TO

Baxter Road Long-Term Planning
Summary of Findings

Vincent Murphy on behalf of Select Board and Town Administration of Nantucket

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PROJECT NUMBER
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Photo credit: Jennifer Lachmayr, Arcadis (Aug 8, 2021)

Contents

APPENDICES

1. Introduction

Arcadis was engaged by the Town of Nantucket to lead an alternatives analysis for the unique Baxter Road area, located along the Siasconset (Sconset) bluffs. The assessment, entitled "**Baxter Road Long-Term Planning**" included an alternatives analysis for technically feasible solutions to address bluff and toe erosion in the area.

Historically, the bluffs have been subject to periodic erosion, and the rate of bluff erosion is expected to be exacerbated by sea level rise (SLR) and increased storm intensity due to climate change.[1] Over time, the upland area behind the bluffs has been developed with residential uses and supporting infrastructure including roads and utilities. With ongoing bluff erosion, the homes and infrastructure are or will soon be at risk.

Over the years, the Town, property owners, and the public have debated the best long-term solution for the erosion in this area. Groups of involved residents have commissioned copious studies and implemented a series of interventions intended to address erosion concerns. Currently, the erosion protection methods being used include:

- Sand Nourishment
- Maintenance activities such as management of drainage
- Vegetation for bluff stabilization (where the slope allows)
- Sand-filled jute-fiber bags at the bluff's toe
- Geotextile tubes (geotubes) along a high-risk portion of the bluff

Of these existing interventions, the geotubes are the ones at the center of the ongoing debate, running 947 ft alongshore from 87 to 101 Baxter Rd (protecting 2 houses and that portion of the road and infrastructure). Homeowners to the north and south of the geotubes have been striving to have them expanded since their emergency installation process began in 2013. Since then, there have been a long series of notices of intent and appeals. While geotubes are often considered "softer" than other shore protection alternatives such as riprap (stone revetments) or seawalls, they still may be considered hard armoring, which is restricted by the Massachusetts Wetlands Protection Act and the Nantucket bylaws.[2] There are challengers to the spectrum of stabilization alternatives due to concerns such as sand source and quality, aesthetics, beach access, potential environmental impacts, and unintended consequences such as sand migration, deposition and downdrift erosion.

The intent of this study was not to debate the use of geotubes, but to assess a range of innovating alternatives and their feasibility within the area. However, as the geotubes are an existing system, they must be considered in this assessment. Analyses were completed with the existing system in place for most alternatives, with a single variable changing each iteration.

The Town also wished to explore the range of perspectives, priorities, life cycle costs, and preferences within the community. For this reason, strategic stakeholder engagement was crucial from the outset of the project. To prevent damage to existing infrastructure there is a clear need to maintain and increase protection, while planning for eventual retreat. There are a multitude of sensitivities and complexities within these issues, and this memo aims to capture the key ones. However, the focus here is on the alternatives and recommendations.

In late June 2021, the Nantucket Conservation Commission voted to remove the geotube project after finding that the permit requirements were not being met, most recently for a lack of required sand nourishment.[3] Removal of the current system and replacement with another form of toe stabilization will have environmental and cost impacts. It will take time for the system to establish a new dynamic equilibrium. If the geotubes are removed without any plan or protection in place, each violent storm will lead to further bluff collapse. Potential consequences will leave the

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[1] https://www.nantucket-ma.gov/1977/FEMA-Coastal-Erosion-Hazard-Map
[2] Chapter 67 of the Nantucket Bylaws pertains to coastal management https://ecode360.com/12120302
[3] https://www.ack.net/stories/concom-orders-sbpf-to-remove-geotubes-from-sconset-beach,24933

Town and the community exposed to a range of risks including damage to roadways and utilities, emergency and public access limitations, and environmental impacts from damage to residential properties. It is likely that this removal decision will be appealed, and efforts have been proposed to make up the sand shortfalls.[4]

1.1 Baxter Road Long-Term Planning Goals and Scope

The goals of the project are to:

1. **Compare technically feasible alternatives** - Bluff protection (which is required to protect public infrastructure and buildings) cannot be achieved without toe stabilization. Therefore, all alternatives that provide bluff protection include toe stabilization.
2. **Develop a prioritized action plan** for adaptation over time, based on the alternatives analysis and stakeholder engagement.
    - The engagement process was integral to the project because stakeholders have been divided for decades on how to address or to adapt to erosion risks in the area. There are erosion risks related to the economy, ecology, development, infrastructure, and public safety.

