2 April 2020

WRL Ref: WRL2018024 LR20200402

Mr Matt Potter
Principal Engineer
Maritime & Aviation
Royal HaskoningDHV

By e-mail: matt.potter@rhdhv.com

Water Research Laboratory

Dear Matt,

Ocean Beach Nourishment Exercise: April to December 2019

1. Introduction

The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering at UNSW Sydney was engaged by Royal HaskoningDHV on behalf of Central Coast Council to monitor a nourishment trial undertaken at Ocean Beach on the NSW Central Coast (Figure 1). During the nourishment works, sediment originating from the Ocean Beach ebb tide shoal navigation channel was delivered to a zone between the Ocean Beach SLSC and Augusta Street between April and September 2019. WRL progressively monitored the movement of the sand on the beach throughout the nourishment works using a remote sensing ensemble comprising drone photogrammetry, airborne LiDAR scanning and fixed camera monitoring. This report summarises the data collection methodology, analysis techniques and conclusions about sediment transport processes throughout the trial exercise.

Figure 1: Oblique aerial view of the nourishment progress on 1st August 2019

Water Research Laboratory | School of Civil & Environmental Engineering | UNSW Sydney
110 King St, Manly Vale NSW 2093 Australia
T +61 (2) 8071 9800 | ABN 57 195 873 179 | www.wrl.unsw.edu.au | Quality system certified to AS/NZS ISO 9001

2. Data collection methodology

Intensive monitoring of elevation changes within the study site were collected through targeted UAS surveys and airborne LiDAR scanning (ALS) between April and December 2019 as outlined in Table 1. Additional information about shoreline changes were provided by installation of a fixed camera on the Ocean Beach lifeguard tower. Broad sediment transport processes were also analysed through review of PlanetLab satellite imagery which is captured every few days and has a resolution of 3 m per pixel.

Table 1: Survey data analysed in this report

Survey ID	Survey	Date completed	Data source	XYZ Accuracy (m)
1	Pre nourishment works	03/04/2019	UAS photogrammetry	±0.05
2	Post June 2019 ECL storm	14/06/2019	Manned aircraft LIDAR	±0.12
3	3 months into nourishment	16/07/2019	UAS photogrammetry	±0.05
4	4 months into nourishment	01/08/2019	UAS photogrammetry	±0.05
5	Immediately post nourishment	05/09/2019	UAS photogrammetry	±0.05
6	3 months post nourishment	13/12/2019	UAS photogrammetry	±0.05

2.1 UAS Photogrammetry

Unmanned Aerial System (UAS or drone) photogrammetry surveys were completed of the site throughout the monitoring period using a Phantom 4 RTK multirotor equipped with a high resolution camera. This platform is a fully autonomous survey-grade mapping UAS which carries an on-board RTK-GNSS receiver. During flights, the Phantom 4 maintains connection to the CORSnet network of permanent GNSS receivers which results in high precision navigation and image geo-tagging. Photogrammetry processing was completed using the Pix4D software package to produce a geo-rectified orthomosaic image and 3D digital elevation model. The XYZ accuracy of each dataset was validated to a mean RMS error of ±0.05 m through comparison with six ground control points (GCPs) and independent check points that were measured using RTK-GNSS in GDA94/MGA Zone 56 datum.

2.2 Airborne LiDAR Scanning (ALS)

Analysis has also been undertaken on airborne LiDAR scanning (ALS) data that was collected of the site under a separate project between WRL and Central Coast Council. Through this project, bi-annual aerial LiDAR surveys are undertaken using a Piper PA 44 Seminole 44 twin-engine aircraft equipped with a Riegl VQ480i LiDAR unit and a Canon EOS 5DSR 50 MP camera combined with a Sigma 24 mm F1.4 Art Series Lens. The XYZ accuracy of the LiDAR data was verified as ±0.12 m through reference to 50 ground based control points that were surveyed using RTK-GNSS as well as through comparison with previously collected UAS photogrammetry data.

2.3 Camera based shoreline monitoring

A camera based monitoring system was installed by WRL onto the Ocean Beach lifeguard tower to document progress of the nourishment works and to quantify sub-daily changes to the intertidal shoreline between survey deployments. This custom camera system collected hourly images during daylight hours between 25th April 2019 and 12th February 2020 with a field of view that faced towards Ettalong Point (Figure 2). The weekly position of the mid-tide shoreline was extracted from the collected imagery using custom built coastal imaging software package. This methodology is described in Harley et al. (2019) and is based on:

- A precise survey of the camera and multiple ground control points within the field of view;
- Using the above information to calculate the roll, tilt, azimuth and lens distortion of the camera as well as the ability to rectify the oblique images into real world coordinates; and
- Using the predicted tide level associated with each image to infer the elevation of a detected shoreline.

The time-lapse imagery captured by the monitoring camera was also useful in documenting the key milestones of nourishment progress as shown in Figure 3.

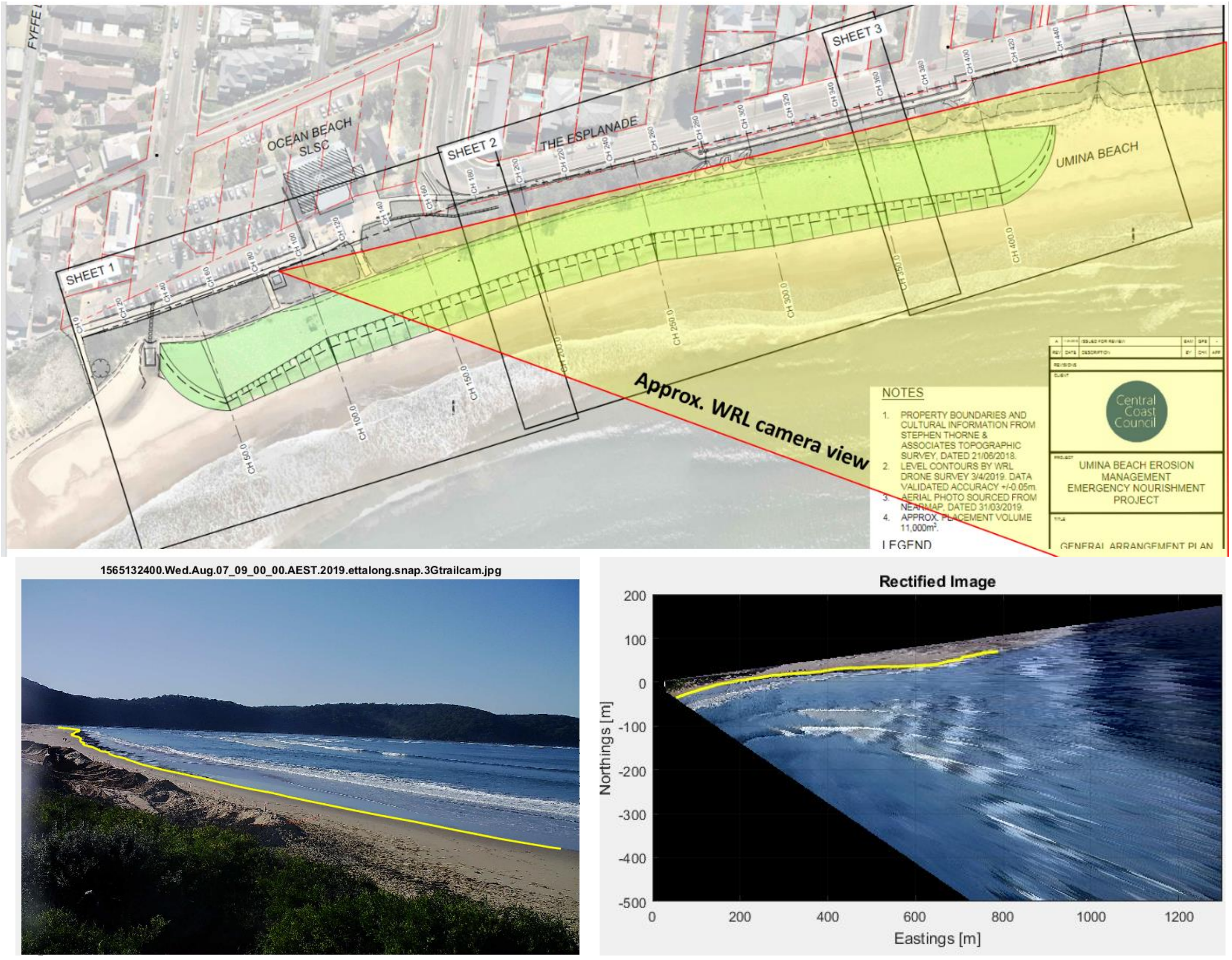
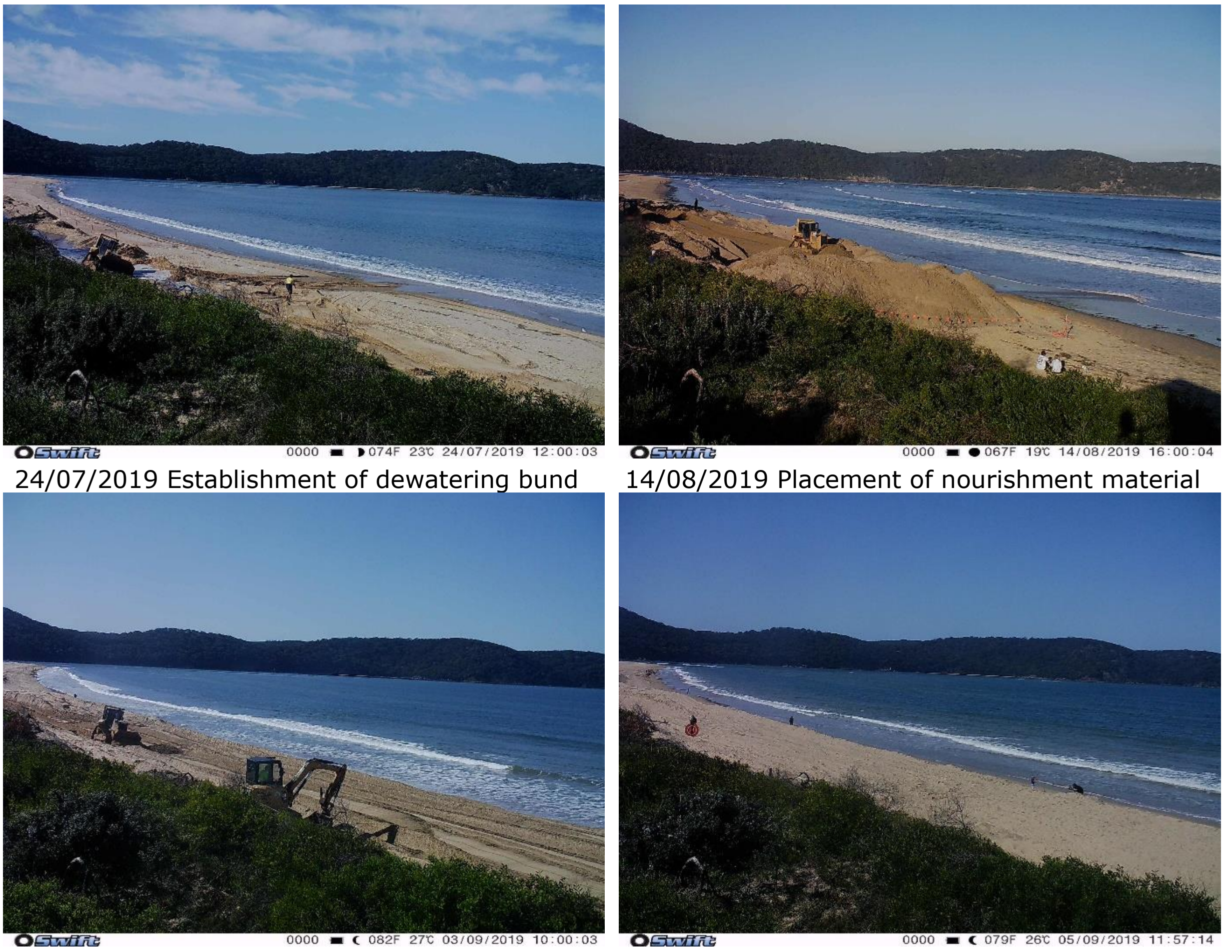


