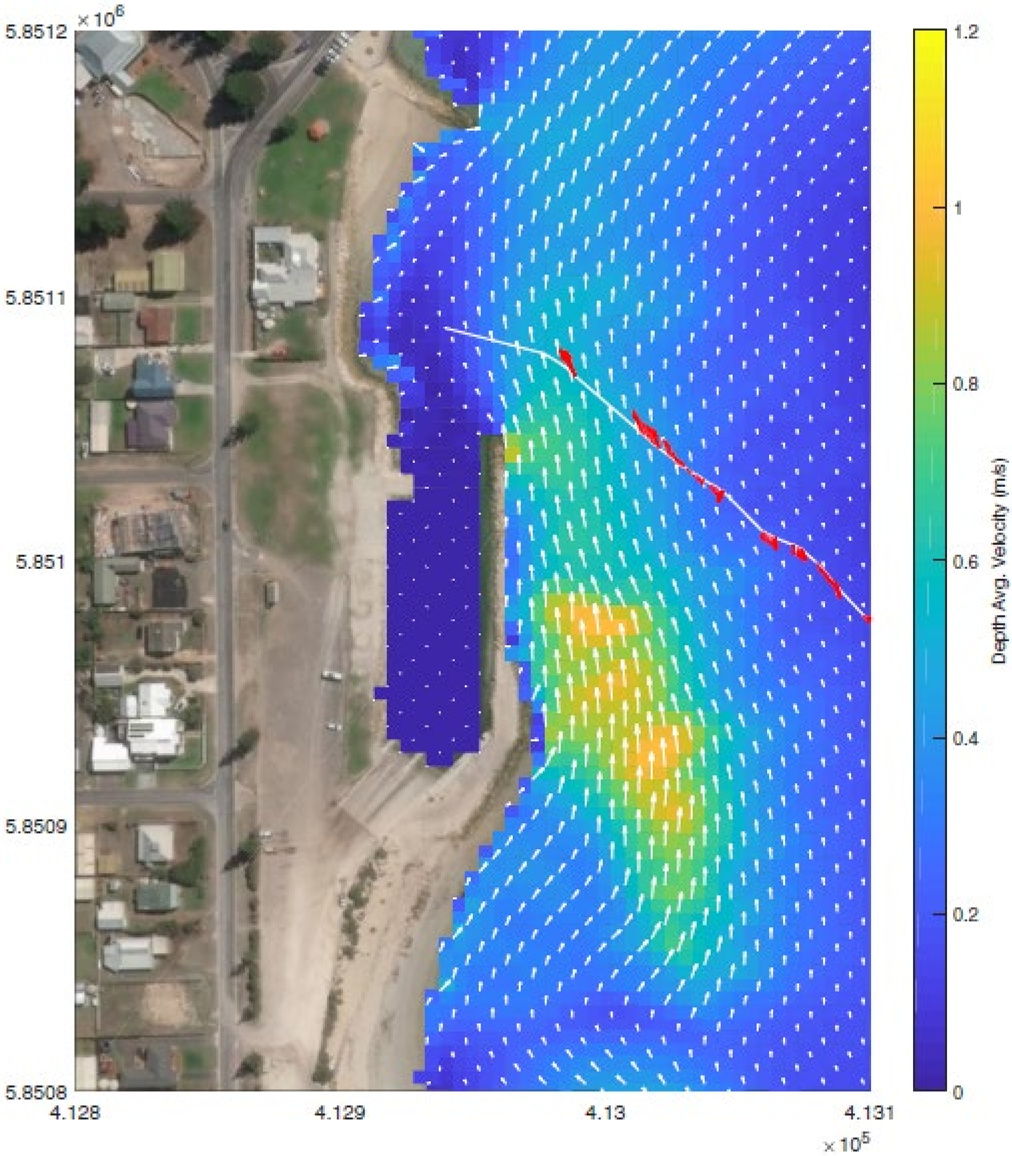


Figure 4.11: Depth averaged current map from the Delft3D-FWF model. White line is the vessel transect path (ADCP Transect 0). Red vectors are the available depth averaged current measurements.

4.5 Shoreline Process Models

A limitation of 2D hydrodynamic models such Delft3D, is the ability to accurately replicate sediment processes at the shoreline. As such, potential longshore transport rates have been modelled using specific shoreline sediment transport models:

- Beachport foreshore: The updrift side of the groynes along the Beachport foreshore are at capacity, suggesting the offshore extent of the groynes are sufficient in trapping longshore transport and maintaining adequate beach width. A key unknown is whether there exists a differential in transport rates along the foreshore that may be contributing to the eroded beach width observed in some locations. To assess this the Kamphuis longshore transport model was applied. The underlying equation of the Kamphuis model (Kamphuis, 1991) is based on dimensional analysis and calibration using laboratory and field data. The model is based on the principle that the longshore transport rate (LST, incl. bed load and suspended load) is proportional to longshore wave power per unit length of beach and includes the effects of particle diameter and bed slope (van Rijn, 2002).
- Southend shoreline: At Southend, the trapping efficiency of the groynes appear to be a product of their length. As such the cross-shore distribution of longshore transport and the potential for dominant cross-shore transport are of interest and have been modelled using the COSMOS model. The COSMOS model is a 2DV model of nearshore hydrodynamics, sediment transport and seabed evolution (morphodynamics). It can be run in a number of modes, including as a profile based numerical model that provides a deterministic description of the littoral drift and cross-shore profile changes under ambient and storm conditions. It has been widely used to simulate the longshore transport potential of beach profiles and is a model that is internally developed and maintained by Baird.

  In profile mode, COSMOS simulates the cross-shore distribution of the wave height, setup and longshore current at a single profile, providing a detailed description of the longshore sediment transport distribution based on the profile bathymetry. The model accounts for irregular waves, water levels, tidal currents, wind stresses, bottom friction, wave refraction and shoaling, wave breaking and non-uniform sediment distributions.

It is noted that both the Kamphuis and COSMOS models are forced with boundary conditions derived from the regional Delft3D model. In this way, the influence of any proposed management option on the incident wave and hydrodynamics can be captured and fed into the shoreline models where appropriate.

4.6 Shoreline Position Model

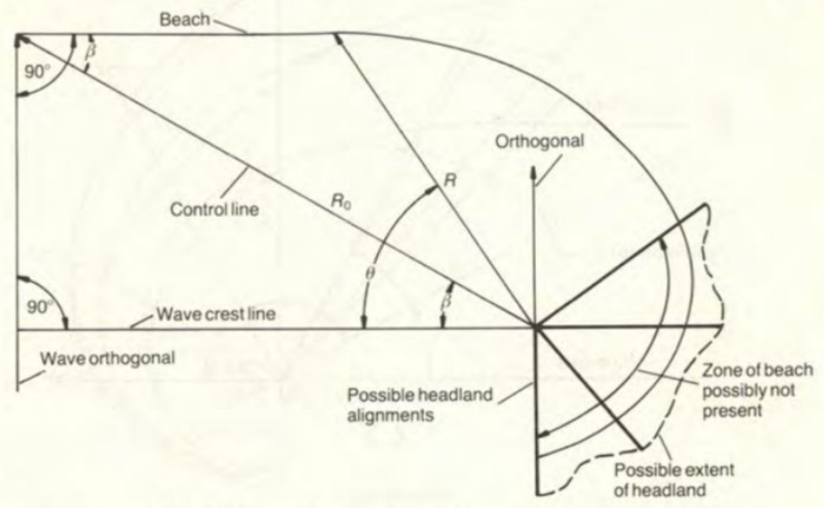
The parabolic beach shape equation (PBSE) is a widely used model for assessing the expected static equilibrium shape of a beach between two controlling points (e.g. hard structures). This method was first investigated and applied by Evans and Hsu (1989), with subsequent application of the method remaining largely the same, when used at beaches under the same conditions (e.g. sandy beaches with swell incident at the beach from a narrow directional band), a small tidal range with longshore sediment movement largely affected by swell energy, and storm waves mostly responsible for cross shore sediment movement (Evans and Hsu, 1989). In line with these conditions, it is assumed that the mapped beach shape is the shape under prevailing ambient conditions, as would occur once sediment transport onto and off of the beach had reached an equilibrium (i.e. the beach shape is governed by the direction of the incident waves, and partially by wave period, rather than the water level or wave height).

The shoreline position model is shown below in Figure 4.12, along with the accompanying definition sketch depicting the parameters that are required inputs to the equation, including:

- R_0 = Control line length
- β = Wave obliquity

- C = constants generated by regression analysis to fit the peripheries of the 27 prototypes and model bays
- θ = Angle between wave crest and radius to any point on the bay periphery in static equilibrium (Evans and Hsu, 1989)

$$R/R_0 = C_0 + C_1(\beta/\theta) + C_2(\beta/\theta)^2$$



4.6

Figure 4.12: The parabolic bay shape equation with accompanying definition sketch (Evans and Hsu, 1989)

Limitations of this method that should be considered when assessing resulting mapped shorelines along Beachport Foreshore include:

- The tidal level associated with the resulting mapped shorelines using the model aren't agreed upon, but a conservative assumption is to treat it as the mean water shoreline, with the shoreline associated with higher water levels to sit landward of the mapped shoreline. CIRIA (2020) states that the waterline could also be assumed to be the mean high-water line, but the level of conservatism built into assuming it is the mean water line is better suited to this application.
- A consistent limitation pointed out in the literature is that of the subjectivity of the downcoast control point selection. As outlined in Lausman et al (2006), the visual and manual nature of placement of the control points used in the model can lead to placement of different control point locations between users looking at the same beach, leading to a level of uncertainty inherent in the method. This is also discussed in González et al (2001) and CIRIA (2020).

A key controlling input to the model is the incident wave direction. The incident wave direction has been defined for this study using the calibrated hydrodynamic and wave models along the Beachport shoreline and the Southend shoreline.

5. Beachport Foreshore

For groynes along the Beachport foreshore it is noted that beach compartments are all "full" and each groyne is actively bypassing sediment (Worley Parson, 2015). This observation is supported based on Baird's site inspection (June 2019) and examination of aerial imagery and suggests an ample supply of sediment for alongshore transport across the length of the coastline.

However, little to no beach width exists at the southwestern extent of the beach compartments located between the groynes to the north of the Beachport Jetty. This is a result of the groynes either being too short or the spacing too great for them to compartmentalise the beach effectively.

5.1 Conceptual Sediment Transport Model

The literature review presented in Section 2 identified that the key coastal process along the Beachport shoreline was longshore drift due to wave action that drives sediment transport along the foreshore. From the description of the groyne fields at Beachport and following our own site inspections, this primary driver of sediment transport along the coast is considered valid.

Based on all information at hand the conceptual sediment transport model presented in the Rivoli Bay Study (Worley Parsons, 2015) is considered appropriate in describing the key processes at the site, as shown in Figure 5.1.

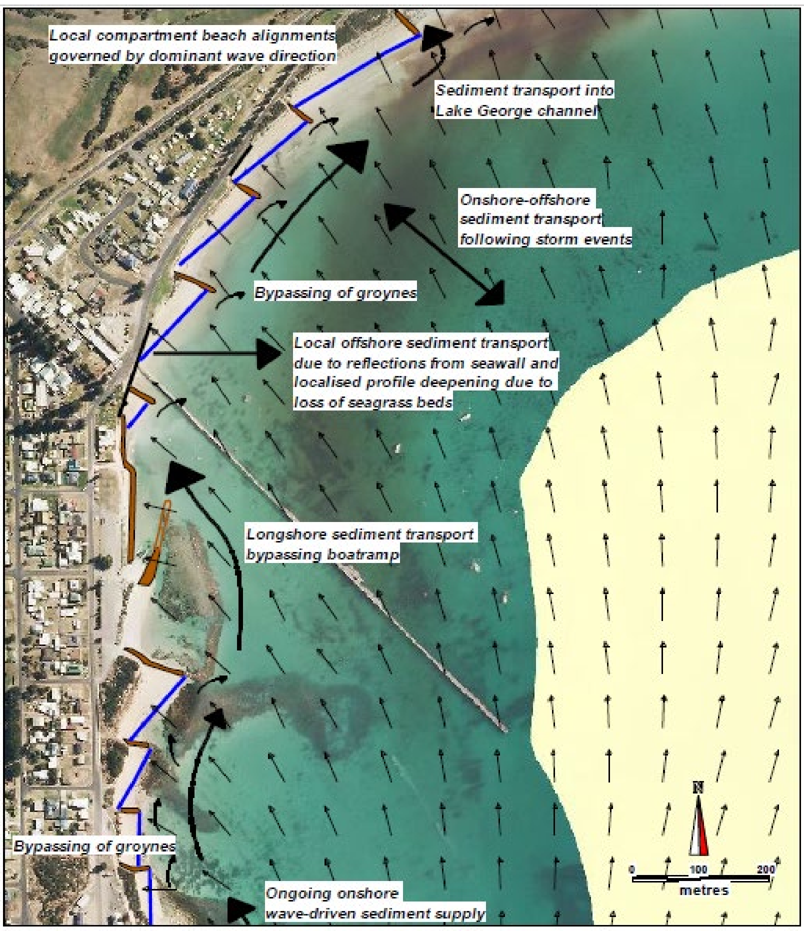


Figure 5.1: Conceptual Sediment Transport model for Beachport Foreshore (reproduced from Worley Parsons, 2015)

5.2 Shoreline Trends

To gain an understanding of the intra-annual variability in beach condition, Baird has developed a dataset of historical shoreline behaviour to supplement other bathymetric and beach profile data, using the CoastSat toolbox (Vos et. al., 2019). CoastSat is an open-source software toolkit that enables time-series of shoreline position to be obtained at any sandy coastline from approximately 30 years of publicly available satellite imagery. The toolkit exploits the capabilities of Google Earth Engine to efficiently retrieve Landsat and Sentinel-2 satellite images. Positional accuracy of the shoreline mapping is dependent on image quality (e.g. resolution and interference from clouds etc.), however has been shown to produce a positional accuracy of less than 10m and as good as 2m (Vos et. al., 2019). While the positional accuracy is not as high as surveyed cross shore profiles the availability of historical satellite imagery provides a far greater temporal resolution of shoreline position that is typically a limitation of surveyed data sets. This allows for the relative shoreline change to be identified on sub weekly timescales with longer term and seasonal trends captured.

A sample of the shorelines extracted at Beachport, 224 in total between 1988 and 2020, is presented in Figure 5.2.

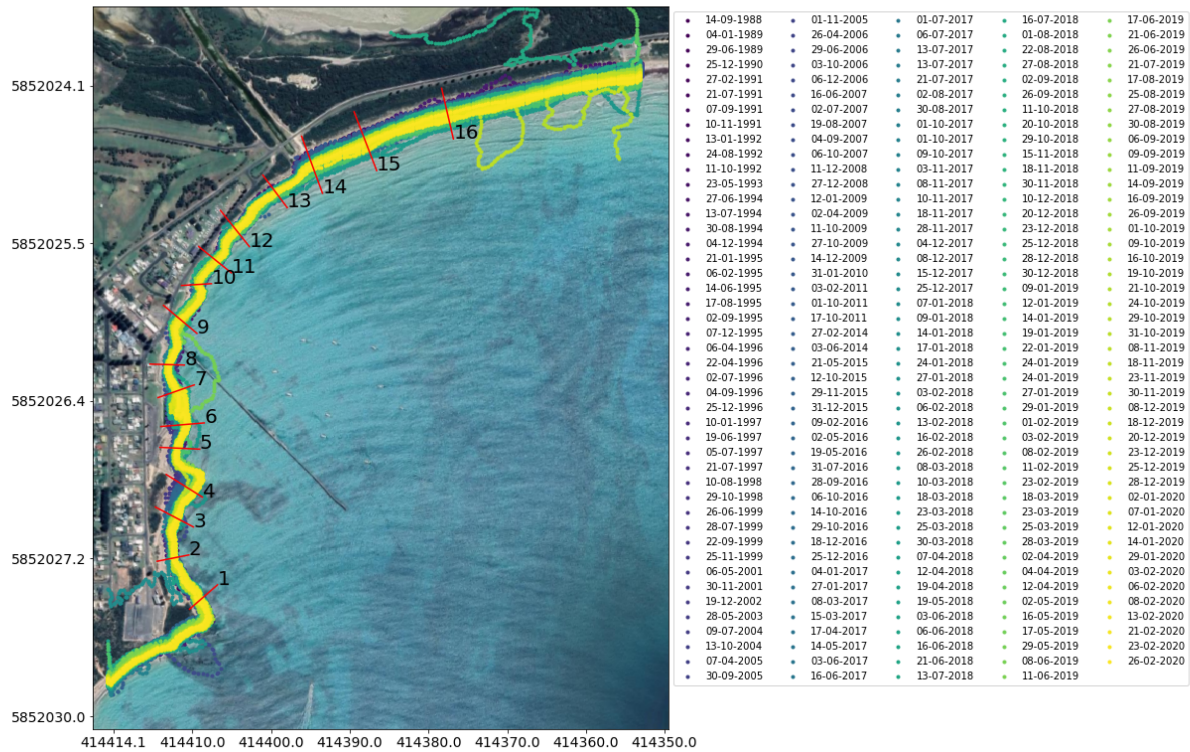


Figure 5.2: Mapped shorelines from the CoastSat Toolbox at Beachport. Shoreline dates range from 1988 (dark blue) to 2020 (yellow).

Figure 5.3 presents the timeseries of shoreline position (beach width) at 16 transects along the Beachport shoreline, as shown in Figure 5.2, for the full period of available data (left plots) and the data rich period of 2015 – 2020 (right plots) for clarity.

No clear long-term trends are observed, with beach width typically varying about a longer-term average. This observation suggests that the Beachport shoreline has an ample supply of sediment. However there appears a step change increase in beach width circa 2015 at a number of transects. This is likely associated with the increased resolution of the satellite imagery from the Sentinel-2 satellite which commenced operation in 2015 and not of a material change in the beach position.

When the post-Sentinal-2 period is considered (2015-2020), a clear annual signal is evident in the timeseries. Most notable at Transects 11 to 16, beach width decreases during the winter months (June to September) and increases during the summer months. The signal is also observed at Transects 4 to 10, however less pronounced due to the smaller relative beach width changes and accuracy of the analysis. This annual signal aligns with the seasonal wave climate where larger wave conditions occur during the winter months and suggests a broader shoreline response to the incident wave climate during the winter months. Again, with beach width recovering during the summer period and no progressive recession identified, there appears sufficient supply of sediment to the beach compartments. The lack of an identifiable long term trend in the shoreline data is consistent with the shoreline analysis presented in the Rivoli Bay study (Worley Parsons, 2015).

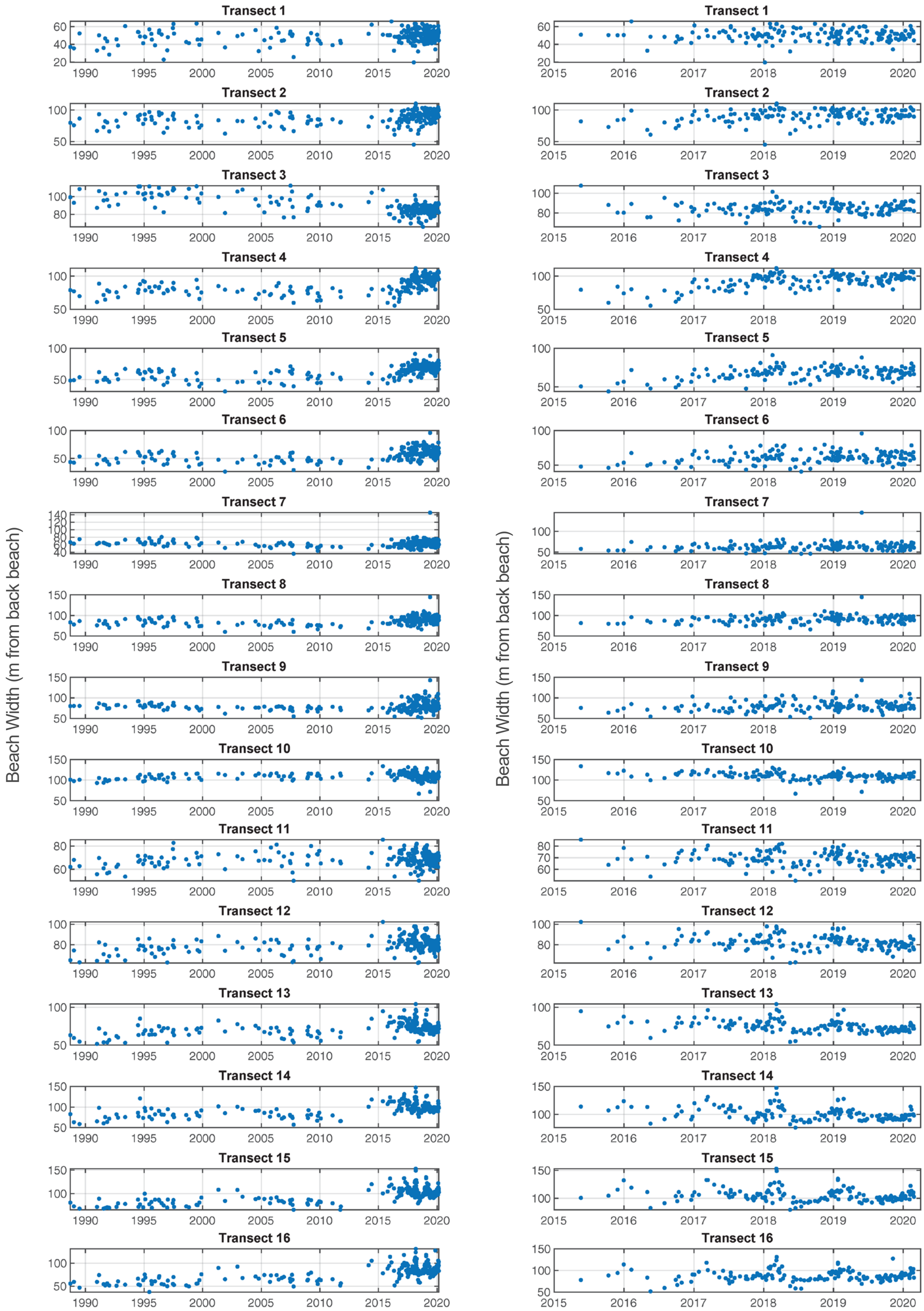


Figure 5.3: Shoreline Position Timeseries for 16 Transects at Beachport (see Figure 6.4). Left side plots show all available data between 1988 and 2020, Right side plots show period between 2015 and 2020.

5.3 Shoreline Process Model at Beachport

A set of profile models along the Beachport foreshore were established within the Kamphuis longshore transport model to identify if any discontinuity in longshore transport rate exists between groyne compartments that may be exacerbating the reduced beach widths that are observed at the southern end of the beach compartments.

Figure 5.4 presents the location of the cross-shore profiles for which shoreline modelling was completed. Each profile is described in the shoreline modelling by the grain size of sands on the beach face, orientation profile and the nearshore slope out to the breaker line, the latter being calculated from analysis of available survey data, with priority given to LiDAR and multibeam datasets. Available sediment data was used to define the sediment distribution adopted in the mode, which was based on the B2, B3, BB1 and BB2 sediment samples (see Section 2.2.7) with D_{50} values between 0.3 and 0.4mm.

The full duration of the measured data record, June to December 2019, was simulated to provide an estimate of the longshore transport potential. Boundary wave conditions were first simulated with the regional scale numerical model over this period to capture the difference in relative exposure, in terms of wave height and change in incident wave direction, of each beach compartment.

A summary of the cumulative potential longshore transport volumes at the five profiles is presented in Figure 5.5. Note that the cumulative volumes are potential transport volumes and assume an infinite sediment supply and alongshore uniformity of the shoreline. Given that the beach compartments are at capacity, this is considered a valid assumption.

The results indicate that longshore transport is primarily driven by episodic storm conditions. Wave directions along the Beachport shoreline remain relatively consistent over the simulation period and hence the longshore transport is a function of elevated wave heights within the northern embayment of Rivoli Bay.

Further, differences in the longshore transport potential between beach compartments shows the rate reduces going northward from XS0 to XS4, though the overall difference is minor with the model estimating rates within 10%. This outcome is considered within the range of model uncertainty and therefore it is unlikely that an alongshore differential in transport potential is significantly contributing to the shoreline position along this section of Rivoli Bay coast.

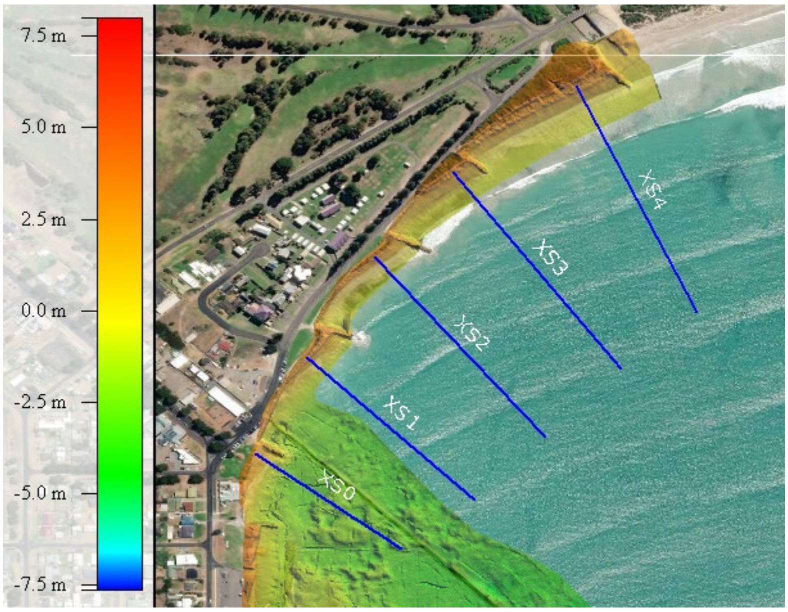


Figure 5.4: Cross shore profile locations for the shoreline process modelling at Beachport

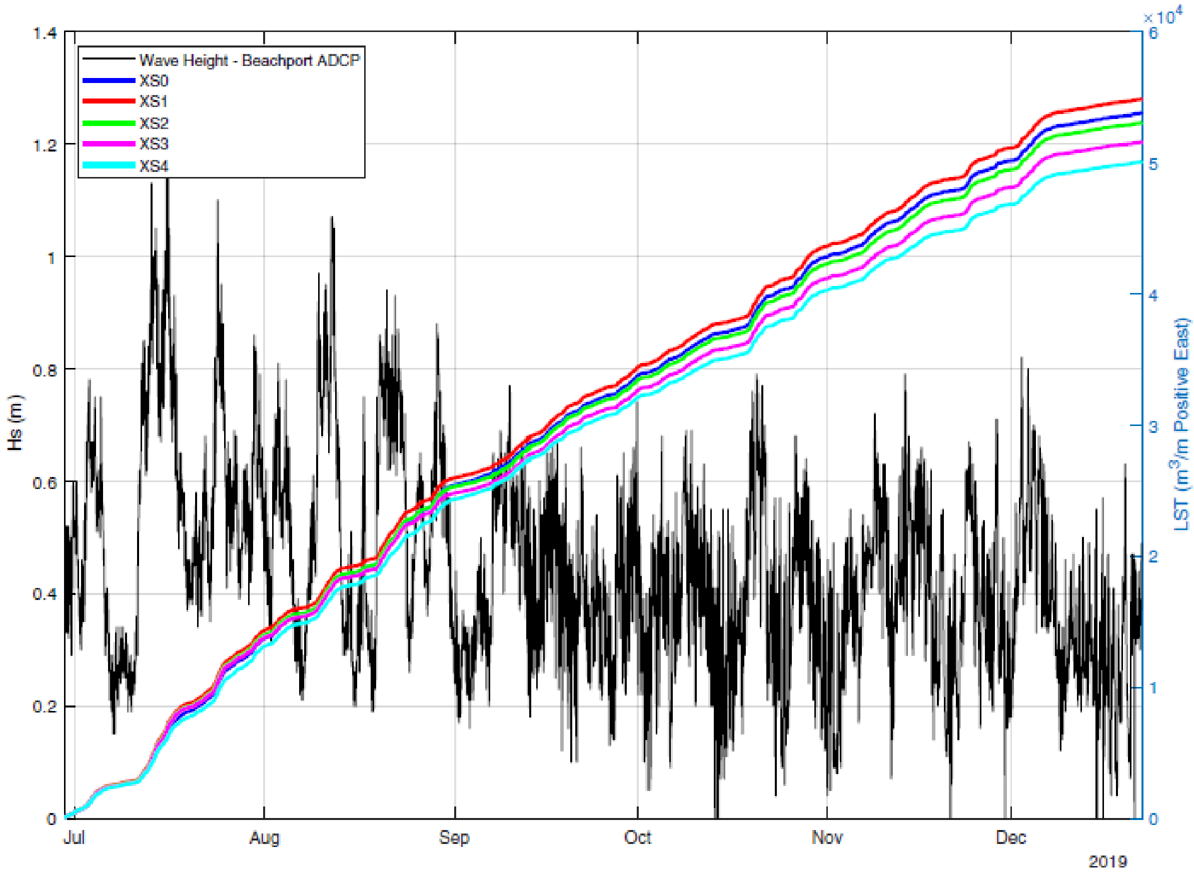


Figure 5.5: Cumulative Potential Longshore Transport Volumes over the duration of the measured dataset at Beachport.

5.4 Seasonal Conditions at Beachport

A required input to the shoreline position model is the direction of the prevailing swell waves (input to the PBSE as the wave crest line as shown in Figure 4.12). Baird's Delft3D model for the Beachport Foreshore has been run over Summer and Winter periods to determine the prevailing wave direction affecting Beachport beaches across these seasons. The conditions experienced during Summer are shown in the spatial plot from the 27th of November 2019 in Figure 5.6, and timeseries plots across the full modelled summer period in Figure 5.7. The timeseries plots are taken from the location shown in Figure 5.6, being a location representative of the incoming wave direction at Beach Compartment 8, with the spatial plot in Figure 5.6 being representative of the average conditions over the modelled period.

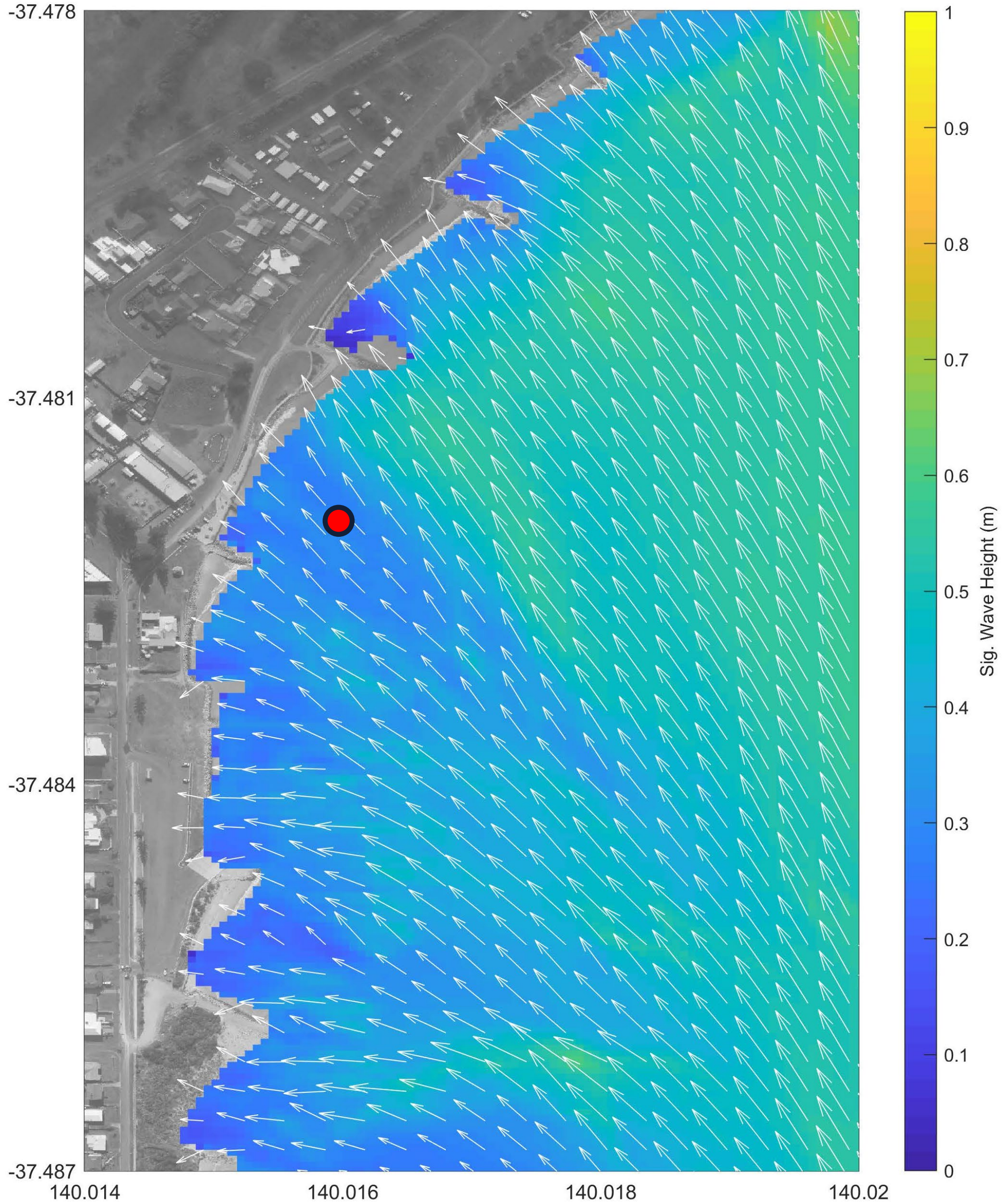


Figure 5.6: Spatial plot of wave height and direction at Beachport Beach 8 on the 27th of November 2019 at 10am (summer condition). Red point indicated location of timeseries data in Figure 5.7.

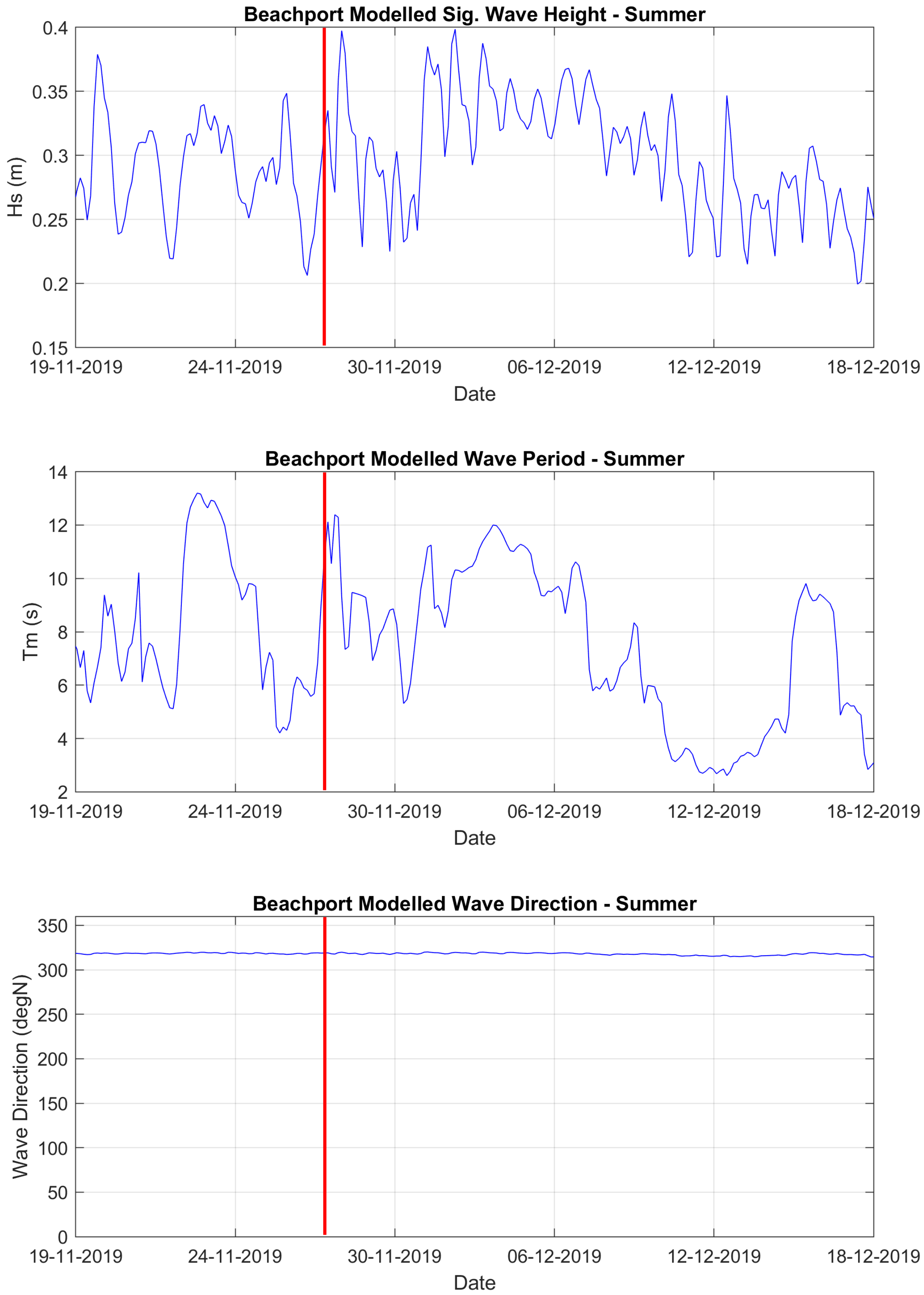


Figure 5.7: Timeseries wave conditions (Location shown in Figure 5.6) under summer conditions. Red time mark indicates timestep plotted in Figure 5.6.

The conditions experienced during Winter are shown in the spatial plot from the 12th of August 2019 in Figure 5.8, and timeseries plot across the full modelled winter period in Figure 5.9. The timeseries plots are taken from the location shown in Figure 5.8; being a location representative of the incoming wave direction at Beach Compartment 8, with the spatial plot in Figure 5.8 being representative of the average conditions over the modelled period.

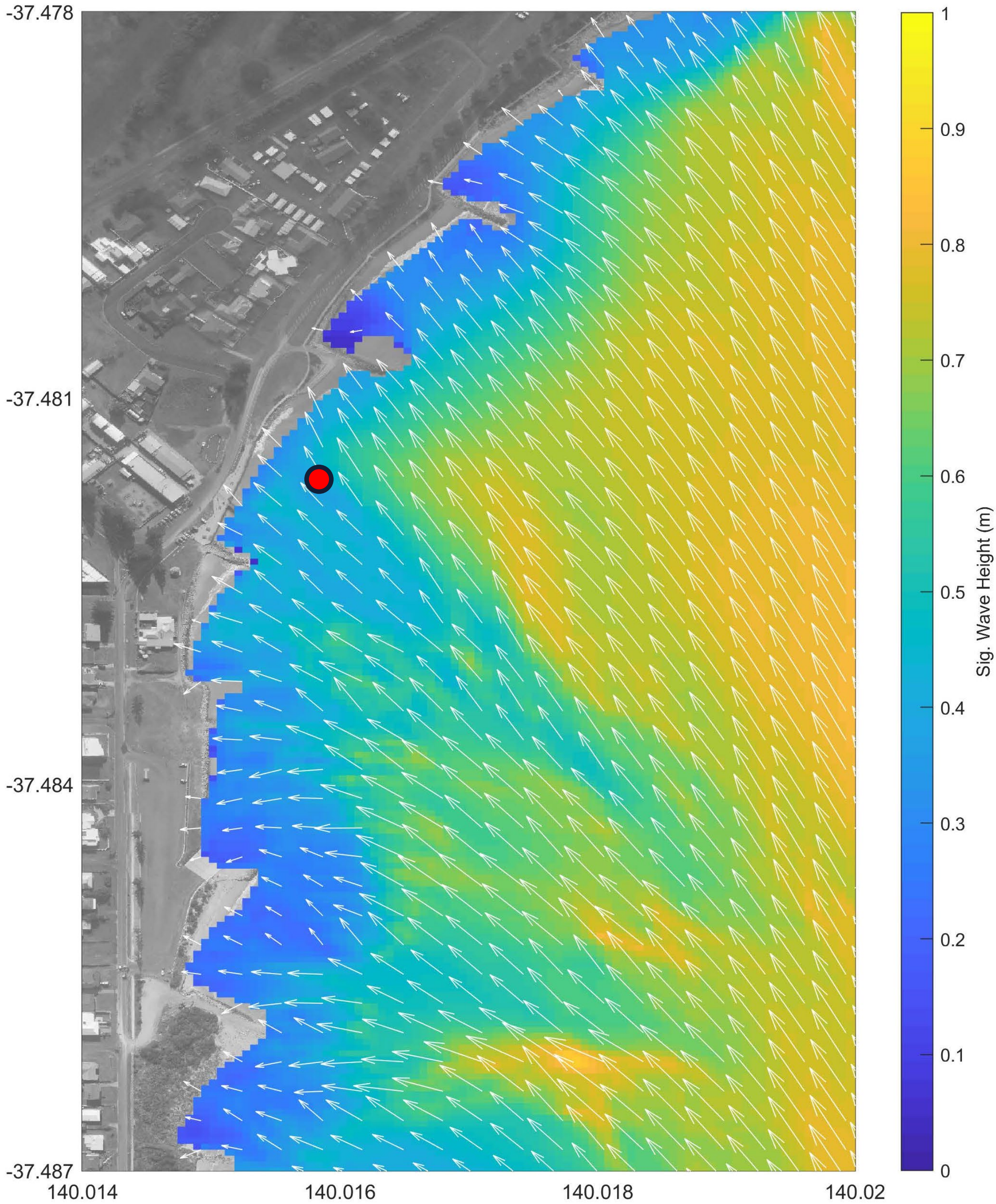


Figure 5.8: Spatial plot of wave height and direction at Beachport Beach 8 on the 12th[th] of August 2019 at 7am (winter condition). Red point indicated location of timeseries data in Figure 5.9.

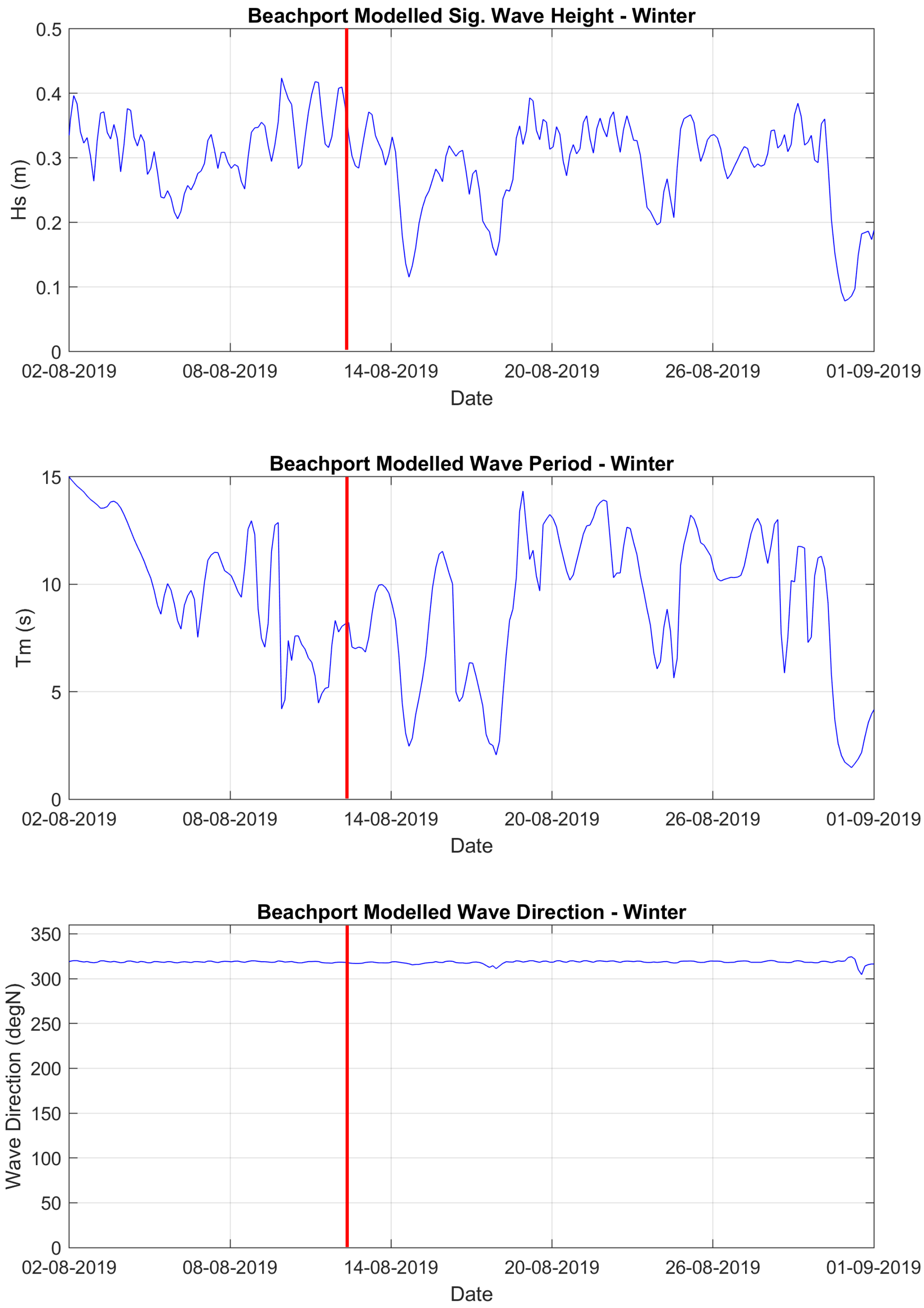


Figure 5.9: Timeseries wave conditions (Location shown in Figure 5.8) under winter conditions. Red time mark indicates timestep plotted in Figure 5.8.

5.5 Potential Mitigation Options

Each beach compartment along the Beachport foreshore appears consistently at capacity, based on available historical imagery, with the beach width and orientation aligning with the length of the groynes and incident wave directions. However, there are areas where severely reduced beach width at the south-western portion of the beach compartment is a cause for concern for adjacent infrastructure. These outcomes suggest there is ample sediment supply travelling north along the coastline but there is a misalignment between the beach compartment orientations and the adjacent foreshore. As such, maintaining adequate beach width is a function of coastal structure layout along this heavily engineered coastline.

Identification of the existing groyne and beach compartments follows the numbering laid out in (2017), as presented in Figure 5.10. It is noted from the literature review (Baird, 2020b), discussions with Council and site visits by Baird that beach compartments south of the Beachport boat ramp (Beaches 1 to 5), are generally stable and at or near capacity, with accumulated sediments from Beach 4 being used for sand nourishment at more northern beaches as part of the Sand Management Plan for Beachport Town Beaches (WRC, 2017). Wind blown sand from southern beaches that are at capacity is also an issue that is currently managed as part of the Sand Management Plan.

Figure 5.10: Numbering of Beaches and Groynes at Beachport (WRC, 2017)

A key issue identified from the literature review is the lack of beach width in beach compartment 8, in the vicinity of the vertical timber seawall. Proposed management options to address this have included the lengthening of existing groynes (Groyne 9), the addition of another groyne in beach compartment 8 and the construction of a sloped revetment in front of the vertical seawall. The latter is not considered an effective option for promoting and maintaining beach width in this location in and of itself, predominantly due to its alignment to incoming waves. Modifications to the existing groyne field will therefore be assessed based on detailed analysis of the shoreline processes.

