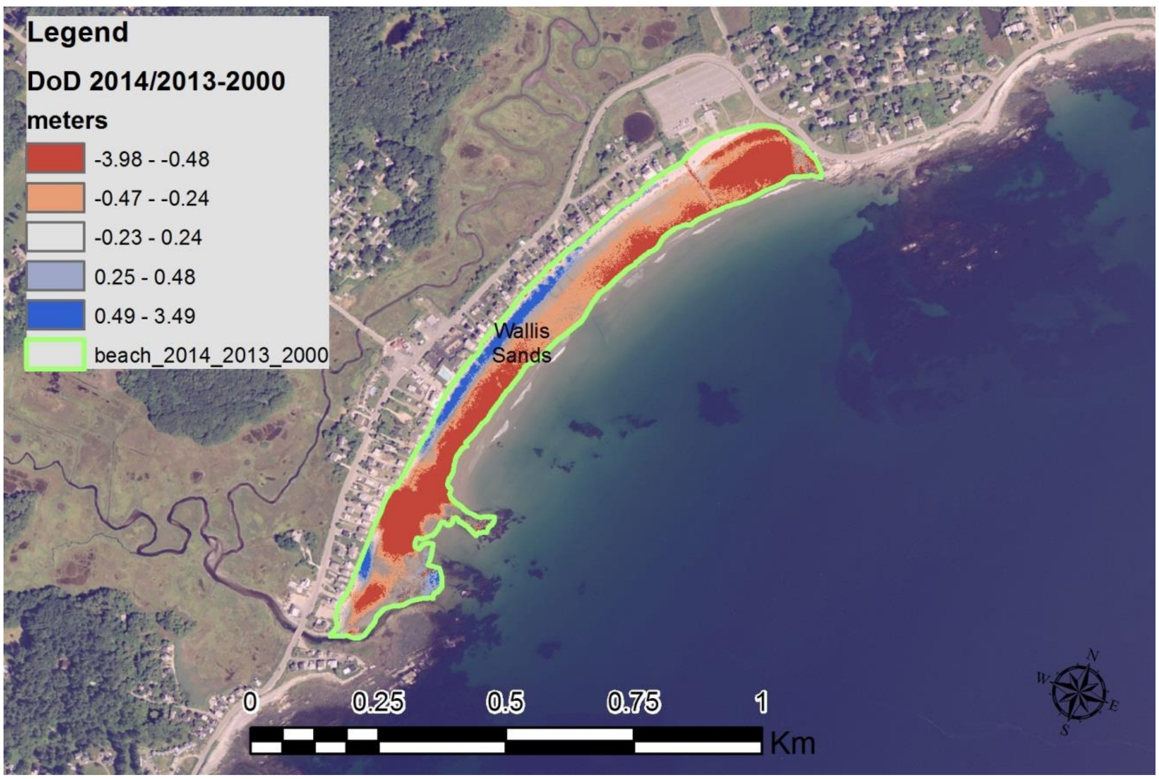
# New Hampshire Beaches: Shoreline Movement and Volumetric Change

2017

BOEM/New Hampshire Cooperative Agreement (Contract M14ACOOO10) Technical Report



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# New Hampshire Beaches:
# Shoreline Movement and Volumetric Change

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## Map Projections

All map data were projected in WGS84 UTM Zone 19N and reference NAVD88 vertical datum

## Recommended Citation

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# New Hampshire Beaches: Shoreline Movement and Volumetric Change

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New Hampshire Geological Survey

## Abstract

In order to assess the stability (landward or seaward migration) of the New Hampshire coastline and assess volumetric changes of the beaches, short-term changes (years) were analyzed using lidar data and long-term trends (decades) were analyzed using shorelines drawn from charts and orthophotography. Multiple vintages of airborne lidar spanning the last decade and a half were analyzed to detect changes in volume of sand and gravel beaches of New Hampshire's coast using a simple DEM of Difference (DoD). Due to its relatively short length, the entire coast was analyzed at a fine (1-2m) spatial resolution. All beaches showed variability in trends, but most had a net loss of sediment. However, the two largest beaches in the state (Hampton Beach and Seabrook Beach) show similar variability to the other beaches, but with more gains than losses. In addition to the volumetric analysis, shorelines were delineated from charts and orthophotography dating back to the mid-1800s and early 1900s. The trend of the shoreline position was determined for shore-perpendicular transects using the Digital Shoreline Analysis System (DSAS). The large southern beaches show net seaward movement (accretion) and the smaller northern beaches show a net shoreward movement (erosion), similar to the pattern seen in the lidar data. By combining the two datasets, long-term and short-term trends of shoreline change and sediment budgets in New Hampshire can be summarized. A break in process seems to occur between the large southern beaches and the generally smaller northern beaches. Such data can provide insights for coastal managers to help focus beach management strategies (e.g., beach nourishment).