Reaching consensus among the stakeholders is a very challenging goal, with the interested parties having strong opposing visions of desirable outcomes. This is discussed in further detail in Section 3. Stakeholder Engagement.

The project tasks were designed to provide an overview of near-term actions and longer-term critical decision points which the Town can use to focus investments, depending on changing conditions. The work completed includes:

1. Compiling and reviewing existing information
2. Engaging stakeholders
3. Analyzing alternatives
4. Developing this summary of findings memo

Caveat: The study is not a comprehensive study of the coastal processes in the area or an engineering study to design any particular intervention. Section 2.2 outlines how existing information was compiled, as it was the key data source for the assessment.

The study area includes Baxter Road and related public infrastructure from the Sankaty Head Lighthouse to Butterfly Lane in Sconset, including the adjacent private parcels (Figure 1).

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[4] https://www.ack.net/stories/concom-gearing-up-for-expected-sbpf-appeal,25646

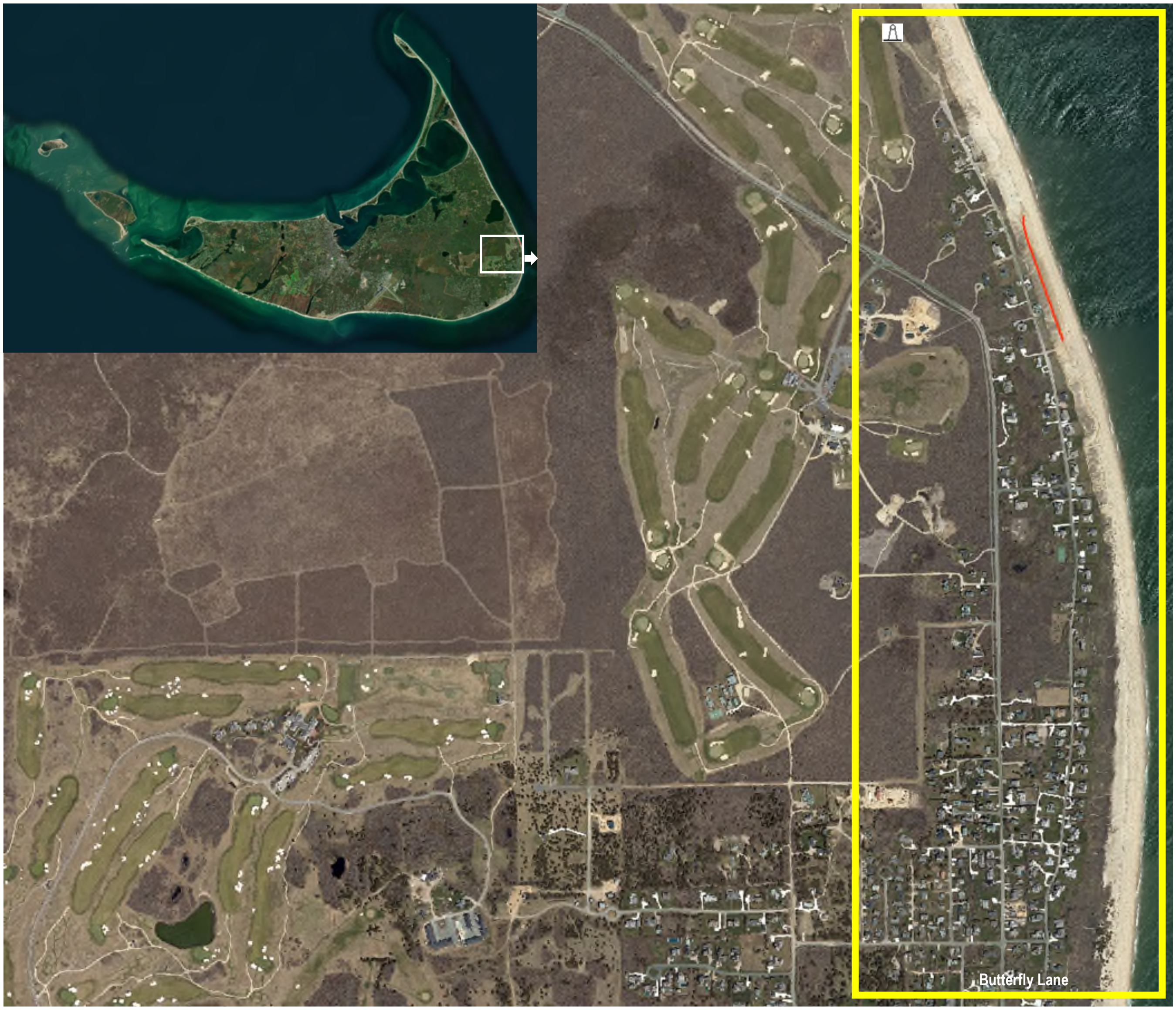

Figure 1: Study area along the coast, with Sankaty Head Lighthouse to the north and Butterfly Lane to the south and present geotubes outlined in red.

1.2 Coordination with and Relationship to the Town's Coastal Resilience Plan

The planning process for the Baxter Road Long-Term Planning Project (Project) was undertaken concurrent with the ongoing island- and county-wide Coastal Resilience Plan (CRP). The alternatives analysis, stakeholder input, and overall project continue to inform the CRP, particularly around coastal resilience solutions for the Sconset area of the island. This Study also provides a template for similar focused study that may be necessary elsewhere on the island to refine the resilience solutions under development through the CRP. The Draft CRP was published September 24, 2021 and includes targeted risk reduction projects for Sconset. Projects in the Baxter Road area, based on the alternatives analysis presented in this Summary of Findings have been included in the CRP. The Baxter Road Relocation project and Sconset Bluff Nearshore Breakwaters Feasibility Study are listed as Priority 2 projects with estimated project deadlines by 2030 and 2025, respectively. Additionally, an Island-wide Sediment

Transport Study and Sediment Budget are listed as Priority 1 projects with estimated project deadlines of 2024 for both projects.

1.3 Project Mission Statement

The project team developed a mission statement based on the scope of work and understanding of the planning context for this area. This statement was further refined based on input from stakeholders:

The Baxter Road Long-term Planning Project will create a community-supported actionable roadmap to implementation of short- and long-term solutions for the Baxter Road area that help the community respond to rising seas and eroding coastlines through adaptation practices such as protection, accommodation, shoreline retreat, or no action.

2. Past, Present, and Future Conditions: Erosion Hazards and Interventions

Previous shorelines, transects, and shoreline stabilization structures data were reviewed using the Commonwealth of Massachusetts Office of Coastal Zone Management (CZM) MORIS tool to determine past erosion processes and rates.[5] The islands of Nantucket are very prone to erosion due to their geologic history of being formed by loose sediments and rocks deposited as glaciers retreated after the last ice age (~18,000 year ago)[6]. The bluffs along the study area have the highest elevations in the island, over 70 ft above sea level.

As a large portion of the homes along Baxter Rd. were built between 1900 and 1920[7], it is historically and architecturally significant. The area has a bluff walk, a historic lighthouse, and a long stretch of beach accessible to the public. Presently, the homes and other assets are at imminent risk due to erosion. Siasconset's bluffs have eroded over 100 ft in places between 1990 and 2014, which averages to over 4 ft per year.[8] With future SLR, bluff erosion rates are anticipated to continue their general increase.[9] The retreat of the bluff has led to the costly (minimum $500k each) relocation or removal of several homes, as well as the approximately $4,000,000 relocation of the lighthouse, over time. In a previous Town study, consultants Milone & MacBroom recommended that the road should be relocated when the top edge of the bluff was within 25 feet of the road.[10]

Figure 2 presents a timeline of events, with those related to intervention attempts on the top and main erosion-inducing storm events on the bottom. While this timeline begins in 2010, there is a history of coastal storms causing erosion (results of engagement surveys called out storms occurring in 1992, 1993, and 2005 as particularly notable). As each event caused the bluff to retreat further, homeowners came together to explore alternatives. A 2006 alternatives analysis explored a range of structural, stabilization, and nourishment options, as well as retreat and

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[5] http://maps.massgis.state.ma.us/map_ol/moris.php

[6] https://pubs.usgs.gov/of/2011/1222/html/setting.html

[7] https://www.nantucket-ma.gov/AgendaCenter/ViewFile/Agenda/_10282020-9210

[8] June 2020 Woods Hole Siasconset Beach and Bluff Surveys (Semi-annual beach and bluff surveys from 1994 to date), 2018 Post-Storm Surveys, and the 2020 Town of Nantucket Coastal Risk Assessment and Resiliency Strategies https://thetrustees.org/content/state-of-the-coast-the-islands/ (p.31)