Figure 2: Camera field of view (top), oblique camera view and digitised shoreline (bottom left); rectified image showing shoreline and wave breaking on ebb tide shoal (bottom right)



24/07/2019 Establishment of dewatering bund

14/08/2019 Placement of nourishment material

03/09/2019 Bund extended to the west

05/09/2019 Completion of works

Figure 3: Key milestones of nourishment progress viewed from monitoring camera

3. Wave events

The influence of wave events on sediment transport throughout the nourishment trial was considered through assessment of data recorded by the Sydney deep water wave buoy operated by Manly Hydraulics Laboratory offshore from Long Reef, Sydney. The largest wave event recorded during the monitoring period occurred on the 4th June 2019, which produced a peak significant wave height (Hs) of 7.3 m from a southerly direction. A wave event of this size in the Sydney region is considered to have an 8 year average recurrence period (ARI) (Shand et al. 2010). The second largest wave event during the monitoring period occurred on the 22nd August 2019 which produced a peak Hs of 6.2 m from a southerly direction (< 2 year ARI Shand et al. 2010). The timing of each UAS photogrammetry deployment and wave events is provided in Figure 4.

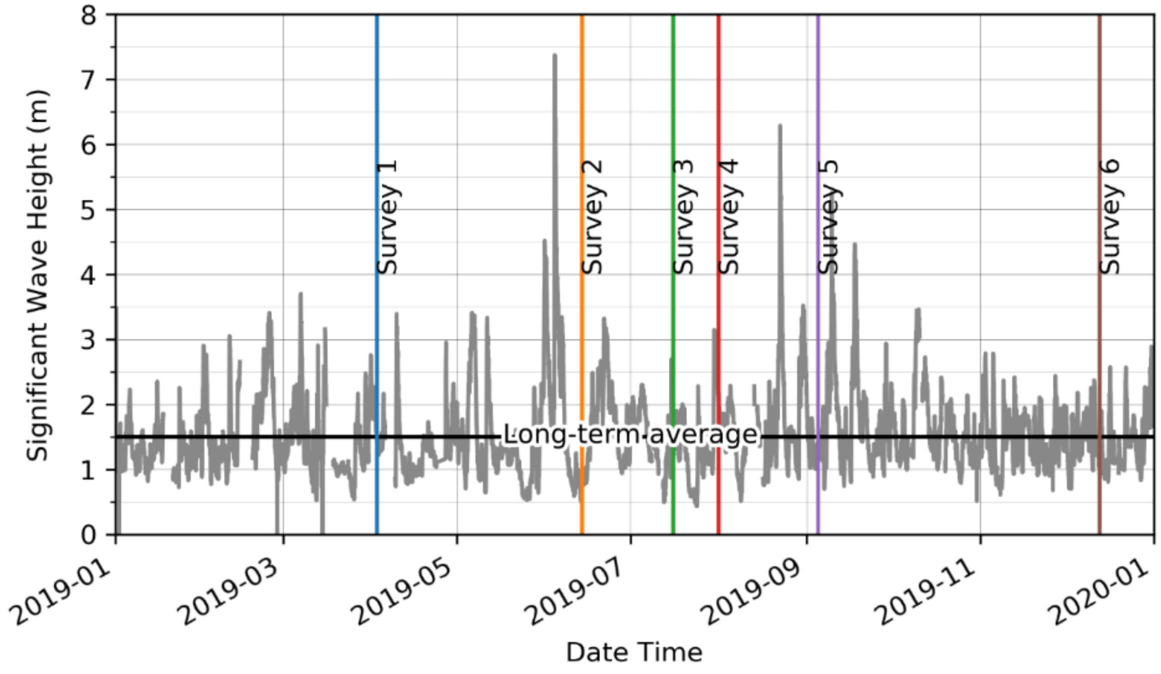


Figure 4: Offshore significant wave height recorded at Sydney wave buoy (MHL, 2020)

4. Analysis techniques

A range of analysis techniques has been applied to the UAS photogrammetry and ALS survey data to investigate the nourishment works and to understand the general sediment dynamics of the site including:

- Extraction of shore normal transects;
- Calculation of volume changes within the nourishment bund;
- Vertical elevation change maps; and
- Analysis of trends in contour movement.

In addition to this, analysis included camera based shoreline monitoring of the mean sea level (MSL) contour at weekly intervals during the monitoring period.

4.1 Transect data

A total of sixteen shore normal transects were extracted from survey datasets at 50 m alongshore intervals between Ocean Beach and Ettalong Point with transects OB_02 to OB-07 located within the placement bund. Transect plots are provided in Appendix A and transect locations are shown in Figure 8. This analysis identified that the bund had a peak elevation of+5 m AHD located 80 m to the east of Ocean Beach SLSC (OB-04) in September 2019 although this sediment reverted back to a more natural beach slope by December 2019. The impact of the June 2019 storm is also visible in the transect plots as a general erosion of material in the intertidal zone between +2 to 0 m AHD. Transects OB_02 to OB-07 also show that the bulk of nourishment placement occurred between between April and September 2019.

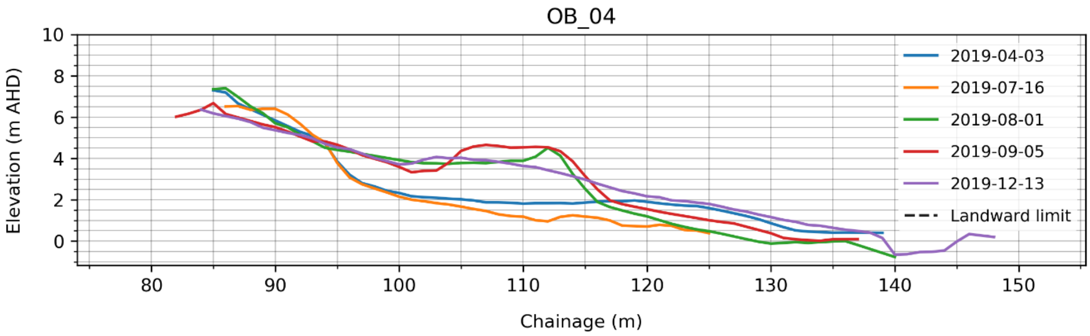


Figure 5: Transect OB-04 located 80 m to the east of OB SLSC showing nourishment progress

4.2 Volume changes within nourishment bund

The profile evolution throughout the nourishment works and the spatial extent used for volume change calculations are shown in Figure 6 with calculations provided in Table 2. An accurate estimate of the total volume of nourishment material delivered during the trial is complicated by the long duration of the works and the impact of the large southerly storm events in June and August 2019. It is WRL's best estimate that between 9,000 and 12,000 m^3 of nourishment material was placed on the beach between April and September 2019 and that the bulk of this material was placed in July and August 2019.

Table 2: Volume change calculations throughout monitoring program

Survey Date	Cut	Fill	Cumulative Fill	Volume Change	Cumulative Volume	Min_Z	Avg_Z	Max_Z
	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)	(m)	(m)	(m)
3/04/2019								
14/06/2019	1741	20	20	-1721 <cut>	-1721	-0.4	0.38	1.07
16/07/2019	179	654	674	475 <fill>	-1246	-1.34	-0.1	0.63
1/08/2019	130	4029	4703	3899 <fill>	2653	-3.74	-0.84	1.10
5/09/2019	915	7022	11725	6107 <fill>	8760	-2.64	-0.55	1.85
13/12/2019	900	1285	13010	385 <fill>	9145	-1.46	-0.03	1.19

4.3 Vertical change maps

A spatial representation of the erosion and accretion that occurred between each survey is provided through vertical change maps that highlight elevation changes between successive surveys (Figure 7). This analysis identified that a large mound of sand with a height up to 3 m was placed adjacent to the Augusta Street carpark in late July before being redistributed along with additional sediment to the east and west by September. The signal of the June 2019 storm was also visible with the nearshore beachface lowering by 1 to 1.5 m between the April and July surveys. The region between Ocean Beach SLSC and Barrenjoey Road tended towards accretion in the three months after the completion of the nourishment while Ettalong Point experienced erosion with redistribution of sand to the east and west.

