NEW HAMPSHIRE DEPARTMENT OF Environmental Services

New Hampshire Inventory of Tidal Shoreline Protection Structures

Blondin, H. (2015, October 28). [King tide waves crash against Hampton seawall]

March 2016

R-WD-16-09

New Hampshire Inventory of Tidal Shoreline Protection Structures

Prepared by:

Hannah Blondin, Environmental Technician

New Hampshire Coastal Program
Watershed Management Bureau | Water Division
New Hampshire Department of Environmental Services

Portsmouth Regional Office
Pease International Tradeport
222 International Drive, Suite 175
Portsmouth, NH 03801
(603) 559-1500 |www.des.nh.gov

Thomas S. Burack, Commissioner
Clark Freise, Assistant Commissioner
Eugene Forbes, Water Division Director

March 2016

ACKNOWLEDGEMENTS

This project was funded, by NOAA's Office for Coastal Management under the Coastal Zone Management Act in conjunction with the New Hampshire Department of Environmental Services Coastal Program.

The New Hampshire Department of Environmental Services Coastal Program wishes to thank the following people and organizations for their assistance in preparing this report:

Kirsten Howard, Steve Couture, Kevin Lucey, Chris Nash, Neil Olsen, Dori Wiggin, and Chris Williams of the New Hampshire Department of Environmental Services.

Brendan Newell, Steve Miller, and Rachel Stevens of the New Hampshire Fish and Game Department Great Bay National Estuarine Research Reserve.

Cheryl Coviello of GZA GeoEnvironmental, Inc.

Julie LaBranche of the Rockingham Planning Commission.

Liz Durfee of the Strafford Regional Planning Commission.

Dr. David Burdick and Dr. Paul Kirshen of the University of New Hampshire.

Alyson Eberhardt of New Hampshire Sea Grant and the University of New Hampshire Cooperative Extension.

Table of Contents

I. Introduction

A. Background

The New Hampshire Inventory of Tidal Shoreline Protection Structures (Inventory) project creates, for the first time, an important baseline dataset of engineered shoreline protection structures. The dataset is intended to inform integrated shoreline management decisions that optimize the natural function of the shoreline, while protecting upland infrastructure from coastal hazards such as sea-level rise or storm surge that can cause slow or extreme erosion as well as property and infrastructure damage. Interest in integrated shoreline management has increased among multiple stakeholder groups over the past few years as the New Hampshire Coastal Zone communities have continued to experience population growth and development, water quality degradation, sea-level rise, and intensifying coastal storms.

In December 2014, the New Hampshire Shoreline Management Conference was held to improve understanding of the advantages and disadvantages of various engineered armoring and soft shoreline management options for the state's unique coast in the context of climate change and sea level rise. Participants were able to understand how future climate change risks impact current shoreline management decisions and were exposed to different best practices and new strategies for shoreline management that incorporate both the protection of municipal and state infrastructure and the protection and enhancement of coastal ecosystems as well as cultural resources.

Coastal development and armor stabilization such as walls and rip rap, designed to protect the shoreline from erosion and infrastructure damage, can sometimes generate erosion of habitats seaward or adjacent to the structure, and often fail during major storm events, intensifying impacts of storms. Further, armored shorelines often support a lower abundance and diversity of flora and fauna by disrupting and fragmenting habitat areas. In contrast, living shoreline approaches often include the restoration of natural habitats such as salt marshes and oyster reefs in order to absorb and mitigate storm impacts. Hybrid techniques also exist that utilize a combination of offshore reef breakwaters or stone containment with marsh planting to achieve a natural shoreline protection that supports biodiversity and ecosystem health.[1]

Following the conference, several data needs were identified to help advance integrated shoreline management and policies that promote important assets like human health and safety, natural resources, economic development, cultural and historic resources, and recreation opportunities, among others. One important data need identified was a ***comprehensive, spatial inventory of engineered shoreline protection structures*** along the New Hampshire tidal shoreline that could be combined with existing high quality data about natural habitats like salt marshes, sandy beaches and natural rocky shores.

[1] Gittman, R. K., Peterson, C. H., Currin, C. A., Fodrie, F. J., Piehler, M. F., & Bruno, J. F. (2015). Living shorelines can enhance the nursery role of threatened estuarine habitats. *Ecological Applications*, 26(1), 249-263.

This integrated dataset will improve our quantitative understanding of the state of the New Hampshire tidal shoreline, including the proportion of the shoreline that is armored with manmade engineered structures and the proportion that supports natural habitats.

The dataset will serve as the basis for a desktop coastal shoreline vulnerability assessment as well as an effort to develop a condition rating system that will be tested on several pilot sites on the New Hampshire Seacoast. Combined with additional analysis, the Inventory will ultimately aid efforts to identify candidate sites for living or soft shoreline protection. The Inventory provides important baseline information to policymakers on the New Hampshire Coastal Risk and Hazards Commission[2] and in state and regional agencies as they consider more comprehensive shoreline management approaches.

B. Goals and objectives

The goal of this project is to develop a spatial inventory that identifies engineered shoreline protection structures in order to establish a baseline dataset of tidal shoreline armoring. The purpose of the Inventory is also to inform policy questions about integrated shoreline management in New Hampshire, such as where the removal of an engineered structure should be considered or where it is appropriate or necessary to consider a living shoreline approach. The Inventory will be informative when overlaid with existing data about shoreline habitats, including salt marshes, sandy beaches and rocky shores. Integrating information about natural habitats is necessary to understand the system-wide impacts that shoreline management decisions may have. The New Hampshire Coastal Shoreline Inventory Project objectives are to:

a. Provide baseline information about existing engineered shoreline structures, including total spatial extent and coarse information about type of structure.
b. Integrate information about key coastal habitats, including salt marshes, sandy beaches and rocky shores.
c. Serve as the baseline/screening dataset for a site-specific inventory, a shoreline vulnerability assessment and a candidate site evaluation for living shoreline approaches.