Proposed options, aimed at restoring beach widths at the southwestern end of the beach compartments, are:

- **Placement of an Additional Groyne in Beach Compartment 8 (Option B1)**. The addition of a groyne north of the jetty would promote the retention of a beach volume in front of the vertical timber seawall. The length, orientation and profile of a new groyne structure can be optimised based the shoreline processes defined in the modelling and estimates made of the future shoreline position.
- **Modification to the Existing Groyne 8 (Option B2)**. The shoreline alignment within Beach Compartment 8 is at least in part a function of the size, length and orientation of Groyne 8. Changes to the footprint of the groyne can be assessed based on the incident waves to estimate the future shoreline position under various reconfigured groyne options.
- **Extension of Groyne 9 (Option B3)**. Modification to the beach compartment will be considered through the extension of Groyne 9. With ample sediment supply, it is anticipated that an extension of the groyne will result in a wider beach compartment and the optimal lengthening of the groyne will be assessed.
- **Modification to the Existing Groyne Field (Option B4)**. The discontinuity of the shoreline between beach compartments is a result of the trapping efficiency of the existing groyne structures, whereby sediment builds up on the southern side of the structures. Once the sediments bypass the structure heads, they are transported towards the northern end of the next compartment, thereby starving the southern ends of sediment. Options to increase the effective permeability of the groyne structures can be considered, such as reducing crest elevation of the groynes and potentially removing the landside connection, to improve the continuity of the shoreline position between beach compartments. Such approaches have been effectively implemented by Baird at other locations, an example of which is shown in Figure 5.11.

Figure 5.11: Example of low crested groyne to promote both beach width stabilisation and continuity of the shoreline between beach compartments.

The feasibility and effectiveness of the above options are assessed below using a combination of the regional Rivoli Bay model and the shoreline response prediction model for groyne compartments, with incident boundary conditions for the shoreline model being developed in regional scale hydrodynamic and wave model.

The options that have been investigated are aimed at restoring beach widths at the south western end of the beach compartments; each of these options have been investigated using the parabolic beach shape equation (PBSE) model (see Section 4.6) to determine at a conceptual level what effect addition and modification of structures may have on the stable beach shape within beach compartment 8.

5.6 Options Analysis

To assess the relative merits of each of the mitigation options, the numerical model systems developed for Beachport were applied with the outcomes presented in the sections below.

The shoreline model outlined in Section 4.6 was applied to Beach 8 and compared against the observed beach as it existed in 2018 when a high-resolution aerial imagery was captured of the area. Application of the model resulted in a predicted beach alignment as shown in Figure 5.12. The predicted beach shape follows the line of the beach as it existed at the time, with the predicted shoreline intersecting with the hard shoreline (i.e. rock revetment) where the existing beach meets this shoreline. This provides a clear indication as why the beach does not fill more of this compartment, being a function of the incident wave direction and the length of the beach compartment. Having been well validated against the existing conditions, the same analysis was then used to determine potential beach alignments under the range of options identified as potential solutions to maintaining a beach in this area.

Figure 5.12: Beach shape predicted using the parabolic beach shape equation according to the beach shape parameters as they were in 2018

5.6.1 Option B1

Option B1 had the following objectives:

- Placement of Additional Groyne (Beach 8).
- Promote retention of beach volume in front of the vertical seawall.
- Improve the stable beach widths.

The below layout (Figure 5.13) shows the minimum groyne length required to ensure a stable beach in front of the vertical seawall at Beachport, according to the PBSE. It has been assumed that the desired width of beach at the centre of the created compartment should be approximately the same width at the centre of the compartment to the north (north of groyne 9), approximately 13m.

To achieve the beach width mentioned above, a groyne of 50m in length, constructed perpendicular to the coast at the centre of Beach 8 would be required. The estimated beach shape for the northern half of Beach Compartment 8 with the inclusion of the 50m groyne is also presented in Figure 5.13. It is noted that to achieve this shoreline position an initial nourishment of the beach compartment would likely be required.

Figure 5.13: Beach shape predicted using the parabolic beach shape equation according to the beach shape parameters for Option B1

5.6.2 Option B2

Two methods of modifying Groyne 8 have been analysed, including reorienting the groyne at its existing length and extending the groyne along its existing orientation. It has been found that purely utilising reorientation of the groyne does not produce the desired result, with a stable beach remaining at or landward of the vertical seawall (Figure 5.14).

Figure 5.14: Beach shape predicted using the parabolic beach shape equation according to the beach shape parameters for Option B2 (groyne reorientation)

A second iteration of Option B2 has been analysed, extending the groyne along its existing orientation to achieve a similar width of beach at the centre of the cell as discussed above for Option B1. The length of groyne required to achieve this theoretically stable beach width (85m total length, 45m extension on the existing groyne) is shown in Figure 5.15.

Figure 5.15: Beach shape predicted using the parabolic beach shape equation according to the beach shape parameters for Option B2 (groyne lengthening)

5.6.3 Option B3

A final option was explored at Beachport in line with holding a beach in front of the vertical seawall; by extending Groyne 9 sufficiently to hold sediment within this compartment. The full extent of the groyne required to hold the beach plan shown below in Figure 5.16 is 85m, indicating a groyne extension of 20m.

Figure 5.16: Beach shape predicted using the parabolic beach shape equation according to the beach shape parameters for Option B3

5.6.4 Option B4

A review of the groyne structures along the Beachport shoreline was completed (from site visits and WRC, 2017) and beach compartment alignments considered in the context of the dimensions of the structures. As noted in assessment of Options B1, B2 and B3, the groyne structures to the north of the boat ramp are not adequately sized to retain beach widths along the alignment of the developed foreshore, with the groyne compartments generally too long for the existing groynes to be effective. However, these groynes do provide some function and the shoreline appears relatively stable across Beach Compartments 9 to 12.

As such, no modifications (outside those considered in Option B1, B2 and B3) are currently recommended in these areas. Any changes to the north of Groyne 9 would best be done following implementation of a mitigation measure that addresses Beach Compartment 8.

The shoreline along Beaches 1 to 5 is discontinuous with the groynes being effective in their trapping efficiency. There is therefore scope to increase the effective permeability of the groyne structures, by reducing crest elevation of the groynes particularly along the upper beach and landside connection.

A review of the modelled wave data and LiDAR survey was completed to identify the active beach face and natural berm level along these beaches. As presented in Figure 5.17, the natural beach berm level tends to form around +2mAHD (+1.5mAHD at Beach 1, +2.5mAHD at the Beach 4). The groyne crests are variable, generally sloping down in the offshore direction with crests between +2.5 to +4mAHD across the back beach area and closer to +1mAHD at their seaward ends.

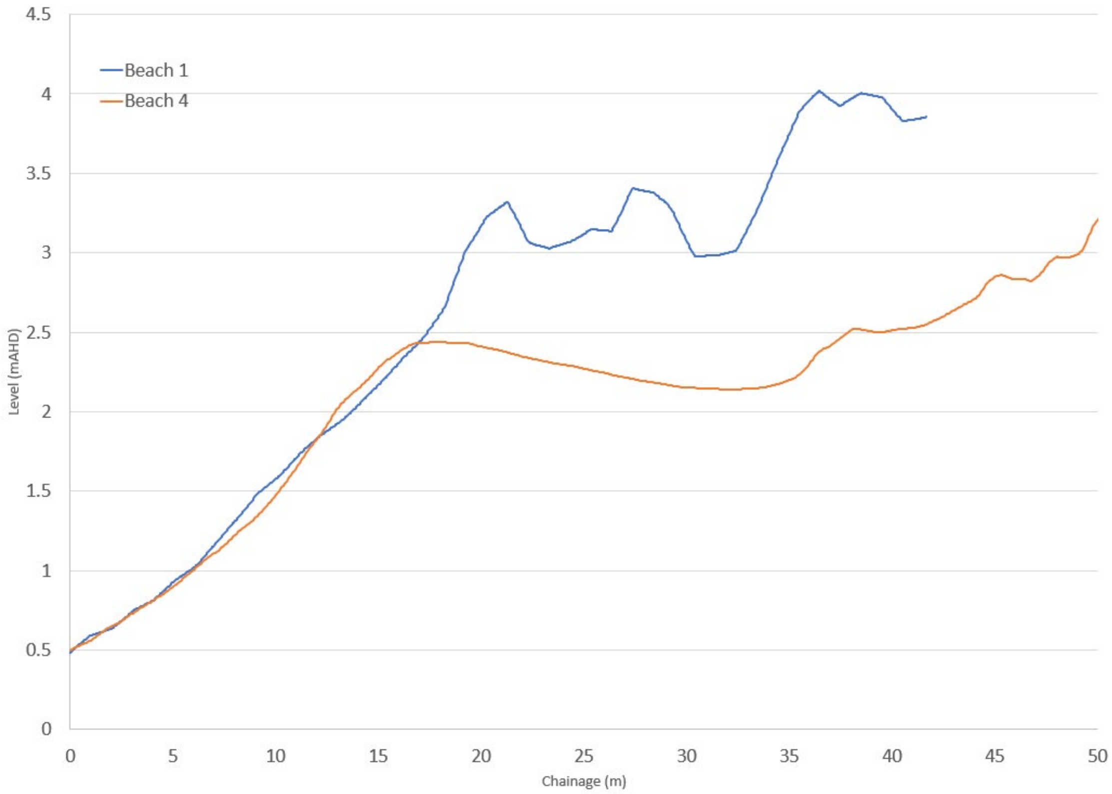


Figure 5.17: Surveyed Profiles from Beachport Beach Compartments 1 and 4

To improve the continuity of the shoreline position between beach compartments, the groyne crests could be lowered to be 0.5m below the natural berm level. Where the groyne crest is already below this level (i.e. as it slopes down in the seaward direction), the existing groyne profile would be retained. In this way, the nearshore trapping efficiency of the groynes are retained while the permeability of the structure is increased by way of increased overwash during larger seastate conditions (with associated wave runup at the shoreline).

There is no definitive design guidance for low crested groynes and no reliable analytical tool to estimate the bypass volume over the lower crest level, however real-world examples of low crested groynes have been shown to be effective in retaining a stable beach compartment while preserving a continuous shoreline alignment between compartments (e.g. Drummond Cove, Geraldton WA; Maroochydore Beach, Qld; Munna Point, Qld), with the reprofiling consistent with design guidance summarised in van Rijn (2013).

Implementation of this option could be done initially on a partial trial basis (on Groynes 2 and 3 at first) with a monitoring program implemented to ensure the intended function and response is being achieved.

5.6.5 Recommended Option for Beach Compartment 8

Following investigation of the originally identified options, a final optimised option, a resultant combination of B1 and B2, has been investigated. Previous results confirm the thinking that the groynes along this stretch of the coastline are spaced too far apart and therefore cannot maintain a suitable beach width.

The optimised option has slightly extended and rotated Groyne 8 in combination with placement of a groyne in the centre of Beach 8. The groyne in the centre of Beach 8 has been shortened slightly from that presented in Option B1 above, as the combination with the extension and rotation of Groyne 8 results in less length at this new groyne to achieve acceptable stable beach shapes. The layout of groynes and expected beach shapes are presented in Figure 5.18, showing groyne 8 extended out to 44m and with the seaward end of the groyne rotated north by 20º, and the new groyne in the centre of Beach 8 at a length of 38m perpendicular to the shoreline in that location.

Figure 5.18: Beach shape predicted using the parabolic beach shape equation according to the beach shape parameters for Option B4

6. Southend Foreshore

The Southend foreshore has experienced significant changes over the past 40 years. Severe erosion in the early 1980's led to the construction of five groyne structures through the late 1980's and 1990's in an attempt to stabilise the shoreline. The groyne field has interrupted the natural eastward movement of sediment along the shoreline under littoral processes, with accretion on the western beach (west of the Lake Frome outlet) and erosion on all beach compartments to the east of the Lake Frome outlet, which continues to this day.

The groyne field at Southend is presented in Figure 6.1 with numbering of the five groynes (G1 to G5) moving eastward following the approach adopted in Worley Parsons (2015). Beach compartments named Compartment 1 to Compartment 4 are shown in Figure 6.1 for the purposes of discussion in this report.

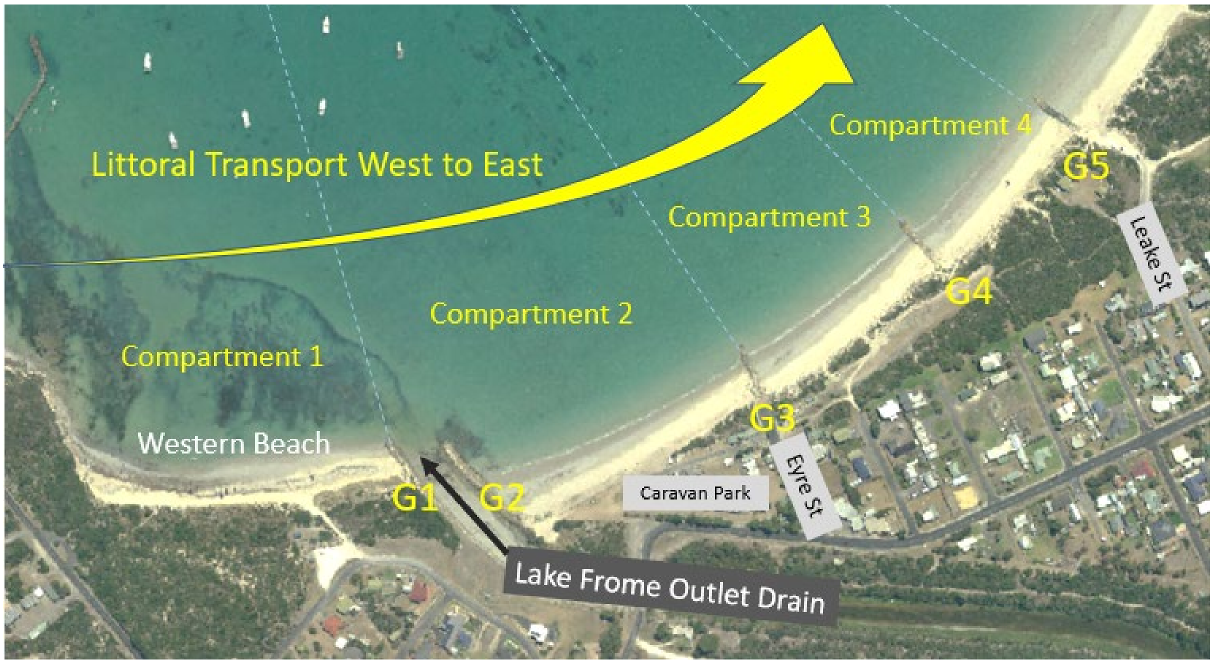


Figure 6.1: Southend shoreline showing the five groynes (G1 to G5) and the Lake Frome outlet (aerial image 2015)

It is noted from the literature review (Baird, 2020b), discussions with Council and site visits by Baird, that coastline recession has been a major issue at Southend since at least the early 1980s when erosion at the Lake Frome outlet first threatened the Southend Caravan Park.

A general summary of the construction timeline of the groyne field and modification of the shoreline sediment transport is as follows:

- The historical account of coastal recession at Southend cites the Lake Frome outlet as being chiefly responsible for the observed loss of beach width, initially contributing to loss of seagrass communities in the nearshore, removing the natural defence to wave exposure and increasing erosion potential along the shorelines of Southend (Wavelength, 2018).
- Training walls (groynes) were constructed either side of the Lake Frome outlet in 1985 and 1987 (eastern and western sides respectively, G2 and G1). Subsequently, significant build-up of the western beach and a reduction of sediment transported to the eastern beaches was observed, as the groynes reduced the natural west to east movement of sand.

- Due to the configuration of the outlet groynes, sediment that was transported around the training wall from the Western Beach side (G1) was trapped between the groynes in the outlet drain (between G1 and G2) which act as a sediment sink and reduce sediment supply to the eastern beaches.
- In an attempt to reduce the rate of erosion on the eastern side of the outlet, three groynes were constructed between 1993 and 1995 between Eyre and Leake Street (G3, G4 and G5). Whilst the groynes have slowed down the rate of erosion along the shorelines of beach compartment 2, 3 and 4 they have not completely mitigated coastal erosion impacts in this area. They do provide some function as demonstrated by the discontinuity of the shoreline alignment between beach compartments. As discussed for Beachport, this discontinuity is a result of the local trapping efficiency of the structures (albeit limited), whereby sediment builds up on the western side of the structures.

6.1 Conceptual Sediment Transport Model

The literature review presented in Section 2 identified that the key coastal processes at Southend were longshore drift due to wave action that drives sediment transport in an easterly direction along the foreshore. However, cross shore transport is also identified as playing a significant role, most notable by shifting beach sands offshore of the groyne extents. From the description of the groyne fields at both Southend and following our own site inspections, these identified primary drivers of sediment transport along this section of coast are considered valid.

Based on all information at hand the conceptual sediment transport model presented in Rivoli Bay Study (Worley Parsons, 2015) is considered appropriate in describing the key processes at the site, as shown in Figure 6.2.

The distinct discontinuity in the coastline across the Lake Frome outlet makes clear the trapping capacity of the outlet structures, both in terms of retaining beach volume on the western beach and through the trapping of sediment that bypasses the western entrance structure (G1). As a result, downdrift erosion has resulted in a steady loss of beach width within the beach compartments to the east of the outlet structures (Compartment 2, 3 and 4). While cross-shore and alongshore transport play a role in this outcome, the relative contribution of each is not currently defined.

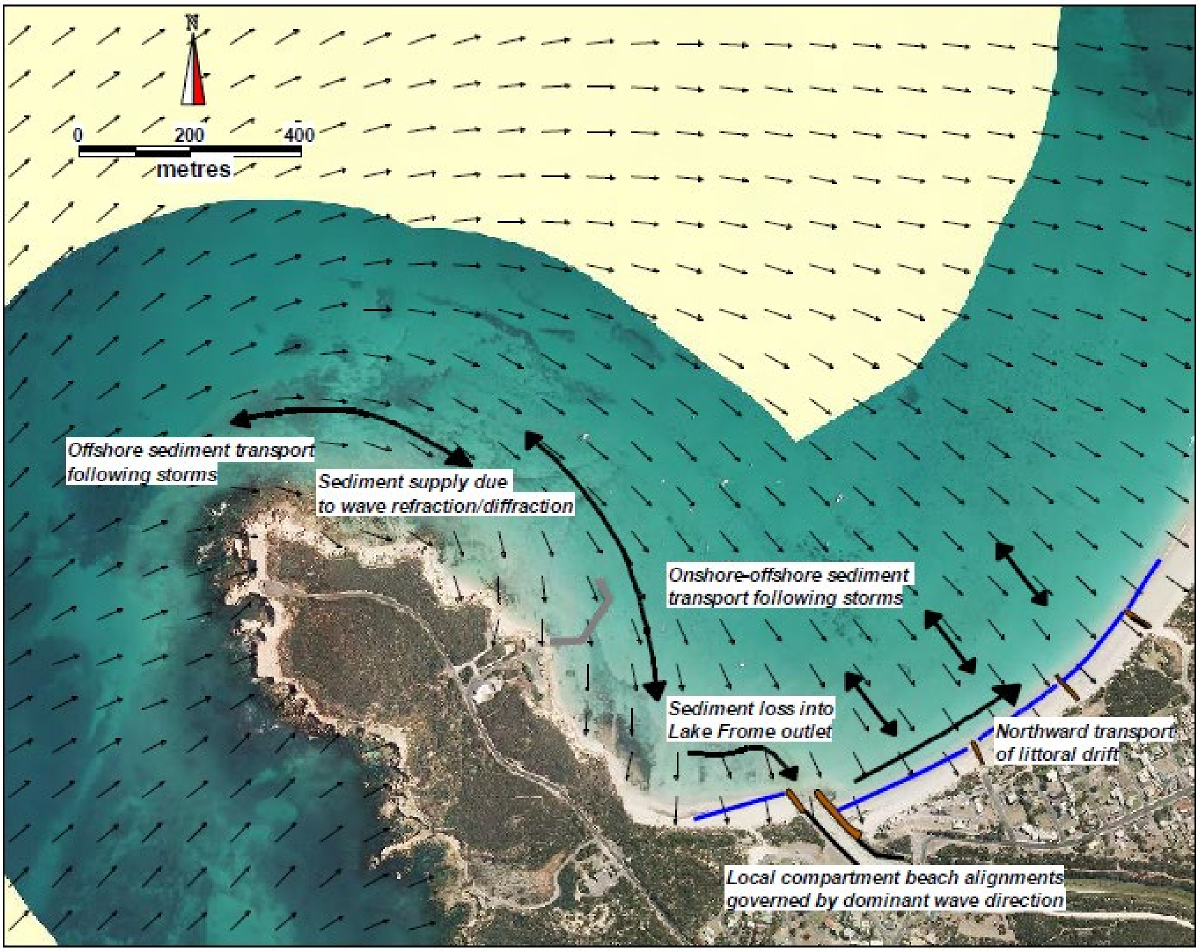


Figure 6.2: Conceptual Sediment Transport model for Southend Foreshore (from Worley Parsons, 2015)

6.2 Shoreline Trends

An assessment of historical shoreline position at Southend has been completed using both satellite imagery analysis of shoreline position and analysis of historical transect data. While the transect data is a more accurate dataset, as it is based on ground survey, the satellite imagery is able to provide a much higher temporal resolution of data and hence intra-annual trends can be identified where present.

6.2.1 Satellite Imagery Analysis

An analysis of historical trends in shoreline position at Southend was completed using the CoastSat toolbox (see Section 5.2) with results presented in Figure 6.3 and Figure 6.4. It is noted that the analysis at Southend is limited by the quality of satellite imagery that was accessible, with the site seemingly at the extremities of the satellite paths. As a result, a significant number of images were discarded, and intra-annual changes are not readily discernible. However, longer term trends are identifiable and when considering more recent data (post 2005) the analysis shows:

- transects to the west of the Lake Frome outlet (Transects 1 to 3) appear stable with little change in the mean beach position (Figure 6.3);
- transects to the east of the Lake Frome outlet between Groyne 2 and Groyne 5 (Leake St) show a clear recessionary trend (Figure 6.4). For transects 4 to 11, the change in mean position is estimated at approximately 10m to 15m over the duration of the data (~15 years); and

- Transects to the east of the Leake Street Groyne show an even higher rate of shoreline recession with the results from transects 12 to 16 indicating the change in mean position of 20m to 30m over the 15 year duration of the data (Figure 6.5).

These outcomes are broadly consistent with the finding in Wavelength (2018) for long-term erosion allowances (S2) for the Southend shoreline. For the shoreline along Southend, the annual S2 allowances were reported in four shoreline sections from west to east in Wavelength (2018).

- Section 1 west of the Lake Frome outlet the shoreline is assumed stable;
- Section 2 and Section 3 between Groyne 2 and Groyne 5 (Leake St) annual erosion of 0.5m is adopted; and
- Section 4 east of Groyne 5 an annual erosion of 1.3m was adopted.

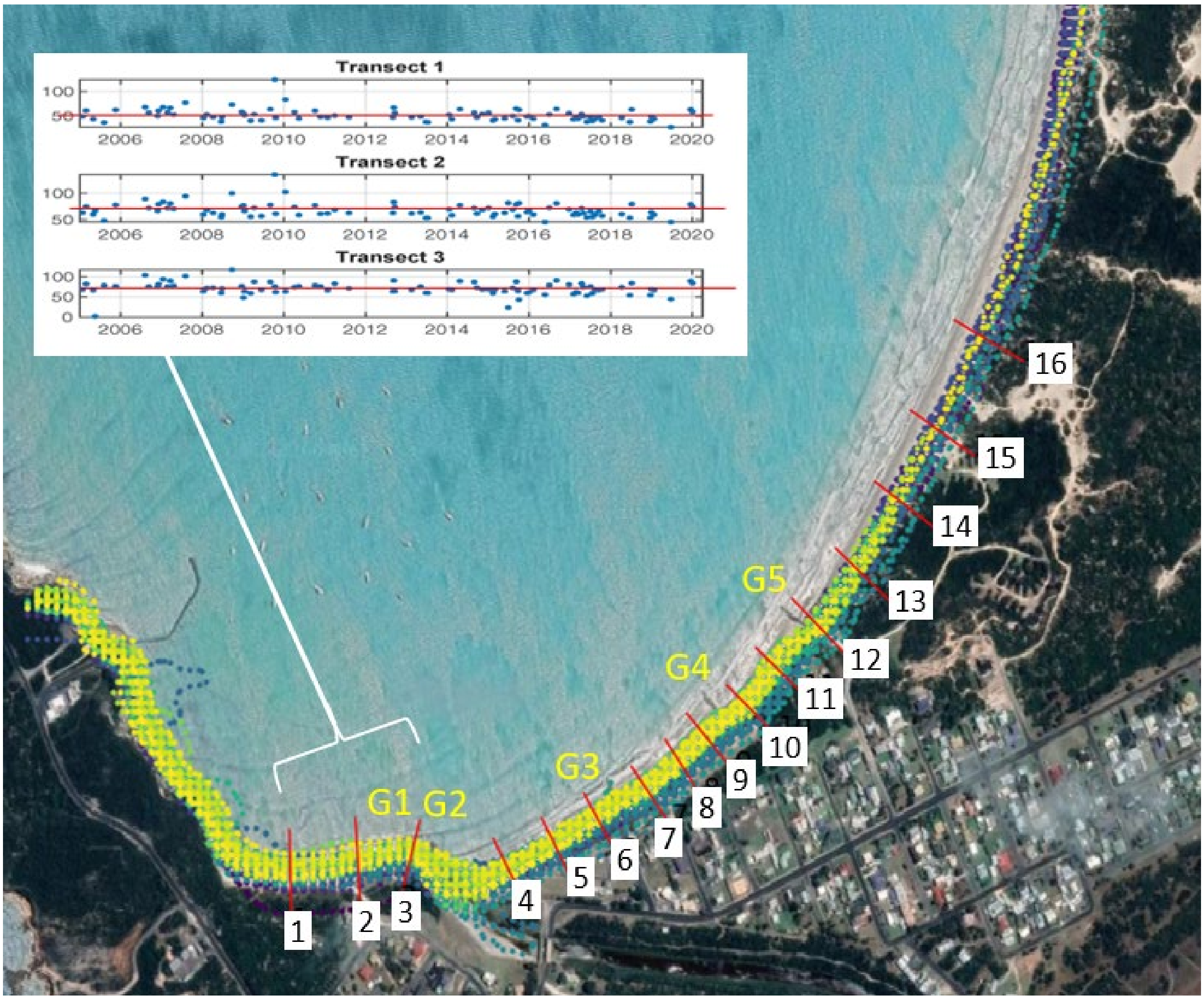


Figure 6.3: Mapped shorelines from the CoastSat Toolbox at Southend. Shoreline dates range from 1988 (dark blue) to 2020 (yellow). Analysis of the shoreline position on the western beach from Transect 1 Transect 2 and Transect 3 show the shoreline is relatively stable over the period 2005 to 2020.

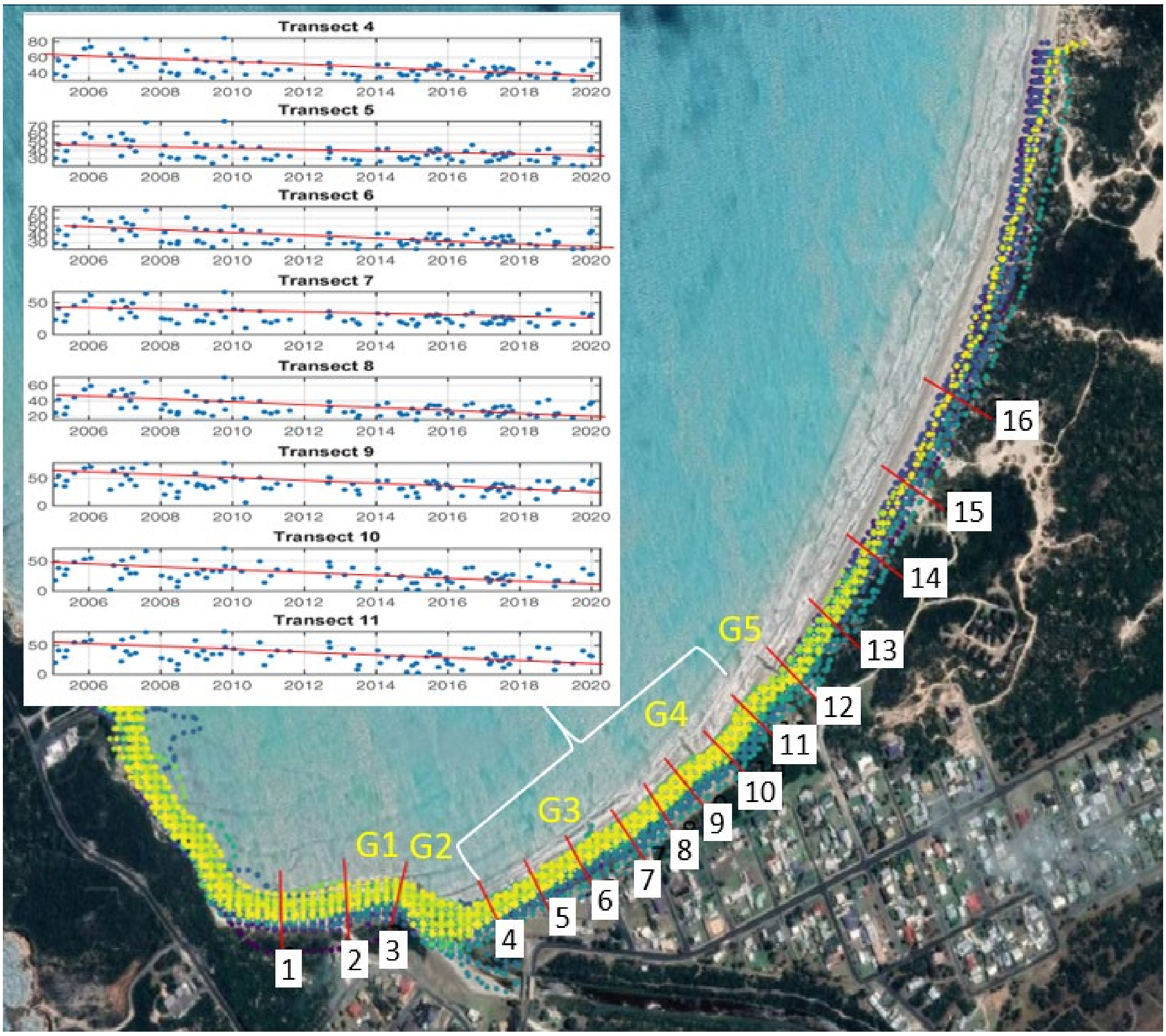


Figure 6.4: Mapped shorelines from the CoastSat Toolbox at Southend. Shoreline dates range from 1988 (dark blue) to 2020 (yellow). Analysis of the shoreline position for beach compartments east of the Lake Frome outlet in Transect 4 to Transect 11 show the shoreline is eroding by 10m to 15m over the period 2005 to 2020.

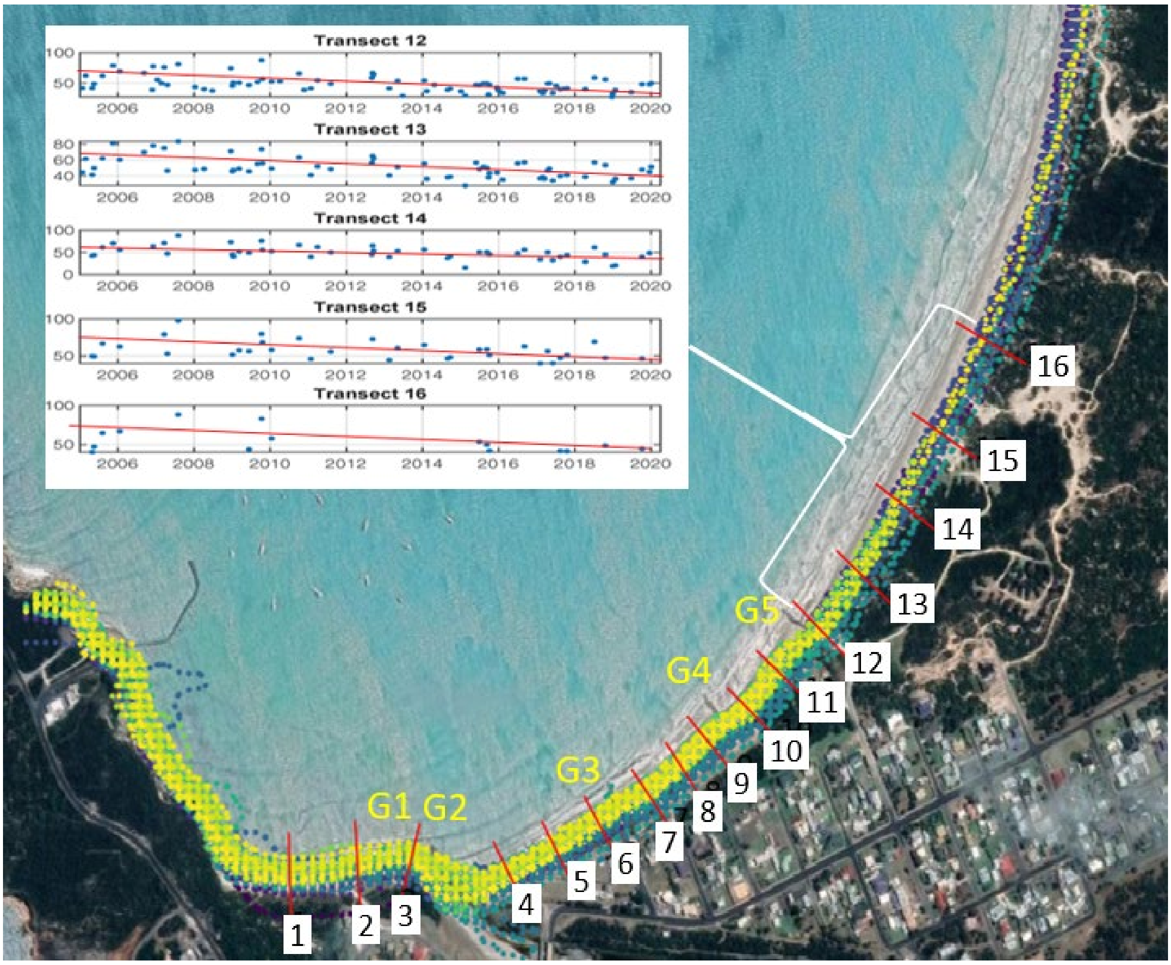


Figure 6.5: Mapped shorelines from the CoastSat Toolbox at Southend. Shoreline dates range from 1988 (dark blue) to 2020 (yellow). Analysis of the shoreline position for the shoreline north of Groyne 5 (Leake Street) show the shoreline is eroding by 20m to 30m over the period 2005 to 2020

6.2.2 Historical Transects Analysis

The Department for Environment and Water (DEW) have conducted transect surveys at profile locations along the Southend shoreline and offshore on an approximately annual basis in recent years. The fixed transect locations are shown in Figure 6.6. The length of the historical record varies by transect, with survey capture dating back to the period before the groyne field was established.

- For the transect numbered 725028 adjacent groyne 4 and the transects to the east, the capture commenced in 1990;
- Transect 725001, Transect 725004 and Transect 725006 the data commences in 1977, 1984 and 1986 respectively; and
- On the western beach Transect 725005 has an initial capture date in 1956, with the next data captured in 1984 and regularly thereafter. From 725008, 725009 and 725010 the data commences in 1987.

The transect data has been analysed to understand the changes along the Southend shoreline prior to the construction of the Lake Frome outlet groynes and the subsequent shoreline changes following the establishment of the groyne field. The volume changes measured on the transects has also been used to benchmark the sediment transport modelling reported in later sections.

Figure 6.6: Location of historical survey transects collected by DEW through Southend

To illustrate the changes on the shoreline measured post construction of the Lake Frome outlet groynes, Transect 725008 from Compartment 1 is shown in Figure 6.7 and Transect 725006 from Compartment 2 is shown in Figure 6.8:

- The accretion on the Transect 725008 profile in Figure 6.7 clearly shows how the shoreline of the western beach in Compartment 1 has grown over the 33-year period. The highest rate of change occurs in the 20-year period 1987 to 2007 following the construction of the western groyne (G1) with a shift of approximately 50m at the 1mAHD level of the profile. Over the more recent period 2007 to 2020 the profile has been relatively stable indicating the western beach has achieved a relative equilibrium. The shoreline is comparatively steeper today (2020) compared with the initial profile in 1987 / 88.
- On the eastern side of the outlet groynes in Compartment 2 the survey data of Transect 725006 in front of the Caravan Park is presented in Figure 6.8. The profile changes clearly show the erosion on the profile over the period. The profile data shows a significant landward shift of the profile between the 1986 to 1990 surveys at the time immediately following construction of the Lake Frome outlet groynes. Between 1990 and 2002 the profile shows recovery of the profile (accretion) followed by steady erosion in the profile surveys 2007 to 2020. The position of the dune crest captured in the initial 1986 survey has been steadily eroded landward a distance of approximately 12m over the 33-year period to 2020.

The transect data was analysed to characterise the dynamics of the shoreline prior to the establishment of the groyne field along the Southend shoreline. This is shown graphically in Figure 6.9 with an aerial image from the early 1980's which shows the natural shoreline and entrance to Lake Frome drain in its original state. Based on the transect survey analysis of the shoreline areas to the offshore depth -1mAHD:

- for the western beach (Compartment 1) in the period 1984 to 1987 the data showed the shoreline was nominally stable with a small rate of accretion (500m³ annually).
- In beach Compartment 2, the rate of erosion was estimated at 7,500m³ annually based on the data from 1984 to 1986
- In beach Compartment 3 and Compartment 4 the rate of erosion was estimated at 5,000m³ annually based on the data from 1977 to 1983

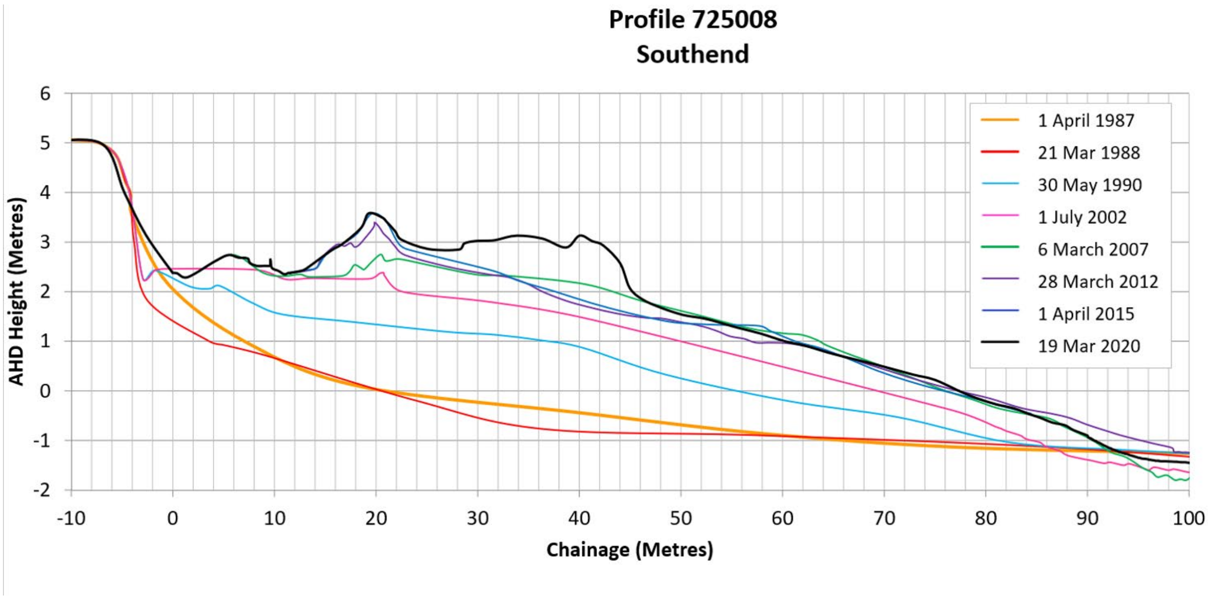


Figure 6.7: Survey data from Southend Profile 725008 – 1987 to 2020 illustrating accretion in beach Compartment 1

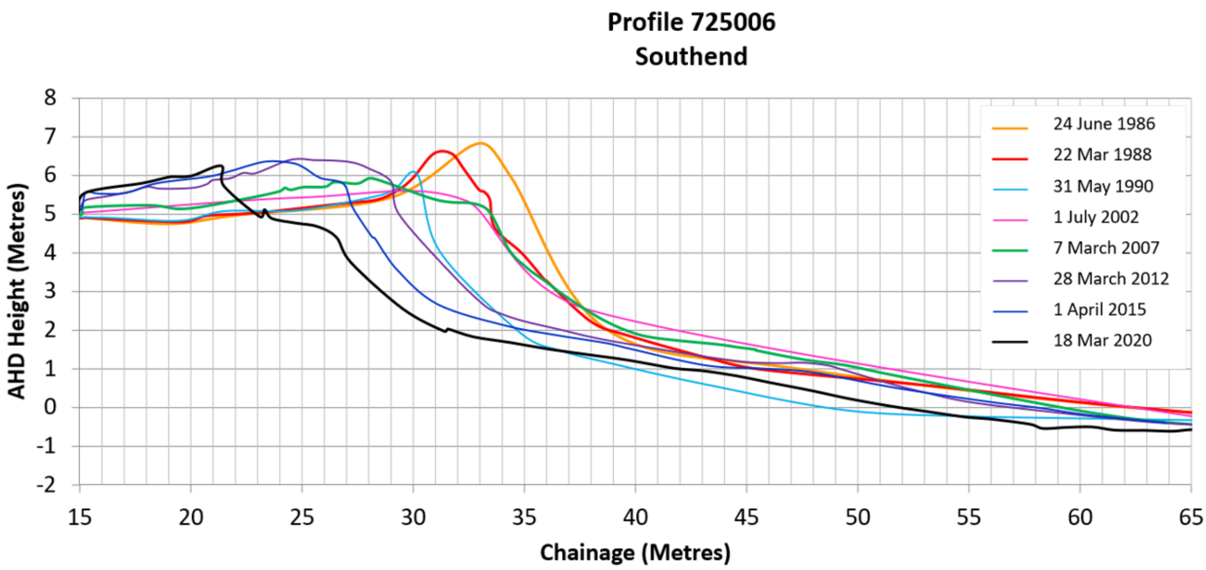


Figure 6.8: Survey data from Southend Profile 725006 – 1986 to 2020 illustrating erosion in beach Compartment 2

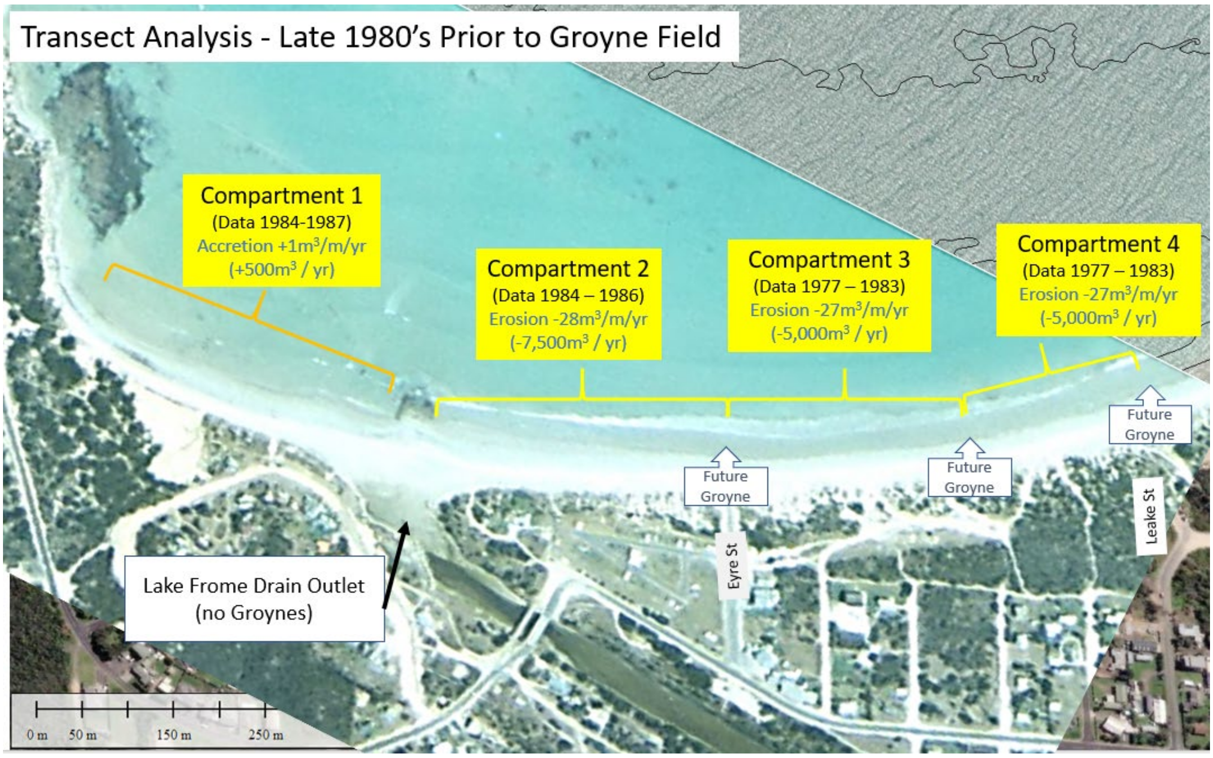


Figure 6.9: Analysis of shoreline transect data in the period prior to the groyne field showing Compartment 1 in accretion and all other Compartments experiencing significant erosion. Imagery capture from early 1980's prior to the groyne field establishment.

6.2.3 Sediment Transport Rate for Southend

To develop the understanding of the sediment transport rate along the Southend shoreline further analysis of the historical transect data has been completed.

- The date of construction for the Southend groynes is summarised in Figure 6.10. It is noted that sand replenishment works valued at $380,000 were undertaken by DEWNR over the period 1983 to 2014 along the Southend shoreline as reported in Wavelength (2018). The exact date, volume and location for the replenishment works has not been determined as part of this study, however the process is noted in Figure 6.10 as they will have contributed to the overall sediment budget within the beach compartments throughout the period (i.e. these are an additional source of sediment into the system).
- The construction of the Lake Frome outlet groynes in the period 1985 to 1987 immediately disrupted the eastward longshore transport along Southend. The years following construction are a useful measure of sediment transport rates along the Southend shoreline as during this period the majority of sediment transport along the western beach was trapped on the western side of the newly built groyne 1.
- Analysis of the transects on the west of Groyne 1 in the 2-year period (1988 to 1990) immediately following the construction of the Lake Frome outlet groynes show a volume of 18,000m^3/yr accreted within Compartment 1 over the 2-year period between surveys. The volume was determined by calculating the area below the transects using integration and multiplying this by the length of the Compartment 1 beach. This process is shown in Figure 6.11
- The sediment capture on the western beach (Compartment 1) has continued over the 30-year period since 1990, albeit at a much-reduced rate compared with the first few years after the Groyne 1 construction. The rate of accretion between 1990 and 2007 was estimated at +1,500m^3 annually from the transect data, reducing to a rate of +700m^3 annually in the most recent period

2007 to 2020. As Compartment 1 has reach capacity, sediment is now transported around Groyne 1 to the beach compartments further east.

