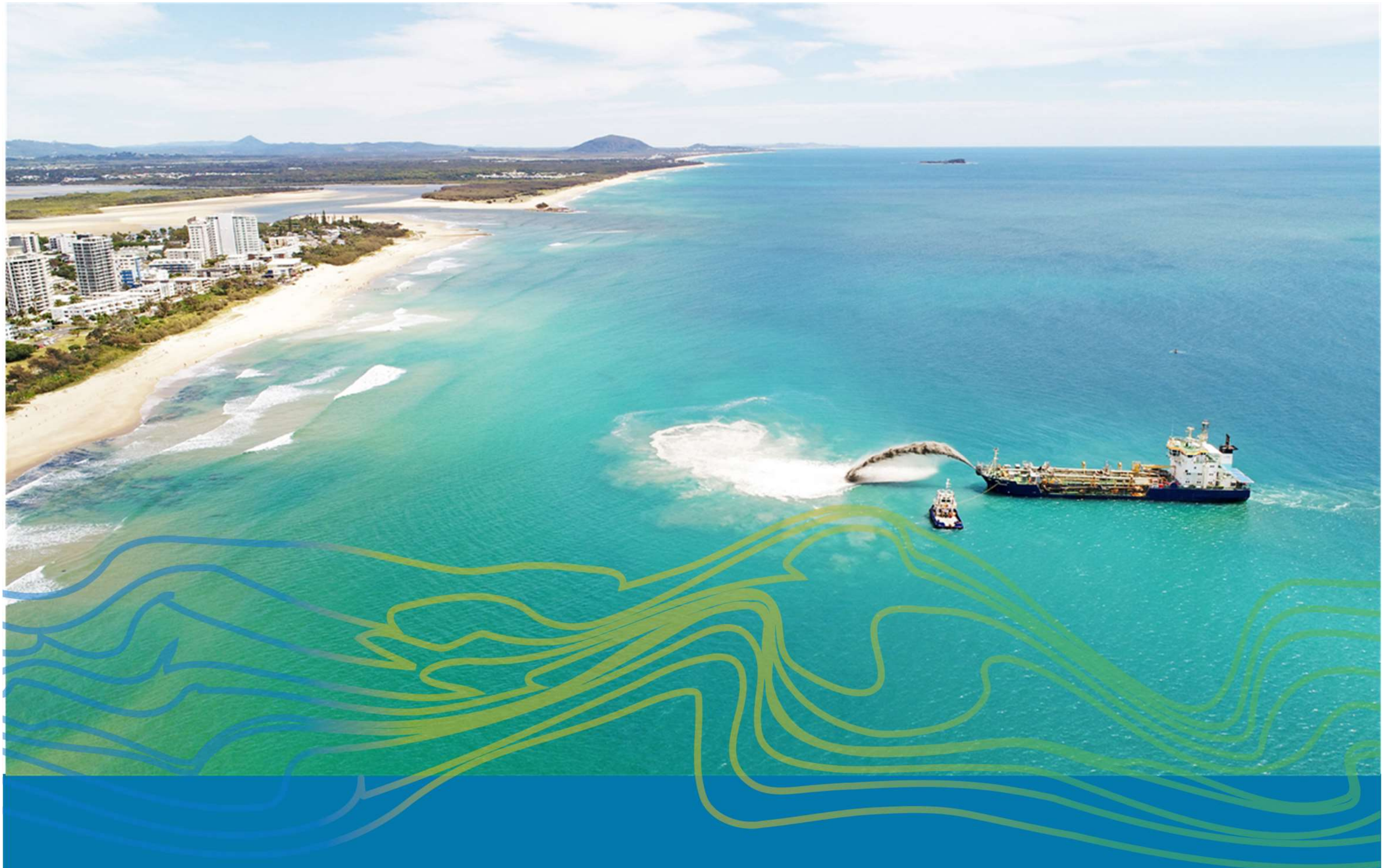

Monitoring Report

Maroochydore Beach Nourishment Trial

Sunshine Coast Council

7 June 2023

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

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1 INTRODUCTION

Sunshine Coast Council engaged Water Technology to develop and monitor a beach nourishment trial at Maroochydore Beach to test nearshore nourishment on the Sunshine Coast. The Maroochydore beach nourishment trial is to determine how effective nearshore sand nourishment is at Maroochydore.

This technical report details the trial's outcome following several months of site investigation following placement of 38,000m^3 of sand in approximately 8m depth offshore Maroochydore Beach, from 16 to 20 November 2022. The Port of Brisbane supplied the sand. The sand originates from the Spitfire Channel, between Bribie Island and Moreton Island. This sand is a clean, white sand, well-sorted sand and of very similar grade and appearance to the Maroochydore Beach sand. The “Brisbane” dredge carried out 17 rotations to complete the trial.

Figure 1-1 indicates the location of the area investigated for nourishment and the location of four beach compartments, each approximately 500m wide, from the Alexandra Headland to the Maroochydore River estuary. The location of sand deposition occurred on the northern section of the nourishment area to avoid covering existing reefs offshore Alexandra Headland.

Figure 1-1 Nearshore Nourishment Area

2 BACKGROUND

2.1 Maroochydore Beach management overview

Sunshine Coast Council actively manages the beach amenities at Maroochydore Beach.

Studies show that there is a limited supply of sand on the Sunshine Coast. Maroochydore Beach has been subject to significant erosion events, and adding new sand helps restore sand to the beach and protect the area from erosion.

Council manages the beach sand volume by dredging clean sand from the Maroochydore River estuary and pumping it onto Maroochydore Beach, forming a beach berm. This sand pumping occurs approximately every two years.

Following these beach nourishment works, the sand is moved from the berm into the surf zone by coastal processes, such as waves and currents. This can result in beach scarps and thinning out of the beach berm. Over time, the sand diffuses along the shore towards the North or South, depending on coastal processes. As a result, the net longshore sand transport tends to go slowly towards the North.

While sand availability is not an immediate concern, a major storm could lead to massive coastal erosion at any time. Also, ongoing sea level rise is reducing the beach volume.

2.2 Nearshore nourishment monitoring activities

Nearshore sand nourishment is an alternative method where sand is deposited on the wet portion of the beach. Coastal processes move the sand towards the shore, rather than towards the submerged portion of the beach.

The winter 2016 large-scale Gold Coast nearshore beach nourishment demonstrated that this is an effective and low-cost technique to increase beach volume for a long period of time, thereby reducing coastal hazards, beach management costs and improving beach amenities. Maroochydore Beach is a different environment to the Gold Coast Beaches, with less wave energy, a different beach morphology, reefs and coffee rocks, and a different community.

Therefore, a wide range of information has been gathered and analysed during the Maroochydore nearshore nourishment trial to understand the effect of the project, including:

- Metocean data, such as wave and sea level data
- Dredge logs, providing the location and volume of sand placed during the works
- Upper and intertidal beach profile topographic survey
- Multi-Beam Echo Sonar Survey in the nourishment area
- Morphological observations
- Community feedback via online survey

3 MONITORING AND FINDINGS

3.1 Metocean and coastal processes

Figure 3-1 shows the record of water levels in the Mooloolaba harbour gathered by the Queensland Department of Environment and Science from November 2022 to February 2023. The water level in the ocean can be forecasted using astronomical tide calculations. The Figure shows the difference, called “residual”, between the theoretical astronomical tidal levels and the measurement. The water levels were slightly more elevated than the astronomical tide the month after the nourishment, with typically a +100mm residual. Such positive residual increases the risk of coastal inundation and erosion.

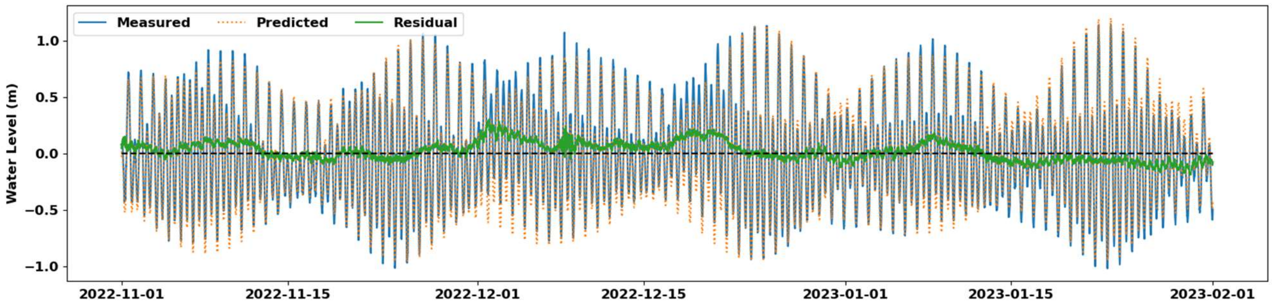

Figure 3-1 Water level at Storm Tide Gauge

Figure 3-2 shows the wave parameters recorded at the Mooloolaba wave river buoy by the Queensland Department of Environment and Science from November 2022 to March 2023. The Glossary provides background information on recorded wave parameters, including Significant Wave Height (Hs), Peak Period (Tp) and Wave Direction. For convenience, the water level residuals have been plotted over Hs, and this shows that the residual is often positive during and after storms. The Significant wave height peaked slightly over 3.0m on two occasions during this period, in early December and mid-February.

