Changes at the Mouth of the Avon-Heathcote Estuary in Christchurch, New Zealand

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Introduction

The Avon-Heathcote Estuary is regarded as one of the city's sites of exceptional biodiversity value within Christchurch and Banks Peninsula areas. It, along with the adjacent unbuilt environments, is vital for water birds, with nationally and internationally significant concentrations of wetland and coastal birds in the area at times. The high proportion and importance of the wetland and coastal bird species make the Christchurch City area the "wetland bird capital of New Zealand".

The Avon-Heathcote Estuary (AHE) ebb-tidal delta, throat cross-sectional area and tidal prism may be out of equilibrium due to post-Canterbury Earthquake Sequence (CES) bathymetry changes (Measures et al. 2011, Measures & Bind 2013), or it may be in a state of continual adjustment (dynamic equilibrium). The history of AHE geomorphology is discussed in Findlay and Kirk (1988) who estimate from the changes in the estuary mouth cross-section that the "tidal compartment" (hereafter, tidal prism) of the Avon-Heathcote Estuary has been increasing over time, implying net erosion and sediment export to the coast. Thompson (1994) examined the ebb tidal delta, South Brighton spit and inlet morphology using cameras and beach profiles, attributing in one case profile change to effective tidal flushing of sediment out of the estuary.

The research project will include analysing shoreline and cross-section change, the significance of sediment transport (including fluvial sediment) and ebb or flood dominance. The shoreline changes around the estuary mouth are crucial data for understanding inlet, spit and beach have transformed in recent years.

Figure 1: 3D View of Avon Heathcote Estuary (Source: Google Earth Pro)

Methodology

Existing Data Set

- Profiles (Thompson 1994)
- Aerial Photos (LINZ data service 2016)
- Tides (CCC and LINZ 2019)
- DEM (Measures et al 2011, 2013)

Unmanned Aerial Vehicle via Photogrammetry

In this project, a UAV (drone) was flown at the Avon-Heathcote Estuary at low tide to capture images of the estuary mouth, tidal flood delta, and end of the spit as shown in the study area map (Figure 1). The UAV used has an inbuilt RTK GPS on board with a D-RTK 2 Mobile Station which provides real-time differential data to the drone. There is a base station running, correcting data in real time (Figure 2). Ground Control Point (GCP) markers will be used to determine the accuracy of data after processing the UAV images as a check. Processing is done using Pix4D Mapper and Trimble Business Centre (TBC).

Beach Profiles and Bathymetry

Beach profiles are collected using the integrated high precision Real Time Kinematics-GPS positioning system. The beach profile will be compared with existing data to detect changes. Bathymetry data is collected using a remote-controlled jet boat with sonar depth sounder linked to a GPS benchmark on land. Transects across the estuary mouth were surveyed at high tide. All the data are converted to New Zealand Vertical Datum 2009 (NZVD2009) for comparison with the existing data set.

Figure 2 :**(a).**Phantom 4 RTK drone used for image capture **(b).** D-RTK 2 Mobile Station **(c).** GNSSS base station set on a known bench mark (EKNU) for RTK profiling **(d).** GNSS Rover used for collecting profile data

Shoreline Change Analysis

The image acquired from the UAV is compared with past aerial images, available on LINZ data service, to help gain a better understanding of how the shoreline at the estuary mouth is changing, and how the dynamics of the estuary affect South shore beaches. The comparison is made using the DSAS is a computer software application that computes rate-of-change statistics from multiple historical shoreline positions residing in a geographic information system. DSAS was freely available from the NOAA Coastal Services Center website as an ArcGIS Desktop 10.6 plugin.

The analysis provides the shoreline change envelope (SCE), net shoreline movement (NSM), and the weighted linear regression (WLR). SCE is defined as the distance between the farthest and the closest shoreline to the baseline of each transect. NSM is the distance between the oldest and most recent shorelines for each transect.

Result

Data processing of the UAV data was processed using 15 days trial version of Pix4Dmapper software. There is a total of 567 images processed from 2 flights flown at the height of 100m. There are multiple outputs such as the generation of geo-referenced ortho-mosaic, DSMs, 3D point clouds and textured mesh models in a variety of formats. The ground sampling distance (GSD) for the ortho-mosaic is 3cm.