C. Limits of Study

The New Hampshire Department of Environmental Services (NHDES) Coastal Program makes these data available with the understanding the dataset is not assured to be complete. Although the Coastal Program has made every attempt at accuracy, attributes including, but not limited to, presence/absence, length, and location may be inaccurate. Individuals who use the data understand that NHDES, NHDES Coastal Program, and State of New Hampshire are not responsible for any inaccuracies or assumptions made with this dataset. It is recommended that the user read the metadata in its entirety before using the data. NHDES is not responsible for the use or interpretation of this

[2] New Hampshire CRHC website.

information, or for any inaccuracies in the locations, types or lengths of engineered structures. All information is subject to verification. The information provided in the Inventory shapefile is not guaranteed to be complete. Engineered shoreline protection structures may not be exact in length or location. The data provided should be used in combination with other sources for permitting decision making, but should not be used for enforcement decisions within NHDES or legal decisions that occur outside the purview of NHDES. These data should be used for planning, management and educational purposes. Individuals who use these data also agree to use proper citation when displaying the data in other presentations or publications, or when using the data for other studies.

D. Description of location

This study includes the 17 New Hampshire Coastal Zone communities: Dover, Durham, Greenland, Exeter, Hampton, Hampton Falls, Madbury, New Castle, Newfields, Newington, Newmarket, North Hampton, Portsmouth, Rollinsford, Rye, Seabrook and Stratham. The study area encompassed all tidal waters including, but not limited to, tidally-influenced waters along the Atlantic Coastline, Great Bay, the Piscataqua River, Portsmouth Harbor, the Squamscott River, the Bellamy River, the Lamprey River, the Oyster River, the Cocheco River, the Salmon-Falls River, the Winnicut River and intertidal marshes. Although New Hampshire only encompasses 18 miles of open-ocean coastline on the Gulf of Maine, it contains over 326 miles of tidal shoreline, including marine and estuarine salt marsh, based on the mapping completed for this project at a scale of 1:1500 (Figure 1).

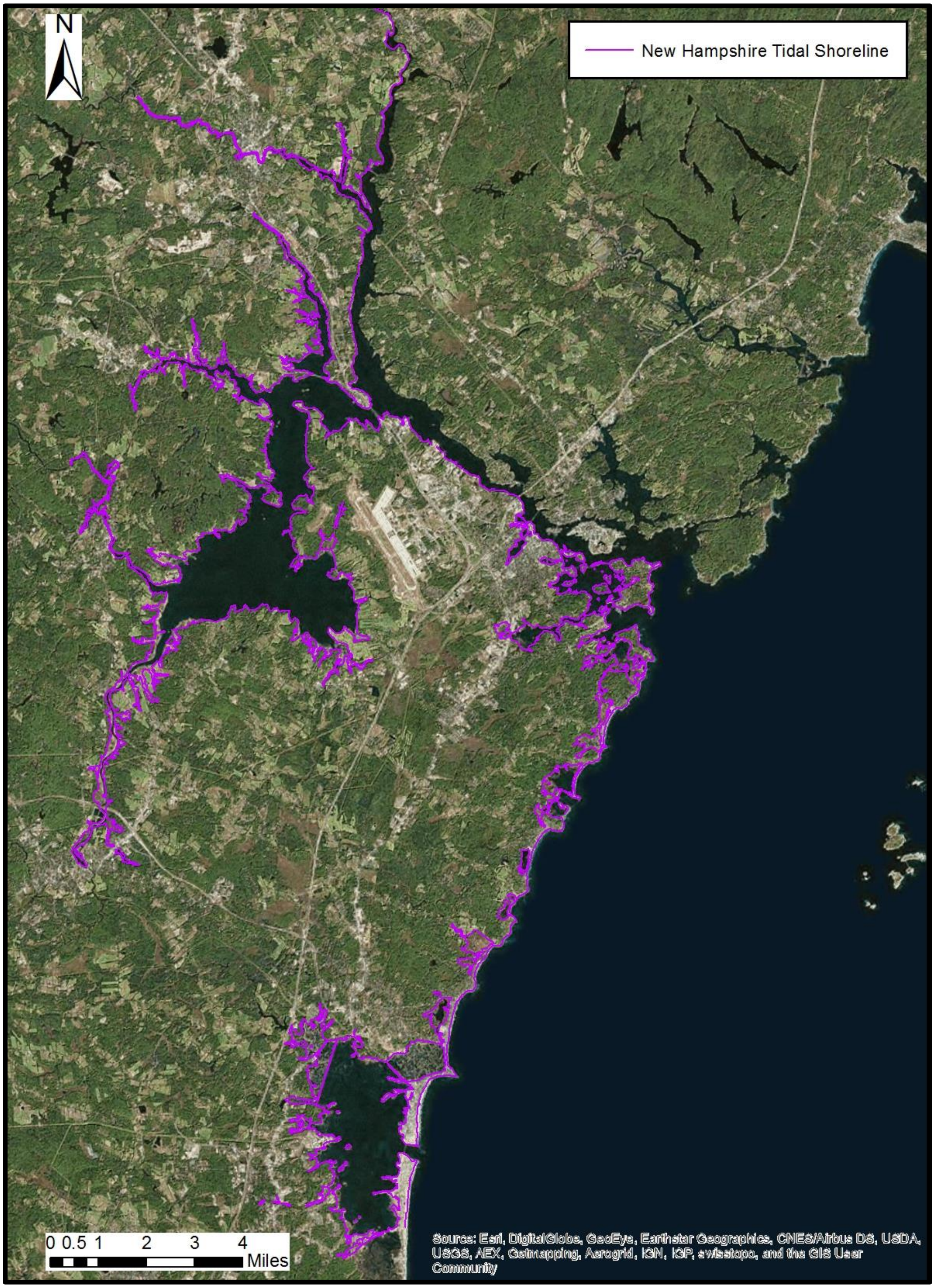

Figure 1: Study Area. Engineered shoreline structures were digitized on all tidal waters and marine and estuarine salt marsh within New Hampshire. New Hampshire's tidal shoreline consists of 326 miles at a map scale of 1:1500.

