Report
on

Bathymetric and Shoreline Change in Endicott Lagoon, Alaska between circa 2010 – 2016

Submitted
to

Ms. Beth Sharp
Wildlife and Habitat Specialist
Hilcorp Alaska, LLC
3800 Centerpoint Drive, Suite 1400
Anchorage, AK 99503

by

Tom Ravens, Caixia Wang, Dana Brunswick, and Todd Burns

College of Engineering
University of Alaska, Anchorage
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Executive Summary

This report quantifies bathymetric change and shoreline change in the circa 2010-2016 time period relative to change in the circa 1990-2010 time period. In the 1990-2010 period, rapid sedimentation (up to 5 cm/year) was observed in the northwest part of the Endicott Lagoon proximal to the causeway (Figure 1a). In the 2010-2016 period, bathymetric data showed a decrease in sedimentation rate in the northwest part of the lagoon proximal to the causeway, and an increase in sedimentation rate (to about 5 cm/yr) in the southeast part of the Lagoon proximal to the causeway (Figure1b).

Quantitative shoreline change observations made in this study at selected areas for Duck Island, Howe Island, and the shoreline proximal to the base of the causeway and the Inner Breach (Figure 2), for the 2009-2014 period, found average erosion rates of 0.05, 0.20, and 0.20 m/s, respectively. Shoreline change rates were spatially variable as the study domain included areas of accretion as well areas with erosion rates of up to 2 m/yr. The erosion observed in the 2009-2014 period was consistent with the erosion observed in the 1990-2010 period.

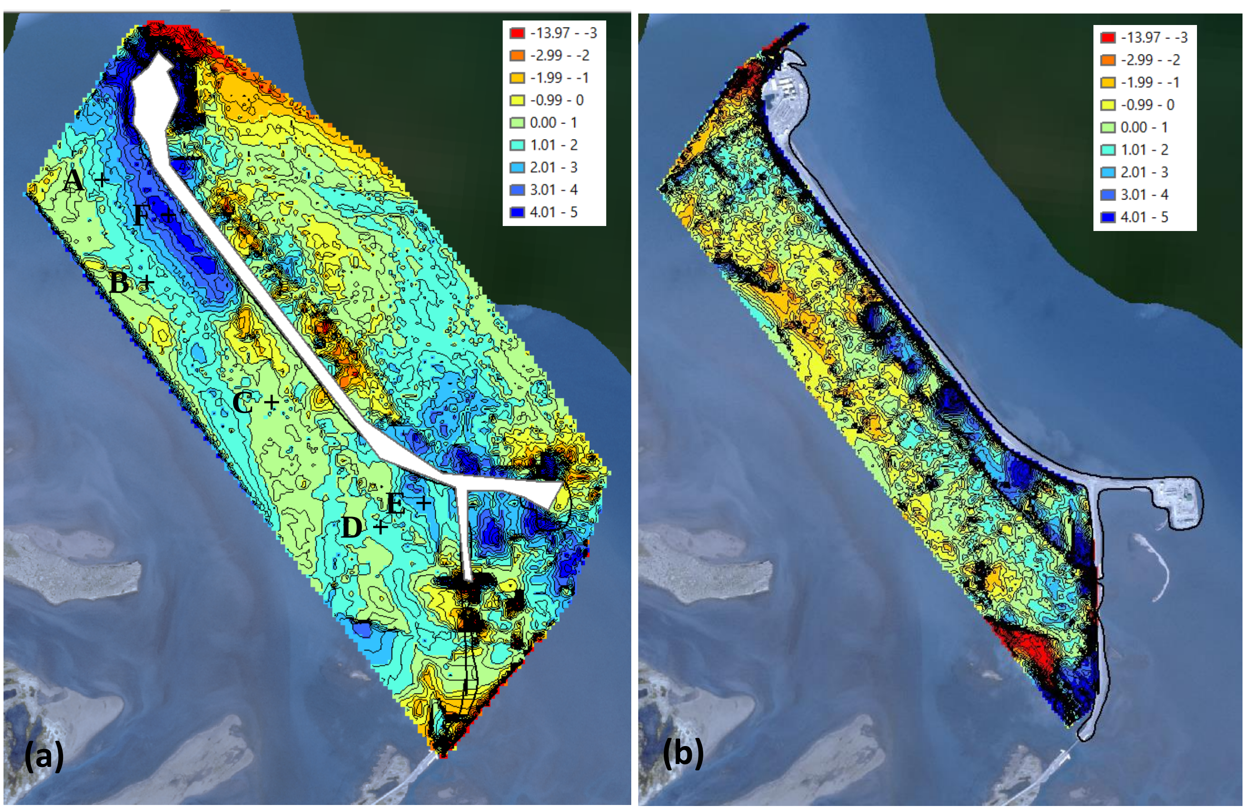


Figure 1. (a) 1989-2010 deposition rate (cm/yr), and (b) 2010-2016 deposition rate (cm/yr).

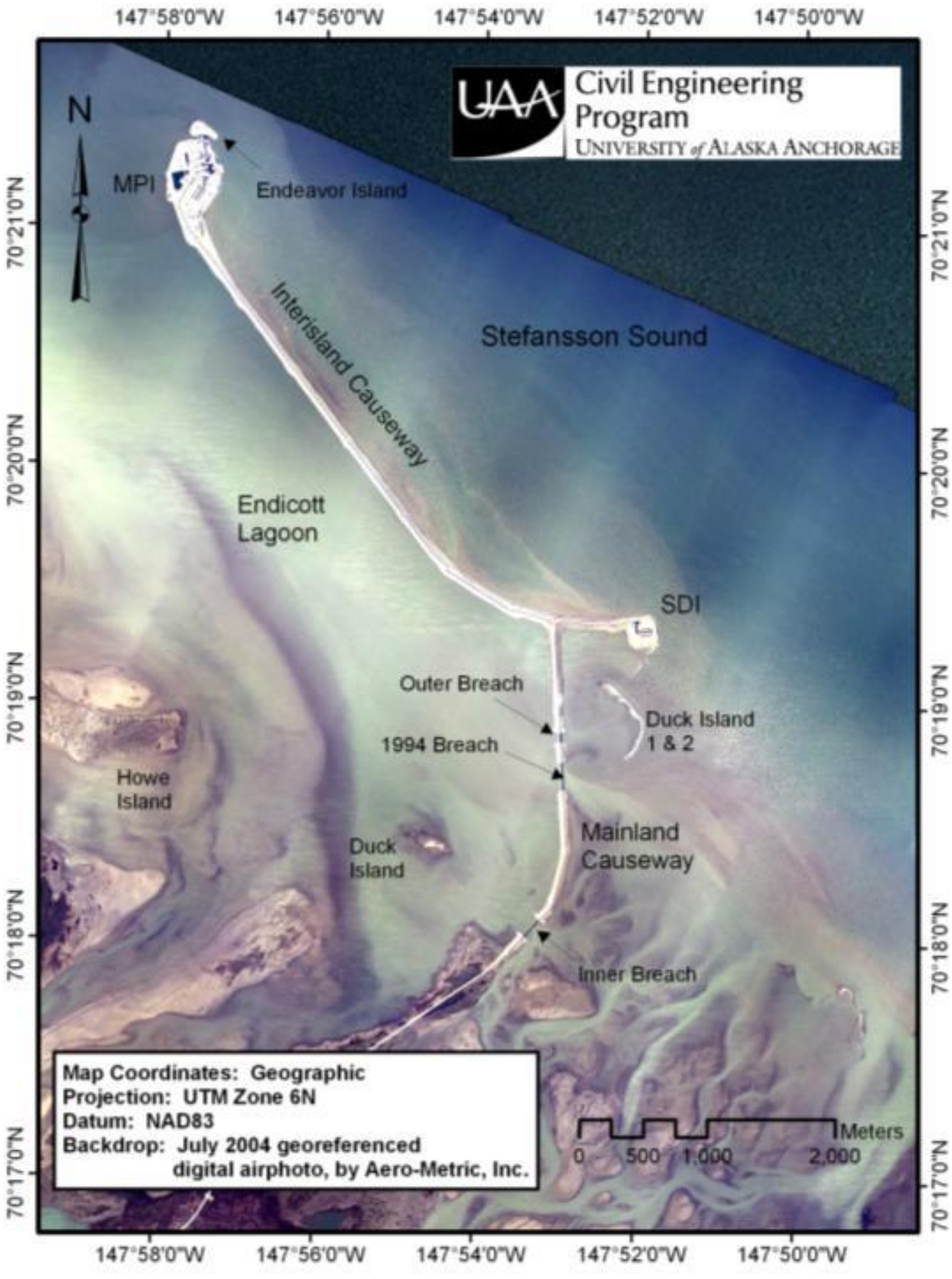


Figure 2. Map of Endicott Lagoon area (from Yager 2011, Figure 1.2).

Introduction

The goal of the present study was to determine to what extent the sedimentation and erosion, evident in the Endicott Lagoon area prior to 2010, continued into the current decade. The survey and analysis is required by North Slope Borough Ordinance 19.70.050 which states that a Bathymetry and Coastline Geomorphology Study of the Endicott Lagoon will be conducted every 5 years.