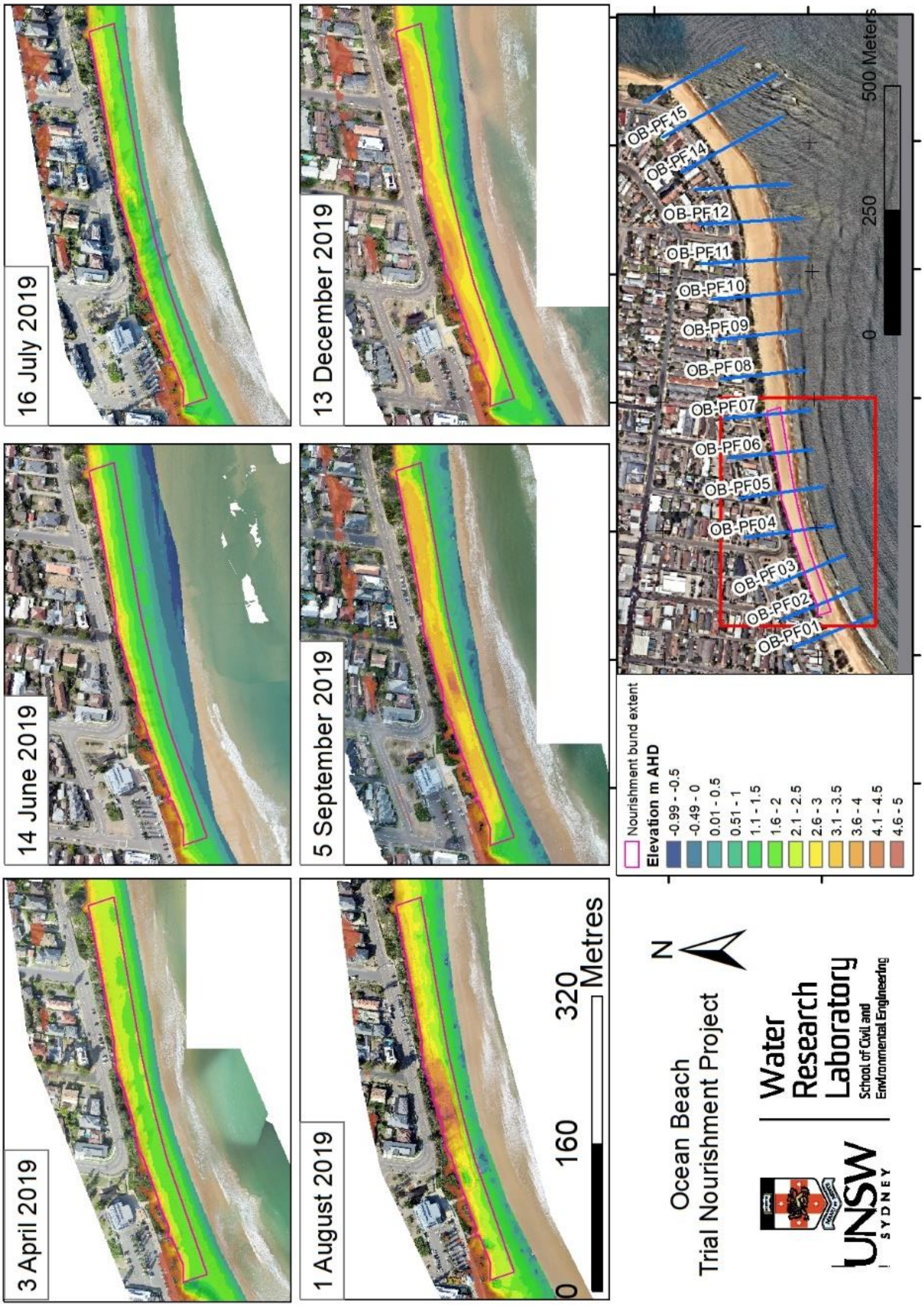


Figure 6: Elevation changes in nourishment placement zone throughout project

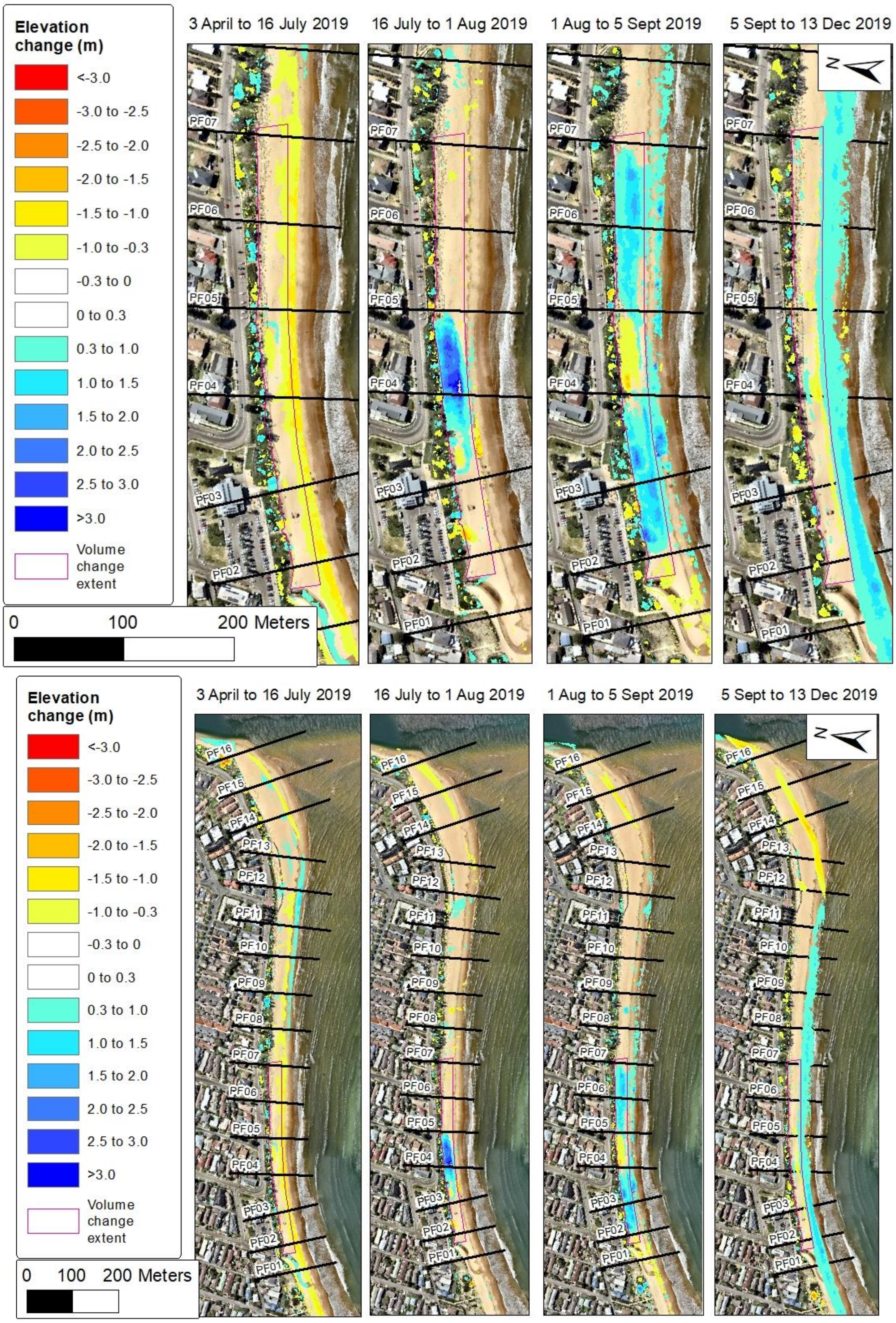


Figure 7: Vertical elevation changes throughout monitoring within the nourishment placement zone (top) and for Ocean Beach to Ettalong Point (bottom)

4.4 Contour movement

A number of shoreline indicators exist to measure beach width variability including the mean high water springs (MHWS) shoreline at an elevation of 0.7 m AHD for short term processes and the 2 m AHD contour for longer term changes. The trend in the position of these contours has been extracted from surveys at 50 m alongshore intervals to indicate whether a location has been eroding or accreting during the monitoring period (Figure 8). This has been calculated using the *linear regression rate* statistic (unit: m/year) determined by fitting a least-squares regression line to all shoreline points for a transect (Figure 9). Results indicate that between April to November 2019, the 0.7 m contour generally accreted at a rate of 10 m per year between Ocean Beach SLSC and Barrenjoey Road while Ettalong point eroded at a peak rate of -40 m per year. Additionally, the 2 AHD m contour accreted at a rate of 20 to 40 m per year in the vicinity of Ocean Beach SLSC which is most likely attributed to placement of nourishment material. The 2 m AHD contour was stable or accreting along most of Ocean Beach with the exception of a small region between Augusta Street and Barrenjoey Road that showed a mild trend of erosion.

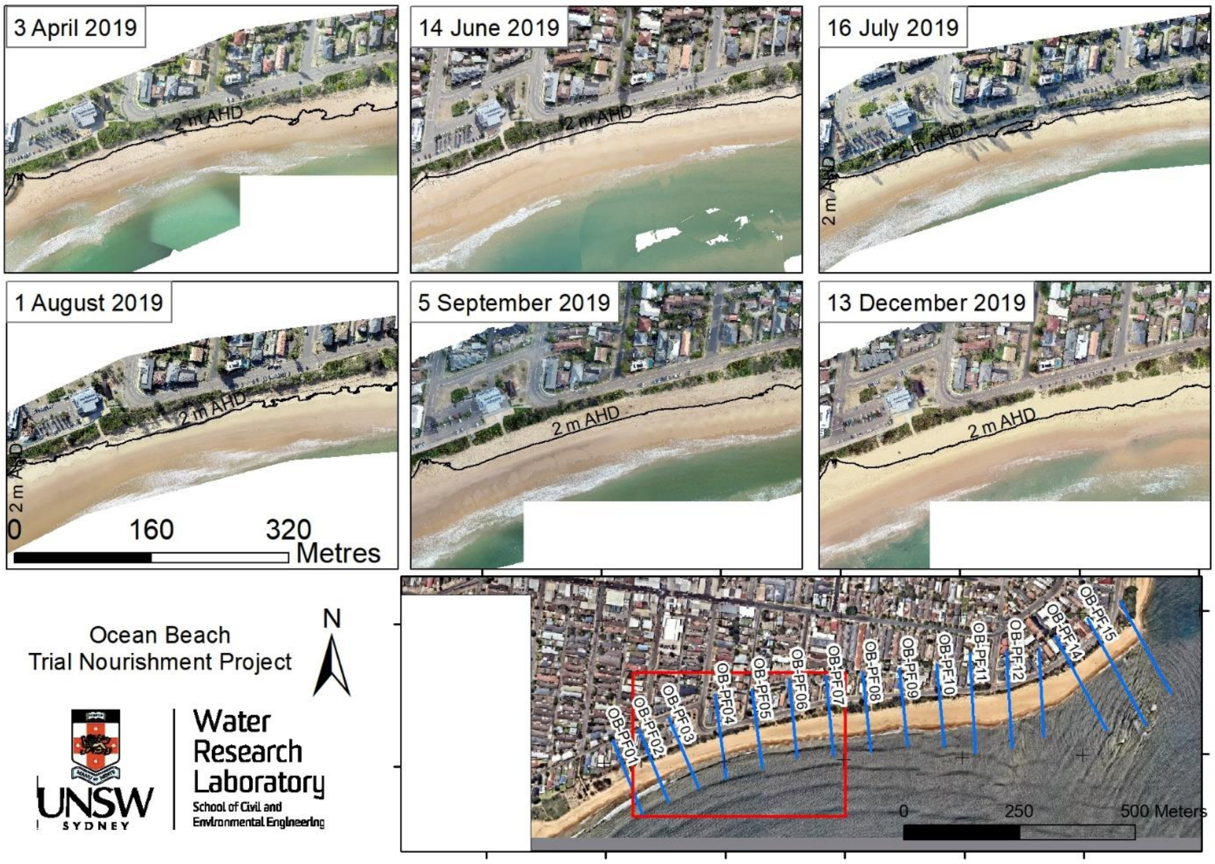


Figure 8: Movement of the 2 m AHD contour within nourishment bund during monitoring period