[9] https://www.nantucket-ma.gov/DocumentCenter/View/35045/Coastal-Risk-Assessment-and-Resiliency-Strategies-Report-January-2020-PDF

[10] https://records.nantucket-ma.gov/WebLink/ElectronicFile.aspx?docid=118657&dbid=0&repo=TownofNantucket

no action.[11] The report concluded that bluff toe stabilization with geotubes were a preferred alternative. It stated that they were feasible despite the Wetlands Protection Act because many homes were grandfathered before the act was enacted in 1978.[12] In 2013, emergency authorization and permits were issued, and a Memorandum of Understanding (MOU) was reached between the Town and the Siasconset Beach Preservation Fund (SBPF). The geotubes were designed and installed from 2013 to 2015 and included a requirement for dune nourishment targeted to be 22 cubic yards per linear foot per year (cy/lf/yr). The MOU included failure criteria related to sand nourishment volumes, monitoring, maintenance, and repairs. If the criteria are not met, SBPF must pay for removal of the geotubes.[13] The required sand volumes have been a challenge to maintain since 2016, due to shortages and price constraints (the cost has increased from $20 to $75-$90 per cubic yard). There has been discussion about the variations in how erosion rates are calculated, with many estimates for volume requirements being below 22 cy/lf/yr.

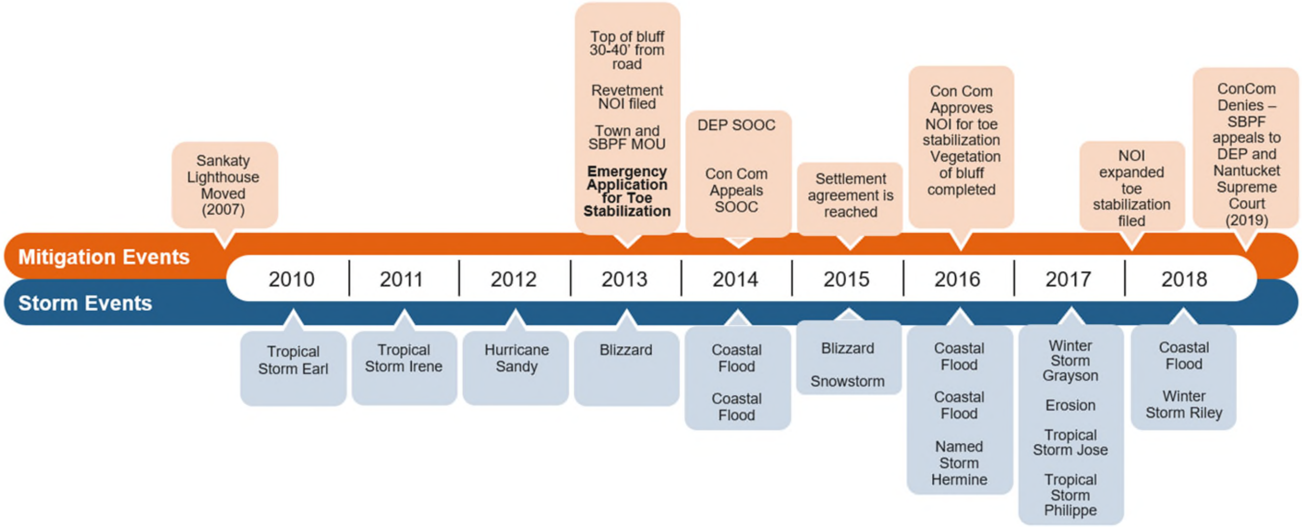

Figure 2 Timeline of recent storm and mitigation events related to the project study area [14]

Projected sea level rise is expected to increase the rate of erosion across much of the island. While estimating the effects of SLR on erosion rates is an evolving science, analysts have begun to develop methodologies for estimating potential changes. In 2019, FEMA developed Coastal Erosion Hazard Maps that provide a key dataset for estimating future conditions. These data (Figure 3) show projected coastal erosion hazard areas for 2030, 2050, and 2100, providing a baseline understanding of current and future erosion zone delineation for multiple sea level rise (SLR) scenarios. The FEMA future erosion lines in Figure 3 are based on the 2012 NOAA Intermediate High

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[11] 2006 U.S. Army Corps of Engineers Sconset Beach Nourishment Project Alternatives Analysis by Epsilon Associates, Inc. in Association with Woods Hole Group, Inc.