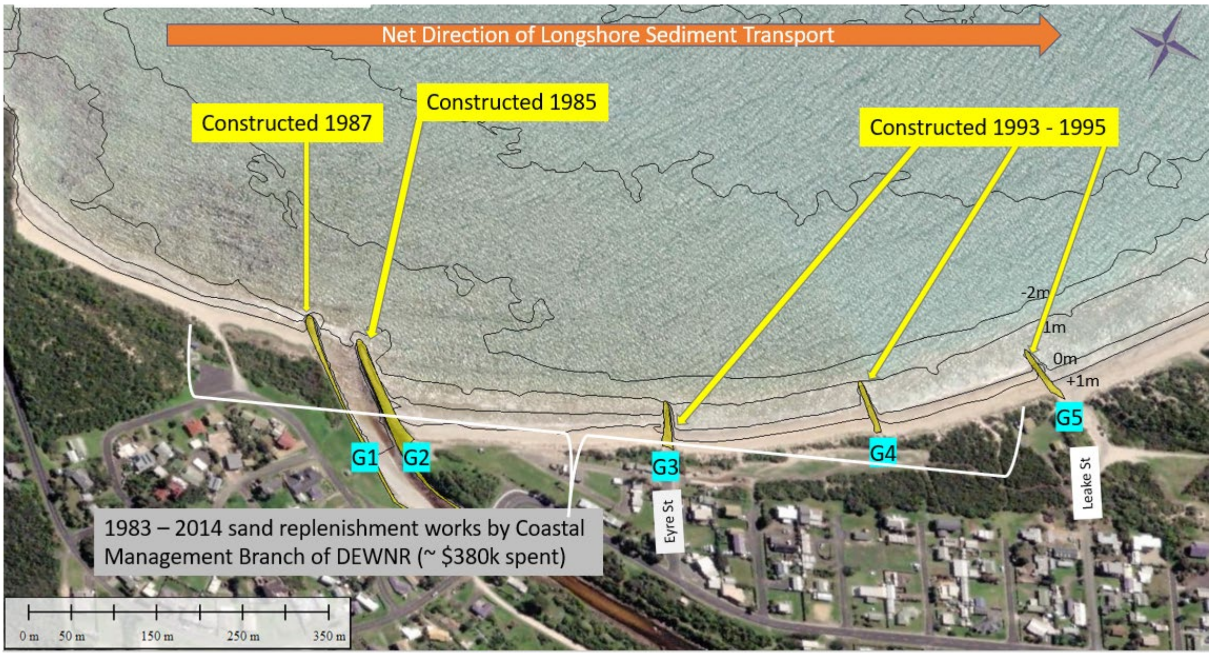


Figure 6.10: Summary of groyne field development timeline and sand replenishment works in the Southend shoreline.

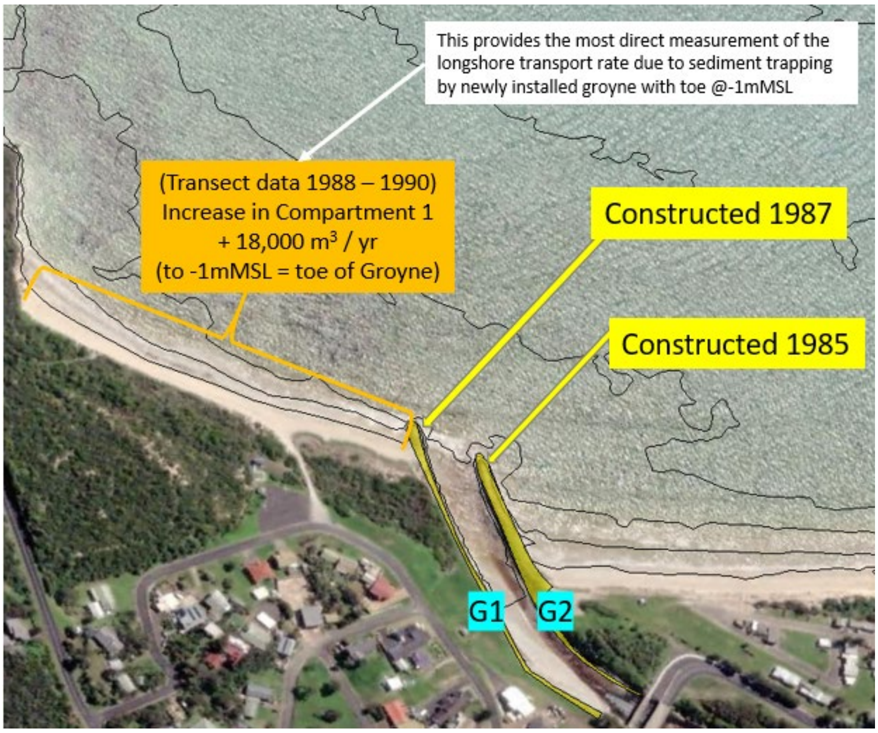


Figure 6.11: Profile analysis for Compartment 1 in the 2-year period (1988 – 1990) immediately following the construction of the Lake Frome outlet groynes show a volume of 18,000m^3/yr accreted within Compartment 1. During this period the majority of sediment transport along the western beach was trapped on the western side of the groyne (depth of the toe at -1m AHD).

A similar integration technique was applied to the transect data for the beach compartments east of the Lake Frome outlet across specific periods summarised in Table 6.1.

Table 6.1: Summary of annual volume changes in Beach Compartments (volume to nearest 500m^3)

	Pre-Groynes	Post Groyne to 2020	2018-2020
Compartment 1 Transect	+ 500m^3	+1,000m^3	No Change
Compartment 2 Transect	-7,500m^3	-1,000 m^3	-2,000 m^3
Compartment 3 Transect	-5,000m^3	-1,500 m^3	-2,000 m^3
Compartment 4 Transect	-5,000 m^3	Not Available	-1,500 m^3

A summary of the sediment transport pathways along the Southend shoreline and an indicative sediment budget for the present day was calculated using the most recent profile data (2018-2020) and is summarised in Figure 6.12. This shows:

- the flow of sediment is eastward under the general littoral transport process;
- the sediment transport rate is estimated at 30,000m^3 annually along the western shoreline, calculated from the transects down to a depth of -2m AHD, nominally the depth of closure. The sediment transport rate increases moving eastward under the relatively higher exposure to wave energy increasing to a rate of 33,000m^3
- Within Compartment 1 the system is in a state of net balance with localised erosion and sedimentation within the compartment;
- Between the Lake Frome outlet groynes, the outlet drain acts as a sediment sink (loss of sediment from the system);
- Compartment 2 is currently experiencing a net erosion rate of approximately 2,000m^3 annually;
- Compartment 3 is currently experiencing a net erosion rate of approximately 2,000m^3 annually; and
- Compartment 4 is currently experiencing a net erosion rate of approximately 1,500m^3 annually.

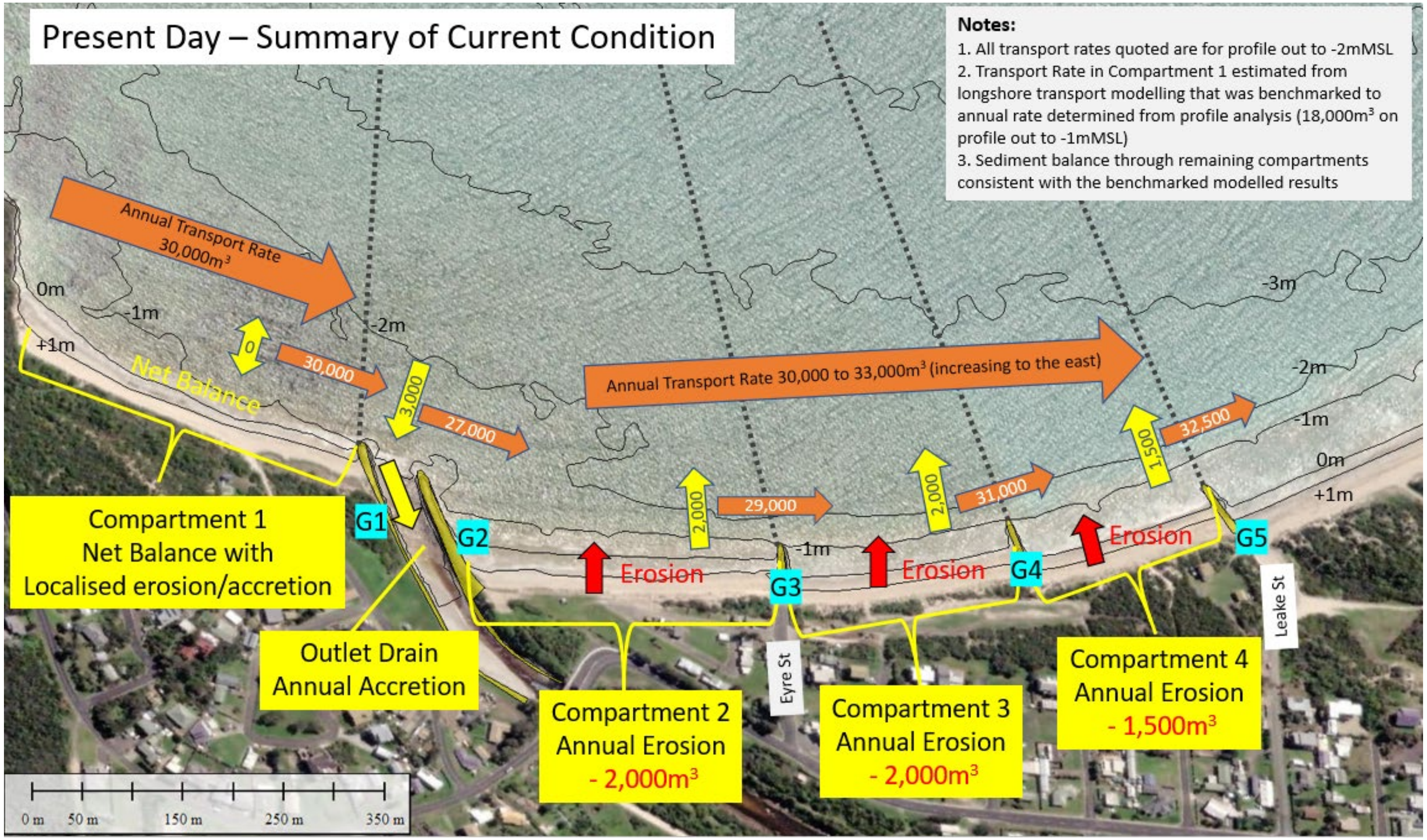


Figure 6.12: Summary of the Southend sediment transport pathways for the present day and estimate of transport rates and sediment budget based on transect data collected by DEWNR (calculated volumes are rounded to the nearest 500m^3)

6.3 Shoreline Process Model at Southend

A set of profile models along the Southend shoreline were established to specifically resolve the longshore sediment transport distribution across the surfzone. The cross-shore distribution of the longshore transport provides a measure of the trapping efficiency of the existing groynes and also provide a basis for development and assessment of potential modifications to the groyne field at Southend. Further, the relative longshore potential transport rates between compartments provides an indication of the sediment budget within each beach compartment and if there is a longer-term sediment deficit.

The location of the cross-shore profiles at Southend for which shoreline modelling was completed is presented in Figure 6.13. Each profile extended out to the 5m depth contour based on available survey data, with priority given to LiDAR and multibeam datasets. The seaward extent of the profiles broadly aligned with the Southend ADCP deployment locations and therefore the model was forced with measured water level and wave conditions. Available sediment data was used to define the sediment distribution adopted in the model, which was based on the S1, S3 and S4 sediment samples (see Section 2.2.7).

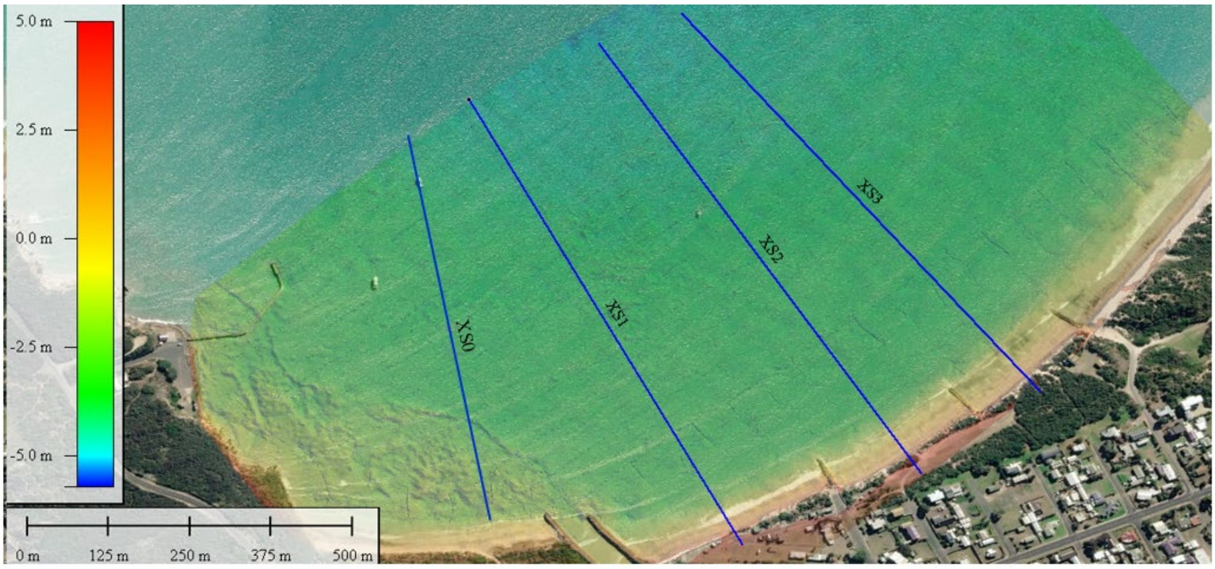


Figure 6.13: Cross shore profile locations for the Shoreline Process modelling

The full duration of the measured wave data record, June to December 2019 (approximately 6 months), was simulated in the model to provide an estimate of the longshore transport (LST) potential and the time-averaged cross shore distribution. A summary of the cumulative potential longshore transport volumes at the four profiles is presented in Figure 6.14. Note that the cumulative volumes are potential transport volumes and assume an infinite sediment supply and alongshore uniformity of the shoreline. These criteria are not met at Southend; however, the results provide a quantitative estimate of the relative transport potentials between beach compartments.

The results in Figure 6.14 indicate LST is a function of elevated wave heights within the southern embayment of Rivoli Bay which increases under larger wave conditions such as the July and August periods where wave height exceeds 1.2m with a noted steep increase in the curve. During milder wave conditions such as the mid-September to mid-October period the LST rate reduces, and the curve is flatter. It is noted that the shoreline process model (COSMOS) captures the cross shore transport and profile change under storm conditions in the model analysis. Notably, storm conditions cause a seaward shift in the nearshore bar and as a result a temporary seaward shift in the cross shore distribution of LST. This cross shore process is integrated in the reported LST rates from the modelling.

Potential transport rates increase towards the east as summarised in Table 6.2 and most notable in depths less than -2mMSL. The increase in transport rates to the east is attributable to the relative exposure of the shorelines to offshore conditions, noting that transport under elevated wave conditions is the primary driver. This increase in transport potential indicates a sediment volume imbalance along this section of coast that drives the observed beach volume loss.

For each of the four transects, the modelled longshore transport rate was examined against the seabed contours, to understand the cross-shore variation relative to the groyne features. The results are shown in Table 6.2.

Table 6.2: Modelled longshore Transport Volume - Summary by Cross Section by seabed depth

Depth (m MSL)	XS0	XS1	XS2	XS3
-5m to -3m	20,000	19,000	21,000	16,000
-3m to -2m	21,000	37,000	25,000	22,000
-2m to -1m	15,000	24,000	27,000	36,000
-1m to 0m	25,000	18,000	28,000	33,000
0m to 1m	1,000	2,000	1,000	1,000
TOTAL	82,000	100,000	102,000	108,000

Figure 6.15 to Figure 6.18 presents the averaged cross-shore distribution of the longshore transport from the simulations for cross sections XS0, XS1, XS2 and XS3 respectively. The profile plots and the data in Table 6.2 indicates:

- the bulk of the longshore transport occurs around the 0m MSL to -3mMSL contour. This aligns with the ADCP transect data (Transect 5) which showed strong alongshore currents shoreward of the -3mMSL contour.
- Transport is seen to occur at depths out to ~-4mMSL (up to 400m from the shoreline) however at lower rates that would not impact shoreline dynamics.
- Transport potential at XS1, at the location where shoreline recession in front of the caravan park has been noted, is lower compared compartments to the east over depths less than -2mMSL. The relative changes in transport potential are due to the alignment of the shoreline to the incident nearshore waves, however, may also be a result of the steeper nearshore profile below mean sea level.
- A large proportion of the longshore transport occurs offshore of the -1mMSL contour, which is the approximate seaward extent of the existing groynes at Southend. For the respective cross sections, the longshore transport volume captured from +1mMSL down to -1mMSL compared to the total longshore transport volume from +1mMSL to -3m MSL is 42%, 25%, 36% and 37% for XS0 to XS4 respectively. This confirm the assumption that the groynes are not of sufficient length to be an effective trap of the longshore sediment volumes.

Figure 6.19 provides an indicative littoral zone extent, offshore of the -1mMSL contour, defined from the COSMOS profile modelling and multibeam survey. This demonstrates that the majority of the longshore transport occurs within a cross-shore area that extends beyond the end of the existing groyne structures (G3, G4 and G5).

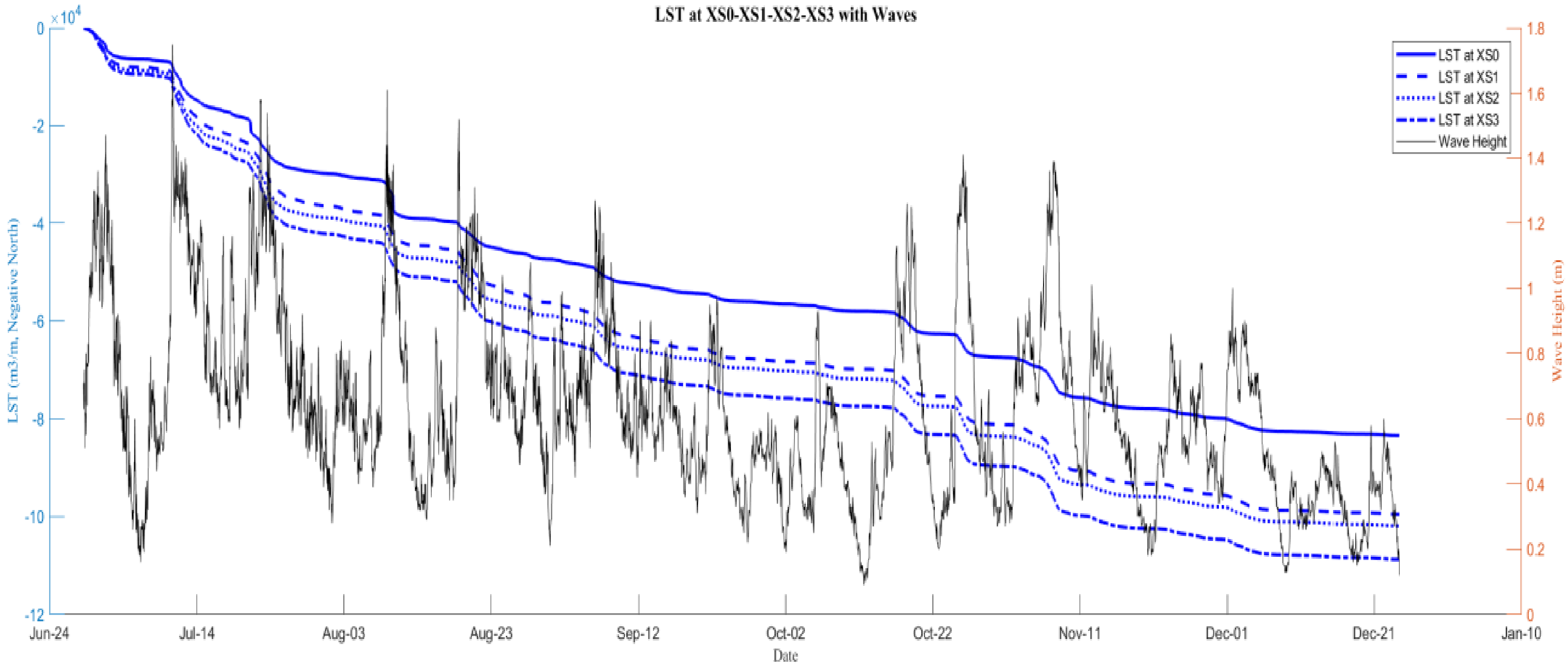


Figure 6.14: Cumulative Potential Longshore Transport Volumes over the duration of the measured dataset.

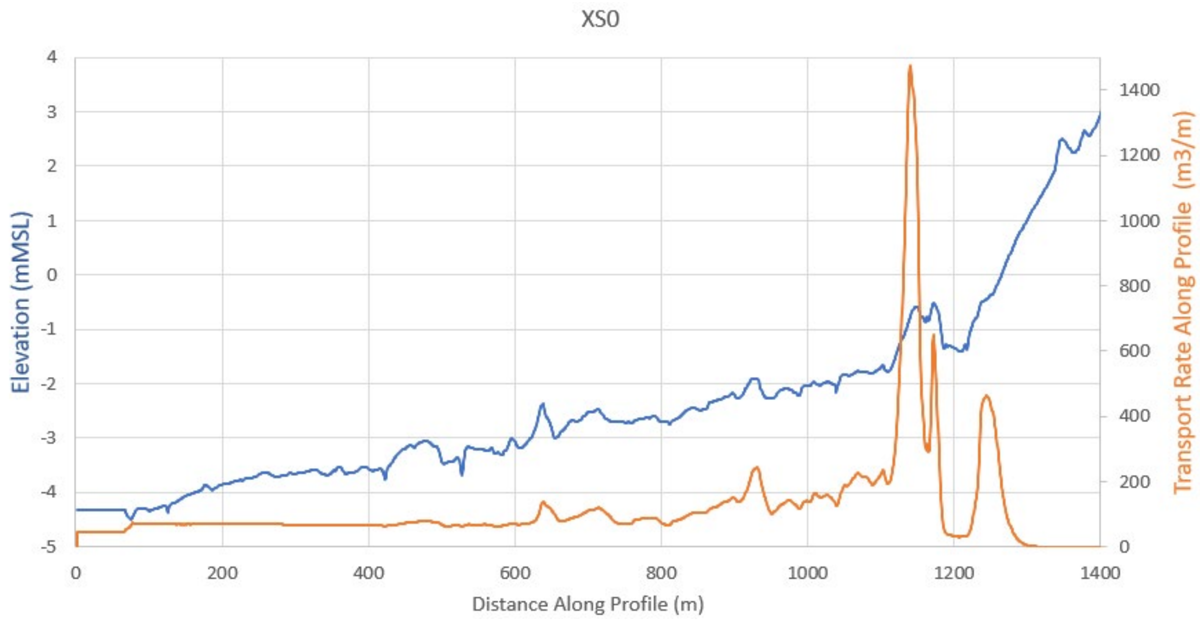


Figure 6.15: Cross-shore Distribution of the Longshore Transport Potential at the Southend Profile XS0

Figure 6.16: Cross-shore Distribution of the Longshore Transport Potential at the Southend Profile XS1

Figure 6.17: Cross-shore Distribution of the Longshore Transport Potential at the Southend Profile XS2

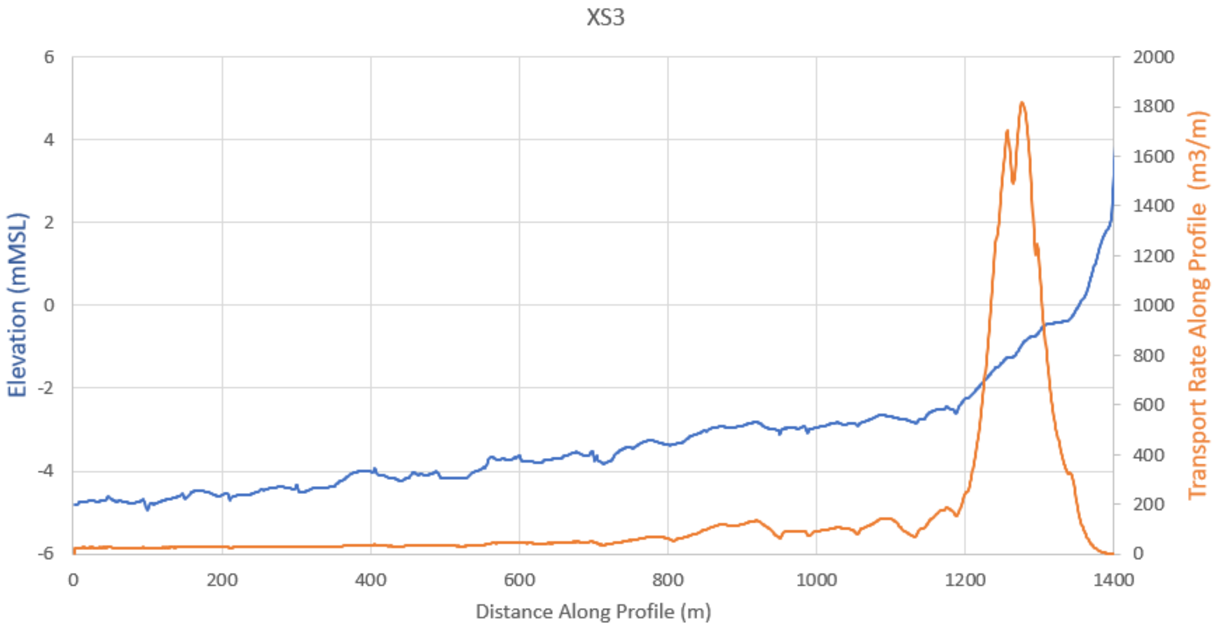


Figure 6.18: Cross-shore Distribution of the Longshore Transport Potential at the Southend Profile XS3

Figure 6.19: Cross-shore Distributions of the Littoral Transport quantifying the extent of the Littoral Zone at Southend

6.4 Spatial Transport Potential

To improve the spatial assessment of the potential management options, the validated regional scale Delft3D numerical model was updated to include increased resolution through the southern section of Rivoli Bay at Southend with the hydrodynamic grid (FLOW) and wave grid (SWAN) updated from 40m x 40m grid resolution to 5m x 5m grid resolution. The existing condition (base case) was run with sediment transport process active in the model to examine sediment transport potential along the Southend shoreline. The grid in southern Rivoli Bay over Southend and an example of model wave conditions around Cape Buffon in typical winter wave conditions is shown in Figure 6.20.

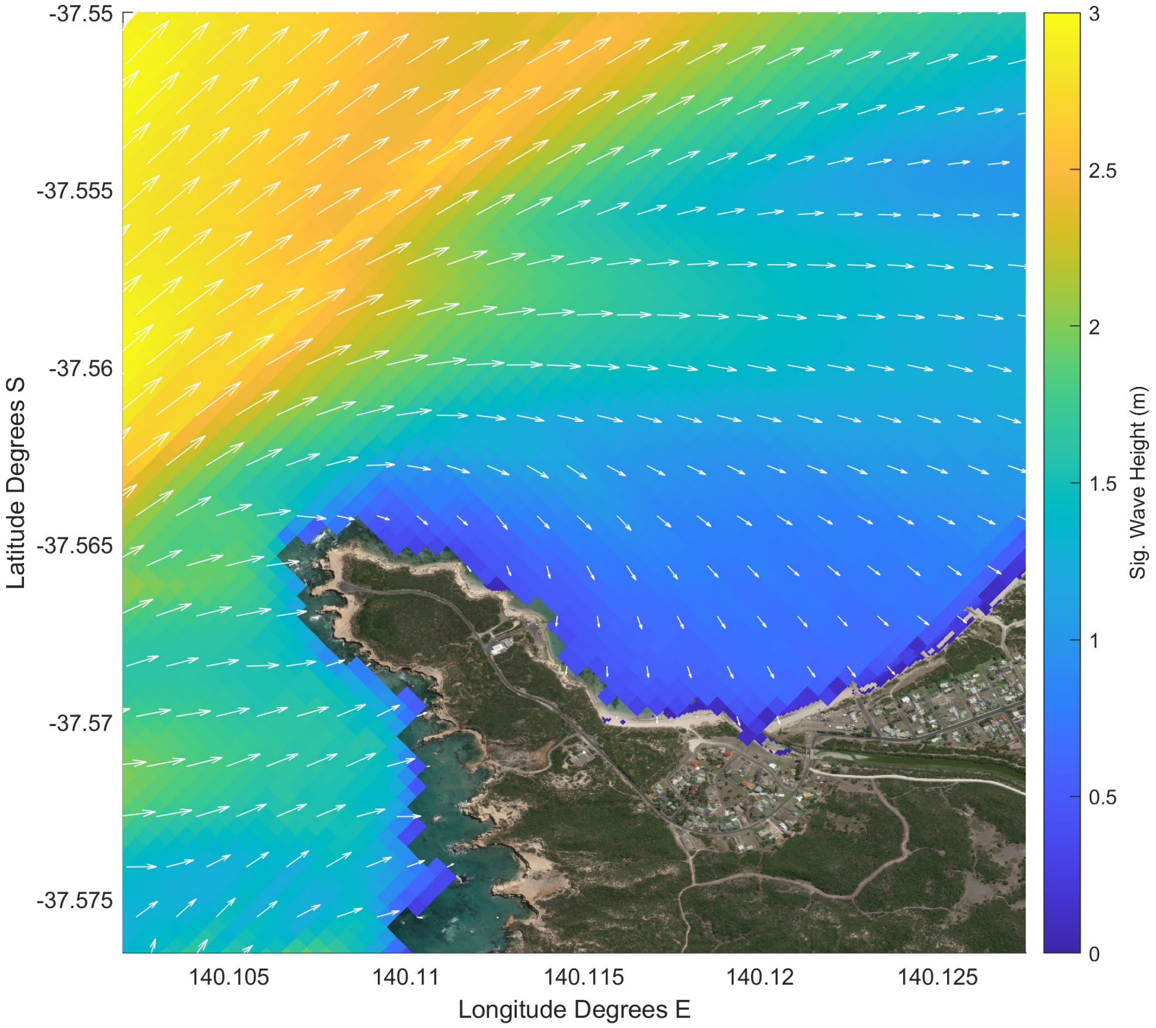


Figure 6.20: Model wave height (Hs) and mean wave direction, highlighting refraction processes around Cape Buffon (Model Timestep: 20 August 2019 at 0500 UTC).

An example of the modelled wave conditions from the high resolution 5m grid domain for the base case is shown for the Winter case along the Southend shoreline in Figure 6.21 (timestep shown is 20th August 2019 at 0500 UTC).

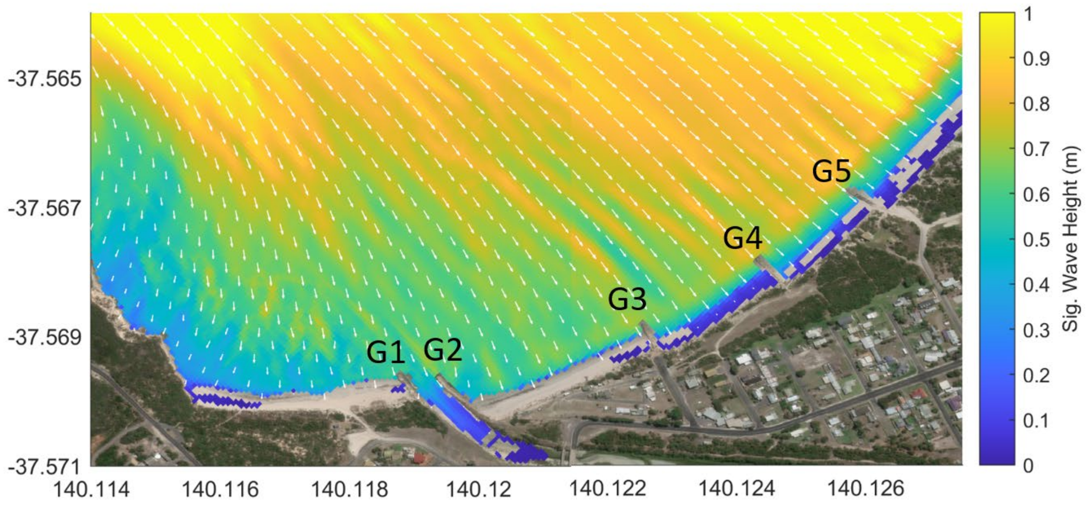


Figure 6.21: Modelled Significant Wave Height. Southend Existing Case Bathymetry (Model Timestep: 20 August 2019 at 0500 UTC)

Spatial transport potential along the Southend shoreline under existing condition (base case) were analysed from a long duration model simulation covering the winter period (4 weeks). The spatial transport potential includes the combined processes of bed load and suspended loads. The mean transport rate was output from the model simulation calculated in each grid cell of the model over the full 4-week duration. The model outcome is shown in Figure 6.22 that indicates the transport rate is highest along the shoreline area and increases moving east.

Under existing condition (Figure 6.22) is it seen that the active region near the shoreline extends beyond the offshore footprint of the 3 groyne structures east of the Frome Lake outlet (G3, G4 and G5). This further confirms the lengths of the groynes are inadequate to retain the majority of longshore transport within the beach compartments.

It is noted that the four-week simulation for the Summer period shows the same general outcomes at marginally reduced scales due to the lower wave conditions (refer Section 6.4.1).

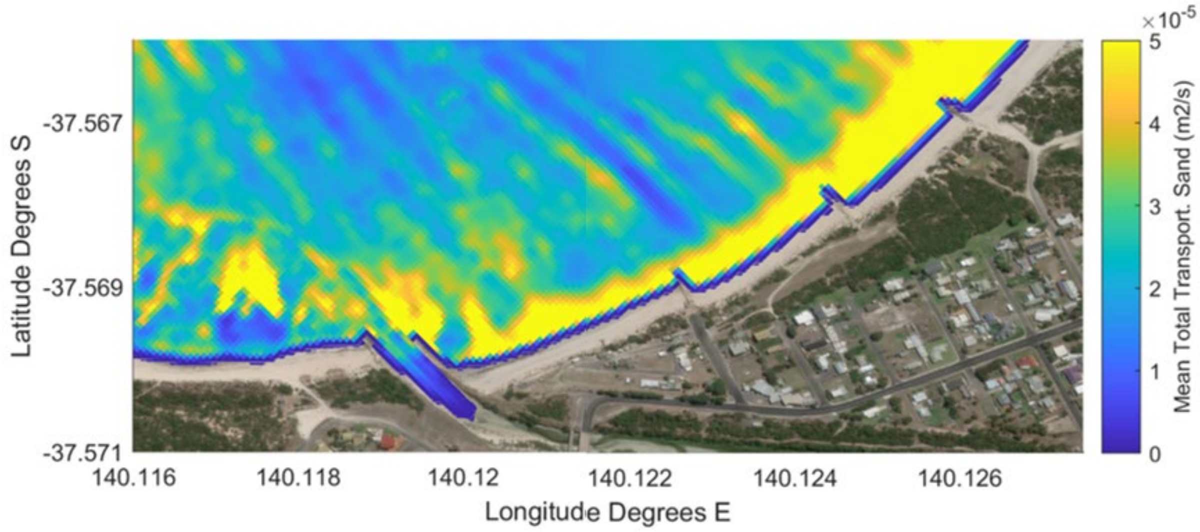
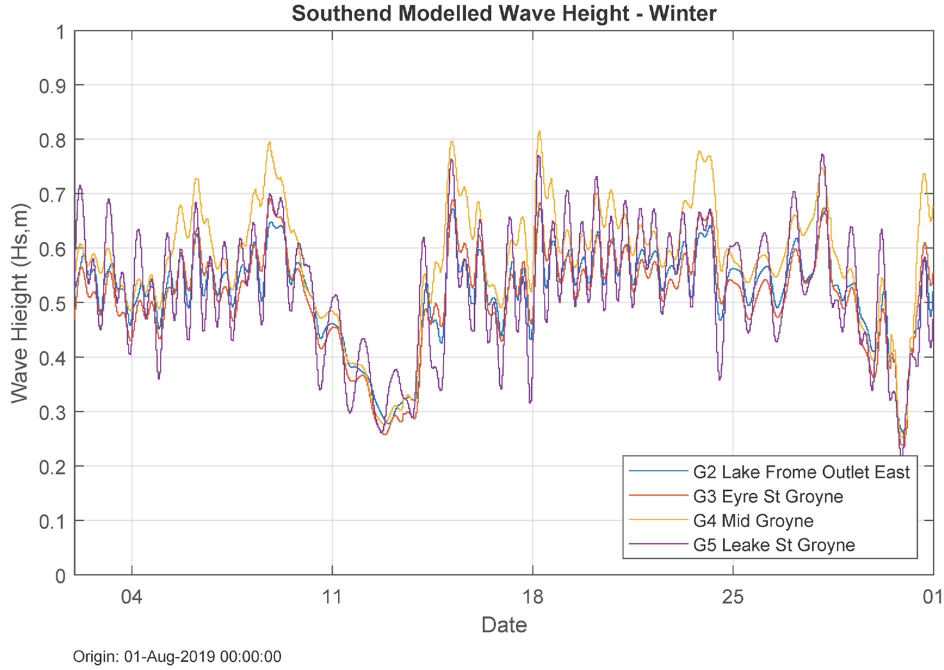


Figure 6.22: Mean Total Sediment Transport – Winter Base Case

6.4.1 Wave Conditions at Groyne Structures

The modelled wave height and wave direction at reporting locations assigned just offshore of each of the groyne structures G2 to G5 is shown in Figure 6.23 for the winter period and Figure 6.24 for the summer period.



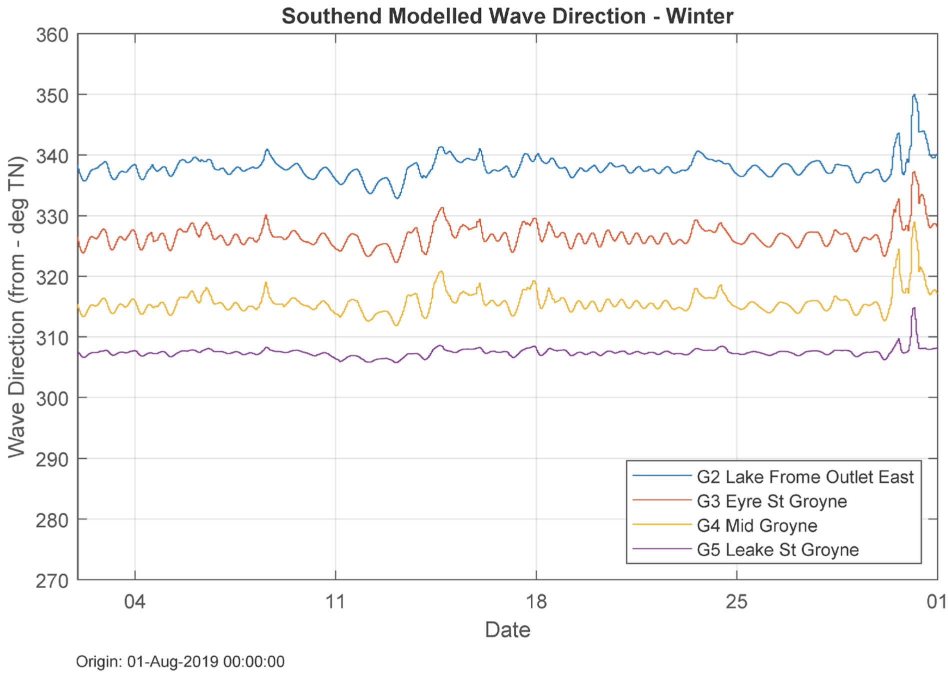
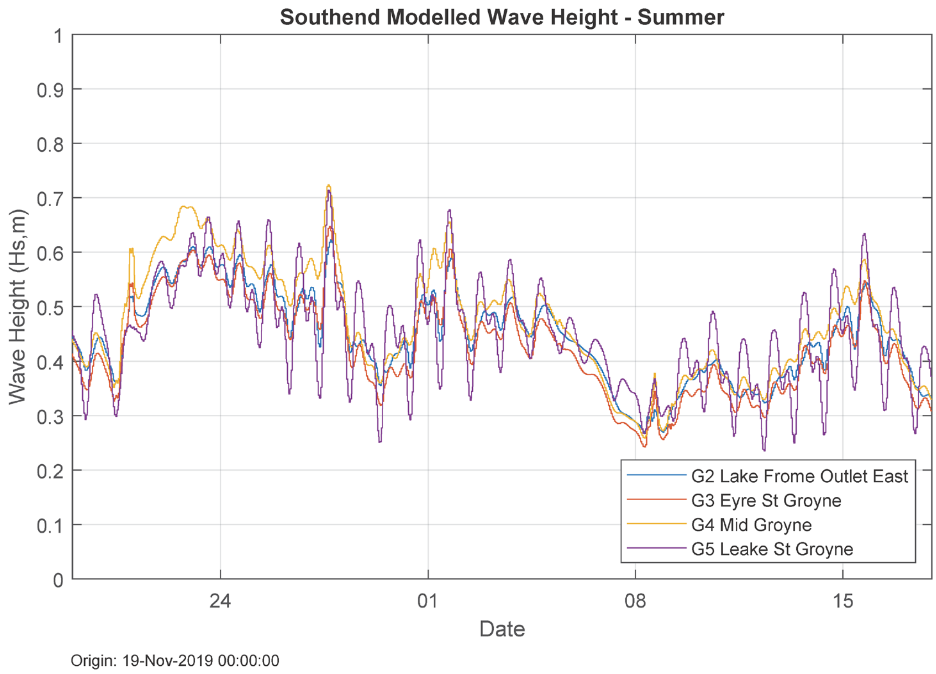


Figure 6.23: Modelled wave height (upper plot) and wave direction (lower plot) for Southend Winter period (August 2019) at the reporting locations just offshore of the four groyne structures G2 to G4.



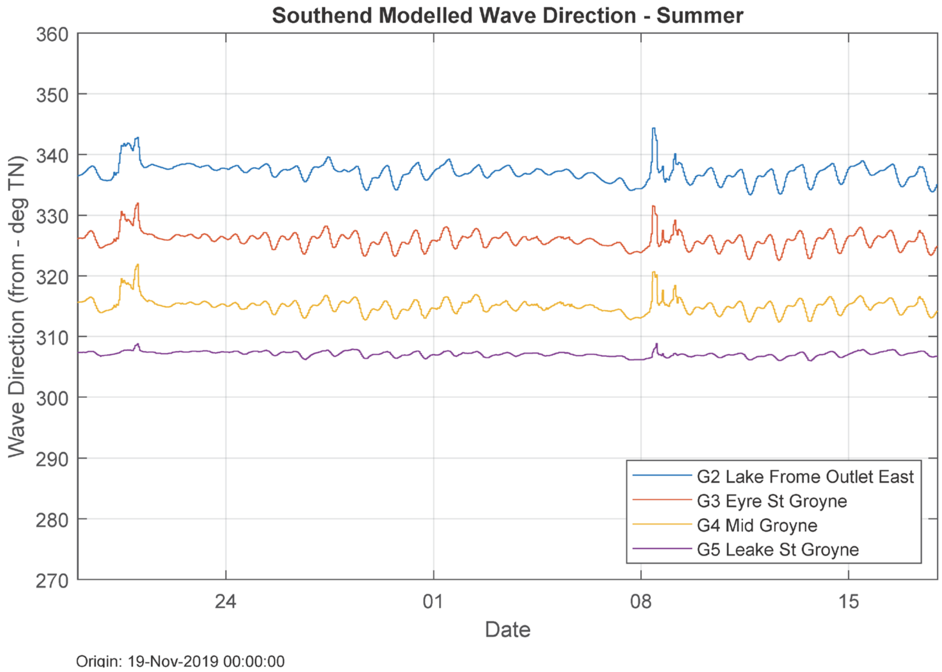


Figure 6.24: Modelled wave height (upper plot) and wave direction (lower plot) for Southend Summer period (December 2019) at the offshore location of the four groyne structures G2 to G4.

From the modelled wave conditions shown in Figure 6.23 and Figure 6.24 it is noted:

- the wave conditions in the winter period are more energetic than the summer period and that the wave height is generally increasing moving eastward along the Southend coastline. Conditions at each of the groyne heads are dependent on the relative position along the shoreline (eastern locations are more 'exposed') and the water depth at the structure head. As such, conditions at G2 and G3 are comparable, with conditions higher at G4. The end of the Leake St Groyne (G5) is located at a shallower depth and hence conditions are more tidally dependent.
- modelled wave direction at the head of each groyne structure is very consistent in the winter and summer, with minor deviations around the key direction within 5 degrees of the principal direction.

In Figure 6.25 the average wave direction approaching each of the Southend groynes is shown from the modelled winter and summer periods. The wave direction approaches approximately normal to each of the respective groyne structures. Moving east from groyne G2 to groyne G5, the wave direction rotates counter-clockwise about 10 degrees in each segment, influenced by the diffraction process around Cape Buffon and refraction in the southern section of Rivoli Bay. Of note, the mean wave direction approaching the eastern outlet groyne G2 is from 337˚TN, acute to the alignment of the groyne structure which is aligned on the axis 136˚ - 316˚.

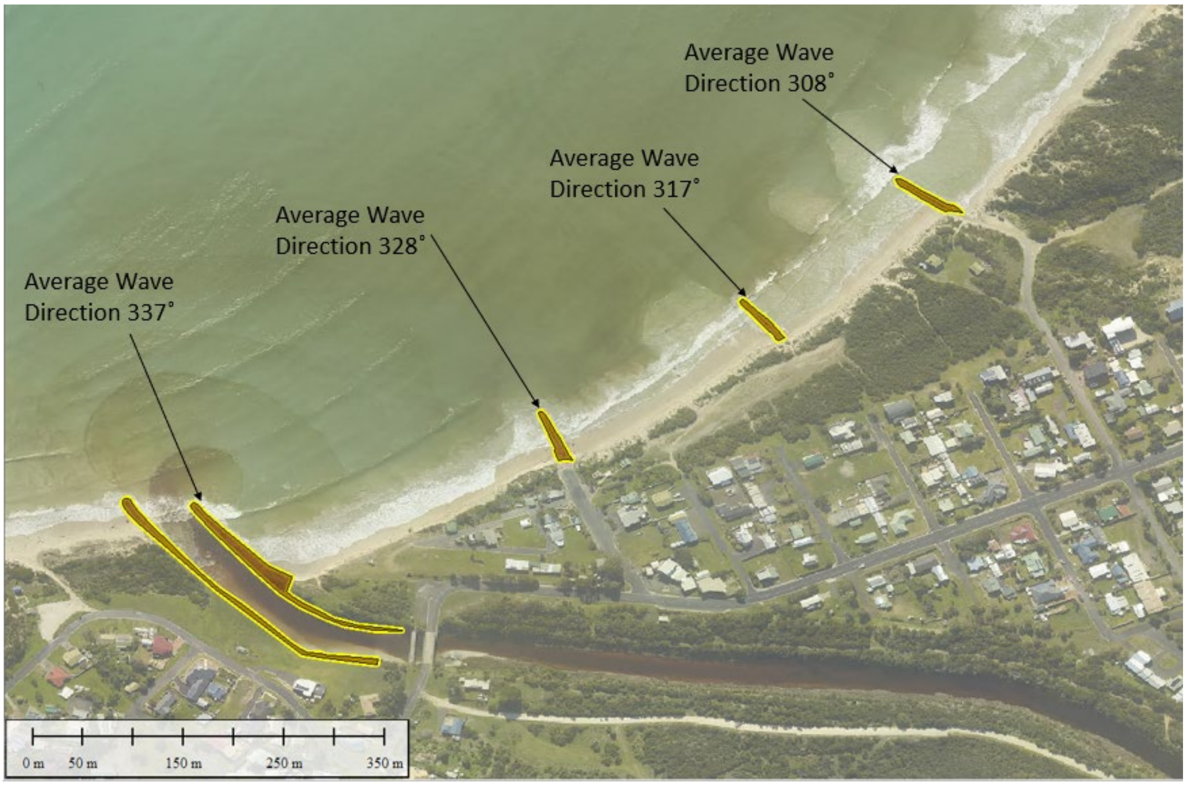


Figure 6.25: Modelled Average wave direction at each of the groynes based on representative winter and summer model cases.

6.4.2 Trapping Efficiency of the Lake Frome Outlet

The base case model was used to assess the sediment lost into the Lake Frome outlet as summarised in Figure 6.26. The winter and summer model scenarios showed approximately 15% to 20% of the east bound sediment passing offshore of the western Groyne cross section (G1) is lost into the outlet cross section.