E. Advisory Team

The advisory team provided guidance and offered expert input to the project leads on the work plan, project area, and methodology and structure key for the Inventory. The team also ensured that the project deliverables are useful for a variety of audiences.

Project leads:

- Hannah Blondin – NHDES Coastal Program
- Kirsten Howard – NHDES Coastal Program

Advisory team members:

- Dave Burdick – University of New Hampshire, Jackson Estuarine Laboratory
- Steve Couture – NHDES Coastal Program
- Cheryl Coviello – GZA GeoEnvironmental Inc.
- Liz Durfee – Strafford Regional Planning Commission
- Alyson Eberhardt – University of New Hampshire Cooperative Extension
- Paul Kirshen – University of New Hampshire, Department of Civil and Environmental Engineering
- Julie LaBranche – Rockingham Planning Commission
- Kevin Lucey –NHDES Coastal Program
- Steve Miller – New Hampshire Fish and Game Department Great Bay National Estuarine Research Reserve
- Chris Nash – NHDES Shellfish Program
- Brendan Newell – New Hampshire Fish and Game Department Great Bay National Estuarine Research Reserve
- Neil Olsen – New Hampshire Geological Survey
- Rachel Stevens – New Hampshire Fish and Game Department Great Bay National Estuarine Research Reserve
- Dori Wiggin – NHDES Wetlands Bureau
- Chris Williams – NHDES Coastal Program

II. Background Research

Two existing assessments that informed the methodology for the Inventory are the Massachusetts and Virginia inventory projects.

A. Massachusetts

Massachusetts completed an extensive shoreline inventory in 2009. The Massachusetts Department of Conservation and Recreation Office of Waterways hired private consulting firm Applied Science Associates, Inc. (currently known as RPS ASA). ASA used orthophotographs, LIDAR data and other information at a scale of 1:5,000 to map and characterize the engineered structures located within Massachusetts' five coastal regions, including the North Shore, Boston Harbor, South Shore, Cape Cod and the Islands, and South Coast. The study took approximately four years, with three years dedicated solely to the inspection and survey of each structure. Publicly-owned structures were located, recorded, described and inspected, while private structures were only located. Data was gathered on each publicly-owned structure to describe the condition, height, length, age and material. This information resulted in a condition rating and priority ranking for each structure based on the ability of the structure to protect from coastal hazards. The final report made management recommendations based on these findings. The study also found that 27 percent of the ocean-facing shoreline in Massachusetts is armored with some form of a public or private coastal structure. The spatial information from the study is available on the Massachusetts Ocean Resource Information System (MORIS) public viewer.[3]

B. Virginia

The Virginia Institute of Marine Science (VIMS) has been completing a shoreline inventory one municipality at a time since 2000. Data collection is performed in the field from a small, shoal draft vessel that is navigated at slow speed parallel to the shoreline. GPS coordinates are used to document the locations of engineered shoreline structures. The GPS coordinates shapefile is then overlaid on an aerial photograph and digitized to create output shapefiles for each city/town in the Chesapeake Bay. Statewide information regarding the percentage of shoreline that is armored is not readily available, however the shapefile for each municipality can be found on the VIMS website.[4]

[3] Office of Waterways. (2009). *Massachusetts Coastal Infrastructure Inventory and Assessment Project*. Massachusetts Department of Conservation and Recreation. Report.

[4] Center for Coastal Resource Management. (2015). *Shoreline Inventories.* William & Mary Virginia Institute of Marine Science. Web.

III. Methods

The engineered structures were digitized at a scale of 1:1500 using the 2013 Coastal High Resolution True Color aerial photograph collected by the Piscataqua Region Estuaries Project on August 24, 2013 (1-foot resolution)[5] and the 2010-2011 Regional Very High Resolution Aerial Photography (6-inch resolution)[6] available on New Hampshire GRANIT (Figure 2). The 2013 imagery was used because it is the most recent available aerial photograph. However, this imagery was taken in the late spring, causing obscurities from tree canopies. The 2010-2011 imagery, taken in the late fall, was used to provide supplemental information in cases where obscurities in the 2013 made determinations difficult. The New Hampshire Tidal Waters[7] layer was merged with the areas of marine and estuarine salt marsh from the 2012 National Wetlands Inventory Coastal Update data to determine the shoreline boundary for the Inventory.[8]