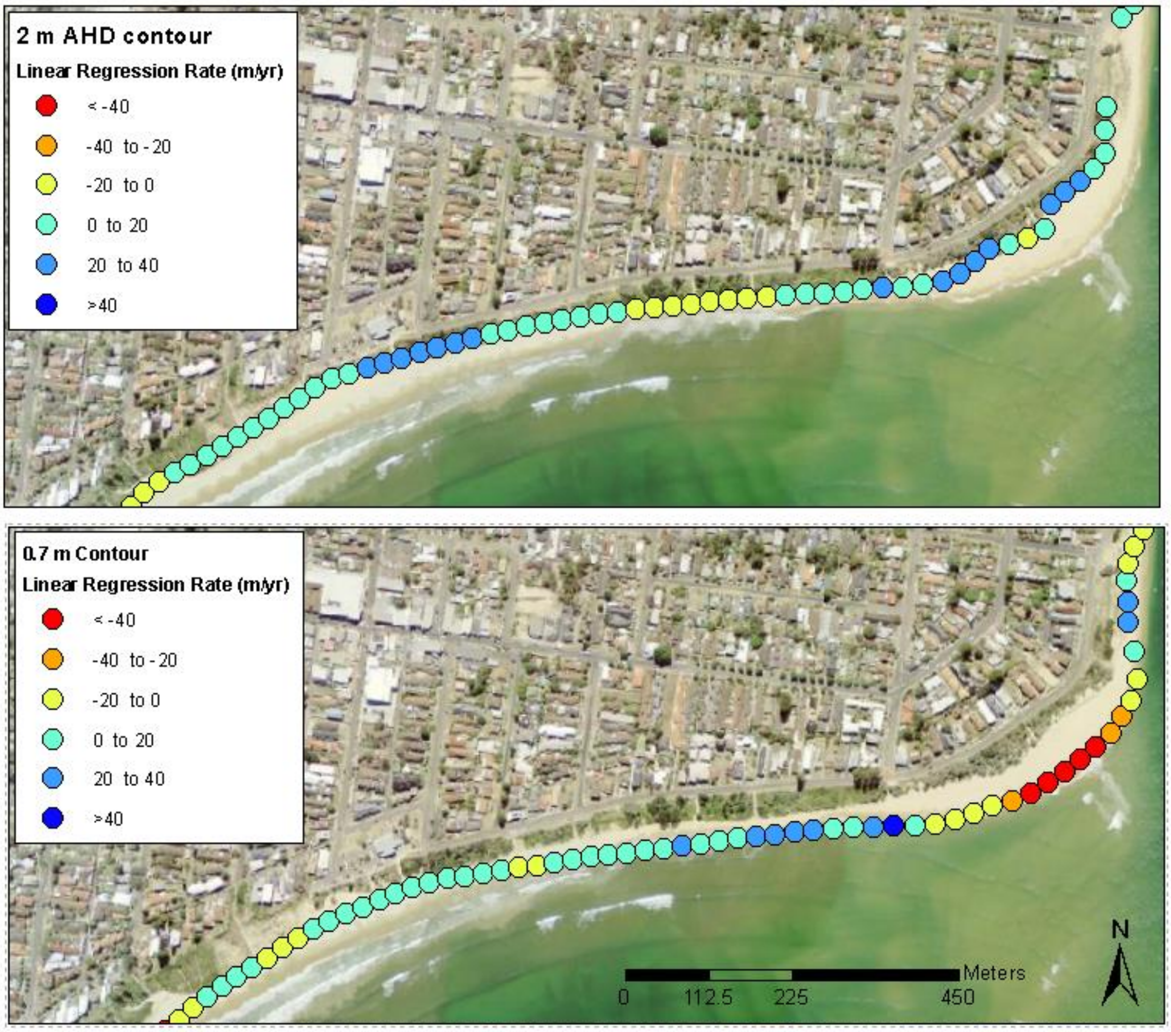
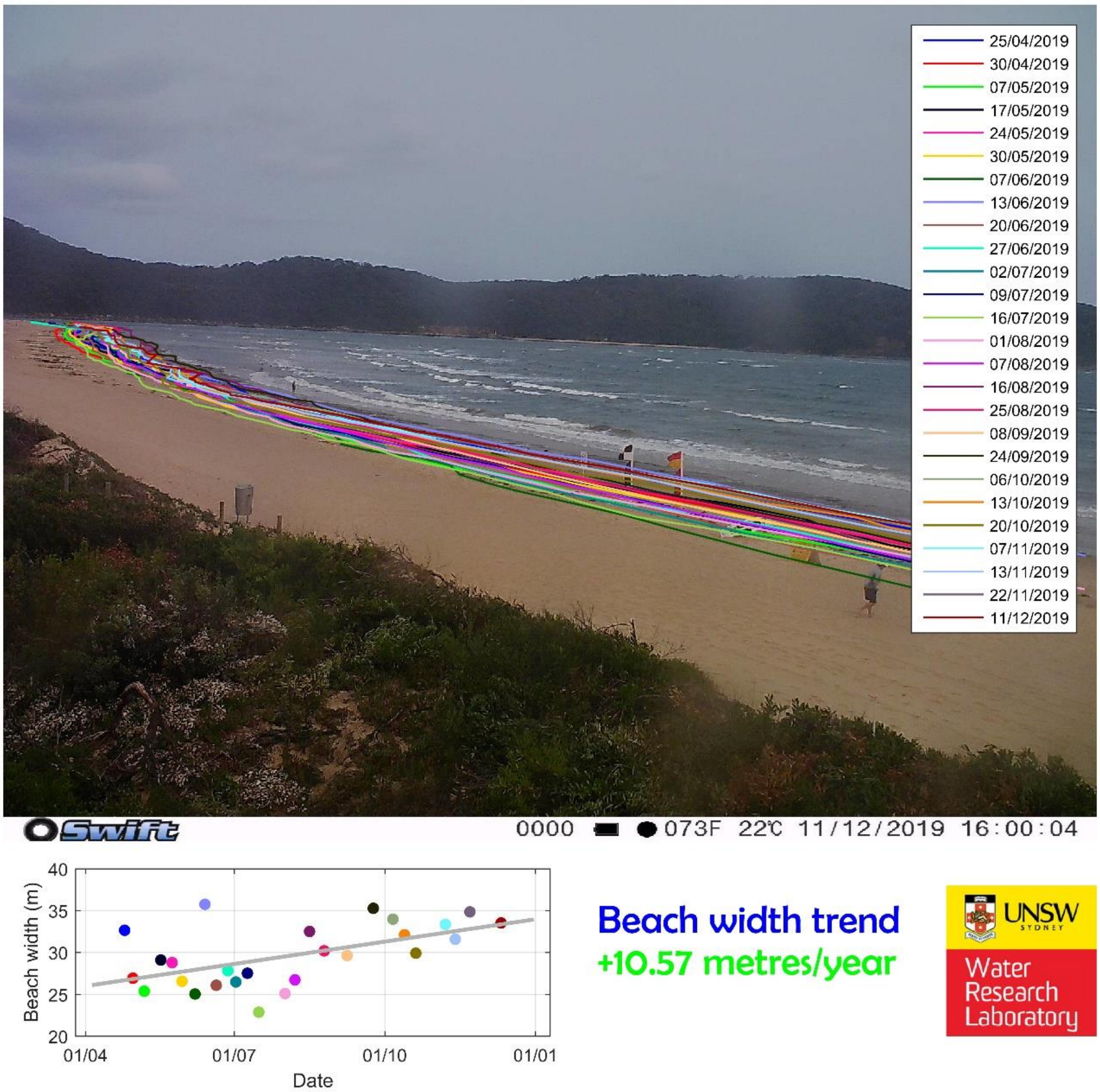


Figure 9: Analysis of the linear regression rate of movement between April and Dec 2019 of the 2 m AHD contour (top) and the 0.7 m AHD contour (bottom)

4.5 Camera based shoreline monitoring

The position of the instantaneous waterline was extracted from the camera based monitoring system from images taken at the same stage of the tide (within 0.1 m). The position of the MSL shoreline was then averaged into a beach width over the 800 m region between Ocean Beach SLSC and Augusta Street (Figure 10). Results indicate that Ocean Beach had an overall accretionary trend at a rate of +10 m per year for the period between April and December 2019. The widest beach width identified during the monitoring period occurred on 13th June 2019 when a low tide terrace bar welded to the shoreline, whereas the most landward waterline captured during monitoring occurred on 4th June 2019 midway through a major storm (Figure 10). While shorelines extracted during storm conditions are useful for understanding processes such as wave runup, they have been excluded from analysis of beach width. This is because storm conditions are usually dominated by factors such as wave setup, runup and barometric setup which are not accounted for in the analysis technique. The accuracy of camera derived shorelines were investigated through comparison with field measurements (Figure 11) with results showing very close agreement in changes to the shoreline position.