## Introduction

Beaches are an important tourist draw for the State of New Hampshire, but little work has been done to quantify the trends of erosion and deposition along those beaches.

Beach managers often engage in extensive beach modification strategies, from dune restoration, to sand nourishment and grading activities, without good background knowledge of the current trends in erosion or accretion. This study aims to provide background information of long-term trends of shoreline position (erosion or accretion) and volumetric changes along the New Hampshire Atlantic coast. New Hampshire has the shortest coastline in the United States at roughly 18 miles (Figure 1). This relatively short coastline allows for detailed spatial analysis that should prove useful to land managers.

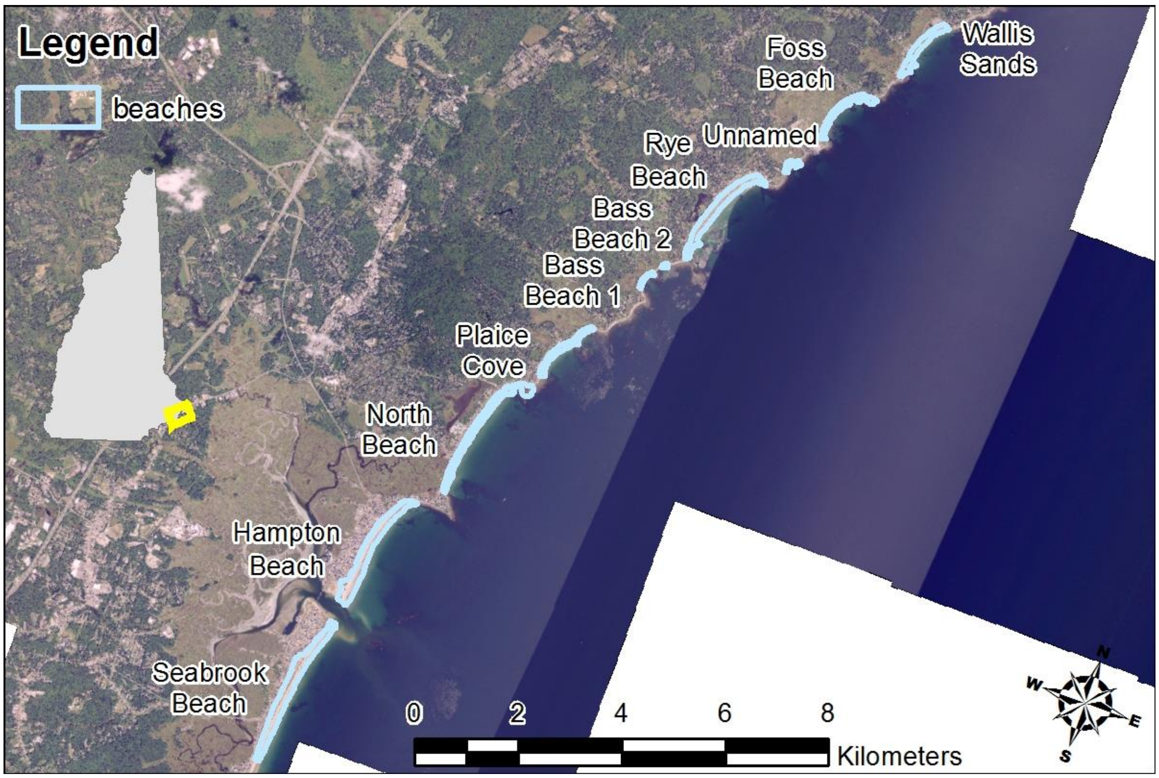


Figure 1. Location map. The beaches from south to north are Seabrook, Hampton, North, Plaice Cove (North Hampton), Bass Beach 1 and 2, Rye Beach (Sawyer, Jenness, Cable), Unnamed, Foss Beach (Rye North Beach), and Wallis Sands (Pirate's Cove).