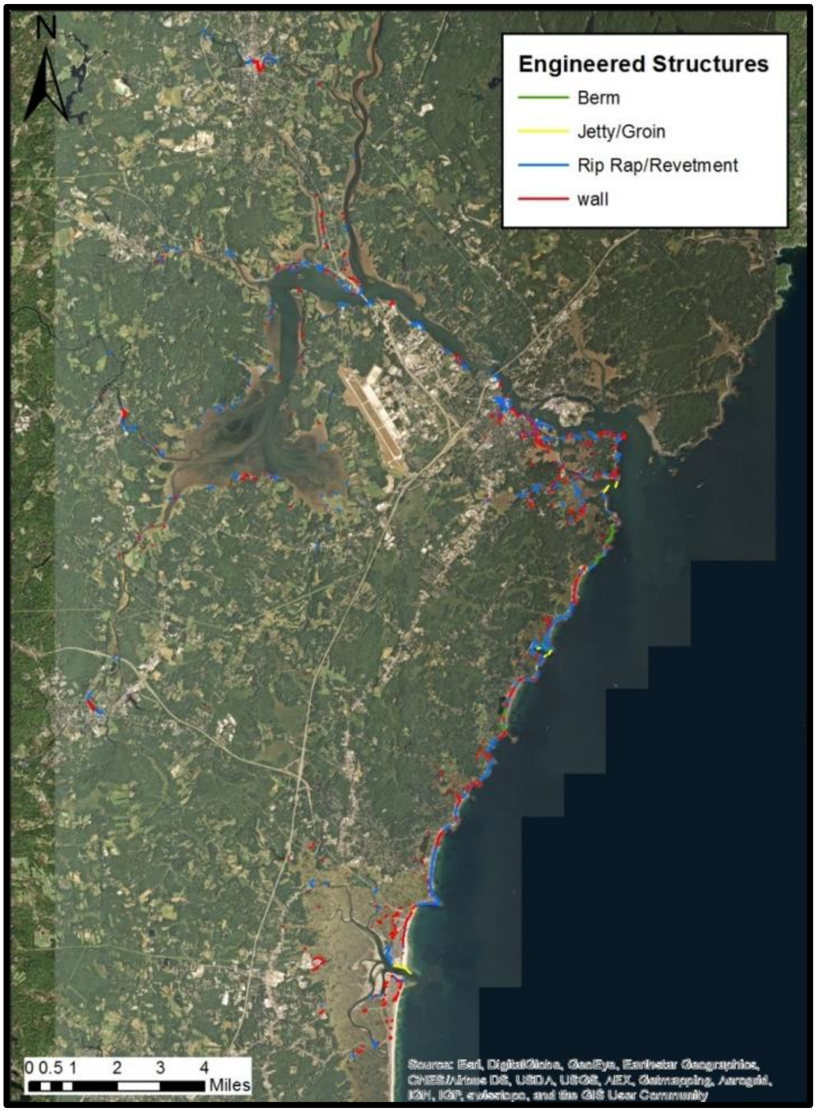

Figure 2: The field-verified inventory of the engineered structures along the tidal waters of New Hampshire.

Following digitization of the structures, field verifications were

---

[5] Piscataqua Region Estuaries Partnership. *2013 Coastal High Resolution Imagery - True Color (RGB)*. Collected by the Piscataqua Region Estuaries Project. Imagery collected August 24, 2013, at low tide.

[6] New Hampshire Department of Transportation and New Hampshire Geological Survey. *2010-11 Regional Very High Resolution Aerial Photography – RGB.* Collected by Photo Science. Imagery collected in 2010-2011.

[7] New Hampshire Department of Environmental Services. *Tidal Waters.* Created by the New Hampshire Department of Environmental Services (November, 2011).

[8] U.S. Fish & Wildlife Service and National Wetlands Inventory. *National Wetlands Inventory*. Published by U.S. Fish & Wildlife Services (May 2014).

completed for nearly all structures, with the exception of several inaccessible back marsh areas, as well as some structures on private property. The "Collector for ArcGIS" App for iPhone was used to make changes and additions to the Inventory while in the field. Following the completion of field verifications, a "non-structured" line was drawn in ArcGIS to display all areas that do not contain armor structures. A "New Hampshire Tidal Shoreline" line was also drawn as a separate shapefile to show the boundary of the tidal waters and salt marsh that were digitized (Figure 1).

Several attributes were added to the structure shapefile including community, watershed (HUC 8), sub-watershed (HUC 12), elevation, length, latitude, longitude and conservation status. The total miles of armored shoreline for the entire seacoast and for individual geographic areas such as the Atlantic Coast and the Great Bay Estuary were calculated by completing an erase analysis in ArcGIS. The Engineered Structures layer was overlaid with the New Hampshire Tidal Shorelines line shown in Figure 1 to obtain an output that contained only the tidal shorelines where engineered structures do not exist. The length of this line was divided by the total miles of New Hampshire Tidal Shorelines line to produce the percent of shoreline that is not armored. By calculating this number for the state as a whole, as well as individual geographic areas, the proportion of armored shoreline for different areas was determined.

A. Inventory Attributes

All Inventory attributes were initially calculated and determined using remote ArcGIS tools. The Engineered Structure presence, type and rough location attributes were verified in the field.

1. Engineered Structures (polylines):

This attribute was determined with orthophotographs in ArcGIS and was later verified in the field for presence, length and type. The four key types of shoreline structure are named and defined as:

- Rip rap (Figure 3).
- Wall (Figure 4).
- Berm (Figure 5).
- Jetty/groin (Figure 6).

Figure 3: Example of a rip rap structure.

Figure 4: The picture on the left is an example of a concrete sea wall, while the example on the right is an example of a stone wall.

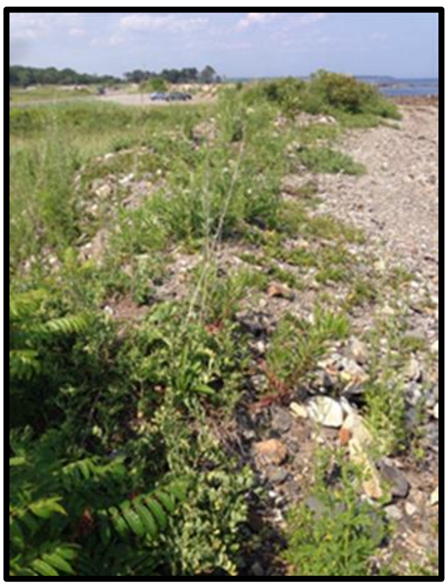

Figure 5: Example of a berm structure.

Figure 6: Example of a jetty structure.