13 June 2019 Tide level -0.29 mAHD

4 June 2019 Tide level -0.34 m AHD

Figure 10: Results of camera based shoreline monitoring at Ocean Beach (top), most seaward waterline identified during monitoring period (bottom left) and waterline midway through a storm event (bottom right)

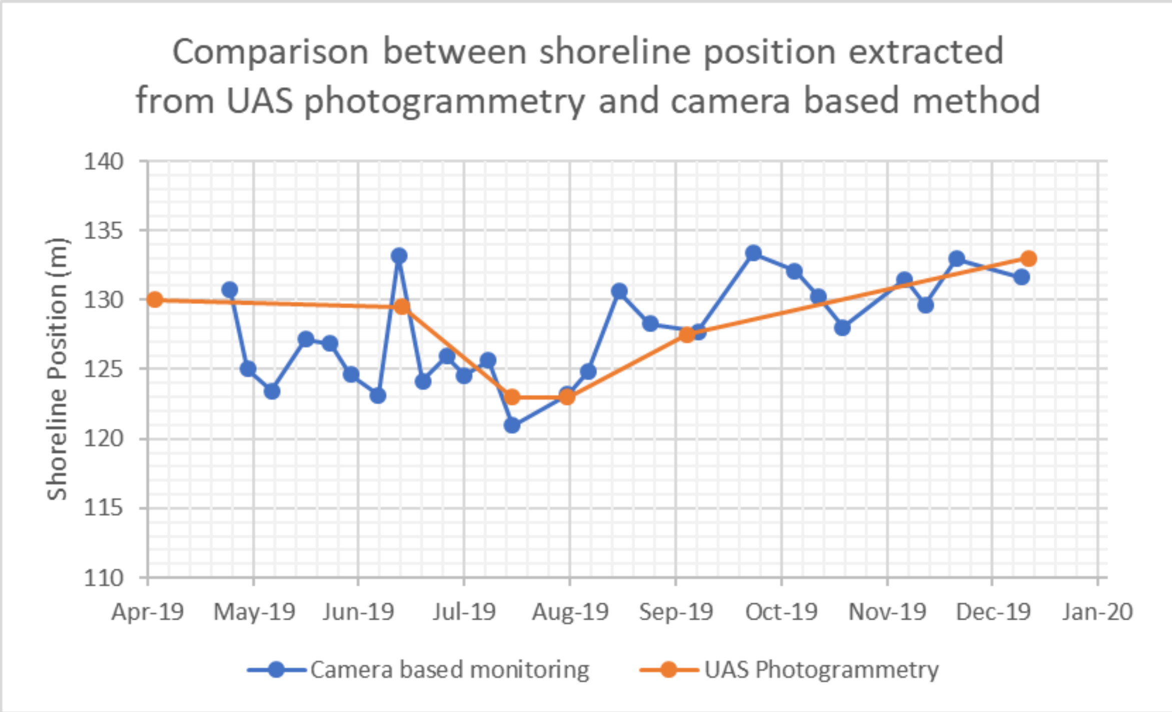


Figure 11: Comparison between camera derived MSL shorelines and measured survey data

4.6 Long term coastal processes at Ocean Beach

The coastal processes at Ocean Beach during the nourishment trial were investigated in the context of long term changes to the site. The variability in the position of the 0.7 m contour over the past 30 years is provided in Figure 12 along with survey data collected during the 2019 nourishment trial. This analysis identifies that the 2012 shoal blowout event coincided with the start of a recessive trend in shoreline position that persisted for a number of years. Inclusion of the recent survey data captured in 2019 indicates that this recessive trend is no longer present at Ocean Beach and that shoreline positions have almost recovered to positions that existed prior to the 2012 shoal blowout event. A long term trend towards beach recovery has existed at Ocean Beach since 2019, at Augusta Street since 2017 and at Barrenjoey Road since 2015. This observation is consistent with the theory that the shoal blowout disrupted sediment feed from the shoal onto the beach and that this process varied in strength and duration along the beach. The accretionary trend present at Barrenjoey Road is noteworthy in its consistency compared to a history of Ettalong Point having a high degree of variability in width. If this rate of accretion persists into the future until 2025 then this location will approach the widest position recorded that occurred in the mid-1990s. It is likely that the long term trend towards accretion of the 0.7 m contour that has occurred at Ocean Beach over the past few years has overwhelmed any signal introduced by the relatively small volumes of sand associated with the nourishment trial.

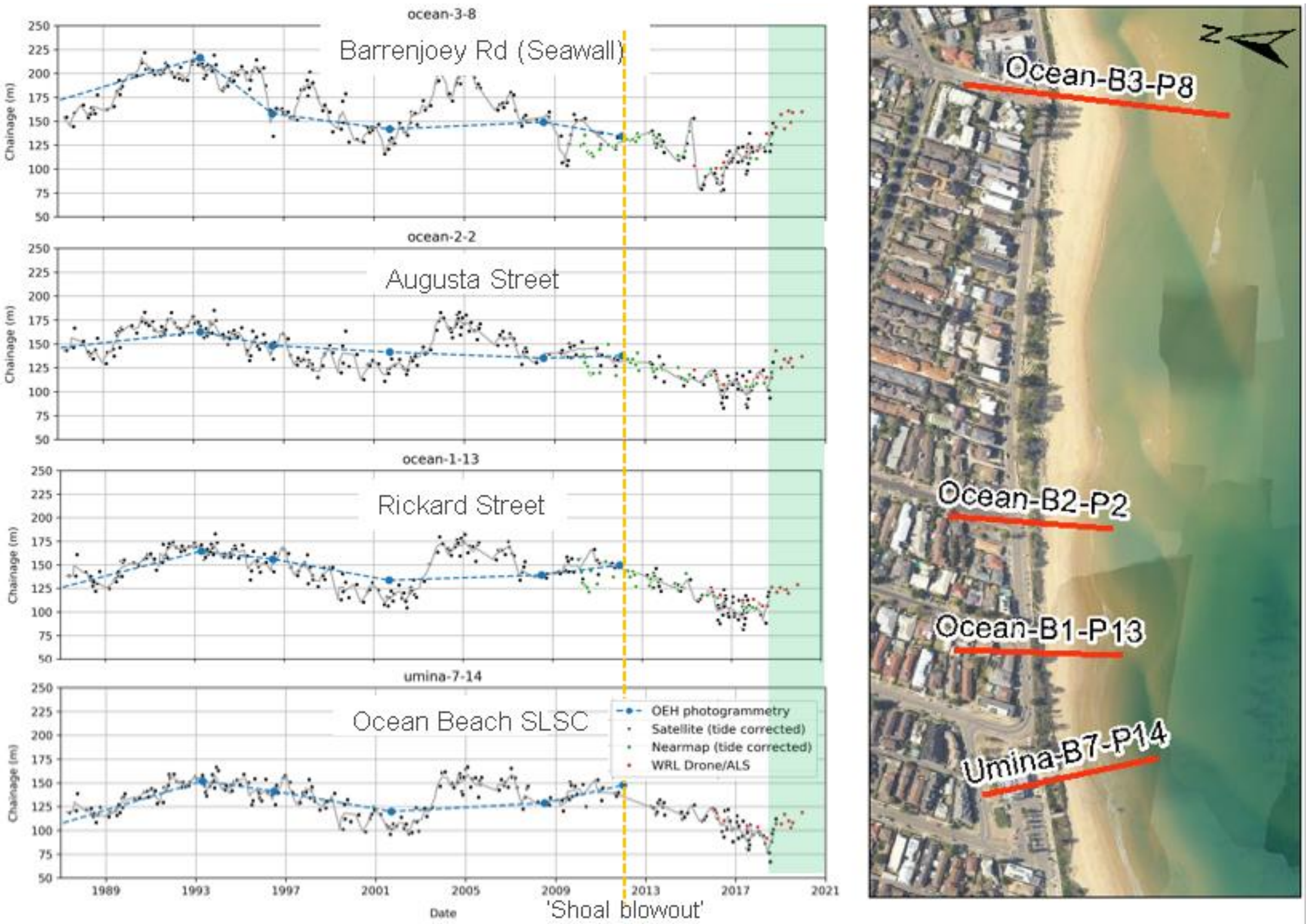


Figure 12: Shoreline variability during nourishment trial (green shaded area) compared to 30 year historical context

5. Discussion and conclusions

Analysis of the intensive monitoring program identified the following characteristics of the nourishment trial:

- The placement bund was 400 m long and 25 m wide.
- There was an average vertical change due to nourishment placement of +1m to +1.5 m.
- A peak vertical change of +3 m was present in the middle of the bund (OB-04) in September although this sand was in a more natural beach slope alignment by December 2019.
- Review of time-lapse imagery and discussions with Council staff indicate that this 'hump' was most likely redistributed through the regular beach raking program at Ocean Beach.
- Analysis of survey data indicates that the 0.7 m contour generally accreted at a rate of 10 m per year between Ocean Beach SLSC and Barrenjoey Road between April and November 2019 while Ettalong point eroded at a peak rate of -40 m per year.
- The 2 AHD m contour accreted at a rate of 20 to 40 m per year in the vicinity of Ocean Beach SLSC throughout the monitoring period which is most likely attributed to placement of nourishment material, with a secondary attribution of underlying accretion following recovery from the 2012 shoal blowout.
- Camera based monitoring of the MSL shoreline calculated that the beach region between Ocean Beach SLSC and Augusta Street is accreting at a rate of+10 m per year which is consistent with analysis of measured survey data.

The following comments can be made about sediment transport processes at Ocean Beach:

- The beach between Ocean Beach SLSC and Barrenjoey Road generally accreted throughout 2019 with the 0.7 m contour accreting at a rate of +10 to +20 m/year.
- The alignment of Ettalong Point shifted throughout 2019 with sediment redistributed towards the west and accumulating at Barrenjoey Road.
- Storm wave events occurring in June 2019 (8 year ARI) and August 2019 (<2 year ARI) caused the beach to erode by 2 to 4 m.
- There has been a long term trend towards beach recovery at Ocean Beach since 2019, at Augusta Street since 2017 and at Barrenjoey Road since 2015.
- Ocean Beach has almost returned to the shoreline positions that existed prior to the 2012 shoal blowout event that caused disruption to the sediment feed onto the beach for a number of years.
- It is likely that the long term trend towards accretion of the 0.7 m contour that has occurred at Ocean Beach over the past few years has overwhelmed any signal introduced by the relatively small volumes of sediment associated with the nourishment trial.

Yours sincerely,

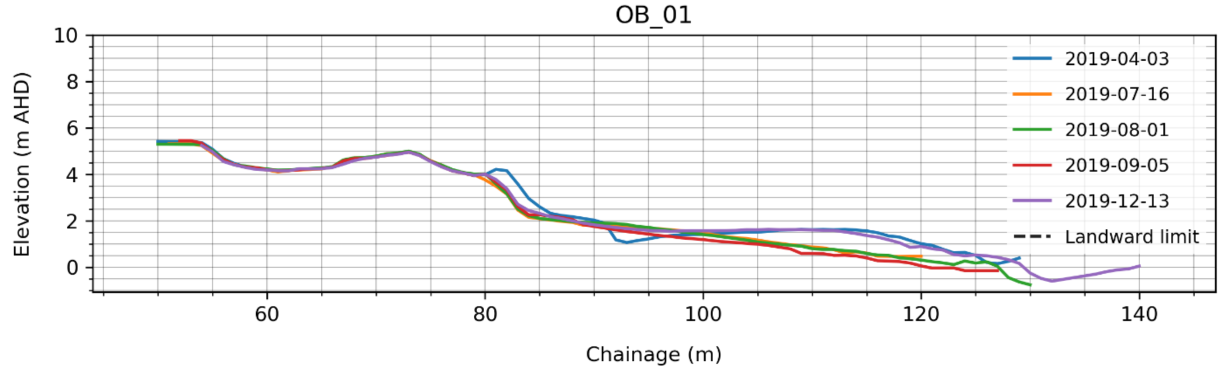
Grantley Smith
Manager

6. References

Harley M D; Kinsela M A; Sánchez-García E, Vos K, (2019), 'Shoreline change mapping using crowd-sourced smartphone images', Coastal Engineering, vol. 150, pp. 175 - 189, http://dx.doi.org/10.1016/j.coastaleng.2019.04.003