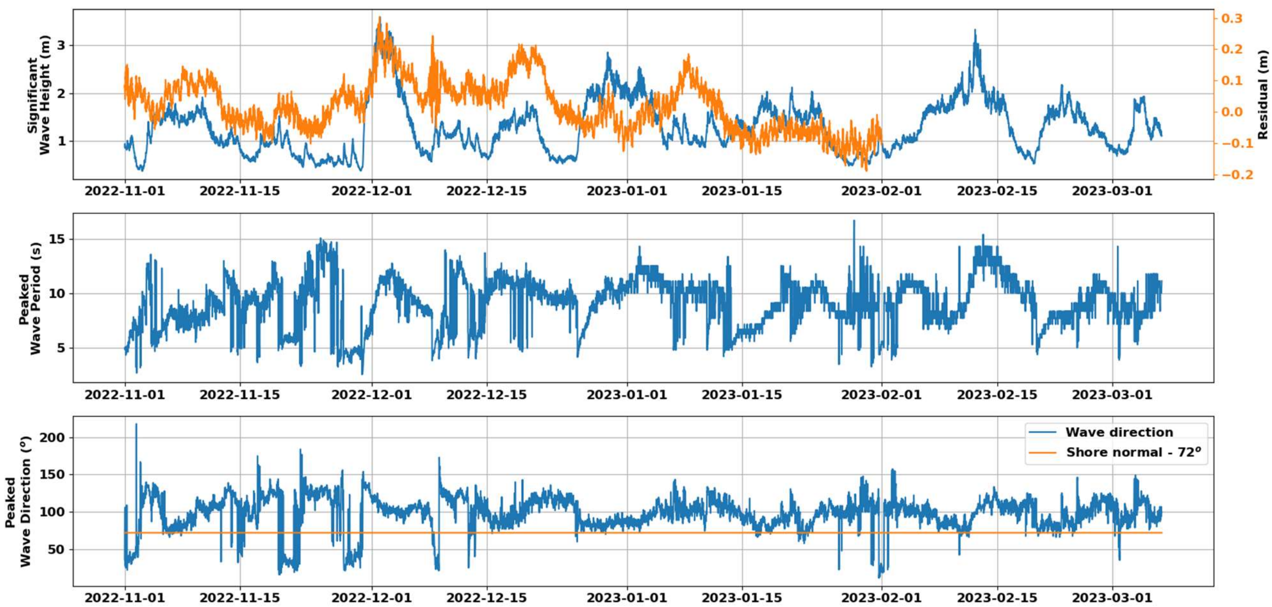

Figure 3-2 Mooloolaba wave parameters

Figure 3-3 shows directional wave energy parameters during and after the nearshore nourishment works. A storm early in December kicked off a prolonged trend of south-easterly waves and positive residual. These smooth southerly wave conditions of summer 2023 slowly generated a net flow of sand towards the North.

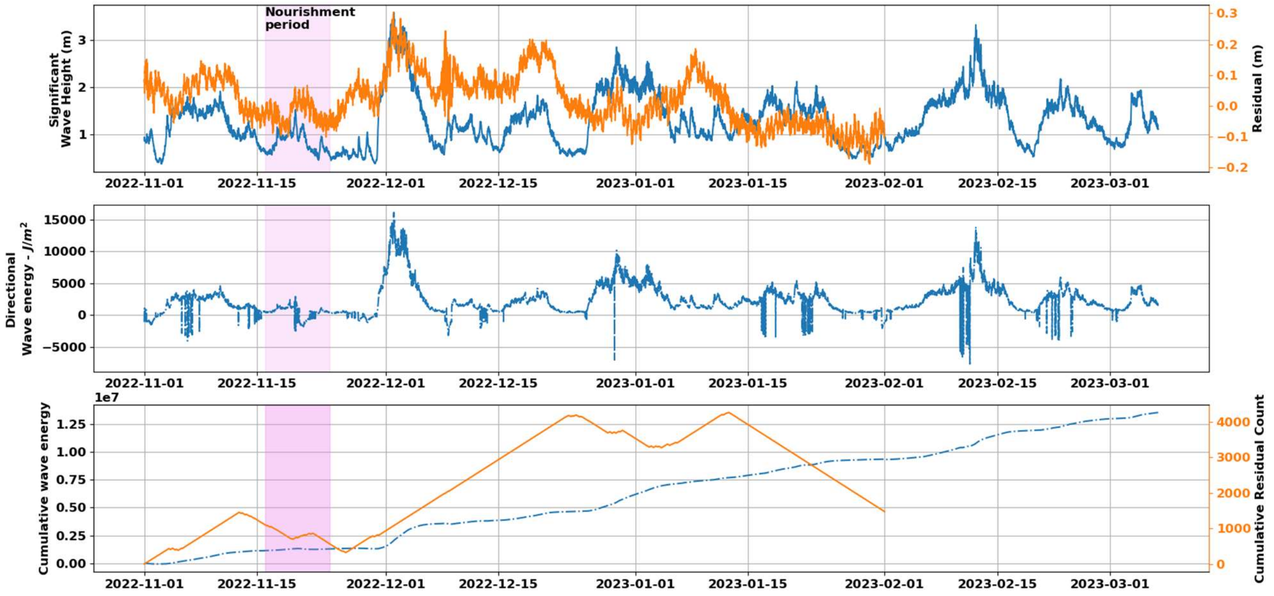

Figure 3-3 Directional surf-zone energy

3.2 Surf observation

Council commissioned a video monitoring program to review surf quality at Maroochydore Beach before and after nourishment. Video monitoring is routinely used to visualise how wave breaking processes evolve over time, for instance at Tweed Heads or to determine surf quality at the Palm Beach artificial reef.

The University of Sunshine Coast prepared a surf observation report to assess the impacts of the nearshore sand nourishment on surf amenities at Maroochydore Beach approximately a week after the nearshore nourishment. The method used processed beach video monitoring data and a machine learning wave peel tracking algorithm which calculates the location of wave breaking. This allows tracing wave peel angle to be traced. There is a close relationship between wave peel angle and wave rideability.

Overall, the data gathered was a limited snapshot of the surfing conditions. However, it showed that surf quality didn’t change significantly following the sand nourishment.

The surf amenity report has been attached in Appendix A.

3.3 Beach morphology

3.3.1 Bathymetric survey

The Port of Brisbane carried out three Multi Beam Echo Sonar (MBES) bathymetric surveys, attached in Appendix B on Figure 4-1, Figure 4-2 and Figure 4-4 in in Appendix B.

Figure 4-4 in Appendix B shows the seabed changes over one year before the nourishment works. During that period, an expansive natural sand bar formed at 7.5m. Some sand was found to have naturally moved on the Alexandra Headland reefs. Sand was also found to move in deeper depth, down to -10.0m.

3.3.2 Nearshore reefs

The Alexandra Headland reef fauna and flora was mapped to understand its extent and ecological values. The nearshore nourishment was placed 300m North of the Alexandra Headland reef to avoid impact on the reef.

Figure 4-4 in Appendix B shows the seabed change, approximately 24 days (approximately one month) following the nearshore nourishment works. The sand placement is located at the North of the nourishment area, well away from the Alexandra Headland reef system. As such, the impact of the nearshore sand nourishment trial on the Alexandra Headland Reef was negligible.

This Figure also overlays the “Brisbane” dredge location while placing sand either by rainbowing or bottom dumping. The nourishment was performed at approximately -8.0m, as per Contract and Permits.

3.3.3 Bathymetric changes

Figure 4-5 in Appendix B shows the change in bathymetry between the pre-nourishment and post-nourishment MBES surveys, over approximately one month. This period included the early December 2022 storm. The Figure shows that the nourishment sand is generally located 50m landward from the dredge location at the North of the sand deposition area. The south dredge locations remained well aligned with the sand deposition area.

Out of the 38,000m^3 of sand placed by the “Brisbane”, approximately 16,000m^3 remained near the original sand deposition area. Therefore, 60% of the nearshore sand volume moved out of the initial sand deposition area following the early December storm. This sand would have moved in the surf zone or the intertidal beach. The surf-zone, including the sand bar and beach through systems, cannot be surveyed accurately because of wave breaking and shallow water hazards.