2. Town: (NHDES)

The town is the community in which the structure exists. This attribute was determined by completing an overlay analysis with New Hampshire Political Boundaries layer in ArcGIS.[9]

- Dover
- Durham
- Exeter
- Greenland
- Hampton
- Hampton Falls
- Madbury
- New Castle
- Newfields
- Newington
- Newmarket
- North Hampton
- Portsmouth
- Rye
- Seabrook
- Stratham
- Rollinsford

3. Watershed: (HUC 8)

Digital hydrologic unit boundary, level 8. This attribute was determined by completing an overlay analysis with the Level 6 Hydrologic Unit Boundaries for New Hampshire[10], level 8, in ArcGIS.

- Salmon Falls-Piscataqua

4. Sub-watershed: (HUC 12)

Digital hydrologic unit boundary, level 12. This attribute was determined by completing an overlay analysis with the Level 6 Hydrologic Unit Boundaries for New Hampshire[11], level 12, in ArcGIS.

---

[9] University of New Hampshire. *New Hampshire Political Boundaries at 1:24,000 Scale*. Published by Complex Systems Research Center, University of New Hampshire (January 1992).

[10] U.S. Dept. of Agriculture, Natural Resource Conservation Service, and NH Dept. of Environmental Services. Watershed Boundaries. *WSHED: HU_8_NAME*. Created by NRCS and DES, Water Resources Division using MYLAR (September 2012).

[11] U.S. Dept. of Agriculture, Natural Resource Conservation Service, and NH Dept. of Environmental Services. Watershed Boundaries. *WSHED: HU_12_NAME*. Created by NRCS and DES, Water Resources Division using MYLAR (September 2012).

- Bellamy River
- Berry’s Brook-Rye Harbor
- Great Bay
- Hampton Harbor
- Lower Lamprey River
- Lower Salmon Falls River
- Oyster River
- Piscassic River
- Portsmouth Harbor
- Squamscott River
- Taylor River-Hampton River
- Winnicut River

5. Latitude:

The y-coordinate midpoint for each structure in decimal degrees. This attribute was calculated using the “Calculate Geometry” function in ArcMap.

6. Longitude:

The x-coordinate midpoint for each structure in decimal degrees. This attribute was calculated using the “Calculate Geometry” function in ArcMap.

7. Elevation:

The elevation range category of the structure. This attribute was calculated using the zonal statistics tool on the Seacoast Digital Elevation Model.[12]

- 0-5 feet
- 5-10 feet
- 10+ feet

8. Length:

The length of the structure. This attribute was calculated in feet using the “calculate geometry” function to determine the length of the digitized polylines in ArcMap.

9. Conservation Status:

Identifies whether the structure sits on public conserved lands, private conserved lands, or non-conserved lands. This attribute was determined

[12] U.S. Geological Survey. *LIDAR for the NorthEast*. Collected by Photo Science, Inc. (October-December, 2010).

by completing an overlay analysis with the New Hampshire Conservation/Public Lands layer.[13]

- Private conservation = Privately owned conservation lands.
- Public/conserved lands = Publicly owned conservation lands.
- Non-conserved lands = Not determined to be public or private property.

IV. Results

This study provides a comprehensive spatial overview of New Hampshire's Tidal Shoreline. After digitizing 326 miles of tidal shoreline at a scale of 1:1500, results showed that approximately 12 percent of New Hampshire's tidal shoreline is armored by some type of engineered structure. This percentage equates to 40 miles of armored shoreline (Figure 2).

It is important to distinguish and compare different areas within Coastal New Hampshire because although 12 percent of New Hampshire's tidal shoreline is armored, this one statistic does not tell the complete story of shoreline armoring along the state's coast. The Atlantic Coast (Figure 7), the Piscataqua River/Portsmouth Harbor (Figure 8), and the Great Bay Estuary (Figure 9) were evaluated as individual geographic areas. For example, 70 percent (15 miles) of the Atlantic Coastline is armored, while only 7 percent (5 miles) of the Great Bay Estuary is armored. Table 1 displays the percentage of armored shoreline and the miles of armored shoreline for these three geographic areas within the coastal watershed. Table 2 and Figure 10 show a comparative breakdown of percent armored shoreline and miles of armored shoreline for each of New Hampshire's 17 coastal zone municipalities.

[13] Society for the Protection of NH Forests. CONSNH. Conservation Lands. *Conservation/Public Lands*. Created by ESRC, UNH, and Cartographic Associates, Littleton, NH, using MYLAR (April 2013).