# Methods

## Beach Delineation

Analysis of shorelines using lidar was restricted to sand and gravel beaches facing the Atlantic Ocean from Odiorne Point in the north to Seabrook Beach at the southern end of the New Hampshire coast. Analysis was restricted to beaches so that any observed changes would be limited to actual changes in shoreline configuration and exclude bedrock or other durable areas unlikely to change. Initial classification of beach type was done with a combination of Environmental Sensitivity Index lines (ESI 2004) that were classified as sand or gravel and did not rest on wave cut bedrock platforms. The exclusion of sand and gravel beaches above bedrock platforms was justified due to the lack of potential for observed changes at low water times. Beaches were further refined using high resolution aerial imagery and lidar data. Landward beach extents were generally delineated with high resolution imagery and low water limits were generally delineated using a combination of lidar intensity and vertically exaggerated hillshades of the lidar terrain. Intensity imagery was useful owing to the characteristic of the laser in lidar systems to be absorbed by water. As a result, areas of low intensity are likely to be water. Additionally, the vertically exaggerated terrain helped differentiate the sloping beach surface from the flat water surface. The horizontal extent of beaches was generally drawn from headland-to-headland, depending on the extent of sand and gravel. As a result, in some cases multiple named beaches were joined into a singular evaluation unit (i.e. Wallis Sands and Pirate's Cove), while in one case (Bass Beach) was divided into two beaches because of the presence of a till headland dividing two areas of gravel.

## Lidar

Lidar survey data from 9/2000, 6/2007, 7/2010, 5/2011, 9/2011, 12/2013, and 4/2014 were obtained and projected into UTM zone 19N (Table 1). When applicable, vendor supplied LAS point classifications were used to determine ground/non ground returns. Some datasets were not supplied with classifications, so LAStools (Isenburg 2011) were used to classify ground and non-ground points. Further refinement of ground points was done manually using ArcGIS LAS tool bar (ESRI 2014). DEMs were gridded at 1-2 meters depending on the average point count of ground returns for beaches, as determined using ArcGIS tools. Grids were snapped to a common reference point to ensure alignment. Bare earth DEMs were created using the natural neighbors interpolation method in ArcGIS. The resulting DEMs were subtracted from each other to produce a DEM of Differences (DoD) with the older surface subtracted from the newer surface, such that erosion is represented as negative values and accretion is represented as positive values. These DoDs were clipped to individual beaches and multiplied by 100 and converted to integer values to represent centimeters of change. The VAT of these were then exported as text files in csv format for further analysis.

| **Date** | **Source** | **Cell size** | **Vertical Accuracy** |
|---|---|---|---|
| 9/2000 | NOAA/USGS/NASA | 2m | 20cm |
| 6/2007 | USACE JALBTCX | 1m | 30cm |
| 7/2010 | USACE JALBTCX | 1m | 17.2cm |

| | | | |
|---|---|---|---|
| 5/2011 | USGS | 2m | 15cm |
| 9/2011 | USACE JALBTCX | 1m | 20cm |
| 12/2013 | USGS | 1m | 18.9cm |
| 4/2014 | USGS | 1m | 18.9cm |

Table 1. Information for lidar data sources

## Error Analysis

Two methods were used to quantify the potential for error in the results of the DoD layers. The first and simplest method used the propagated reported error from each dataset. For each dataset, there was a reported root mean square error (RMSE) typically in the range of 15 to 30 cm. The combined errors from the two datasets that went into the DoD were used to define a range of values, known as a Level of Detection (LoD) to exclude values (both positive and negative) that could not be confidently identified as different from zero (i.e., no change) (Wheaton et al. 2010). The LoD was defined as the square root of the sum of the squares of the two surveys. For example, if collection A has an error of 15 cm and collection B has an error of 20cm, the LoD would be $\sigma = \sqrt{(15^2 + 20^2)}$ 25 cm and any DoD result between -25cm and 25cm would be ignored in total volume change estimates. Because all DoD grids were 1m on each side, each cell represents 1 square meter. As a result, the height (in meters) of the DoD cell essentially is a volume of erosion or deposition. This was accomplished by using the count of cells multiplied by the value from the integer csv file and excluding ranges within the DoD range. This was then converted back to meters for summary. The vendor supplied RMSE was used for all calculations, but an additional set of points was drawn along areas that should show no net change from year to year, such as roads, parking lots, seawalls and jetties.

The second method of error analysis followed the methods of Anderson and Pittlick (2014), which essentially involves multiplying the area of analysis by the average error in the survey. This average error value was derived from the above RMSE analysis, in which the average result from all point values was applied as the survey error. The resulting error represents a volume that was both added and subtracted from the raw DoD totals.

A third check on the sum totals of overall volume change for the entire period of record was explored by simply subtracting the oldest (2000) from the newest (2014/2013 depending on beach) lidar collection. While excluding much of the granularity of the stepwise method, this eliminates much of the potential source of error by limiting the number of variables involved. An overview of the comparison of the total volumetric change for the entire time period is shown in Figure 2.