Background

The Endicott Lagoon area on the North Coast of Alaska (Figure 2) experienced significant bathymetric and shoreline change in the circa 1989-2010 period as documented in the Masters Thesis by Garrett Yager (2011) and in a report by Andrew Balser (2010). Figure 3 (below) depicts the rate of bathymetric change between 1989 and 2010 based on bathymetry measurements (Yager 2011). Yager (2011) determined that the construction of the Endicott Causeway in 1986 created a relatively quiescent hydrodynamic environment in the northwest section of the Endicott Lagoon (just south of MPI, Figure 2), and that the high sedimentation rates in this area (and in the Lagoon, generally, Figure 2) occurred in response to the reduced hydrodynamic intensity.

Balser (2010) assessed shoreline change in the Endicott Lagoon area based on aerial photos from 1949, 1979, 1998, 2004, and 2008. Balser found no area-wide pattern of erosion between 1949 and 2008. However, there were three specific locations where erosion was noted: (1) the base of the Endicott Causeway at the Inner Breach (Figure 2) where up to 250 ft of erosion was observed following causeway construction in 1987, (2) the eastern tip of Howe Island (Figure 2) where there was about 50 ft of erosion between 1998 and 2004, and (3) Duck Island (west of the causeway) where significant progressive erosion was observed between 1979 and 2008 (Figures 2 and 4).

The goal of the present study was to determine to what extent the sedimentation and erosion, evident in the Endicott Lagoon area prior to 2010, continued into the current decade.

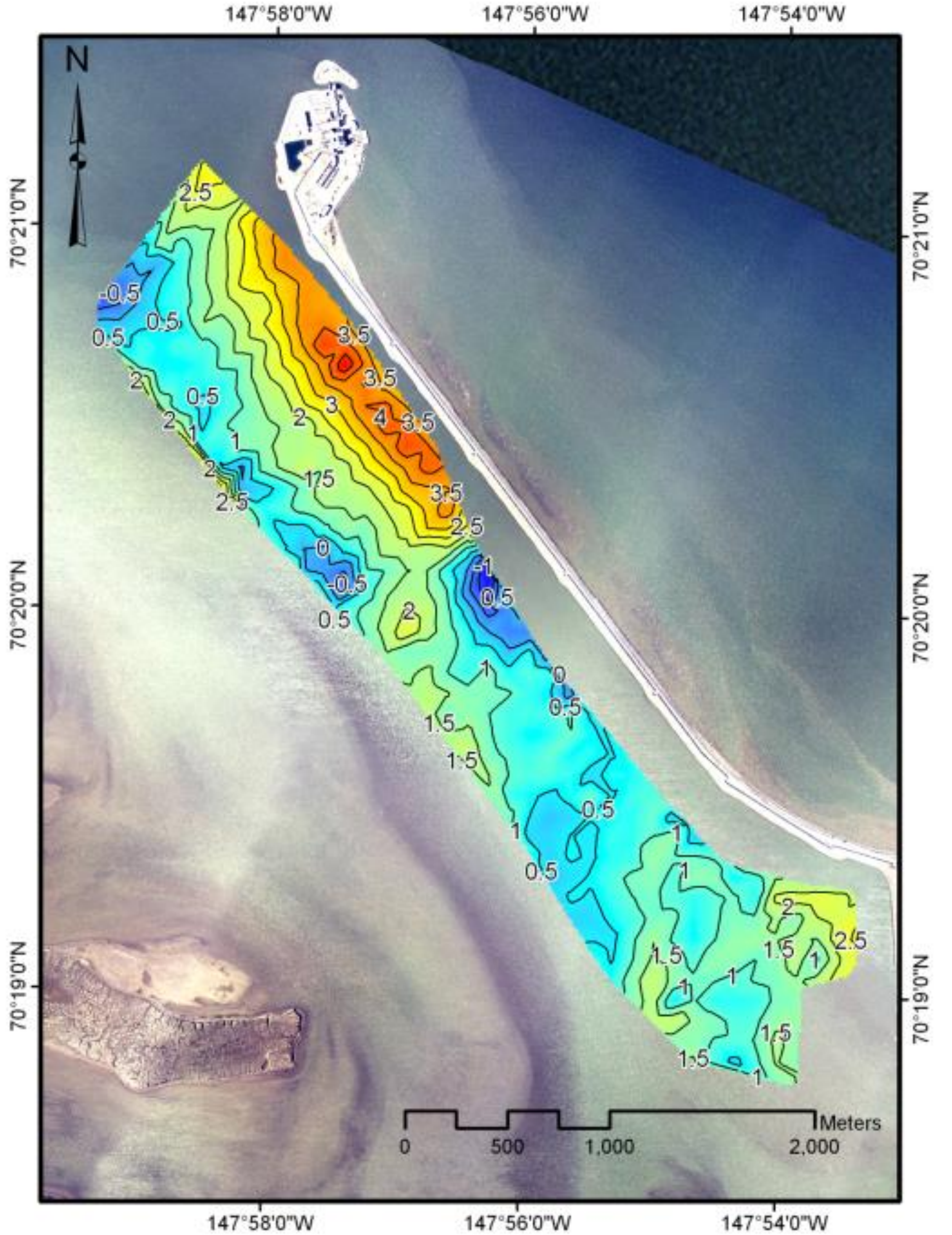


Figure 3. Measured rate of bathymetric change (cm/s) in the Endicott Lagoon between 1989 and 2010 (Yager, 2011, Figure 9.36).

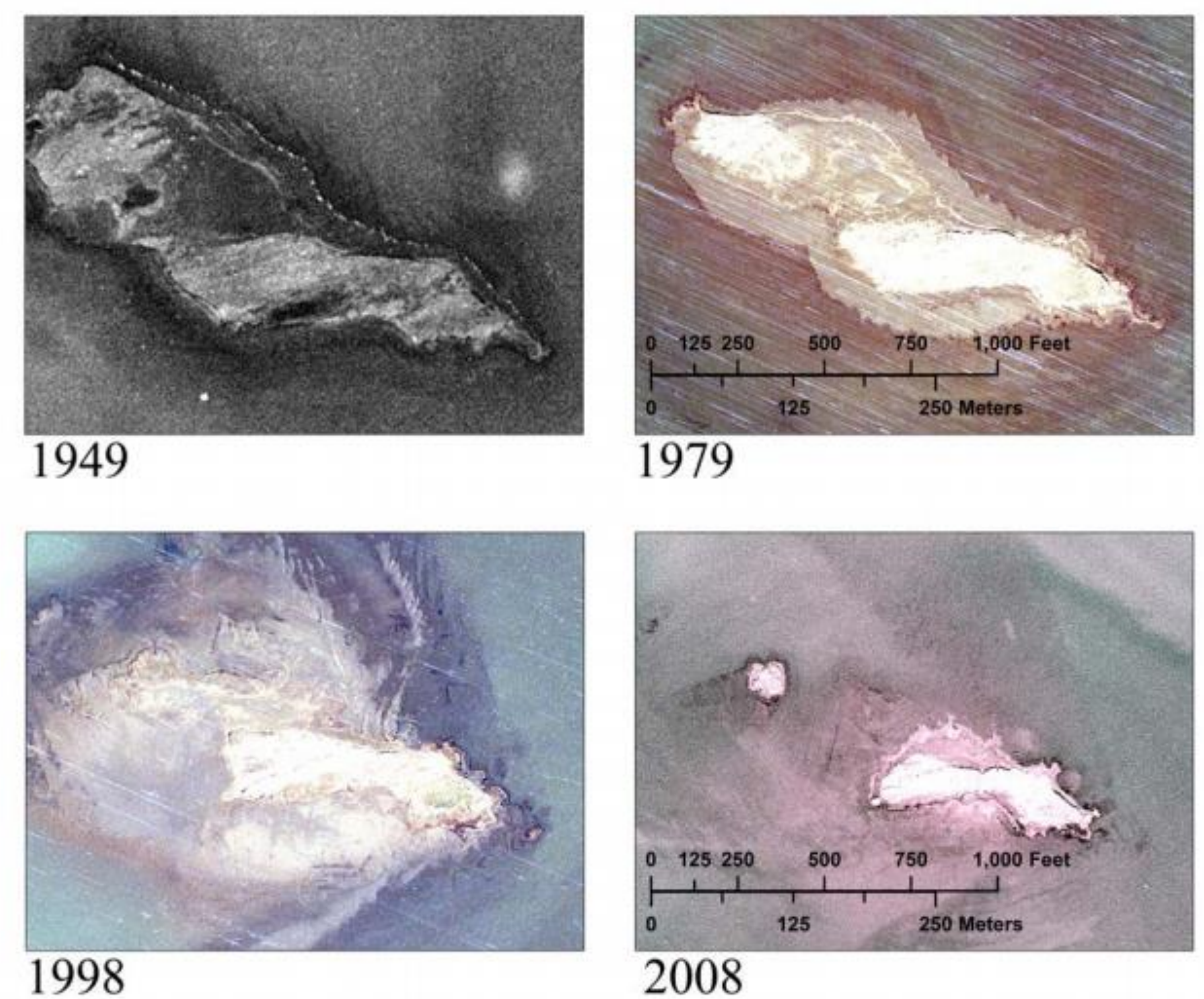


Figure 4. Aerial photos of Duck Island in 1949, 1979, 1998, and 2008 showing the progressive erosion of the island (from Balser 2010).