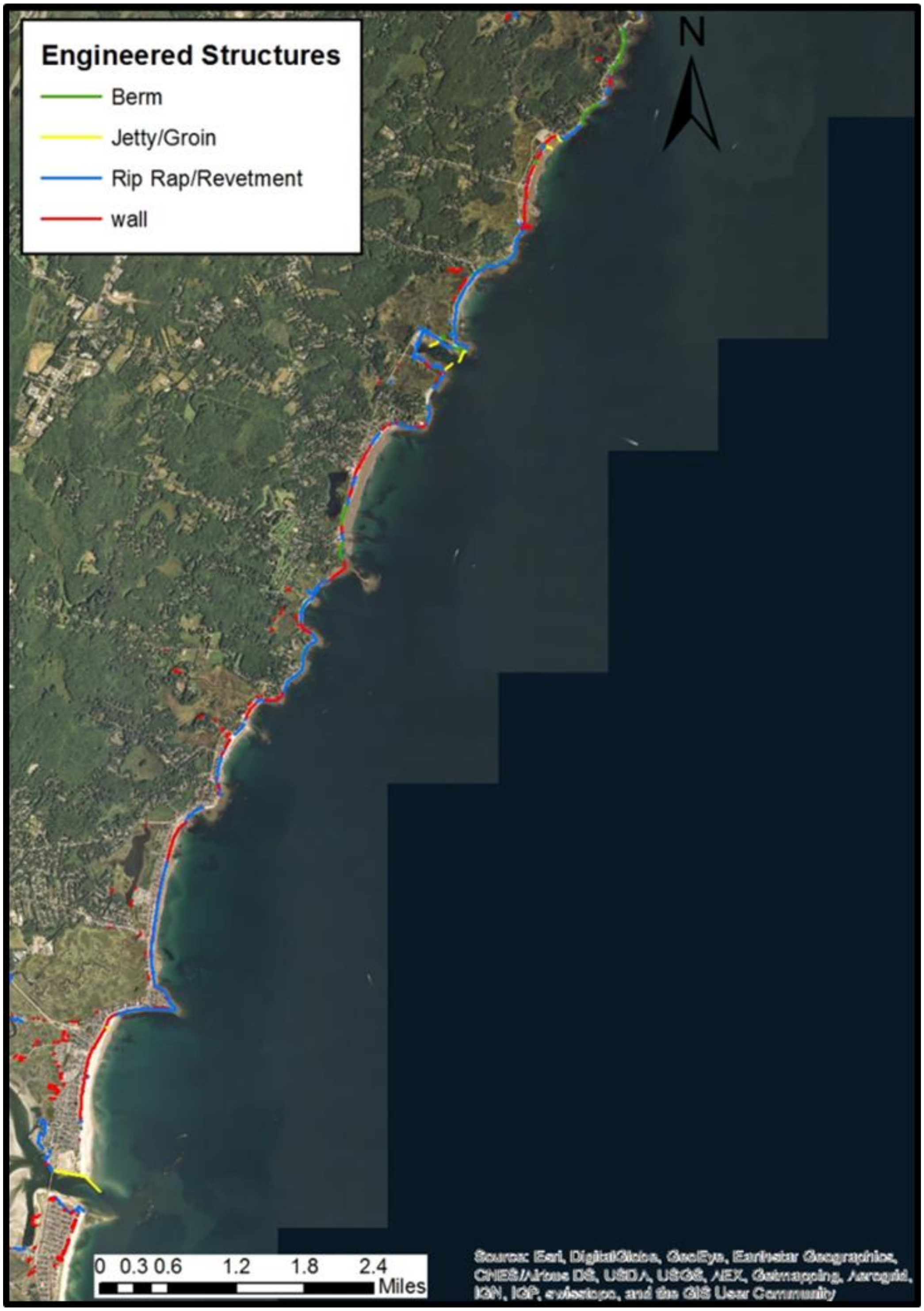

Figure 7: The Atlantic coast area of the Inventory.

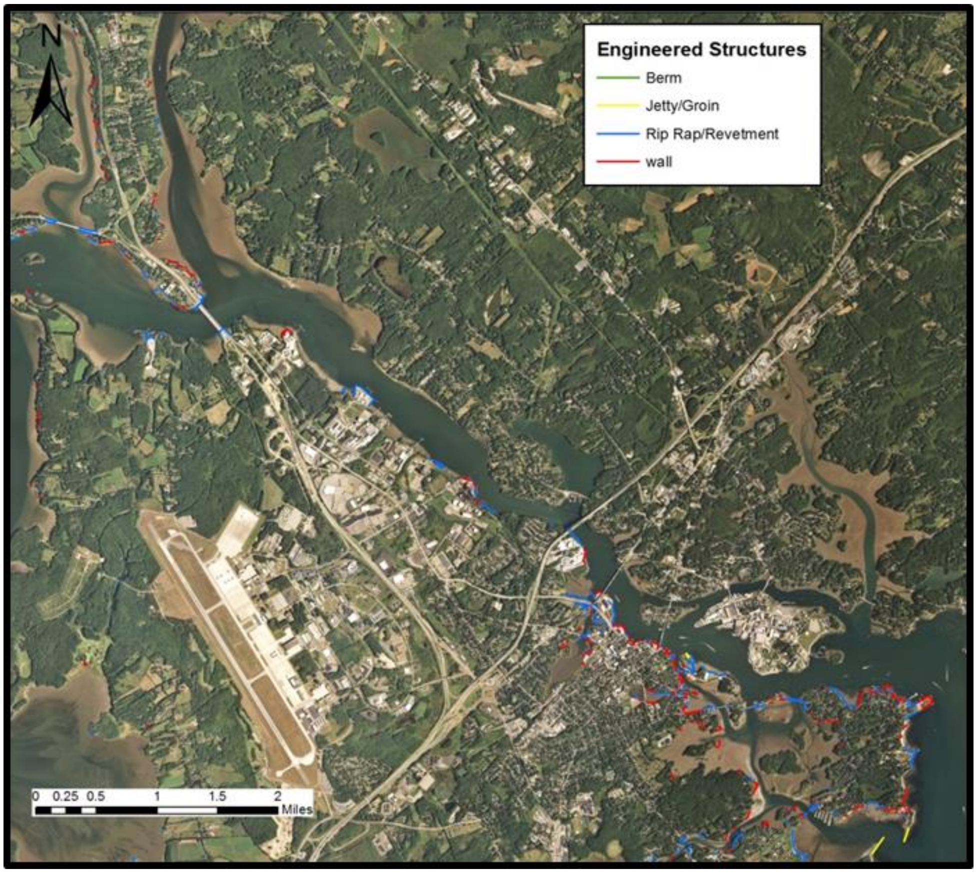

Figure 8: The Piscataqua River and Portsmouth Harbor area of the Inventory.