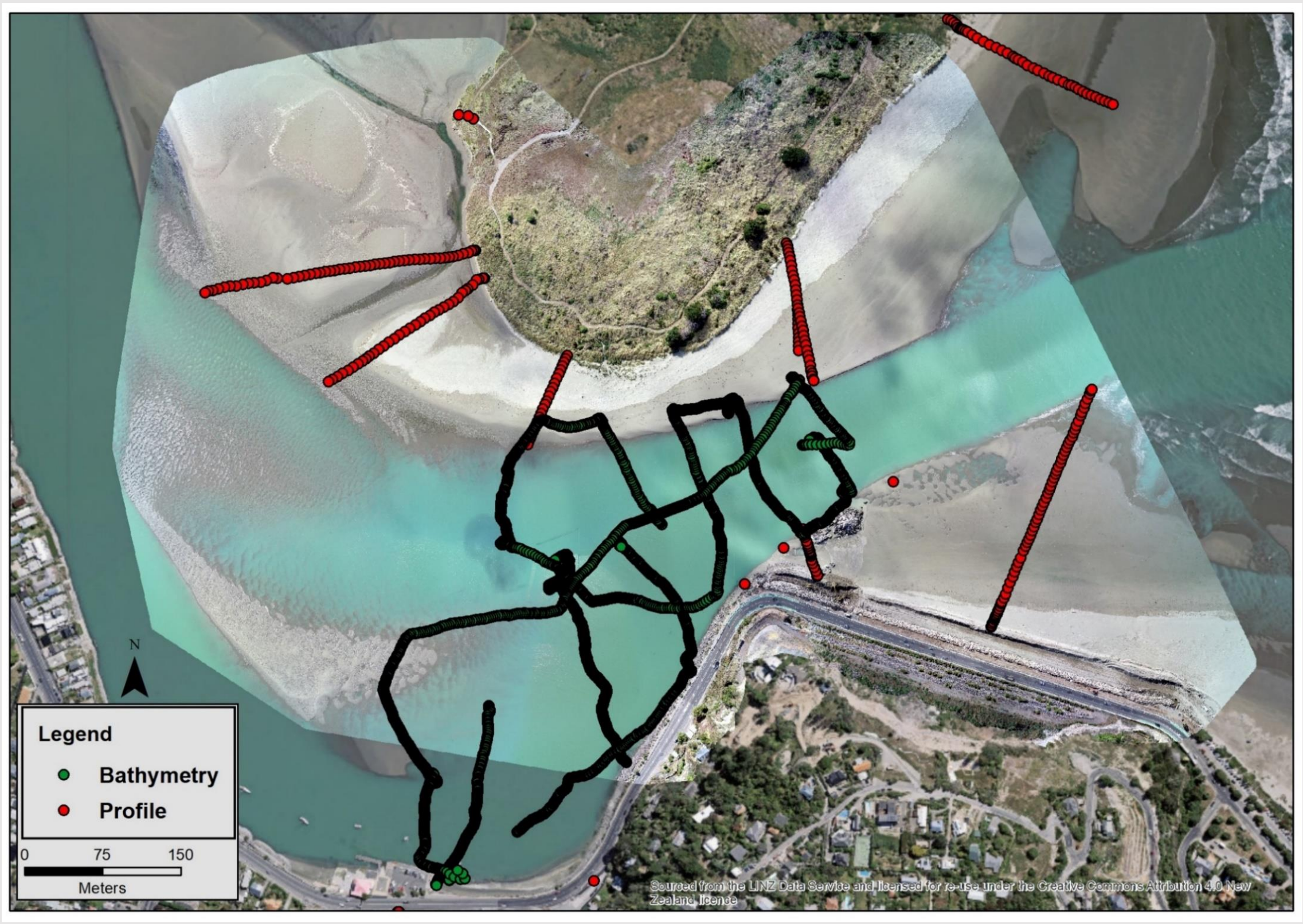

Figure 3 : Map showing the Ortho-mosaic from UAV, Bathymetry and beach profiles

The beach profile data will be compared with Thompson (1994) profiles to able to look at changes. The issue with Thompson profile was the absence of geo-location for the starting point of the profiles.