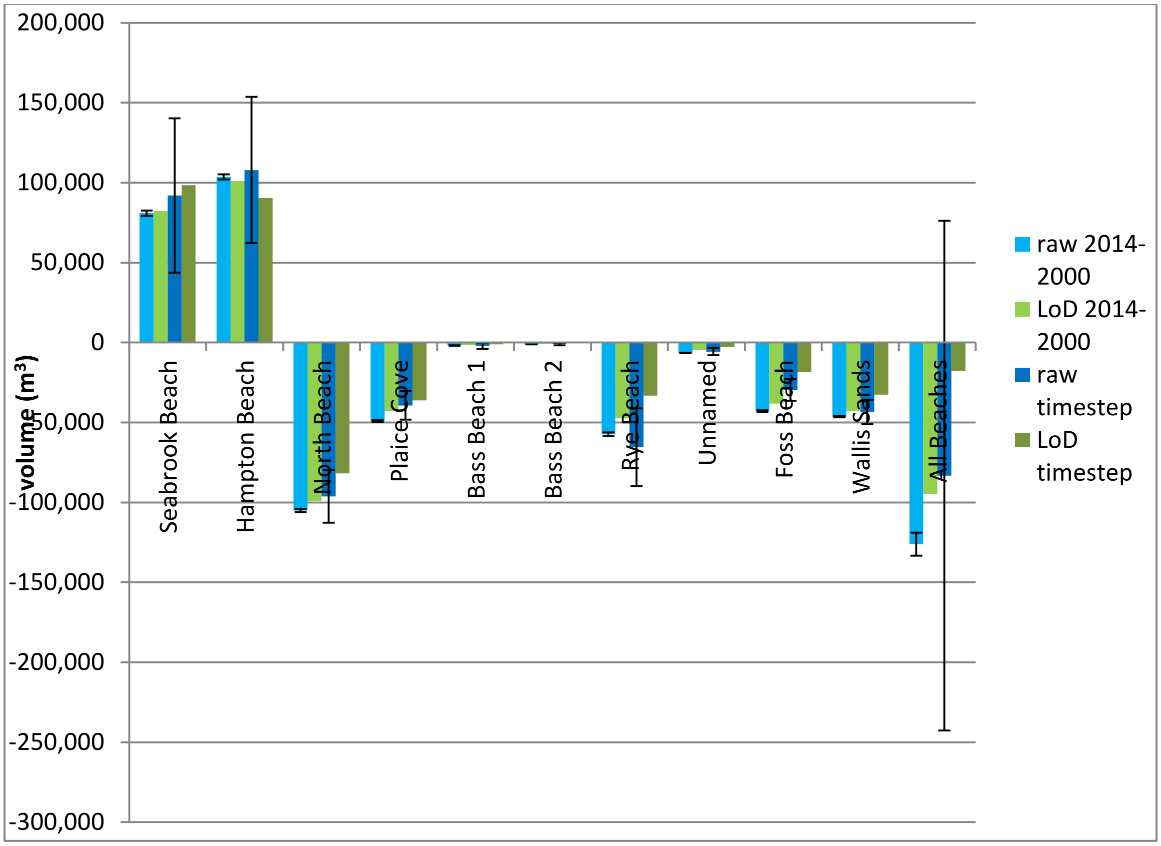


Figure 2. Method comparison showing different ways of quantifying error.

## Shorelines

Shorelines were analyzed using the Digital Shoreline Analysis System (DSAS), an ArcGIS toolbar by the USGS (Thieler et al. 2009). Shorelines were digitized from NOAA charts, USGS maps, aerial photography wet/dry lines, and from the lidar terrain (Figure 3). An offshore shoreline was drawn roughly paralleling the coast 300 m offshore and transects were cast with a spacing of 50 m. Lidar shorelines were derived by comparing the Mean High Water for the Fort Point tidal gage(NOAA Station ID: 8423898) which was converted from the tidal datum to the vertical datum of the lidar data (NAVD 88). This was done for speed and simplicity because of the short shoreline and relatively small level of tidal differences along the study area. For comparison, The 9/2011 lidar dataset was converted using the NOAA VDatum tool, which showed similar results to the above method, with offsets typically less than 0.5m. This small difference was deemed to be small enough to justify the more expedient method. Because of the uncertainty in how the lidar-derived Mean High Water mark compares to the aerial photo derived mean high water mark, the lidar shorelines were treated as a separate dataset and not included in the longer term dataset. The Linear Regression Rate (LRR) was used as the metric for change.