[12] The Wetlands Regulations at 310 CMR 10.30(3) provides, in part, that a coastal engineering structure 'shall be permitted' when required to protect buildings constructed prior to 1978 from storm damage. http://sconsetbeach.org/wp-content/uploads/2014/12/DEP-decision-regarding-2014-Con-Com-appeal.pdf

[13]

[14] NOI stands for Notice of Intent, MOU for Memorandum of Understanding, SOOC for Superseding Order of Conditions, DEP for Dept. of Environmental Protection, ConCom for the Nantucket Conservation Commission, and SBPF for the Siasconset Beach Preservation Fund

SLR projections, which project 4.1 ft MSL by 2100.[15] This is important to note because more recent SLR projections are significantly higher.

Based on these projections, there are 70 residential buildings and several miles of road and infrastructure (water, sewer, drainage, electric, phone, internet, and cable utilities) at risk from erosion. The FEMA methodology specifically did not account for geotubes or any other coastal engineering structures. Any existing structures were removed from the input data and hazard areas were interpolated across the surrounding predicted area. The analysis was performed by classifying different shoreline types (Sandy Dunes/Beaches, Coastal Bluff), obtaining shoreline and bluff edge data spanning 1846 to 2010, to develop a linear regression rate for erosion. Projected erosion rates were modified by a SLR increase factor. The results indicate that erosion rates are not uniform across the study area, and generally decrease moving to the south. It should be noted that these projections do not include shoreline protection measures such as toe protection or nourishment activities.