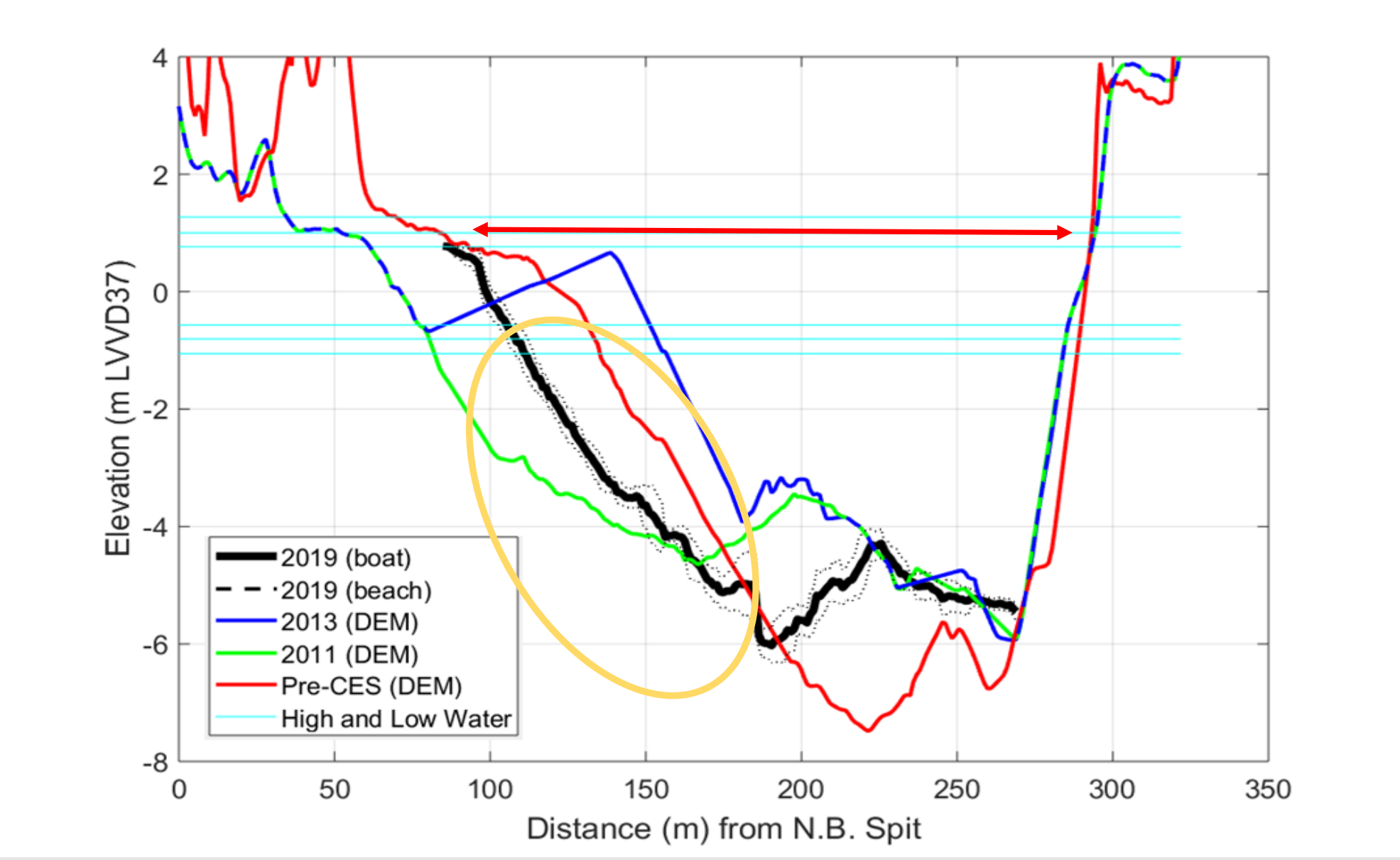

Figure 4 : Profile compared to existing DEM (2011,2013) and bathymetry.

The profile shows the elevation has change by 2 meters compared to 2013. The main channel is shallower compared pre-quake and has become wider (Figure 4).