The coastal sand bars generally migrated onshore during that first month, especially the bar south and North of the sand deposition area. However, immediately onshore from the sand deposition area, the bar remained in position and appeared to have welded to the nearshore nourishment sand mounds.

3.3.4 Upper Beach Survey

A topographic survey of the intertidal beach was carried out on 6 December 2022, a few days following the nourishment works and is indicative of pre-nourishment beach conditions. Further surveys followed the 3rd February 2023 and 6th March 2023. The intertidal beach sand quality appears to have not changed during this period, with no physical change noted to the intertidal sand.

Figure 3-4 shows the Maroochydore upper beach volume change over time following the nearshore nourishment. The beach volume has increased in all four compartments as shown on Figure 3-5.

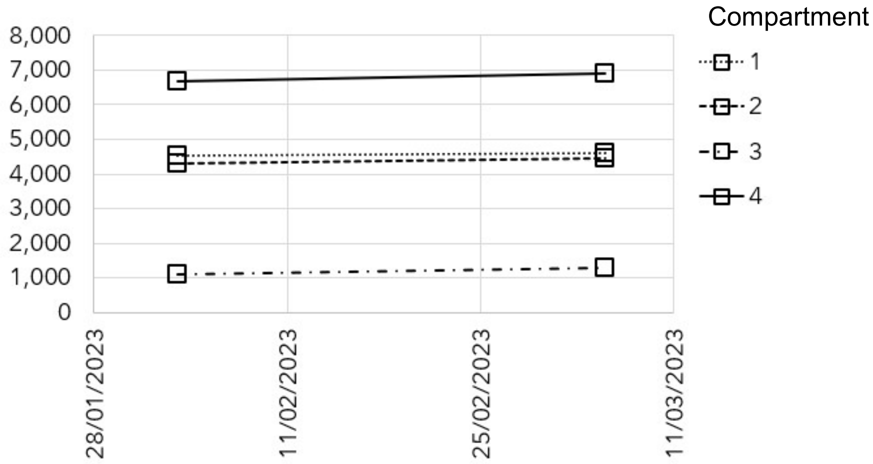

Figure 3-4 Upper beach volume change in the four compartments

Figure 4-6 in Appendix B shows the upper beach changes three months following nourishment. There was no beach erosion except near the Maroochydore River Entrance. Sand accumulation is generally higher upstream and downstream the sand deposition area, specifically North of compartment 3 and South of compartment 2. The beach volume increased consistently in Compartment 1 and Compartment 4 as well.

The increase in Compartment 1 may be associated with both southerly waves and nearshore nourishment. This suggests that the sand placed during the nearshore nourishment has diffused and spread along the coast rather than generated a strong shoreline response. The total accretion volume across the four compartments is approximately 17,300m^3. This volume corresponds to approximately 45% of the nearshore sand nourishment volume. However, not all of this sand accretion can be directly attributed to the nearshore nourishment effects because the Alexandra Headland sand bypass and the Maroochydore River estuary sand morphology influence the sand budgets of Compartment 1 and Compartment 4.

The beach topographic surveys show that Maroochydore Beach has been resilient to the February 2023 storm. This is uncommon since summer storms often reduce beach volume on the Sunshine Coast.

Also, past nourishment works associated with the Maroochydore River entrance sand management works have always been followed by rapid beach volume reduction. The nearshore nourishment has not been followed by beach erosion. These effects are typical of beach nourishment on a berm and nearshore beach nourishment.

3.3.5 Sand budget and morphological feedback

Figure 3-5 summarises the effect of the nourishment campaign 3 months after the nearshore nourishment works were completed. This summary arises from the merged upper beach survey and bathymetric survey shown in Figure 4-7 Appendix B and from the metocean analysis.

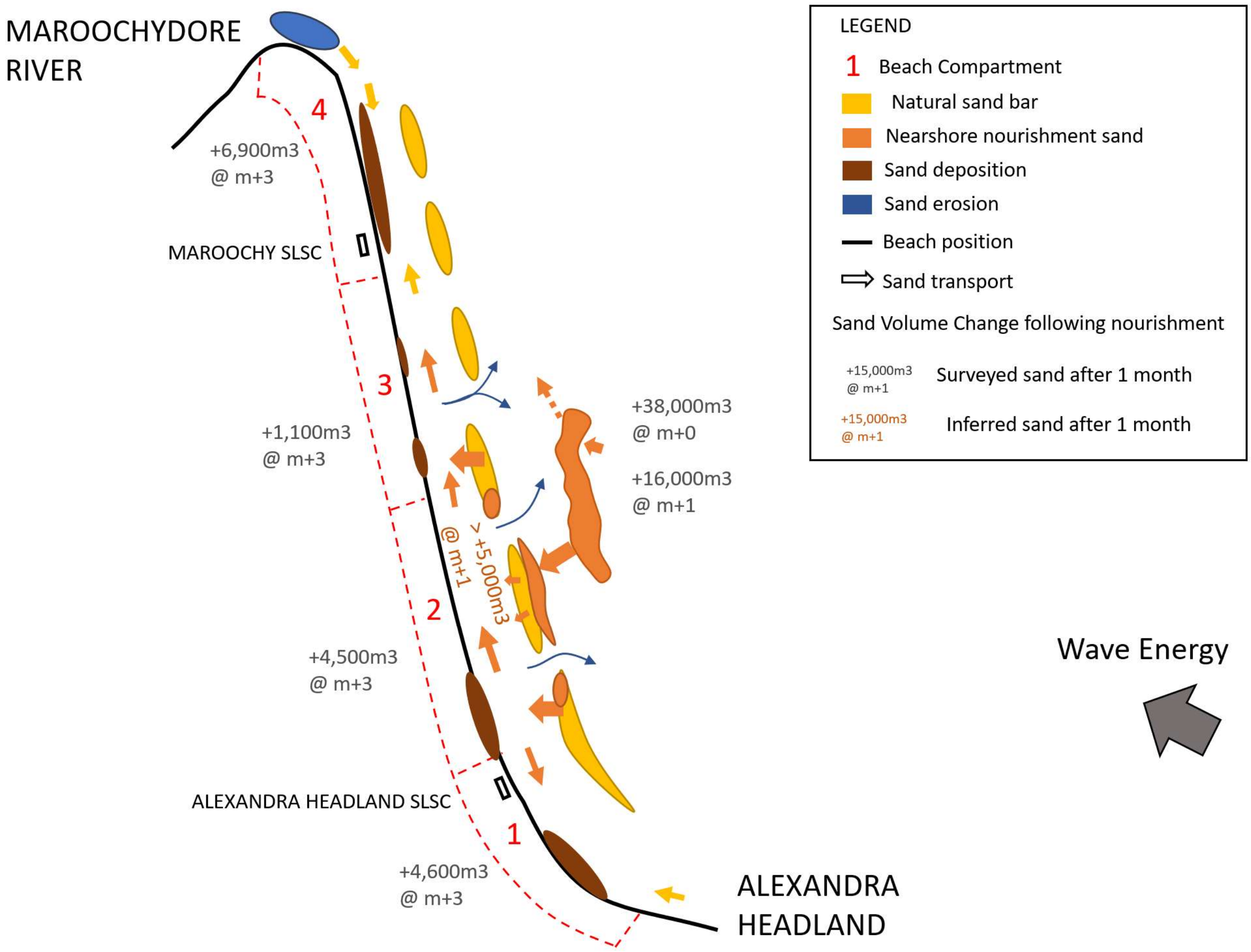

Figure 3-5 Beach morphological changes and nearshore nourishment sand budget

The convergence of sand transport in Compartments 1 and 4 likely contributed to sand volume gain in these Compartments. A significant fraction of the sand has spread across the surf zone or onto the intertidal beach.

After one month following the nearshore beach nourishment trial:

- 16,000m^3 of sand remained at the initial sand deposition area (40%) in a reserve deposit
- The northern edge of the sand deposit spread sand northward and shoreward, while the southern edge of the sand deposit fed the surf zone and bulked up the sand bar shoreward from the deposition area. Sand bars moved onshore North and south of the deposition area.
- A significant sand deposition occurred with over 17,000m^3 of sand gain in the intertidal area
- At least 5,000m^3 of sand (12%) remained in the wave-breaking zone
- A small volume of sand (2 to 5%) leaked to the North of the sand deposit

3.4 Projection

The nearshore nourishment sand will likely continue to move towards the shoreline and along Maroochydore Beach, with the net sand volume in the surf zone and intertidal beach increasing. The remaining volume of the sand deposit will likely reduce over time, particularly after storms. A beach berm may form this winter at Maroochydore Beach if mild wave conditions persist.