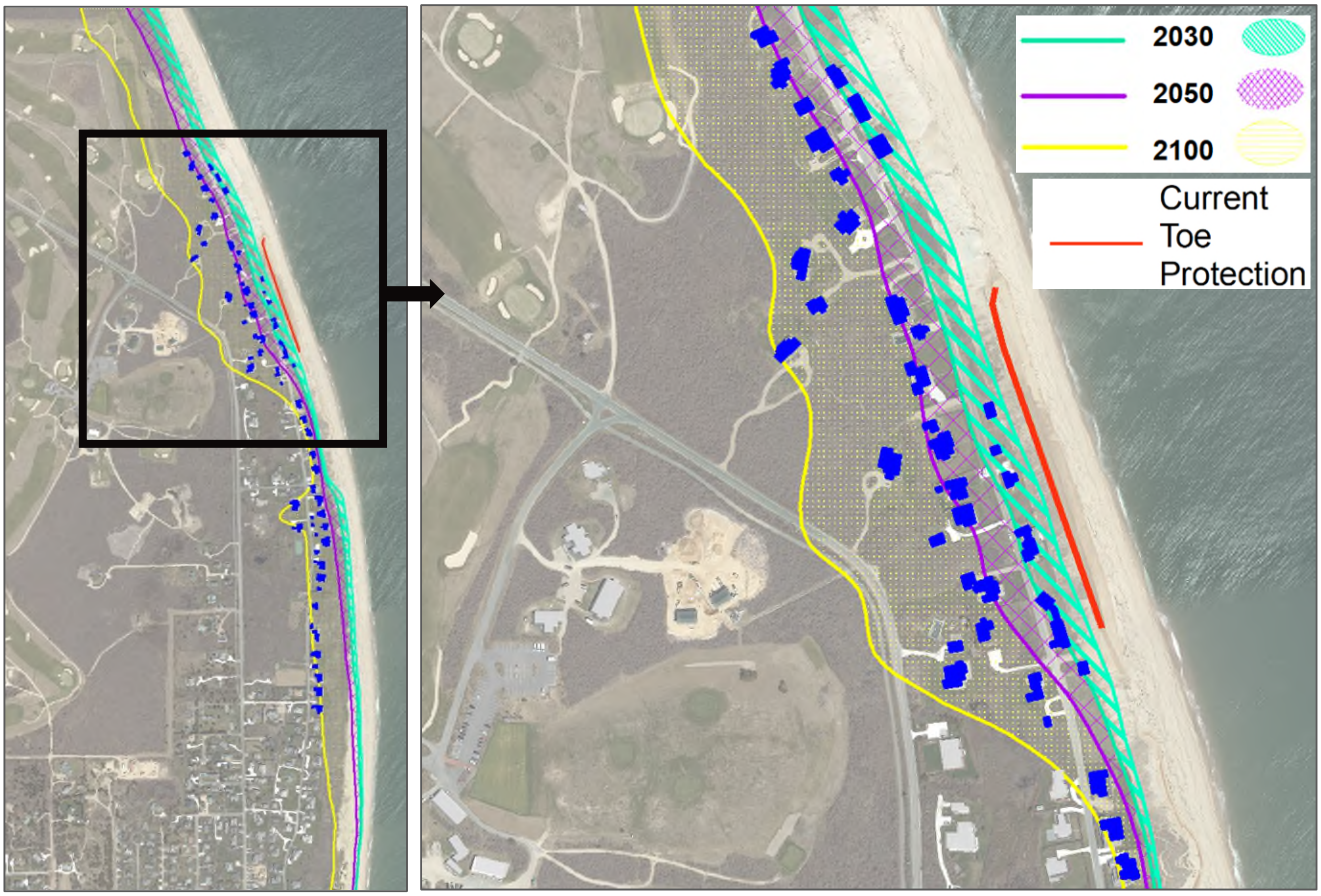

Figure 3: The 70 buildings which are projected to be at risk by 2100 are shown in blue based on FEMA Coastal Erosion Hazard Maps from July of 2019 (Source: https://arcg.is/1fuXXD0)

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[15] Relative to Local Mean Sea Level (MSL), starting from 2010, based on the USACE SLR Calculator https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html

2.2 Review of Existing Information

The Town has maintained a record of documents related to Baxter Road as a publicly available archive on the Town's website, most of which are dated after 2010.[16] These documents contain, but are not limited to, the following:

1. Previous analyses and planning studies
    a. Coastal, financial, and permit-related
2. Memos and updates
3. Homeowner submitted documents
4. Public meeting documentation
5. Permit applications

In addition, stakeholders engaged for this project were asked to fill out a registry form and to provide any additional documents which would be important for the Project Team to review.

A registry containing over 450 documents related to Baxter Road was compiled for this project. The project team completed a review of these documents and referred to them, as relevant, to understand the history of the Baxter Road project, review prior work, and in the process of developing adaptation alternatives.

The engineers leading the alternatives analysis focused on technical reports and monitoring data from private firms and public agencies, including the Woods Hole Group and USGS. These resources were reviewed with the goal of developing a clear understanding of the research to date. Many reports summarized the findings of field data analysis and various interpretations of the raw data representing the performance of the current shore protection system. When appropriate, team members reached out to the authors for additional clarification on survey methods and analysis techniques. Several conclusions and recommendations were considered and integrated, as were parameters and information on sediment characterization and shoreline analysis island-wide. For example, recommendations regarding continuing the field monitoring campaign were incorporated into the considerations for all the alternatives.

3. Stakeholder Engagement

The stakeholder engagement process was intended to keep the community involved throughout the project and to ensure that their ideas and concerns were addressed where possible. The project team mapped out how each alternative would be selected by integrating performance-based design criteria vetted by stakeholders. A unified set of criteria were used to outline the selection process in a fact-based way. The team wanted local context to aid in identifying appropriate criteria related to coastal processes, economic factors, and ecological considerations.

Based on the initial discussions, the team focused on:

- Acknowledging all groups for how hard they have worked up to this point and validate concerns.
- Identifying common interests and goals.
- Identifying what solutions are working around Sconset.
- Identifying what stakeholders need from the process to support the outcomes.
- Seeking input on potential compromises.

For the first meeting, it was important for stakeholders to review and understand the project scope, provide feedback, and provide their perspectives.

A survey was sent out before the first meeting to collect initial information on perspectives and concerns. With the open-ended questions, respondents were referencing the tensions between opposing views. Many respondents

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[16] https://www.nantucket-ma.gov/DocumentCenter

were worried about their home and access to utilities, access for emergency services, and economic impacts from loss of property taxes. Others saw a need to address sediment contributions and prevent property owners from seeking structural solutions to hold the shoreline. They felt that the owners were putting the interests of themselves ahead of the island's interests and worried about impacts to other parts of the island. It was clear that for each resident, their passion stemmed from love for their community and a desire to preserve their vision for the future.

It was concluded that initially, the participants for each meeting should be grouped based on perspectives and background. The Town identified groups of interested individuals and groups for participation, and they were placed into Focus Groups as described in Table 1.