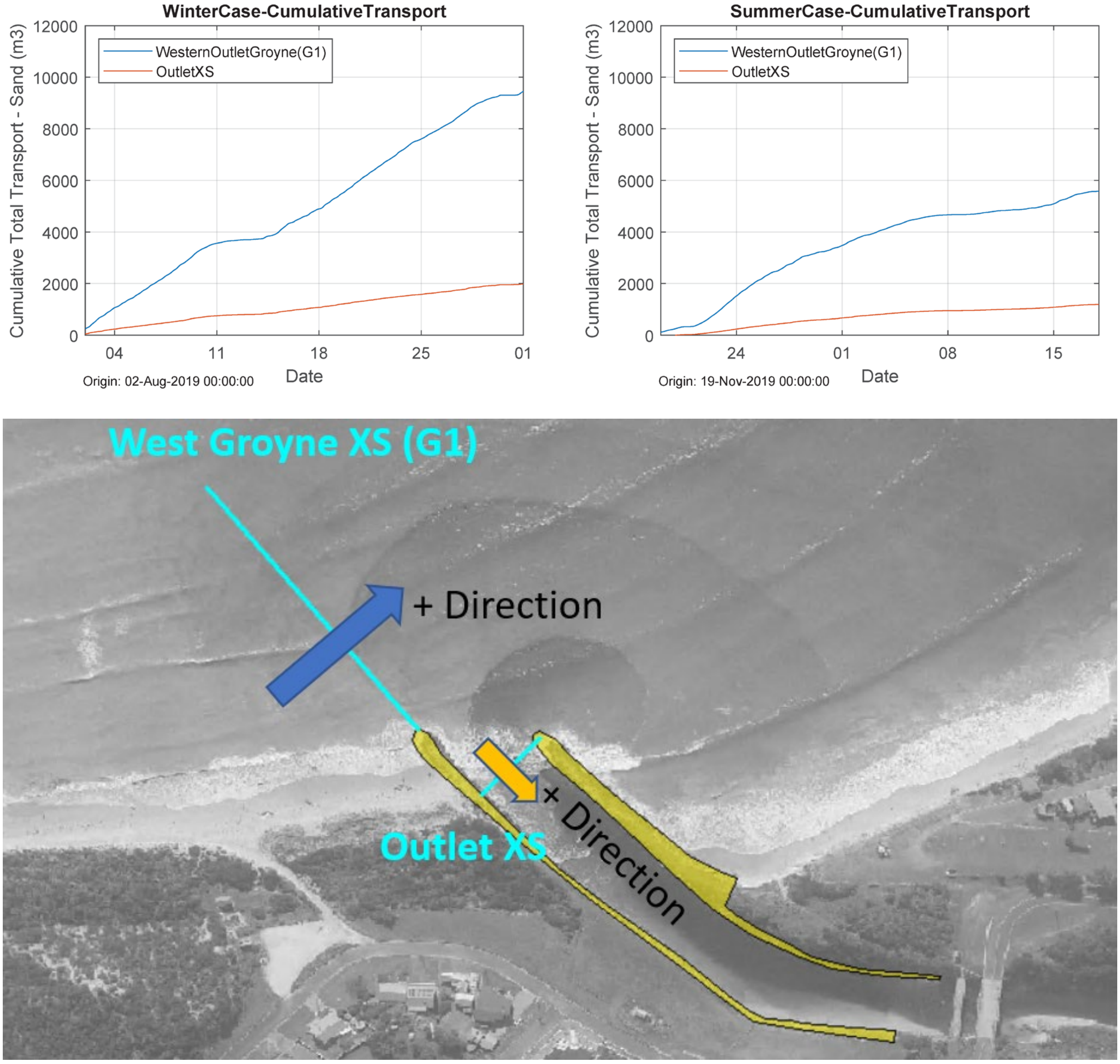


Figure 6.26: Analysis of modelled cumulative sediment transport at the Western Groyne (G1) and the Outlet. The cumulative sediment transport volume is shown for the winter case (top left) and summer case (top right). The two Cross Section extents are shown in the lower plot with the direction of positive sedimentation indicated.

6.5 Potential Mitigation Options

Options to reduce the rate of shoreline recession and restore beach widths along the Southend foreshore are aimed at reducing the trapping efficiency at the Lake Frome entrance, reducing the wave exposure of the shoreline (and hence transport potential) and maintaining an adequate beach width. To achieve these outcomes, the following options were proposed:

- **Reducing the trapping potential of the Lake Frome Outlet (Option S1)**. The Lake Frome outlet groynes act to capture sediments in the outlet channel and trap sediments from being transported to the eastern groyne compartments. The removal of both outlet groynes would allow greater movement of sediment to the eastern compartments. Their removal would effectively block the Lake Frome outlet, which is already heavily silted, returning it to a naturally intermittently open entrance, but promote the easterly transport of sediment.

- **Reducing the trapping potential of the Lake Frome Outlet (Option S2)**. Since the construction of the Lake Frome Outlet Groynes, significant accretion of the beach to the west has been observed. Removal of the outlet groynes altogether would potentially have a major impact on this section of the beach, and hence optimisation of the western Lake Frome Outlet Groyne would be assessed in combination with removal of the eastern outlet groyne to balance dual objectives of maintaining beach width to the west of the Outlet while promoting further eastward transport.
- **Offshore breakwater or Submerged Offshore Reef Fronting Caravan Park (Option S3)**. The relative contribution of cross shore and alongshore transport, has been defined through the shoreline process modelling and it was identified that longshore transport past the offshore extent of the groynes under elevated wave conditions was the principal driver of sediment transport along this shoreline. As such, options to reduce the exposure of the coast in front of the caravan park (between Groynes G2 and G3), thereby reducing longshore transport rates and cross-shore transport potential (under storm conditions) could be investigated. Two alternatives that can be considered, are an offshore detached breakwater (Option 3a) and a submerged reef structure (Option 3b).
- **Modification to the Existing Groyne Field East of Lake Frome Entrance (Option S4)**. Options could include:
  - a) Lengthening and reprofiling the existing groynes. Defining the optimum length of the groynes will be based on the definition of the surf zone width over which longshore transport is found to occur and the effectiveness of the groynes will depend on the relative contribution of cross shore and alongshore transport on the modified shoreline position. Reprofiling of the existing groynes requires establishing an effective crest height informed through modelling of wave run-up levels on the beach. Both will be assessed via the shoreline process model.
  - b) Modification of the distance between groynes. This option will assess the addition of new groyne and repositioning of Groynes G3, G4 and G5 to optimise the effectiveness of the groyne compartments.

The list of mitigation options is outlined in Table 6.3 with the key design considerations for each summarised as justification as to which options were carried forward in the model assessment.

Table 6.3: Southend Mitigation Options summary

Option	Assessment Basis / Design Parameters
Option S1	This option has **not been carried forward at this stage**. The complete removal of the western breakwater would result in the western beach at Southend eroding from its current shoreline position, an outcome that would result in a loss of the amenity currently provided to the community. Reduction in the length of the breakwater to a point which could allow maintaining the beach width (preserving amenity) whilst also allowing greater transport of sediment eastward may be examined as part of future management of the Southend shoreline.
Option S2	The eastern outlet groyne is removed completely all the way back to the point of the current shoreline. Under this option the western outlet groyne remains unchanged to maintain the western beach amenity. This option assumes the outlet remains open.
Option S3a	A detached breakwater is placed 300m offshore of the eroding section of coast fronting the Caravan Park, to provide a barrier to incoming waves and reduce cross-shore wave energy. The ratio of the length of the offshore breakwater (200m) vs distance offshore (300m) was set to promote formation of a salient and avoid the formation of a tombolo (USACE Part V Chapter 3).

Option	Assessment Basis / Design Parameters
Option S3b	A submerged reef option was **not carried forward** in the model analysis at this stage. This option is a variation of the detached breakwater option (Option S3a). This option should be further explored following successful application of Option S3a, as a submerged structure will provide a better environmental outcome in terms of habitat creation and visual amenity.
Option S4a	For this option the model extended the three groynes east of the outlet seaward, with the length determined to achieve a ratio of spacing between groynes to groyne length of between 2 and 3. G3 was extended 45m, G4 was extended 35m and G5 extended 30m seaward.
Option S4b	Additional groyne structures in Southend not likely to be supported as the preferred strategy from perspective of beach amenity and cost of establishment / maintenance. **Option not carried forward.**

The list of design options assessed in the model are summarised as:

- Base Case (present day)
- Option S2 – Removal of the eastern outlet groyne
- Option S3a – Addition of detached offshore breakwater
- Option S4a – Lengthening the three groynes east of the outlet

Each of the options is shown conceptually in Figure 6.27 to Figure 6.30.

Figure 6.27: Southend Base Case – Groynes G1 to G5 labelled moving eastward

Figure 6.28: Option S2 – Removal of the eastern outlet groyne G2

Figure 6.29: Option S3a – Inclusion of Offshore breakwater

Figure 6.30: Option S4a – Lengthening the three groynes east of outlet (G3, G4 and G5)

6.6 Options Analysis

To assess the relative merits of each of the mitigation options the numerical model systems developed for Southend were applied in the sections to follow. A summary of the analysis techniques and the intent and purpose in assessment is outlined below:

- The shoreline process model was applied to define the baseline potential longshore transport within each beach compartment at Southend.
- The regional coupled hydrodynamic and wave model system was downscaled across Southend to define the influence of the various entrance and groyne structure and assess the Options for sediment bypassing of each structure based on the high resolution 2D domain.
- The shoreline position model was then applied to estimate the shoreline alignment under each Option. This analysis assumes that there is an overall balance in the sediment budget within each beach compartment, which is shown below to not always be the case.

Consistent with the modelling completed in the sections above, each of the options was assessed through modelling of a representative one-month period for both winter and summer periods, both from within the data collection period which was shown to be a good representation of the longer term metocean climate (see Section 3.2.2).

6.6.1 Spatial Wave Conditions

An example of the modelled wave conditions from the high resolution 5m grid domain for the base case and the three design options is shown for the Winter cases along the Southend shoreline in Figure 6.31 to Figure 6.34 (timestep shown is 20th August 2019 at 0500 UTC).

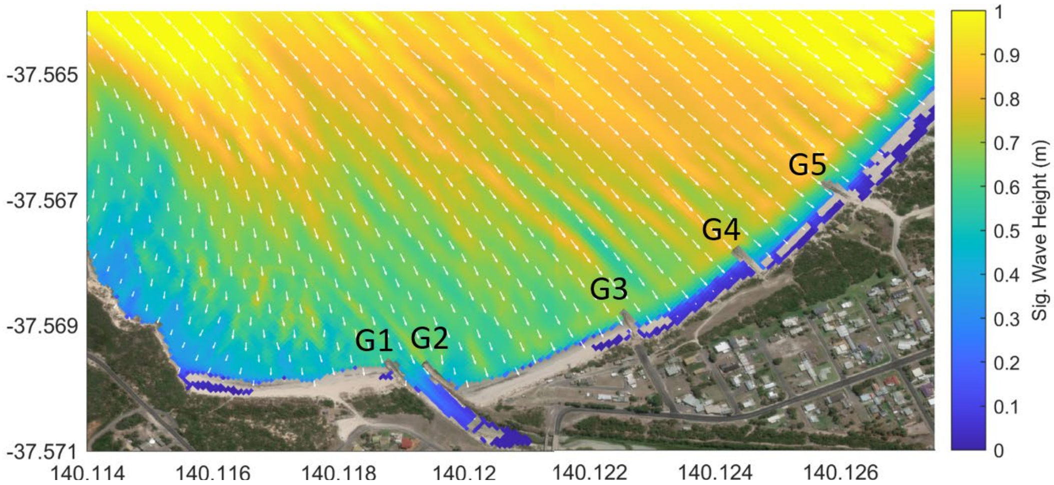


Figure 6.31: Modelled Significant Wave Height. Southend Existing Case Bathymetry (Model Timestep: 20 August 2019 at 0500 UTC)

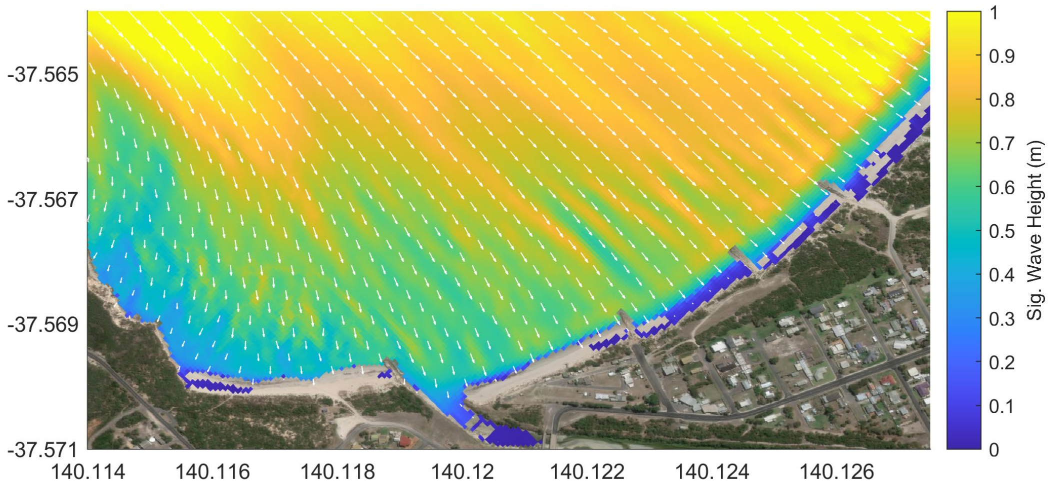


Figure 6.32: Modelled Significant Wave Height. Southend Option S2 case, removal of Groyne 2 (Model Timestep: 20 August 2019 at 0500 UTC)).

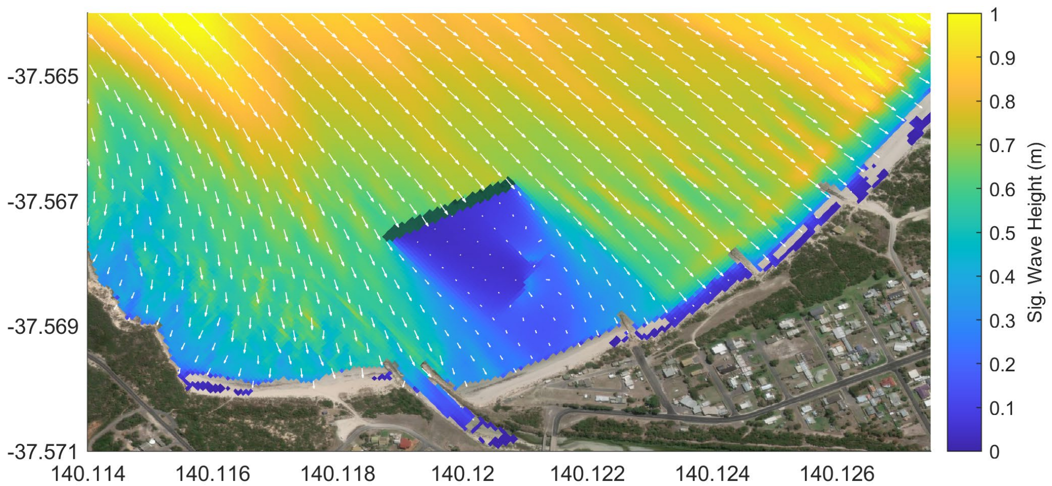


Figure 6.33: Modelled Significant Wave Height. Southend Option S3a case, Offshore breakwater (Model Timestep: 20 August 2019 at 0500 UTC).

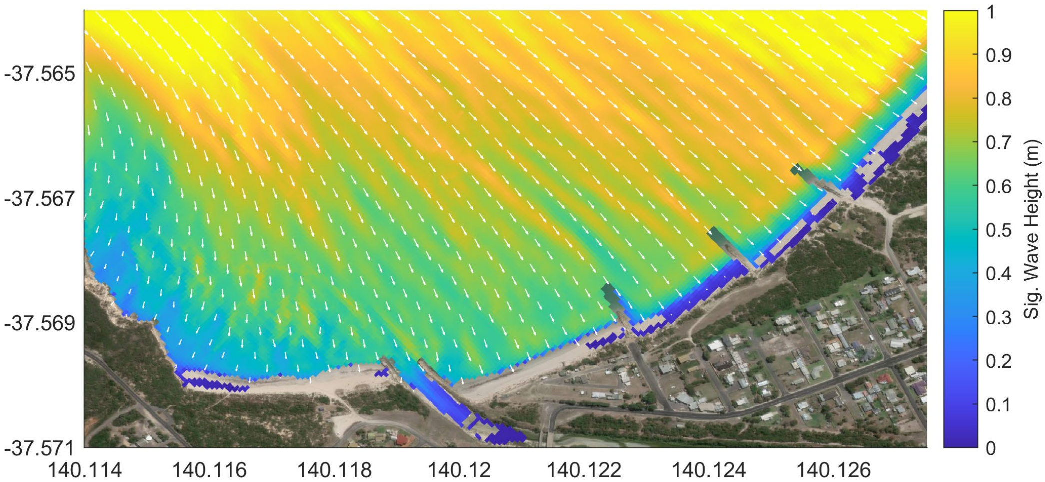


Figure 6.34: Modelled Significant Wave Height. Southend Option S4a case, extension of Groyne 3, Groyne 4 and Groyne 5 (Model Timestep: 20 August 2019 at 0500 UTC).

6.6.2 Spatial Transport Potential

The base case model and three design options were analysed over the winter period (4 weeks) to examine the sediment transport potential along the Southend shoreline from the combined processes of bed load and suspended loads. The mean transport rate was output from the respective model cases calculated in each grid cell of the model over the full 4-week duration. The model outcomes are shown in Figure 6.35 to Figure 6.38 indicating the transport rate is highest along the shoreline area and increasing moving east. A summary of the comparison between the base case and 3 Option cases shows:

- The base case in Figure 6.35 shows the active region near the shoreline extends beyond the offshore footprint of the 3 groyne structures east of the Frome Lake outlet (G3, G4 and G5). This further confirms the length of the groynes is inadequate to retain the majority of longshore transport within the beach compartments;
- For the Option 2 case in Figure 6.36 the removal of the outlet eastern groyne structure results in enhancement of sediment transport processes at the western end of the compartment relative to the base case;
- For Option 3a case shown in Figure 6.37 the offshore breakwater removes the transport influence entirely in the lee of the structure over the 1-month period. The beach compartment east of the outlet fronting the caravan park shows significant reduction in sediment transport. There is a reduction in wave conditions in the next compartment between G3 and G4 with a reduction of approximately 5% in transport noted in the model against the base case;
- For the Option 4a case the extension of the three eastern groynes shows that the sediment transport process along the shoreline is largely contained within the compartment at Groyne 3 and Groyne 4. For Groyne 5 far greater capture is achieved however the transport processes extend further offshore than the extended Groyne Option.

It is noted that the four-week simulation for the Summer period show the same general outcomes at marginally reduced scales due to the lower wave conditions (refer Section 6.4.1).

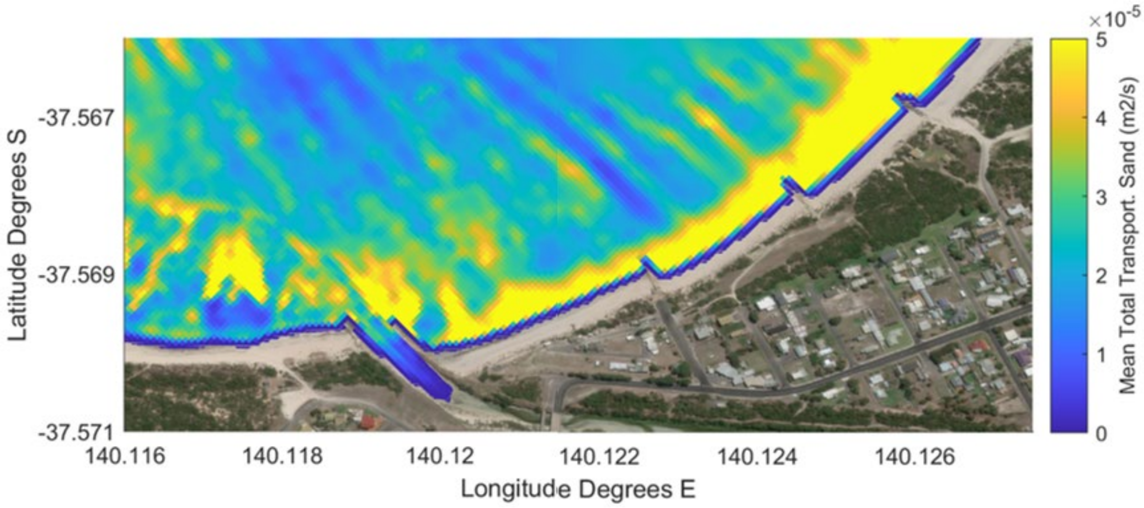


Figure 6.35: Mean Total Sediment Transport – Winter Base Case

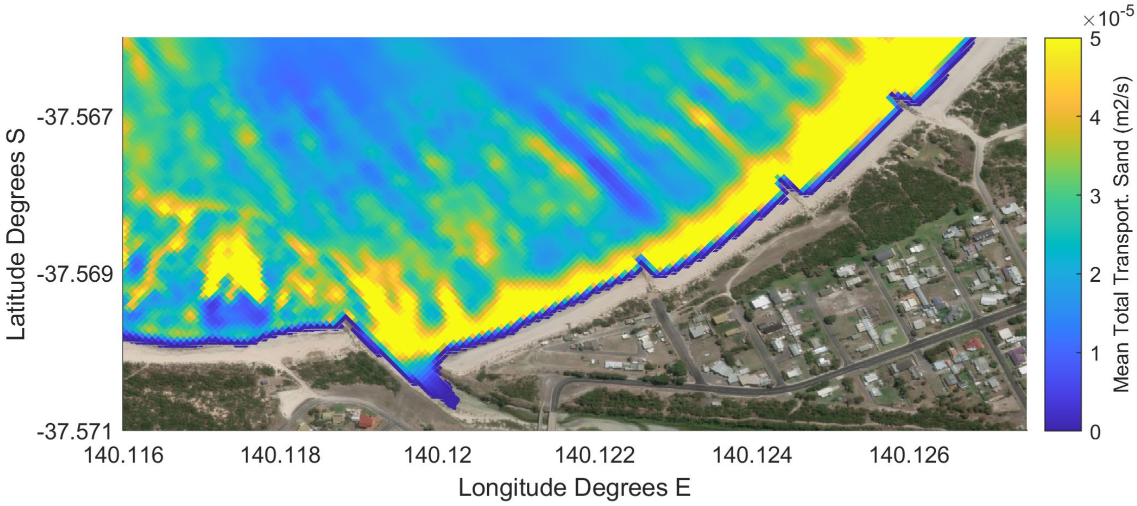


Figure 6.36: Mean Total Sediment Transport – Winter Option 2

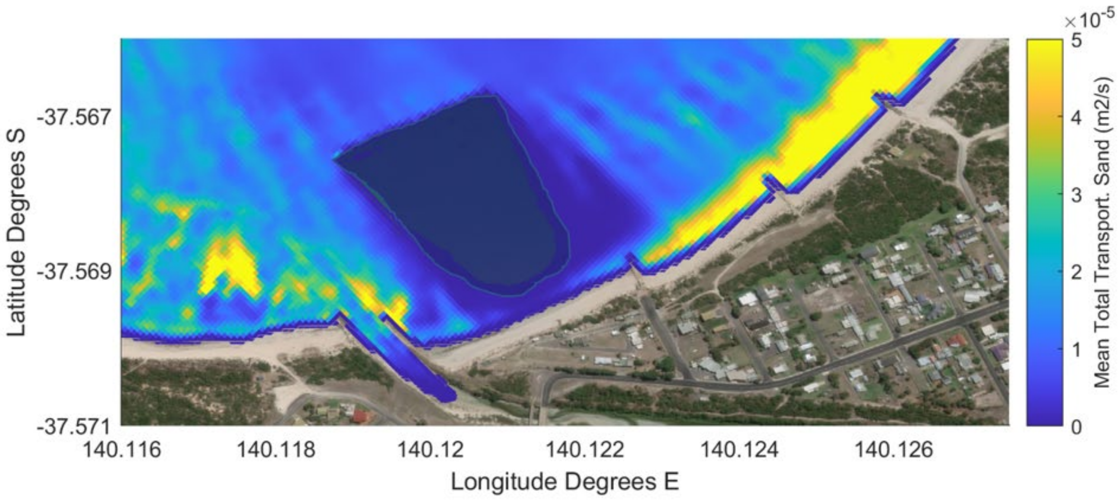


Figure 6.37: Mean Total Sediment Transport – Winter Option 3a

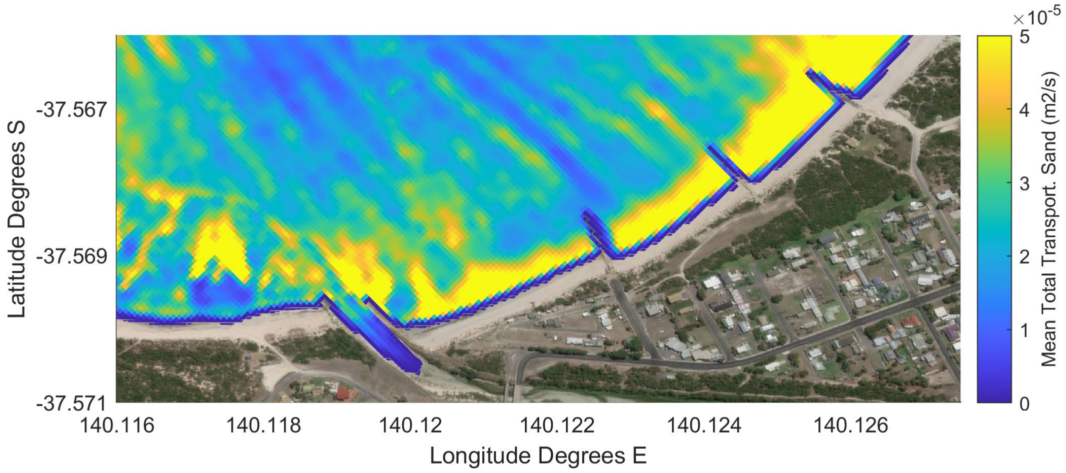


Figure 6.38: Mean Total Sediment Transport – Winter Option 4a

6.6.3 Longshore Transport Estimates

To provide a quantitative estimate of the three model cases, the results from the shoreline process model (Section 6.3) were combined with the transport potential outcomes (Section 6.6.2) and benchmarked against the beach profile analysis to develop a representative overview of annual sediment transport regime along the Southend shoreline.

The results from the model were analysed within specific offshore seabed contours to determine the transport rates relevant to the beach compartment response, as follows:

1. offshore of the groyne structures out to a depth of -3m MSL contour under the assumption this depth approximates to the start of the wave breaker zone where transport processes are most active.
2. along the shoreline area contained within the groyne structures. For groynes G1 to G4 this is a depth of ~1.0 m MSL contour, whilst for groyne G5 this is ~0.5 m MSL contour.

This representation is shown in Figure 6.39 for the base case. The transport rate along the shoreline has been normalised based on the calculated transport rate of 30,000m^3 annually around the western outlet groyne (G1) from the transect analysis (Figure 6.12).

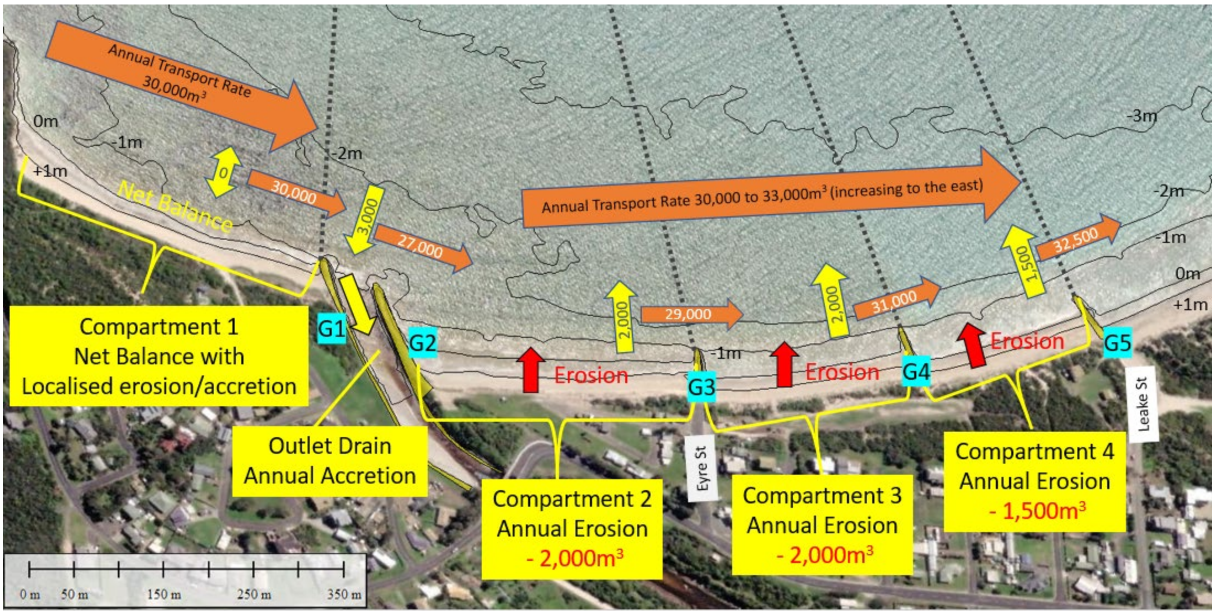


Figure 6.39: Base case representation of Annual Longshore Transport rate for the Southend Shoreline

The base case volumes have been scaled to represent an annualised volume based on model outcomes from the 6-month period examined and reported in the shoreline process model. The cross-section results from XS0, XS1, XS2 and XS3 have been used to represent the four beach compartments in the base model in Figure 6.39 numbered from left to right.

The base case representation in Figure 6.39 indicates that the annualised transport rate increases moving eastward along the shoreline. As stated previously the increase in transport rates going east is attributable to the relative exposure of the shorelines to offshore conditions. This increase in transport rate moving eastward presents a sediment volume imbalance along this section of coast that drives the observed beach volume loss. In simple terms the demand for sediment in each of the compartments is higher than the volume supplied into it. The sediment sink, between the Lake Frome outlet groynes is noted as capturing an annual volume of 3,000m^3. This volume is based on the analysis of sediment moving around the western breakwater (G1) from Compartment 1 to Compartment 2 and the amount that is lost from the sediment budget.

Base Case

The effectiveness of the Base Case groyne field in trapping the long shore transport was assessed by examining the rate captured within the groyne structures against the total rate out to a depth of -3m MSL. The results are summarised in Table 6.4.

Table 6.4: Analysis of Southend Longshore Transport Volume Captured by Groyne Field

Compartment	Depth of Offshore Extent of Groyne	% Captured of Transport to -3m MSL depth
Compartment 1: West of G1	-1m MSL	42%
Compartment 2: G2 to G3	-1m MSL	25%
Compartment 3: G3 to G4	-1m MSL	35%
Compartment 4: G4 to G5	-0.5m MSL	15%

It is evident from the results in Table 6.4 that there is significant volume of sediment moving eastward offshore of the groynes that is not captured by the groyne field. The most effective groyne is Groyne 1 on the west side of the Lake Frome Outlet capturing 42% of the sediment. This is evidenced in the accretion on the western beach and stability of this beach compartment (beach compartment 1). The three beach compartments east of the Lake Frome outlet suffer from a lack of trapping efficiency, most notably at Groyne 5 (Leake St Groyne) where the seaward extent only reaches the -0.5m MSL depth resulting in a trapping efficiency of 15%.

Option 2

For the Option 2 scenario where Groyne 2 is removed, thereby reducing the capacity of the sediment sink within the outlet, the changes to the system are described in Figure 6.40. The removal of the eastern outlet groyne (G2) results in additional sediment supply to beach compartment 2 (between G2 and G3). It is noted that the outlet remains open under this scenario and there will likely still be some loss of sediment into the outlet drain albeit at a much-reduced rate compared with the base case. The removal of the eastern groyne (G2) provides a small increase to the sediment supply in beach compartment 2, with transport rates unchanged through all other compartments and the overall net effect to the system being negligible in terms of shoreline changes from the base case, other than a realignment of the shoreline in front of the caravan park as shown in the upper plot in Figure 6.44.

It is noted that there may be an opportunity to close the outlet drain altogether as part of this option, however the potential for flooding impacts would need to be assessed if this were to occur.

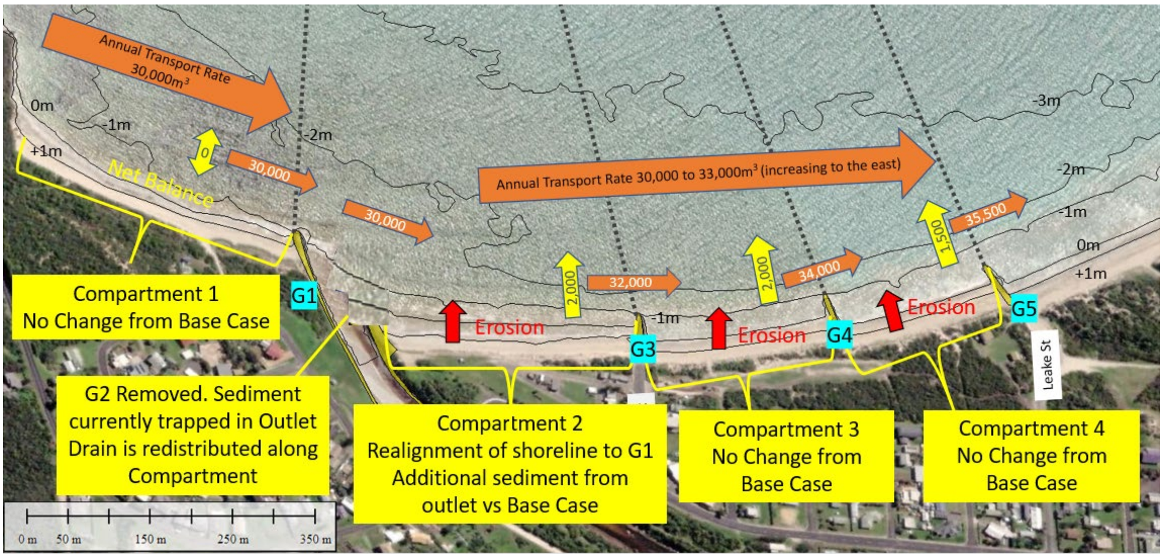


Figure 6.40: Option 2 case representation of removal of the eastern outlet groyne (G2) and changes to the Annual Longshore Transport rate for the Southend Shoreline

Option 3a

For the Option 3a scenario, the impact of the offshore breakwater on transport rates is shown in Figure 6.41. The introduction of the offshore breakwater has a profound effect on the transport rate in Compartment 2, dramatically reducing the longshore transport rate.

Model outcomes indicate a 97% reduction in transport volumes, due to the offshore breakwater eliminating the key driver of longshore transport (i.e. the incident waves). The supply of sediment from Compartment 1 through the longshore transport mechanism is unchanged with the presence of the offshore breakwater. As a result, sediment from Compartment 1 would be directed around Groyne 2 into the west end of Compartment 2 at similar rates to the base case. Over time a salient would be expected to form on the beach of Compartment 2 in the calm zone behind the offshore breakwater where the wave height and longshore current speed are reduced, leading to the sand being deposited on the shoreline (Hanson et. al., 1990).

In the two beach compartments to the east of the Eyre Street Groyne (G3), the inclusion of the offshore breakwater results in a reduction of the modelled transport rate of between 5% and 20% compared with the base case. Of note, the sediment supply from Compartment 2 to the compartment's eastward would be greatly reduced due to the elimination of the littoral process in the lee of the breakwater. It is expected that the reduction in sediment supply from compartment 2 to the compartments east would result in exacerbating the erosion pressure in the beach compartment 3 and compartment 4 that are currently experienced.

In summary the offshore breakwater shows great potential for reducing the wave conditions in the lee of the structure and promoting stability and accretion in beach compartment 2, at the expense of the beach compartments to the east (compartments 3 and 4) which would likely suffer increased erosion pressure due to a reduction in longshore sediment supply. Further, potential shallowing of bathymetry on the western beach is also possible.

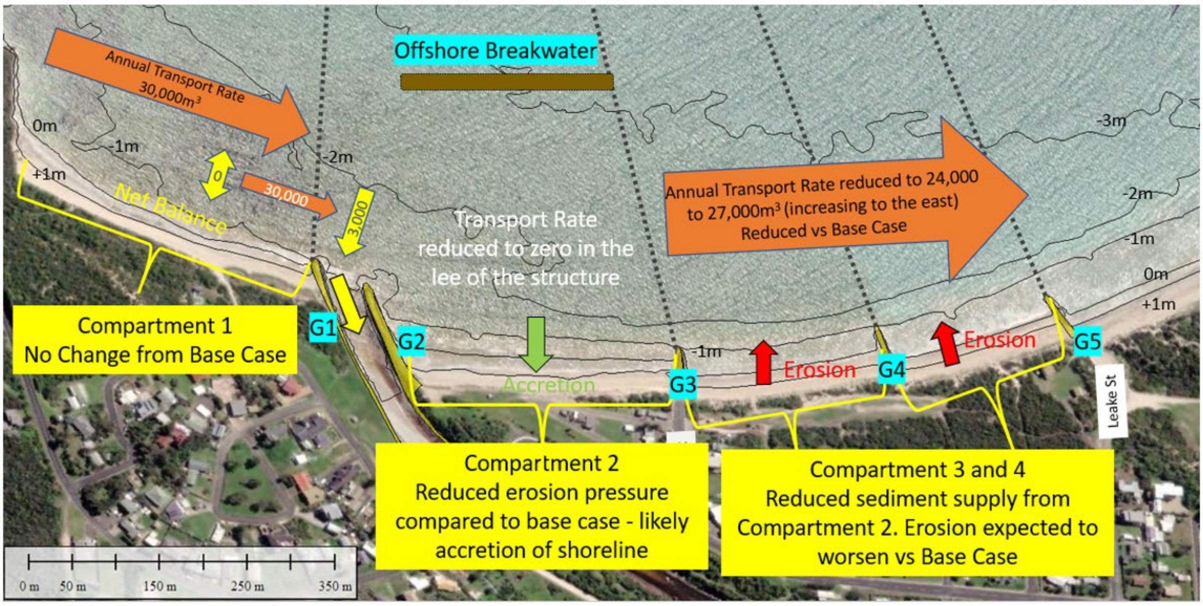


Figure 6.41: Option 3a case representation of offshore breakwater and changes to the Annual Longshore Transport rate for the Southend Shoreline

Option 4a

For the Option 4a scenario the extension to the groynes is shown in Figure 6.42 with the resultant changes to the transport potential. The extension of the groyne system is found to be very effective at increasing the trapping efficiency of the groyne field:

- At Groyne 3 (Eyre St) the trapping effectiveness increases by approximately 110% when compared against the base case.
- At Groyne 4 (Eyre St) the trapping effectiveness increases by approximately 100% from the base case.
- At Groyne 5 (Eyre St) the trapping effectiveness increases by 400% against the base case.

The increase in trapping efficiency of the structures would lead to a build-up of sediment on the eastern end of the beach compartments and downdrift erosion on the western side of the groyne features, similar to what is currently observed along the Southend shoreline. Over a period of time realignment of the beach may occur as a new equilibrium is established.

A projection of the shoreline growth in front of the caravan park is shown in the lower plot of Figure 6.44. It is noted that in extreme events the erosion on the western end of Compartment 2 in front of the caravan park may continue under Option 4a if Groyne 2 remains in its current location. Removal of Groyne 2 would move this erosion pressure further west into what is currently the sediment sink between Groyne 1 and Groyne 2, an area that could accommodate this demand for sediment in extreme events much better than the present location in front of the caravan park.

Whilst beach width will fluctuate due to storm events the extension of the groynes is expected to address the recessional trend by ensuring adequate longshore volume is captured between groynes during typical ambient conditions thus providing a sediment buffer in the respective compartments to serve as natural protection against erosion in extreme storm events.

It is noted that the increased efficiency of the Southend groyne system under Option 4a as it is currently presented (extensions of G3 by +45m, G4 by +35m and G5 by +30m) would likely place greater erosion pressure on the beaches further east of the Leake St groyne. Optimisation of the groyne lengths to balance the bypass volumes between compartments (i.e. increase the bypass volume of G5) would be recommended as part of detailed design process should this option be pursued.

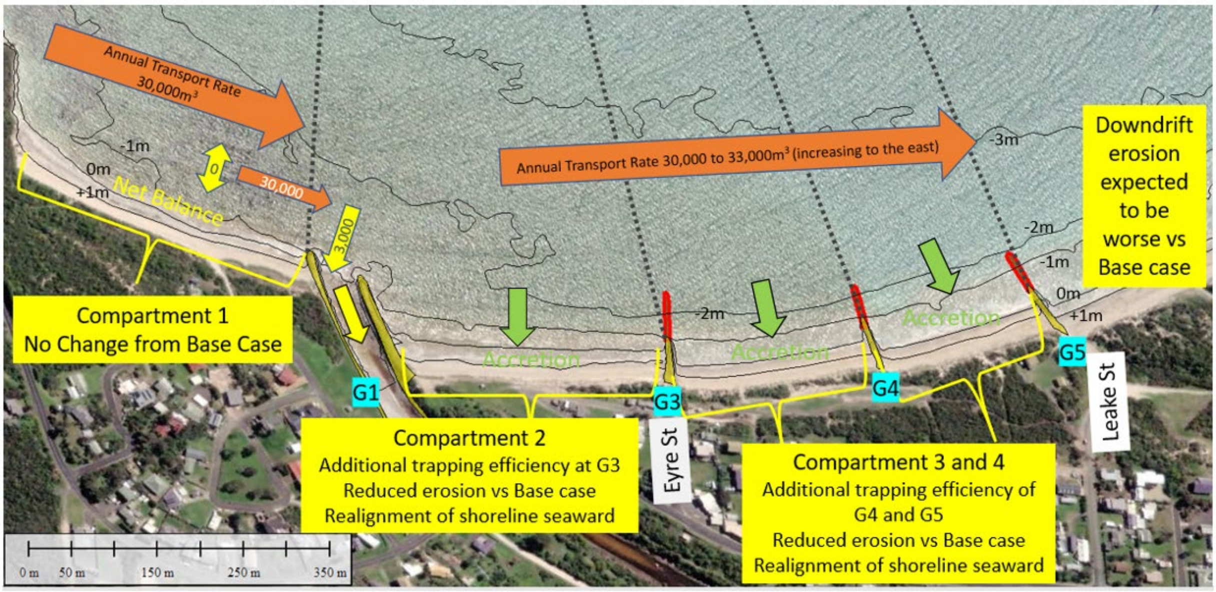


Figure 6.42: Option 4a case with extension to groynes G2, G3 and G4 and the representation of changes to Annual Longshore Transport rate for the Southend Shoreline

6.6.4 Shoreline Position Analysis

The shoreline position model outlined in Section 4.6 has been applied for Southend in the section of beach east of the outlet structures in front of the Caravan Park. The wave direction at the eastern outlet from Figure 6.25 (337˚TN) has been used as the basis for the calculation, with the downdrift control point assigned at the Eyre Street groyne structure (G3) approximately 295m east. It is noted the diffraction process typically seen at the Beachport beaches where waves arrive oblique to the groyne structures is not in evidence at Southend, rather the waves approach the coast normal to the structures which may limit the application of the method.

To ensure the applicability of the model, the predicted shoreline under the existing case (base case) is shown in the upper plot of Figure 6.43 which shows:

- the model predicts a beach alignment that is generally consistent with the observed shoreline.
- erosion of the shoreline at the western end of the compartment is not reproduced likely due to influence of the entrance groyne (i.e. wave reflection and enhancement at the shoreline due to the orientation of the groyne); and
- the alignment and shoreline position at the eastern end of the compartment is underestimated due to large compartment length over which the angle of wave approach would change (not accounted for in the model).

Overall, the shoreline position model is considered a useful tool to make comparison of the base case to the predicted shoreline alignment for the option cases:

- In the upper panel of Figure 6.44, the predicted shoreline is shown for Option S2 where the eastern outlet groyne has been removed. The predicted shoreline position follows the alignment of the Base case and continues through to the western outlet groyne.
- In the lower panel of Figure 6.44 the prediction of the shoreline under the assumption of an extension to the Eyre St groyne is shown (Option S4a), with the shoreline position moving offshore due to increased trapping efficiency.

Figure 6.43: Southend prediction of the Base Case shoreline between Groyne 2 and Groyne 3.

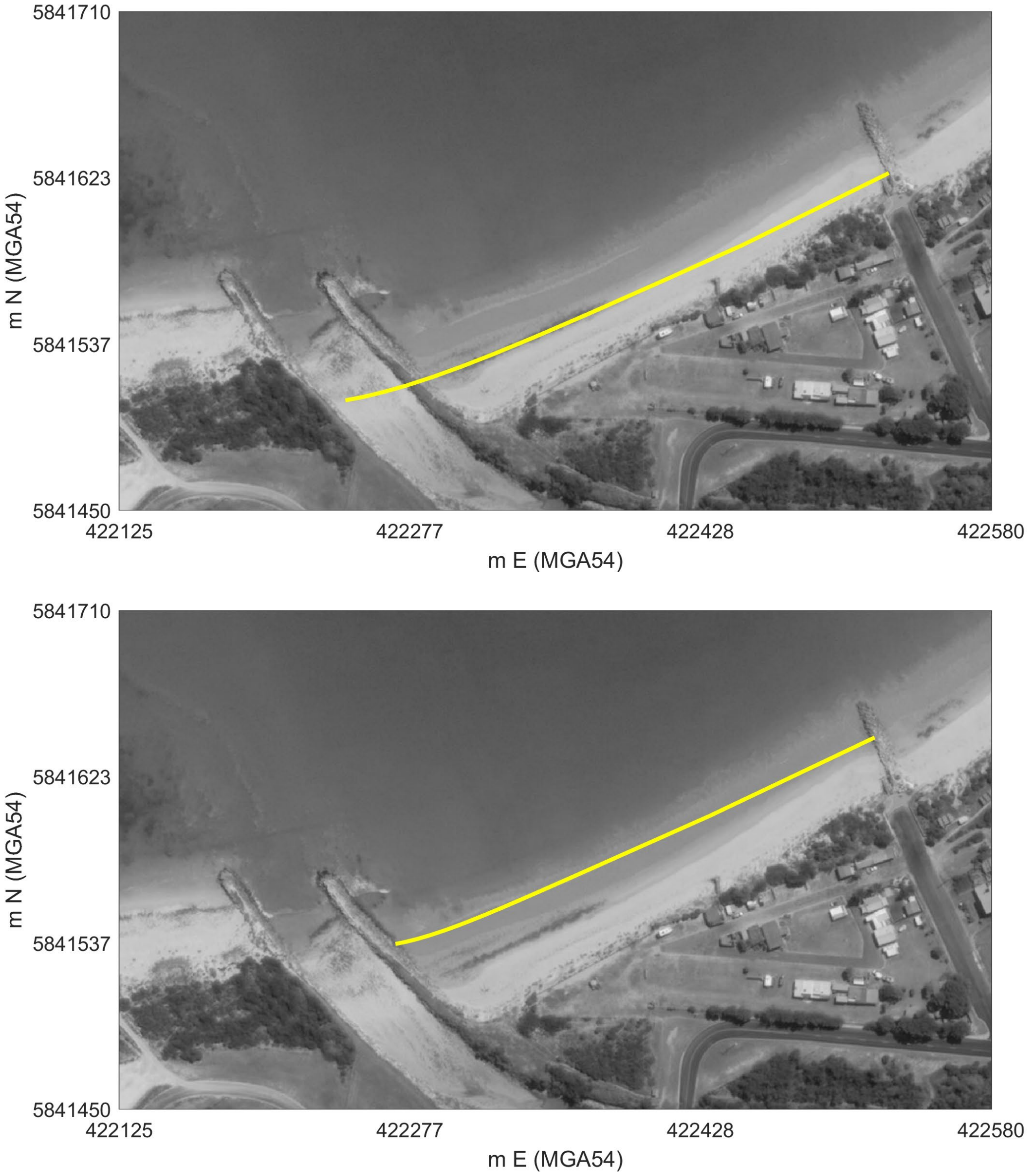


Figure 6.44: Southend predictions for shoreline between Groyne 2 and Groyne 3. Upper plot: Option S2. Lower plot: Option S4a.

