# RHODE ISLAND

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# Chapter 1:  RHODE ISLAND

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## INTRODUCTION

With approximately 400 miles of coastline and an elevation that is at or near sea level in most areas, Rhode Island is particularly vulnerable to coastal hazards such as flooding and storm surge. At least 71 hurricanes have hit Rhode Island since 1635, the most damaging of which was the Hurricane of 1938, which killed 262 people and caused $100 million in damage (1935 dollars).[1] Rising sea levels, as are being seen along the Atlantic coast, will exacerbate the effects of these coastal storms and pose increased threats to the people and property along Rhode Island's coast. The developmental planning and management of lands along the coast will be key in mitigating the potential effects of sea level rise in the state.

### Purpose of this Study

This study develops maps that distinguish coastal areas likely to be protected as the sea rises from areas where shores will likely retreat naturally, either because the cost of holding back the sea is greater than the value of the land, or because there is a current policy of allowing the shore to retreat.[2] This report is part of a national effort by the U.S. Environmental Protection Agency to encourage the long-term thinking required to deal with the impacts of sea level rise issues. The nature of rising sea level prevents the issue from being a top priority; but it also gives us time to reflect on how to address the impacts. Maps that illustrate the areas that might ultimately be submerged convey a sense of what is at stake, but they also leave people with the impression that submergence is beyond their control. Maps that illustrate alternative visions of the future may promote a more constructive dialogue.

For each state, EPA is evaluating potential state and local responses to sea level rise, with attention focused on developing maps that indicate the lands that would probably be protected from erosion and inundation as the sea rises. These maps are intended for two very different audiences:

- *State and local planners and others concerned about long-term consequences.* Whether one is trying to ensure that a small town survives, that coastal wetlands are able to migrate inland, or some mix of both, the most cost-effective means of preparing for sea level rise often requires implementation several decades before developed areas are threatened.[3] EPA seeks to accelerate the process by which coastal governments and private organizations

[1] State of Rhode Island Emergency Management Agency. "Reducing Risks from Natural Hazards in Narragansett, Rhode Island," obtained from: http://www.state.ri.us/riema/nflood.htm, November 20, 2002.

[2] For purposes of this study, "protect" generally means some form of human intervention that prevents dry land from being inundated or eroded. The most common measures include beach nourishment and elevating land with fill, stone revetments, bulkheads, seawalls, and dikes. Shore protection does not include activities that protect structures but allow lands to erode or become inundated.

[3] Titus, J.G., 1998, "Rising Seas, Coastal Erosion and the Takings Clause: How to Save Wetlands and Beaches Without Hurting Property Owners," *Maryland Law Review*, 57:1279–1399.

plan for sea level rise. The first step in preparing for sea level rise is to decide which areas will be elevated or protected with dikes, and which areas will be abandoned to the sea.

- *National and international policy makers.* National and international policies regarding the possible need to reduce greenhouse gas emissions require assessments of the possible impacts of sea level rise, and such assessments depend to a large degree on the extent to which local coastal area governments will permit or undertake sea level rise protection efforts.[4] Moreover, the United Nations Framework Convention on Climate Change, signed by President Bush in 1992, commits the United States to taking appropriate measures to adapt to the consequences of global warming.

This study analyzes state and local coastal management and development patterns to the extent that they are foreseeable. The maps that accompany this study illustrate the areas that local planning officials expect will be protected from erosion and inundation by rising sea level. Those judgments incorporate state policies and regulations, local concerns, land use data, and general planning judgment. We hope that this report can be used as a tool to help estimate the cumulative impacts of shoreline armoring. This analysis does not, however, analyze whether hard structures, soft engineering, or some hybrid of the two approaches is most likely. Those decisions will depend on a variety of factors, including both economics and the evolution of shore protection methods in Rhode Island.

[4] Titus, J.G., et al., 1991, "Greenhouse Effect and Sea Level Rise: The Cost of Holding Back the Sea," *Coastal Management,* 19:171–204; and Yohe, G., 1990, "The Cost of Not Holding Back the Sea. Toward a National Sample of Economic Vulnerability," *Coastal Management* 18:403–431.

**Current and Future Trends in Sea Level**

Sea level has risen 6 to 8 inches in the last century, according to tide gauge records. The observed rate, however, varies geographically. In northern portions of Europe and North America, the land is uplifting in response to the ice sheet melting after the last glacial period; so sea level is falling relative to those coasts. Along the mid-Atlantic coast of the United States, the land is sinking in response to the uplift to the north, and so the sea has risen 12 to 16 inches in the last century. In deltas and areas with substantial groundwater extraction, the land is sinking and as a result sea level appears to be rising by an inch every three years!

The rate of sea level rise in the last century has been more than twice the average rate over the last few thousand years. One possible explanation is global warming: The 1$^{o}$F warming of the last century has expanded the upper layers of the ocean enough to raise the sea 1–2 inches, and the retreat of mountain glaciers and small ice caps around the world has contributed enough water to the oceans to raise the sea another 1–2 inches. Nevertheless, the rise in sea level has not accelerated during the last century.

How much will the sea rise during the next century? The Intergovernmental Panel on Climate Change estimates that global warming is likely to contribute 3/4 to 3 feet over the next century, which would be in addition to the rise caused by other factors. Therefore, it is reasonable for US planners to assume a 1 to 4 foot rise in the next 100 years, with 2 feet most likely. Those calculations assume that no major loss of ice occurs in Antarctica. Over the next 200 to 300 years, the ice sheets in Greenland and Antarctica could contribute enough water to raise sea level 5 to 10 feet.

**Report Outline**

In the sections that follow, we describe the:

- methods by which we assess the likely sea level rise responses;
- state policies that affect the management of coastal lands; and
- municipal policies that affect the management of coastal lands, particularly land use planning decisions.

**List of Contributors**

Table 1 lists the individuals at the town and state level who provided us with comments through initial interviews and during the stakeholder review process.

**Table 1**

**GOVERNMENT PARTICIPANTS AND REVIEWERS**

| **Contact Name and Title** | **Affiliation** |
|---|---|
| Janet Freedman, Coastal Geologist | State of Rhode Island, Coastal Resources Management Council |
| William R. Haase, AICP, Town Planner | Town of Westerly |
| James Lamphere, Town Planner | Town of Charlestown |
| Clarkson Collins, AICP, Director of Community Development | Town of Narragansett |
| Marilyn F. Cohen, AICP, Director of Planning | Town of North Kingstown |
| Robert W. Gilstein, Town Planner | Town of Portsmouth |
| Robert M. Wolanski, Town Planner | Town of Middletown |
| Lisa Bryer, AICP, Town Planner | Town of Jamestown |
| Patrick Hanner, Planner | Town of East Providence |
| Kirsten Mean, Town Planner | Town of Barrington |
| Lee Whitaker, Town Planner | Town of East Greenwich |
| Dan Geagan, Senior Planner | City of Warwick |
| Katrina Deutsch | Block Island Conservation Commission |

## METHODS

It is first necessary to identify the lands that we believe may be affected by sea level rise. Lacking a definitive method for assessing lands at risk, we make a general determination that all lands under the 20-foot elevation contour are of potential interest for sea level rise analysis.[5] Additionally, where necessary, we extend the study area to be at least 1000 feet from the shoreline.

[5]We use the 20 foot contour as the general landward boundary of this analysis for multiple reasons. First, because digital elevation models are frequently incorrect, the area shown near the 20 foot contour may actually be significantly lower. Second, we do not wish to apply a particular amount of projected rise in sea levels; instead, we intend for this study to apply to the general impact of sea level rise regardless of the extent.

Through conversations and interviews with state planners we develop decision guidelines that identify a land use or type category and its likelihood to be protected.[6] Next, we discuss area-specific differences anticipated by the planners. Through this approach we delineate the possible responses into four degrees of protection:

- Lands almost certain to be protected by human intervention (e.g., structural measures or beach nourishment), [7]
- Lands that are likely to be protected though human intervention, but where some uncertainty remains,
- Lands where protection is legal, but will mostly likely be left to natural processes, and
- Lands where policy dictates that protection will not or cannot occur.[8]

Using GIS data layers from the Rhode Island Geographic Information System (RIGIS) and from Applied Science Associates, Inc. (ASA) of Narragansett, and the Environmental Systems Research Institute's ArcView GIS application we are able to construct maps of these responses.[9]

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[6]This report makes projections about future events and is therefore subject to uncertainty. Changes in political climate and policies would change the responses of state and local planners as we have presented them. Improvements in technology could alter the cost or effectiveness of protection and affect individuals' decisions to abandon or protect their property. It is impossible to forecast changes in policies or other factors and we thus base our response maps on the current policies and legislation.

[7]Within the report we differentiate between protection by nourishment and structural protection. For the purposes of our mapping exercise, however, we group these two measures together as "protection." This project does not attempt to answer the question of who will provide the funding for these activities. Although determinations may be made that protection is more likely in areas that money is currently being spent to protect, it is difficult to project the availability of funding in the future as political climate, the economy, and other factors that influence public and private spending are subject to change.

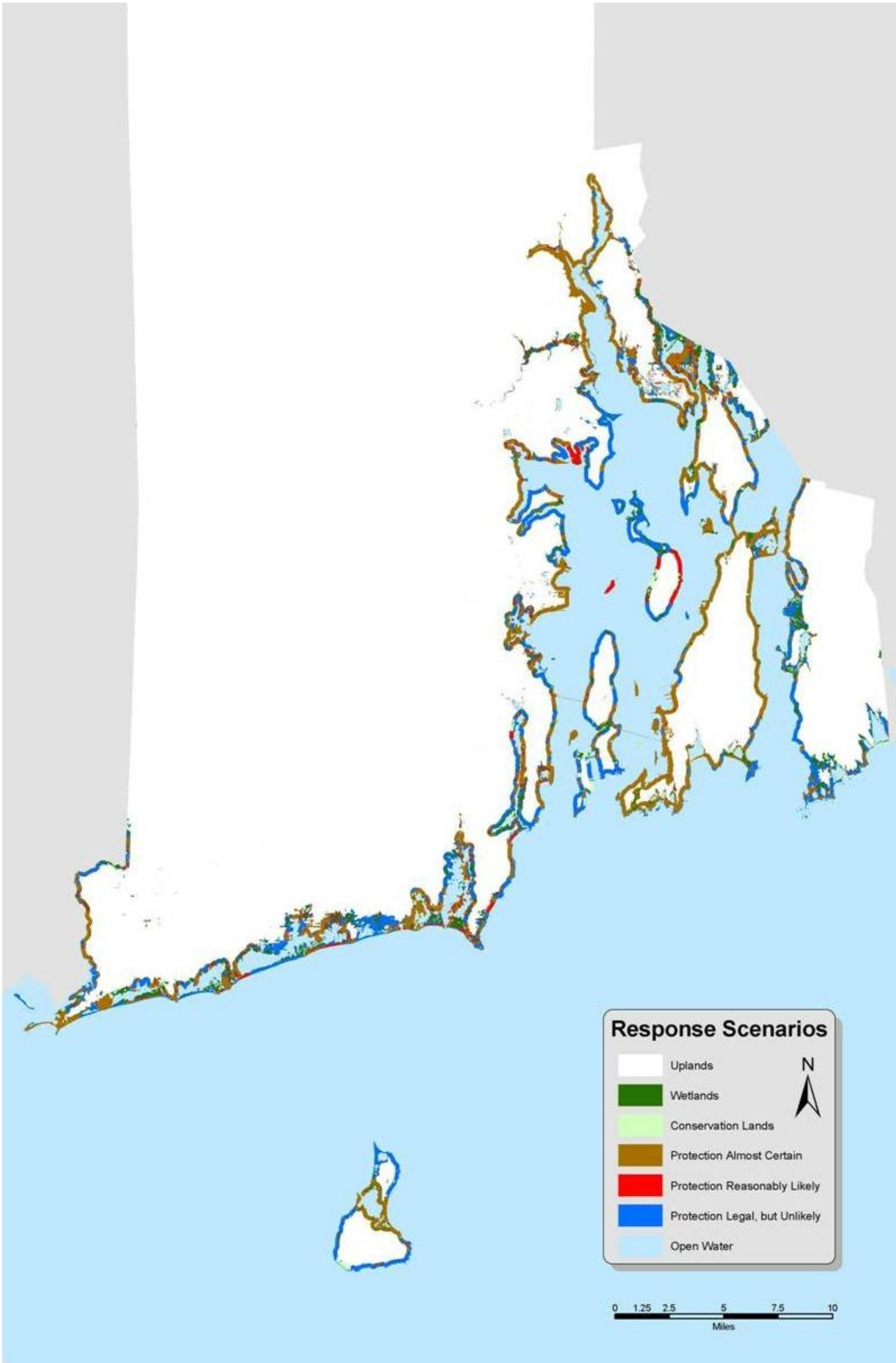
[8]When we first interviewed CRMC staff, we asked interviewees to think about the possibility of shoreline protection under three distinct "scenarios": 1) a strict enforcement of the current policies; 2) a "most likely" response that incorporates assessments of future development and the viability of response options; and 3) a response giving increased priority to wetland migration. From these scenarios, we extrapolate the likelihood of protection designations. Those lands that would only be protected under scenario 1 are designated as "shore protection legal, but unlikely." Lands identified as protected under all three scenarios are designated as "shore protection almost certain." Finally, lands protected under scenarios 1 and 2, but not 3 are designated as "shore protection likely." The category "no shore protection" was added using GIS data provided by the state that depicts lands designated as protected open spaces and Audubon lands.