Over the next year, the effect of the nearshore nourishment will wear off, and the sand will likely bypass or enter the Maroochydore Estuary. The sand may move towards Sunshine Beach, feeding this beach system in the next decade.

3.5 Community feedback

Community feedback related to the trial was gathered via an online survey during the nearshore nourishment campaign. 32 responses were received. While this is a small sample, the project team is grateful for the feedback, as it can be used to improve future coastal management projects.

The purpose of this survey was to gather insights into the community views on coastal management on the sunshine coast, the level of support for beach nourishment works, as well as the public opinion on the beach nourishment trial while it was underway. Council beach safety crew encouraged feedback via the online survey when queries were voices during the operation, this is likely to bias the survey since it represents a relatively small number of responses.

There are differing opinions with most respondents expressing negative opinions (19 out of 32). The responses were nearly evenly split across three groups, as follows:

- For the first group perceive that any form of nourishment activities is too expensive because the works are ineffective and temporary (10/32)
- The second group perceived that nourishment activities can cause environmental risk and should be avoided (9/32)
- The third group perceived that nourishment activities are globally positive (9/32)

The feedback helps gain a deeper understanding of the public perception of this issue and will assist Council in working towards addressing these issues for future coastal management projects.

We would like to thank all the participants who took the time to complete the online feedback survey on the nearshore beach nourishment trial.

4 CONCLUSION

The nearshore nourishment trial successfully increased the volume of sand available on Maroochydore Beach by 38,000m^3. The trial has not affected Alexandra Headland reefs or sand quality and water quality at Maroochydore Beach.

Three months after the sand placement, 60% of the sand placed during the nourishment has moved onshore into the surf zone and onto the intertidal beach. As a result, the intertidal Maroochydore Beach gained a significant volume of sand, over 17,000m^3.

The online survey provided a relatively small sample feedback, this suggests that community should be consulted more broadly prior to larger scale nourishment campaign. Also, monitoring information should be provided to the community.

The trial effectiveness demonstrated that nearshore nourishment could be used more broadly to manage coastal hazards and beach amenities along the Sunshine Coast. The sand management practices along the Sunshine Coast should be reviewed to account for these findings. In particular, nearshore nourishment using local sand should be investigated. This would significantly reduce the duration and cost associated with nearshore nourishment, allowing larger sand nourishment volumes, and targeting a durable reduction of vulnerability to natural hazards.

APPENDIX A
SURF MONITORING REPORT

Monitoring the impacts of sand nourishment on surf amenity

Final Report

Photo: Daniel Millington

Prepared by:

Dr Javier Leon

University of the Sunshine Coast

January 2023

Acknowledgements

We acknowledge the people who are the Traditional Custodians of the Land on which this project stands. We pay respect to the Elders, past, present, and emerging, and extend that respect to other Aboriginal and Torres Strait Islander Peoples.

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Executive Summary

- Recreational use of beaches and coastal environments has long been recognized as an important activity for the health, social and economic benefits to direct participants and the broader population

- As pressure from competing coastal uses mounts, together with the threats from climate change, a major challenge for managers of the coast is to understand and compare benefits associated with multiple activities.

- Sand nourishment at Maroochydore Beach was trialled with the aim to protect the area from the effects of severe weather.

- The aim of the proposed research project was to assess the impacts of the nearshore sand nourishment on surf amenity at Maroochydore Beach using a machine learning wave peel tracking (WPT) algorithm.

- Surf amenity based on ride length, duration and speed did not change significantly between the pre- and post-sand nourishment dates (15th Nov 2022 and 24th Nov 2022 respectively). However, comparisons using the WPT metrics were not overly insightful due to obstruction to the pre- sand nourishment field of view by trees.

- Undesirable wave reflection was noticed in the post sand nourishment surf amenity assessment. This was possibly due to coarser grain size in the swash zone causing steeper shorefaces and hence wave reflection; however, it also could simply have been due to the slight change in wave direction and period between pre- and post-nourishment dates, or just a naturally occurring coincidence. Bathymetric survey data should be analysed to investigate further.

- Overall, the data gathered was a limited snapshot of the surfing conditions. It showed that the surfing regions didn't change significantly after the sand nourishment. More temporal data without tree obstructions would be required to detect subtle differences in surf amenity. This could be achieved with a permanent beach camera and server based WPT processing.

Contents

Introduction

It is estimated there are 50 million surfers worldwide, based on projections for 2020 by the International Surfing Association (ISA, 2014). This figure is consistent with previous estimates of 25-35 million surfers in 2013, with a growth rate of 12-15% per year (Ponting and O'Brien, 2013). Country-specific studies point at a population of 500,000 surfers in the UK (Mills and Cummins, 2015) and 2.9 million in the United States, with a growth of 7.3% between 2017 and 2018 (SIFA, 2019). Humans' connection to the sport of surfing has long been part of the local culture of iconic surf geographies world-wide (Aramoana Waiti and Awatere, 2019; Lazarow et al., 2008). Surfing's sense of connection between human and nature has been noted as a driver of behaviors towards greater environmental protection and an ethic of care for coastal landscapes (Booth, 2020; Fox et al., 2021; Lazarow, 2010). From a social perspective, surfing has been shown to contribute to multiple aspects of wellbeing, including community cohesion, strong family relationships and healthy lifestyles (Suendermann, 2015; Wheaton et al., 2021).

Recreational use of beaches and coastal environments has long been recognized as an important activity for the health, social and economic benefits to direct participants and the broader population (Pascoe, 2019; Windle et al., 2017). As pressure from competing coastal uses mounts, together with the threats from climate change, a major challenge for managers of the coast is to understand and compare benefits associated with multiple activities in order to sustain the functions and services offered by such complex natural systems (Blackwell, 2007). For example, increased nearshore development coupled with rising sea levels has led to infrastructure and buildings at risk to erosion from large storm events that has prompted responses from local councils to develop beach management strategies which can involve large-scale works such as sand replenishment and building of coastal structures. These works can maintain or improve surf amenity with careful design but can also diminish surf amenity (Thompson et al., 2021).

In New Zealand, surfing amenity was reportedly lost as a result of dredging activities in the ports of Lyttleton and Otago, and a dune management program in Piha Bar (Atkin et al., 2019; Hume et al., 2019). Such losses may translate into economic terms, as demonstrated by McGregor and Wills (2017) in Madeira (Portugal) and Mundaka (Spain), where the disappearance of two iconic waves due to the construction of a seawall and dredging was associated with a subsequent slowdown in local economic growth. Such unintended impacts are not uncommon across the world, as the effect of coastal infrastructure on surfing amenity is still poorly understood and rarely quantified before and after construction (Corne, 2009; Jackson et al., 2007; Scarfe et al., 2009). Man-made coastal alternations can also have unintended positive impacts for surfers and local economies. In Australia's Gold Coast, a world-class wave formed thanks to sediment being bypassed from the Tweed River to form the so-called 'Superbank' at Snapper Rocks (Castelle et al., 2009; da Silva et al., 2021; Reineman, 2016). Furthermore, Thompson et al. (2021) have recently reported on the success of the artificial reef at Palm Beach, Gold Coast at increasing surf amenity, a structure purposely designed to enhance surf amenity and coastal protection.

Assessment of surf amenity has been traditional undertaken using qualitative approaches, for example, by community response from surfers. However, an objective and quantitative assessment is more insightful and objective but has been seldomly done (Thompson et al., 2021).

The aim of the proposed research project is to assess the impacts of nearshore sand nourishment on surf amenity at Maroochydore Beach using a quantitative approach. The objectives are to implement a semi-automated approach to quantify surf amenity using video based on methods proposed by Thompson et al. (2021) and to monitor surf amenity before and after sand nourishment placement.

Methods

Study site

A Nearshore Nourishment Trial at Maroochydore Beach took place from Wednesday 16 November to Thursday 24 November 2022 at Maroochydore Beach. Surf amenity was monitored using a video camera mounted on a tripod from level 6 (~19m AHD) and level 7 (~22m AHD) balconies of Beachfront Towers on the 15th November and 24th November 2022, respectively (Figure 1).

Figure 1: Location map showing study site with location of video camera (red star) and sand nourishment placement (orange polygon).

Data collection

Video was recorded using a High-Definition (HD 1080p) digital video camera mounted on a levelled tripod for approximately 1 hour. During the video recording, a surfer wearing a GPS watch caught as many waves as possible for validation of the wave peel tracking algorithm. The position of the surfer at the corners and along the centre of the field of view was used to rectify the imagery.

Wave data was downloaded from the publicly available Mooloolaba wave buoy (Mooloolaba wave monitoring | Environment, land and water | Queensland Government (www.qld.gov.au)) and tidal levels were extracted from the publicly available Mooloolaba tide predictions (2022—Mooloolaba tide gauge predicted interval data - Mooloolaba tide gauge—predicted interval data - Open Data Portal | Queensland Government).