Based on the results displayed in Figure 6.44 there are two general outcomes that are predicted by the shoreline position model in comparison to the base case:

1. The removal of the eastern outlet groyne (G2) does not influence the position of the shoreline from the current state in front of the Caravan Park, with the prediction showing the general shoreline alignment from the base case continued across to meet the western groyne. This is due to the fact that the groyne compartment is already relatively long with the eastern outlet groyne not significantly influencing the shoreline alignment within the compartment (predominantly a function of the incident wave angle and the orientation of the eastern outlet groyne that is angled to the west of the incident wave directions); and
2. The extension to the Eyre St groyne (G3) as per Option S4a, would result in a seaward translation of the current shoreline position due to increased trapping efficiency within the compartment. It is noted that based on the base case prediction, the seaward translation at the eastern end of the compartment is likely underestimated by around 10m.

6.7 Summary of Options Analysis

In summary, the results from the model cases show:

- Removal of the eastern outlet groyne (G2) (Option 2) would allow additional sediment to be directed into the beach compartment in front of the Caravan Park, significantly reducing the sediment sink that is currently in place at the outlet of Lake Frome between groynes G1 and G2. The modelling of eastbound sediment transport potential around the western groyne (G1) shows approximately 15% to 20% is lost into the outlet in its current arrangement. It is noted however that removal of G2 would extend the beach compartment length further than its current dimensions, and the storm induced erosion risk for the compartment would still be present.
- The modelling of Option 3a shows clearly the offshore breakwater reduces the wave energy approaching the Southend shoreline, with a complete reduction in the long-shore and cross-shore process. This option predicts that shoreline stability and accretion in beach Compartment 2 would occur and would lead to the formation of a salient in front of the caravan park, at the expense of the beach compartments to the east (Compartments 3 and 4) which would suffer increased erosion pressure due to a reduction in longshore sediment supply. It is noted the offshore breakwater concept has been modelled to test the effectiveness of the option at Southend, with the placement informed by engineering design guidelines for offshore detached breakwaters to promote the formation of a salient in the lee of the structure (USACE Table V-3-6, Dally and Pope 1986). Should this option be preferred, optimisation of the breakwater in terms of its size, position, form and alignment should be refined in future detailed design studies, informed by an assessment of available rock material in the local area and the re-use of rock material from removal of the eastern Lake Frome outlet groyne structure (Option 2) if this was to occur at the same time. For reference, the volume of rock to construct the offshore breakwater concept presented has been calculated assuming a length of 200m, side slope at 1V to 1.5H and seabed at 3m depth (mMSL) with approximately 7,000m^3 of material required. It is noted that the impact to the sediment supply into compartment 3 and compartment 4 would need to be further understood and addressed if this option were to be pursued.
- The analysis of Option 4a in the model to extend the existing groynes was shown to be very effective in increasing the trapping efficiency of the groynes for the compartments east of the outlet. This approach on its own would require a large volume of rock to extend the structures sufficiently offshore.

The recommendation from the analysis is for Option 2 and Option 4a to be implemented concurrently. The following is a summary of the actions and projected improvements from the current situation:

- Retention of Groyne 1 in its current location preserving the western beach shoreline amenity;
- Removal of Groyne 2 with a view to reusing the rock where possible to extend the groynes further east;
- Extension of Groyne 3, Groyne 4 and Groyne 5 would be undertaken to increase trapping efficiency.

With the removal of Groyne 2 the sediment trap in the Lake Frome outlet would provide an immediate boost to the source of sediment to Compartment 2 and going forward the longshore transport from Compartment 1 to Compartment 2 would be more efficient. Removal of the eastern outlet groyne (G2) would also provide a source of rock, albeit in weathered condition, that could be used to deliver material for an extended groyne at Eyre St (Option 4a).

Extension of the eastern groynes (Groyne 3, Groyne 4 and Groyne 5) would increase trapping efficiency and is expected to address the recessional trend currently observed by ensuring adequate volume of sediment is captured between groynes during typical ambient conditions thus providing a sediment buffer in the respective compartments to serve as natural protection against erosion in extreme storm events.

Under this scenario, the shoreline alignment in front of the Caravan Park is expected to stabilise and over time accretion of the shoreline would be anticipated under general ambient conditions with a new equilibrium shoreline projected to shift to that indicated in the lower plot of Figure 6.44. Beach nourishment could provide an initial enhancement to the compartment volume and achieve the predicted shoreline position sooner.

Presently it is noted that localised erosion appears to be enhanced on the eastern side of Groyne 2, at the western end of the Caravan Park. This is likely associated with an influence from the groyne structure itself as a result of wave reflections at the structure (due to the alignment of the groyne to the incident wave direction). Under the recommended scenario, Groyne 2 would be removed however the same localised erosion enhancement would be expected near the base of Groyne 1. This location at the base of Groyne 1 however is located away from the Caravan Park and is currently well supplied with sand being the Lake Frome outlet sediment sink.

The groyne extensions (G3, G4, G5) should seek to improve capture of longshore transport whilst balancing the bypassing potential of each structure such that the sediment budget within each compartment is equalised. Adopting this principal, the groyne extensions are proposed to be optimised based on LST rates and distributions from the sediment transport mode as follows:

- Groyne 3 (30m extension to -2mMSL);
- Groyne 4 (25m extension to -1.5mMSL); and
- Groyne 5 (25m extension to -1.5mMSL).

The general arrangement of this recommended option including optimised extension to the groyne is shown in Figure 6.45. Should this option be adopted, additional studies to quantify the volume of rock that could be provided from the removal of Groyne 2 and investigation of suitable construction approaches, their cost and limitations to extend the groynes should be completed. This would inform the final design and optimisation of the groyne extensions to achieve an acceptable balance between increased trapping efficiency and the cost of the works.

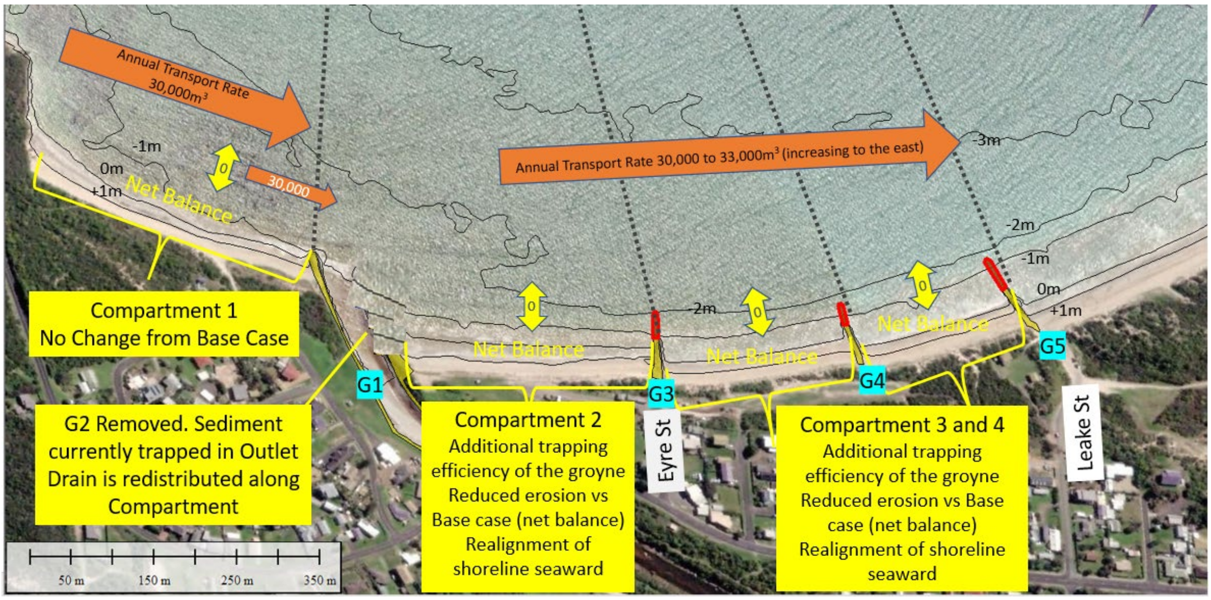


Figure 6.45: Final recommended option for Southend shoreline. Removal of Groyne 2 (eastern side of outlet) reduces the sediment sink in the outlet boosting sediment supply into Compartment 2. The groynes to the east are extended to achieve a balanced sediment transport budget offshore of the groynes and remove erosion pressure from the beach compartments.

It is noted that the eastward transport from Compartment 4 (bypassing of Groyne 5) would be reduced compared to the existing case, and as a result downdrift erosion may be expected in the short term while the groyne compartments reach their equilibrium volume. After this time, the bypass volume at Groyne 5 would increase and the potential for downdrift erosion would be reduced. The length of Groyne 5 could also be optimised to better balance the accretion and erosion differential either side of the structure.

Further consideration of the preferred option/s should be completed that considers the proposed protection measures for the shoreline informed by community and stakeholder engagement, economic assessment of options (cost benefit analysis, multi-criteria analysis) to deliver a strategy consistent with the long-term coastal adaptation planning and management of Southend.

6.8 Modification to the Existing Groynes

As discussed and recommended for the southern beaches of Beachport, reprofiling of the existing groynes to lower their crest levels can increase the effective permeability of the structures and create a more consistent shoreline position between adjacent groyne compartments. Further, lowering the crest level can improve visual and user amenity of the beach.

A review of the modelled wave data and LiDAR survey was completed to identify the active shoreline and natural berm level along these beaches. However, the LiDAR survey did not provide a clear indication of a berm feature. This may be due the beach being in an eroded state at the time of capture, although this could not be ascertained from the available data. Based on the wave climate, it would be expected that a berm would establish around a level of +2.5mAHD. A review of the historical profiles data (see Section 6.2.2) indicates a berm level of +2.5mAHD that is most discernible in the profile data pre-2000. The existing groyne crests are significantly higher than this level, generally sloping down in the offshore direction with crests around +4mAHD or greater at their landward end down to +1.5mAHD at their seaward ends. Figure 6.46 shows the three eastern groynes from the site visit in January 2020.

Figure 6.46: Photo taken in January 2020 from Compartment 2 looking east across the three eastern groynes at Southend (G3, G4 and G5).

The groyne crests are large emergent structures at present and to improve the continuity of the shoreline position between beach compartments, the groyne crests could be lowered to be at or up to 0.5m below the natural berm level. A lowered crest towards the landward end could be established between +2 to +2.5mAHD, with the existing profile maintained down to a crest of +1.5mAHD at the shoreward end. A crest level at +2 to + 2.5mAHD would allow for wave runup over the structures during elevated nearshore conditions that would promote the overwash of sediment between beach compartments.

It is noted that this would only be recommended in combination with the recommended mitigation option (i.e. groyne lengthening) so as to improve the nearshore trapping efficiency of the groynes.

As noted previously there is no definitive design guidance for low crested groynes and no reliable analytical tool to estimate the bypass volume over the lower crest level. It is recommended that the reprofiling be used to source material for the groyne extensions, thereby reducing initial capital cost, however that a monitoring program be implemented to ensure the intended function and response is being achieved. Should it be required, additional material could be added to the low crested structure to optimise the design.

7. Beachport Boat Ramp

Since the construction of a breakwater in 2014 on the ocean side of the basin, there has been significant sediment accumulation in the Beachport Boat ramp area. The extension by approximately 100m in length to the north (parallel to the rock revetment armouring the shore) was constructed to form a larger protected basin to improve conditions for boat launching at the boat ramp. While allowing a significant amount of longshore transport to bypass the area, sediment in the form of fine sands manages to work its way into the basin area, creating a considerable ongoing burden in the maintenance of navigable depths.

The focus of this assessment is to develop an understanding of the longshore drift process along the boat ramp basin eastern breakwater and its influence as a source of sediment and driver for sedimentation in the entrance of the basin.

The prevailing action for sediment transport along the Beachport foreshore is identified as longshore drift due to wave action in a northerly direction. However, longshore transport along the coast to the north does not account for the accumulation of sands in the boat ramp area and the potential for north to south sediment transport into the boat ramp marina basin is not well defined.

7.1 Conceptual Sediment Transport Model

A number of transport mechanisms have been hypothesised as being contributors to the significant sedimentation observed within the boat ramp area, including wind and wave driven transport over and through the breakwater extension, the influence of an anti-clockwise shore current that may be driving sediment transport into the boat ramp area, or reflected long wave energy from the shorelines to the north.

In the measured data for the Beachport location collected approximately 100m from the end of the jetty the measured current speeds were noted as being low velocity and flowing predominantly southward as a result of a tidal circulation within Rivoli Bay (see Section 3 and Appendix A). The alongshore current associated with the wave conditions acts in a northward direction. This results in varying nearshore current conditions at Beachport, with currents going northward along the shoreline (wave driven) and current direction heading southward (tidally driven) offshore. This reversal of currents was observed in the roving ADCP transects collected for the project and replicated by the local scale model (see Section 4.4.1).

Based on the low velocity of the measured currents from the ADCP location and the hydrodynamic modelling outcomes, the anti-clockwise shore current is not considered a primary driver of sedimentation into the boat ramp area. Although such an anti-clockwise circulation is present due to the tidal circulation within Rivoli Bay, the associated current magnitudes are small (typically <0.1m/s) and as a result would be unlikely to have the capacity to drive significant suspended sediment loads (for sediments of D50>0.15mm) that oppose the principal northerly nearshore littoral flows along the Beachport shoreline. This analysis is supported by the current map presented in Figure 7.1, that is typical of the current field in the vicinity of Beachport when current speeds at the ADCP location exceed 0.1m/s. It also seen in Figure 7.2 that close to the boat ramp entrance current speed and direction is dominated by the surf zone (wave generated) current that consistently flows north, consistent with the incident swell.

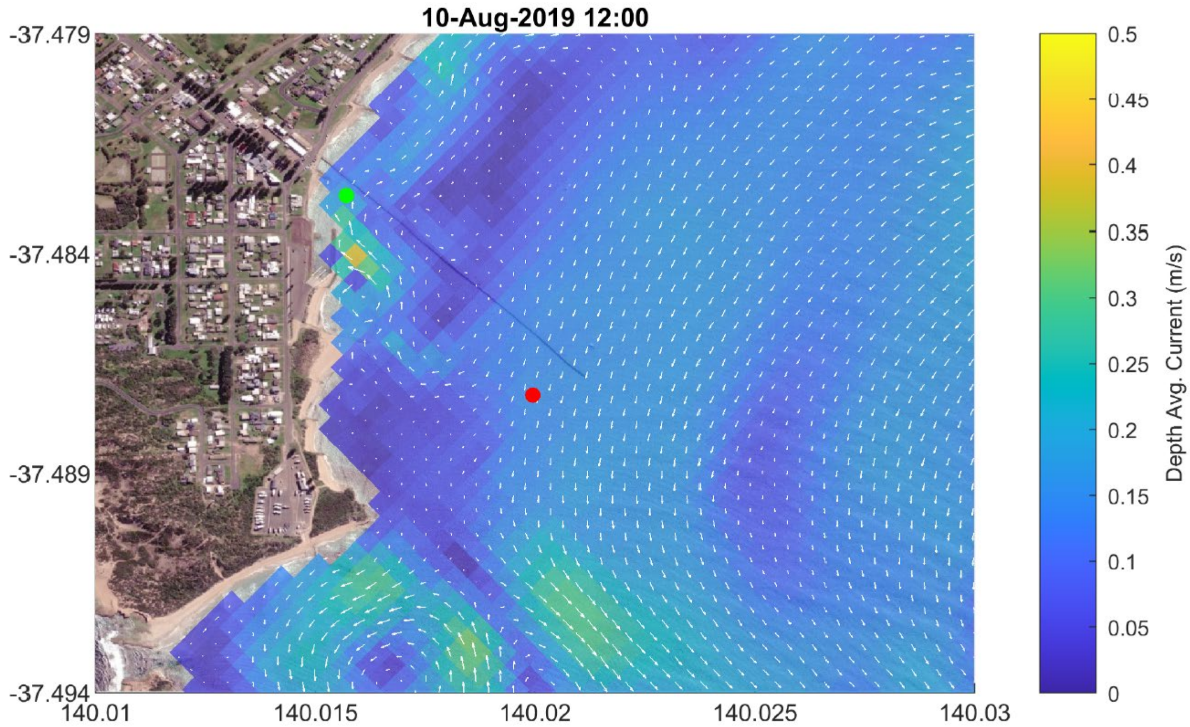


Figure 7.1: Current Speed and Direction (ambient tidal and wave driven currents) in the nearshore region of Beachport. Red point is the ADCP measurement location. Green point is an output near the Boat Ramp entrance.

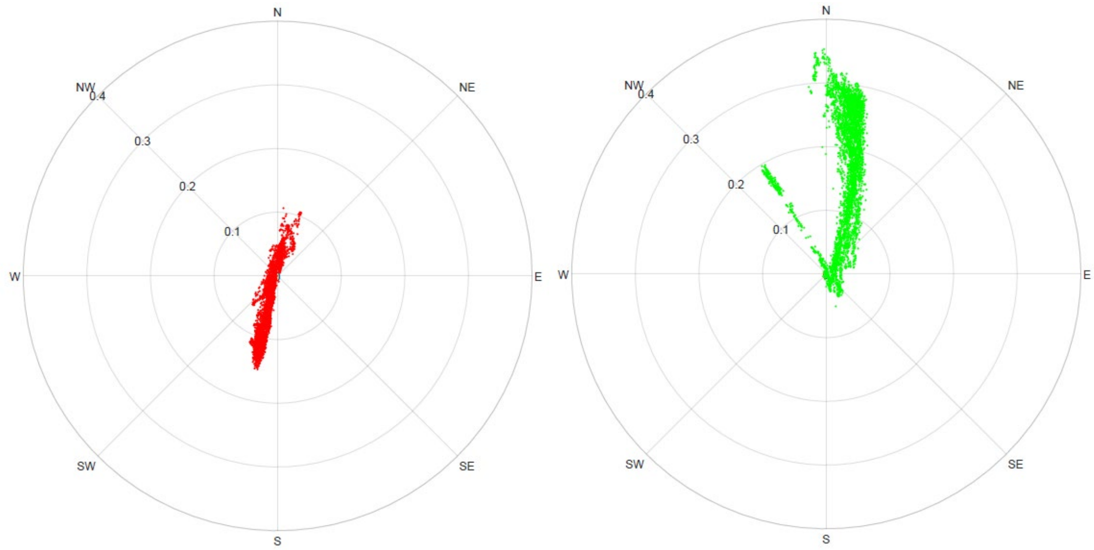


Figure 7.2: Scatter Plots of Modelled Current Speed and Direction (depth averaged in m/s) over the Winter Period at the ADCP Measurement Location (red) and near the Boat Ramp entrance (green).

A key finding from the data collection campaign is the presence of significant long wave energy within the Beachport area, indicating the presence of not only bounded long wave energy associated with swell wave grouping, but unbounded (free) and reflected long wave energy (as demonstrated in Section 3.2.1) within the Beachport area. The observed free long waves are present in the area due to the freeing of bound long waves that propagate into Rivoli Bay with swell energy as it translates over the shoals near the main headland. These free long waves propagate into the bay and refract more strongly than the swells. In addition to the incident free long waves are bound long waves associated with the incident swells and long waves reflected from the shore. Most long wave energy in the bay is associated with incident and reflected free long waves.

Following site observations at the Beachport boat ramp, review of data received from the metocean data collection campaign and confirmation with coupled hydrodynamic and wave modelling, the primary mechanism for the siltation observed with the boat ramp area is summarised in Figure 7.3, and as follows:

- Alongshore wave driven currents develop along the boat ramp breakwater to sufficient magnitude to mobilise sediment into suspension, resulting in a suspended sediment plume at the entrance to the boat ramp area. Such currents were observed in the ADCP current transects taken near the boat harbour entrance, which demonstrated the presence of strong northward flowing nearshore currents, with opposing flows in deeper water.
- Incoming long wave energy and surfbeat (an oscillation of the mean water level in the nearshore as a result of wave grouping), generates long period oscillation of the water level in the boat ramp area and an exchange of flows in and out of the area with a long period (2 to 3 minutes), allowing a portion of the suspended sediment generated along the outside of the breakwater to settle within the boat ramp area.

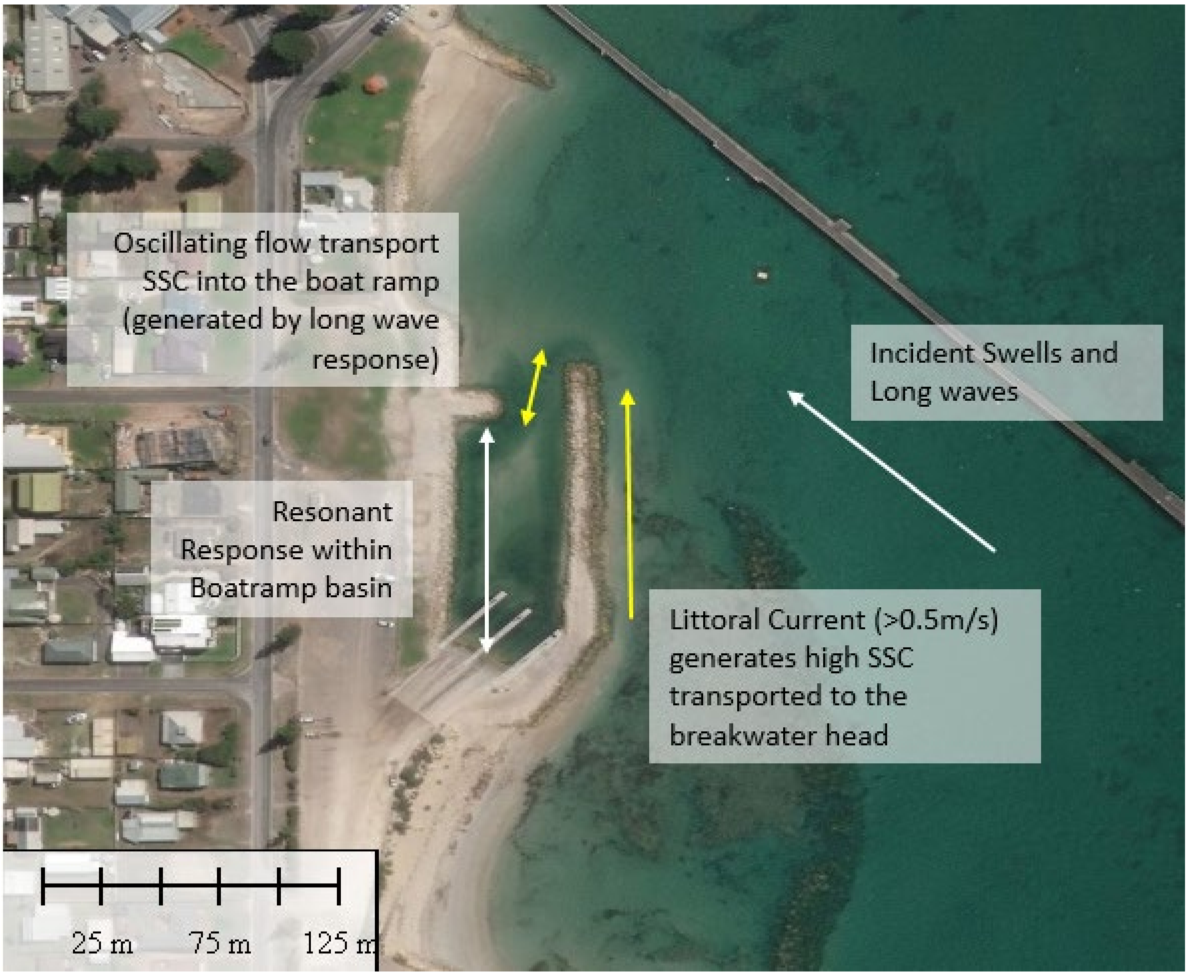


Figure 7.3: Conceptual Sediment Transport model for Beachport Boat Ramp

7.2 Delft3D Online Sediment Transport Modelling of Beachport Boat Ramp

The Delft3D model, including the Surfbeat module with short-wave and roller energy forcing as presented in Section 4.4, was used to further investigate the long period waves and wave-induced flows inside and near the Beachport boat ramp area. The southern boundary is located close to the ADCP/RBR wave measurement location, such that the incident wave conditions can be chosen according to the measured data.

Two runs were conducted for the two wave conditions (19-22 August and 3-6 December) discussed in the RBR data analysis. Wave conditions at the boundary are:

1. $H_{m0,swell}$ = 0.7 m, T_p = 16 s, MWD = 145°N, Spread = 10°, $H_{m0,free\ long,inc}$ = 0.12 m
2. $H_{m0,swell}$ = 0.6 m, T_p = 13 s, MWD = 145°N, Spread = 10°, $H_{m0,free\ long,inc}$ = 0.08 m

Incident free long waves were added at the boundary according to the wave spectra in Section 3.2.1. The spectra were scaled such that the simulated long wave height at the measurement location matched the measured long wave height. Owing to the complexity of the modelled processes, the model was run in a steady-state mode, i.e. constant wave conditions at the boundary for a 24 hours simulation time (equivalent) at constant tide levels of +0.4 m MSL and -0.4 m MSL. This is consistent with the persistence of such conditions at the site and representative of conditions across the full tidal cycle.

The simulation results are presented below as spatial plots of the significant long wave height and wave-induced currents. These parameters are defined as:

- $H_{m0,long}$ is the significant long wave height
- U_{avg} is the mean value of the wave-induced velocities (steady current)
- U_{rms} is the root-mean-square value of the oscillatory wave-induced currents (√2 times standard deviation)

Figure 7.4 presents the spatial map of long wave height which shows that long waves are amplified in the surf zone. However, amplification of the long wave height is also clearly visible in the boat ramp basin due to a resonant response, with an anti-node at the southern end of the harbour and a node near the entrance.

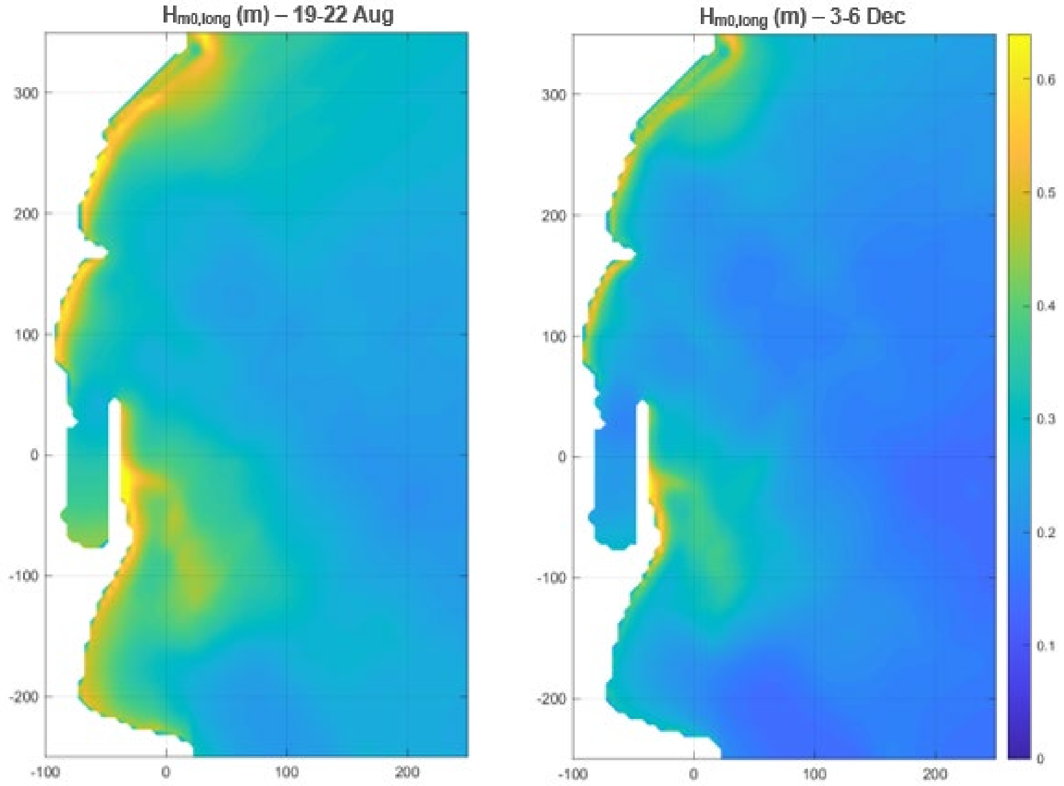


Figure 7.4: Spatial Maps of Long Wave Height (m) at the Beachport boat ramp site for two typical ambient conditions. Note the increase wave heights at the southern extent of the boat ramp basin.

The long wave spectra are presented in Figure 7.5, which show a strong amplification in long wave energy for both conditions at a period of 180 s (3 minutes) within the boat ramp basin and coincides with the first amplification mode of the basin. Long wave heights near the southern end of the two conditions increase to $H_{m0,long}$ = 0.38 m and 0.25 m, from offshore conditions of $H_{m0,long}$ = 0.12 m and 0.08m, respectively.

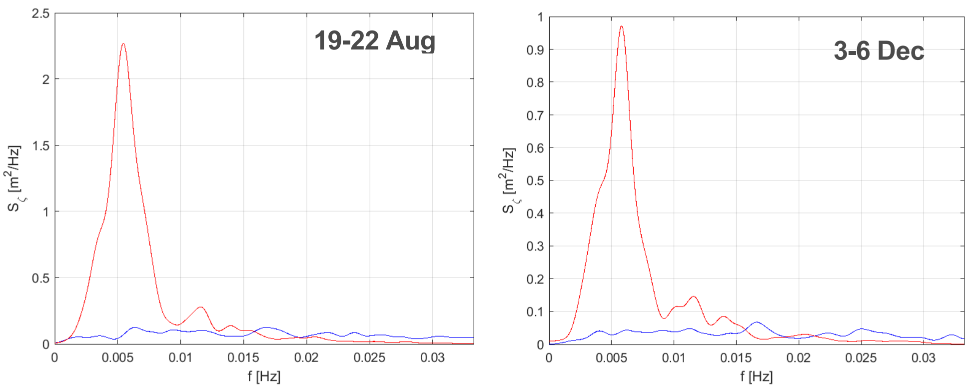


Figure 7.5: Low-frequency wave spectra at the ADCP/RBR location (blue) and the southern end of the boat ramp area (red)

Figure 7.6 presents the spatial map of wave induced currents, both steady and oscillatory. In keeping with the long wave height, wave-induced currents are also strongly amplified in the surf zone. Of particular note, however, are the results in the vicinity of the Boat ramp entrance. Steady currents are generated in a northerly direction along the eastern side of the breakwater and dissipate past the northern extent of the structure. No steady flow enters the boat ramp area, however oscillatory currents (U_{rms}) are present through the entrance, strongest at the northern extent of the breakwater (location of the node of the basin response), which reduce to zero at the southern extent of the boat ramp area (at the anti-node of the basin response).

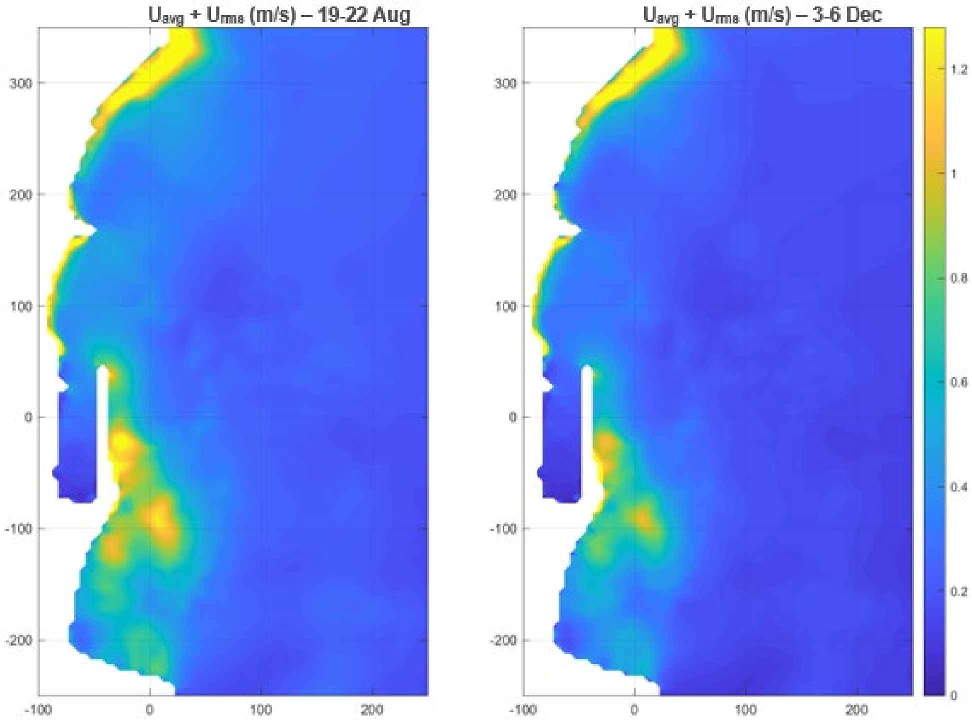


Figure 7.6: Average wave-induced velocities (Steady plus oscillatory) at the Beachport boat ramp site for two typical ambient conditions. Note the increased current speeds through the boat ramp entrance and reduction towards the southern extent of the boat ramp basin.

For sediment transport modelling and scenario testing of the Beachport boat ramp, the Delft3D sediment transport module is applied. In Delft3D the sediment transport and morphology module support both bedload and suspended load transport of non-cohesive sediments and suspended load of cohesive sediments. The seabed in the vicinity of the boat ramp was schematised as fine sand (non-cohesive) with a D_{50} of 0.2mm based on the available sediment sampling results (see Section 2.2.7).

With the sediment transport module activated, the model allows the sediment to be actively transported through the model domain under the hydrodynamic forcing (currents / waves) with the processes of suspension, settling and resuspension explicitly simulated.

The same hydrodynamic model scenarios as presented above were simulated with sediment transport activated to quantify the sediment transport pathway/s resulting from steady and oscillatory currents in the vicinity of boat ramp breakwater. Figure 7.7 provides the averaged sediment transport vectors (total transport = bed load + suspended load) for a 24-hour period.

Figure 7.7: Total (Average) Sediment Transport Vectors (white) under Ambient Conditions on the 8th January 2020. An average of 30m^3/day is estimated to be transported into the Boat Ramp across the entrance section (orange).

Total sediment transport through the boat ramp basin entrance was also estimated from the model simulations, across the section depicted in Figure 7.7. The cumulative transport across the boat ramp basin entrance was estimated at 30m^3/day, on average, based on the simulations that are representative of typical ambient conditions at the site. This scales up to approximately 900m^3/month, which is comparable to estimates based on the dredging campaign completed in October 2019 (5,882m^3 removed after 6 months following the April dredging campaign; i.e. 1000m^3/month).

From this, the sediment transport processes are clear:

- Sediment is brought into suspension in the surf zone along the breakwater where wave-induced velocities are high,
- This sediment is transported to the north along the breakwater in the direction of the mean flow,
- At the northern extent of the breakwater, oscillatory flows transport sediment (both in suspension and bed load) through the entrance and into the basin,
- Sediment is deposited inside the basin where velocities are lower,
- Transport is increased under high tide conditions.

With an established numerical model capable of replicating the sediment transport mechanism that leads to siltation of the boat ramp, the study has access to a tool that can assess potential options for reducing the siltation in the boat ramp basin.

7.3 Potential Mitigation Options

Options to reduce the accumulation of sediment within the protected, and hence tranquil, basin are limited given the location of the boat ramp adjacent to a prominent sediment transport pathway and the need to preserve protection to the boat ramp area.

Potential options were identified from concepts raised in community discussion, within previous studies and from Baird's assessment of key processes at the site. All options assume that the protected basin will be maintained, in some form, and the orientation and position of the ramp will not be moved. The range of potential options initially considered included:

- **Modifying the entrance confirmation to the boat ramp basin (Option BR1).** Either narrowing the boat ramp basin or decreasing the entrance width to reduce the response of the basin to long wave energy and/or reduce the sediment pathway into the basin entrance.
- **Trapping or deflecting the northbound sediment supply (Option BR2)**. Either the placement of a groyne, normal to the Boat Ramp breakwater, to intercept and trap northerly longshore transport or a breakwater extension that aims to deflect northbound sediment transport away from the Boat Ramp entrance. Trapping northerly transport would create a sand deposit that can be included in the Sand Management Plan for Beachport Town Beaches. This option would starve the seabed adjacent to the breakwater extension of sand and eliminate the source of sediment that feeds siltation of the boat ramp basin.
- **Reducing the magnitude of the wave generated current speed along the protective groyne (Option BR3)**. Enhancement of the submerged/low-crested offshore breakwater (currently made up of geotextile containers) that would induce wave breaking away from the structure and reduce alongshore current speeds at the structure. This aims to extinguish the suspended sediment transport pathway along the protective groyne structure;
- **Improving the circulation in and through the basin area to breakdown the resonant response to long waves (Option BR4)**. Segmentation of the protective groyne structure to produce openings in the structure or reduction in the length of the breakwater structure, that aim to breakdown the resonant response to long wave energy and remove or reduce the sediment transport pathway through the boat ramp entrance.
- **Changes to sand management practices along the Beachport coastline (Option BR5)**. The strategy for management of sand in Beach 5 could be reviewed in the context of potential sources of sedimentation to the boat ramp site. The WGA (2017) report cites 'sand blowing over the groyne to the immediate south of the original outer breakwater shore connection' as contributing to the sedimentation at the boat ramp (Groyne 6 / Beach 5). While not considered the primary mechanism for sedimentation, changes to sand management may reduce this contribution.

The list of considered options is outlined in Table 7.1 with the key design considerations for each of the options summarised. Following a high-level assessment of the potential options (as discussed in Table 7.1), a subset of options was selected for detailed analysis.

Table 7.1: High-Level Assessment of Concepts for Beachport Boat Ramp

Option	Objective
Option BR1a	Narrow the Boat Ramp Basin with the aim of changing the dimensions of boat ramp to reduce response of the basin to the long waves. The width of the Boat Ramp basin does not influence the response to long waves (the length of the basin is the key

Option	Objective
	dimension), hence this option is not considered to be effective in reducing sedimentation. **Option not carried forward.**
Option BR1b	Extend the breakwater structure on the landside entry structure to the boat ramp basin. Narrowing the entrance would aim to reduce the sediment pathway into the basin entrance. While the reduction in the entrance width would reduce the cross-sectional area of the entrance to receive sediment, the narrowing of the entrance would increase long wave induced oscillating current speeds and potentially increase the exchange of sediment through the entrance. **Option not carried forward.**
Option BR2a	Add a perpendicular groyne to the Boat ramp breakwater (Groyne 6) in order to trap northbound sediment that is directed along Groyne 6 to the entrance of the Basin. Trapped sand could then be included in the Sand Management Plan for Beachport Town Beaches. This option would impact on the seagrass bed to the east of the breakwater structure, disturbing these sensitive communities. Further, the sand deposit would not be easily accessible and the build-up of sand against the Boat Ramp breakwater may increase the potential for windblown sand transport into the basin area. **Option not carried forward.**
Option BR2b	Add breakwater deflection structure to the seaward northern end of the Boat ramp breakwater (Groyne 6) with the aim of deflecting the northbound sediment transport away from the Boat Ramp entrance. **Option to be carried forward for detailed assessment.**
Option BR3a	Rebuild the submerged offshore breakwater. A submerged structure to the east of the boat ramp basin would induce wave breaking away from the boat ramp structure and reduce alongshore current speeds at the structure. This aims to extinguish the sediment transport pathway along the protective Boat Ramp groyne structure. Rebuilding the previous geotextile submerged structure would likely create a disturbance to sensitive seagrass communities to the west. **Option not carried forward.**
Option BR3b	Construct an offshore breakwater (either submerged or emergent crest) to induce wave breaking away from the boat ramp structure and reduce alongshore current speeds at the structure. This aims to extinguish the sediment transport pathway along the protective groyne structure. Nearshore depths provide for a suitable area to construct an offshore detached structure. **Option to be carried forward for detailed assessment.**
Option BR4a	Improve circulation through the basin by creating an opening/s along Groyne 6 to breakdown the resonant response to long wave energy and remove or reduce the sediment transport pathway through the boat ramp entrance. An opening towards the southern end of the basin would provide the best option for reducing longwave resonance (by breaking down the primary resonant axis), however this could not be done without creating

Option	Objective
	an opening for either incident wave energy and/or sediment to enter the boat ramp basin. **Option not carried forward.**
Option BR4b	Breakdown the resonant response to long wave energy by shortening the breakwater (Groyne 6) length, thereby removing or reducing the sediment transport pathway through the boat ramp entrance. **Option carried forward for detailed assessment.**
Option BR5	Changes to sand management practices along the Beachport coastline (Option BR5). The strategy for management of sand in Beach 5 could be reviewed in the context of potential sources of sedimentation to the boat ramp site. **Option was not carried forward; however a review of sand management practices is recommended.**

The feasibility and effectiveness of the following selected options was assessed in the local Beachport numerical model:

- Option BR2b – Add breakwater nib to the seaward end of the Boat ramp breakwater (Groyne 6). The initial length of the Nib was adopted as 25m.
- Option BR3b – Construction of a detached offshore breakwater. Initially, an emergent breakwater (i.e. crest above high tide) was adopted.
- Option BR4b – Shortening the breakwater (Groyne 6) length. The breakwater was shortened by approximately half its length.

Each of the options is shown conceptually in Figure 7.8 to Figure 7.10. It is noted that each of the selected options were refined through iterative analysis to ensure each was optimised to achieve the intended outcomes.

Figure 7.8: Option BR2b - Breakwater Deflection Structure to direct northerly sediment transport.

Figure 7.9: Option BR3b - Construction of a detached offshore breakwater

Figure 7.10: Option BR4b - Shortening the breakwater (Groyne 6) length (breakwater length to be removed shown in green).

7.4 Model Results – Long Wave Hydrodynamics

As per the modelling completed in the sections above, each of the options was assessed with the two steady state simulation cases (note, for brevity the December 2019 condition is presented below, with results typical of both conditions modelled). This provides a basis for assessing how each of the desired outcomes are achieved against existing base case scenarios.

The spatial map of long wave height and wave induced currents, both steady and oscillatory, for the selected options are presented as follows:

- Option BR2b: long wave height (Figure 7.11) and wave induced currents (Figure 7.12)
- Option BR3b: long wave height (Figure 7.13) and wave induced currents (Figure 7.14)
- Option BR4b: long wave height (Figure 7.15) and wave induced currents (Figure 7.16)

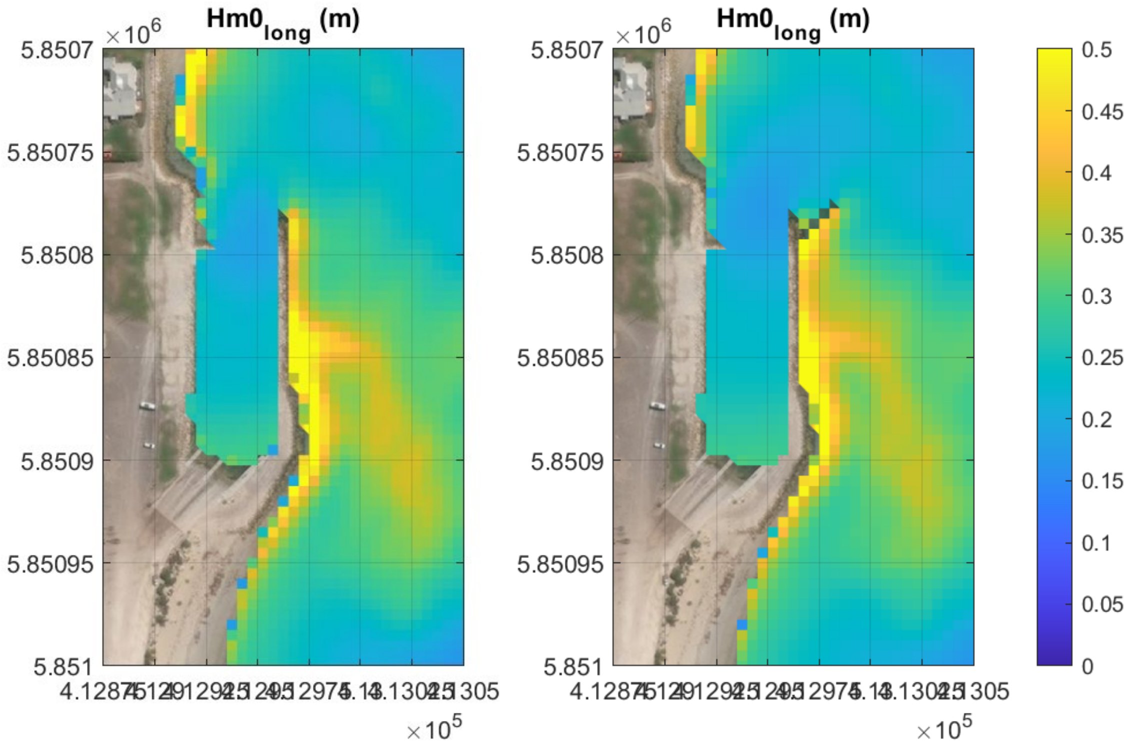


Figure 7.11: Spatial Maps of Long Wave Height (m) at the Beachport boat ramp site under typical ambient conditions for Existing Conditions (left) and Option BR2b (right).

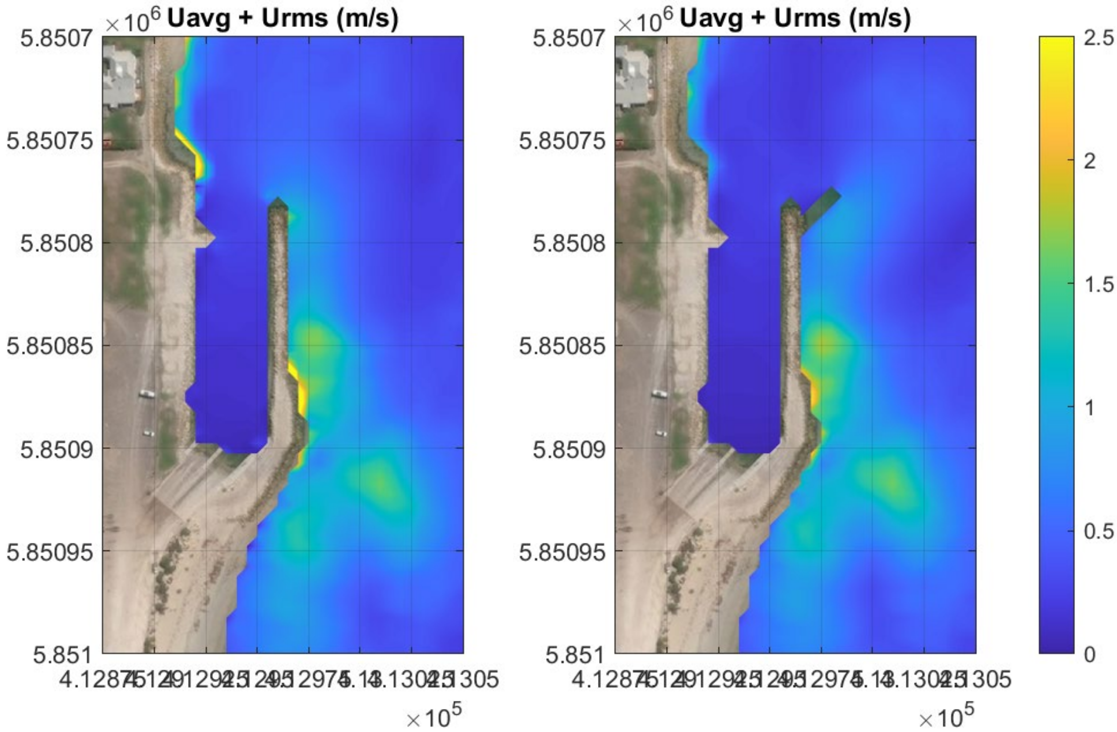


Figure 7.12: Average wave-induced velocities (Steady plus oscillatory) at the Beachport boat ramp site under typical ambient conditions for Existing Conditions (left) and Option BR2b (right).