[9]This analysis relies on data layers obtained from the Rhode Island Geographic Information System (www.edc.uri.edu). Data layers used include Statewide Elevation Model (USGS 1:250,000 scale, 7.5 minute quads), Town Lines, Historic Districts, Audubon Society Lands, Protected Open Space, Barrier Beach Classification, Coastal Water Classification, Narragansett Bay Water Classification, 1995 Land Use, and Wetlands. ASA, Inc's. manmade structures (isolated from the Habitat data layer) are also used. All data are in (or have been converted to) Rhode Island NAD 83 State Plane feet.

To obtain information on local-level expectations and to improve the accuracy of these maps, we reviewed the draft maps with town planners and then revised the maps accordingly.

Finally, it should be noted that this study focuses on land, not infrastructure. One might reasonably assume that if people protect a community, someone will also protect at least one of the roads that connect the community to the rest of the nation. If the intervening land is very low and undeveloped, that road might become a narrow causeway across marsh or open water; or it might be replaced by a low bridge. Although the former form of protection would retain land whereas the latter would allow land to become inland, the difference is unimportant for our purposes; so we generally do not show such roads as protected land. For a number of major roads, however, protection of the road would accompany protection of the narrow corridor of land use along the road, which may include both commercial and residential land uses. Hence, in those areas where the maps appear to show roads as being protected, one should interpret them as indicating that a corridor along the road is also being protected.

Map 1 illustrates our statewide results.




**Map 1: Statewide Results for Rhode Island**

## STATE POLICIES AND PRACTICES

In this section, we identify the state regulations and policies that apply to Rhode Island's coastal lands.

### Existing Policies

The Coastal Resource Management Council (CRMC) was established in 1971 by Chapter 46-23 of the General Laws of Rhode Island.[10] Appendix A provides a more detailed description of the council, its history, and its policies. The policies of the CRMC are outlined in the State of Rhode Island Coastal Resource Management Program (CRMP), referred to as the Redbook.[11] CRMC determines permissible anthropogenic activity in coastal areas of Rhode Island by the "type" of water that the property in question is adjacent to and the "shoreline feature" that characterizes the land.

CRMC recognizes six "types" of water in their policies. These types are based mainly on the prevailing use of the water and the level and type of development on the adjacent coastline:

- Type 1 waters are conservation areas. They are defined as "waters that are within or adjacent to the boundaries of designated wildlife refuges or conservation areas,….that have retained natural habitat…[and/or] are particularly unsuitable for structures due to their exposure to severe wave action, flooding, and erosion." All of the waters adjacent to the ocean-facing coast on the south shore are type 1 waters. There are also small areas of Narragansett Bay that are classified as type 1.

- Type 2 "low intensity use" waters are found in high scenic areas and typically support some low intensity recreational uses. The majority of waters in the coastal lagoons along the south shore are classified as type 2.

- Type 3 waters are used for "high intensity boating." Recreational boating activities dominate these waters and they support a large number of marinas and other water-dependent businesses. Many of the small inlets in Narragansett Bay are categorized as type 3, as are the upper reaches of the Point Judith Pond.

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[10]See Coastal Resource Management Program, "The Program's Enabling Legislation (1971) as Amended."

[11] The Coastal Resource Management Program was federally approved in 1978 and has had a series of amendments since that time. For this project we reference the most recent amendments to the Program, current as of April 25, 2001.

- Type 4 "multipurpose" waters include all of the large areas of open water in Narragansett Bay and in Long Island and Block Island sounds. They are used for both recreational and commercial purposes as well as serving as habitat for fish and wildlife.

- Type 5 waters are commercial and recreational harbors. They support tourism, recreational activity, and some light commercial activities. These waters include such harbors as Newport, Bristol, Warren, Wickford, and East Greenwich in the bay and Old Harbor (Block Island) and Watch Hill Harbor on the coast.

- Type 6 waters are industrial waterfronts and commercial navigation channels. In Narragansett Bay these waters include the Port of Providence, Tiverton, Quonset Point, Coddington Cove, and Melville. Coastal waters defined as type 6 are found in Galilee and Jerusalem.

"Shoreline features" include beaches and dunes, barrier islands and spits, coastal wetlands, headlands, bluffs and cliffs, rocky shores, and manmade shorelines. A more detailed description of these features is included in Appendix A, in the section titled *Geomorphologic Types and Physical Processes Along the Rhode Island Coast.*

Using these two pieces of information, the CRMC constructed "activity matrices" for each water type. Coastal property owners can reference these tables to determine whether a desired activity is allowed on their property and if so, what type of permit is necessary. We provide these matrices in Appendix B. In these matrices, activities are found on the vertical axis and coastal features are found on the horizontal axis. At the intersection of each combination of activity and coastal feature there is an "A" or "B" if the activity in question is permitted and a "P" where it is prohibited. An "A" permit requires that the proposed activity be in accordance with the standards defined in the Redbook and that property owners provide proof of compliance. A "B" permit is slightly more difficult to obtain and requires that the proposed activity address some additional requirements and other issues identified by the council. Where a "P" is found at the intersection of the two factors the activity has been deemed prohibited. Appendix A, in the section titled *Development Setbacks from the Shore (RICRMC)* and *Further Comments on Coastal Planning,* summarizes many of the policies that are presented in these matrices.

The activity of interest for our purposes is shoreline protection. The state of Rhode Island recognizes three categories of shoreline protection. Nonstructural shoreline protection includes vegetation and some structural, yet temporary materials such as sandbags, snow fencing for dune restoration, and in one case coconut logs (used to stabilize a slope until vegetation took hold). These methods are useful only for short-term, emergency erosion control and are not considered viable means of protecting property against sea level rise. Structural shoreline protection includes facilities such as bulkheads, revetments, groins, jetties, and seawalls. Another form of protection sometimes employed is beach nourishment, which consists of supplementing the beach's natural supply of sediment. Generally, CRMC's policy on erosion control is to grant permits for structural facilities in appropriate areas only when the applicant has proven in writing that nonstructural protection has not worked in the past or that the present site conditions do not lend themselves to anything but structural protection and the structural shoreline protection will not adversely affect adjacent or downdrift properties.[12]

**Table 2**

**STATE-WIDE DECISION RULES [1]**

| Land Characteristic | Level of Protection [2] | Source |
|---|---|---|
| Existing Structural Protection | Protection Almost Certain | Environmental Sensitivity Index (ESI) Atlas database compiled for the area by Research Planning, Inc. (RPI)., distributed by NOAA Hazmat (Seattle, WA), obtained from Applied Science Associates, Inc., 2002[3] |
| Protected Open Space and Audubon lands | No Protection | Protected Open Space, RIGIS, 2002. |
| | | Audubon Lands, RIGIS, 1989 |
| Rock Outcrops | Protection Unlikely | Wetlands, RIGIS, 1988[4] |
| Historic Districts | Protection Almost Certain | Historic Districts, RIGIS, 1989 |
| Undeveloped Barrier Beaches | Protection Unlikely | Barrier Beaches, RIGIS, 1999 |
| Low Density/Undeveloped Land Uses [5] | Protection Unlikely | 1995 Land Use/Land Cover, RIGIS |
| 150 Foot Buffer Around Wetlands | Protection Likely | Data processing based on Wetlands Data, RIGIS, 1993 |
| Remaining Lands [6] | Protection Almost Certain | 1995 Land Use/Land Cover, RIGIS |

Notes:
1. These general procedures describe the initial guidelines used to create the response maps, before site-specific modifications were made. All site-specific departures from this procedure are discussed in the body of this report. Exceptions that were made to these general guidelines from input at the state level appear in the "Town-Specific Variations to State-Wide Decision Rules" section. Additional exceptions noted by town-level planners during stakeholder review appear in Table 5.
2. In cases where land areas overlap, classifications higher in the table take precedence.
3. Includes all polygons identified as "manmade structures."
4. Includes areas designated as "estuarine rocky shores."
5. Unprotected land uses include medium low density residential (114), low density residential (115), urban open space (162), agricultural lands (200s), forest land (300s), brushland (400), barren land (700s except for strip mines, quarries, gravel pits (740), and transitional areas (750).
6. This category captures all areas and land uses that do not fall into any of the other categories.

[12] The CRMC Coastal Resources Management Program (Redbook) and policies relevant to this project were identified through email and interview communications with Janet Freedman, coastal geologist with the Rhode Island Coastal Resource Management Council.

### State-Wide Decision Rules

Table 2 summarizes the general procedures that this report uses to identify the likelihood that specific areas will be protected. In this table, we review the general decision guidelines that result from the state policies. The planning maps depart from this general approach in many cases for site-specific reasons, which are documented in the following section of this report.

## RESPONSES TO SEA LEVEL RISE

Based on the data that we gathered from our interviews with CRMC staff and town planners, we summarize our interpretation of Rhode Island's likely responses to sea level rise. The maps present these findings graphically. Dark green lands represent wetlands, which will be left undefended from inundation. Light green areas are conservation lands that are designated as natural open space.[13] Areas that appear in blue depict lands where protection against sea level rise is unlikely. In many cases, only nourishment is legal and may not be a feasible option for shoreline protection. The color brown represents lands almost certain to be protected in the future. The areas that appear in red are lands that are likely to be protected unless the state takes an even more aggressive approach to wetlands preservation or other circumstances lead to unanticipated land use or development pattern changes.