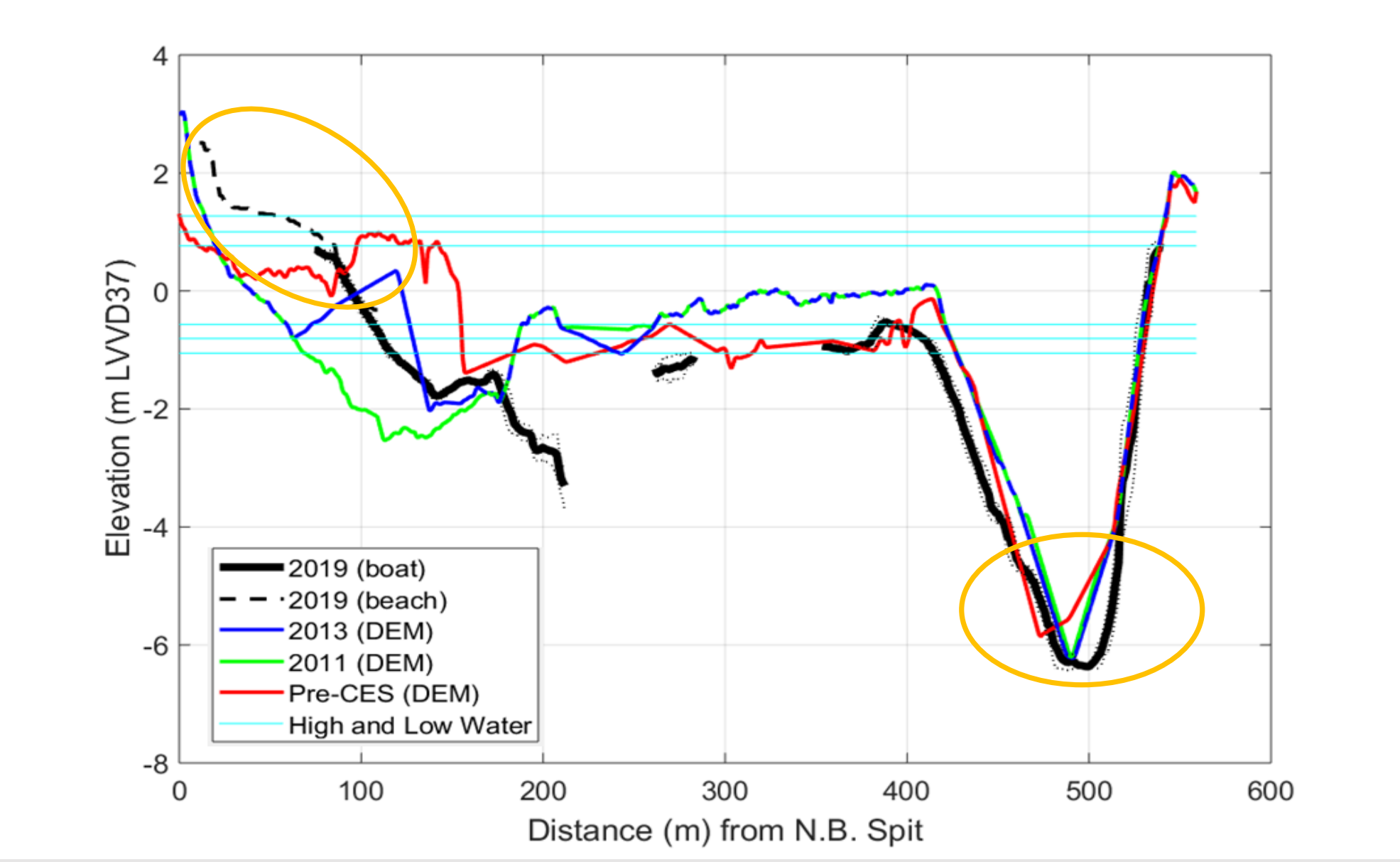

Figure 5 : Beach Profile 6 compared to existing DEM (2011,2013) and bathymetry

The profile shows that the main channel is stable and has not moved since the earthquake. The beach berm has increased by 2 meters in elevation. Large sand bar after the CES is now eroding back down. From cross-section extracted from echo-sounder surveys of the neck of the estuary by NIWA, show that the mouth cross-section shape and area varied significantly since the earthquake(Figure 5).