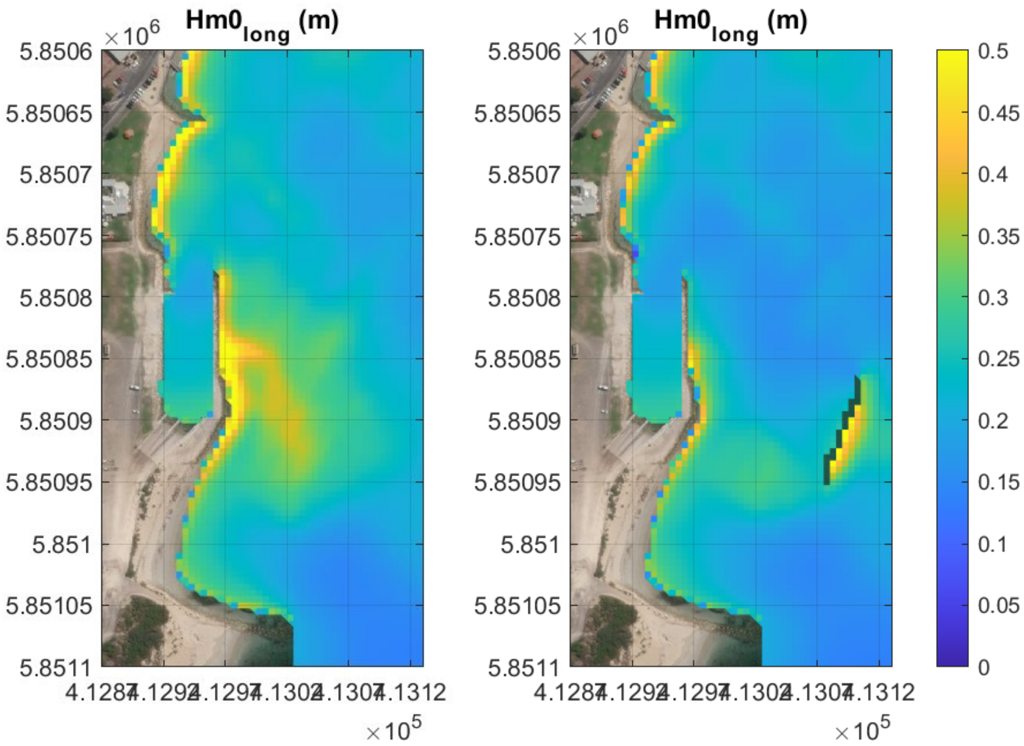


Figure 7.13: Spatial Maps of Long Wave Height (m) at the Beachport boat ramp site under typical ambient conditions for Existing Conditions (left) and Option BR3b (right).

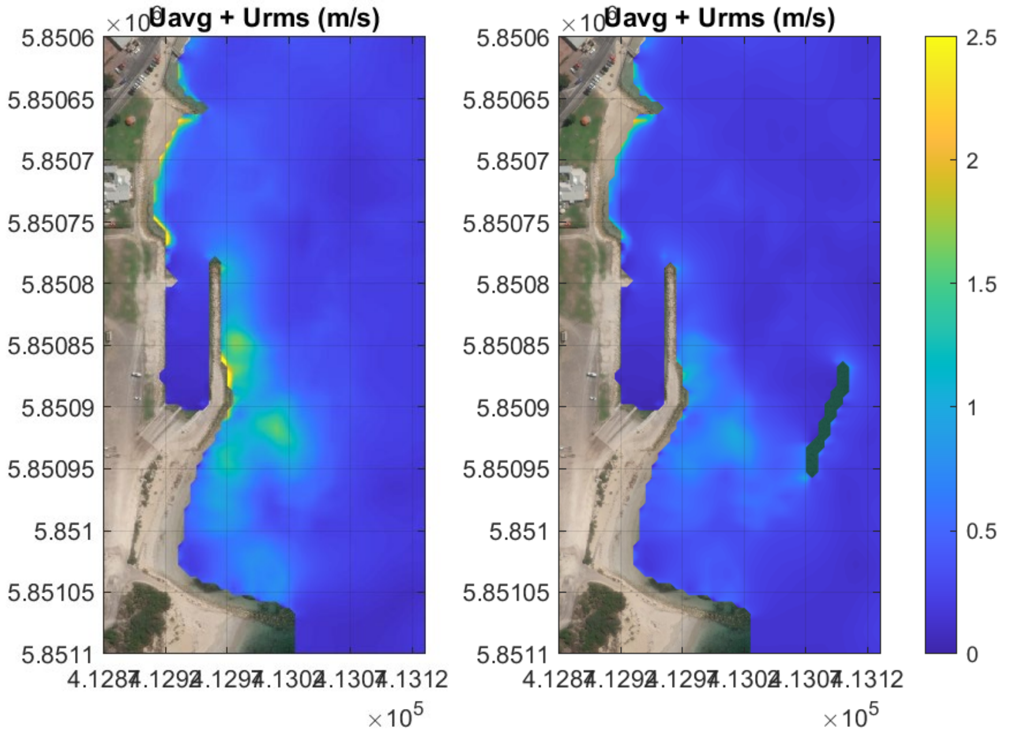


Figure 7.14: Average wave-induced velocities (Steady plus oscillatory) at the Beachport boat ramp site under typical ambient conditions for Existing Conditions (left) and Option BR3b (right).

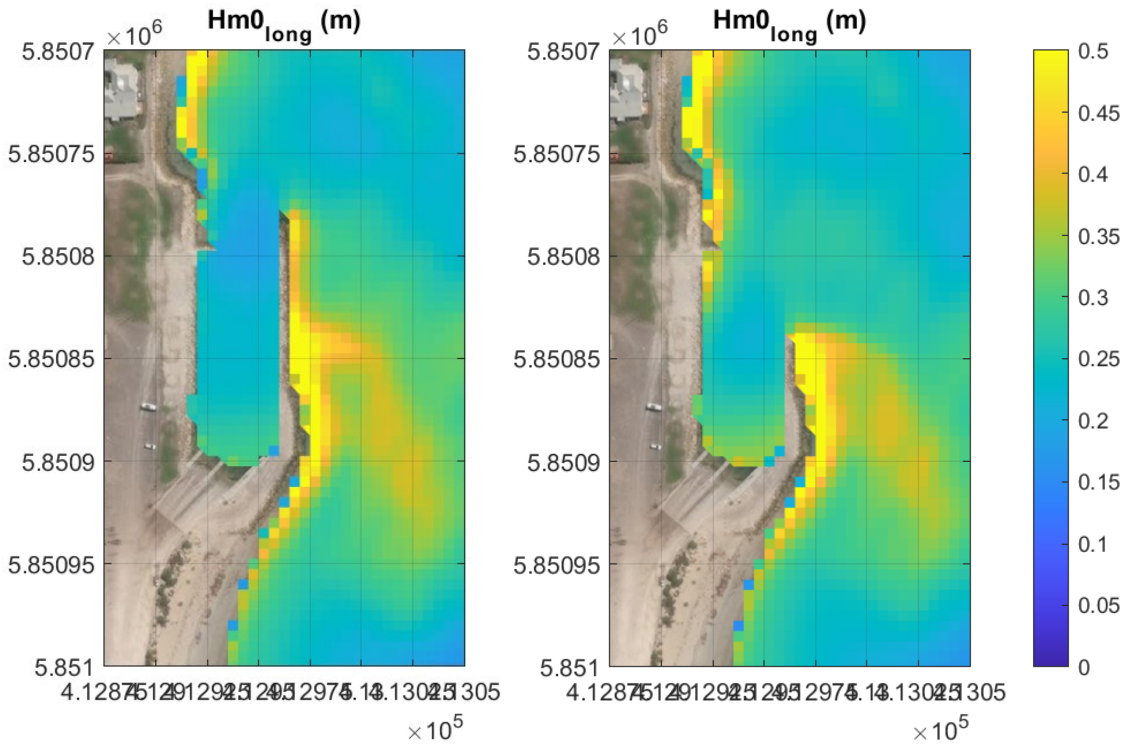


Figure 7.15: Spatial Maps of Long Wave Height (m) at the Beachport boat ramp site under typical ambient conditions for Existing Conditions (left) and Option BR4b (right).

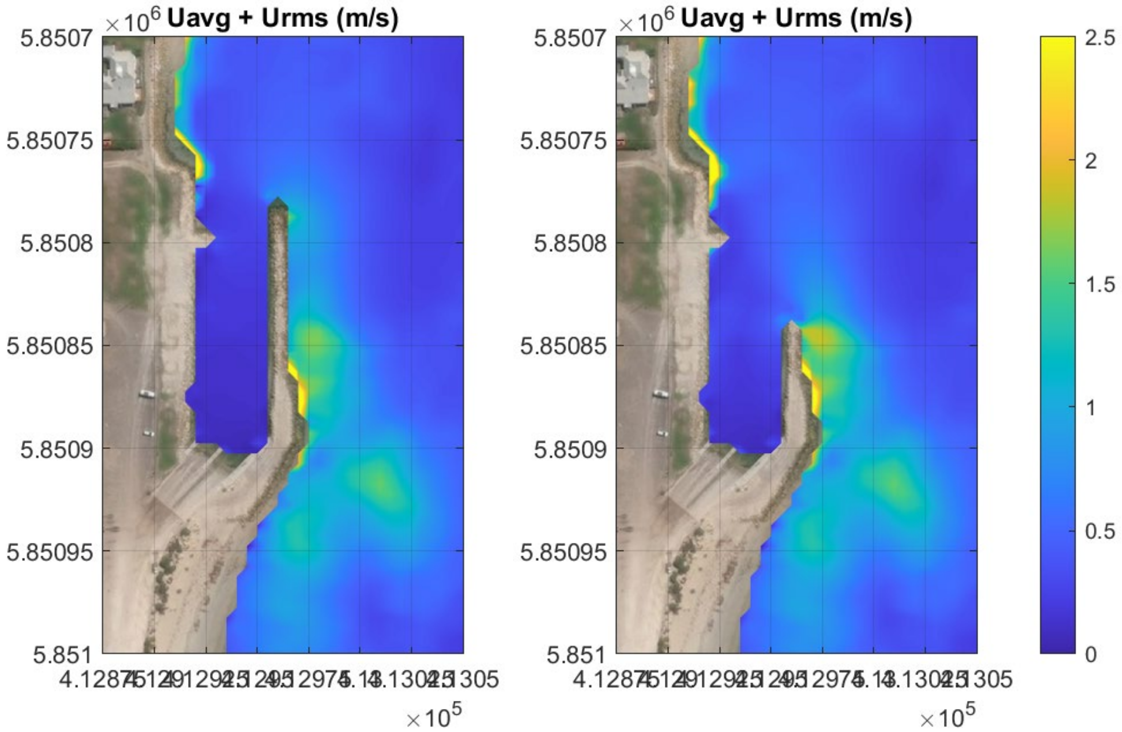


Figure 7.16: Average wave-induced velocities (Steady plus oscillatory) at the Beachport boat ramp site under typical ambient conditions for Existing Conditions (left) and Option BR4b (right).

The model results indicate that Options BR2b and BR3b are reasonably effective in reducing the long wave energy and wave induced currents within the boat ramp basin. While amplification of the long wave is still evident in the case of Option BR2b, the resulting wave induced currents (the key driver for sedimentation at the boat ramp) are reduced. Results from Option BR4b indicate an increase in long wave response within the boat ramp basin with a shortened breakwater. This is due to the increase exposure to the incident long wave energy that shoals in the shallow nearshores areas.

With consideration of these results, sediment transport modelling was not pursued for Option BR4b. Instead, alternative for Options BR2b and BR3b were assessed, including:

- Option BR2c: reduced deflection structure length to 15m
- Option BR2d: increased deflection structure length to 35m
- Option BR3c: submerged offshore breakwater with crest level at MLWS

To assess the effect of each option on potential sedimentation in the boat ramp basin, the cumulative sediment transport through the basin entrance was compared between model simulations (see entrance section definition in Figure 7.7). Rather than providing a deterministic estimate of annual sedimentation volumes for each option, which would require long duration simulations that are impractical with this numerical model setup, the assessment will provide relative estimates against the existing condition based on the steady state simulations described previously. The results are summarised graphically in Figure 7.17.

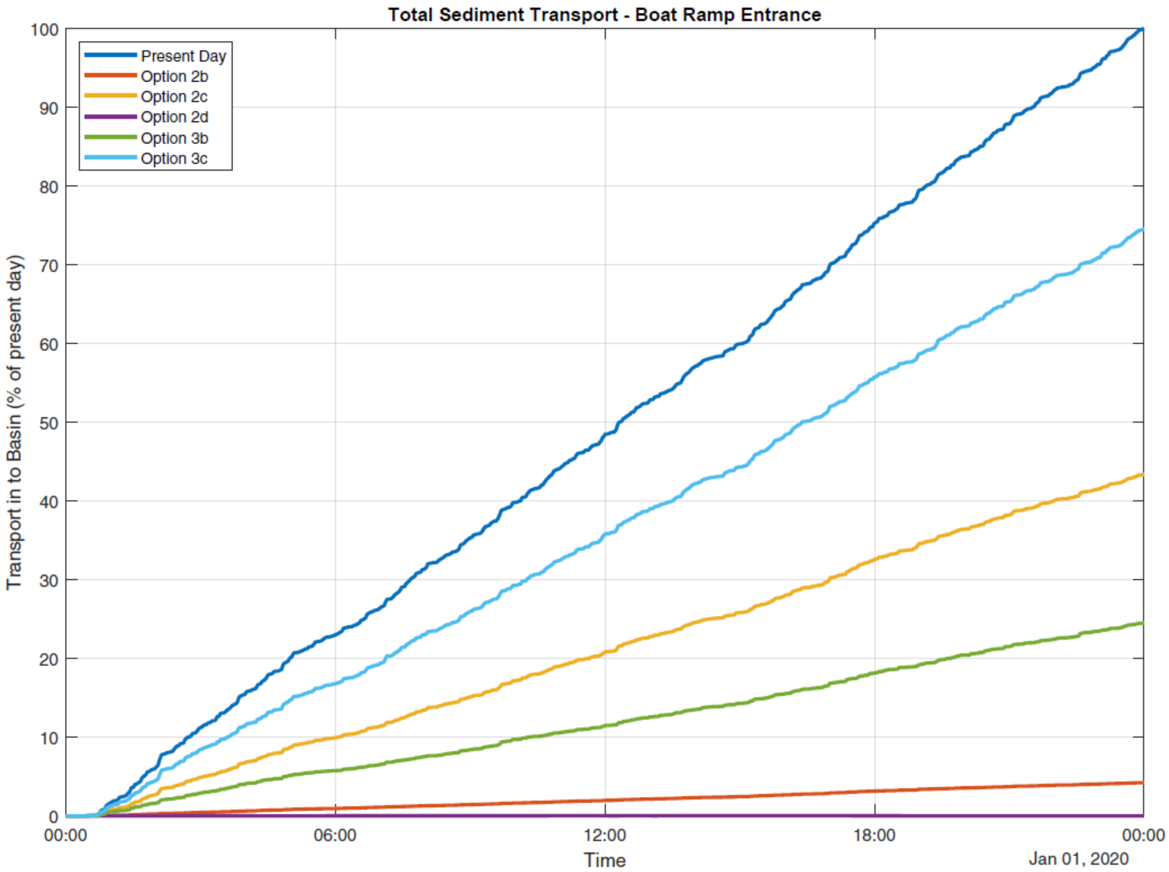


Figure 7.17: Relative cumulative sediment transport into the boat ramp basin (as a % of the existing condition) under Option BR2 and BR3.

The modelled outcomes indicate that sediment transport rates through the boat ramp entrance can be significantly reduced with a deflection structure constructed at the end of the breakwater; with a 95% reduction predicted with a structure length of 25m (Option BR2b). Reducing the structure length to 15m (Option BR2c) achieves a ~50% reduction when compared to the present-day condition. An offshore breakwater (Option BR3b) could reduce sedimentation rates by up to 75%, with a 25% reduction achieved if a submerged breakwater structure (Option 3c).

7.5 Recommendations – Beachport Boat Ramp

The construction of an extension to the existing boat ramp breakwater (Groyne 6), in the form a small deflection structure that is orientated to the NE located at the northern end of the existing breakwater (see Figure 7.8), can be effective in reducing sedimentation rates within the Boat Ramp basin. The deflection structure guides sediment laden currents away from the boat ramp entrance, thereby removing the principal source of sediment (suspended sediments at the breakwater end) that drives the existing sedimentation currently observed at the boat ramp. The fate of sediments deflected by this structure have not been fully assessed in this analysis, however a general shoreward bed load transport would be expected to occur under swell forcing. This is not expected to impact on the boat ramp basin. To assess the cost-benefit trade-off of this option, a specific modelling study should be completed to optimise the length of deflection structure and quantify the potential impact to the beaches to the north for consideration with recommended changes to the groyne field set out in Section 5.6.5.

7.6 Consideration of Glenn Point Location for Alternate Boat Ramp Location

Given the management issues at the Beachport Boat Ramp, Council requested that Glenn Point be assessed as a potential alternative for a Boat Ramp. Glenn Point is located at the southern end of the Beachport coastline and is in the lee of Penguin Island that affords the site protection from the offshore wave climate. The exposure of the site to offshore waves is shown in Figure 7.18, which indicates that wave conditions are significantly reduced by the presence of Penguin Island. However, when considering the conditions across a typical annual period, as presented in Figure 7.19 based on data from the model simulations, it is noted that wave conditions are regularly above 0.5m (Hs) and at long wave periods, making the location less than ideal for boat launching (against the criteria of AS 3962). Without a breakwater structure for protection, it is likely that a boat ramp at this location would require restricted launch windows to operate safely.

The design of a breakwater structure at this location to improve conditions for boat launching would need to consider the impact to sediment transport that moves towards the Beachport Foreshore, so as not to interrupt supply. To this end a detached shore parallel breakwater would be best suited, however the incident wave conditions and water depths in the area would result in a substantial structure. While conditions in the lee of the structure could be made sufficiently calm for most periods, a vessel transits into open water would be met with beam on conditions that may pose a navigational safety risk.

Further, as presented in Figure 7.1, the tidal hydrodynamics of the area generate an eddy flow feature in the lee of Penguin Island within the nearshore off Glenn Point. This eddy feature can peak at current speeds (depth averaged) of 0.4m/s however are not constant, and the numerical model indicates that the flow offshore of the potential boat ramp location is variable. Such conditions are not considered appropriate for a boat launching facility.

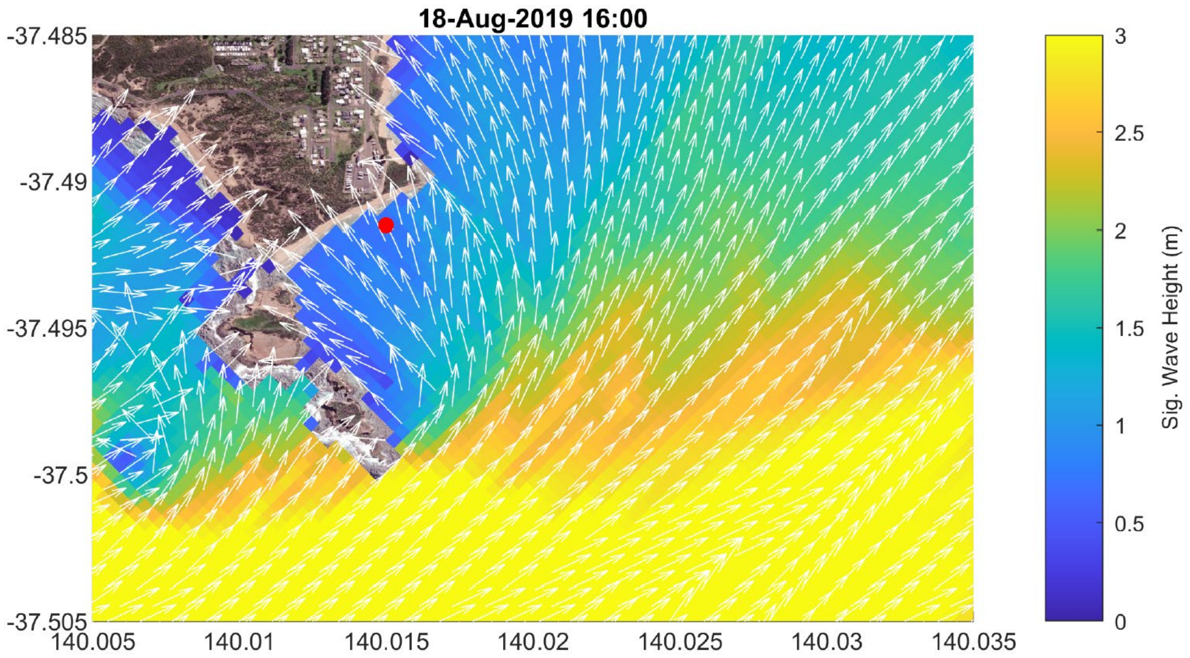


Figure 7.18: Wave Rose of modelled wave conditions at Glen Point Boat Ramp (combined Summer and Winter simulations)

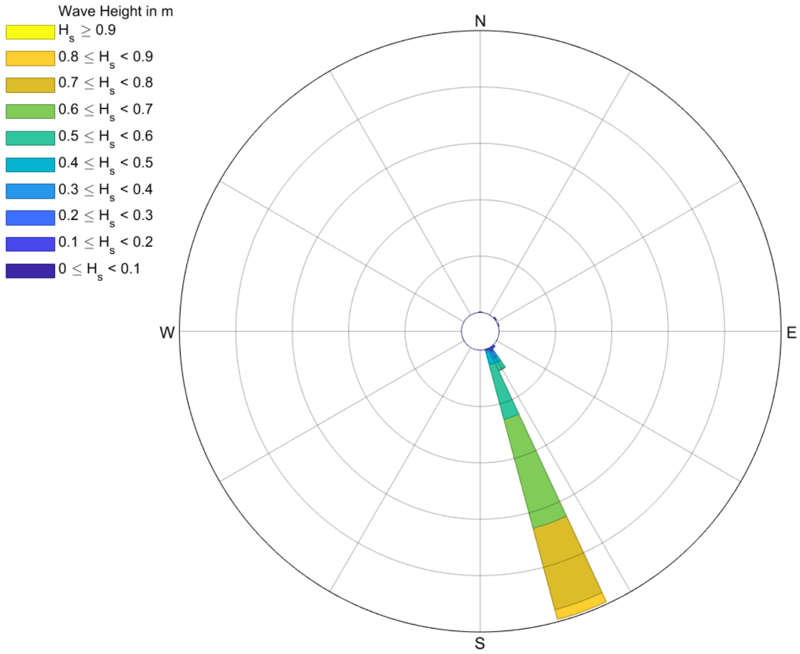


Figure 7.19: Wave Rose of modelled wave conditions at Glen Point Boat Ramp (combined Summer and Winter simulations)

8. Summary and Recommendations

At the outset of this study a set of key processes were identified from the available literature and data (see Section 2) as warranting specific assessment and analysis as they were considered integral to developing suitable options designed to:

- Improve beach stability in Beachport;
- Improve beach stability in Southend; and
- Reduce siltation issues at the Beachport boat ramp.

These key processes have been quantified in this report, which provide a sound basis for identifying and assessing potential mitigation options.

The following provides a brief summary of the key processes:

1. Improved definition of the hydrodynamics of Rivoli Bay and their potential to drive sediment transport (particularly anti-clockwise currents within the western region of the Bay and implications at the Beachport Boat ramp)
   - In the measured data for the Beachport ADCP location, collected approximately 100m from the end of the jetty, the measured current speeds were noted to be low and flowing predominantly southward as a result of a tidal circulation within Rivoli Bay. A similar outcome is observed from the Southend ADCP data, with a westerly flow out of Rivoli Bay being predominant. Typically, these tidal circulation currents are in order of <=0.1m/s and are considered too low to drive significant sediment transport towards the boat ramp.
2. Quantification of longshore sediment transport along the Beachport and Southend shorelines;
   - Shoreline sediment transport modelling, driven by modelled and measured hydrodynamics and currents, has defined the longshore sediment transport as relatively low (compared to open coast shorelines). However, of note is the nearshore width over which the littoral transport occurs. At Southend, the littoral transport process was estimated to extend well beyond the existing groyne structures, which has implications for the length of groyne required to compartmentalise the beach effectively. At Beachport, an analysis of beach width indicates that there is ample longshore transport supply and the groyne compartments are at or near capacity with a shoreline alignment consistent with the incident wave directions.
3. Definition of the longwave climate within Rivoli Bay and implications for coastal processes;
   - An analysis of measured long waves has established that there is significant long wave energy within Rivoli Bay. The long wave energy is free, reflected and also associated with swell groups (bounded long waves). Modelling of bounded long waves in the numerical model demonstrated a resonant response in the Beachport boat ramp basin consistent with the site observations and conceptual sediment transport model for the area.
4. Nearshore transformation of waves, including the occurrence and potential for focusing at the Beachport shoreline.
   - Results from the nearshore wave modelling suggest that bathymetry does act to disperse and focus wave energy variably along the Beachport shoreline. The southern ends of Beaches 7 and 8 appear particularly exposed, which aligns with the shoreline areas with minimal beach width however is not considered the primary driver of reduced beach width at these locations. Rather inappropriate groyne compartment design results in a beach alignment that is inconsistent with the develop shoreline.

A range of potential mitigation options have been addressed in this report with a select number being assessed based on detailed coastal process investigations. Recommended management options have been identified, each assessed as feasibly achieving the desired outcomes for each location and are summarised below.

Outcomes from this options analysis demonstrate the feasibility of implementing selected options, with the recommended mitigation approaches worthy of more detailed analysis and concept level engineering design. It is noted that the scope of this study was to assess options at a concept level. Before any options can be implemented a detailed process-based investigation, cost-benefit analysis and detailed engineering design would be recommended.

8.1 Beachport Foreshore

A total of 4 options were individually assessed at the Beachport foreshore. From these, a final optimised option was developed. The optimised option extends and rotates Groyne 8 in combination with placement of a new groyne in the centre of Beach 8 (Groyne 8a). Groyne 8a was optimised in combination with the change to Groyne 8 to achieve acceptable stable beach widths and alignments. The layout of groynes and expected beach alignments are presented in Figure 8.1. Groyne 8 is extended to 44m in length and rotated north by 20º, with the new Groyne 8a set at a length of 38m perpendicular to the shoreline in that location.

Figure 8.1: Layout of the Recommended Option at Beachport foreshore including the extension and rotation of Groyne 8 and a new Groyne in the centre of Compartment 8

8.2 Southend Foreshore

At Southend, a total of 6 options were individually assessed with 3 carried forward for detailed analysis. The recommended option is for two of the assessed options to be implemented concurrently. The following is a summary of the actions and projected improvements from the current situation:

- Retention of Groyne 1 in its current location preserving the western beach shoreline amenity
- Removal of Groyne 2 with a view to reusing the rock where possible to extend the groynes further east
- Extension of Groyne 3, Groyne 4 and Groyne 5 would be undertaken to increase trapping efficiency.

Figure 8.2 summarises the expected sediment transport regime following implementation of the recommended option.

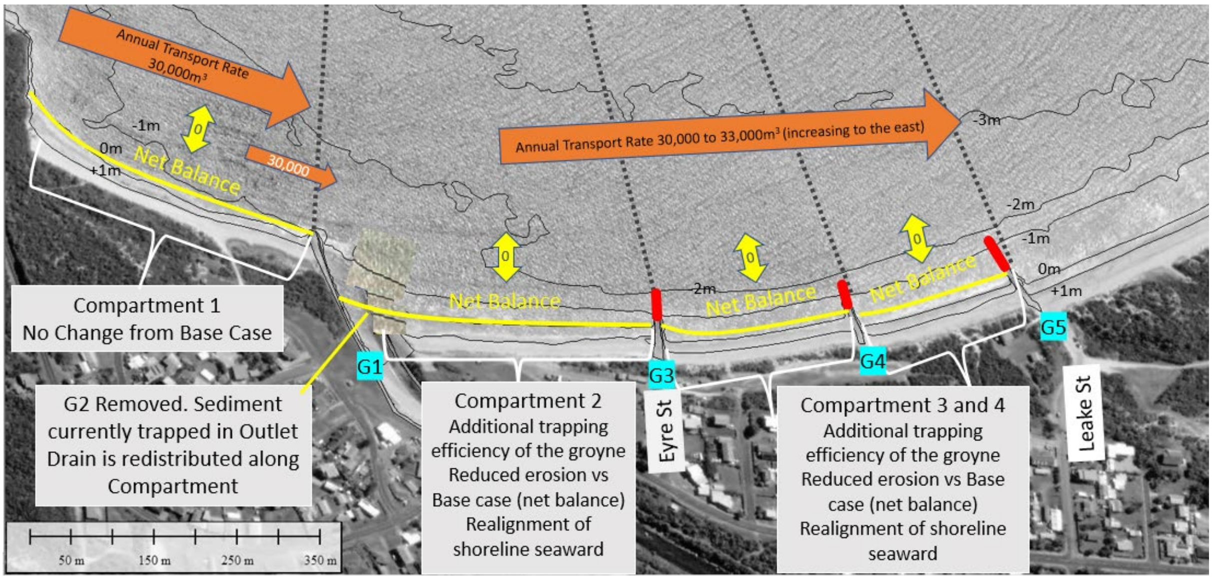


Figure 8.2: Final recommended option for Southend shoreline including removal of Groyne 2 and extension of Groynes 3, 4 and 5

8.3 Beachport Boat Ramp

A total of 9 options were individually assessed with 3 carried forward for detailed analysis at the Beachport Boat Ramp. The recommended option is to construct an extension to the existing boat ramp breakwater (Groyne 6), in the form a small deflection structure as shown in Figure 8.3. Extending from the northern end of the existing breakwater and orientated to the NE, the deflection structure is effective in reducing sedimentation rates within the Boat Ramp basin. The deflection structure guides sediment laden currents away from the boat ramp entrance, thereby removing the principal source of sediment (suspended sediments at the breakwater end) that drives the existing sedimentation currently observed at the boat ramp. The final length of the extension requires a detail investigation to optimise the cost of the structure, the reduction in sedimentation and the fate of the deflected sediments.

Figure 8.3: Recommended Option for the Beachport Boat Ramp that includes a Breakwater Deflection Structure at the Northern End

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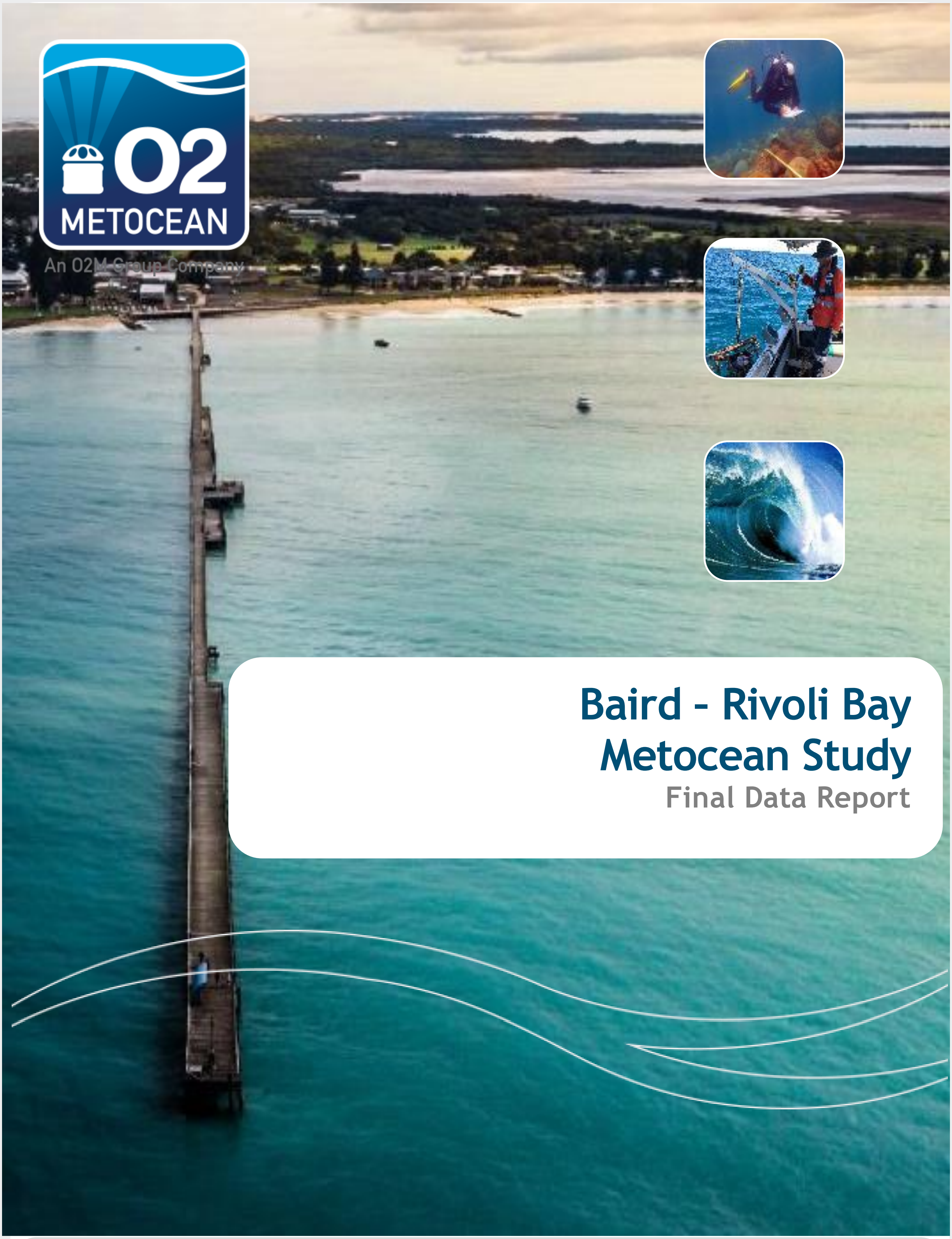
Appendix A

Metocean Data Collection Report – O2 Marine



Baird - Rivoli Bay Metocean Study

Final Data Report

CLIENT: Baird Australia Pty Ltd

STATUS: Rev 1 **REPORT No.:** R200033

ISSUE DATE: 09 March 2020

Important Note

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Transmission Register

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Acronyms and Abbreviations

Acronyms/Abbreviation	Description
ADCP	Acoustic Doppler Current Profiler
Baird	Baird Australia Pty Ltd
CTD	Conductivity, Temperature, Depth profiler
GPS	Global Positioning System
H_S	Significant wave height
Km/h	Kilometers per hour
m/s	Meters per second
MMS	Metocean Monitoring Station
QA/QC	Quality Assurance / Quality Control
RBR	RBR Logger Sensor Company
SA	South Australia
T_P	Peak period
UTC	Universal Time Coordinated
UTM	Universal Transvers Mercator
WGA	Wallbridge Gilbert Aztec Ltd
WGS	World Geodetic System

Table of Contents

Figures

Tables

1. Executive Summary

This report contains the details of a data collected over a six months Metocean monitoring program undertaken by O2 Metocean on behalf of Baird Pty Ltd at Rivoli Bay in South Australia. The monitoring period spanned approximately between the 28th June 2019 and the 24th December 2019. Wave, current and water level data were collected at two fixed locations, and current transects were collected at numerous locations throughout the bay. In addition to data collection, a short-term Fourier transform and filtering technique was applied to indicate the presence of long-period waves.

It has to be noted that the data collected only present the oceanographic conditions recorded at specific locations and may do not represent the oceanographic and hydrodynamic conditions present across the whole bay.

At the Beachport ADCP location, currents were principally oriented on an approximately North-South axis with a significant asymmetry between the currents entering and leaving the bay. At the Southend ADCP location currents were principally oriented on an approximately East-West axis, again with appreciable asymmetry.

Short-term Fourier analysis indicated significant wave heights in excess of 1 m at both sites, with highly restricted peak wave direction (onshore). The filtering techniques applied indicated that the long-wave signal was appreciably lower than the total wave signal at both sites during the period of deployment.

The vessel mounted ADCP transects revealed high spatial and temporal variability in current speed and direction, however it is noted that the peak speeds during these transects were low with respect to the maxima recoded by the ADCPs.

2. Introduction

2.1. Project Overview

Wattle Range Council in Southern Australia (SA) invited Baird Australia Pty Ltd (Baird) to develop a numerical model for Rivoli Bay in SA, with a particular focus on the townships of Southend and Beachport. The purpose of the model is to inform future investment in infrastructure and maintenance on the Rivoli coastline. The project will deliver on the recommendations of the Wallbridge Gilbert Aztec Ltd (WGA) Report on Maintenance Options for the Beachport Boat Ramp, Wavelengths Southend Adaptation Strategy and the Worley Parsons Rivoli Bay Study.

The purpose of the numerical model is to:

- Assess potential options to improve beach stability in Beachport;
- Assess potential options to improve beach stability in Southend; and
- Assess potential options to reduce siltation issues at the Beachport boat ramp.

O2 Metocean was engaged by Baird to collect metocean data (i.e. Waves, Current and water level) at Beachport and Southend townships in Rivoli Bay, SA.

The metocean data will serve to calibrate and validate the performance of the numerical models to allow confidence in the use of such models for the purposes of engineering design and environmental impact. To achieve these requirements O2 Metocean designed a 6 months data collection program with three monthly site visit to service the deployed instrumentation and data download the following data was collected:

- 6 months of wave current, and water level measurements at Beachport;
- 6 months of wave current, and water level measurements at Southend; and
- 1 day of vessel mounted current measurements along transects parallel to the shore line at within the bay of Rivoli Bay at agreed locations.

The agreed approximate deployment locations of seabed instrumentation measuring currents and wave parameters at both Beachport and Southend in Rivoli Bay, SA are shown in Figure 2-1.

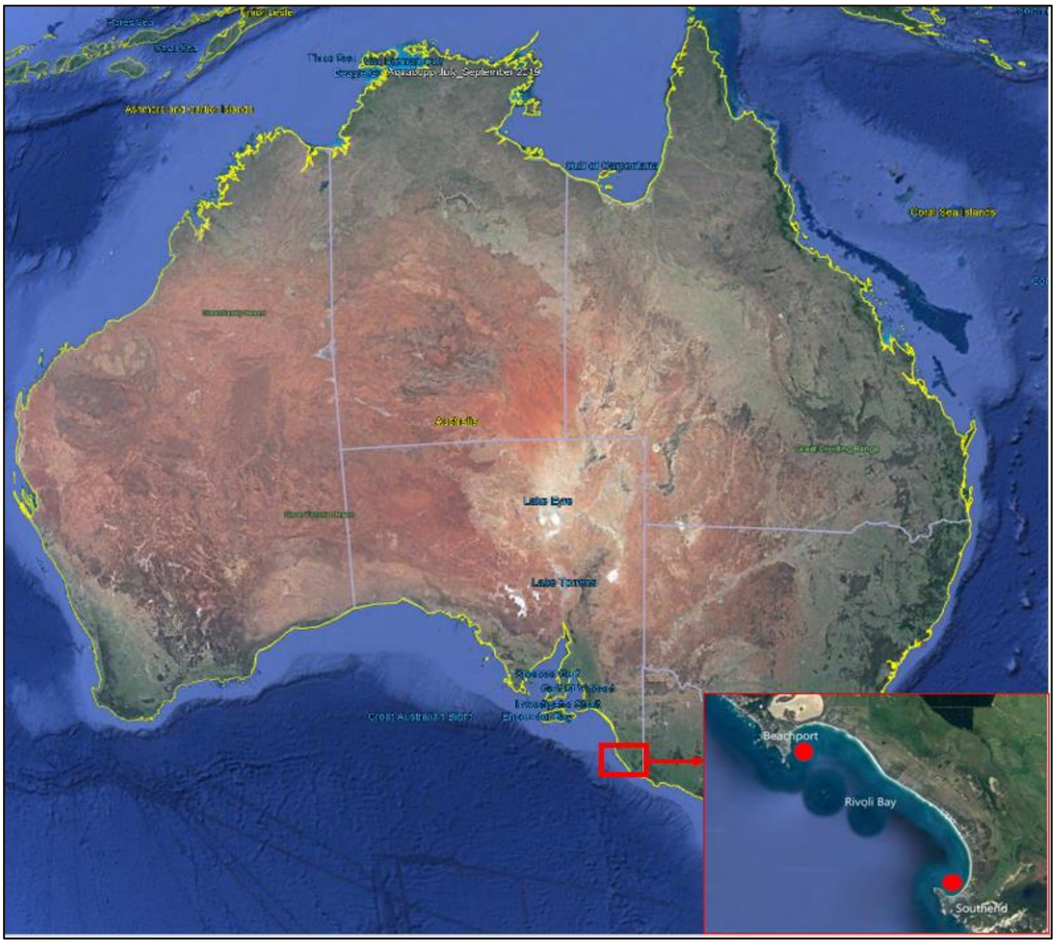

Figure 2-1 Rivoli Bay in South Australia and measurement locations at Beachport and Southend.

2.2. Scope of Services

The scope of services for the Metocean Data Collection – consists of:

Baseline characterisation of metocean (waves and currents) conditions to calibrate and validate hydrodynamic modelling in Rivoli Bay. The scope includes:

- 6 months of wave and current measurements at Beachport location. Measurements are taken using
  - Teledyne RDI Acoustic Doppler Current Profiler 600 kHz (ADCP) which measures currents every 0.5m through the water column and waves at the surface;
  - RBR logger measuring long period waves for 6 months.
- 6 months of wave and current measurements at Southend location. Measurements are taken using
  - 600 kHz RDI Acoustic Doppler Current Profiler (ADCP) which measures currents every 0.5m through the water column and waves at the surface;
  - RBR logger measuring long period waves for 3 months during the winter months (June – September);

- One day of vessel mounted current measurements is planned using a small vessel with ADCP undertaking agreed transects around Rivoli Bay with particular focus on the Beachport boat ramp;
- Provision of one interim data report with raw and QA/QC'd data provided to Baird after the service visit in September 2019;
- Provision of one final data report with raw and QA/QC'd data provided to Baird after the service visit in January 2020.

2.3. Objective of This Report

The primary objective of this report is to provide information on the progress of the metocean data collection program and a brief overview of the data collected to date to support the numerical model. Detailed discussion of the data processing, QA/QC, interpretation and conclusion are included in this report.

3. Field Methodology

Two locations were selected for this project to collect wave, current and depth data in Rivoli Bay (section 3.2). The locations names are Beachport and Southend as shown in Figure 1-1. ADCPs and RBR pressure sensor were deployed on bottom mounted instrument frames and deployed at each location o measure the required parameters. The periods of the data collection to date are provided in Table 3-1.

3.1. Project Datum

3.1.1. Time

Time is provided in South Australia local time:

Winter (UTC +0930 hours).

Summer (UTC +1030 hours)

3.1.2. Geographical Datum

Geographical positions are provided in latitude and longitude in degrees, decimal minutes (UTM Zone 54, WGS84).

3.2. Instrument Locations

The locations for the deployment of the metocean instrumentation is shown in Figure 3-1 was selected in consultation with Baird. The Beachport instrumentation were deployed at a depth of 4 m (LAT). The Southend instrumentation were deployed at a depth of 3.5 m (LAT).

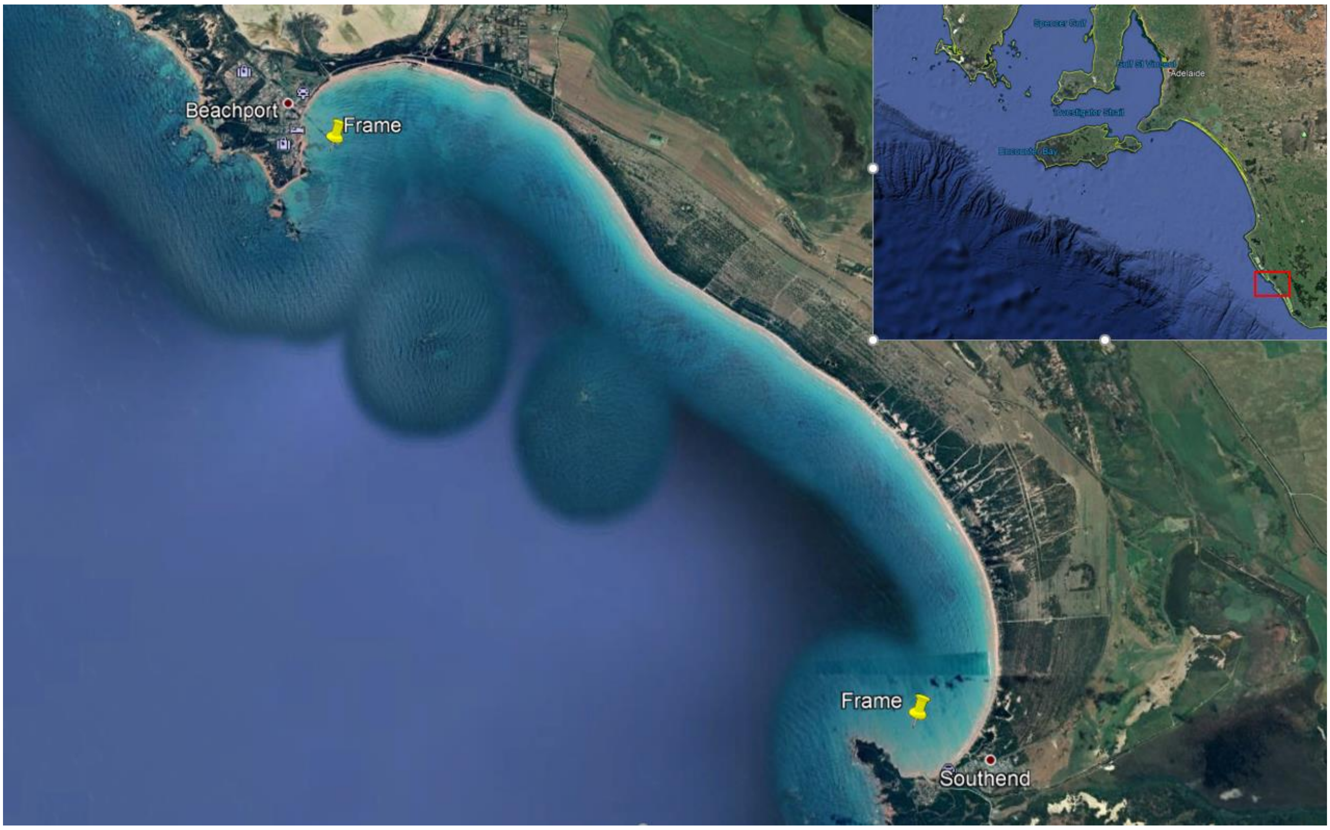

Figure 3-1 Approximate locations of Metocean instruments.

3.3. Seabed Instrumentation Deployment and Retrieval

Bottom mounted seabed frames equipped with one 600kHz ADCP and RBR pressure loggers were deployed at both locations. The frames were designed for shallow water measurement of currents and waves. The RDI waves sampled in bursts; recording 20 minutes wave burst every hour, and one-minute current burst every 20 minutes (excluding the period of wave sampling). The RBR sampled continuously at 1 Hz.

All proposed frames for instrument deployment and associated hardware are constructed with materials that minimise the influence of magnetic deviation of the instrument’s internal compass, minimise corrosion and biofouling, and provide adequate margins of safety during deployment and retrieval.