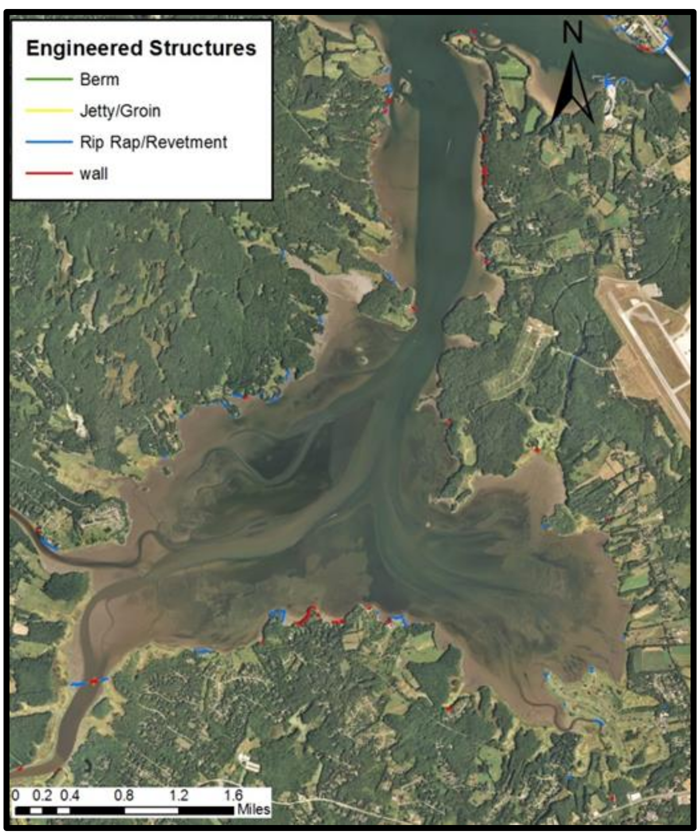

Figure 9: The Great Bay Estuary area of the Inventory.

Table 1: Percent armored and miles of armored and unarmored tidal shoreline by geographic area as of November, 2015

Geographic Area	Percent of geographic area armored (%)	Miles armored	Miles unarmored
Atlantic Coast	70	14.78	21.11
Great Bay Estuary	7	4.51	64.43
Piscataqua River/Portsmouth Harbor	29	10.40	35.86
New Hampshire Tidal Shoreline	12	39.75	286.07

Table 2: Percent armored and miles of armored and unarmored tidal shoreline by municipality as of November, 2015

Community	Percent of community armored (%)	Miles armored	Miles unarmored
Dover	7	3.36	43.44
Durham	4	1.72	41.60
Exeter	6	0.66	11.23
Greenland	5	0.90	16.02
Hampton	19	6.98	29.15
Hampton Falls	1	0.13	118.05
Madbury	1	0.01	1.88
New Castle	35	3.56	6.68
Newfields	5	0.30	5.76
Newington	5	1.17	20.30
Newmarket	7	1.20	15.63
North Hampton	21	1.59	6.04
Portsmouth	27	6.44	17.38
Rollinsford	3	0.19	6.82
Rye	23	9.30	31.60
Seabrook	9	2.38	24.01
Stratham	1	0.16	18.89

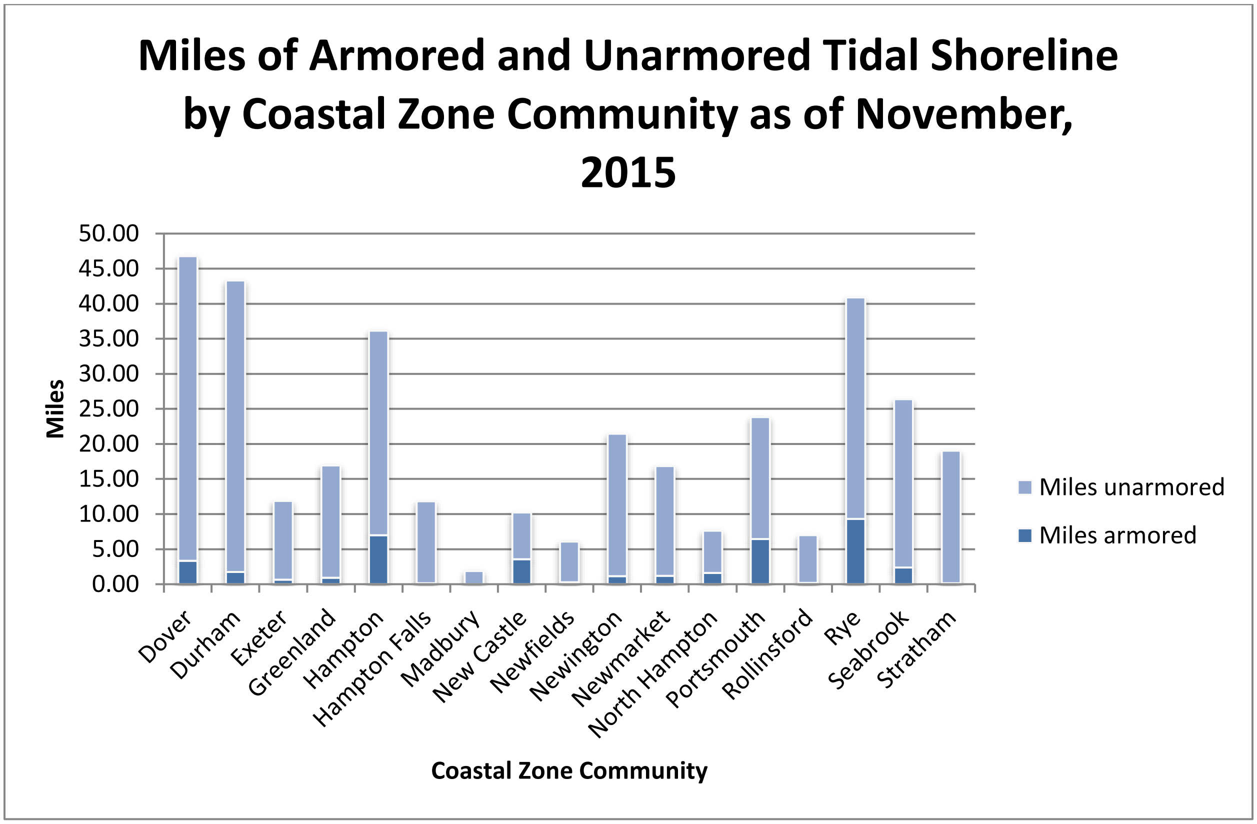

Figure 10: Graphic representation of the comparison of miles of armored and unarmored among the 17 coastal zone communities in New Hampshire.