Methodology

Data used for bathymetric and shoreline change analysis is summarized in Table 1 below.

Table 1. Availability of bathymetric data for Lagoon bathymetry analysis and aerial photography for shoreline change analysis.

Year	Lagoon bathymetry data available	Aerial photograph available
1949	-	✓
1979	-	✓
1989	✓	-
1998	-	✓
2004	-	✓

2008	-	✓
2009	-	✓
2010	✓	✓
2014	-	✓
2016	✓	-

Bathymetric change

In order to determine bathymetric change in the circa 2010 – 2016 time period, relative to changes in the previous time period (1989-2010), bathymetric data was collected in the Endicott Lagoon area by Coastal Frontiers during the summer of 2016 along transects previously surveyed in circa 1989 (Figure 5). The bathymetric data collected by Coastal Frontiers was provided to the University of Alaska Anchorage (UAA) in the fall of 2016. Bathymetric data along selected transects from circa 1989, 2010, and 2016 were analyzed in order to determine bathymetric change rate in the most recent period (2010 - 2016) relative to change in the previous period (1989-2010).

In addition, in order to develop contours indicating sediment deposition/erosion rates in the 1989-2010 period and in the 2010-2016 period throughout the lagoon, data from the bathymetric surveys were used to create a Triangulated Irregular Network (TIN) and raster surface for each of the three times. The raster surfaces were used to calculate the change in bathymetry between surveys and the rate of bathymetric change.

Shoreline change analysis

In order to determine shoreline change in the study area circa 2010 - 2016, georeferenced aerial photos were obtained and shoreline positions were extracted. Following the work of Balser (2010), our work focused on Duck Island, Howe Island, and the shoreline proximal to the base of the causeway. A georeferenced photo from 2016 was not readily available so we did the analysis based on 2009, 2010, and 2014 photos. In order to do the shoreline change analysis, it was important to choose a feature for delineation of the shoreline position. Intensive visual examination of the photographs led us to use bluff top edge as shoreline indicator because 1) it is relatively distinct and could be identified within all of the photos; 2) its position is not influenced by water level in time at which the photographs were acquired; 3) it is constantly reshaped by hydrologic processes. To generate shorelines in the three focused study areas from aerial photos (2009, 2010 and 2014), the shoreline reference features (i.e. the top edge of bluffs) for each photo were digitized in ArcGIS 10.3 at a scale of 1:1000. All shoreline vectors were in transverse Mercator projection for their State Plane Coordinate System (SPCS) Alaska zone 4 on the North American Datum of 1983 (NAD 83). To make sure consistent shorelines across three photos for analysis, only bluff edges which can be interpreted from all three photos were delineated and analyzed.. Shoreline analysis was performed using Digital Shoreline Analysis System (DSAS)

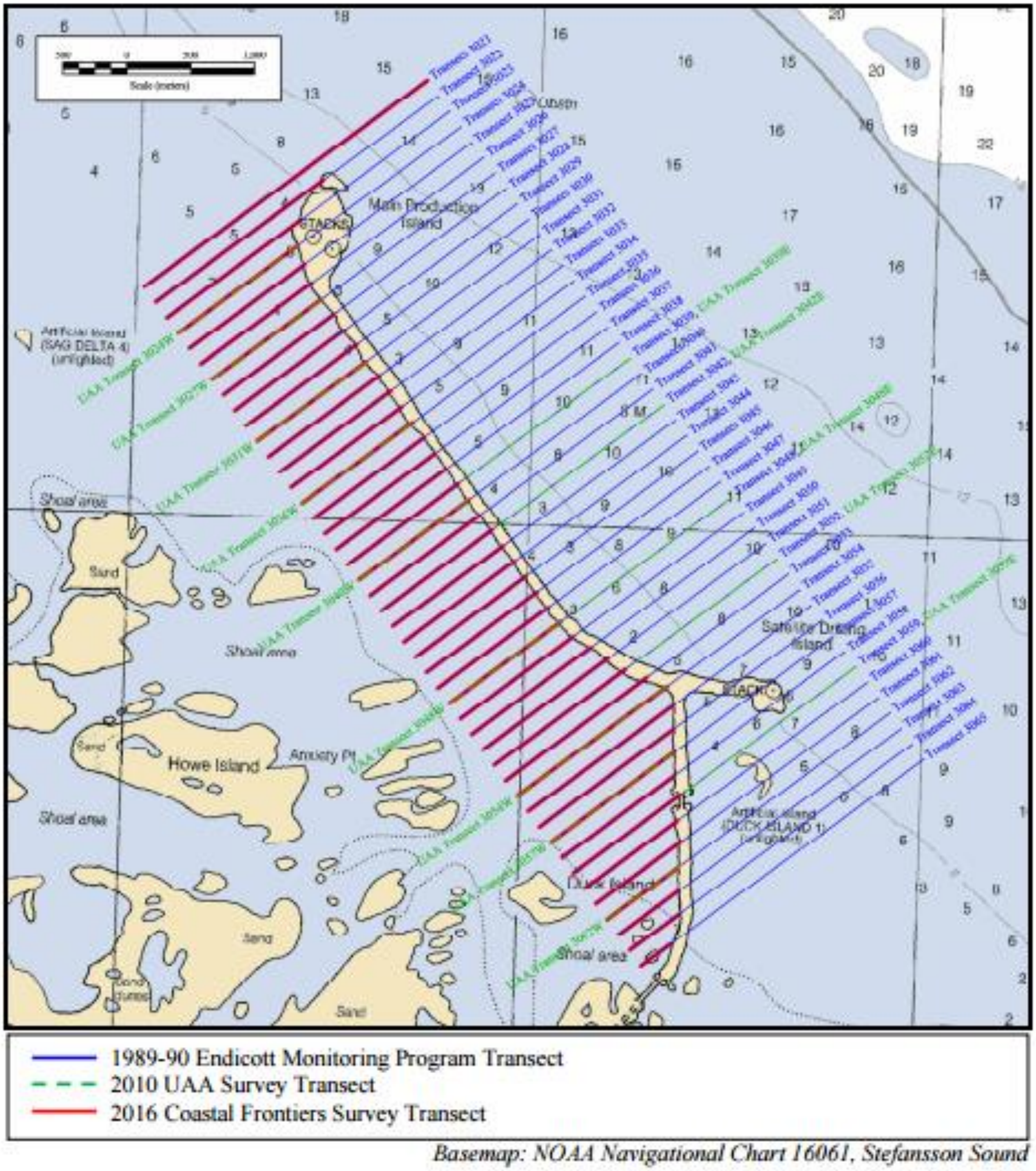


Figure 5. Map of Endicott Lagoon showing transect locations for bathymetric measurement in 1989-1990, 2010, and 2016. Note, the map used in this figure shows the Inner Breach and the Outer Breach, but it does not show the 1994 Breach (Figure 2).

(Thieler, et. al., 2009). It is the predominant analytical tool used to calculate shoreline changes and is run as an extension within ArcGIS. To analyze changes, a number of transects were cast perpendicularly from a user-created baseline. DSAS records the position of the intersection between the transect and each shoreline (Fig. 6). An ordinary linear regression is applied to fit to all shoreline positions at each transect to calculate a rate of change. The linear regression rate is reported as the rate of shoreline change (in distance/year) in our results. Transects were cast at a one meter interval along the baseline. When calculating regression based shoreline change rates, a confidence interval of 2σ (95.5%) was used.

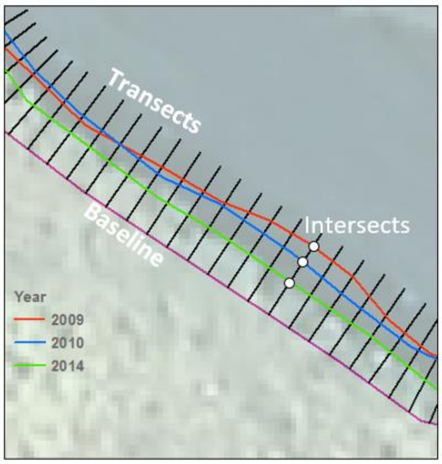


Figure 6. Example of the employment of the Digital Shoreline Analysis System (DSAS) to perform change analysis at Duck Island.

Results and Conclusions

Bathymetric change

Figure 7 provides example bottom profile data for transect 3024 for three times: 1989, 2010, and 2016. Appendix A provides similar profile data for transects 3027, 3031, 3035, 3040, 3048, 3054, 3057, and 3062. Based on this profile data, the average bottom elevation change between 1989 and 2010 and between 2010 and 2016 for each transect – as well as the corresponding average annual rate of change for the transects - are provided in Table 1 (below). Figure 8 (below) depicts the variation in accretion rate in the Endicott Lagoon visually both in space in time. It shows a general reduction in accretion rate in the northwest part of the Lagoon in the 2010-2016 period relative to the 1989-2010 period. It shows a general increase in accretion rate in the southeast section of the Lagoon in the 2010-2016 period relative to that in the 1989-2010 period.