Data analysis

Video was analysed using the wave peel tracking (WPT) algorithm proposed by Thompson et al. (2021). In short, the machine learning algorithm detects the wave peeling region (boundary between the breaking wave and face of the wave, Figure 2) and tracks it as the wave crest breaks and travels towards the shoreline. The algorithms can then calculate the duration, length, breaking direction (right vs left) and speed of waves from rectified imagery.

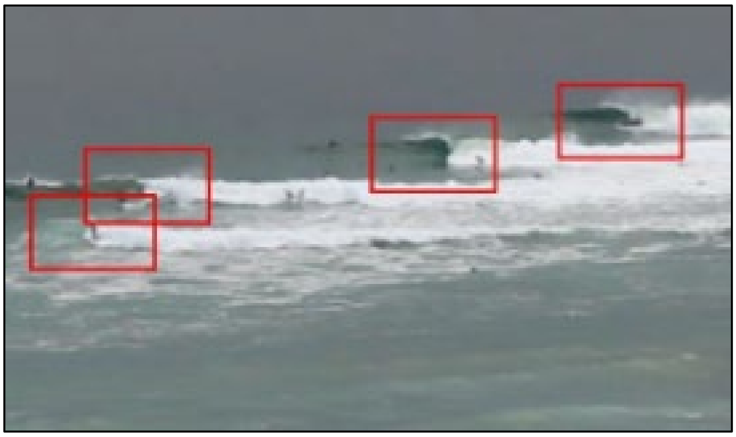

Figure 2: Examples of wave peel regions 9red polygons). From: Thompson et al. (2021).

Results and Discussion

Wave and tide data

The wave conditions were very similar during both pre- and post-nourishment monitoring days (Table 1). Waves were small (Hs 0.7m @9s) from the ESE and small (Hs 0.5m @10s) from the SE during the pre- and post-nourishment monitoring, respectively. Tide levels were around 1.3 m on both days, but tide was rising during the pre-nourishment monitoring and falling during the post-nourishment monitoring.

Table 1: Wave and tide data during monitoring

Metric	15/11/2022 (10:34am – 11:24am)	24/11/2022 (10:44am – 11:34am)
Avg. H_s (m)	0.70	0.51
Max. H_{max} (m)	1.5	1.0
Avg. T_p (s)	8.8	10
Avg. Direction (deg)	99	128
Avg. Tide (m LAT)	1.35 (rising from 1.28 – 1.42)	1.25 (falling from 1.41 – 1.09)

Wave Peel Tracking

Video rectification was successful, but the lower section of the pre-nourishment monitoring (15 November 2022) was blocked by some trees due to shooting from a lower elevation (level 6) (Figure 3). Unfortunately, the lower level was the only available for the monitoring date. This was solved for the post-nourishment video. However, the masking of some waves made the exact comparison between monitoring dates unfeasible.

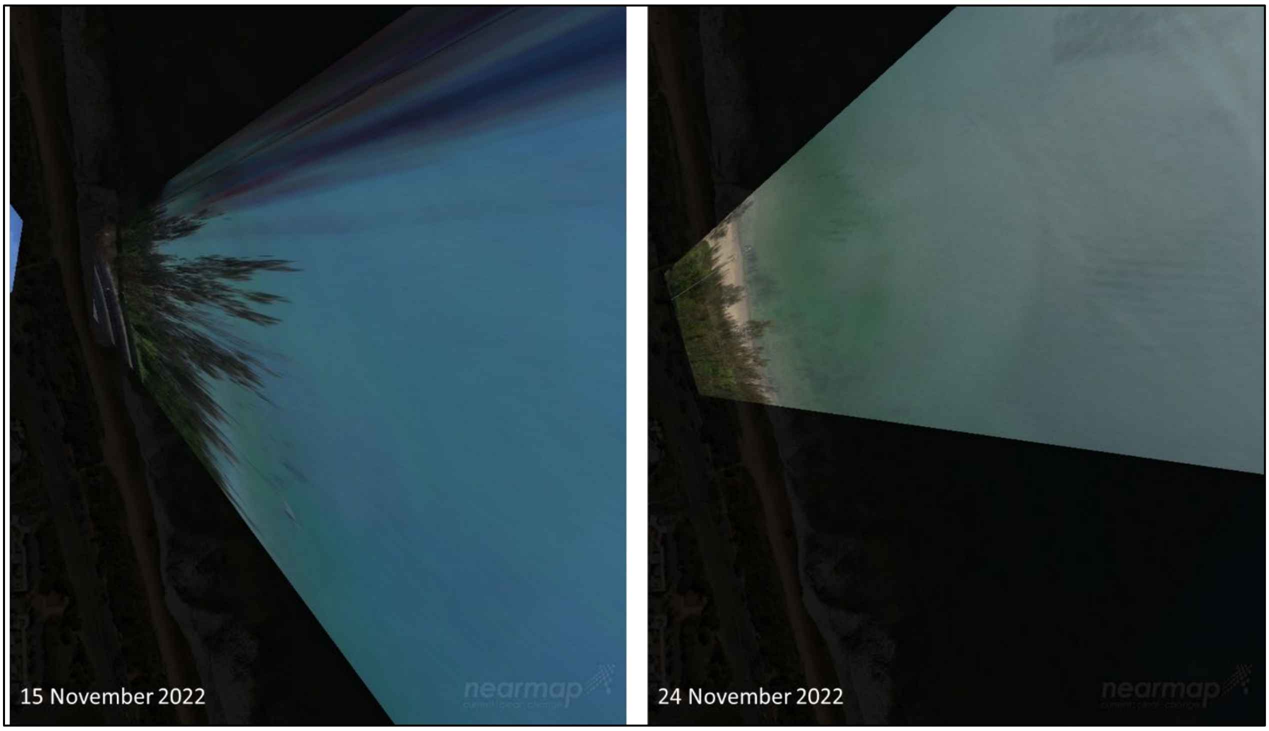

Figure 3: Video rectification for both monitoring days

The tracking of individual waves agreed with the few GPS tracks recorded by the surfer. Figure 4 shows the GPS tracks (top panel), total number of individual waves detected and tracked overlaid on oblique (bottom panel) and rectified imagery (right panel).