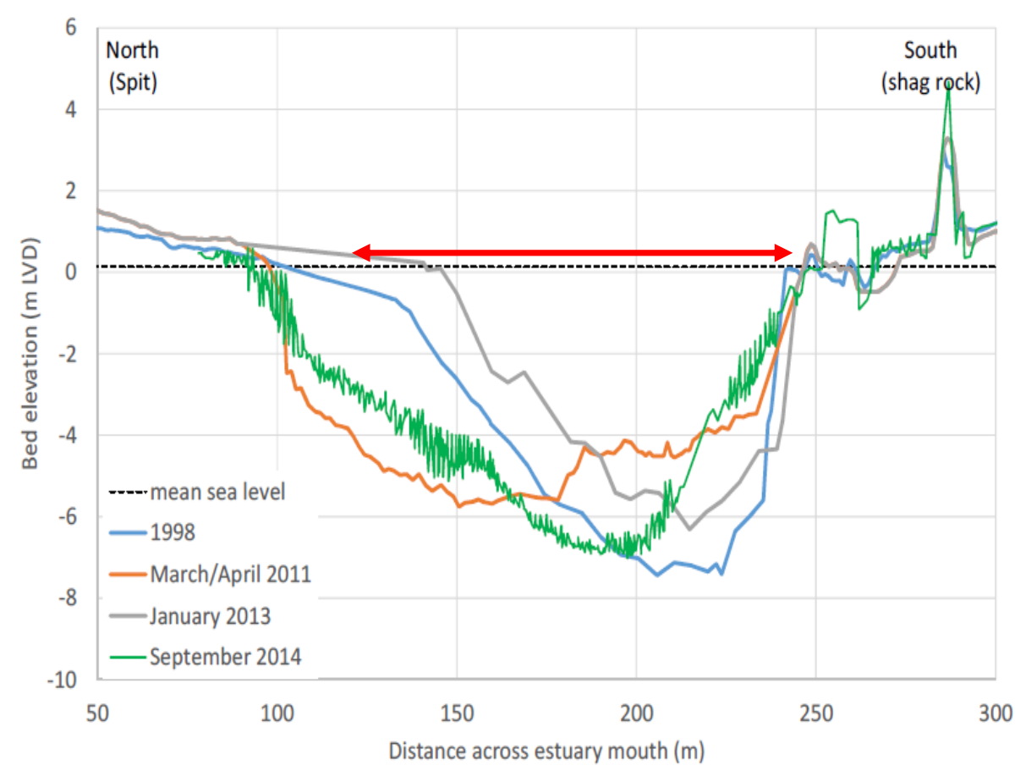

Figure 6 : Recent NIWA surveys of the mouth.

The increasing tidal prism of the estuary will increase flow rates through the estuary mouth and tidal channels, enlarging the channels, the mouth and the tidal deltas. Based on the expected increase in tidal prism it is estimated that the estuary mouth will increase in width by 20-30 m with a 0.5 m sea level rise and 40-50 m with a 1.0 m rise (Tonkin and Taylor 2013).