These findings represent our interpretation of current policies, statements, and comments by CRMC and town planners, and assumptions made by the authors. Based on the policies as dictated in the state's CRMP, we determined what means of protection is allowed on all lands within our study area.[14] We then used information provided to us by CRMC staff and town planners to determine which of these areas are likely or almost certain to be protected in the future and which will be left to natural processes.

### Possibility of Shoreline Protection Given Existing Policy and Practices

Based on current policies outlined in the Redbook we assess the possibility of shoreline protection for all lands within our study area given the current rules and regulations regarding coastal areas. Because of differences in elevation, wave action, and beach sediments, we consider ocean-fronting and bay lands separately as decision rules regarding protection may vary. [15]

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[13]These lands were identified using RIGIS layers for Protected Open Space and Audubon Society lands.

[14]Rhode Island Coastal Resources Management Council, *State of Rhode Island Coastal Resources Management Program as Amended,* April 2001.

[15]For the purposes of this study, lands identified as "protected" only include those for which active anthropogenic intervention will be necessary to protect them from sea level rise. Lands that by virtue of their elevation or geomorphology are not vulnerable to sea level rise are not classified as "protected" by our definition.

*Atlantic Coast*

The entire length of the ocean-facing coastline is adjacent to type 1 waters and the land is generally characterized as barriers, headlands, and back bay lands adjacent to coastal lagoons. A large portion of the barriers are undeveloped. Seawalls and revetments are prohibited adjacent to type 1 waters and restricted along other waters because they interfere with coastal processes and inhibit public access to the water. The state does, however, allow for the maintenance and repair of shoreline protection facilities where they might not otherwise be allowed if the structure was built before the creation of the Coastal Resource Management Council in 1971. All areas of the coast that had structural protection in place before 1971 may continue to be protected.[16]

Structural protection is prohibited on the barriers; however, privately held and state-owned lands (other than wetlands or fringing marsh) could be protected by beach nourishment. Lands (other than wetlands or fringing marsh) adjacent to the coastal lagoons (non-ocean facing) and at the interior of Point Judith Pond, Watch Hill Harbor, and on the Westerly waterfront are on type 2–6 waters and could be protected by structural means under current regulations. Thus, existing regulations allow the entire ocean-facing coastline, with the exception of wetlands and fringing marsh, to be protected by nourishment and in some areas by structural protection.[17]

*Narragansett Bay*

All areas of Narragansett Bay that are currently protected structurally can remain protected.[18] According to the Redbook, lands adjacent to type 1 waters and all barrier beaches cannot be protected through structural means. These lands can, however, be protected by beach nourishment unless they are adjacent to areas of submerged aquatic vegetation. Lands adjacent to all other water types can be protected by hard structures. The only land areas that cannot be protected are areas of wetlands and fringing marsh.

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[16]Maps provided by CRMC provided us with the digital data necessary to identify these structures in our maps. See Rhode Island Coastal Resources Management Council (2000). Existing shoreline protective structures on the ocean fronting coast. DRAFT.

[17]Fringing marsh is a dynamic coastal feature and no GIS data were available to identify these areas on our maps. Thus, small areas that we show as one of the four classifications of protection may be more accurately shown as wetlands. Given the ever-changing location of these marshes due to storm activity, etc., however, it is difficult to identify them on a static map such as the one that accompanies this report.

[18]GIS data provided by ASA identify manmade structures along the coast of the Narragansett Bay. The data do not make any differentiation between shoreline protection devices or other types of structures (e.g., piers, docks, and pilings). We make the determination that all structures large enough to be visible on the maps are likely to be protected in the future. However, the lands identified as protected structurally may be overestimated.

**Practical Assessment of Likely Future Actions** [19]

*Atlantic Coast*

The state gives special attention to anthropogenic activity on the numerous barrier beaches on the southern shore.[20] The state prohibits altering undeveloped barriers except where the primary purpose of the project is protection, maintenance, or restoration or improvement of the feature as a natural habitat for native plants and wildlife. Lack of a sediment source because of armoring the coastal headlands, coupled with sea level rise, is likely to result in narrower barriers. This will not necessarily result in negative impacts on an undeveloped barrier, but will create problems on moderately developed and developed barriers. Development on barriers inhibits their natural movement and limits their function as a natural buffer from storms. Consequently, beach nourishment programs may be established to protect structures on moderately developed and developed barriers in the future.[21] Beach nourishment on undeveloped barriers is important when considering the littoral system, but it is not necessary for “protecting” the beaches. Therefore, we assume that undeveloped barriers will not be protected.

Coastal headlands are subject to slightly different policies than barriers. Because there is less development restriction on headlands than barriers, most headlands are or are likely to be densely developed in the future.[22] Protection options include nourishment on low-lying headlands that consist of unconsolidated material like sand and gravel, and armoring in certain areas if it is consistent with the CRMP.[23] Generally, they will be protected by beach nourishment unless they are characterized as "rock outcrops." Rock outcrops are not conducive to nourishment, are not permitted to be protected structurally, and will therefore not be protected.[24]

Other distinctive features of the southern shore of Rhode Island are the coastal lagoons that lie behind the barrier beaches. Most of these lagoons are labeled as type 2 waters. Lands adjacent to these waters can be protected by structures or beach nourishment. However, if a property owner applies to build a seawall to protect from sea level rise on land that would otherwise revert to salt marsh, CRMC staff might recommend denial for the permit.

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[19]A more detailed description of some of the coastal issues that Rhode Island faces can be found in Appendix A, in the section titled *Introduction to Rhode Island's Changing Coast and Demographic Issues.*

[20]Long-term monitoring of the Rhode Island south shore barriers shows that beaches are dynamic features. Sand begins to accrete on the beach days to weeks after a storm. A mature berm forms within months. Although the beach configuration is the same, the location of the coastal features shifts, usually landward.

[21]Current federal policy prohibits the use of federal monies to nourish barrier beaches identified by the Coastal Barrier Resources Act.

[22]According to the Redbook, "coastal headlands" include cliffs and bluffs and are defined as elevated land forms on headlands directly abutting coastal waters, a beach, coastal wetlands, or rocky shore. For regulatory purposes, they encompass all coastal features not defined as a barrier beach.

[23]In general, the state encourages beach nourishment over structural protection wherever possible.

[24]Rock outcrops were identified using the RIGIS Wetlands coverage code 13 "Estuarine rocky shore."

The homes built on property adjacent to coastal lagoons are mostly serviced by septic systems. Even if a permit to erect a dike or seawall around a property were granted, the septic system would most likely fail with the rising water levels. Filling is not allowed in the buffer zone and or in the setback area.[25] New infrastructure, including sewer systems, is allowed by regulations to be constructed in these areas.[26] Taxpayer money is used for the construction of a sewer system, however, and thus the town must vote to go forth with a project.[27] The decision to protect or abandon property would largely be based on the possibility of the installation of a sewer system. We conclude that the more densely developed an area, the more likely it is to win taxpayer approval to build a sewer. We therefore assume that undeveloped lands and those with development density of less than 1 house per acre will not be protected. Areas with greater development densities are more likely to be put on a sewer line and subsequently will almost certainly be protected.[28]

Seawalls and revetments are prohibited adjacent to type 1 waters and restricted along other waters because they interfere with coastal processes and inhibit public access to the water. The state does allow for the maintenance and repair of shoreline protection facilities where they might not otherwise be allowed if the structure was built before the creation of the Coastal Resource Management Council in 1971. For our purposes, it is a valid assumption that any hard structure that exists on land adjacent to type 1 waters has been grandfathered and will be maintained and the lands immediately behind them will certainly be protected. If however, more than 50 percent of the structure is destroyed, the landowner must obtain a new permit for reconstruction. CRMC, however, will not grant such permits in these areas.

The preservation of wetlands is an important goal of the CRMC. Regulations prohibiting filling and nourishment in wetlands and salt marshes are in place to allow for the conservation of these areas. It is possible that in the future, allowing for the additional migration of wetlands might become a priority. Prohibiting both new structural protection and beach nourishment in areas surrounding wetlands ensures that they will be able to migrate naturally. As an illustrative exercise, we have targeted an area of 150 feet around wetlands to be subject to these additional prohibitions on protection. [29]

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[25]"Coastal buffer zones" are natural areas adjacent to the shoreline that must be maintained in their natural, vegetated condition. They are usually contained within the established "setback zone." See RICRMP sections 140 and 150 for definitions and specific regulations regarding these zones. For a more detailed description of these policies see Appendix A section titled *Development setbacks from the shore*.

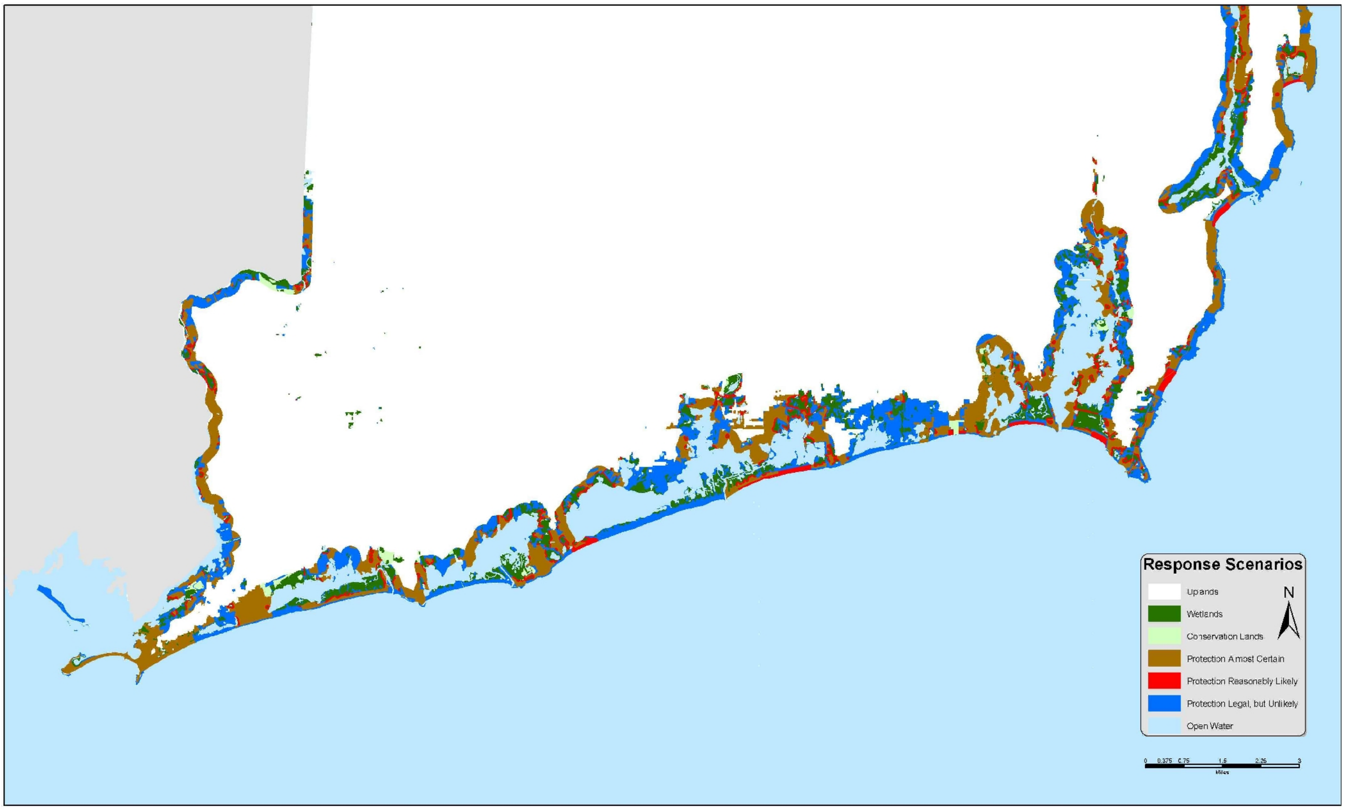
[26]Each coastal lagoon, by definition, does have an adjacent barrier beach that may or may not be developed. No new sewer systems may be installed on barrier beaches.