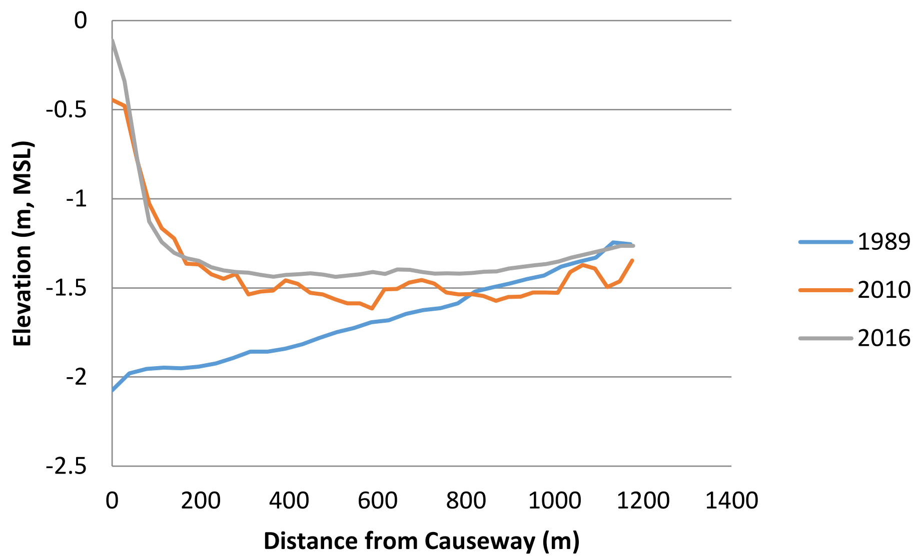


Figure 7. Bottom profiles from transect 3024 from 1989, 2010, and 2016.

Table 1. Average bottom elevation change between 1989 and 2010 and between 2010 and 2016 for each transect – as well as the corresponding average annual rate of change for the transects.

Transect number	Average bottom elevation change, 1989-2010 [m]	Average bottom elevation change, 2010-2016 [m]	Average rate of bottom elevation change, 1989-2010 [m/yr]	Average rate of bottom elevation change, 2010-2016 [m/yr]
3024	0.29	0.097	0.014	0.016
3027	0.32	0.068	0.015	0.011
3031	0.44	0.022	0.021	0.004
3035	0.32	0.005	0.015	0.0008
3040	0.083	0.062	0.0039	0.010
3048	0.16	0.062	0.0077	0.010
3054	0.30	0.029	0.015	0.005
3057	0.19	0.088	0.009	0.015
3062	0.049	0.089	0.0023	0.015

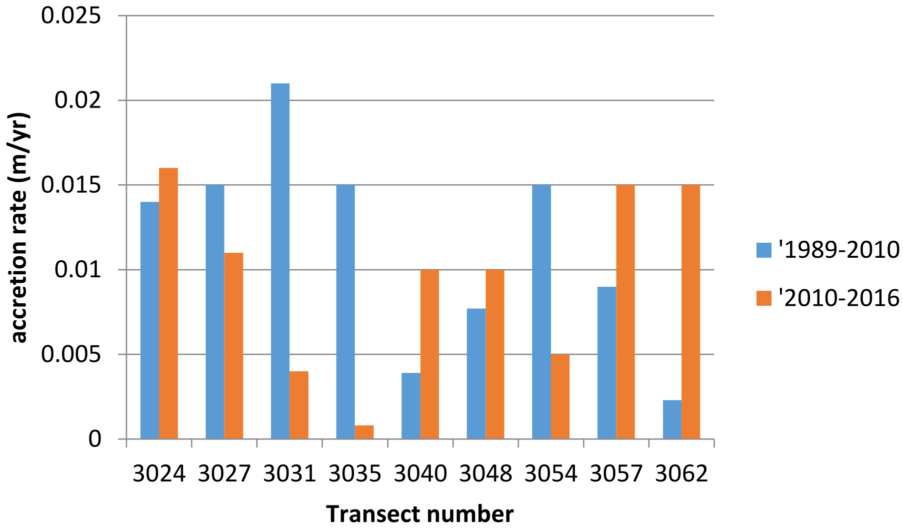


Figure 8. Average accretion rates in the 1989-2010 and 2010-2016 periods in a range of transects ranging from the outer Endicott Lagoon (transect 3024, northwest side of Lagoon) to the inner Endicott Lagoon (transect 3062, southeast side of Lagoon).

The contour plots (Figures 9 and 10) similarly show a reduction in deposition rate in the northwest portion of the lagoon (in 2010-2016, relative to 1989-2010) and an increase in deposition rate in the southeast portion of the lagoon. The contour plot of the 2010-2016 deposition/erosion rate (Figure 10b) also shows relatively rapid erosion west of MPI and in the southern portion of the lagoon area by the breaches (the red areas in Figure 10b). Importantly, the observations of scour by the breaches (evident in Figure 9c) indicates that fish migration through the breaches is not negatively impacted by sedimentary processes in the breaches.

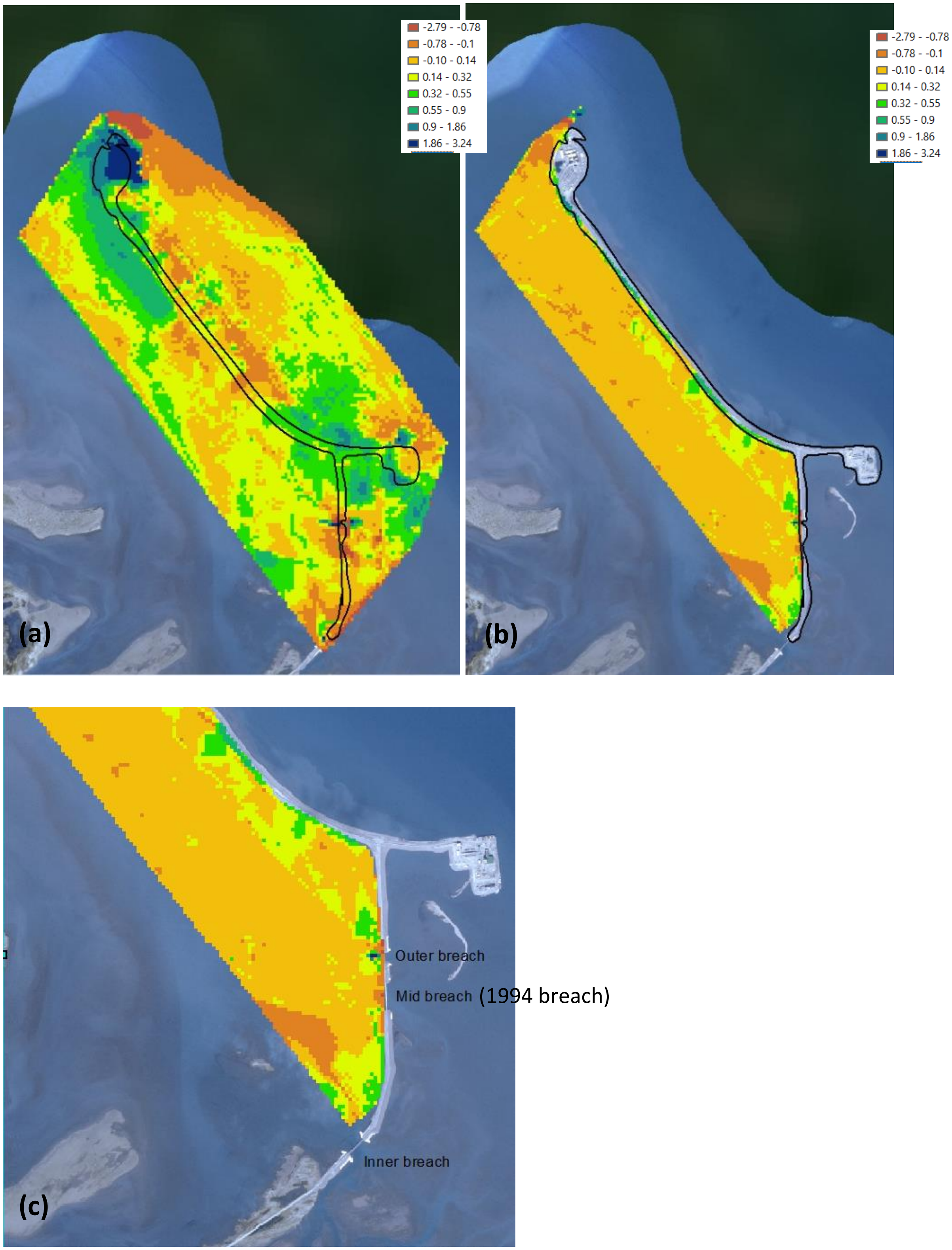


Figure 9. (a) 1989-2010 bathymetric change (m), (b) 2010-2016 bathymetric change (m), and (c) close-up of 2010-2016 bathymetric change proximal to the breaches.