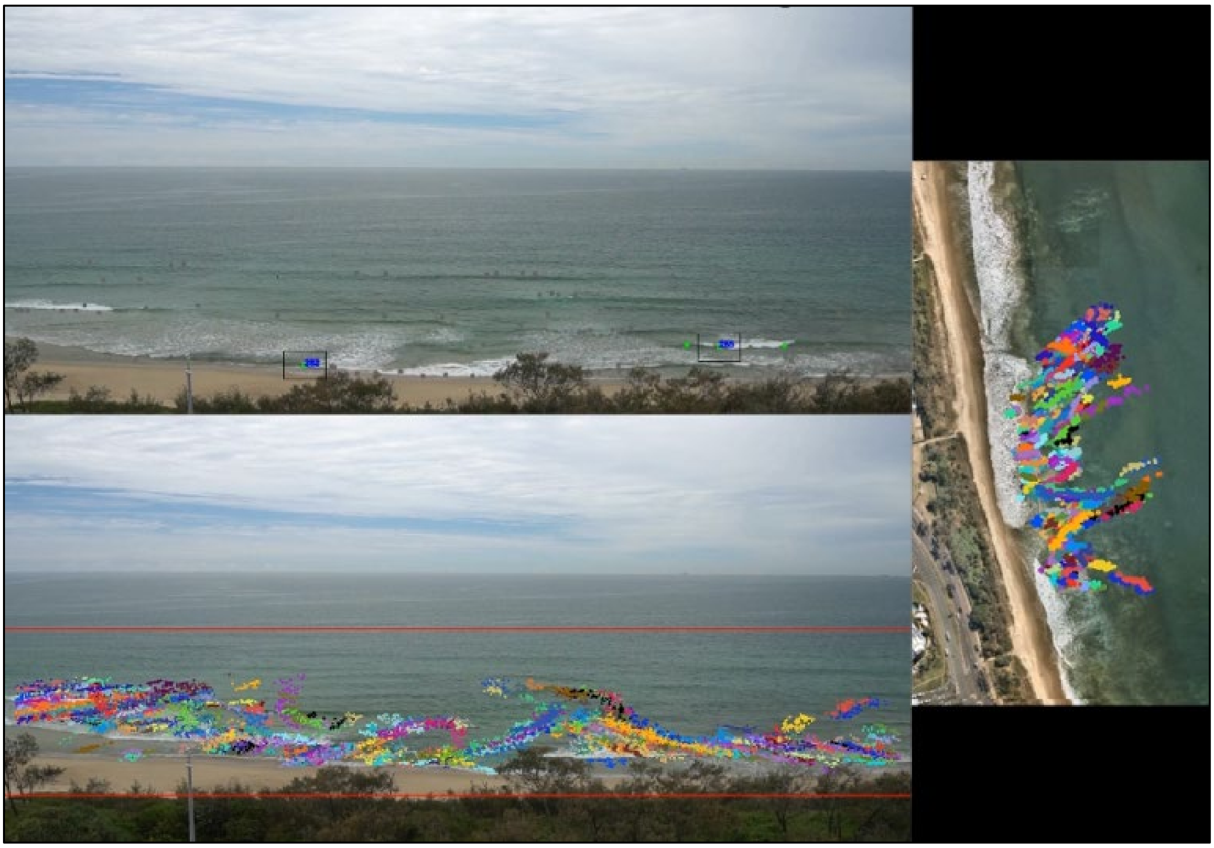

Figure 4: Individual waves detected and tracked on 24/11/2022

The WPT algorithm successfully detected and tracked the direction waves were breaking. Figure 5 shows the proportion and length of waves breaking towards the right and left on both monitoring days. All WPT data was bounded by the overlapping field of view of the 15th and 24th camera field of views (white boundary lines). The location of two well-defined sand bars/reef can be inferred from the proportion of waves breaking towards the left or right on both days.

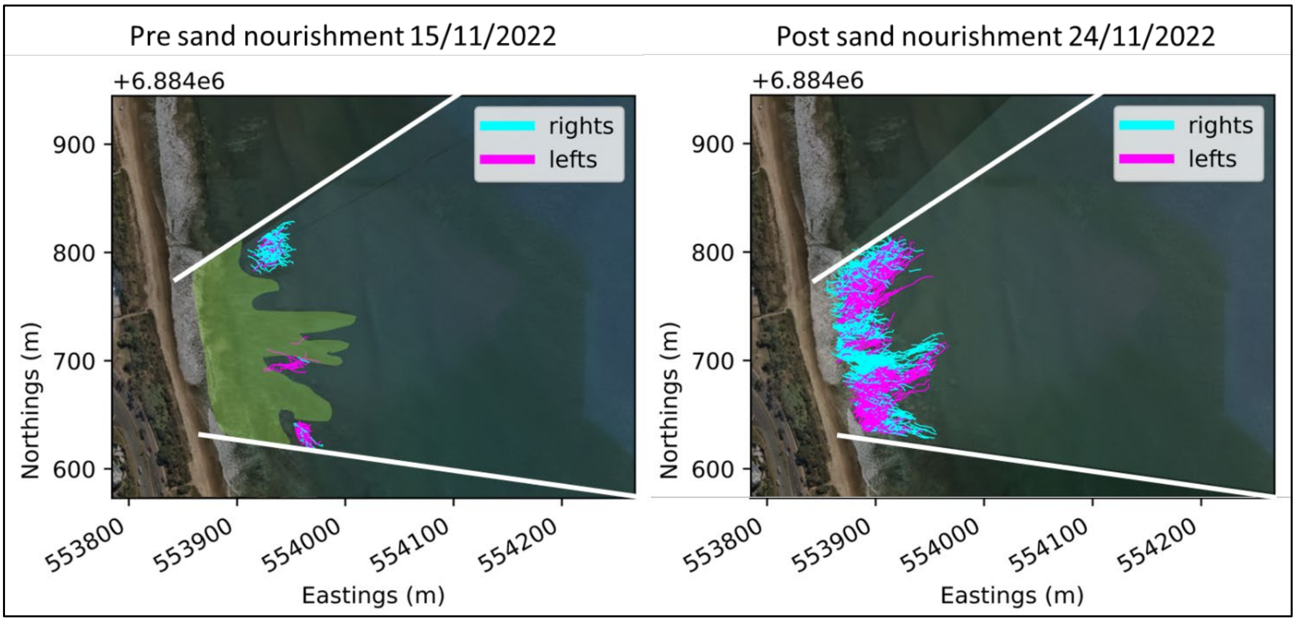

Figure 5: Number of waves breaking to the right and left on both monitoring days

The duration (s) and speed (m/s) of surfing waves were calculated from the WPT tracking algorithm. Figure 6 shows that most waves travelled, on average, for about 4 seconds on both days. This was expected given the wave conditions during the monitoring days and sand bar/reef configuration the studied site. The longest waves broke for 16 seconds.

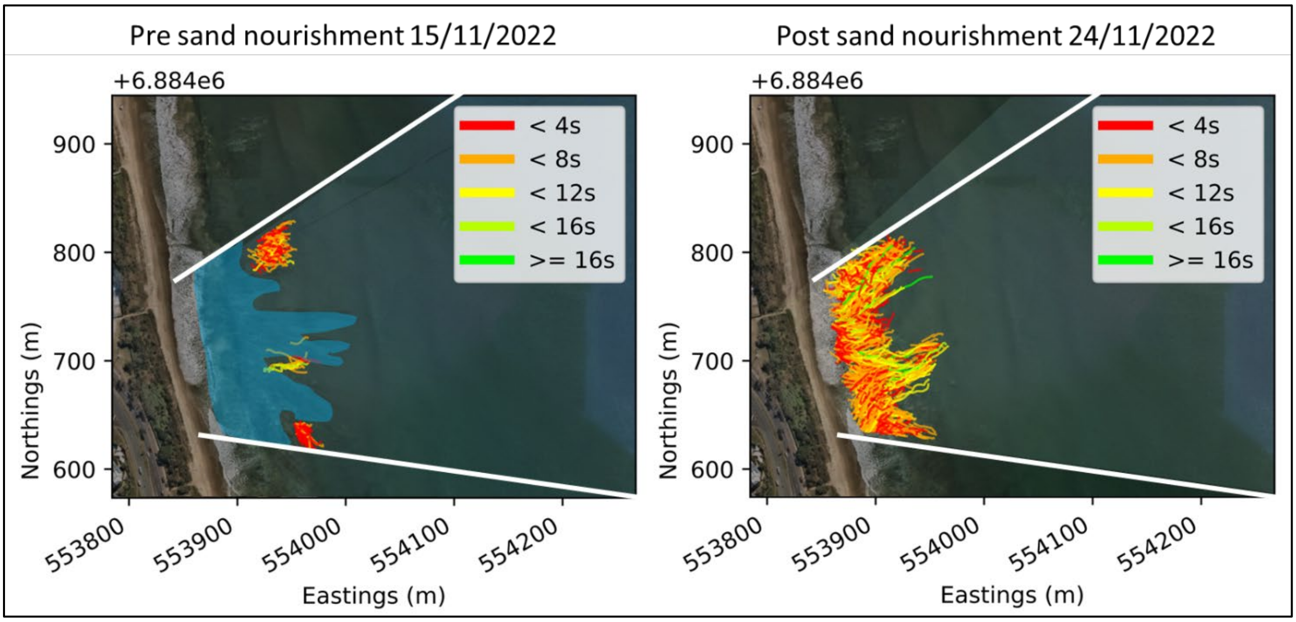

Figure 6: Wave duration (seconds) for both monitoring days

Wave speed averaged 4 m/s on both days (Figure 7). This was expected given the wave conditions during the monitoring days.