Shand, T D, Goodwin, I D, Mole, M A, Carley, J T, Coghlan, I R, Harley, M D and Peirson, W L (2010), NSW Coastal Inundation Hazard Study: Coastal Storms and Extreme Waves, prepared by the Water Research Laboratory and Macquarie University for the Department of Environment, Climate Change and Water. WRL Technical Report 2010/16

Appendix A: Profile Figures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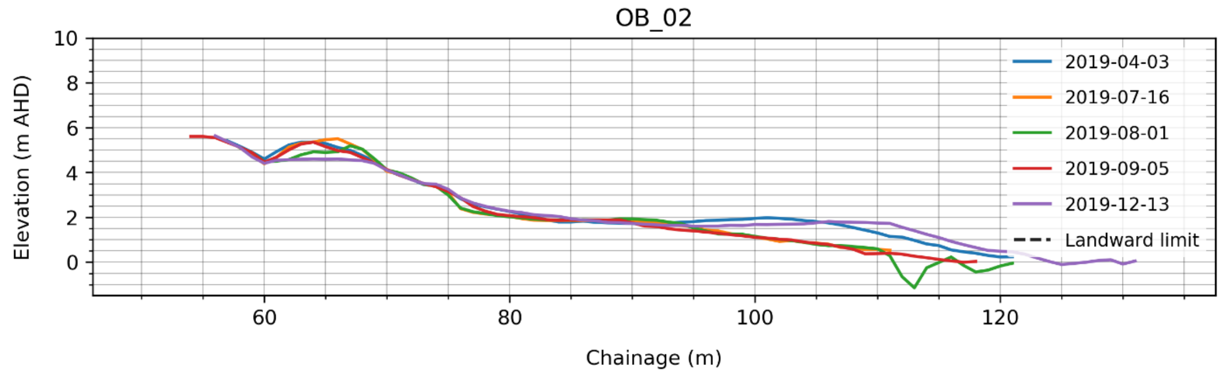
2019-07-16
2019-08-01
2019-09-05
2019-12-13
Landward limit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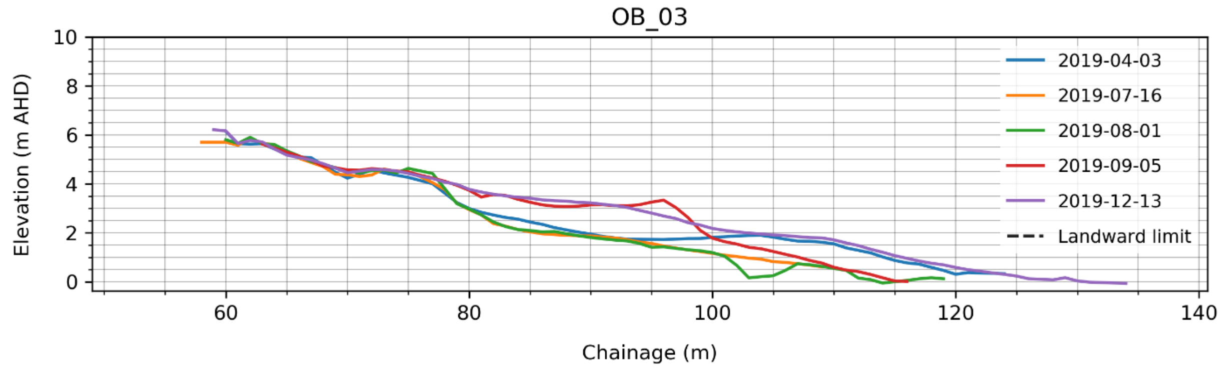
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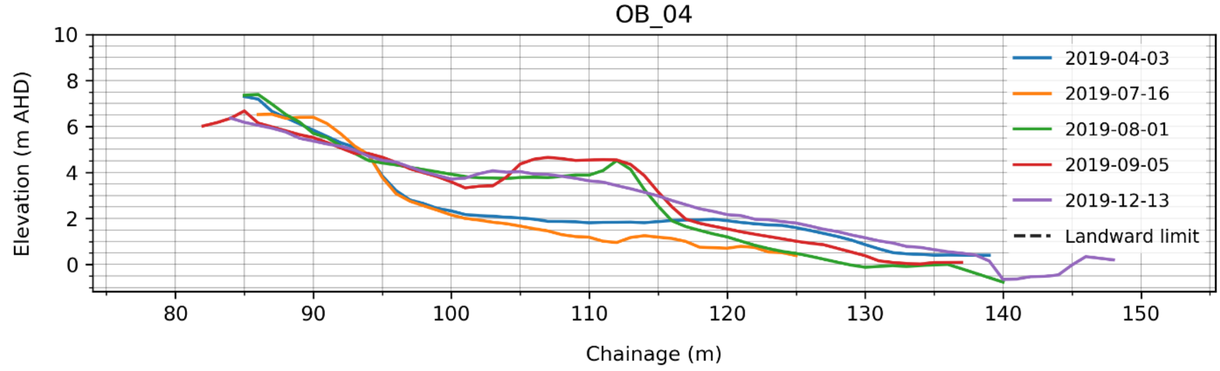
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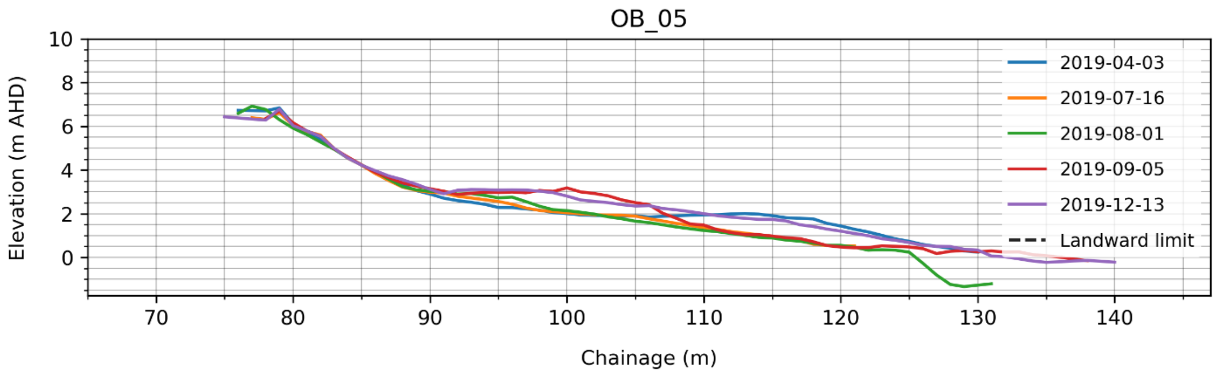