[27]This decision is an assumption and does leave some room for error. For example, a proposal for the construction of a sewer system in a densely populated area in the town of Westerly was recently voted down by the town's residents.

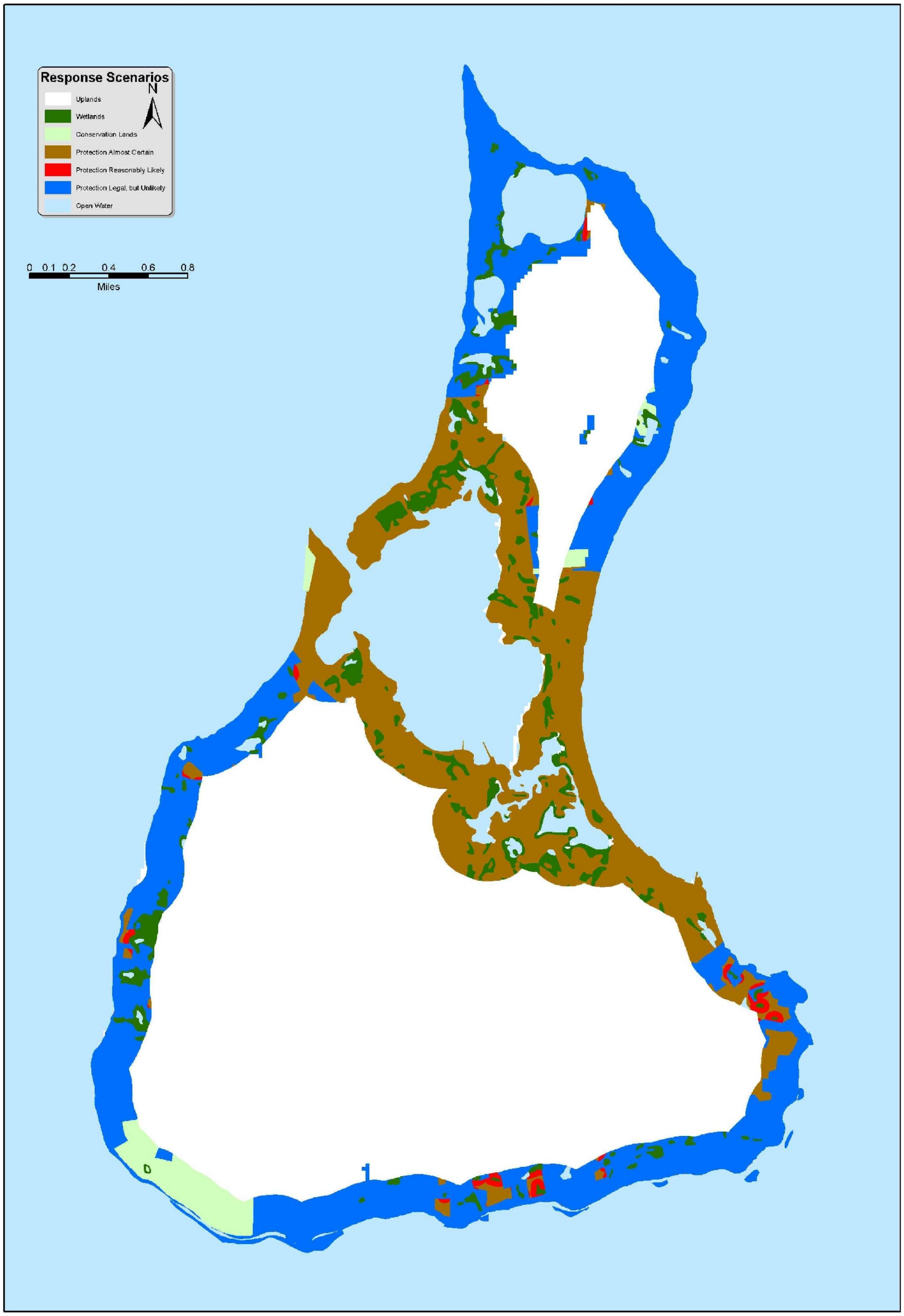
[28]State and town planners helped identify those areas that are not currently developed, but might be in the future. These areas are also likely to be protected. See Table 5 for details.

[29]Note that this exercise was created by the authors and is not based on any specific comments from CRMC regarding the future of wetlands preservation in Rhode Island.

Maps 2 and 3 show the study results for the Atlantic Coast and Block Island, respectively.




**Map 2: Atlantic Coast of Rhode Island: Likelihood of Shore Protection.**




Map 2: Block Island: Likelihood of Shore Protection.

*Narragansett Bay*

Narragansett Bay is characterized by lower wave energy and less erosion than the ocean-fronting coast. There are a few ongoing beach nourishment programs in the bay, but the goal of most of these programs is to create sandy beaches for recreation rather than for protection. In the future, however, beach nourishment may become a more common form of protection from sea level rise on the barriers and in "critical erosion zones."[30]

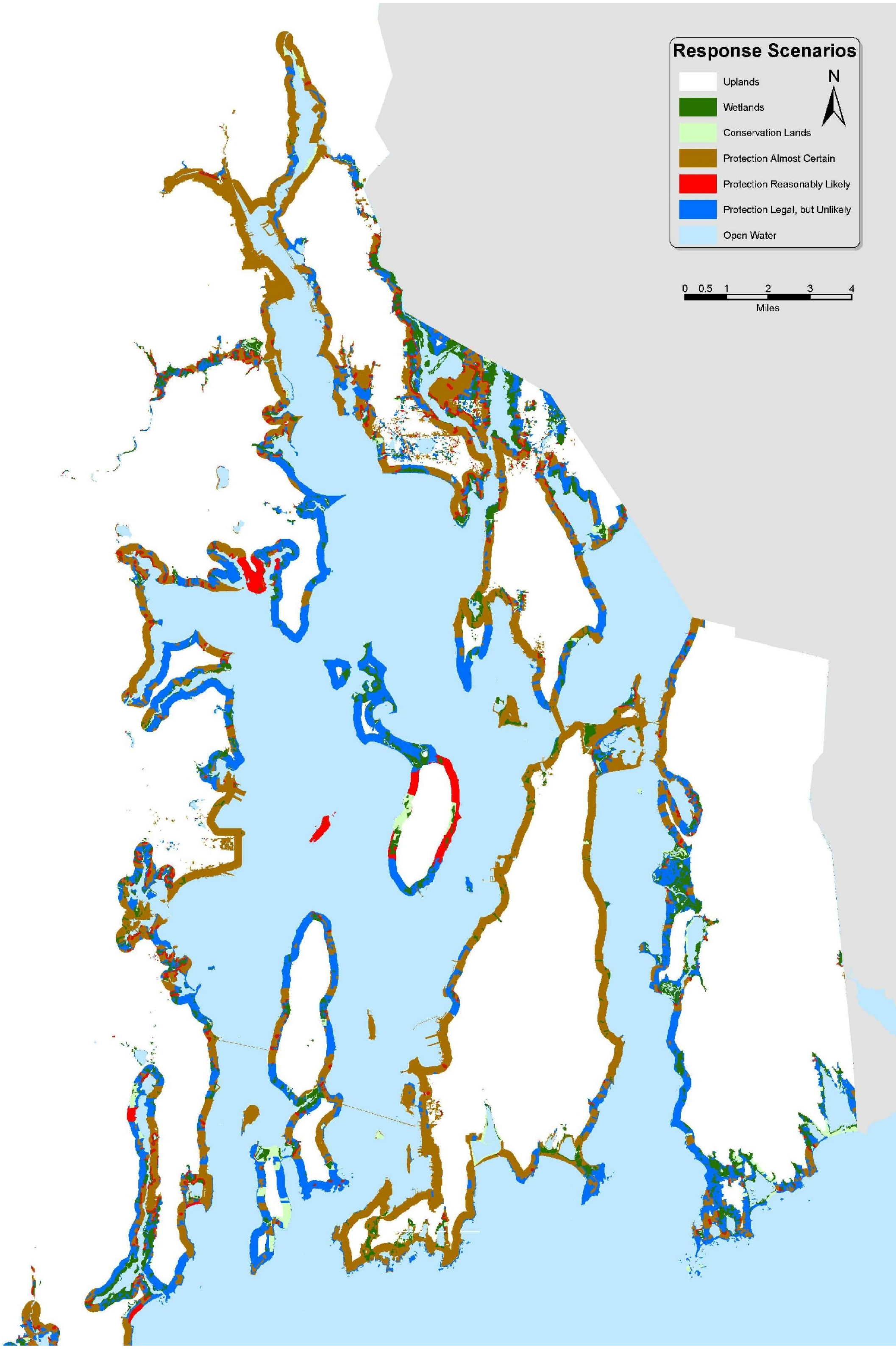
Because much of the intertidal area in Narragansett Bay consists of a gravel substrate, however, beach nourishment will be restricted in some locations to maintain this habitat. For this reason, lands adjacent to type 1 waters will mostly be left unprotected. Any undeveloped barrier will be left unprotected unless it is vital in protecting nearby properties. Barrier beaches labeled as developed or moderately developed will be nourished.[31] Even if the state concluded that other lands adjacent to type 1 waters warrant protection, it is unlikely that beach nourishment would be a viable and widespread protection option in the bay because of its topography.

Much of the shore along the bay is moderately to highly developed. We expand our decision from the Atlantic coast to Narragansett Bay to conclude that undeveloped and low development density lands will not be protected and medium to high density developed lands will almost certainly be protected. We also extend our 150 foot wetland buffer into the bay to designate the lands that might be abandoned in the future to allow for wetlands migration, but where protection is still considered " likely." We also conclude that any area that is currently identified as protected by hard structures using ASA data will remain protected.

Map 4 shows the study results for Narragansett Bay,

[30]Beach nourishment programs may be funded publicly or privately; we do not explicitly assess feasibility in this study.

[31]No areas that meet this description were identified. We compared both USGS maps and ASA maps showing development to the areas identified as undeveloped barriers and none of the areas seemed to match this description.




**Map 4: Narragansett Bay: Likelihood of Shore Protection.**

**Town-Specific Variations to State-Wide Decision Rules**

Specific local-level circumstances and issues may cause the likelihood of protection to deviate from what we summarized in the state-wide decision rules. Through further interviews with CRMC we identified such issues and present them here. [32, 33] Table 3 summarizes additional comments from town planners regarding the likelihood of protection from sea level rise.