V. Future Studies

In order for the Inventory's information to be useful and inform the NHDES Wetlands Bureau permitting assessments, a condition rating needs to be applied to the shoreline protection structures. The NHDES Coastal Program is collaborating with undergraduate students at the UNH School of Engineering and Physical Science to develop a condition rating system as part of Senior Engineering Capstone project. A similar rating system has been developed for all shoreline structures in Massachusetts. Based on the Massachusetts methodology and conversations with the NHDES Coastal Program and the Wetlands Bureau, the environmental and civil engineering students will develop a New Hampshire-specific condition rating methodology to be applied to walls, rip rap and berms along tidal shorelines. The condition rating and classification system the students devise and test will then be applied to all inventoried structures.

The NHDES Coastal Program will also conduct a desktop vulnerability assessment using the Inventory data as part of the basis for selecting pilot site candidates for living shoreline projects.

VI. Availability

The NHDES Coastal Program will house the data and continue to update the Inventory based on new permit approvals. The Inventory will be made publicly available on the New Hampshire Coastal Viewer.[14]

VII. Definitions

Berm	A flat strip of land, raised bank or terrace bordering a river, canal or other shoreline.[15]
Bulkhead	A vertical shoreline stabilization structure that's purpose is to retain soil, but provides little protection from waves. Considered a wall for the purpose of this study.[16]
Coastal hazard	Natural phenomena such as sea level rise, coastal storms, hurricanes, flooding and erosion that can occur as a rapid event or a gradual change, and expose a coastal area to risks and dangers such as property damage, environmental degradation and injury or loss of human life.[17,18]
Coastal erosion	A geological process that involves the breakdown and removal of material along shorelines via the movement of water and wind. This process typically occurs slowly over thousands of years, but can also occur suddenly in the form of a landslide or during an extreme storm event. Sea-level rise, as well as increased storm severity and frequency, are accelerating the progression of coastal erosion.[19]
Engineered shoreline protection structure (armoring structure, armor, hardened	These shoreline structures are built with the intention of minimizing the effects of ocean waves, currents and sand movement in order to stabilize and protect the shoreline or provide calm water areas for boats. These structures are artificial and often made of concrete, rock

---

14 The New Hampshire Coastal Viewer.

15 *Oxford English Dictionary.* (1989). Oxford, England: Oxford University Press.

16 Coastal Systems International, Inc. (n.d.). *Evaluating the Condition of Seawalls/Bulkheads*. Perspective, 2, 2-3.

17 Schwartz, M. L. (2005). Encyclopedia of coastal science. Dordrecht, the Netherlands: Springer.

18 St. Petersburg Coastal and Marine Science Center. (2015). *Coastal Change Hazards: Hurricanes and Extreme Storms.* U.S. Geological Survey. Web.

19 Sea Grant Woods Hole. (April 1998). Cape Cod Coastal Erosion: A Case Study. *Focal Points*. Woods Hole Oceanographic Institute. Web.

shoreline)	or timber. [20,21]
Jetty/groin	Large piles of rocks or concrete built perpendicular to the shoreline.[21]
Living shoreline	This alternative technique to armored shoreline protection structures (i.e., rip rap, walls) includes the use of native vegetation, oyster reefs, sand fill and limited stone to provide shoreline stabilization and protection. Living shorelines aim to mimic the natural landscape, maintain a shoreline's ability to carry out natural processes and provide habitat for species.[22] Also known as a "soft" shoreline approach, green infrastructure, nature-based technique and many other terms.
Revetment	A sloping but orderly organization of rock, concrete or stone.[23]
Rip rap	Unorderly rock, concrete, stone, rubble or other material used to allow for water containment or to protect shorelines and structures from erosion by the sea, rivers or streams.[21]
Sea-level rise	Sea-level rise refers to the increase of the height of the ocean surface relative to the solid surface of the Earth. Changes in sea level have occurred on a wide range of spatial and temporal scales for centuries, however the expansion of the ocean has been more recently accelerated by the dominating factor of thermal expansion and the transfer of water stored in land glaciers to the oceans due to the Earth's warming response to increasing greenhouse gas concentrations in the atmosphere. Sea level rise is often exacerbated in the Northeast due to subsidence of salt marshes, resulting in increased sea-level rise in areas that formerly had protection due to these marshes.[24]
Storm surge	Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tides.[25]
Tidal waters	Refers to any part/area of the ocean or rivers that are subject to the ebb and flow of the daily tides.[26]

[20] Walker, H. J. (1988). Artificial structures and shorelines. Dordrecht: Kluwer Academic Pub.
[21] Surfrider Foundation. (2015). *Shoreline Structures*. Beachapedia. Web. http://www.beachapedia.org/Shoreline_Structures
[22] NOAA Habitat Conservation | Restoration Center. (n.d.). Living Shorelines. Retrieved March 16, 2016.
[23] Coastal & Hydraulics Laboratory. *Coastal Shore Protection Structures and Techniques*. U.S. Army Corps of Engineers (n.d.) Web.
[24] Church, J.A., Clark, P.U., et al. (2013). Sea Level Change – Chapter 13. *IPCC Fifth Assessment Report.*
[25] National Hurricane Center. *Storm Surge Overview*. NOAA.

Wall	An orderly, vertical structure made of concrete, wood, steel, rocks, or other materials on that runs "parallel to the beach at the land/water interface;"[23] and includes seawalls.

[26] Definition of Waters of the United States. 33 C.F.R. § 328.3f (1986).