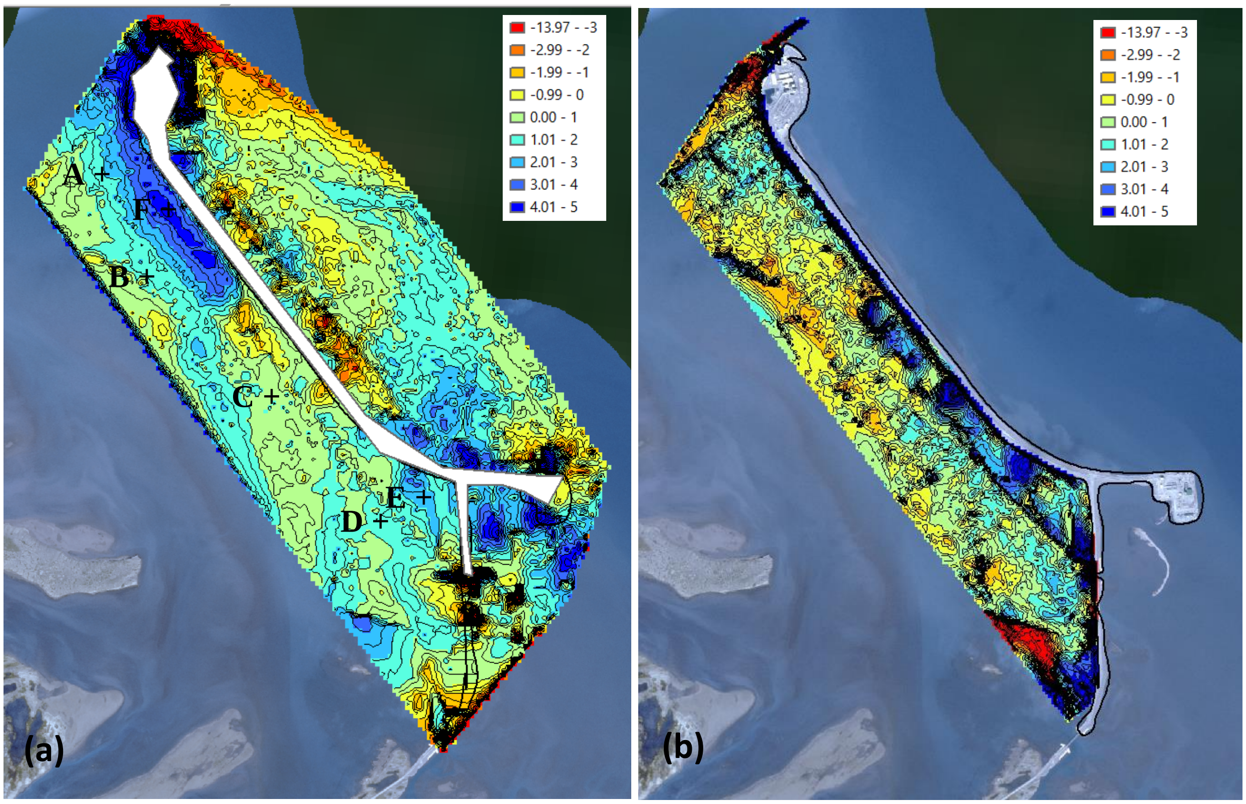


Figure 10. (a) 1989-2010 deposition rate (cm/yr) and (b) 2010-2016 deposition rate (cm/yr).

Shoreline change

For the majority of the three locations (Howe Island, Duck Island, and shoreline by the base of the causeway), the shoreline was digitized from georeferenced aerial photos from 2009, 2010 and 2014. However, portions of the shoreline with indistinct bluff top were not included in the analysis in order to minimize uncertainties associated with interpreting and digitizing remotely sensed imagery.

Figure 11 shows the results of the analysis for Duck Island. Between 2009 and 2014, it was estimated to experience an average erosion rate of 0.05m/year. However, at locations in the eastern and southwestern of the island, the analysis suggests a significant erosion rate of 0.29m/year (outlier in the boxplot graph). Accretion from 0.01 to 0.19 per year was also observed primarily in the northeastern portion of the island.

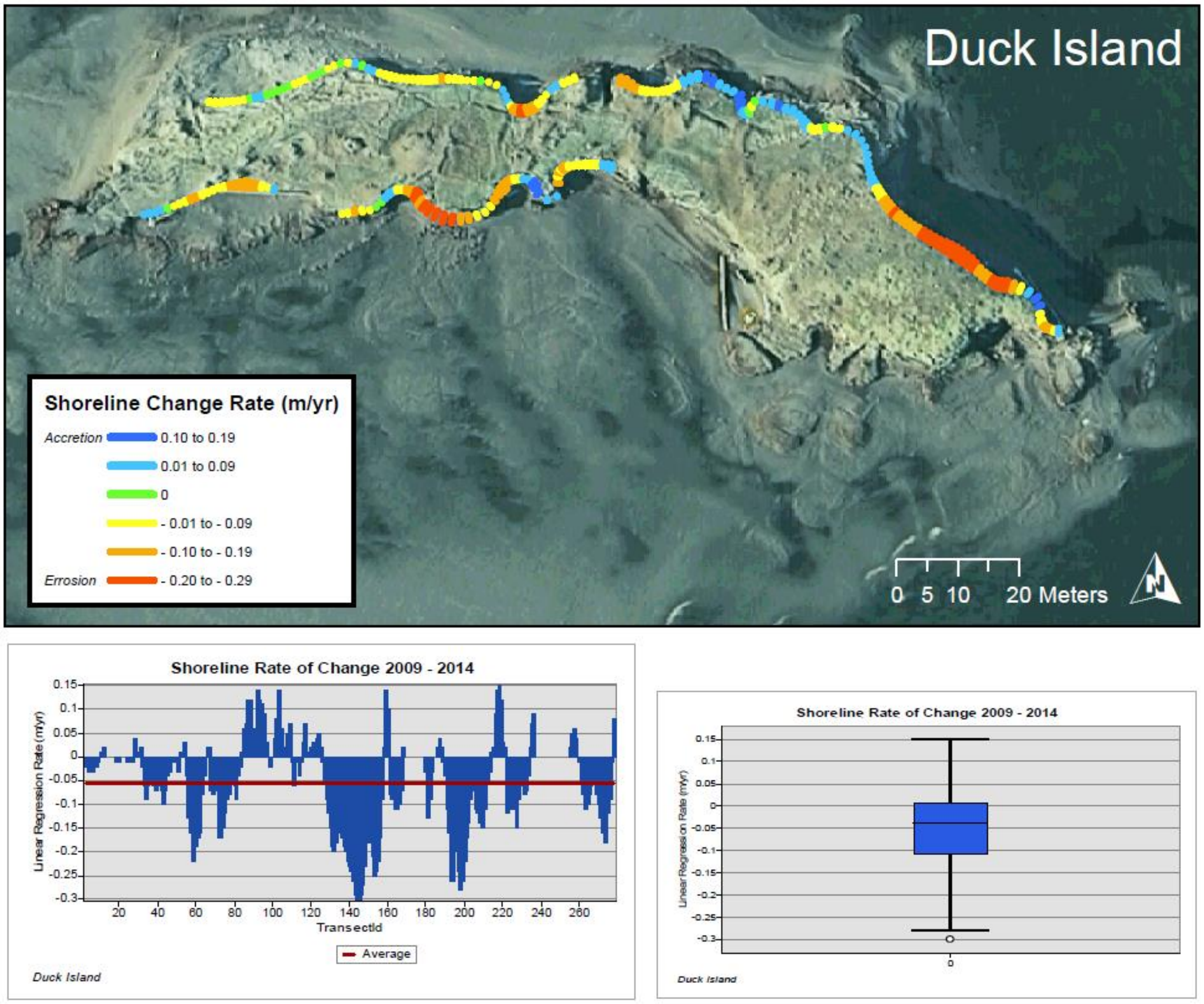


Figure 11. Shoreline change 2009 -2014 for Duck Island.

Howe Island was found to be much more dynamic (Figure 12). Particularly high erosion (1.5 m to 2 m/year) was observed at its eastern and southwestern tips. This indicates that locations found to be highly erosion in the Balser (2010) study, continued to be highly erosional. On average, the erosion rate of Howe Island was about 0.2 m per year in the time period studied. The boxplot graph indicates that the range of erosion rate is more dynamic than that of accretion rate.