*Atlantic Coast*

The Port of Galilee on Point Judith Pond is economically important to the state as a commercial fishery and it will almost certainly be protected.[34] Across the pond in Jerusalem and Snug Harbor there is a good deal of development, but not as much economic value to the area, and these lands are likely to warrant protection, but to a lesser extent. We therefore allow the state-wide decision rules to prevail, leaving this area to be split between the four degrees of protection.

The Westerly waterfront and Watch Hill Harbor also support a good deal of tourism and retail establishments and already rely on structural protection that is likely to be maintained. We conclude that the economic value of these areas warrants their protection against sea level rise.

*Narragansett Bay*

Prudence, Patience, and Hope islands are relatively small islands in the middle of the bay that are part of the National Oceanic and Atmospheric Administration's (NOAA) National Estuarine Research Reserve System.[35] The success of the Research Reserve System is dependent, in part, on maintaining the designated areas as natural systems. Although Prudence Island does host some low-density residential development, it is largely undeveloped. The town of Portsmouth, however, believes that all densities of development will be protected, including developed areas on Prudence Island. For this study, we assume that much of Prudence Island, as well as all of

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[32]We originally constructed our protection likely designation by identifying areas that were likely to be protected, but may be abandoned to allow for wetlands migration. After speaking with town planners, we expand the definition to include any areas that are likely to be protected (but where protection is not certain), regardless of whether the decision to protect or abandon rests on additional migration of wetlands.

[33]In some cases, comments regarding certain areas did not necessitate changes in the protection designation. However, the reasons for protection of certain areas may not have been fully addressed in the state-wide decision rules and we therefore provide further detail on areas that planners felt were of particular interest.

[34]According to National Marine Fisheries Service data, this port grossed the second highest income of all East Coast fisheries in 1999 (http://www.st.nmfs.gov/webplcomm/plsql/webst1.MF_LPORT_YEARD.RESULTS).

[35]NOAA's National Estuarine Research Reserve System was established to provide "living laboratories" for scientists to conduct research on natural resource management issues in estuaries. The system was established by the Coastal Zone Management Act of 1972. For additional information, see http://www.ocrm.nos.noaa.gov/nerr/.

Hope Island, is likely to be protected.[36] Patience Island will not be protected. See Table 5 for more details on the town's expectations.

The Port of Providence (now known as ProvPort; http://www.provport.com/index.html) is an economically important shipping port in the state. It consists largely of a manmade shoreline and will almost certainly continue to be protected. The neighboring towns of East Providence and Pawtucket will also continue to be protected by the manmade shorelines already in place and by additional means, if necessary.

Quonset Point has recently become a controversial area as future uses for the land are debated. Arguments have been made to turn it into an airport, a container port, or even an aquaculture farm. No matter the outcome of this debate, it is unlikely that the land will be left to return to its natural state. It is largely protected by structures and we assume that it will continue to be protected.

The town of Warwick, which is highly developed and low lying, has experience with coastal hazards. The town was hit hard by the hurricanes in 1938 and 1954 and, according to CRMC, it is unlikely that a seawall would be effective in protecting much of the land from sea level rise. The eastern-facing shore on Warwick Neck consists of cobble rather than sandy beaches, and beach nourishment would not be a viable option. There are and will continue to be beach nourishment projects along the Greenwich Bay shoreline, but these projects are in place to maintain the beach and not for erosion control. According to the state, it is unlikely that anything will be done to protect the remainder of this coastal area because of the perceived ineffectiveness of currently available protection technologies given the topography and vulnerability of the area.[37] The town of Warwick's opinion, however, differs from the state's in that they believe that these nourishment programs are likely to continue for the purpose of protecting the shore, especially in the Oakland Beach area of the town. For the purpose of this study, we assume that these lands are likely to be protected.

[36]The northern and southern ends of Prudence Island are designated by the town as unlikely to be protected.

[37]The shores of Warwick Neck that lie on the Warwick Cove are subject to less wave action and protection might be a feasible option there. See Table 5 for details.

**Table 3**

**TOWN-SPECIFIC EXCEPTIONS TO GENERAL RESPONSE GUIDELINES [1]**

| Town | Exception |
|---|---|
| Middletown | Second Beach in Middletown and Easton Beach in Newport are both barrier beaches that protect four freshwater ponds from saltwater intrusion. Because these ponds are major water sources for the towns of Middletown and Newport, the barriers will certainly be protected. |
| Warwick | The Oakland Beach area of Warwick is located on a low-lying peninsula. Beach nourishment has been used in the area and may continue to be used in the future. This area is likely to be provided with some form of protection in the future. |
| | Warwick Cove is home to a large number of commercial marinas. It is likely that these marinas will employ some form of shoreline protection. |
| East Providence | The City of East Providence agrees with the state decision rules. They view their waterfront properties as an asset rather than a liability and they see them as having much development potential. Abandoned brownfields cover much of the undeveloped waterfront and as new technology makes it more cost-effective to remediate these properties, they will be developed as residences, restaurants, hotels, retail businesses, etc. These areas will all certainly be protected. East Providence is currently developing their Hazard Mitigation plan for FEMA and writing policy regarding flood mitigation strategies. Recommendations include encouraging the acquisition of open space and training planning board and land trust personnel on flood mitigation. |
| Jamestown | Fort Wetherhill State Park, town parks, and a number of other areas that fall under our "protected land uses" decision (e.g., developed recreational lands) will not be protected. |
| Narragansett | State- and town-owned beaches are likely to be protected through beach nourishment using dredged materials from the barrier beach overwash fans. |
| | State Highway 108 and other major roads leading to and from developed residential areas, port facilities, and the pier area (e.g., Ocean Road) should be shown as certainly protected. |
| | All commercial areas in Pt. Judith Pond will certainly be protected. |
| Charlestown | Ninigret Park was created on an abandoned airfield. Although severa paved runways remain, it is unlikely that they will be protected. |
| | The entire stretch of East Beach from the end of the town beach to the Charlestown Breachway will remain unprotected. |
| | The ACOE habitat restoration project includes plans to dispose of dredge spoils on ocean-fronting beach areas in front of development at the west end of Ninigret Pond and directly to the east of the Charlestown Breachway. Protection of these areas should be considered likely |
| | The state campground on the west side of the Charlestown Breachway is a major source of income for the state and will be protected. |
| Westerly [2] | No man-made protection is likely anywhere in the town because:<br>-It is relatively easy for property owners to get repetitive flood insurance claims;<br>-Skyrocketing costs of coastal properties make it unlikely that the town or state will be able to acquire the land to preserve it as open space;<br>-Limited state and federal funding is available for this type of activity;<br>-There is significant public opposition to obscuring coastal and shoreline views; and<br>-State and federal regulatory apparatus makes permitting for this activity difficult. |
| North Kingstown | Forge Road and the Forge Road Bridge, which carries Forge Road over the Potowomut River, will certainly be protected. |
| | Calf Pasture Point is a town park and is not likely to be protected. |
| | All of Quonset Point will certainly be protected. |
| | Post Road (Route 1) will almost certainly be protected. |
| | The Jamestown Bridge will certainly be protected. |
| | The west side of the Narrow River is moderately to highly developed and will likely be protected. |

**Table 3**

**TOWN-SPECIFIC EXCEPTIONS TO GENERAL RESPONSE GUIDELINES** [1]

| Town | Exception |
|---|---|
| Portsmouth | Most of the coastline of Portsmouth is developed and land values have increased considerably over the past decade. Reasonable protection efforts will be made in almost all areas of the coast, including even low-density and medium-density development. The exception to this rule would be dedicated open space and wetlands, which will not be protected. |

Notes:
1. The towns of Barrington, East Providence, East Greenwich, and New Shoreham agreed with the conclusions as they are stated in the maps and had no further comments. Tiverton and Warren elected not to submit comments. The authors were not able to provide Pawtucket with the additional detail they required to perform a thorough review, and thus no comments from the town are included in this draft. The towns of Little Compton, Newport, Bristol, Providence, Cranston, and South Kingstown could not be reached for comment.
2. Decisions made by the town of Westerly relied heavily on the issue of funding availability. Because funding is not a primary focus of our study at this time, we present the original state-level decisions made for the town of Westerly in our maps, but note that the town is not in agreement with these decision rules.

## CONCLUSIONS

Rhode Island is a prime example of a state that has been proactive in its coastal zoning policies. Policies that specifically address sea level rise have not as of yet been incorporated into the Coastal Resource Management Plan. The relatively stringent coastal development policies, however, which largely prohibit shoreline armoring in areas of high recreational and/or ecological value, indicate that the state will not permit hard-structure protection of all lands against rising seas.

Barrier beaches and lands adjacent to waters that have been designated as type 1 conservation waters are not permitted to be structurally protected. Although they may be nourished, that type of protection may not be feasible in all areas and many of these lands may therefore be left unprotected from inundation. There are several areas where the CRMP might allow armoring of the shoreline to occur. Permits must be obtained, however, and the RICRMC stands strongly by its policy that all nonstructural measures must be exhausted before a permit to build will be granted.

The Rhode Island Coastal Resources Management Council puts a high priority on managing their coastal lands in the least intrusive way possible. It is therefore not likely that we will see a large-scale armoring of the shore of Rhode Island.

# APPENDIX A:  COASTAL HAZARDS IN RHODE ISLAND

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## Introduction

The United States does not have a comprehensive national policy in response to natural coastal hazards (Van der Vink, et al., 1998). The reasons for this are mainly because of constitutionally protected private property rights whereby owners are allegedly entitled to use their land as they wish, subject to certain public interest constraints and through nuisance laws (Skelton, 1990). The same premise applies in both Rhode Island and Massachusetts.

Thirty years ago the first and only "national shoreline study" was prepared by the U.S. Army Corps of Engineers (ACOE). Erosion is known to be a widespread though not universal phenomenon along the U.S. coastlines. The 1971 report issued by the U.S. Army Corps of Engineers estimated that 20,500 miles were experiencing "significant erosion," of which 2,700 miles were subject to "critical erosion." The report, however, did not precisely define the terms "significant" and "critical." At that time, coastal shoreline erosion was illustrated by the estimate that Massachusetts and Rhode Island had at least 97% of their coasts designated as significantly eroding miles, demonstrating that these were areas where erosion was occurring but development was not imminently threatened.

### Rhode Island at Risk

One of the most visual reminders of any major hurricane, flood, or storm event in Rhode Island is a sudden, dramatic change in the shape of the state's beaches. A visitor to the shore will see that the coastline has retreated -sometimes literally overnight -and large amounts of sand have vanished. As shoreline is lost, the risk of damage to coastal properties increases.

The challenge of preventing and reducing losses due to coastal erosion is upon decision-makers in Rhode Island. They must initially answer some basic questions, for example, what is at risk? What level of risk is acceptable? Considering the limited available financial resources coupled to political constraints, what solutions are feasible? An understanding of geologic processes in the highly dynamic coastal environment is also essential to the development of sound coastal hazard management policy.

### Introduction to Rhode Island's Changing Coast and Demographic Issues

Each summer more than 100,000 state residents and thousands more of out-of-state visitors frequent Rhode Island's beaches, providing millions of dollars in revenue. In Middletown, for example, it is estimated that town beaches provide employment for -75 residents, providing a total economic value of over $1.5 million per year (see: e.g., Johnston, 1997; R.I Sea Grant, 1998).