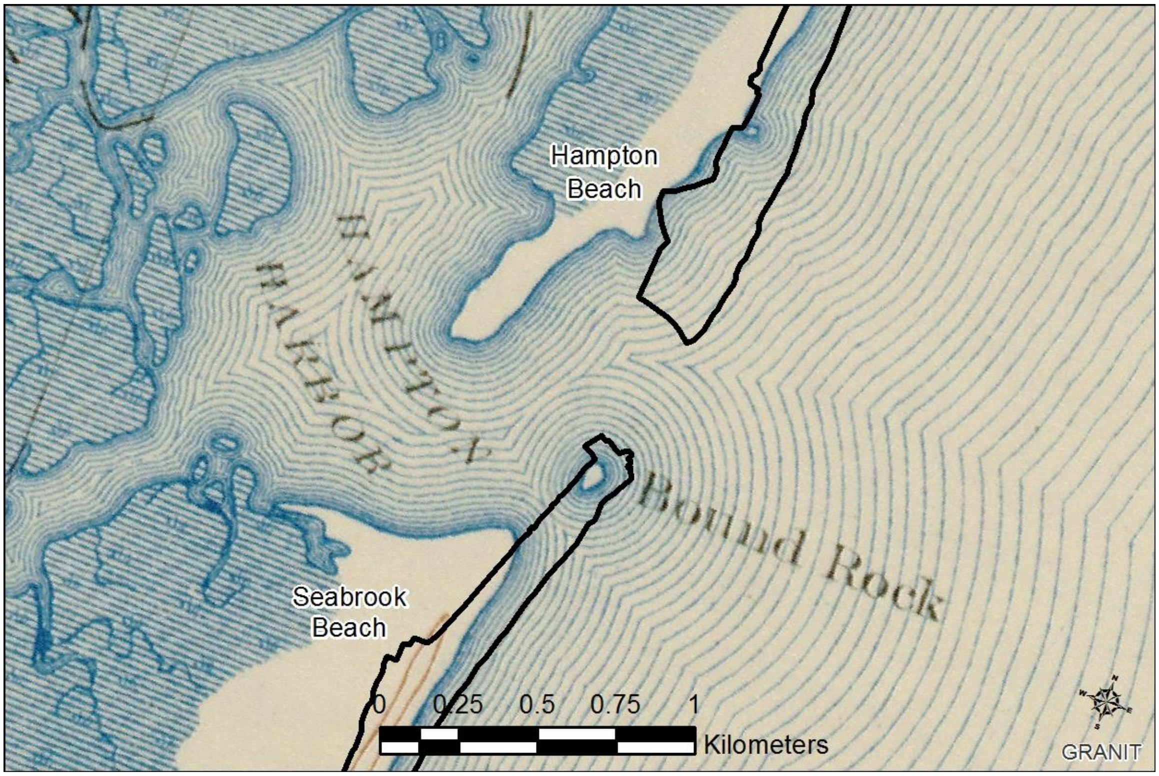


Figure 3. Example of 1894 coastal configuration and modern outlined in black.

## Beach Nourishment

Multiple beach nourishment projects took place during the time period, which could potentially affect both the volumetric lidar analysis and the shoreline position analysis. Because of difficulties in determining exact placement, timing, and volumes of these projects, their effect was ignored, although it should be noted that they may contribute to some underlying difference in the results. A table of the known beach nourishments is below.

| Site | Year | Volume ($yards^3$) |
|---|---|---|
| Wallis Sands | 1963 | 200,000 |
| Wallis Sands | 1972 | 1,0000 |
| Wallis Sands | 1983 | ? |
| Hampton | 1935 | 1,000,000 |
| Hampton | 1955 | 400,000 |
| Hampton | 1965 | 169,000 |
| Hampton | 1972 | 70,000 |
| Hampton | ? | 340,000 |

| | | |
|---|---|---|
| Hampton | 1987 | 21,000 |
| Wallis Sands | 2001 | 40,000 |
| Seabrook | 2005 | ? |
| Seabrook | 2012 | 120,000 |
| Hampton | 2012 | 52,000 |

Table 2. Table showing location, year and volume of beach nourishment projects in NH. Sites shaded grey overlap the lidar period of analysis.