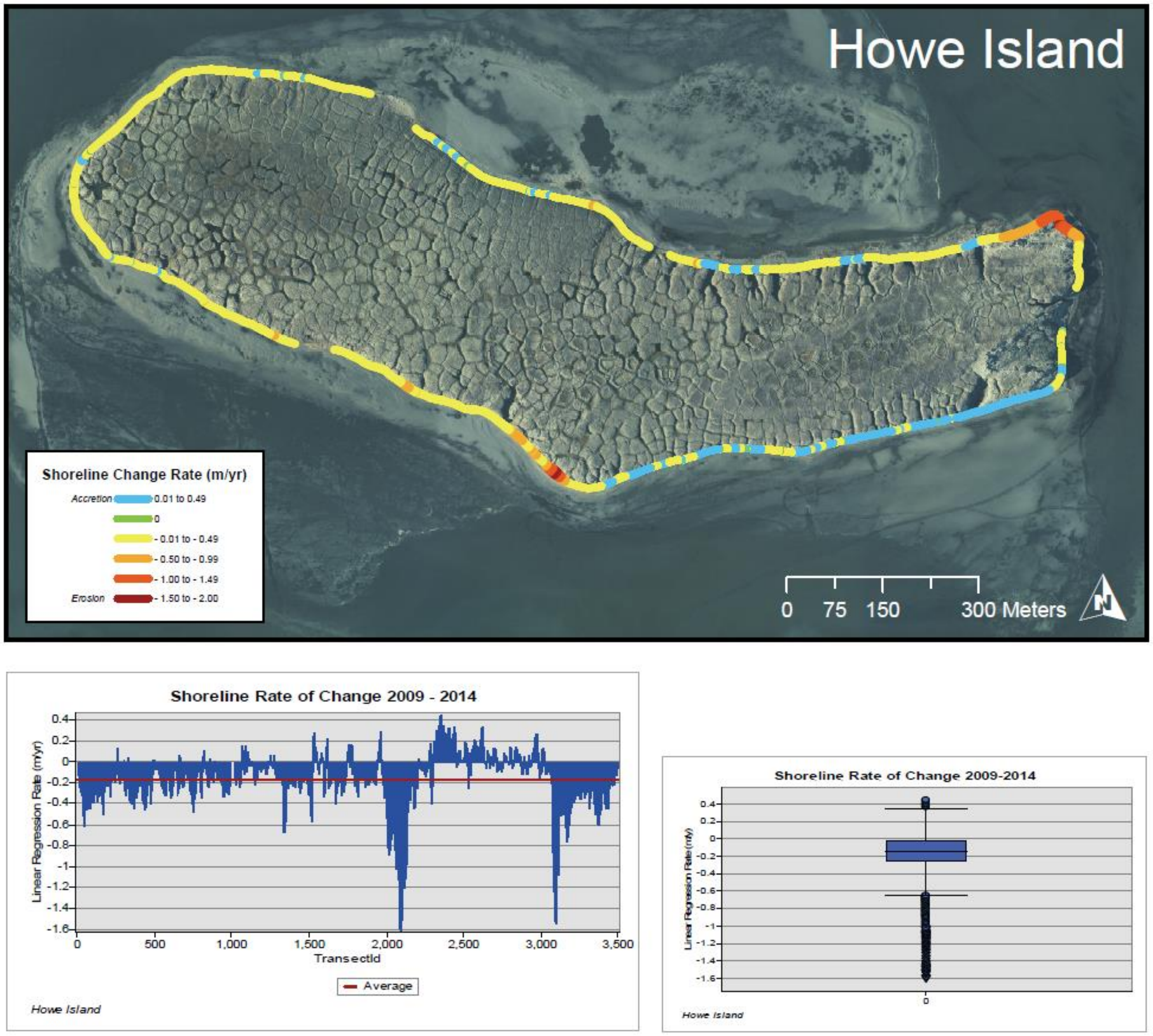


Figure 12. Shoreline change 2009 -2014 for Howe Island.

The shoreline around the base of the Endicott Causeway at Inner Breach was analyzed and summarized in Figure 13. The result shows a more dynamic range of erosion rate with an average rate of 0.2 m per year. The shoreline outside of the lagoon exhibits significant erosion with maximum of 1.49 m per year.

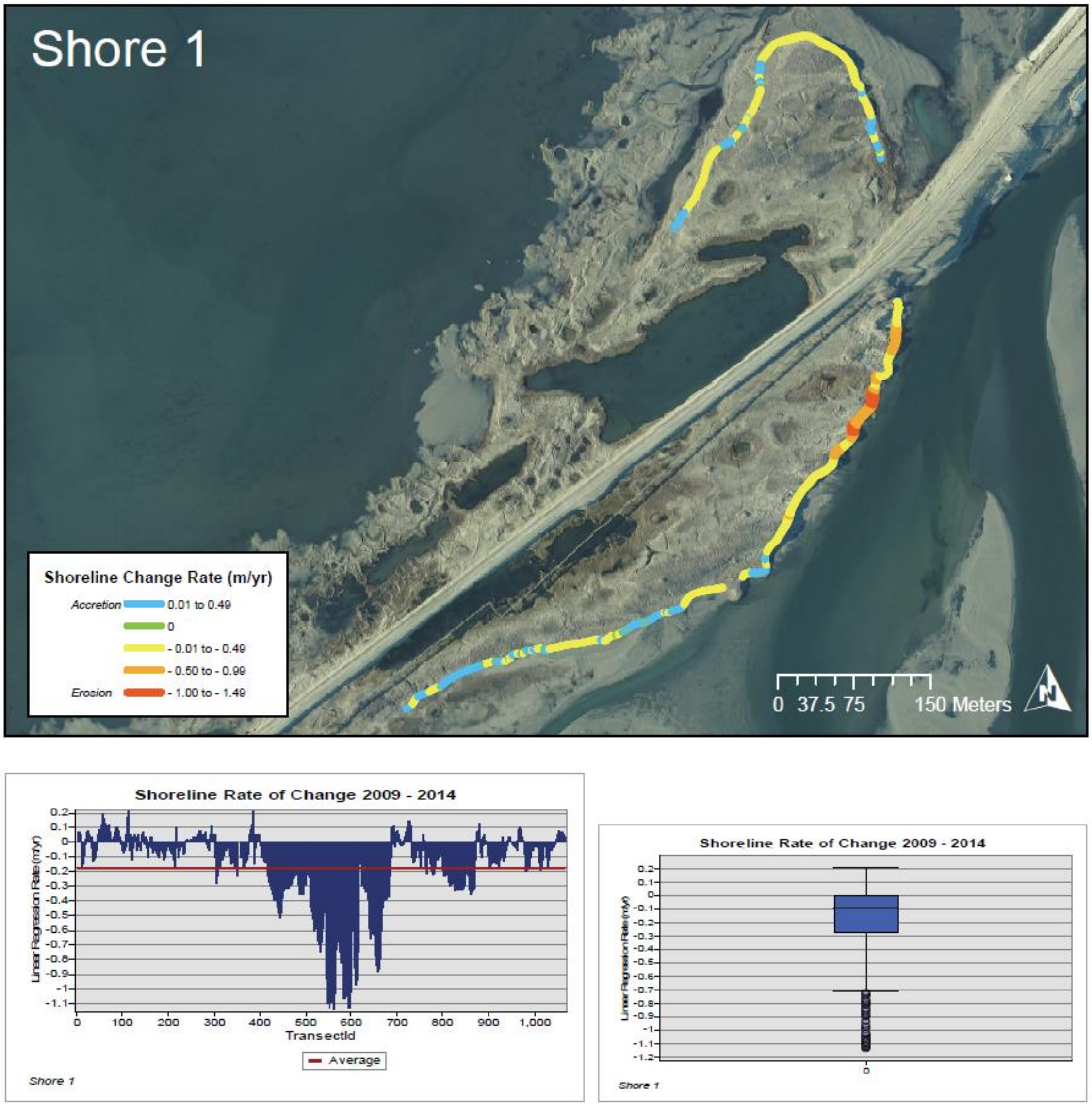
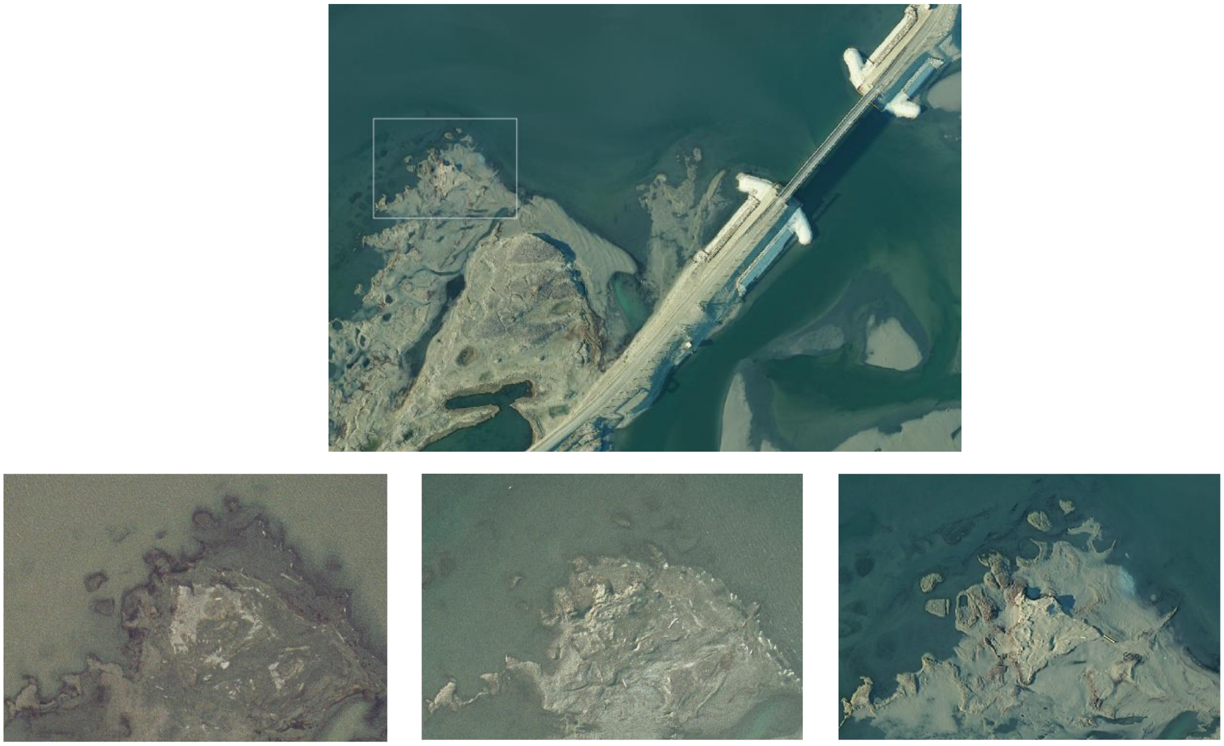