Property located along Rhode Island's shores represents a huge investment. Indications from the most recent published tally of coastal exposure (from significant hurricane damage), in terms of value of insured property, highlight that Rhode Island had more than $83 billion worth of commercial and residential development at risk (IRC, 1995). This figure reflects an increase of 153 percent over little more than a dozen years of data. Rhode Island's value of insured residential coastal property skyrocketed from $17.2 billion in 1980 to $46.1 billion in 1993 for an overall increase of 166 percent (IRC, 1995); no doubt it has become significantly higher today. Washington County experienced a 91 percent increase in the value of residential coastal property exposure during a half dozen year survey ending in 1993 (IRC, 1995). Similarly, in Newport County, an 84 percent gain was seen, and Providence County had a 71 percent increase.

It has been estimated that if a 100-year storm had occurred in 1989, for example, losses of properties in the coastal flood plain would have exceeded $280 million (RI Sea Grant, 1998). Losses would be even higher today, due to both relative sea-level rise and erosion, as well as new construction since 1989. Roth (1997) states that losses would be even higher today, because he believes that millions of structures along the entire Atlantic coastline may not meet building code regulations for hazardous area exposure. Clark (1997) laments that since 1960 the U.S. as a whole has experienced relatively low hurricane activity, while insured coastal exposure values have increased dramatically. Further, she mentions that relatively small changes in hurricane intensity, that was seen in earlier times, or from possible future changes in climate can cause dramatic increases in property losses from episodic storms such as hurricanes. Calculations made of five year costs of about $90 billion from natural disasters in the 1992-1996 timeframe, indicate that hurricanes contributed to 37 percent of that amount; that is, hurricanes contributed the most to the overall total (van der Vink, et al., 1998).

The majority of Rhode Island's south shore is experiencing erosion over the long term, with an average annual rate of retreat of one to two feet (Figure la & 1b). Along exposed sandy shores, for example, Matunuck in South Kingstown, can recede by as much as 30 feet in a single severe episodic storm event (R. I. Sea Grant, 1998). If relative sea-level continues to rise by one foot per century -as is actually being measured at the Newport tide gauge -all of Rhode Island's low-lying coastal areas comprising about 76 percent of the shoreline (R. I. Sea Grant, 1998; see: Figure 2a & 2b) could be adversely affected. Population growth and relative sea-level rise can outstrip the ability of coastal environments to provide resources whereby leading to population redistribution (Constable, et al., 1997).

The majority of Rhode Island's ocean and Narragansett Bay coasts are susceptible to coastal erosion. The amount of erosion from storms -which are the biggest causes of change on the shoreline -is directly related to their number, intensity, and duration. Although they are susceptible to erosion, beaches form the first line of defense against ocean waves, providing a buffer between the waves and coastal properties. When beaches are cut back during storms - especially the more severe storms that occur in fall and winter -they progressively lose this buffering ability making further coastal erosion more likely. (It is important to recognize, however, that natural erosion and sedimentation -redepositing of sand and sediment from year to year, depend upon such factors as nearshore currents, ocean swells and the availability of sediment). As the beach erodes, vulnerable properties are placed at even greater risk.

The present rate of relative sea-level rise for southern New England is about one foot per century due principally to subsidence of the land and thermal expansion of the volume of the ocean (Boothroyd, et. al., 1985). A relative sea-level curve derived from nearby Guilford, Connecticut from benthic foraminifera assemblages in peat cores from coastal salt marshes indicates that in the last 300-400 years the annual rate of rise is 2.9-3.3 millimeters (0.1-0.13'; Nydick, et. al., 1995).

Higher relative sea-level could affect the coastal zone in a variety of ways, including greater shoreline retreat, exacerbating effects of coastal erosion, property destruction, and saltwater intrusion into bays, rivers, and underground water resources. In addition, a general elevation in the water table could result from relative sea-level rise. This could lead to the failure of both septic systems and other drainage systems, such as storm drains, which need to be located at a certain elevation above the water table (see: RICRMP, 1996). This problem could be seen in over 58 percent of Rhode Island's coastal areas (RI Sea Grant, 1998). Elevation of the water table would also affect the river drainage systems of Rhode Island by slowing down runoff and reducing sediments to the coast while increasing the risk of flooding. And, humans have become active agents of change in the earth's atmosphere and oceans.

Many of these parameters are geologically "normal" events that will continue into the future. They are viewed as coastal hazards primarily if the results seem to harm people or produce economic losses for public and/or private property .Therefore, a principal concern of waterfront property owners is frontal erosion and storm-surge flooding from episodic storms. superimposed on relative sea-level rise (see: e.g., Figure 3). The susceptibility of any length of shoreline to erosion is determined by the geomorphologic type of shoreline (for example, beaches and barrier splits), and its exposure to waves and storm surge during severe episodic storms.

In addition, the Governor of Rhode Island enacted an Executive Order (98-13) on December 18th, 1998 proclaiming Rhode Island as a "showcase state" for natural disaster resistance and resilience by providing leadership in a public/private partnership to reduce losses from natural disasters for 14 initial topical areas in a framework of a five-year plan (see: Figure 4). Part of the initiative encourages communities to participate in the National Flood Insurance Program as well as supporting the incorporation of natural hazard reduction educational programs, among others. All of Rhode Island's 39 communities have been classified as prone to flooding by the Federal Emergency Management Agency and there are almost 11,000 policies for insurance coverage providing more than $1.3 billion throughout the state (Pogue and Lewis, 1999). Another major coastal concern is the cumulative impact of individually minor alterations, particularly those brought about by residential development, on the water quality of the littoral environment.

Several Rhode Island barrier/headland complexes have been studied over the years to determine patterns in geomorphology (Stauble, 1989; Fisher, 1980). That is, how each area responds to frontal erosion and relative sea-level rise, and what effect these procedures have on the present, and proposed future management of each locale. Frontal erosion for headlands comprised of stratified glacial sediment and for barriers range up to one meter (three feet) a year (Calabro, 1997). Relative sea-level rise based on the Newport, Rhode Island tide gauge is 24 centimeters over a 100 year average (Calabro, 1997). Projections of relative sea-level to the year 2100 of 65 and 100 centimeters have been considered in geologic studies (see: Calabro, 1997). Major objectives were to develop methods that allows for the most realistic picture of future shoreline change, and to compare and contrast those to others prepared in earlier studies of the Rhode Island south shore.

The 30 kilometer (-19 mile) length of the Washington County shore of Rhode Island has been used as an example to illustrate the interaction of people, agencies and geologic processes. Total shoreline berm volume is about three million cubic meters; considered a base volume to use for beach nourishment budgets. Rhode Island's shoreline, including Narragansett Bay and Block Island, is about 340 miles long (ACOE, 1995c). About 82 percent of the shorefront is privately owned, with about 18 percent owned and managed by Federal, State, or town governments. (ACOE, 1995c ), or by conservation groups. Less than five percent of the shoreline has erosion protection structures (revetments, etc.) and an integrated Rhode Island Coastal Resources Management Plan (RICRMP, 1996) forbids most new construction. The RICRMP also includes 30-year setback lines based on averaged annual erosion rates (see later).

Human consequences of relative sea-level rise in Rhode Island coastal counties reflect increasing population densities. Populations of coastal counties potentially affected by relative sea-level rise are projected to increase substantially by 2040. Urbanization dominates Newport and Providence Counties and in general, the south coast of Rhode Island, though to a lesser extent. Rhode Island shoreline populations subject to potential "disruption impacts" of relative sea level rise are increasing rapidly (see: Galagan, 1990; Pogue and Lewis, 1999).

From 1900 to 1980, Rhode Island's total population grew by 26.6 percent. Growth in coastal communities, however, has been significantly greater (R. I. Sea Grant, 1998). During the 80 year timeframe, communities along the south shore and in Narragansett Bay proper have experienced large percentage increases during that period, for example, North Kingstown has increased by 221.7; Barrington by 116.0; Narragansett by 107.3; Charlestown by 67.4; East Greenwich by 57.0, and, South Kingstown by 41.6 percent (RI Sea Grant, 1998). According to IRC (1995) compilations, coastal population increased here by about seven percent since 1980. This indicates that there is ever increasing demand for land, services and recreation, among others, that can lead to conflicting uses among the growing number of stakeholders.

**Geologic Processes Pose Problems for the Rhode Island Coast**

Where tidal waters meet the land a great variety of geologic landforms can be seen. Where a coast is exposed to the physical forces of the open ocean, as along Washington County, typically sea cliffs and wide sand or gravel beaches predominate. In sheltered marine areas, salt marshes and mud flats are common. The estuarine shoreline of Narragansett Bay is composed principally of narrow beaches of cobbles and pebbles that are often backed by an unvegetated bluff of unconsolidated glacial sediment (Boothroyd, 1985).

One of the most visual reminders of any major hurricane, flood, or episodic storm event in Rhode Island is a sudden, dramatic change in the shape of the state's beaches. A visitor to the shore will see that the coastline has retreated sometimes literally overnight, and large amounts of sand has disappeared. As shoreline is lost, the risk of damage to coastal properties increases. The majority of Block Island Sound and lower Narragansett Bay coasts are susceptible to coastal erosion. The amount of erosion from severe episodic storms, which are the biggest causes of change on the shoreline, is directly related to their duration, frequency, and intensity (Boothroyd, 1985).

The shoreline of Southern Rhode Island is characterized by a series of barrier spits and coastal lagoons, and is subject to almost continual change. There are geologic processes that result in erosion of beaches, dunes, and bluffs as well as short term flooding of low-lying areas from episodic storms. Long term inundation of these same areas can lead to saltwater intrusion into water supplies and back-up of septic systems.

A 100-year storm event is one that, in a given year, has a one percent chance of striking. While this may sound unlikely, we have identified such a storm in earlier times, i.e., the great hurricane of 1938. This event led to the construction of the Fox Point Hurricane Barrier between 1961-1966 at a cost of more than $15 million (ACOE, 1995c). During the 1938 hurricane, the storm surge forced water levels 12 feet above mean high water at Point Judith (Narragansett) and more than 13 feet at Providence (ACOE, 1995a&b). Waves 10 feet high and more were measured on top of the surge elevation. Apparently, such events are not rare according to state records. The state has been struck by 73 hurricanes in the past 350 years, 13 of which have caused severe flooding and erosion (RICRMP, 1996). In this century, the 1938 hurricane left 311 dead and nearly 2,000 dwellings destroyed, and in 1954, Hurricane Carol killed 15 people and destroyed about 3,800 houses (RICRMP, 1996; ACOE, 1995c).

Storm waves riding on the abnormally high relative sea-level of a storm surge can cause erosion (inundation), sedimentation and short-term flooding. In the absence of storm waves and storm surges, erosion or flooding does not occur. Consequently, the frequency of storms combined with intensity and duration is important in determining potential for damage, with the period of the late 1960's to about 1991 being "less active" than earlier times (Wilson, 1999). Locally, in the first half of the 1980's the south shore of Rhode Island experienced few severe storms in contrast to the late 1970's. The early 1990's saw an increase in severity of storm events. Storms that pass to the east, in the vicinity of Cape Cod, generate winds and waves from the northeast, an offshore direction for southern Rhode Island but quite problematic for eastern Massachusetts (O'Connell and Leatherman, 1999).