# Results

## Lidar

All beaches showed considerable variability from survey to survey, but only two beaches (Seabrook and Hampton) showed a net gain of volume totaled over all time steps. The remaining 8 beaches showed a net loss of volume summed over the time periods (Figure 4). Because of the large size of the two beaches showing gains, the view of all beaches taken in together is a bit cloudier. If looking at the LoD method of error analysis all beaches summed together showed a net gain. If however looking only at the raw summary of differences, all beaches together show a net loss of volume. Using the area-method of error analysis, there is a rather large error attached to this figure, meaning the beaches could have either gained or lost volume. Comparing this to the first-last method, which showed a net loss in all beaches together, it is likely that there was a net loss of volume.

Figure 5 is an example of the DoD analysis, but the entire spatial analysis for individual beaches are shown in supplemental figure 1 and will be served on the web via New Hampshire’s Coastal Viewer.

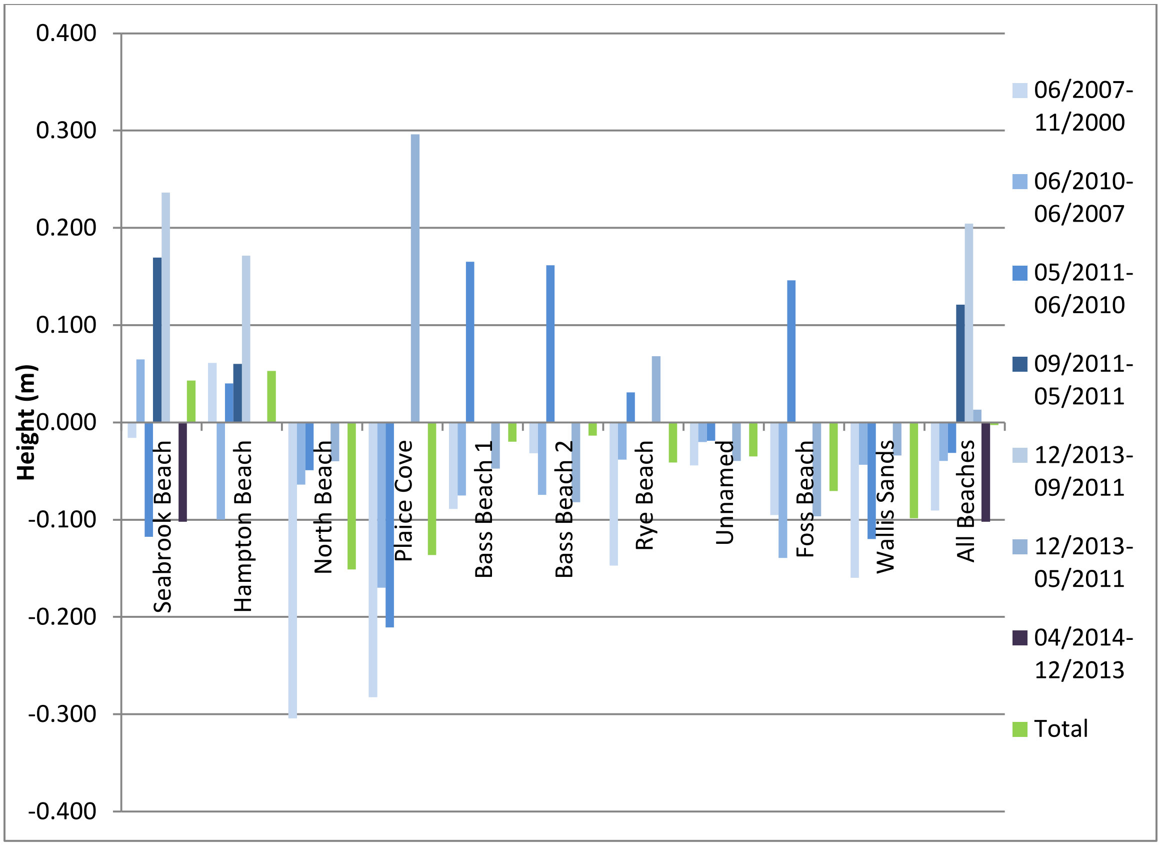


Figure 4. Height changes (volume change/beach area) for each beach and each time step.