Figure 13. Shoreline change 2009 -2014 for Inner Breach.

The previous study (Balser, 2010) suggested a high degree of erosion on the north and northwest peninsular around the base of the Endicott Causeway at Inner Breach. Visual interpretation of that location in year 2009, 2010 and 2014 (Figure 14) indicates the erosion continues. However, due to limited information for seasonal and tidal fluctuations, it is impractical to derive shorelines for analysis solely depending on the acquired aerial photos. This could be future work when sufficient data becomes available about low or high water level at the time when the photo is acquired.



2009 2010 2014

Figure 14. Example of uncertainty for shoreline interpretation on the north peninsular (marked in white rectangle) due to seasonal and tidal fluctuations when images were taken (year 2009, 2010 and 2014).

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Appendix A. Bottom profile data for selected Endicott Lagoon transects from 1989, 2010, and 2016.

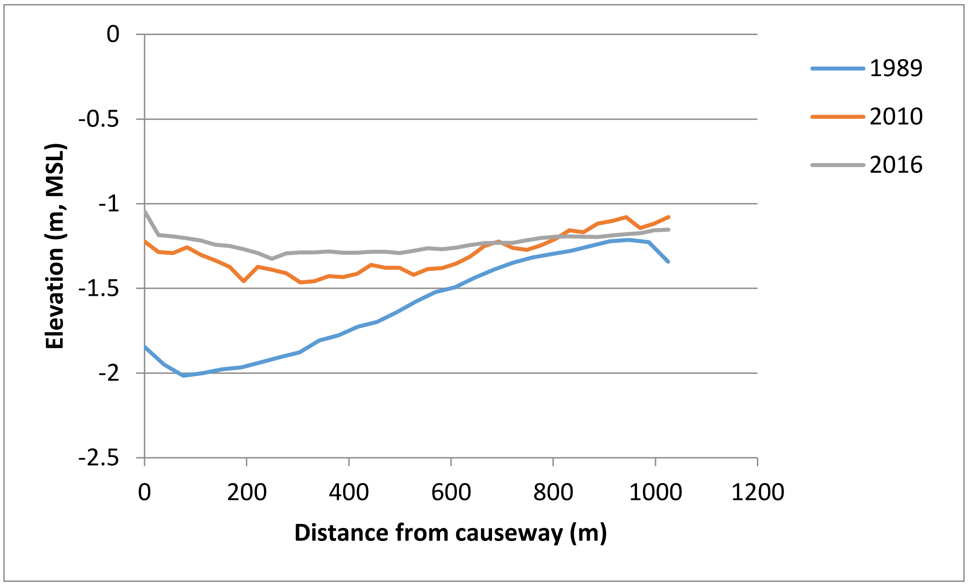

Figure A.1. Bottom profiles from transect 3027 from 1989, 2010, and 2016.

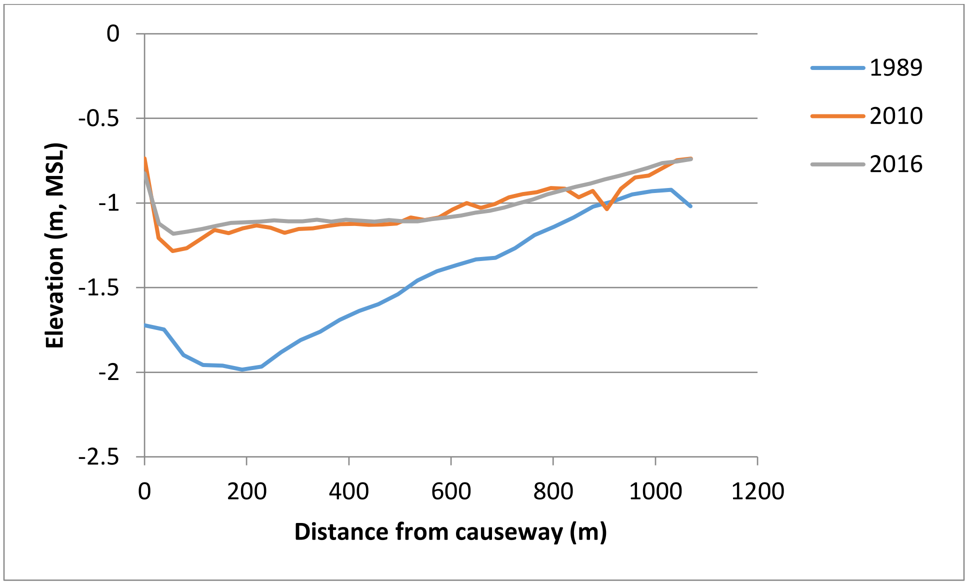

Figure A.2. Bottom profiles from transect 3031 from 1989, 2010, and 2016.

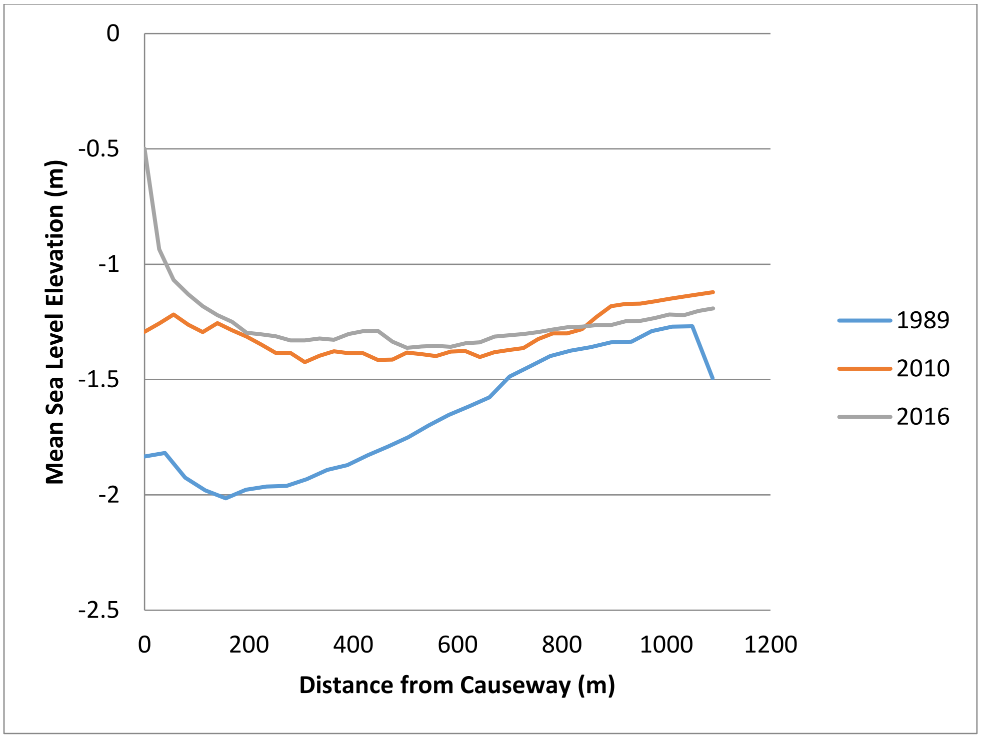

Figure A.3. Bottom profiles from transect 3035 from 1989, 2010, and 2016.