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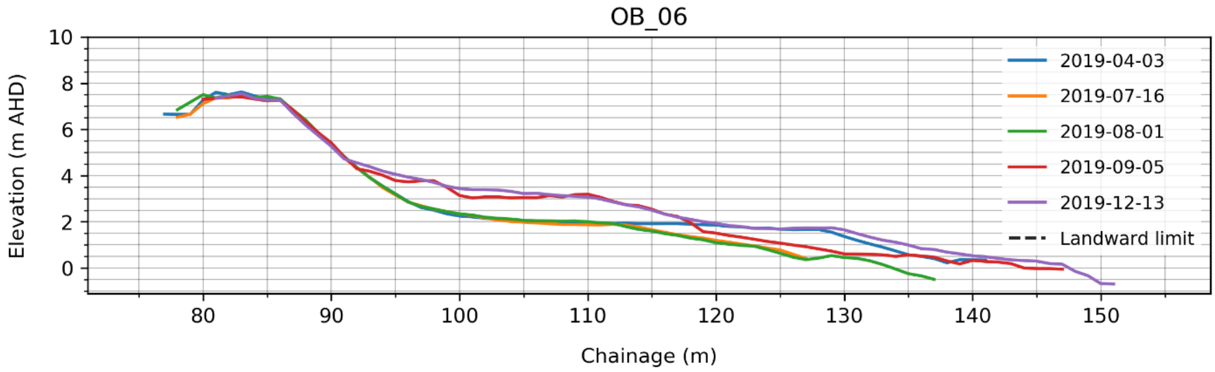
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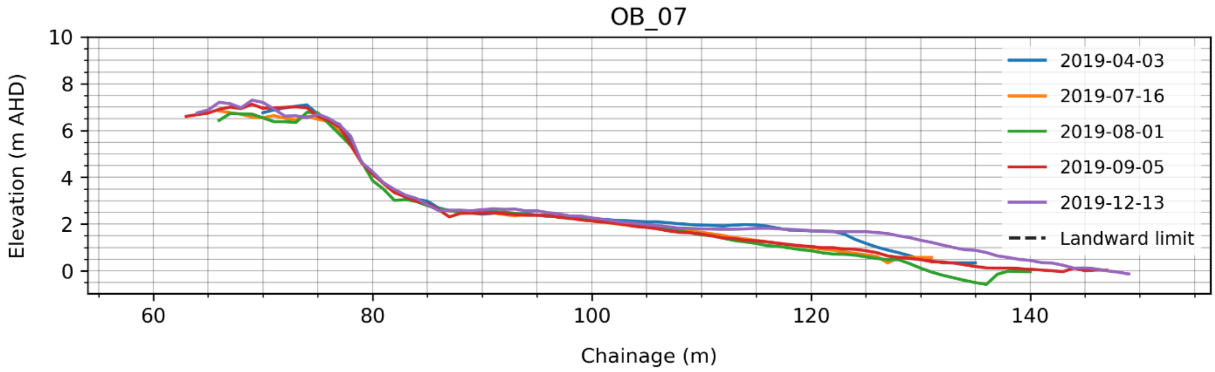
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2019-12-13
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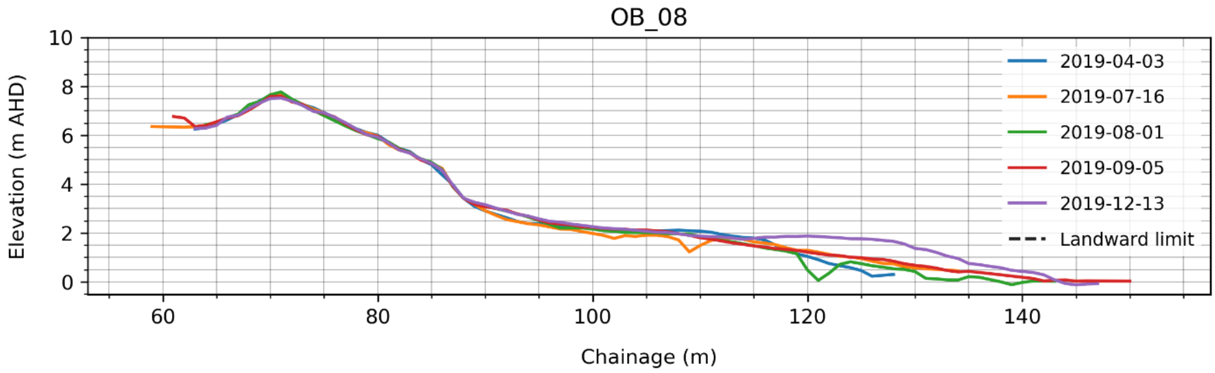
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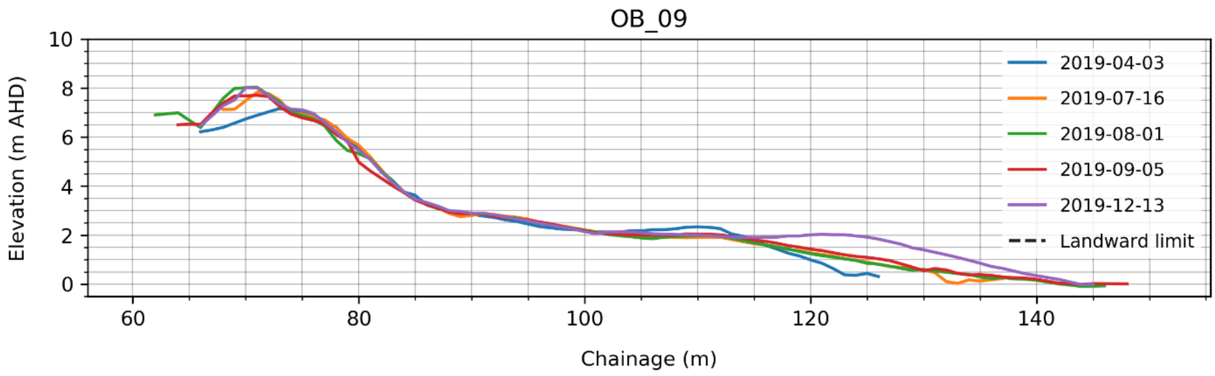
2019-12-13
Landward limit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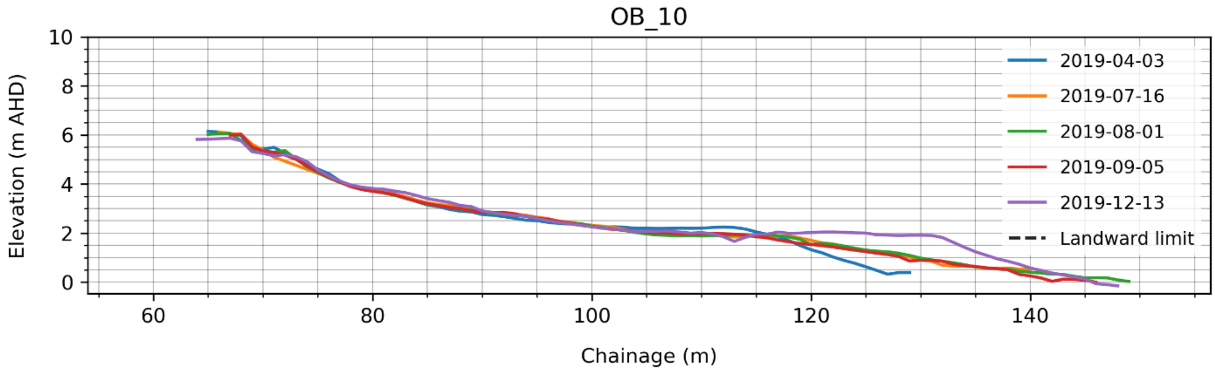
2019-12-13
Landward limit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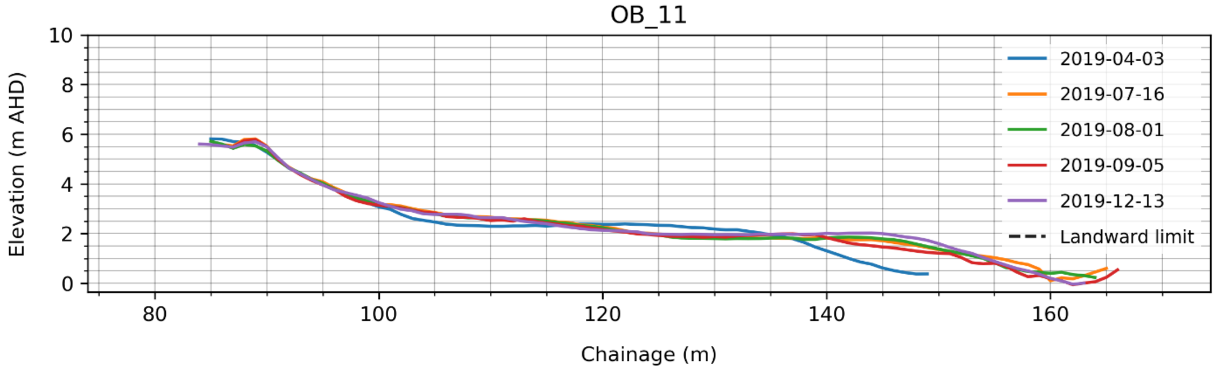
Landward limit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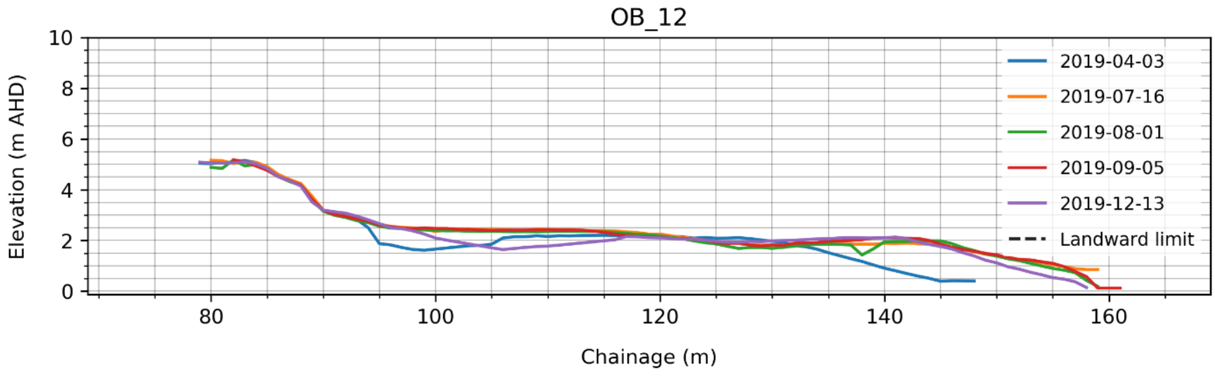
Landward limit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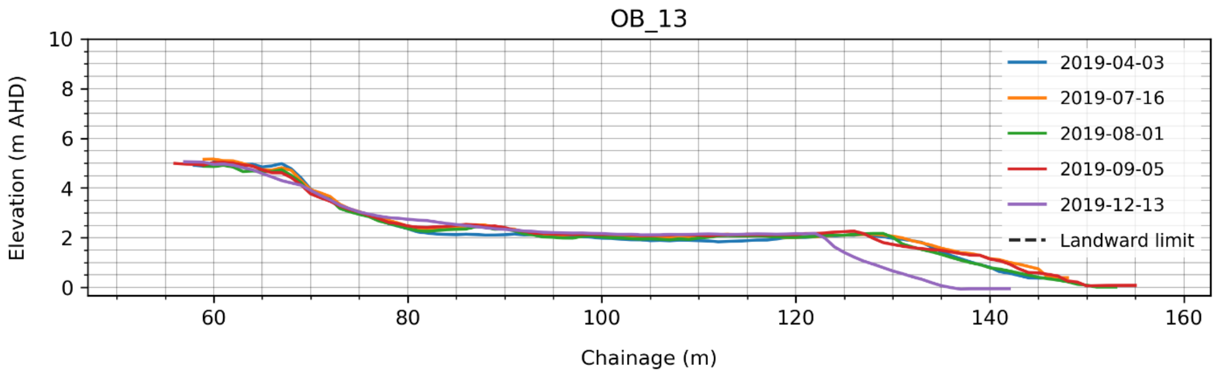