Storms that pass to the west, up the Connecticut River valley, or even in the greater Hudson River valley area as Hurricane Floyd did in September of 1999, generate on-shore winds and waves from the southeast. Sou'easters are the most damaging storms for the Rhode Island coast. Hurricanes are generated in the southern North Atlantic and the wider Caribbean region and may move north to New England following one of the three basic paths-of coastal storms. Again, historically the most damaging hurricanes are those that pass to the west of Rhode Island, the 1938 hurricane passed near the Connecticut River valley (see also: ACOE, 1993).

During quiescent periods sand is returned onshore to the beaches, but not to the dunes. Because of the frequency of storm events which fosters higher wave energy, dune erosion is proceeding landward in southern Rhode Island at an average rate of about one meter (three feet) a year (Boothroyd, 1985). It can be up to seven meters during a single severe storm. The United States Geological Survey characterizes the annual shoreline change for the Rhode Island coast as predominantly "moderately" eroding (Williams, et al., 1995). In general, an average erosion rate of Rhode Island's oceanic shorelines is 0.5 meters per annum (May, et al., 1983). Though, however, when calculating a rate of erosion on specific coastal landform types, i.e., sand beaches, from Massachusetts to New Jersey the rate is as high as 1.3 meters per year (May, et al., 1983).

**Geomorphologic Types and Physical Processes Along the Rhode Island Coast**

Although they are susceptible to erosion, as mentioned, beaches form the first line of defense against ocean waves, providing a buffer between the waves and coastal upland properties. When beaches (berms) are cut back during episodic storms, especially the more severe events that occur in autumn and winter, they progressively lose this buffering ability making further coastal erosion more likely (RI Sea Grant, 1998): It is important to recognize, however, that natural erosion and sedimentation - redepositing of sand and sediment from year to year, depends on such factors as littoral currents, ocean swells and the availability of sediment.

Coastal beaches, are defined in Rhode Island to include expanses of unconsolidated, usually unvegetated sediment commonly subject to wave action. Beaches extend from mean low water landward to an upland rise, usually the base of a dune, headland bluff, or coastal protection structure, pilings or foundation. The dynamic character of a beach is determined primarily by the particle size of the sediment and by the amount of wave and current action. Beaches are formed by sediment that is carried by waves and longshore currents from eroding headlands, from up littoral current beaches in the longshore system, and from the subtidal shoreface portion of the shoreline. Barriers are defined in Rhode Island, as islands or spits comprised of sand and/or gravel, extending parallel to the coast and separated from the mainland by a coastal pond, tidal water body, or coastal wetland. In addition to a beach, barriers have, in most cases, a frontal foredune zone and often, backbarrier dune fields. The lateral limits of barriers are defined by the area where unconsolidated sand or gravel of the barrier abuts bedrock or glacial sediment. This definition of a barrier system is commonly associated with many geomorphic descriptors. These descriptors include, but are not limited to, barrier islands, bay barriers, and spits. Stauble (1989) points out the bayhead barrier system found in Charlestown, Rhode Island may be defined by shape. Spits are further described as tombolo, shingle, cuspate, recurved and flying spits. The terms "bar" and "ridge" were once used to describe a barrier system in Rhode Island, however, they have since been replaced with the term "barrier."

Many of the state's barriers have been mapped and assigned by mandate through the state legislature to the Coastal Resources Management Council (CRMC) into three categories. The barriers or portions thereof designated by the federal government as undeveloped pursuant to their criteria are managed under the Coastal Barrier Resources Act of 1982 (Public Law 97-348), as amended. In these federally designated areas, flood insurance for most forms of construction is typically not available. Briefly, the CRMC was established in 1971 via Chapter 46-23 of the General Laws of Rhode Island. It is the principal body responsible for managing the state's coastal resources and implementing the Coastal Resources Management Plan, which itself was initially approved in May of 1978. The CRMC is composed 17 members appointed by the Governor, the Lt. Governor, and the Speaker of the Rhode Island

House; it must include several local officials representing communities of varying sizes and issues. The CRMC has direct permitting over all activities in the state's coastal waters, coastal wetlands, and on adjacent fast lands.

For regulatory purposes, as stated there are three categories of barriers described in the RICRMP of 1996. Undeveloped barriers are characteristically free of commercial/industrial dwellings, (excepting public utility lines) residential houses, surfaced roads, and structural shoreline protection devices; moderately developed barriers are inherently free of residential houses, commercial/industrial buildings and/or facilities (excepting utility lines) that contain surfaced roads, recreational structures, and/or structural shoreline protection devices. Developed barriers contain houses and/or commercial/industrial structures. They may also exhibit surfaced roads and structural shoreline protection devices (RICRMP, 1996).

Not only do buildings interfere with foredune growth but during severe storm events debris from shattered structures is swept inland, causing additional destruction on the barrier and on adjacent low-lying mainland areas, increasing property damage, and complicating cleanup efforts. As of the mid 1990's, six-five percent of Rhode Island's 27.3 miles of ocean-fronting barriers were undeveloped (RICRMP, 1996). The recreational opportunities and uniquely beautiful open space they provide are of growing importance in an increasingly developed southern New England region.

In Rhode Island, coastal cliffs and bluffs are defined as elevated landforms on headlands directly abutting either coastal waters, a beach, coastal wetland or a rocky shore. Coastal cliffs and bluffs include a wide variety of headland landforms ranging from low bluffs with scarps cut in easily erodible glacial river or lake sediment, or in glacial till, to the dramatic bedrock cliffs of Newport and Narragansett. They are among the most scenic coastal features and are the sites for popular scenic overlooks.

Dunes in Rhode Island are defined as elevated accumulations of sand formed by aeolian processes i.e., wind action. Dunes which are undisturbed appear as hills, mounds, or ridges of sand and are typically vegetated with beach grass and shrubs. The more or less continuous ridge of dunes parallel to, and just inland of the beach is termed the "foredune zone."

For management purposes the seaward limit of the foredune zone is defined as: (1) the furthest seaward point where a noticeable sustained increase in topographic slope begins, or (2) the furthest seaward extent of rooted vegetation in the immediate area, or (3) fifteen feet seaward of the dune crest, whichever is further seaward. The inland edge of the foredune zone is defined as twenty-five feet landward of the dune crest (RICRMP, 1996). It is from the inland edge of the foredune zone that all development setbacks and coastal buffer zones are applied (see later).

The foredune zone is a dynamic feature similar in nature to beaches. While beaches are shaped by the forces of waves, the foredune is created and shaped primarily by the wind and storm surge events. The foredune zone dissipates energy from waves and storm-surge overwash. This results in decreased wave runup and lowered levels of overwash water. Thus, the foredune zone serves as a buffer to help minimize upland property loss during episodic storm events. As reservoirs of sand, the foredune zone provides some sediment to severely eroding beaches. The height and stability of foredunes is enhanced by the growth of beach grass which traps and anchors windblown sand. Although resistant to salt air, beach grass is easily killed by human foot traffic. The shape or form of the foredune zone is of paramount importance. The seaward facing slope of the foredune, termed the dune ramp, naturally forms at the same gradient as the seaward slope of the berm (usually 5-10 degrees). This low gradient surface serves to dissipate and absorb wave energy. Higher gradient slopes on human-altered foredunes often do not absorb the wave energy, the non-absorbed waves erode the foredune and are reflected seaward transporting sand offshore.

Shorefront beaches along the south coast of Rhode Island are often backed by coastal lagoons contained behind relatively narrow, 200 -- 300 meter wide barrier spits in a microtidal, wave-dominated environment (Boothroyd, et al., 1985). The coastal ponds found here are typically narrow shallow lagoons with a fringing reef. The barrier-lagoon systems on the Rhode Island coast as a whole are microtidal, wave-dominated, sediment-starved, and have small tidal prisms (Boothroyd, et al., 1985).

From Boothroyd et al., (1985) the major depositional environments within the lagoons, which are altered by meteorological forcing are: (1) flood tidal deltas; (2) subtidal storm surge platforms; and (3) back-lagoon, low energy basins. The pathways of sediment influx from coastal geologic processes into the coastal lagoons are: (1) tidal inlets (breachways); (2) temporary storm surge channels cut through the barrier spits; and (3) overwash transport of sand that crosses the spits and builds into the lagoons. Sediment transport in the lagoons is caused by water currents generated by wind shear within the lagoon basins and by storm surge generated flow, both of which may be additive to tidal currents. The continued existence of the lagoons is dependent on rate of infill and barrier retreat versus the rate of relative sea-level rise. Based on long term relative sea-level rise - the past 2,500 years for tidal delta sedimentation - calculations indicate that the lagoons will decrease in size as sediment influx exceeds the rate of inundation (Boothroyd, et al.,1985).

As suggested, the Rhode Island coast is considered microtidal with a less than two meter mean tidal range, has low to moderate wave energy impacting on the barrier spits, a mean wave height of 80 centimeters, and is classified as wave-dominated mixed energy (Boothroyd et al., 1985). The natural tidal inlets through the barrier spits are typically narrow and shallow being less than one meter deep. They also close intermittently because long shore transport of sand tends to seal the inlet openings. Discharges of the small tidal prisms into and out of the lagoons are not large enough to keep the inlets open. But all of the larger lagoons now have inlets (called breachways in local terminology) stabilized by jetties constructed in the 1950's and 60's (see: ACOE, 1995c). The stabilized inlets are wider and deeper than were the natural inlets. The largest is Point Judith breachway, in the 1980's being 75 meters wide and up to nine meters deep, which serves the fishing port of Galilee (Boothroyd, et al., 1985).

According to NOAA data, the mean tidal range on the ocean side of the barriers is 1.1 meters with a spring range of up to 1.6 meters. The tidal range inside the lagoons extends from only seven to ten centimeters (mean) to 16 centimeters (spring) because of inlet constriction (Boothroyd, et al., 1985). The exception is Point Judith Pond, where the lagoon and open ocean ranges are similar due to the wide, deep, stabilized inlet (see: ACOE, 1995c).

**Development setbacks from the shore (RICRMC)**

Throughout coastal Rhode Island, multiple setbacks are employed to protect foredunes, coastal features such as beaches, dunes, bluffs, and rocky shores along Narragansett Bay, in order to reduce loss of life and property in designated coastal hazard areas. They are also used to reduce public expenditures for infrastructure and flood disaster relief on barrier islands and beaches.

In Rhode island setbacks are required state-wide 50 feet from coastal features or 25 feet from coastal buffer zone. There are exceptions for water-dependent activities. A calculated 30-year erosion rate allows up to four units to be built, a 60 year erosion rate is employed for siting larger structures in critical erosion areas as established in Section 140 of the CRMC Program. Larger setbacks may be required based on an assessment of the site conditions and other concerns relative to the proposed project. All dune setbacks should be measured from the inland edge of the dune or dike. No development is allowed on the beach face, sand dune, and on undeveloped barrier beaches. Exceptions may be allowed for stabilization, public access, and some public utilities. Access ways may be allowed over the dunes in order to facilitate pedestrian public access to the beach, a requirement of the Coastal Zone Management Act of 1972, as amended (Pogue and Lee, 1999).