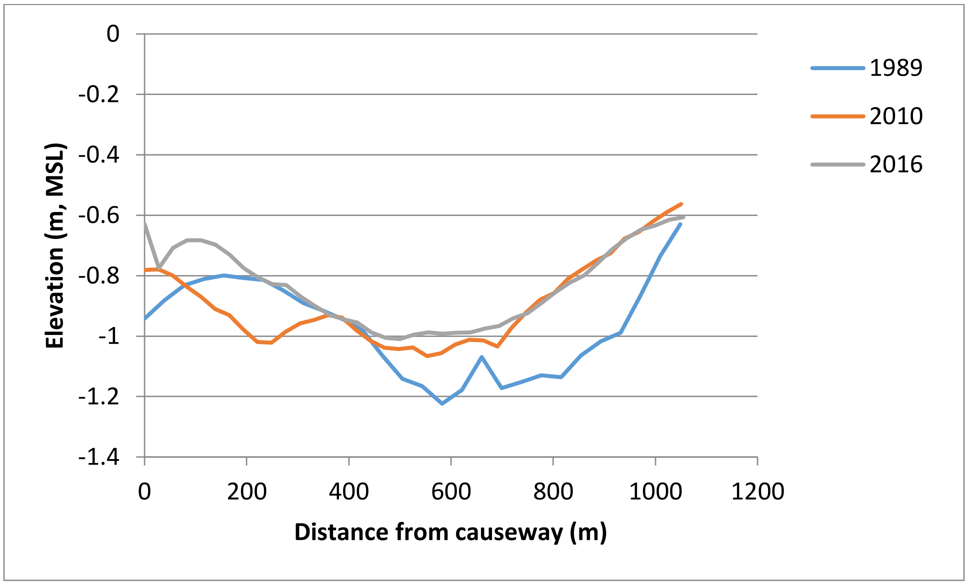

Figure A.4. Bottom profiles from transect 3040 from 1989, 2010, and 2016.

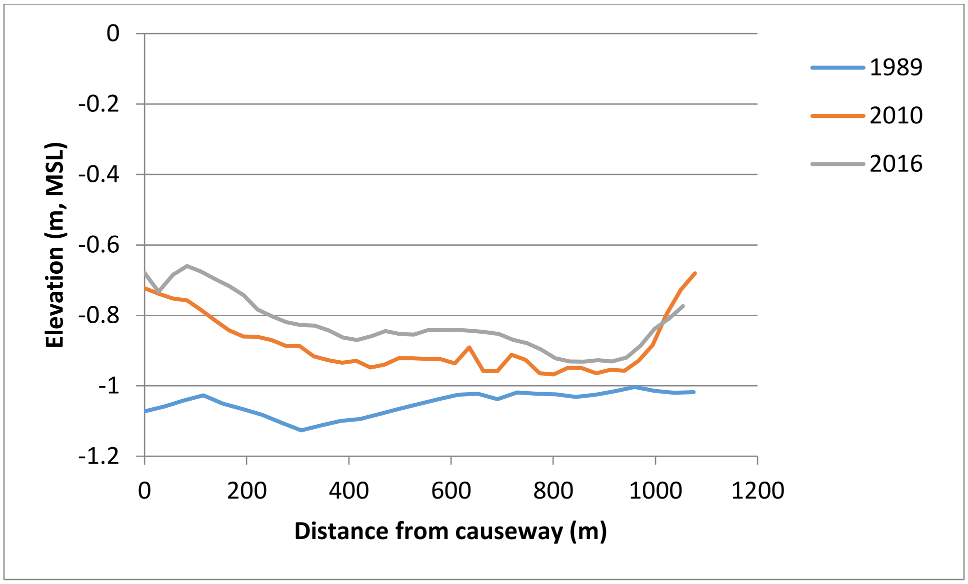

Figure A.5. Bottom profiles from transect 3048 from 1989, 2010, and 2016.

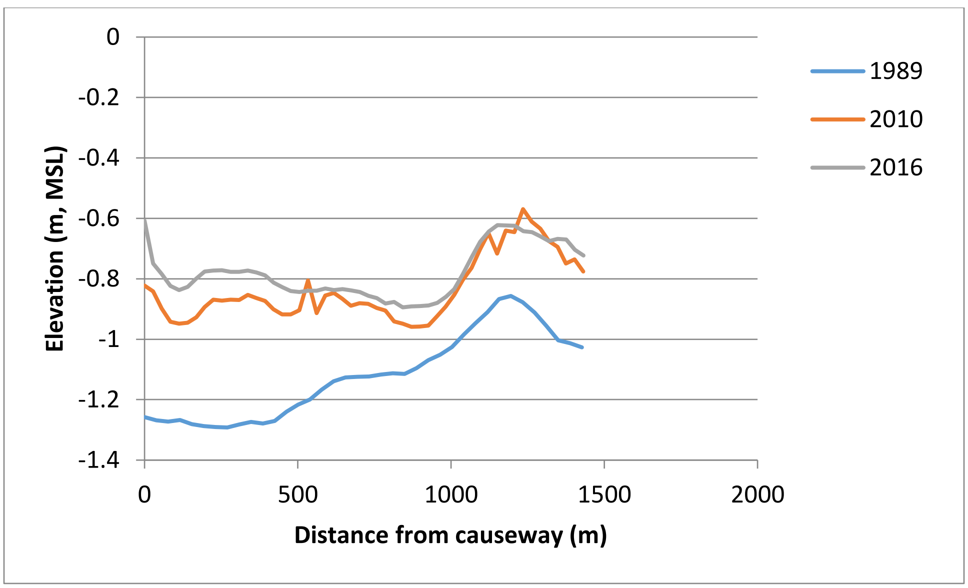

Figure A.6. Bottom profiles from transect 3054 from 1989, 2010, and 2016.

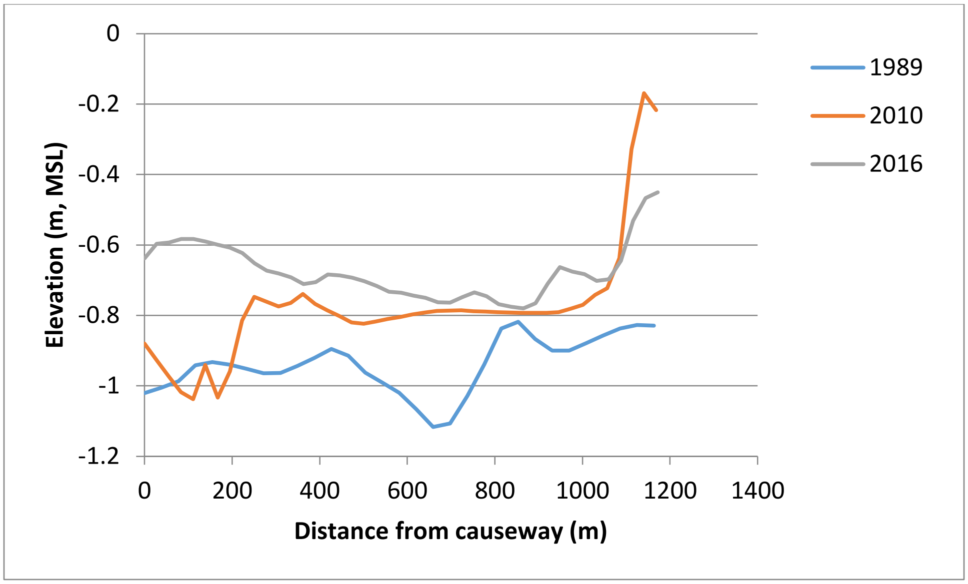

Figure A.7. Bottom profiles from transect 3057 from 1989, 2010, and 2016.

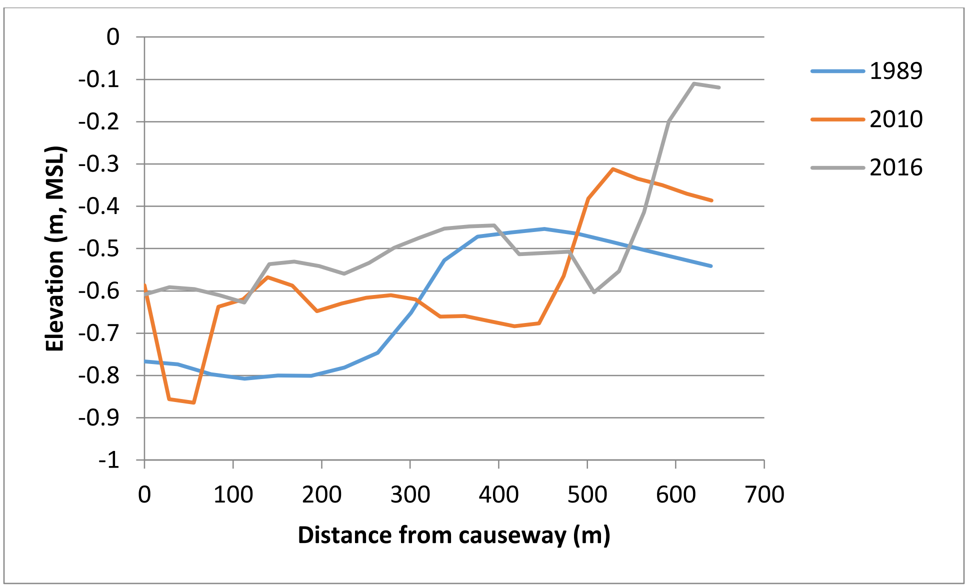

Figure A.8. Bottom profiles from transect 3062 from 1989, 2010, and 2016.