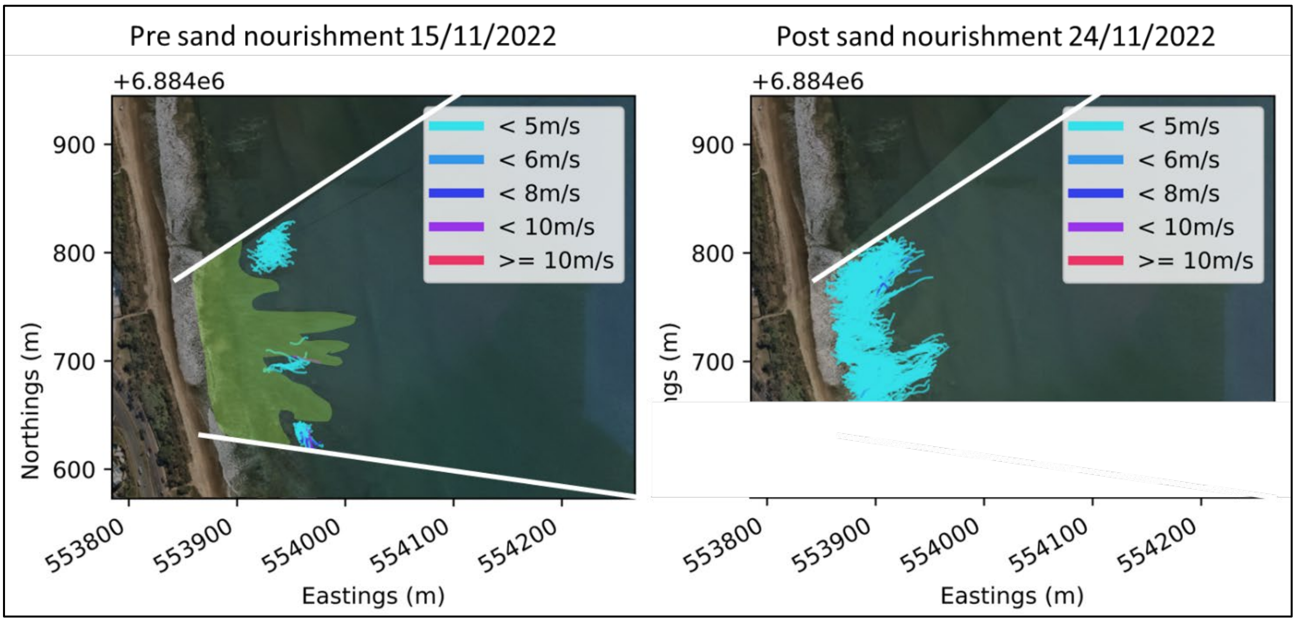

Figure 7: Wave speed (meters/seconds) for both monitoring days

Overall, wave duration, length, and speed, as detected and tracked by the WPT algorithm, were very similar on both the pre- and post-nourishment monitoring days (Figure 8). However, it is important to note that there were significantly more surfing tracks recorded post sand nourishment due to no tree obstruction to the field of view, therefore metrics are not well suited for comparison. Similarly, average ride durations and lengths were slightly greater post sand nourishment; however, this increase was most likely due to truncation of surfing tracks pre- sand nourishment from the tree obstruction.

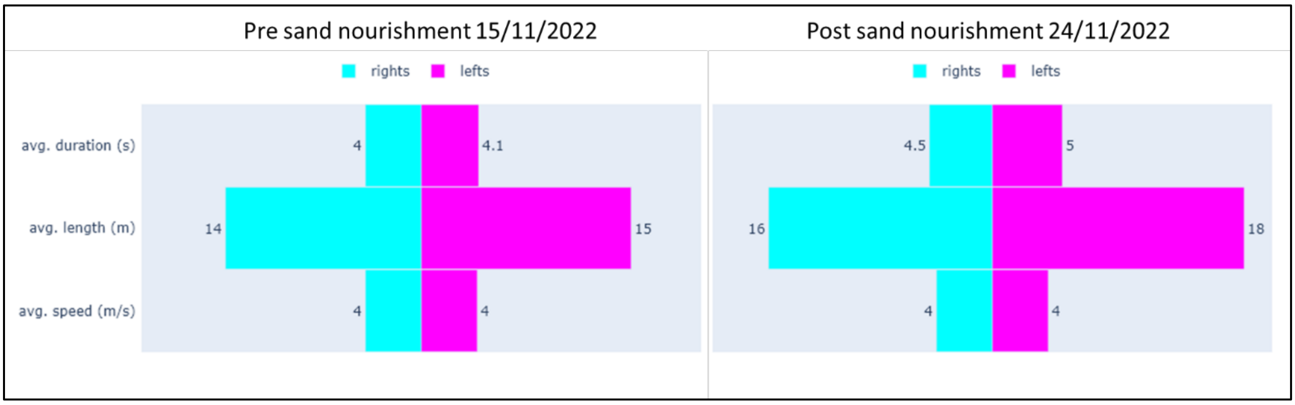

Figure 8: Summary metrics for both monitoring days

The only difference observed between pre- and post0nourishment days was the presence of reflected waves shoreward of the sand nourishment region (Figure 9). The GPS verification surfer observed that it was difficult to catch some waves due to the reflected waves. Beach slopes in the swash zone region were observed to be steep with large grain size sand. This was possibly due to coarser grain size in the swash zone causing steeper shorefaces and hence wave reflection; however, it also could simply have been due to the slight change in wave direction and period between pre and post nourishment dates, or just a naturally occurring coincidence. Bathymetric survey data should be analysed to investigate further.

Figure 9: Presence of reflected waves on the post-nourishment monitoring day

Conclusions and recommendations

Sand nourishment at Maroochydore Beach was trialled with the aim to protect the area from the effects of severe weather. The aim of the proposed research project was to assess the impacts of the nearshore sand nourishment on surf amenity at Maroochydore Beach using video (~1 hour) taken during pre- and post-nourishment days and processed with a machine learning wave peel tracking (WPT) algorithm.

The WPT algorithm quantified surf amenity based on ride length, duration and speed. Surf amenity did not change significantly between the pre- and post-sand nourishment dates (15th Nov 2022 and 24th Nov 2022 respectively). However, comparisons using the WPT metrics were not overly insightful due to obstruction to the pre- sand nourishment field of view by trees.

Overall, the data gathered was a limited snapshot of the surfing conditions. It showed that the surfing regions didn't change significantly after the sand nourishment. More temporal data without tree obstructions would be required to detect subtle differences in surf amenity. This could be achieved with a permanent beach camera at a higher elevation (> ~22 m AHD), without tree obstructions and server based WPT processing.