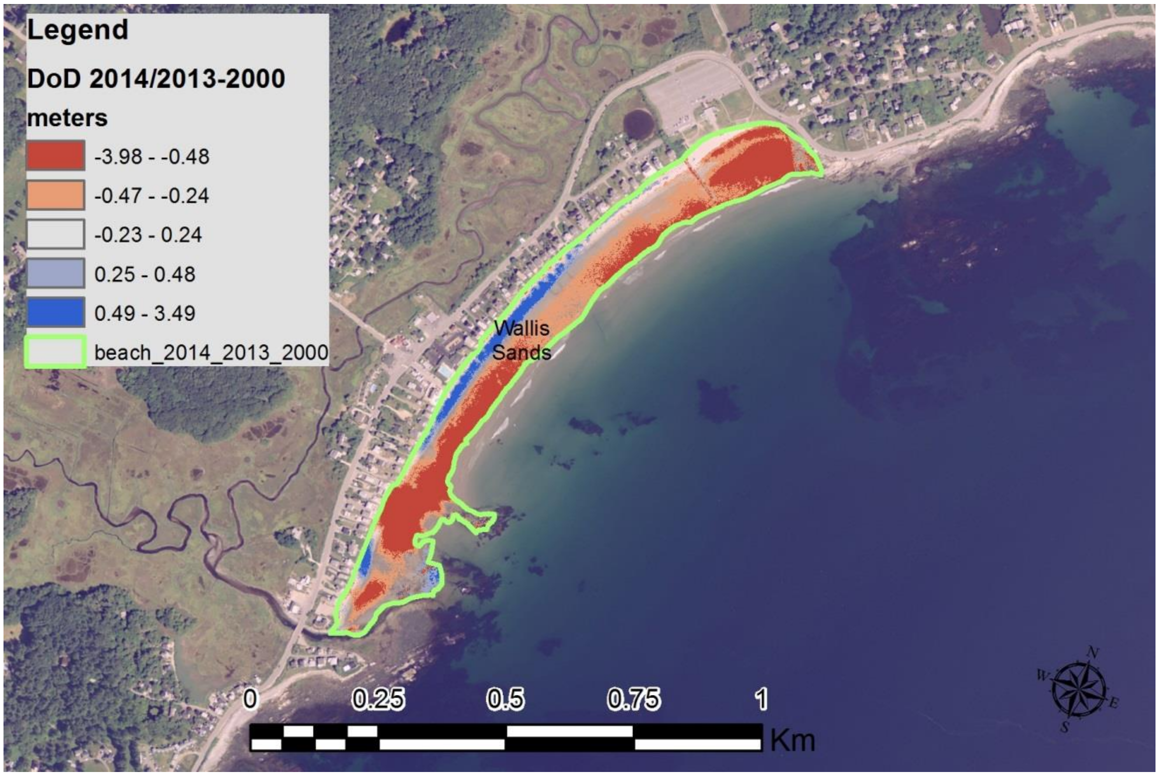


Figure 5. Example of DoD analysis.

Seabrook had a small loss in the time between 06/2007-11/2000. In 06/2010-06/2007, the beach showed a small gain of volume. 05/2011-2010 showed a loss of volume. Later that year the 09/2011-05/2011 showed a gain in volume. 12/2013-09/2011 showed a gain in volume and 04/2014-12/2013 showed a loss of volume. The total change between 2014 and 2000 showed a positive change in volume.

Hampton had gains in 06/2007-11/2000, 05/2011-06/2010, 09/2011-05/2011, 12/2013-09/2011 and Total Change. The time period 06/2010-06/2007 showed a loss.

North Beach showed losses in all years.

Plaice Beach showed losses in all years except for the 12/2013-05/2011 time period.

Both Bass Beaches showed losses in all years except for the 05/2011-06/2010 time period.

Rye Beach showed losses in 06/2007-11/2000, 06/2010-06/2007, and Total Change, and gains in 05/2011-06/2010 and 12/2013-05/2011.

The unnamed beach showed losses in all years except for the 05/2011-06/2010 time period, which showed a mixed signal, with a loss using the LoD method and a gain using the area method.

Foss Beach showed losses in all years except for 05/2011-06/2010.

Wallis Sands had losses in all years.

## DSAS

The DSAS LRR rates were divided into the long term (1855-2015) rates derived from charts and photos, mid-term (1973-2015) rates derived from photos and short term (2000-2014) derived from lidar derived shorelines (Figure 6).