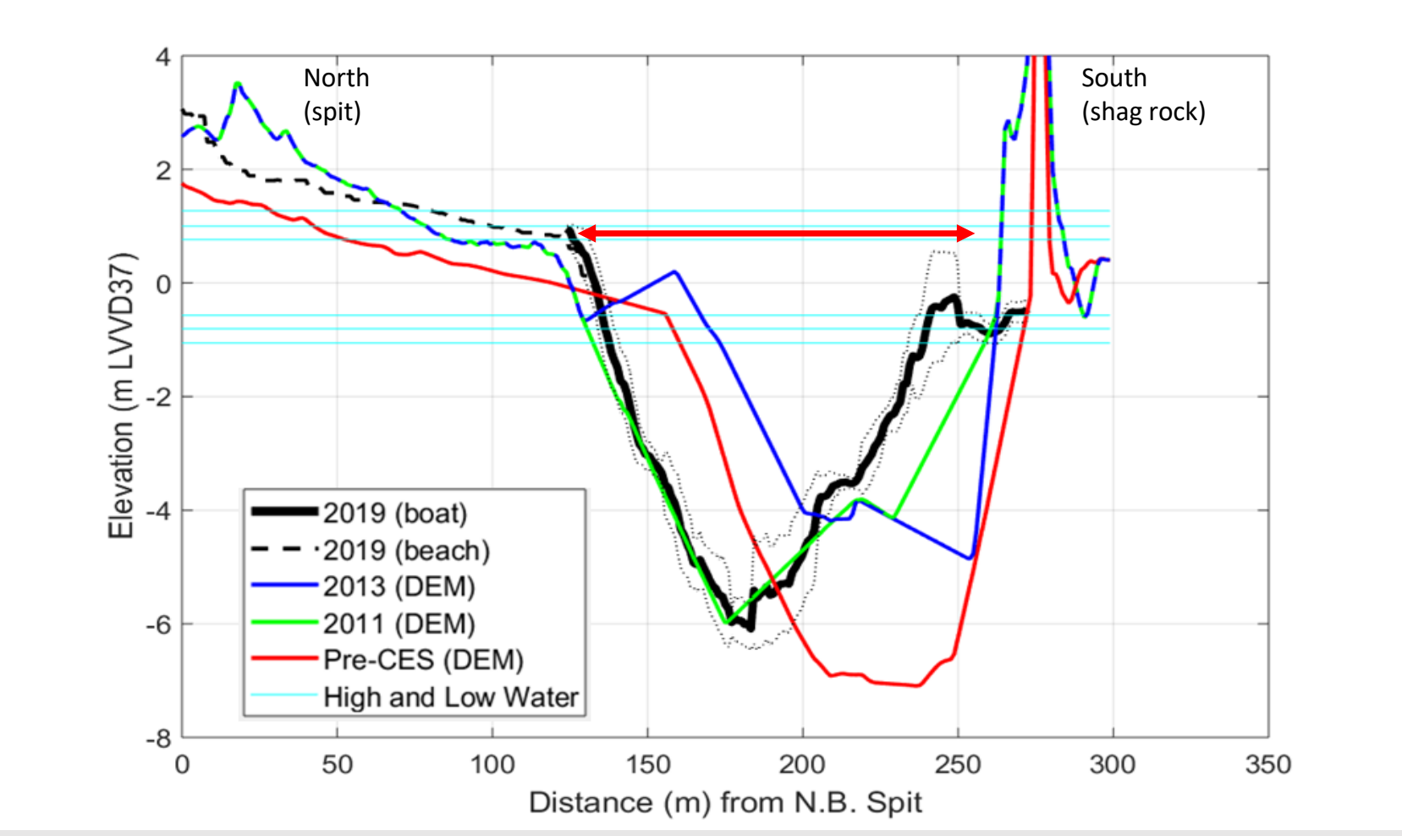

Figure 7 : Profile 4 of the mouth done by team in 2019.

Figure 7 shows a shift in the mouth and has become narrow compared to NIWA 2014. This needs to be investigated further as T & T report states estuary mouth will increase in width by 20-30 m with a 0.5 m sea level rise, but here it is not the case where the mouth has become steep and narrow.

Discussion

Shoreline changes occur over a wide range of time scales and linked with coastal features such as waves, tides, periodic storms, sea level rise (SLR), and human developmental activities (Appeaning Addo et al. 2008). The shoreline position can transform due to predictable short-term variations in sea level that rely on astronomical and meteorological factors (Pugh 2004) and less predictable changes in the form and volume of the sediments along the profile of the shore (Pardo-Pascual et al. 2012).

For the shoreline analysis, vegetation line was used (Boak and Turner 2005) since it was not possible to obtain pre-existing shoreline dataset.

Figure 8 :1847-2005 tip shorelines (from Findlay and Kirk 1988 and Bryan et al 2008)

The rates of net shoreline movement from 2004 to 2019 range from -25.26 m to 35.97 m, where negative values represent erosion, and positive values represent accretion, as shown in Figure 10.