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APPENDIX B
BEACH SURVEYS

B-1 Beach Surveys

B-1-1 Bathymetric Survey

Figure 4-1 Multi-Beam Echo Sonar Survey, 2021

Figure 4-2 Pre-nourishment Multi-Beam Echo Sonar survey

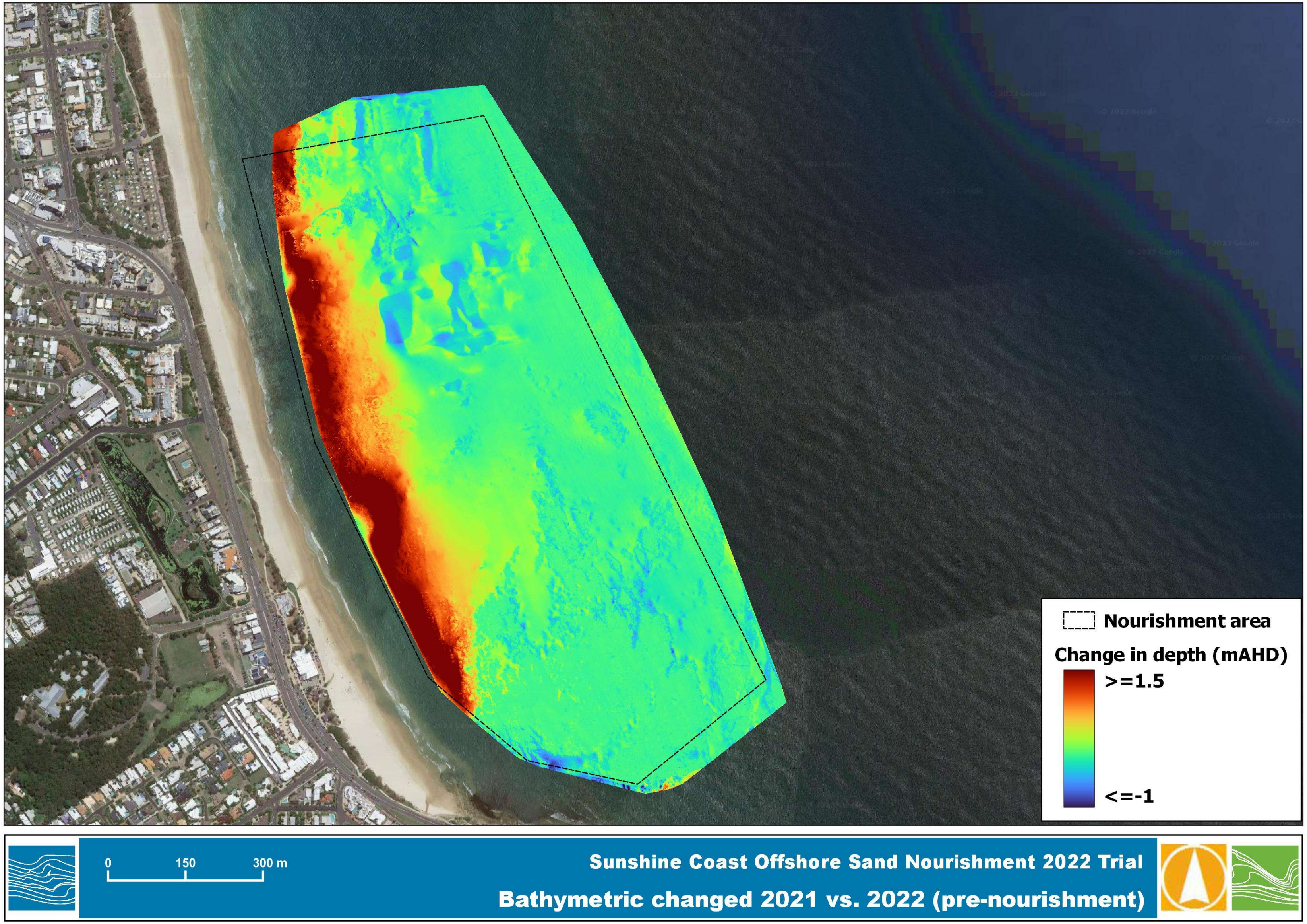

Figure 4-3 One-year bathymetric changes – before nourishment

Figure 4-4 Post-nourishment Multi-Beam Echo Sonar survey - 24 days

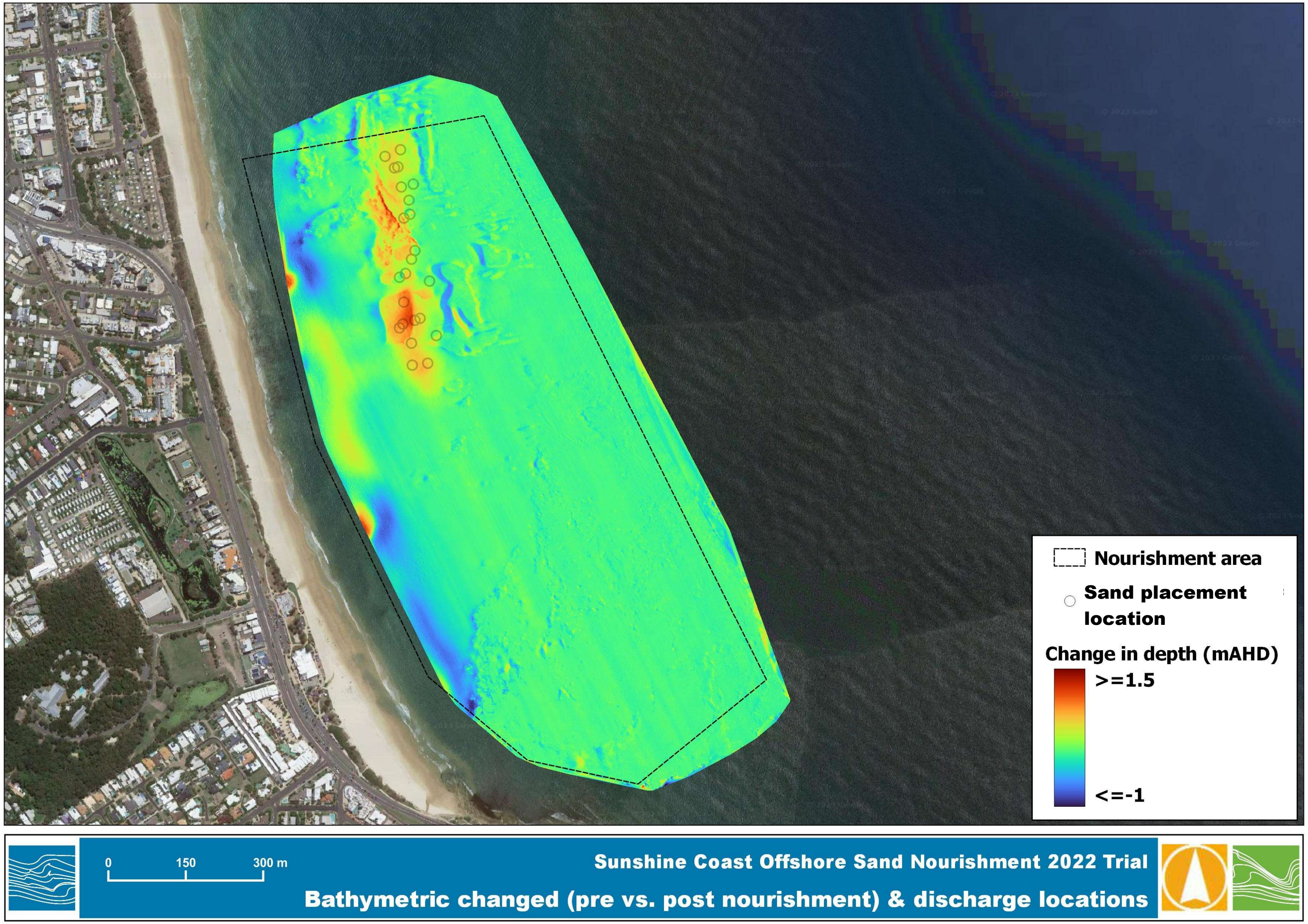

Figure 4-5 One-month bathymetric changes after nourishment

Figure 4-6 Three months beach volume change

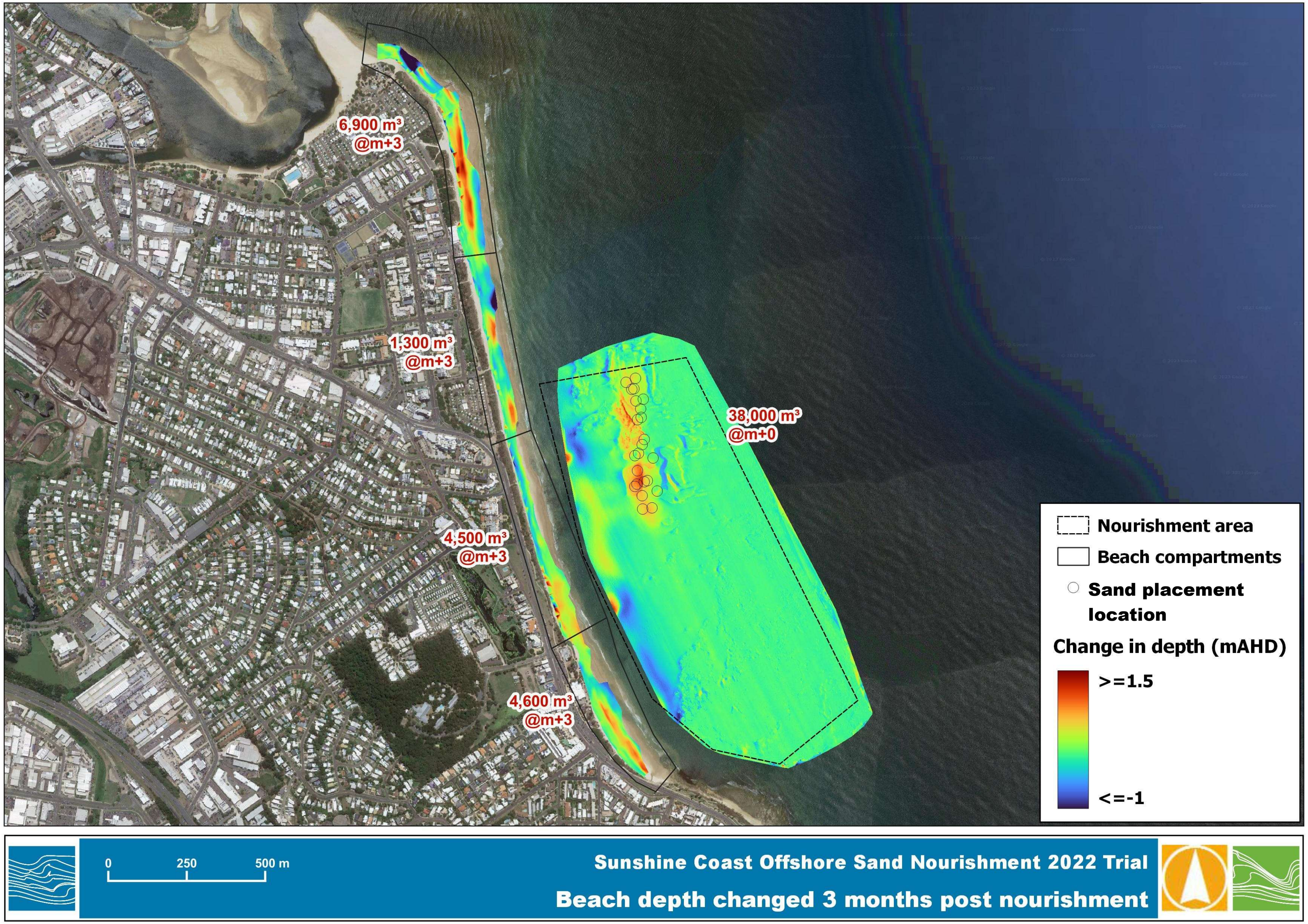

Figure 4-7 Merged topographic and bathymetric beach surveys

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