3.3.1. Instrumentation

3.3.1.1. ADCP

The Teledyne 600 kHz RDI Workhorse Sentinel (Figure 3-2) Acoustic Doppler Current Profiler (ADCP), mounted on a galvanised steel gimbal frame, was deployed at both Beachport and Southend locations. The instrument set up and subsequent pre-deployment tests were performed on site as per manufacturer’s specifications and deployment file saved for record.

Figure 3-2 Teledyne RDI ADCP 600 kHz

3.3.1.2. RBR

An RBR virtuoso logger was mounted to the seabed frame to capture high resolution pressure data. The logger has the ability of sampling at 1 Hz rate with an accuracy of ±0.05% to provide information on long period waves.

Figure 3-3 RBR Virtuoso

3.3.2. Deployment and Retrieval

Deployment and retrieval of seabed instrument frames is performed using the Breakaway 50ft vessel (Figure 2-1) which was fitted with a winch to aid safe deployment and recovery of the seabed frames. The vessels echosounder is used to verify the seabed is flat. After site selection, the frames are winched and carefully lowered over the stern of the vessel. A Gimble frame is used to compensate instrument tilt up to 25° angle. Once the frame is on the seabed the anchor attached to the frame with a 25 m rope is stretched toward the main expected waves direction and deployed.

Retrieval of the frames is undertaken by grappling the rope stretched between the frame and the anchor.

Once the lifting line is on the surface, the frame is winched up to surface while maintaining a vertical position above the frame to minimize strain. Once on the surface the frame is tied off and the vessel transits to the local jetty ~300m away and the jetty crane is used to safely lift the frame onto the jetty.

Figure 3-4 Commercial Vessel *Breakaway*.

3.4. Vessel Mounted ADCP Transects

The vessel mounted ADCP Transects were conducted using Commercial Vessel AB (Figure 2-2). The ADCP was mounted to the side of the vessel at a nominal depth of 0.5 m. The vessel covered the (approximately) cross-shore transects shown in Figure 6-20 at an average speed of 4 knots, while the ADCP sampled at 1 Hz. Transects were carried out at both ends of Rivoli bay on between 07:36 AM and 11:48AM on Jan 08 during Recovery Trip 2. Note that this corresponds to low tide.

.

Figure 3-5 Commercial Vessel *AB*.

3.5. Field Trips

Initial deployment operations were undertaken between 27th to 29th Jun 2019. This field survey was to prepare the equipment and instrumentation for deployment and deployment operations.

The first service visit field trip to recover the instrumentation, download the data and redeploy the serviced instrumentation was undertaken between 11th September to 14th September 2019. The first deployment period thus spans 28th June to 12th September 2019 (Table 3-1).

The final recovery was undertaken by O2 Metocean between 7th to 9th January 2020. This included the vessel mounted ADCP current measurements, downloading of instrumentation from seabed frames and packing up freight for return to Perth. Please note however that the instrumentation, ADCPs and RBR loggers, were recovered by the local vessel operator on the 24th of December 2019. The second deployment period for the instrument frames thus spans 12th September to 24th December 2019 (Table 3-2).

A summary of the field activities performed on each trip is provided in Table 3-3.

Table 3-1 First deployment period

Location Name	Location Lat and Long (WGS84)	Deployment (Start data collection)	Retrieval (Downloaded data)	Depth (LAT)
Beachport	37° 29.221'S 140° 1.198'E	28th June 2019	12th September 2019	4m
Southend	37° 33.831'S 140° 7.063'E	28th June 2019	12th September 2019	3.5m

Table 3-2 Second Data Collection Period

Location Name	Location Lat and Long (WGS84)	Deployment (Start data collection)	Retrieval (Downloaded data)	Depth (LAT)
Beachport	37° 29.220'S 140° 1.201'E	12th September 2019	24th December 2019	4m
Southend	37° 33.812'S 140° 7.068'E	12th September 2019	24th December 2019	3.5m

Table 3-3 Summary of field activities

Field Trip Number	Field Dates	Personnel	Tasks	Summary of key activity (CST)
01-Deployment	27th June to 29th June 2019	N. Turnbull, J Churchill	Mobilise to site, prepare oceanographic equipment, deploy equipment at agreed locations	**27 June 2019** **0540 (WST)** O2 Metocean & Baird personnel depart Perth for Adelaide. **1030** O2 Metocean & Baird personnel arrived Adelaide, collect hire car conduct vehicle checks and travel to Beachport SA. **1515** Arrive at Beachport. Travel to vessel operator yard. Locate equipment and begin preparing for deployment operations **1745** Finish preparations for the day. Return to accommodation. End of operations. **28 June 2019** **0630** O2 Metocean personnel continue preparations of instrumentation at vessel operator boat yard. **0930** Instrumentation and equipment prepared ready for deployment. **1000** Undertake JSEA's and vessel induction with all personnel involved in operations (Vessel, O2 Metocean, Baird). **1015** Load *Breakaway* vessel from Beachport Jetty. **1100**

01- Deployment	27th June to 29th June 2019	N. Turnbull, J Churchill	Mobilise to site, prepare oceanographic equipment, deploy equipment at agreed locations	Transit to Beachport ADCP seabed frame location. Verify ADCP instrumentation still pinging. **1120** ADCP frame deployed with groundline at Beachport location. **1135** Return to Beachport Jetty. **1200** Load Breakaway vessel from Beachport Jetty with Southend ADCP seabed frame. **1215** Depart for Southend deployment location **1245** Arrive at Southend deployment location. Assess Southend deployment location with Baird and Vessel operator for suitable safe location. **1300** ADCP frame deployed with groundline at Southend location. **1315** Attempt to take some sediment grab samples at Southend location. However, due to shallow depth the sampler was unable to take a suitable sample. **1330** Depart for Beachport Jetty. **1410** Arrive alongside Beachport Jetty. Begin demobilizing vessel. **1430** Return to vessel operator boat yard and pack up remaining equipment and freight. **1600** Assist Jim Churchill from Baird with soil/sediment samples on Southend beaches. **1800** End of operations. **29 June 2019** **0800** O2 Metocean and Baird personnel depart Beachport for Adelaide airport. **1230** Arrive Adelaide Airport. **1450** Depart for Perth **1600 (WST)** Arrive Perth airport. End of operations
02 – Service Visit	11th September to 14th September 2019	N. Turnbull	Mobilise to site. Recover, download, service, redeploy oceanographic equipment at agreed locations. Back up data.	**11 September 2019** **0540 (WST)** O2 Metocean personnel depart Perth for Adelaide. **1030** O2 Metocean personnel arrived Adelaide, collect hire car conduct vehicle checks and travel to Beachport SA. **1620** Arrive at Beachport. Travel to vessel operator yard. Locate equipment and begin preparing for service visit.

02 – Service Visit	11th September to 14th September 2019	N. Turnbull	Mobilise to site. Recover, download, service, redeploy oceanographic equipment at agreed locations. Back up data.	**1800** Finish preparations for the day. Return to accommodation. End of operations. **12 September 2019** **0630** Mobilise vessel on Beachport Jetty with equipment and instrumentation required for recovery and deployment operations. Undertake vessel induction and JSEA's. **0900** Transit from Beachport jetty to Southend location. **0925** Arrive at Southend recovery location. **0940** Begin recovery operations **1015** Southend ADCP seabed frame recovered **1030** Demobilise frame onto Southend Jetty. Begin data download and servicing of instrumentation and seabed frame for redeployment. **1300** Instrumentation and seabed frame ready for redeployment. **1330** Load vessel with Southend seabed frame. Verify ADCP is pinging. **1405** Deploy seabed frame at Southend location. **1410** Transit to Beachport seabed frame location. **1450** Arrive at Beachport Jetty. **1510** Begin recovery operations. **1530** Recovered Beachport ADCP. **1600** Demobilise frame onto Beachport Jetty. Begin data recovery and servicing instrumentation and seabed frame for redeployment. **1730** Instrumentation and seabed frame ready for redeployment. **1745** Load vessel with Beachport seabed frame. Verify ADCP is pinging. **1800** Deploy seabed frame at Beachport location. **1830** Demobilise vessel. **1900** Based on information for vessel transects close to shore the Breakaway vessel is not deemed fit for purpose. Begin trying to locate a suitable vessel. Return to accommodation. End of operations.
02 – Service Visit	11th September to 14th	N. Turnbull		**13 September 2019** **0600**

	September 2019	N Turnbull & J Churchill	Mobilise to site. Recover, download, service, redeploy oceanographic equipment at agreed locations. Back up data.	Locate a suitable vessel to undertake vessel mounted surveys in shallow water. **0900** Clean out vessel and prepare a suitable outboard motor for vessel **1000** Weld plate onto vessel to fix ADCP pole and instrumentation. **1040** Verify ADCP and GPS functioning with software. **1200** Deploy vessel from boat ramp and lower pole into water. **1300** Issue with welding not holding the boat pole and plate. **1315** Contact Baird and O2 Metocean office to explain issues with vessel mounted operations. Decision taken to pack up equipment for freight and begin drive back to Adelaide. **1430** Return vessel to owner and tidy up equipment from vessel **1530** Finish packing up freight and equipment for return to Perth. **1600** Depart from Beachport for Adelaide. Drive to Toll Ipec Millicent to send freight back. **2000** Arrive in Adelaide. Check into accommodation. End of operations. **14 September 2019** **0830** O2 Metocean personnel depart Adelaide airport for Perth airport. **1030** Arrive Perth airport. End of operations.
3 – Final Recovery	24th December 2019 (recovery seabed frames by vessel operator) 7th January to 9th January 2020		Mobilise to site, download oceanographic equipment and undertake a vessel mounted current survey	**24 December 2019** 0800 Vessel mobilise from mooring to complete ADCPs recovery 0900 ADCP Port Beach Recovered 1100 ADCP Southend Recovered **7th January 2020**

3- Final Recovery	7th January to 9th January 2020	N Turnbull & J Churchill	Mobilise to site, download oceanographic equipment and undertake a vessel mounted current survey	**0600 (WST)** O2 Metocean personnel depart Perth for Adelaide. **1130 (CST)** O2 Metocean personnel arrived Adelaide, collect hire car conduct vehicle checks and travel to Beachport SA. **1620** Arrive at Beachport. Travel to vessel operator yard. Locate equipment and begin downloading seabed frame instrumentation recovered on 24th December 2019. **1800** Finish downloading instrumentation. Begin preparations for the vessel mounted ADCP transects the next day. **2000** Return to accommodation. End of operations. **8th January 2020** **0630** Arrive at vessel operator yard to prepare instrumentation and vessel for vessel mounted transect operations. **0700** Arrive at Beachport Boat Ramp. Undertake safety briefing and board vessel. **0715** Vessel launched at boat ramp **0725** ADCP instrumentation for vessel mounted transect tested and ready for survey operations. **0736** Begin first transect opposite Beachport Boat Ramp. **0853** Finish transect lines at Beachport. Transit over to Southend. **0922** Arrive Southend. **0925** Begin transect lines around Southend. **1015** Finish transect lines at Southend. Transit back to Beachport. **1035** Arrive Beachport. **1040** Begin transect lines around Beachport. **1200** Finish transect lines at Beachport. **1230** Demobilise vessel at Beachport Boat Ramp. Begin backing up data and packing up freight for return to Perth. **1500** Finish backing up data and packing up equipment for freight back to Perth. Drive back to Adelaide. **2030** Return Hire car and check into accommodation in Adelaide. End of operations **9th January 2020**

	0630 Depart Adelaide for Perth. **0700 (WST)** Arrive Perth. End of operations.

3.6. Pre-deployment testing

Clocks in all instruments were synchronized and set before deployment as follow:

Winter time (UTC +0930 hours)

Summertime (UTC +1030 hours)

Pre-deployment tests were conducted as per the manufacturer's recommendations, namely:

- Operational checks of all transducers, pressure sensor and logging hardware;
- Compass alignment check procedure to correct for magnetic errors introduced by magnetic variability in battery packs;
- Pitch and roll checks in accordance with manufacturer's procedures.

The following notes were taken before or during profiling and deployment of instruments:

- Date, time and site name;
- Site coordinates UTM zone 54, WGS 84 or latitude and longitude;
- Water depth at measurement location;

4. Analysis Methodology

4.1. Bottom mounted ADCP

4.1.1. Currents

Each ADCP measured x, y, z orbital particle velocities, surface elevation, pressure and seawater temperature. The orbital velocities are detected by measuring the radial doppler shift of the water particles along each of the three angled acoustic beams. These are then internally rotated to a north-south, east-west, and vertical coordinate system and converted to velocities using the instrument's internal processor, compass and tilt sensors. The resultant velocity components are then averaged over a specified period prior to recording onto a solid-state memory card.

4.1.2. Waves

Wave parameters are calculated by utilising the Teledyne RDI software package WavesMon. This package resolves wave height, direction and period using a wave triplet method. The triplet method can resolve wave statistics by relating horizontal flow velocity to either pressure, acoustic surface track, or vertical flow velocity. The use of pressure data is prioritised where possible, as this is typically the cleanest method. Unfortunately the ADCP pressure sensor failed during deployment period 2 at the Beachport location (see section 6.2.1), and hence the surface track prioritised for this record.

Further investigation on the data anomaly observed for the Hs wave statistic calculation and ADCP pressure sensor was undertaken. No anomaly was identified during the certificated after deployment pressure sensor test. The ambiguity in the Hs wave statistic resolution, that present a height level of noise, was most likely caused by an excessive turbulence to the surface in the shallow water. However, the other wave parameters as wave direction were clearly processed without ambiguity.

4.2. RBR

4.2.1. Long period waves

Long period waves were evaluated by short-term band-pass filtering water level data. Segment lengths of 60 minutes were used as this is expected to be long with respect to long-period waves, and short with respect to the tides.

Spectral analysis was performed on each segment producing a spectrogram – a representation of the energy surface waves as a function of frequency and time. This spectrogram was used to filter waves between 40 seconds and 10 minutes. The lower cut-off of 40 seconds was selected to provide separation the prevailing swell period which was regularly up to 20 seconds. Herein we refer to the band between 40 seconds and 10 minutes as the *long-wave band*.

Filtered time-series were reconstructed from these spectrograms representing surface oscillations in the long-wave band. Significant wave heights and wave peak period were then calculated for the long-wave band from each filtered time-series. The significant wave height may then be compared to the unfiltered significant wave heights calculated using the ADCP data.

This methodology represents two additional steps from the proposed methodology, namely:

1) Conversion of spectrograms back to filtered time-series, and;
2) Calculation of a low frequency significant wave height from the filtered time series.

We present only the final filtered significant wave height, but wave peak period and spectrograms may be provided on request.

As with any spectral method the results are sensitive to statistical non-stationarity, which may appear as low frequency variability. Alternate methodologies involving continuous wavelet transforms are less affected by this, however interpretation is more complicated. Such methodologies are being explored for the study site. Additionally, this method uses pressure data at a single spatial location. As such it cannot be readily distinguish between freely propagating waves, forced waves, or (as mentioned above) other non-stationary processes.

4.3. Vessel Mounted ADCP Transects

The raw data, collected in the ADCP's roving configuration, were processed and exported using the Teledyne RDI software package WinRiver II. The exported data were trimmed further to remove any points sampled within 0.5 m of the seabed, as these contain many erroneous values due to the acoustic interference of the seabed. The height of the seabed was determined by the ADCPs depth corrected acoustic bottom tracking.

The trimmed values were averaged using rolling mean at each depth cell. This was necessary owing to the signal-to-noise ratio and correlation in the raw measurements, which are affected by the strength of the flow being measured, suspended sediment concentrations, and small-scale features of the flow. A 50 second moving average cell was chosen based on the ADCP standard deviation diagnostic.

5. Conditions

Meteorological data were obtained from the Bureau of Meteorology's Robe Airfield station (station number 26105). The available BOM data were coarse in resolution, with many gaps.

5.1. Wind

During the first deployment period, winds at the nearby were predominantly Easterly to Northerly, with the strongest winds (>40 km/h) having a more Northerly aspect. Peak wind speeds were stronger during the second deployment period (>40 km/h), however the data were too sparse to obtain meaningful directional statistics.

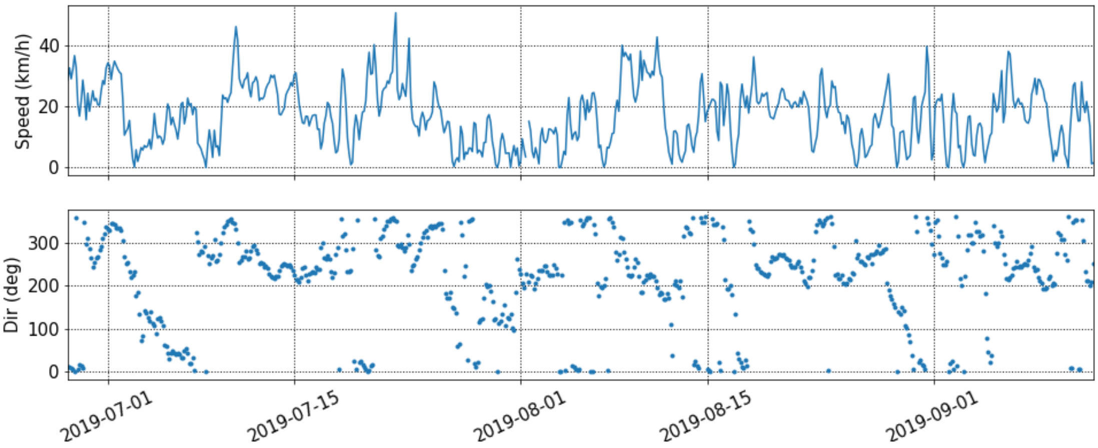

Figure 5-1 Wind speed (km/h) and direction (deg) from the BOM's Robe Airfield station (station 26105) for the first deployment period [28th June – 12th September 2019].

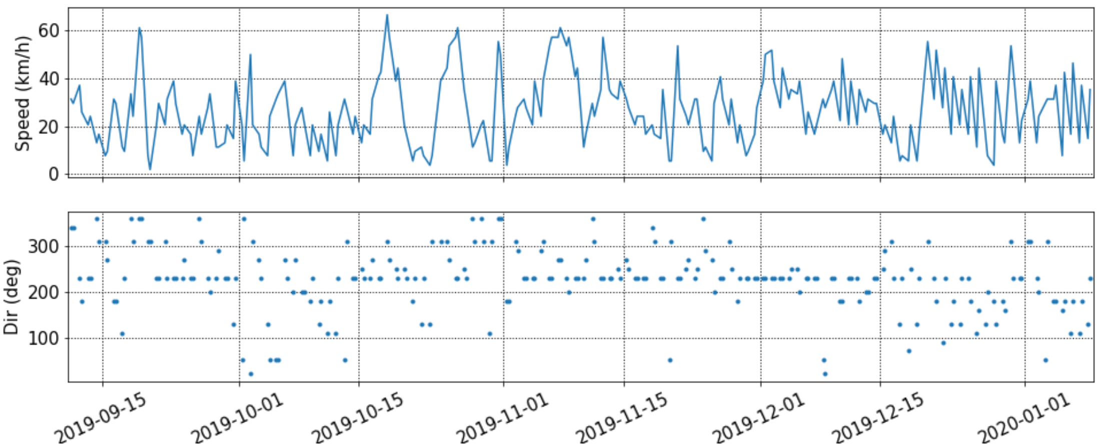

Figure 5-2 Wind speed (km/h) and direction (deg) from the BOM's Robe Airfield station (station 26105) for the second deployment period [12th September – 24th December 2019].

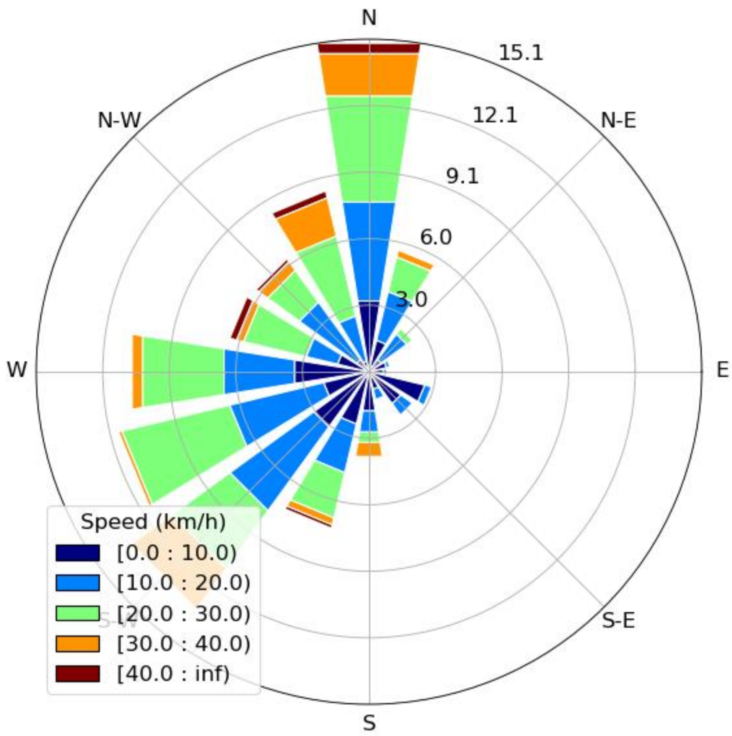

Figure 5-3 Wind roses from the BOM's Robe Airfield station (station 26105) for the first deployment period [28th June – 12th September 2019]

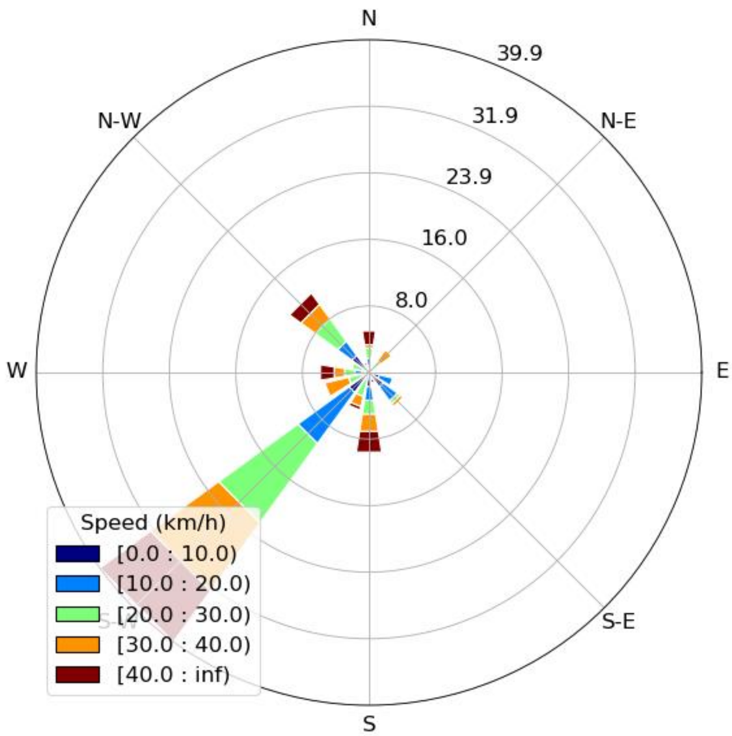

Figure 5-4 Wind roses from the BOM's Robe Airfield station (station 26105) for the second deployment period [12th September – 24th December 2019]

6. Data

6.1. Data Recovery Summary

In calculating data recovery, a contract length of 180 days was used for all records except for the Southend RBR waves which spanned only 77 days. The combined average data recovery for all moored instrument (excludes transects) records was 96%.

Table 6-1 Summary of data recovery for each moored instrument

Site	Record	Contract length (days)	Data loss (days)	Data Recovery (%)
Beachport	ADCP Currents	180	7	96
	ADCP Waves	180	2	99
	RBR Waves	180	0	100
Southend	ADCP Currents	180	0	100
	ADCP Waves	180	0	100
	RBR Waves	77	29	62
	Total	**977**	**38**	**96**

6.2. Beachport

6.2.1. Bottom mounted ADCP

Current

Currents at the Beachport ADCP location were principally on a North-South axis with a significant asymmetry between currents flowing into and out of the Bay. The strongest currents flowed toward the South, occurring principally in short duration events which tended to coincide with periods of sustained Northerly winds.

There was a significant data gap from 11-Nov-2019 19:52 to 18-Nov-2019 9:02 (7 days) in the second deployment period.

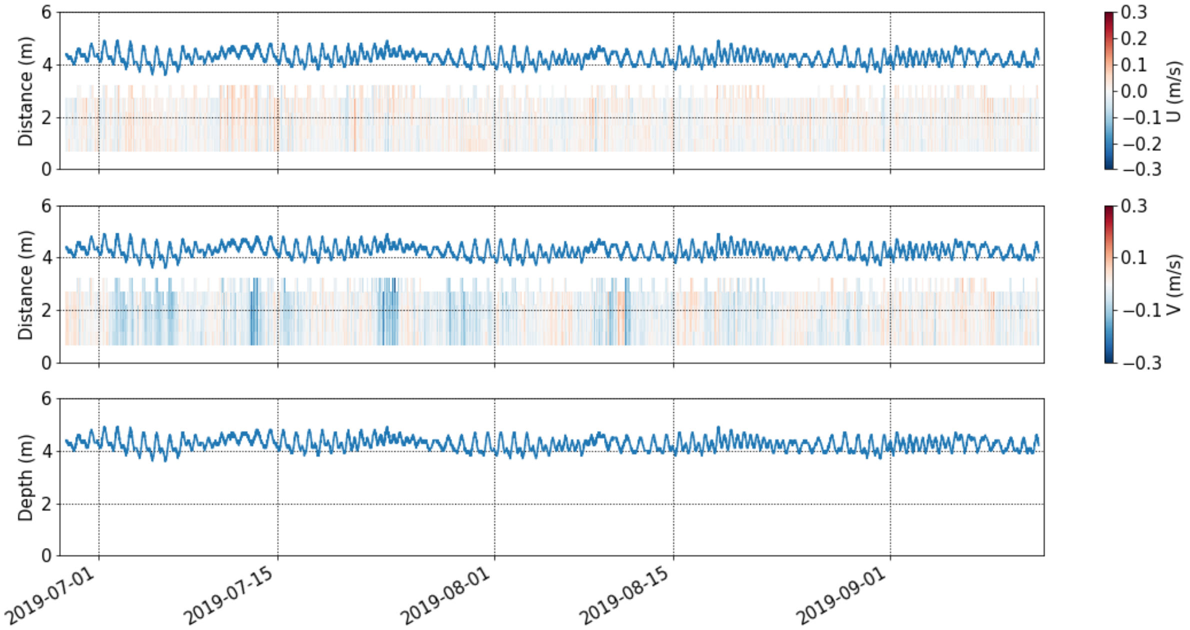

Figure 6-1 Current and depth at the Beachport ADCP location for the first deployment period [28th June – 12th September 2019]. Top: Easterly velocity component; Middle: Northerly velocity component; Bottom: Depth.

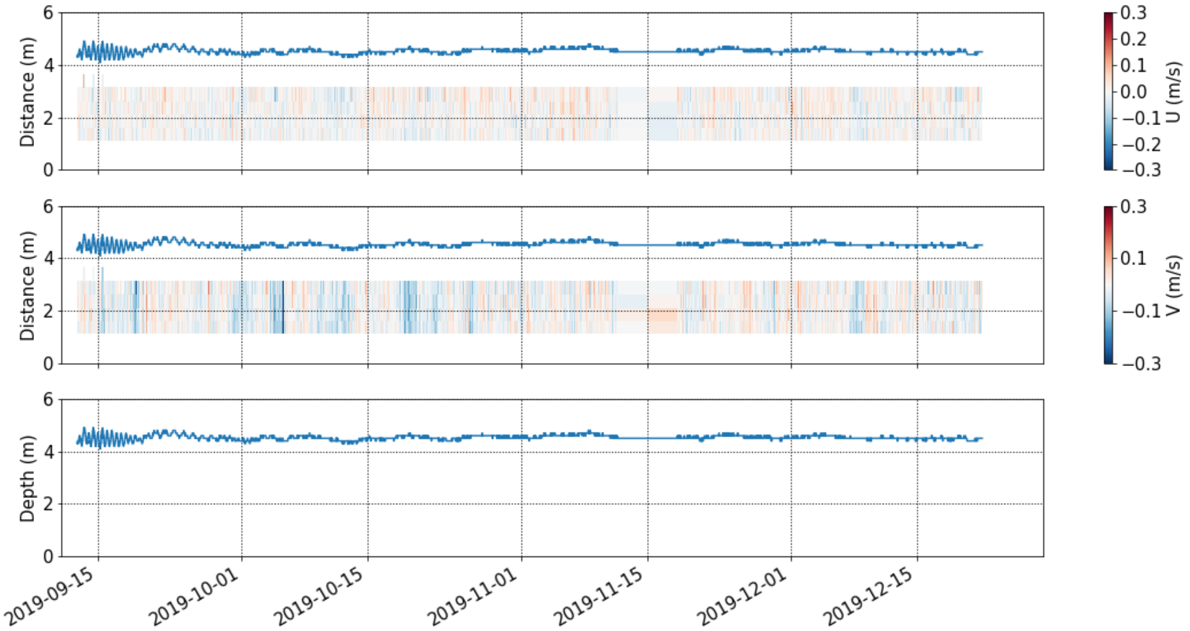

Figure 6-2 Current and depth at the Beachport ADCP location for the second deployment period [12th September – 24th December 2019]. Top: Easterly velocity component; Middle: Northerly velocity component; Bottom: Depth.

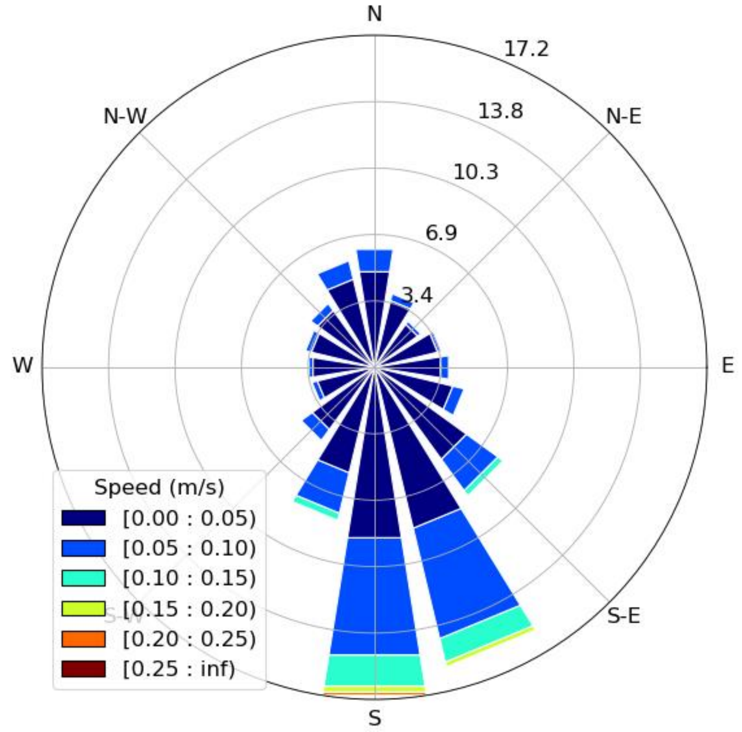

Figure 6-3 Depth average current rose at the Beachport ADCP location for the first deployment period [28th June – 12th September 2019]; current speed (m/s) direction going to.

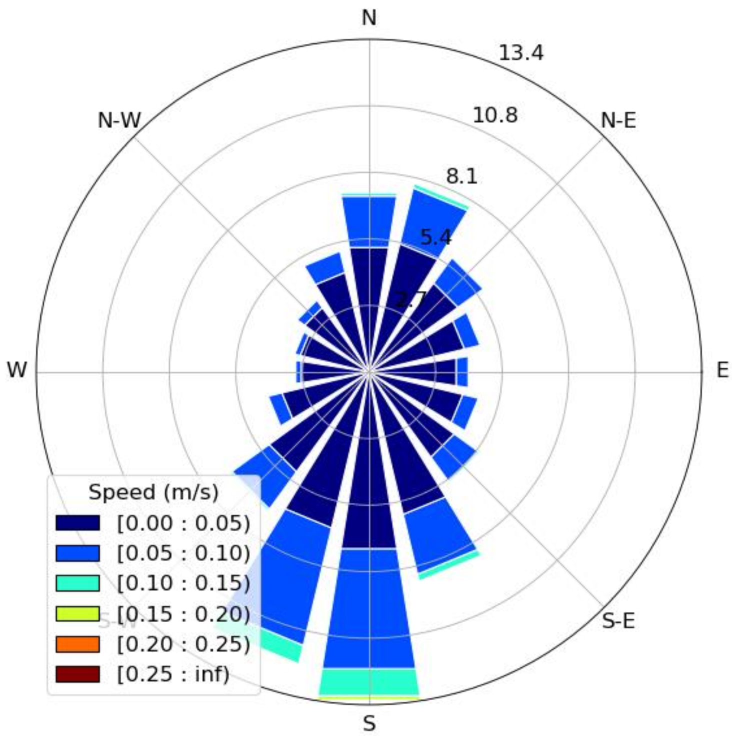

Figure 6-4 Depth average current rose at the Beachport ADCP location for the second deployment period [12th September – 24th December 2019]; current speed (m/s) direction going to.

Waves

South to south-westerly waves were persistent at the Beachport location. During the first deployment period significant wave heights were consistently above 0.2 m, with peaks exceeding 1 m. Peak significant wave heights were lower during the second deployment period, and the time series were noisier owing to the failure of the ADCP pressure sensor (this failure and the requirement for alternate processing techniques is discussed in 4.1.2 above). Peak periods were predominantly in the swell band for both periods.

Data were of high quality for the full first deployment period, while in the second deployment period data were of poor quality after December 22 (2 days).

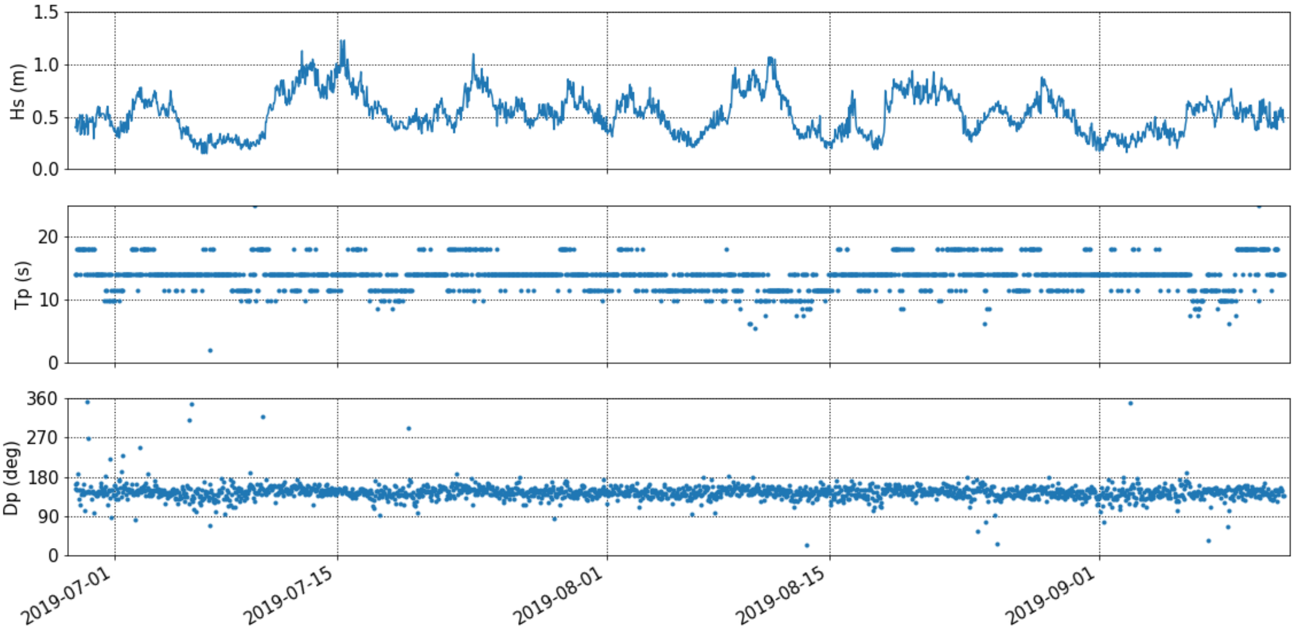

Figure 6-5 Wave conditions at the Beachport ADCP location first deployment period [28th June – 12th September 2019]: Significant height, peak period and Peak direction.

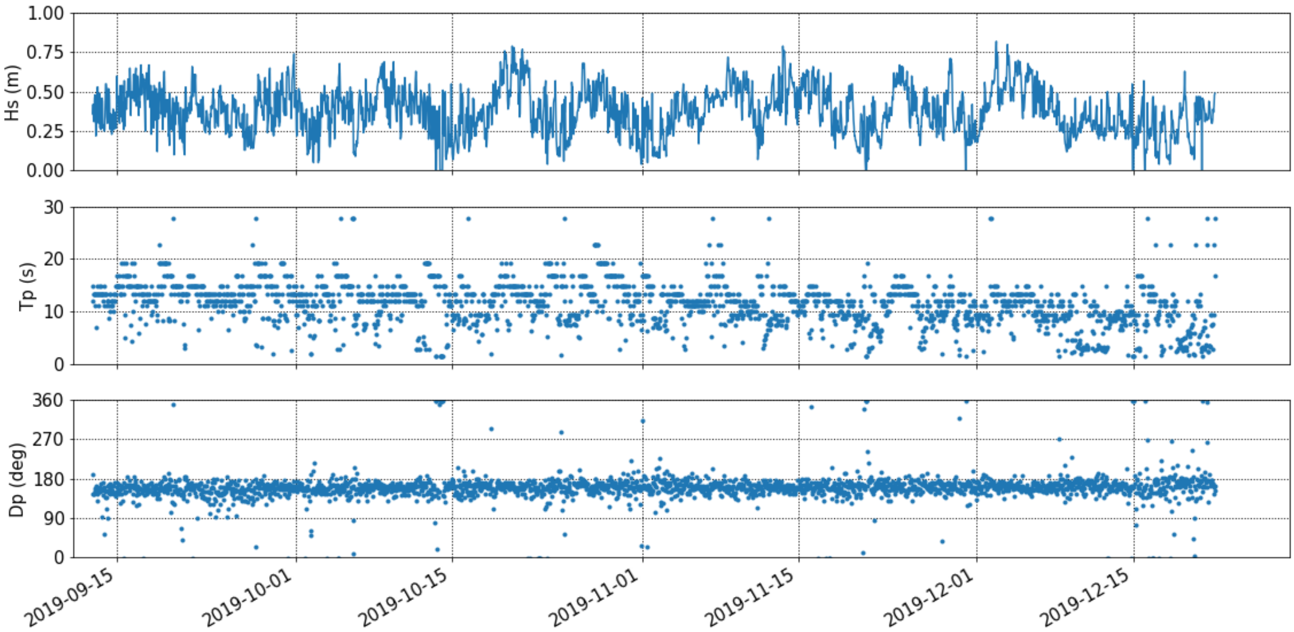

Figure 6-6 Wave conditions at the Beachport ADCP location for the second deployment period [12th September – 24th December 2019]: Significant height, peak period and Peak direction for the monitoring period

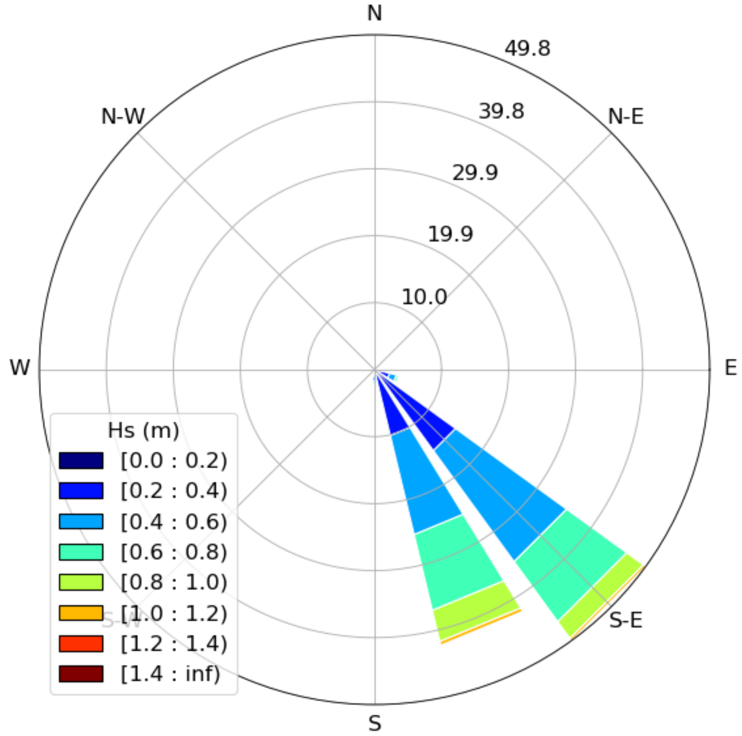

Figure 6-7 Wave roses at the Beachport ADCP location for the first deployment period [28th June – 12th September 2019]; significant wave height (m) against peak direction.

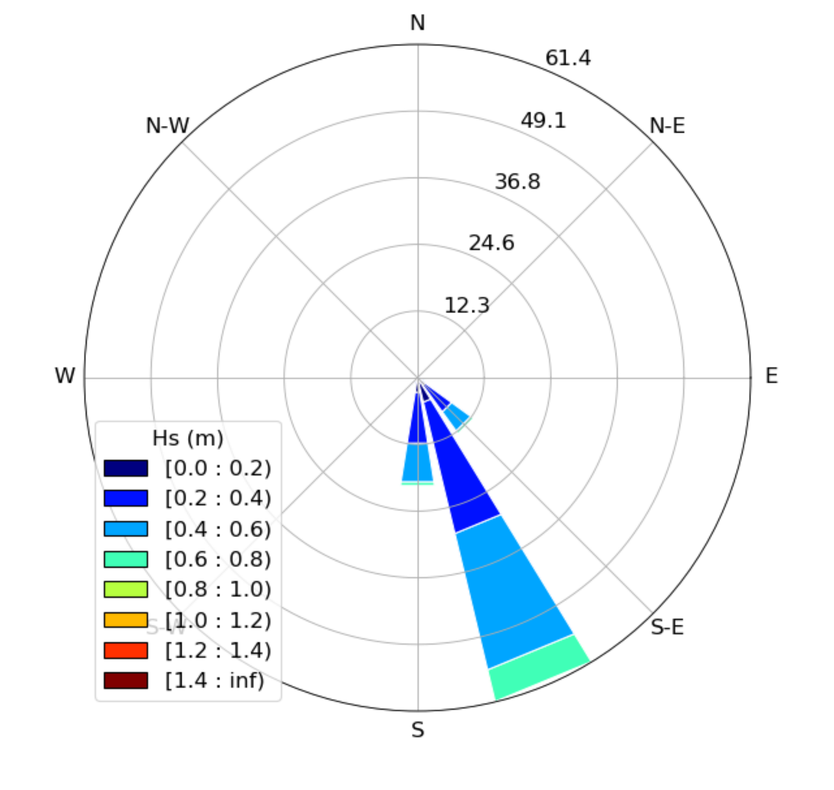

Figure 6-8 Wave roses at the Beachport ADCP location for the second deployment period [12th September – 24th December 2019]; significant wave height (m) against peak direction.

6.2.2. RBR

Long Period Waves

Spectral filtering analysis indicated aperiodic variability in the long-wave band. Long-wave band Hs followed similar trends to the Hs derived from the ADCP, however the bulk of the energy was contained at higher frequencies (i.e. in the swell and sea bands).

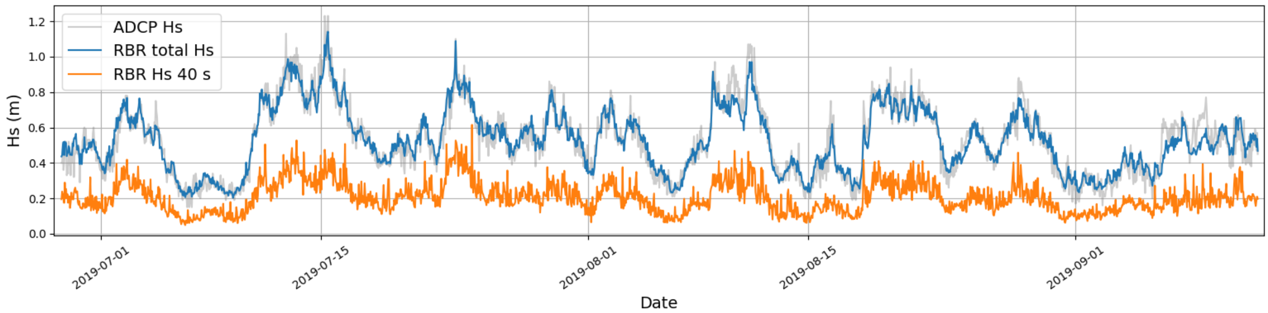

Figure 6-9 Significant wave heights derived from the long-period wave analysis (section 4.2) against long period waves from the ADCP (these data are duplicated from above for illustration purposes) for the first deployment period [28th June – 12th September 2019].

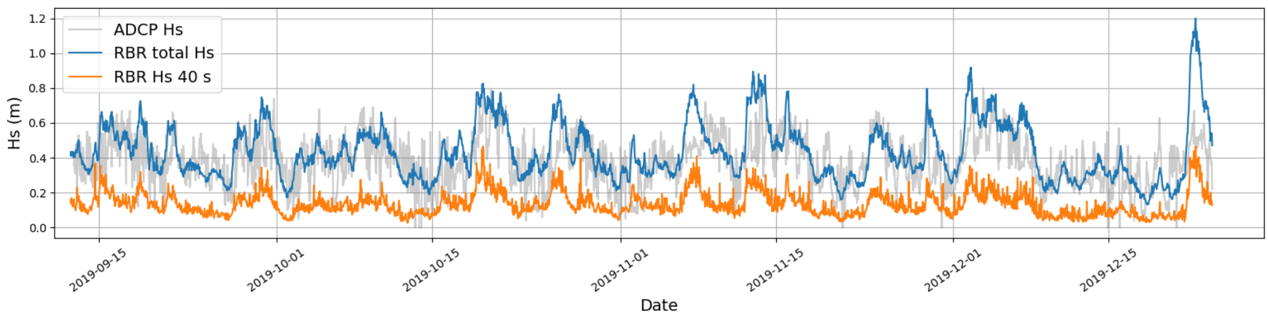

Figure 6-10 Significant wave heights derived from the long-period wave analysis (section 4.2) against long period waves from the ADCP (these data are duplicated from above for illustration purposes) for the second deployment period [12th September – 24th December 2019].

6.3. Southend

6.3.1. Bottom mounted ADCP

Current

The principal axis of currents at the Southend ADCP location was approximately East-West. Again, there was a significant asymmetry in current magnitude, with the strongest currents flowing out of the Bay.