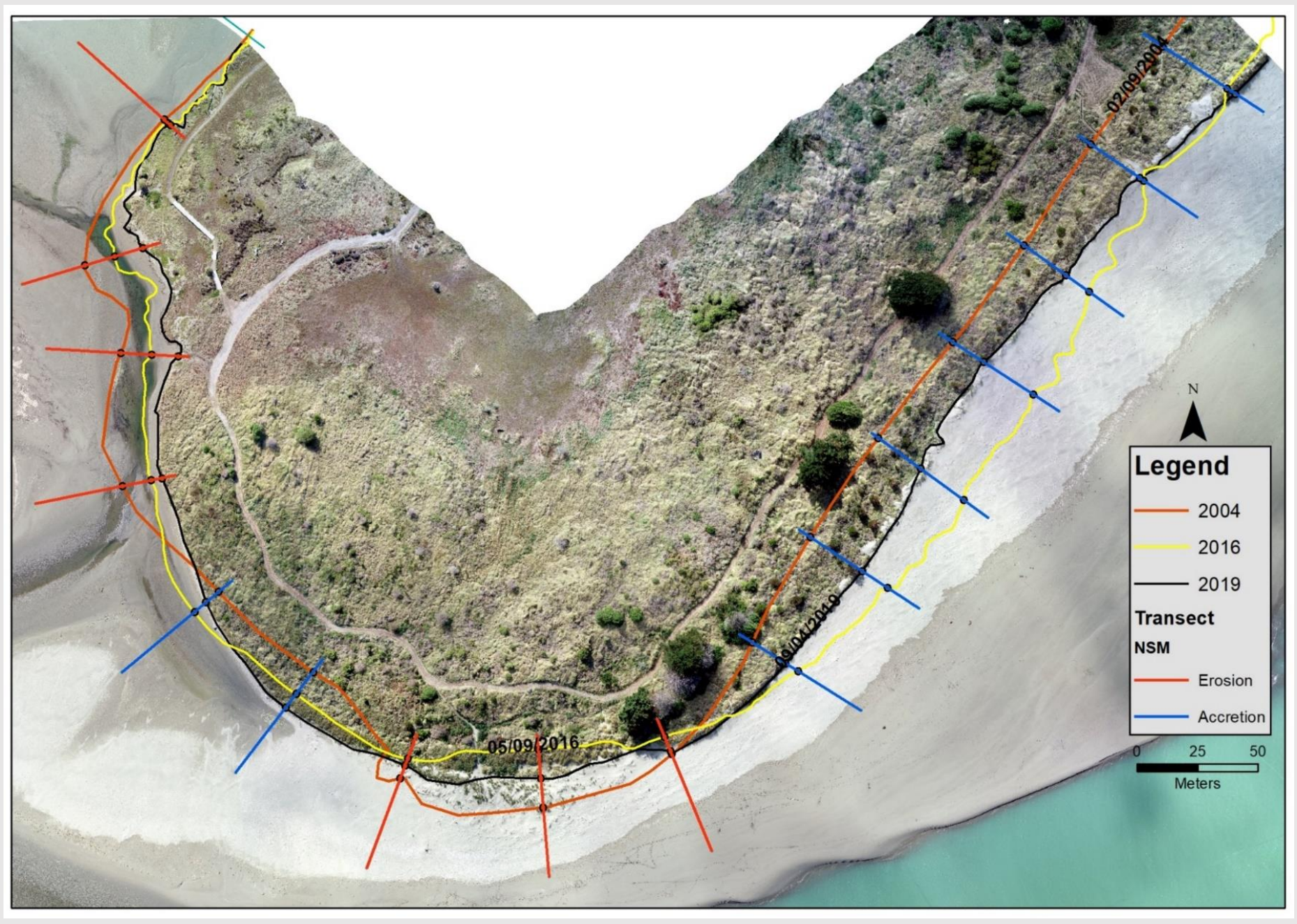

Figure 9 : Transect cast showing accretion(blue) and erosion(red) on the South Shore.