Along with weather and good water quality, the "health " of Rhode Island's beaches determines the fitness of the large coastal tourism economy of the state. Two equally important goals of most municipalities is having a wide enough beach to provide for adequate public recreational opportunities for beach goers together with sufficient beach width for protection from hurricanes and episodic storm events. Because of relative sea-level rise, development practices, and inadequate beach width since the early 1980's, Rhode Island embraced setbacks, rather then beach replenishment, as its primary choice or method of upland shore protection in contrast to New Jersey, for example (see: IBHS, 1998). Although according to IBHS (1998), Rhode Island in terms of state land use planning laws, hazard mitigation is neither a required nor suggested element, however, cities and towns necessarily are to manage coastal features, flood plains, and wetlands (see: Appendix A: Summary of State Land Use Planning Laws).

Individual Sewage Disposal Systems, i.e., septic tanks have the potential to become buoyant or be damaged during a severe storm event causing raw sewage to spill onto the beach. Therefore, no new Individual Sewage Disposal Systems can be constructed within the setback area. Repairs should, whenever feasible, be located outside of the setback area (RICRMP, 1996).

One of the most serious problems which faces the Rhode Island coast stems from the disconnect between sustainability encompassing beach nourishment and the "retreat" policy set forth in the RICRMP. In the face of relative sea-level rise and the consequences of past development practices, the attempt to use beach nourishment and artificially enhanced dune building to move the beach profile seaward to compensate has long term noteworthy implications.

Factors favoring the retreat option include: 1) high measurable recession/erosion rates, 2) increased relative sea-level rise rates over time, and 3) locally limited sources of sand available for beach nourishment purposes. All three are pertinent for the Rhode Island shoreline. Factors favoring stabilization through nourishment include: 1) the increasing values of shorefront property with time -as was noted earlier, 2) protection of valuable upland structures and infrastructure, and 3) maintenance of habitat for endangered species, such as piping plovers in Washington County. Indeed, these factors also are present. The dominant factors that stress maintaining policy response options flexible include uncertainties in what the future will bring and the associated time scales.

Relating to coastal construction control areas more can be said about Rhode Island. The Rhode Island Coastal Program is an example of a strong regulatory program with defined criteria addressing identified resources, activities, and management issue areas. Activities are regulated within and 200 feet landward of defined coastal features --coastal beaches and dunes, barrier beaches, bluffs, cliffs and banks, rocky shores, and man-made shorelines. Complex coastal zoning designates what types of activities are permissible on shoreline features, tied to six state water classifications. About 75 percent of the shoreline is adjacent to Type 1 Waters (Conservation) or Type 2 Waters (Low Intensity Use Areas) where alteration or construction or shoreline features and undeveloped barrier beaches is prohibited. In addition, activities are regulated by different setbacks from beaches and dunes, critical erosion areas, and coastal buffer zones (Bernd-Cohen and Gordon, 1998; RICRMP, 1996).

There are also regulations for specific types of activities (such as dredging, filling, new residential structures) as well as 17 designated coastal hazard areas and 18 identified erosion-prone areas. On barrier beaches, all residential and non-water dependent structures on dunes destroyed > 50 percent may not be reconstructed regardless of insurance carrier coverage. Additions are allowed only to structures designated priority permissible uses. The regulatory jurisdiction for state construction control area is inland 200-feet from coastal features -beach,-dune, coastal bluff, rocky shore, etc. In effect, Rhode Island has complex regulations with exceptions tied to water type and priority uses.

Regarding statewide shoreline stabilization regulations, that is, erosion control devices designed to harden the shoreline, Rhode Island prohibits new structures on lands along type 1 waters. Basically, provisions in Rhode Island indicate that structures (seawalls, rip-rap, revetments, groins and jetties) are allowed with a permit on type 2-6 waters, but applicants must exhaust all nonstructural alternatives. Structures that were built prior to the implementation of the CRMP are allowed to be maintained, but a new permit must be acquired if more than 50 percent of the structure is destroyed. Limitations on the use of riprap to protect septic systems and ancillary structures are also in effect. Permitted structures must demonstrate that erosion exists, that the structure will control erosion, that nonstructural devices are ineffective, there are no reasonable alternatives, and that they will not increase erosion. Further, it must be demonstrated that they will be part of a long-term solution coupled with a financial commitment to a maintenance program. For repair or reconstruction of shoreline stabilization structures damaged > 50 percent requires a new permit (Bernd-Cohen and Gordon, 1998; RICRMP, 1996).

Rhode Island uses a state coastal tracking permit system begun in 1987, with upgraded and input permit data back to 1971. Unfortunately this permit tracking system is of minimal value in assessing resource protection. The CRMP tracks permit data by activity type but not by coastal feature location such as beaches, bluffs, rocky areas, and so fourth. The permit data does not reflect setback or pedestrian access, for example. CRMP policies prohibit new development on undeveloped and moderately developed barrier beaches, and the data indicates that two-thirds of the barrier beaches have had no new permitted development since 1971 (Bernd-Cohen and Gordon, 1998).

Likewise no new shoreline stabilization devices were permitted on undeveloped or moderately developed barrier beaches since 1971. It does impose violation fines and fees within the auspices of the statewide Coastal Resources Management Council (CRMC). The CRMC is the follow-up agency on every cease and desist order and notice of violation. Rhode Island does not delegate local permit and or local planning for the protection of beaches, dunes, bluffs and rocky shores.

**Discussion: For Whom to Save the Beach?**

Saving the shorefront involves managing not only the beach but also the foredune zone; backbarrier flats; headland bluffs; the upper shoreface, wetlands, and tidal inlets/tidal deltas, among other physical features found there. For whom refers to stakeholders such as, shoreline home and commercial business owners, commercial and recreational fisherfolk, as well as both non-resident and Rhode Island beachgoers, coupled with other state taxpayers. In addition, as has been noticed elsewhere, non-human stakeholders for conservation biological-diversity purposes would include both indigenous and introduced flora and fauna life.

Stakeholders who support or oppose policies which may expose populations to coastal erosion and relative sea-level rise include energy; commercial; financial; industrial; public agency; private interest; and governmental organizations. These organizations respond to extreme events from differing political postures. Vested interests determine the degree of mitigation employed by stakeholders to defer impacts of relative sea-level rise and concomitant erosion.

A 1978 survey of the Narragansett Bay proper shoreline revealed that along 25 percent of the shore natural features have been displaced by anthropogenic structures. Many of these have been built since the 1954 hurricane as attempts at "erosion prevention," and were undertaken at great cost by private property owners. Many will not survive a major hurricane that strikes the coast from the south. Many structures are overbuilt for the control of minor erosion between severe storms. Anthropogenically altered shorelines usually have a major impact on the appearance of the shore, interfere with public access to and along the coast, and may alter erosion-accretion processes on neighboring beaches.

**Further Comments on Coastal Planning**

As a supplement to the regulatory program for specific locales, Rhode Island employs use of Special Area Management Plans (SAMP's). Two of the SAMP's cover oceanfront areas. The principal focus of SAMP planning in Rhode Island has been on cumulative and secondary impacts of development in, and adjacent to, poorly flushed estuaries, nonpoint source pollution, groundwater contamination, and on-site sewage disposal systems. Overall, the Rhode Island Coastal Program adopted four SAMP's as a supplement to the regulatory program for specific areas. The Salt Pond Regions SAMP covers 32 square miles. In the mid-1980's less than 12 percent was in public ownership yet as much as 50 percent was undeveloped (Bernd-Cohen and Gordon, 1998).

The SAMP expands the inland boundary to include a watershed; establishes coordinated permit review procedures; amends policies for dredging in Ninigret and Green Hill Ponds to allow dredging in Type 2 waters; and changes water use designations for Port of Galilee to allow port expansion. It also specifies dredging of navigational channels and restoration of overwash channels, and requires disposal of sand dredged materials to replenish the following adjacent beaches -Sand Hill Cove, East Matunuck, Charlestown Beach and Quonchontaug barrier beach. It prohibits, for beach restoration, mechanical removal or redistribution of sand from the intertidal zone of the beach, to increase the profile of the beach scarp, or to construct artificial dunes since they destabilize beaches -increasing erosion along beaches and sedimentation in ponds. It specifies how beach sand shall be placed on the beach and identifies priority areas for acquisition. The SAMP plan sets density limitations for "self-sustaining lands" arid "lands of critical concern." Subdivisions in these areas cannot exceed more than one residential unit per two acres and sewers are prohibited. The goal is to keep residential development low rather than for nitrate pollution prevention in the ponds (RICRMP, 1996).

In the State of Rhode Island and Providence Plantations the situation is more top-down and complex, as indicated earlier. Required is a state Coastal Resources Management Council (CRMC) permit (assent) for activities inland 200 feet from a coastal feature which encompasses beaches and dunes; barrier beaches; coastal wetlands; coastal bluffs, cliffs and banks; rocky shores; and manmade shorelines. The CRMC also regulates seven categories of activities inland of the shoreline features, including: power-generating facilities; petroleum storage; chemical & petroleum processing; mineral extraction; sewage treatment; solid waster disposal; and desalination plants (Bernd-Cohen and Gordon, 1998; RICRMP, 1996).

CRMC permits are tied to zoning of uses adjacent to state: waters classification areas (Type 1-6); coastal shoreline features protection; and regulated activities. For coastal beaches and dunes, construction on beaches adjacent to Type 1 and Type 2 waters and undeveloped dunes is prohibited. Exceptions are made for beach protection, restoration, renourishment and some existing shoreline structures. On dunes, as noted the CRMC regulates specific setback requirements. Setbacks are measured from the landward edge of the foredune zone defined as 25 feet landward of the dune crest. Alteration of foredunes adjacent to Type 1 & 2 waters is prohibited, except for non-structural protection & restoration, and accessways to beach. Alteration adjacent to Type 3-6 waters is permitted if designated priority use with alternatives are considered.

For all barrier beaches, new infrastructure is prohibited, for undeveloped barrier beaches, construction/alteration was prohibited. Only nourishment, dune stabilization, and natural features protection are permitted. On developed barrier islands, new construction is prohibited on barriers on which only roads, utility lines, and infrastructure was present as of 1985. On moderately developed barrier beaches, new development is prohibited with exceptions made for restoration and preservation, existing infrastructure, and existing recreation may be maintained, expanded and rebuilt if destroyed (Bernd-Cohen and Gordon, 1998). As stated earlier, shoreline stabilization structures are regulated by the CRMC. Apparently, as of 1994, state comprehensive planning was adopted which requires local planning and regulation, irrespective of the Rhode Island Coastal Zone Management Plan. About 75% of the shoreline is adjacent 1:0 Type 1 Waters (conservation) or Type 2 Waters (low intensity use areas) where alteration or construction of shoreline features and undeveloped barrier beaches is prohibited. Moreover, activities are regulated by different setback diameters from beaches and dunes, critical erosion areas, and Coastal buffer zones.

**Summary Points: Rhode Island**

Beachfront property along the coast of Rhode Island, as elsewhere, is subject to a variety of natural hazards. Among the most prevalent hazards are those of flooding from storm surges, wind damage from hurricanes and severe episodic storms, as well as short and long term coastal erosion. There is a modern prevalence worldwide for beach erosion. The severity of the impact of these natural hazards generally decreases as one moves inland from the land/sea interface. Consequently, state and municipal building code regulations and property insurance rates, both of which relate to an estate's exposure to natural hazards, vary significantly principally based on a structure's location relative to the shoreline. Dependable and consistent identification of the shoreline as a physical landform and its movement over time results in a more reliable cataloging of the extent of threats from coastal geologic hazards and processes. Individual businesses, and governments make development and investment decisions regarding land use of shorefront and waterview property utilizing accurate coastal hazard data.

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