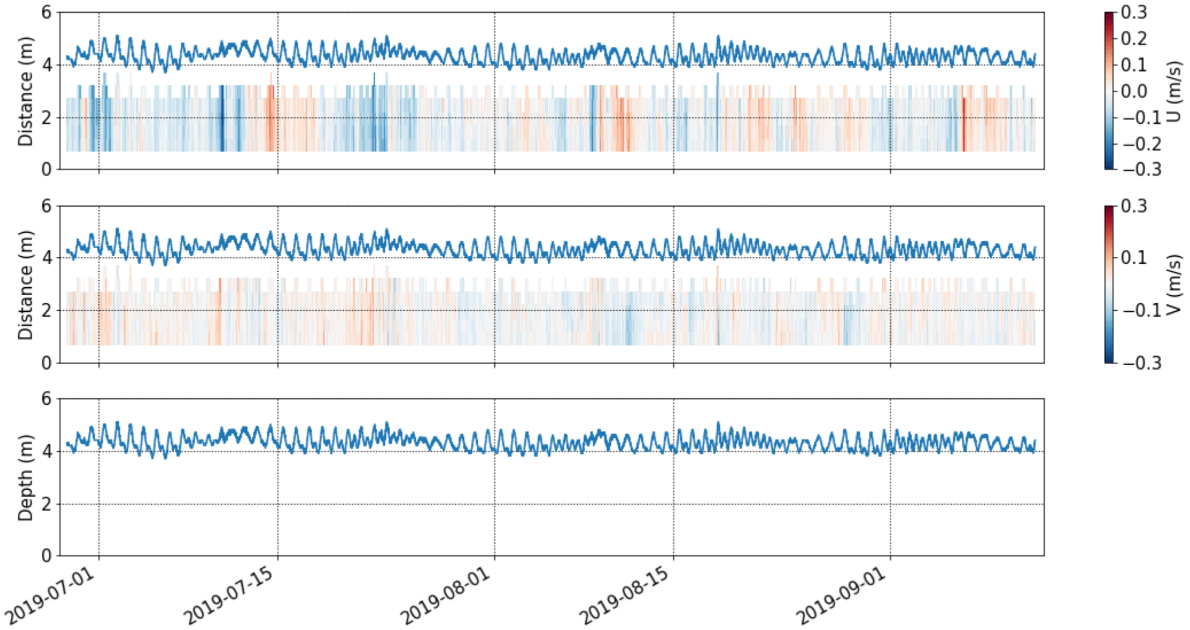

Figure 6-11 Current and depth at the Southend ADCP location for the first deployment period [28th June – 12th September 2019]. Top: Easterly velocity component; Middle: Northerly velocity component; Bottom: Depth.

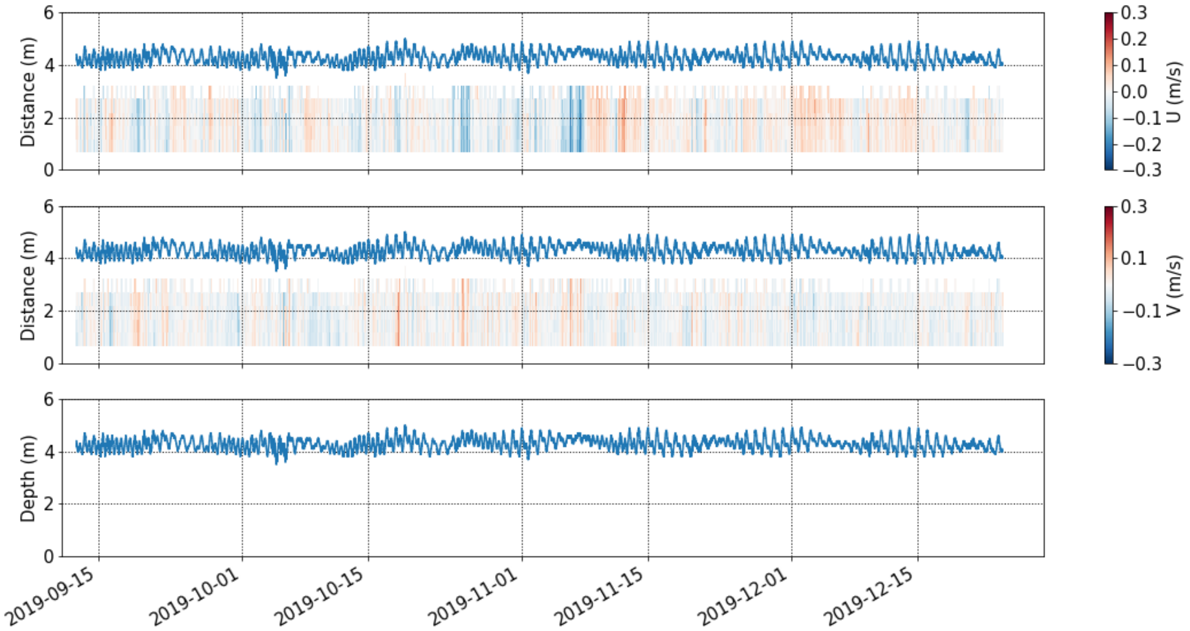

Figure 6-12 Current and depth at the Southend ADCP location for the second deployment period [12th September – 24th December 2019]. Top: Easterly velocity component; Middle: Northerly velocity component; Bottom: Depth.

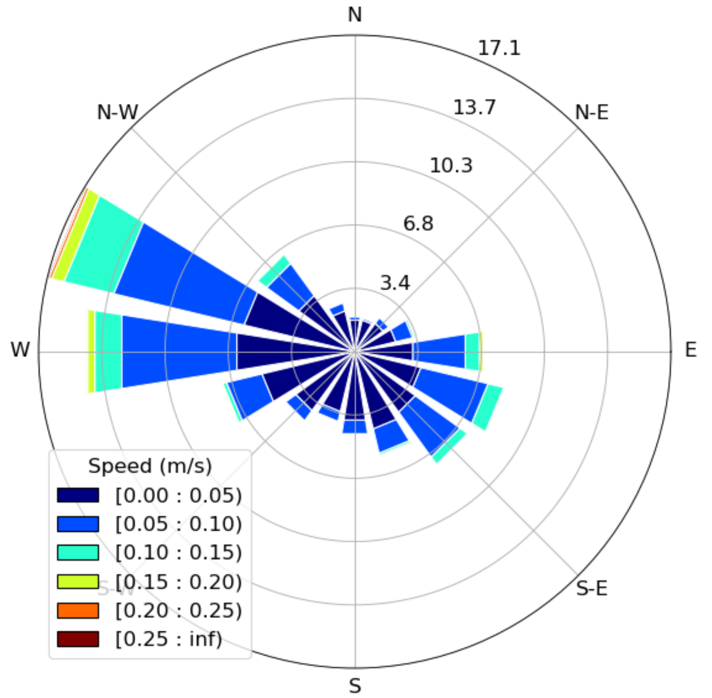

Figure 6-13 Depth average current rose at the Southend ADCP location for the first deployment period [28th June – 12th September 2019]; current speed (m/s) direction going to.

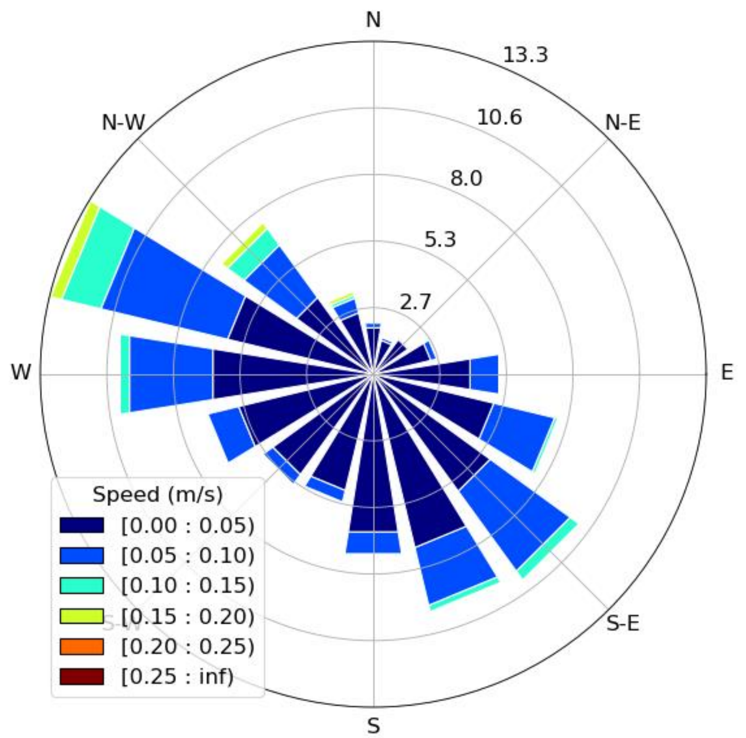

Figure 6-14 Depth average current rose at the Southend ADCP location for the second deployment period [12th September – 24th December 2019]; current speed (m/s) direction going to.

Waves

West to north-westerly waves were persistent at the Southend location. During the first deployment period significant wave heights consistently above 0.2 m, with peaks over 1.5 m. Peak significant wave heights were slightly lower during the second deployment period, reaching around 1.25 m. Peak periods were predominantly in the swell band for both periods.

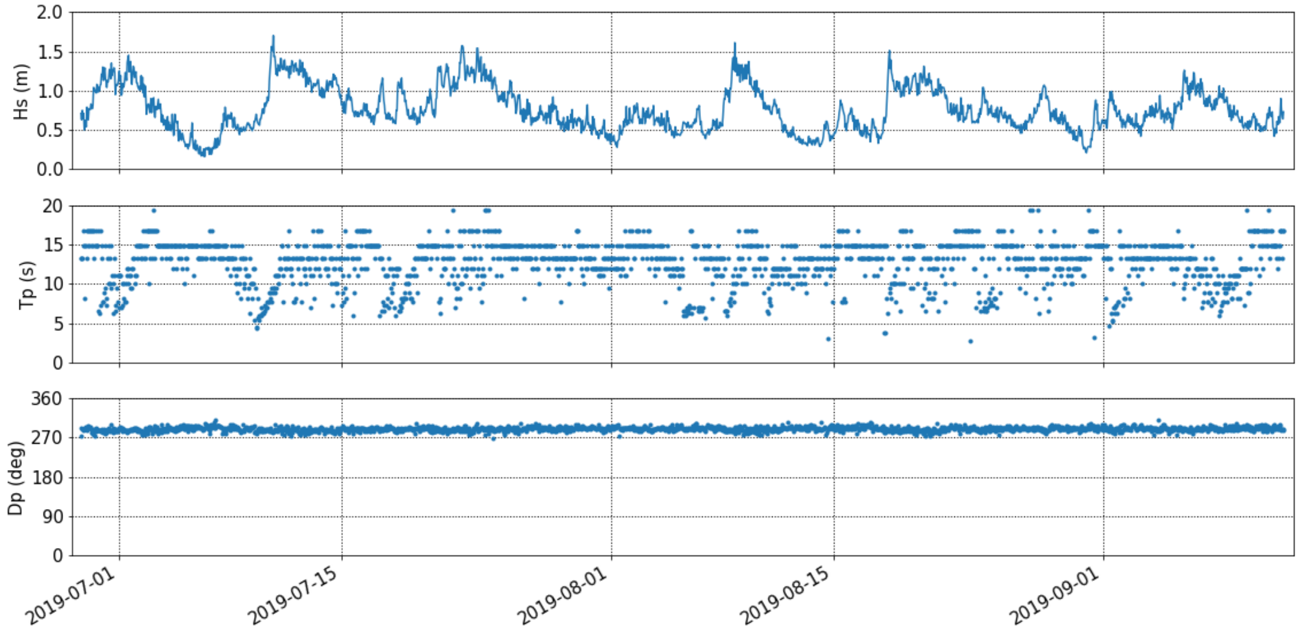

Figure 6-15 Wave conditions at the Southend ADCP location for the first deployment period [28th June – 12th September 2019]: Significant height, peak period and Peak direction

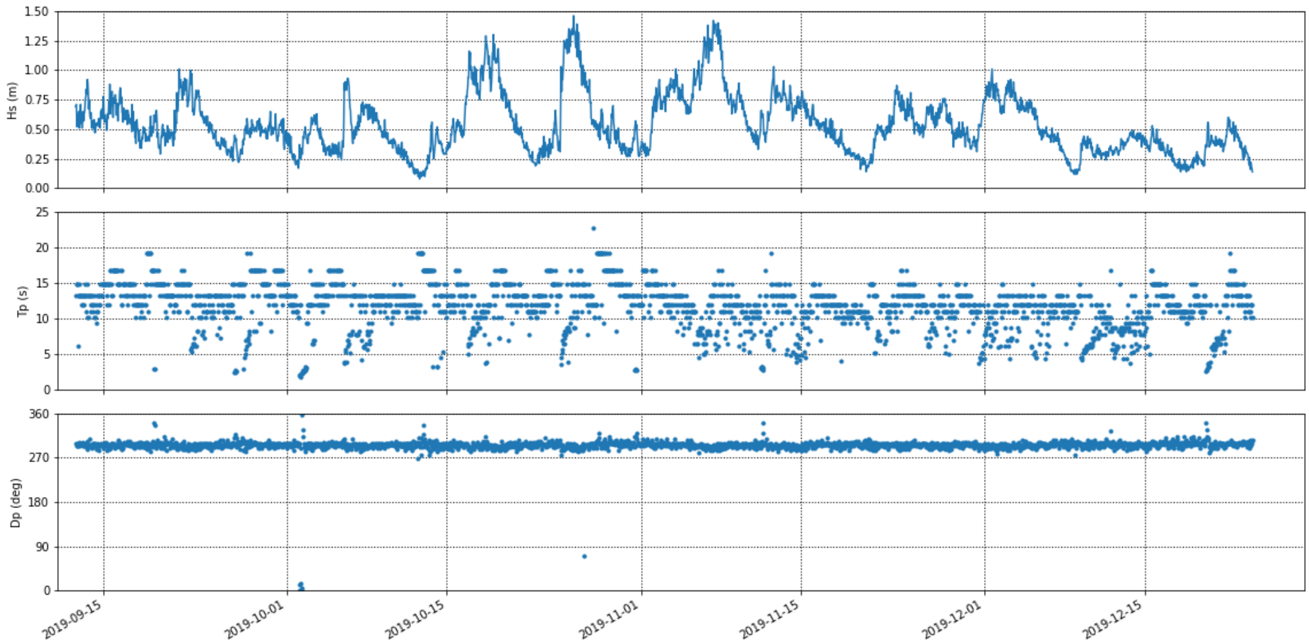

Figure 6-16 Wave conditions at the Southend ADCP location for the second deployment period [12th September – 24th December 2019]: Significant height, peak period and Peak direction

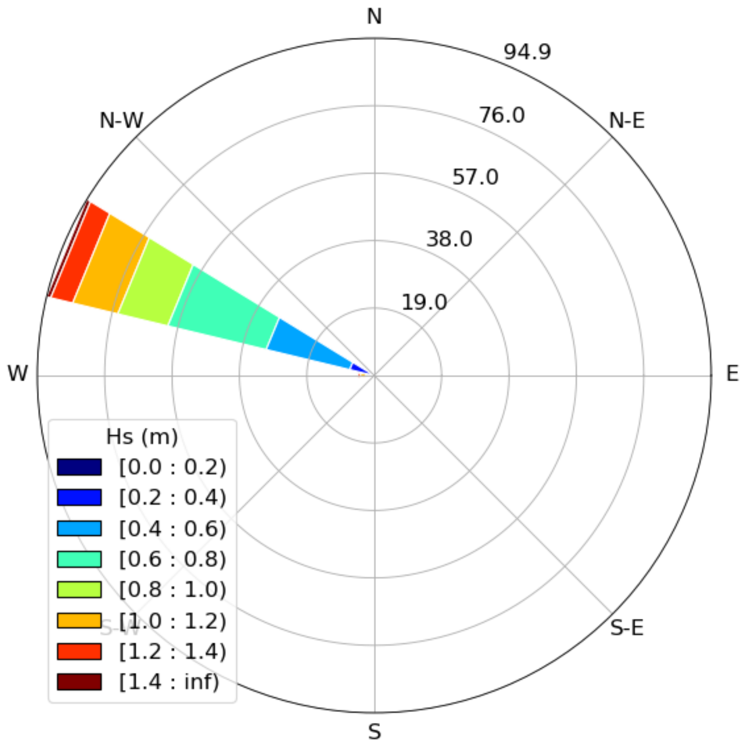

Figure 6-17 Wave roses at the Southend ADCP location for the first deployment period [28th June – 12th September 2019]; significant wave height (m) against peak direction.

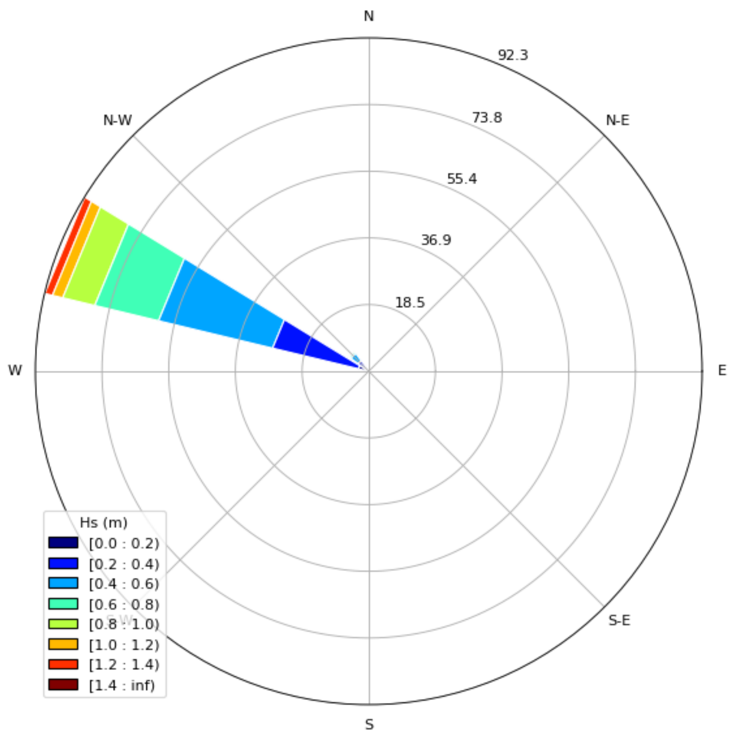

Figure 6-18 Wave roses at the Southend ADCP location for the second deployment period [12th September – 24th December 2019]; significant wave height (m) against peak direction.

6.3.2. RBR

Long Period Waves

Spectral filtering analysis indicated aperiodic variability in the long-wave band. Long-wave band Hs followed similar trends to the Hs derived from the ADCP, however the bulk of the energy was contained at higher frequencies (i.e. in the swell and sea bands).

The RBR instrument stopped logging between 23/07/2019 and 30/07/2019 (8 days) for unknown reasons and again from 23/08/2019 to 12/09/2019 (21 days) due to battery depletion. The RBR battery consumption was higher than anticipated for the sample rate and water temperature.

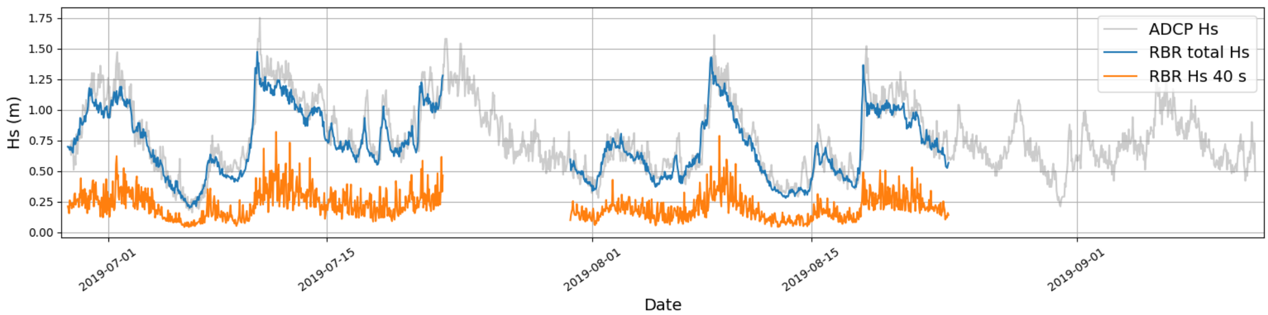

Figure 6-19 Significant wave heights derived from the long-period wave analysis (section 4.2), against long period waves from the ADCP (these data are duplicated from above for illustration purposes).

6.4. Vessel mounted ADCP transects

6.4.1. January 08 Transects

January 08 current transects at both locations revealed generally weak currents and isolated patches of variable current speed and direction (Figure 6-21 to Figure 6-34). It is noted that the transects were made during low tide, and that wave induced currents may influence transects at this scale. It is noted that the ADCP was sampled at maximum capacity to optimise data quality, however the suspended sediment concentration and current speed during the transecting resulted in relatively noisy measurements.

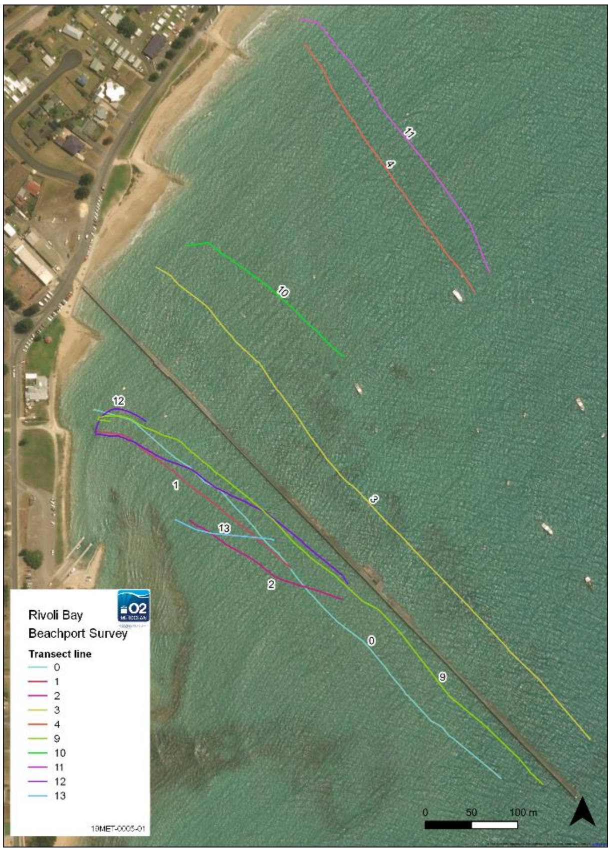

Figure 6-20 Map of ADCP Transects from Jan 08 2020. Left: Beachport transects [0-4 and 9-13]. Right: Southend transects [5-8]

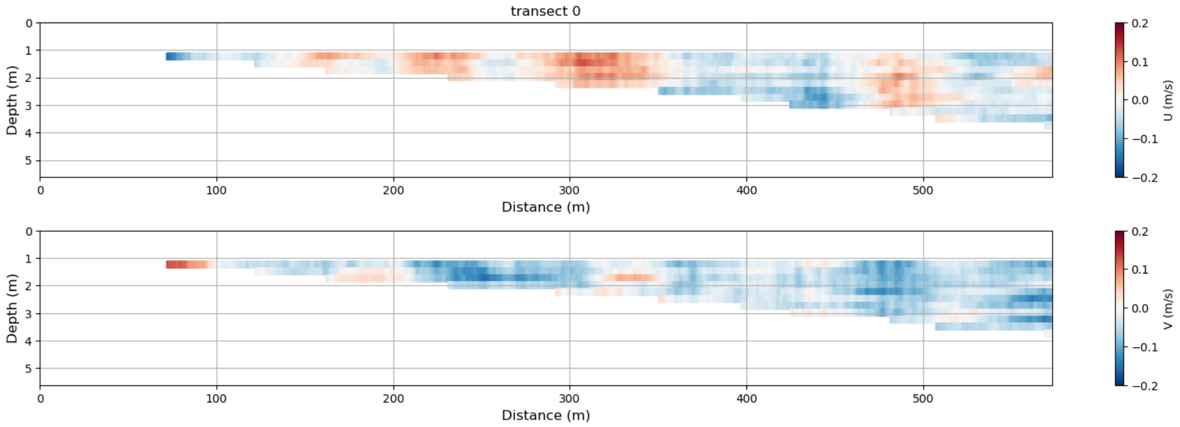

Figure 6-21 Eastward (top) and Northward (bottom) velocity profiles for transect 0

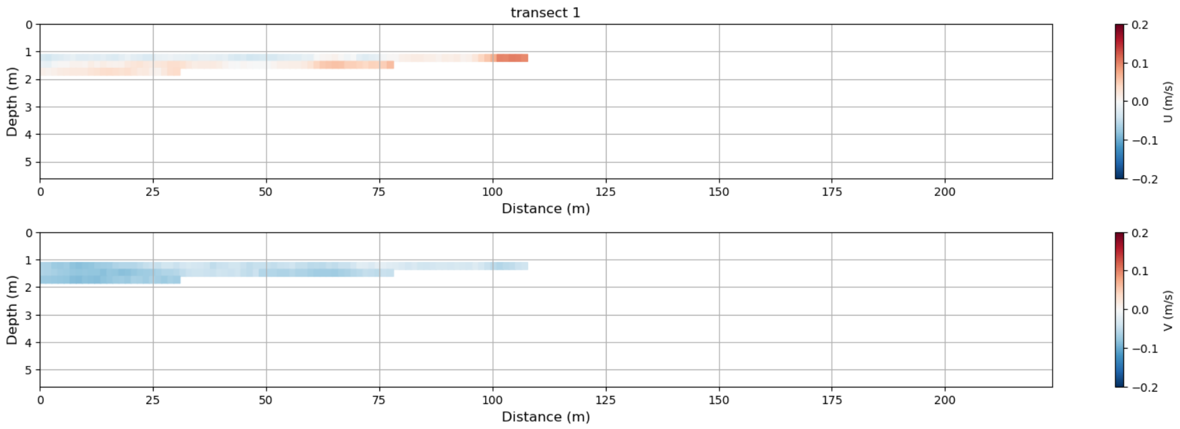

Figure 6-22 Eastward (top) and Northward (bottom) velocity profiles for transect 1

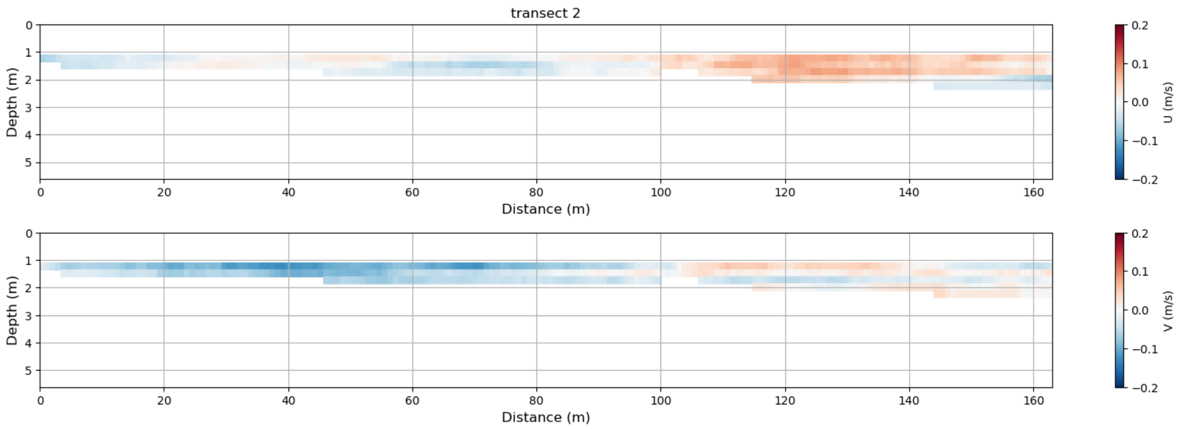

Figure 6-23 Eastward (top) and Northward (bottom) velocity profiles for transect 2

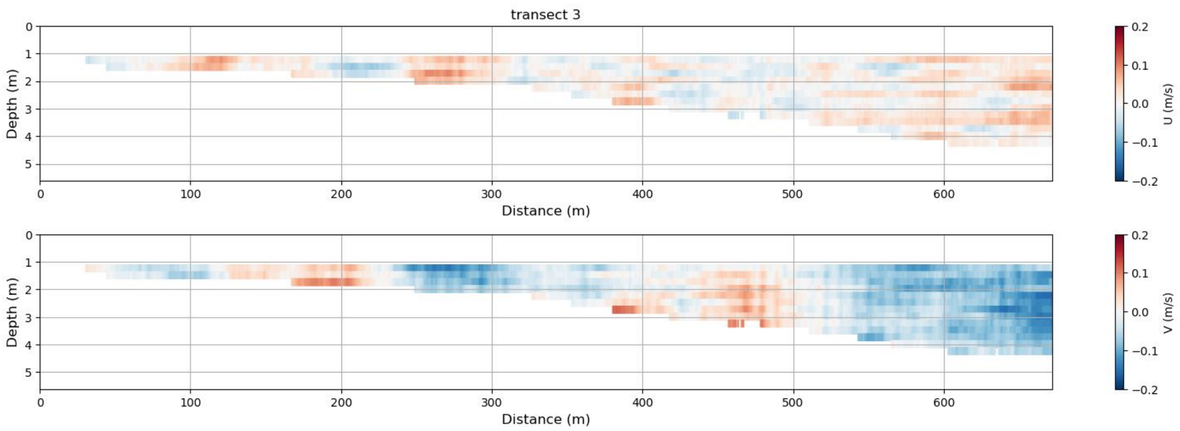

Figure 6-24 Eastward (top) and Northward (bottom) velocity profiles for transect 3

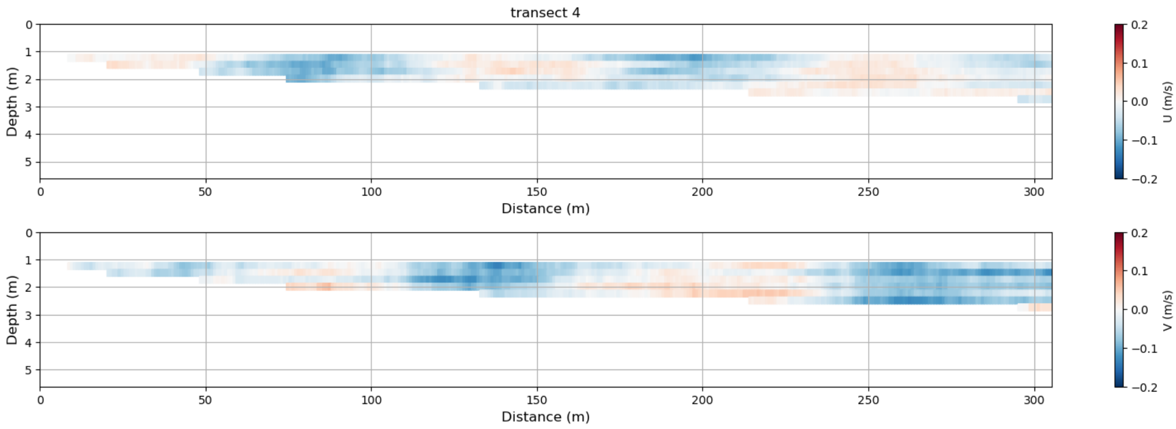

Figure 6-25 Eastward (top) and Northward (bottom) velocity profiles for transect 4

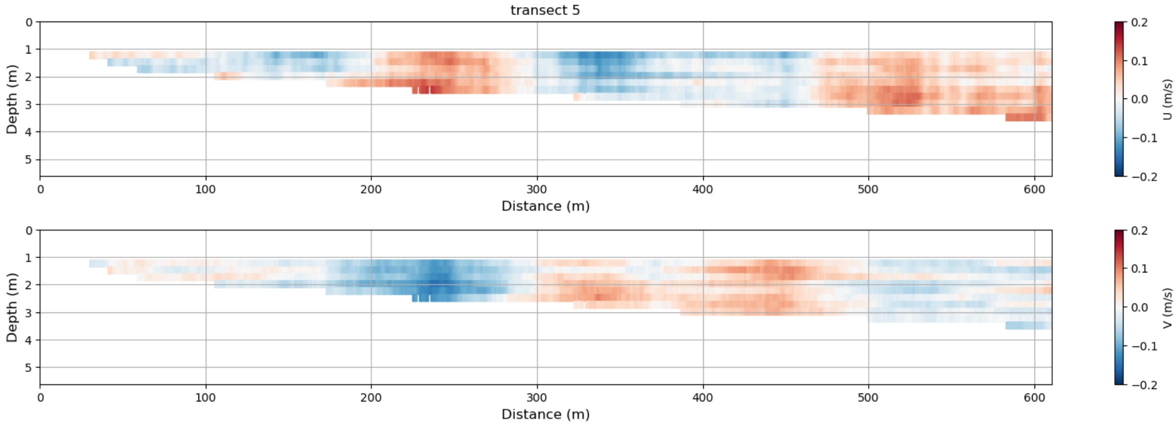

Figure 6-26 Eastward (top) and Northward (bottom) velocity profiles for transect 5

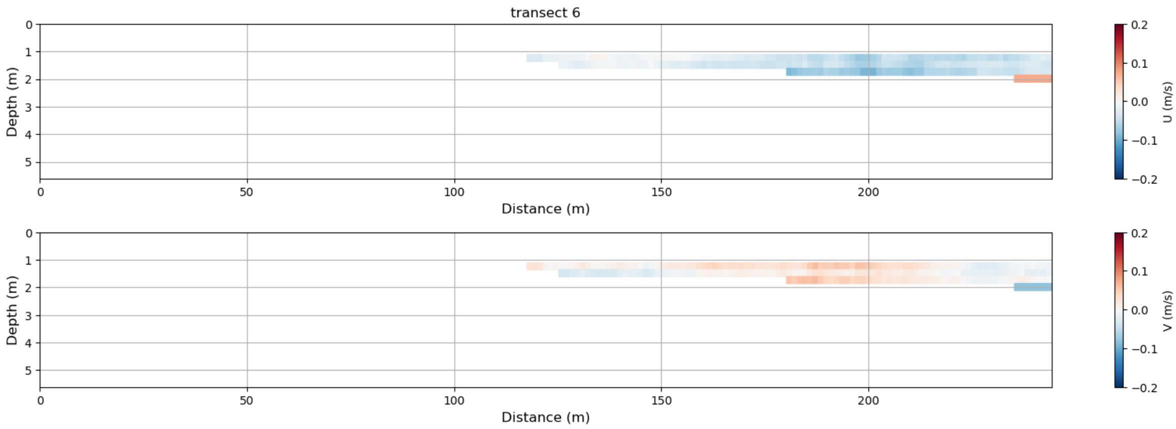

Figure 6-27 Eastward (top) and Northward (bottom) velocity profiles for transect 6

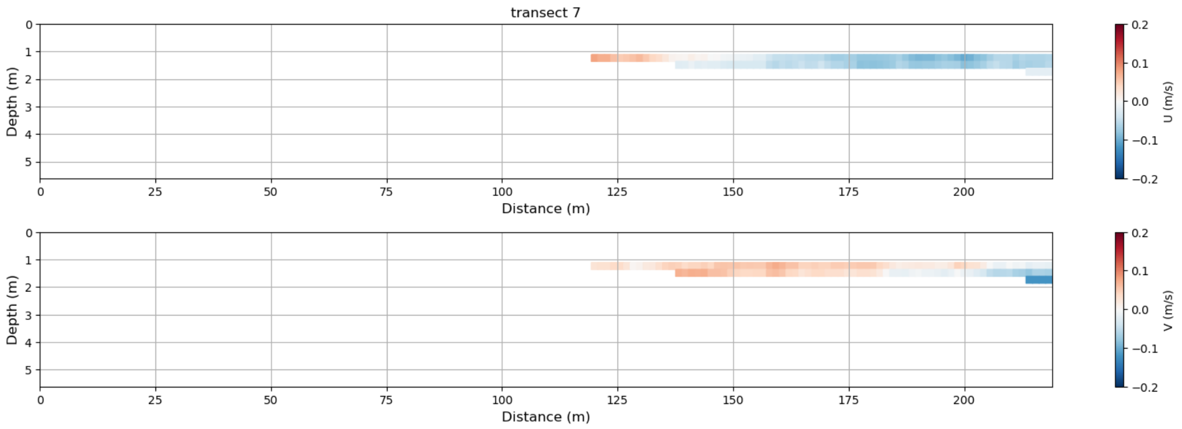

Figure 6-28 Eastward (top) and Northward (bottom) velocity profiles for transect 7

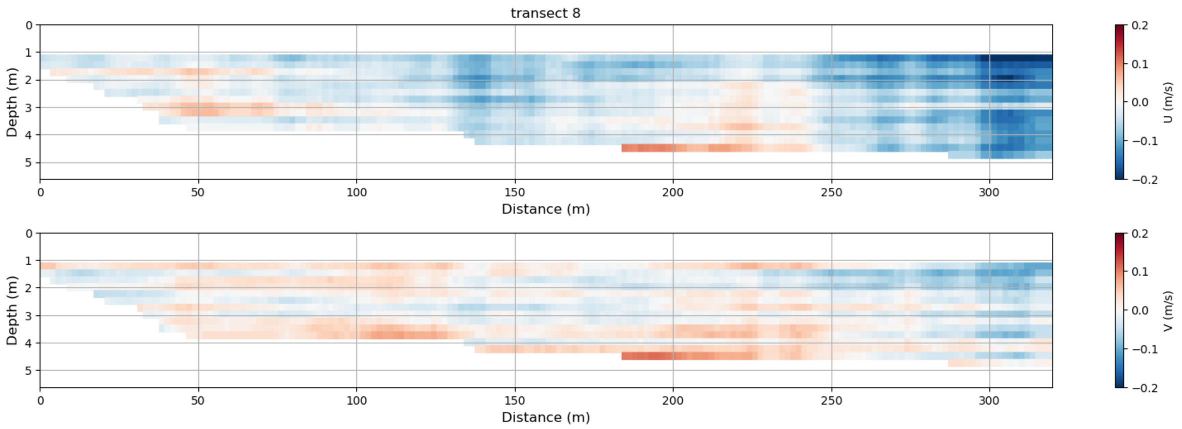

Figure 6-29 Eastward (top) and Northward (bottom) velocity profiles for transect 8

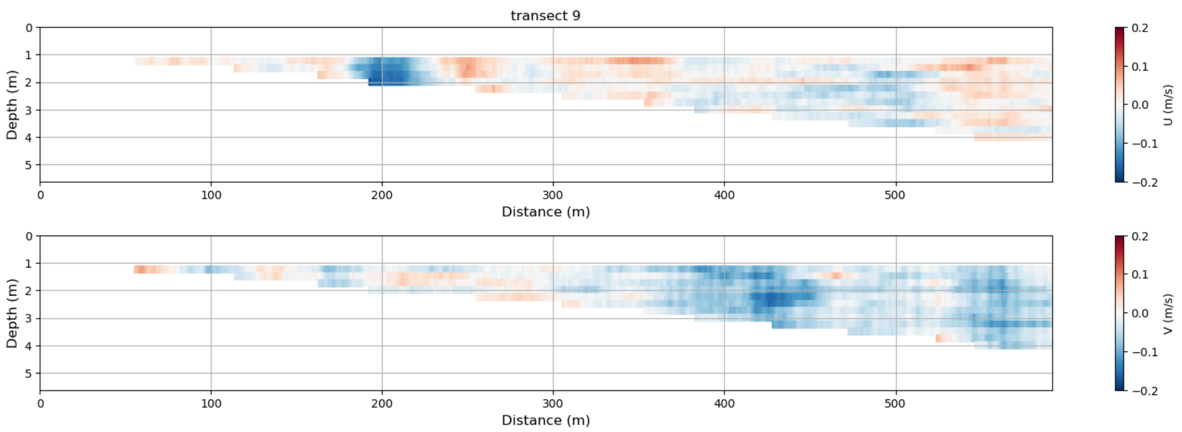

Figure 6-30 Eastward (top) and Northward (bottom) velocity profiles for transect 9

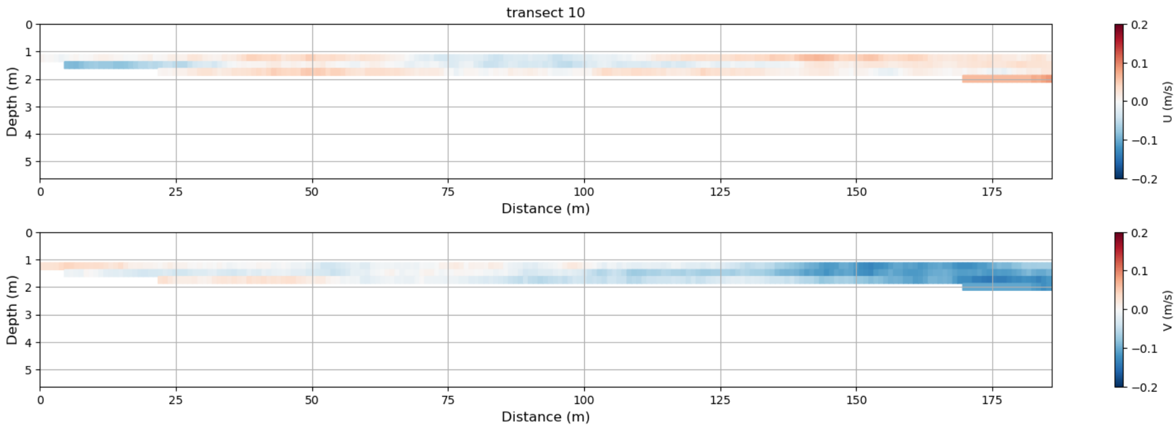

Figure 6-31 Eastward (top) and Northward (bottom) velocity profiles for transect 10

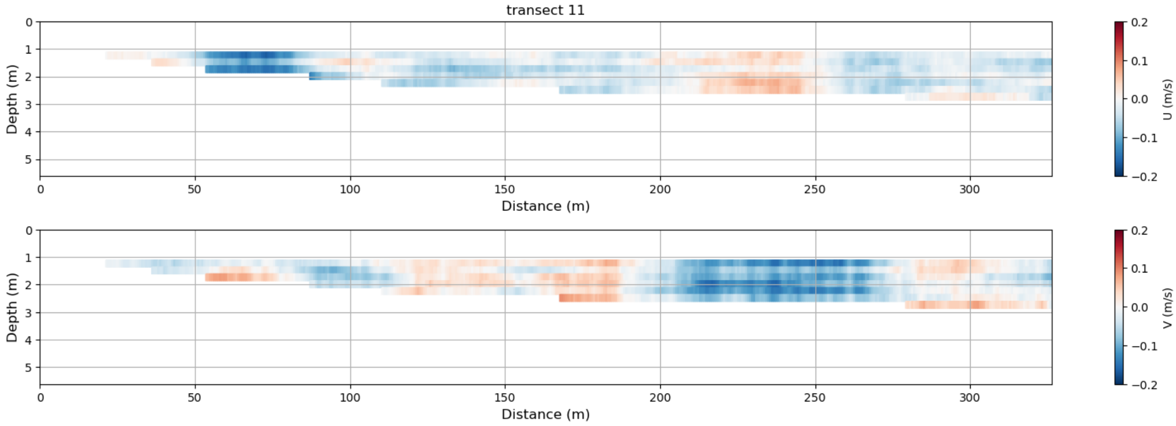

Figure 6-32 Eastward (top) and Northward (bottom) velocity profiles for transect 11

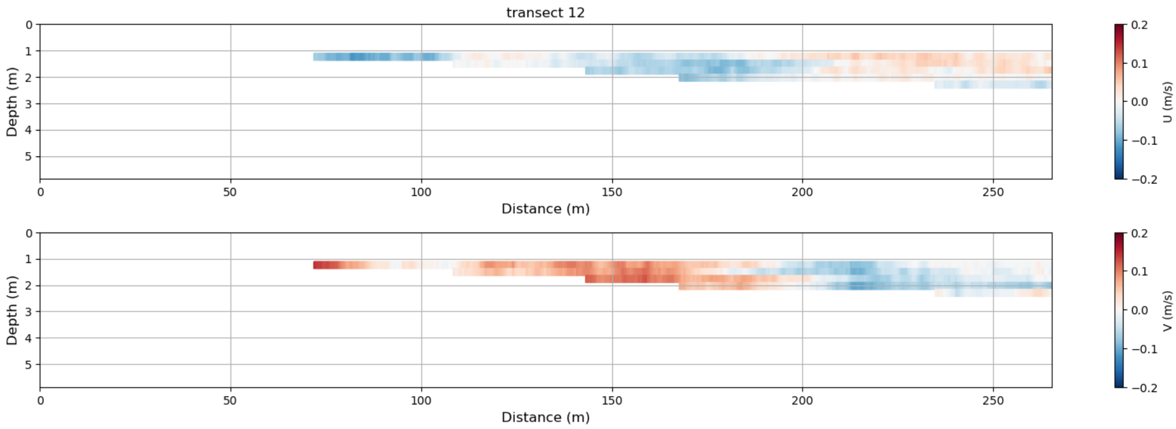

Figure 6-33 Eastward (top) and Northward (bottom) velocity profiles for transect 12

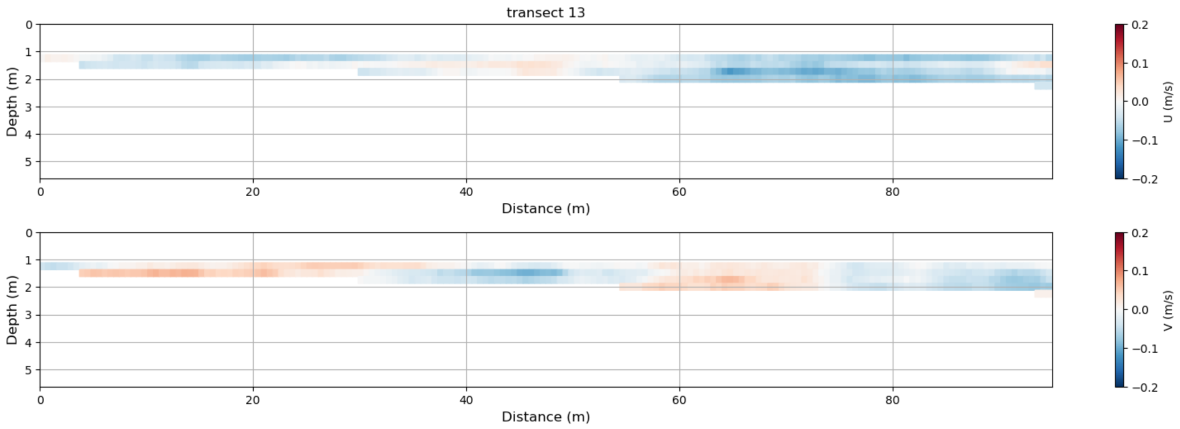

Figure 6-34 Eastward (top) and Northward (bottom) velocity profiles for transect 13

6.5. Data provision

Processed data are provided for:

- ADCP currents;
- ADCP waves;
- RBR long waves, and;
- ADCP transects.

Processed data are provided as both CSV and NetCDF files, with separate files for each deployment period. In the case of transect data, one file is provided for each transect. For all processed data provided, the rawest file format obtained directly from the instrument are provided also. Wherever multiple raw files were combined, all raw files are provided, yet only a single processed file is provided.

The following folder structure is used in the Data Provision folder:

Data Provision/[Name of field trip where data were retrieved]/[Site Name]/[Instrument Name]

It is preferred to use the NetCDF format as unlike the CSV files, these files contain the following metadata as attributes:

- Job name
- Client name
- Client contact
- Variable units

7. Summary

This report contains the details of a data collection survey performed by O2 Metocean in Rivoli Bay between the 28th June 2019 and the 24th December 2019. Waves and currents data were collected at two fixed locations, and current transects taken at numerous locations throughout the bay. In addition to data collection, a short-term Fourier transform, and filtering technique was applied to indicate the presence of long-period waves.

At the Beachport ADCP location, currents were principally oriented on an approximately North-South axis with a significant asymmetry between the currents entering and leaving the bay. At the Southend ADCP location currents were principally oriented on an approximately East-West axis, again with appreciable asymmetry.

Short-term Fourier analysis indicated significant wave heights in excess of 1 m at both sites, with highly restricted peak wave direction (onshore). The filtering techniques and spectral analysis shows that the long waves energy at the sites was low, compared to the sea and swell energy. This may change in shore as the waves shoal and the sets break, or as any long waves present begin to reflect around coastal structures. However, we may consider some limitation in the Fourier analysis applied. The long wave sampling technique use a 60 minute sampling window for the long waves spectral analysis. With any Fourier analysis there is always potential that the energy attributed to any given frequency is non-physical, and that there is a redistribution owing to the nature of the assumptions of the Fourier transform. Key assumptions are that the surface wave field is statistically stationary over the window, and the waves are sinusoidal.

The vessel mounted ADCP transects revealed high spatial and temporal variability in current speed and direction, however it is noted that the peak speeds during these transects were low with respect to the maxima recoded by the ADCPs.