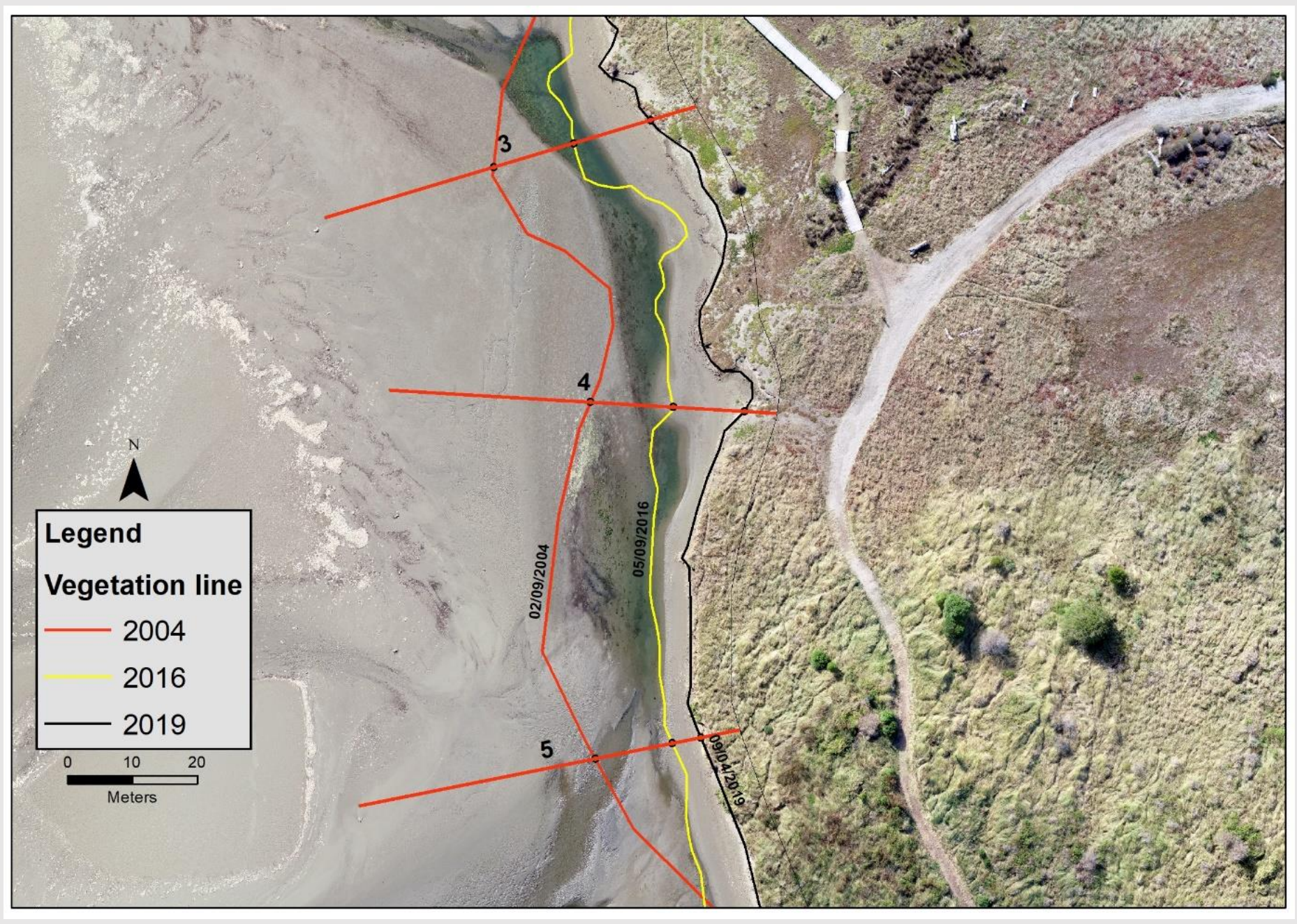

Figure 10 : Illustrates the transects 3,4 and 5 inside the estuary is eroding and the erosion rate ranged from -0.22 to -1.53 m/year for the past 15 years. The net shoreline movement is for the 3 transect is from 16 to 25 meters.

Figure 11 : Showing the evidence of coastal erosion (up 1m erosion scarp).

Conclusion

To conclude from the beach profiles, Clifton Beach at the mouth seems nourished, but dunes on the spit side were eroding at a rate of 1-1.5 m/year since 2004. Moncks Bay sandbar has gone down back to a pre-CES level which suggests the estuary is attempting to go back to its natural form. The secondary flood channel has increased in size, which may be changing the end of the spit.

In general, it cannot be concluded that the CES led to increased erosion or flooding as a result of estuary sediment processes. However, CES also did not reverse the long-term trend of erosion. CES caused infill in the estuary, but that seems to be reversing rather than triggering a shift in equilibrium.

Recommendations for Future Research

- Shoreline analysis (DSAS) using historic multi-decadal shoreline (Findlay and Kirk 1988 and Bryan et al. 2008) and predict future changes related to SLR.
- Use of UAV for spatial and temporal coastal observation and environmental monitoring, as well as monitoring erosion and changes in a tidal inlet. (Long et al. and Turner et al., 2016)
- Land building process on the estuary margins especially South shore
- Aeolian effects on erosion and deposition
- Growth of estuary vegetation on high-water flats
- Does wind, fetch and waves explain erosion hot spots?
- Successful velocity and wave data collection and modelling (channel and flats)

Acknowledgements

I would like to thank the University of Canterbury Geography technician staff for their time and assistance in successfully carrying out the survey. Thanks to Justin, Tim and Musa for the fieldwork assistance.