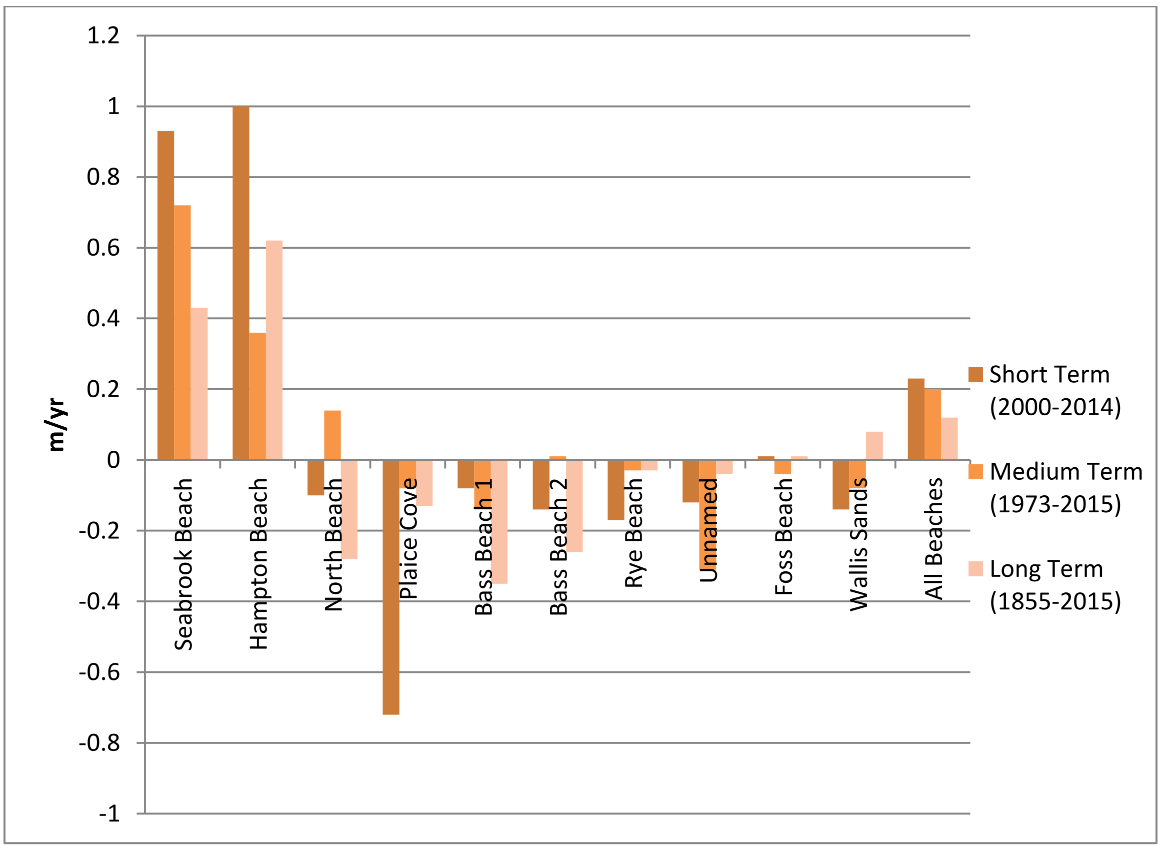


Figure 6. DSAS results of net shoreline movement as measured by Linear Regression Rate for three different time periods.

The entire beach length showed an accretionary (seaward) trend for all time periods, with a long term rate of 0.25m/year.

Seabrook and Hampton Beaches showed accretion in all time periods, with a maximum rate in the short term at Hampton Beach of 1.02 m/year.

North Beach, Bass Beach 2, Foss Beach, and Wallis Sands had mixed signals depending on the time period observed.

Plaice Cove, Bass Beach 1, Rye Beach, and the Unnamed Beach all show losses in all time spans. The biggest loss was in the short-term rate for Plaice Cove of -0.72m/year.

The spatial analysis for the entire coastline is shown in supplemental Figure 2.

### Combined

The total of all the beaches, Hampton and Seabrook beaches showed gains in both the volumetric analysis and the DSAS analysis. Plaice, Bass Beach 1, Rye Beach and Unnamed beach showed losses in both the volumetric analysis and the DSAS analysis. North Beach, Bass Beach 2, Foss beach and Wallis Sands had mixed results, all showing total volumetric losses and a mix of accretion and erosion for some time period in the DSAS analysis.

## Summary

Because the lidar represents such a short time period relative to the time scale of such issues as sea-level rise and persistent geomorphic change, it is advisable to supplement this high resolution, high accuracy data with longer term data derived from the charts and aerial images. There is a general agreement between the two datasets in New Hampshire. Generally speaking, the two large southern beaches (Seabrook and Hampton), show an accretionary trend in both volume and shoreline position. There appears to be some sort of break between these two beaches and those to the north, which show a more mixed but ultimately more erosive trend in both the volumes and shoreline positions. It is beyond the scope of this report to attribute the driving forces behind the observed changes, but numerous explanations exist. One is proximity to sediment sources such as the Hampton Harbor and the Merrimack River. Additionally, the observed differences might be due to some difference in orientation and wave patterns in the area.

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