2019-12-13
Landward limit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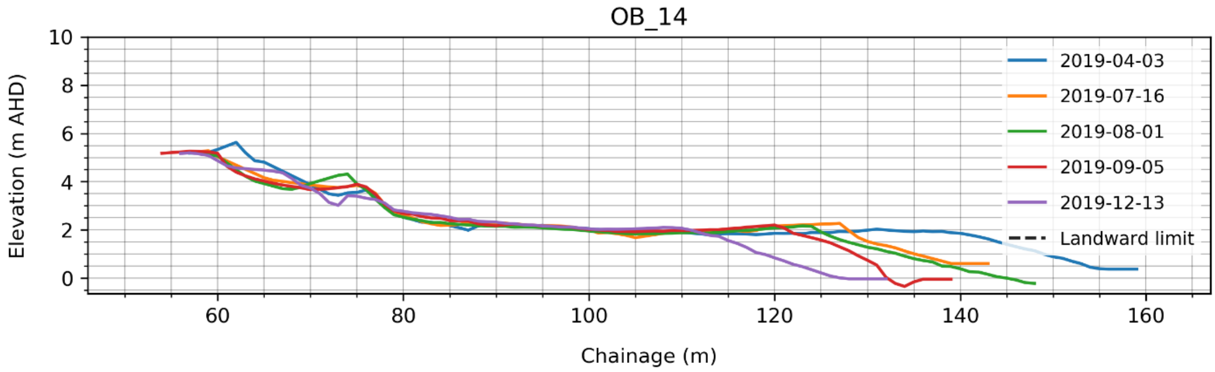
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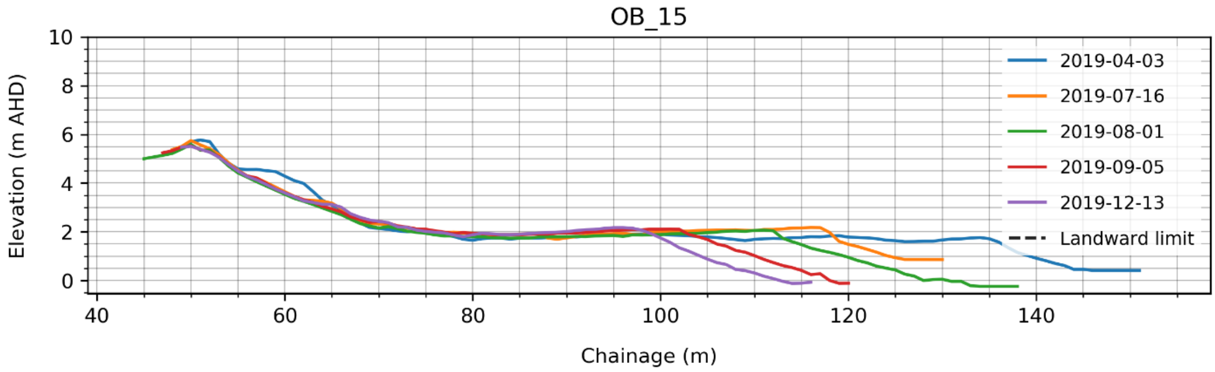
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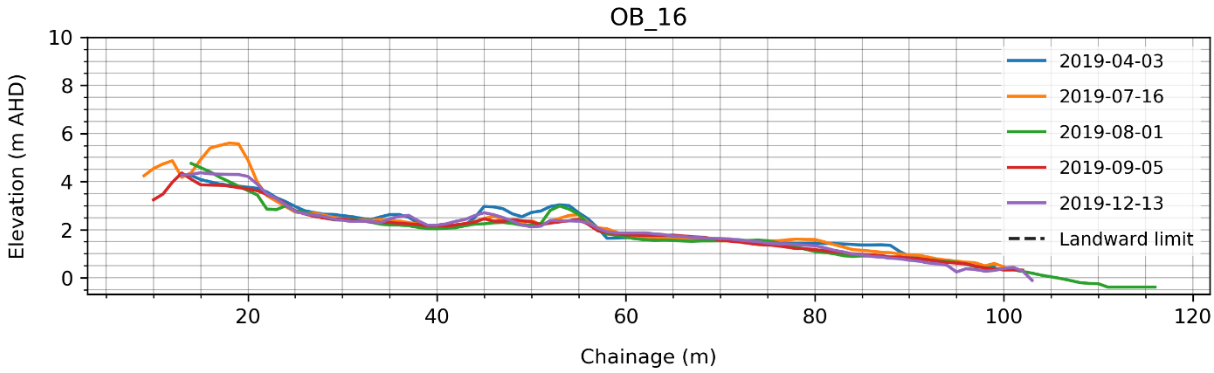
Landward limit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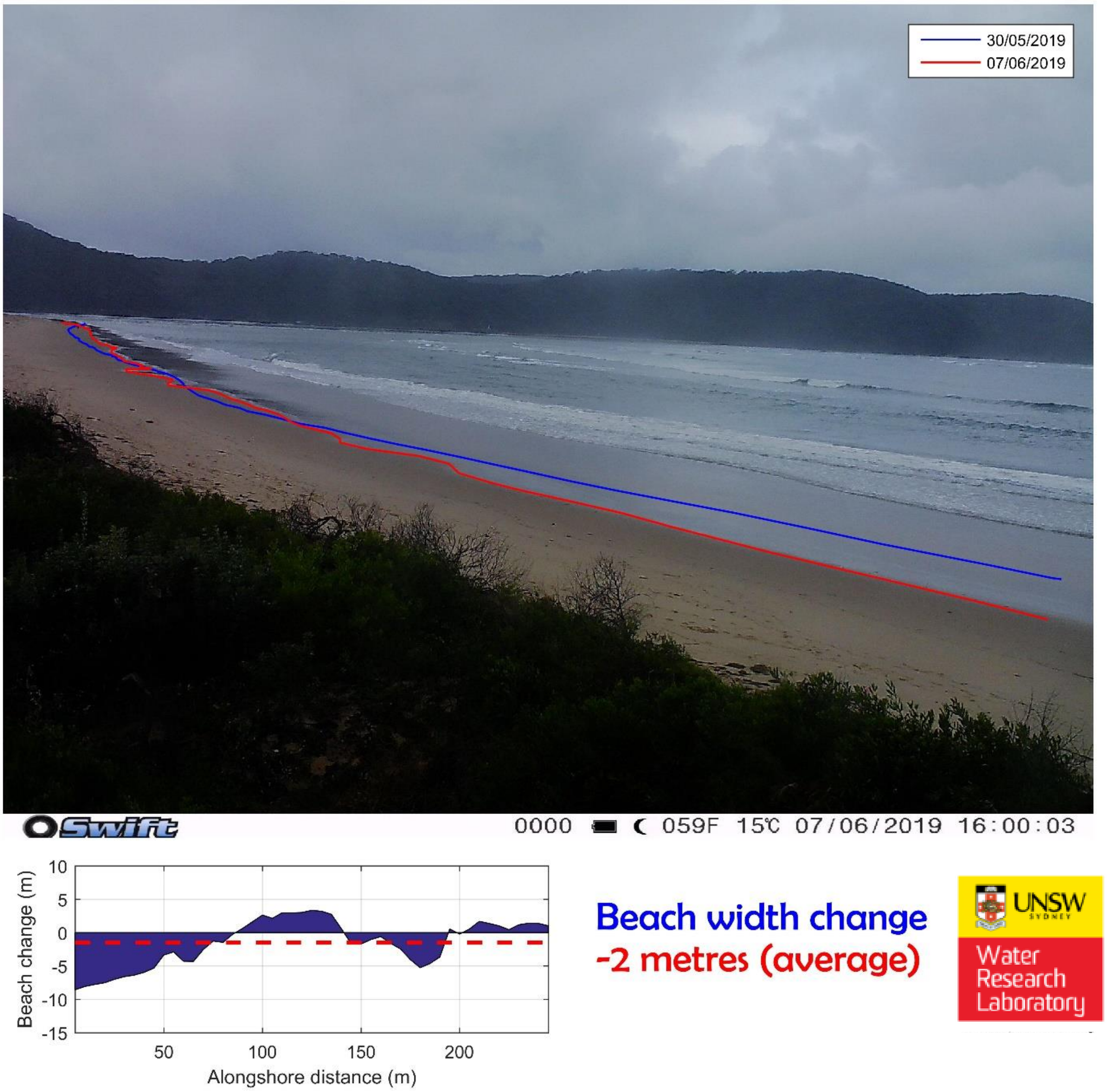
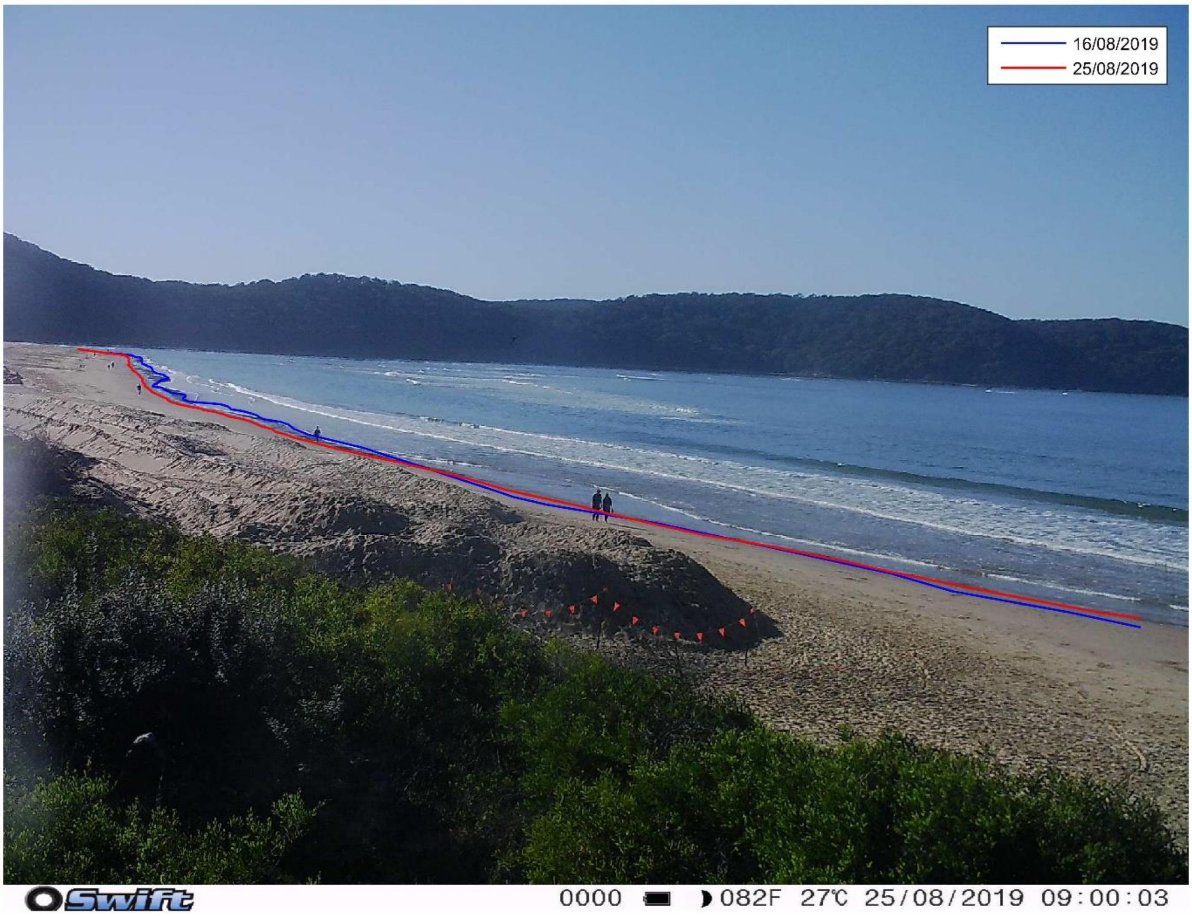
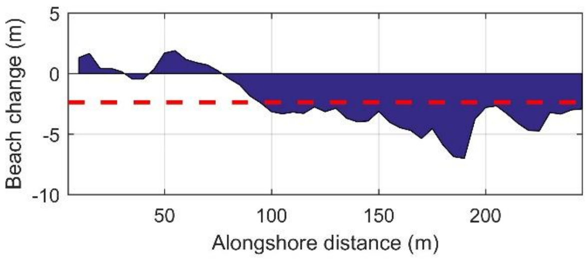
Elevation (m AHD)
Chainage (m)
2019-04-03
2019-07-16
2019-08-01
2019-09-05
2019-12-13
Landward limit

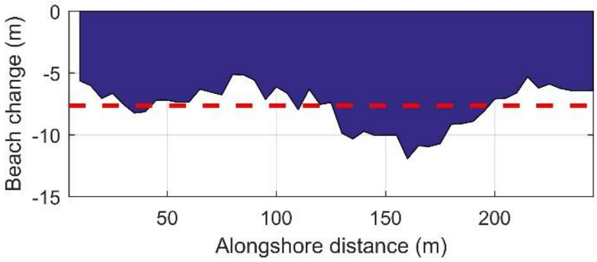
Appendix B Impact of storm events calculated from monitoring camera







Beach width change
-2 metres (average)



Beach width change

-8 metres (average)