Table 1. Stakeholder Focus Groups

Magenta Group	**Orange Group**	**Town Group**
Nantucket Land Council	The 'Sconset Trust	Town of Nantucket department representatives
Nantucket Coastal Conservancy	'Sconset Beach Preservation Fund	Coastal Resiliency Advisory Committee (CRAC)
Quidnet Squam Association	Sankaty Head Golf Club	Nantucket Select Board
Mass Audubon*	Sconset Civic Association	
Greenhills		

*Mass Audubon has not taken a policy position on the project and participated as a neighbor and an interested party.

The Magenta group included interested conservation organizations, and expressed concerns related to potential environmental impacts, beach access, and sand sources. They were concerned about environmental impacts and aesthetics including the cobble bottom habitat for fish, sand quality, sand source/migration impacts, and the bluff walk. This group took a hard stance that fighting Mother Nature is a losing strategy and that the bluff erosion should be the beach nourishment. They had been advocating for the removal of the existing system (the geotubes).

The Orange group was made up of many homeowners who would directly benefit from bluff protection. 'Sconset Beach Preservation Fund (SBPF) has spent over $12M on the current system and is eager to expand it to afford greater protection. Much of these funds have been provided by homeowners who have been anticipating the expansion to provide protection to their homes. This group felt frustrated with all the obstacles to protecting their homes. They understood and embraced the eventual retreat that would be necessary but were most interested in further protection to buy them some more time.

The Town group was interested in learning more and supporting the process. Concerns from all stakeholder groups were considered throughout the process to refine the alternatives and evaluation criteria. For example, due to the Magenta group's desire for softer installations, the viability of expanding jute coir was explored. All groups seemed to have an interest in understanding the feasibility of near shore breakwaters, so this alternative was a focus.

On March 23rd and April 13, 2021, the project team held three stakeholder focus group meetings with the following goals:

1. To share the proposed approach in terms of what the project team has done so far and the roadmap ahead
2. To define the technically feasible alternatives being considered and the consequences of each
3. To listen and understand the various perspectives, gathering feedback, data suggestions, and recommendations

4. To begin to understand what it will take to reach a consensus among opposing views, if possible. What is the acceptable risk in terms of economic, cultural, environmental, public safety, and other aspects?

The first meetings clarified the importance of exploring more deeply the key tensions and trade-offs between the various technical alternatives. The team held another round of meetings on June 22, 23 and 29 with each of the three groups to provide an opportunity to explore the draft alternatives analysis, evaluation criteria, decision points, and actionable solutions. The intent was to vet the alternatives analysis through the three groups, gain input, and use the feedback to further refine the alternatives analysis.

Live polling was conducted at all the meetings, and questions were centered around what should be done leading up to a range of future planning horizons (2050, 2070, 2100). Polling results and meeting discussions further showed that the opposing views were too strong to reach consensus. Many participants repeated that there was no hope for consensus.

The project team also held individual interviews with **facilitators** who were selected from each group. The project team and facilitators worked together to further **articulate key tensions and challenges and attempted to identify mutually acceptable solutions**. The team investigated ways to foster a technical / problem solving space for these meetings. Taking a deep dive into the key technical and environmental considerations, the teams developed potential alternative approaches to address challenges **together**, discussing questions such as:

- What is an environmentally responsible and economically sustainable way to protecting our community?
- What are the key tensions?
- What is the spectrum of concerns / trade-offs being raised?
- How will we consider concerns such as maintenance logistics/costs and trade-offs between the consequences of various alternatives?

As a framework for determining key tensions and challenges, the team pinpointed the primary points of disagreement around the potential set of short- and long-term solutions. Based on stakeholder input, the team identified categories of key technical tensions / problems to be resolved in relation to the alternatives. These categories, as outlined in Table 2, pay particular attention to the range of root needs among the stakeholders.

For each tension/challenge, the concerns, consequences, and root needs, are crucial in identifying which questions need to be asked. The answers to these questions could help ease the tensions and lead to mutually acceptable solutions. This information enabled the team to support the discussion.

Table 2. Context for Key Tensions

Key Tension/Challenge	Related Concerns	Associated Consequences and Root Needs	Critical Questions and Information to be Developed to Resolve the Tension
Opposition to using structural coastal erosion protection measures due to their potential related issues of sand and environmental impacts.	Cobble bottom, erosion rates and sand budget Nourishment volumes, sand quality, and potential ecological implications	There are different estimates for sand volume based on variations in the variables used to calculate volume. Information on factors that impact erosion/wave action: past sediment pathways, littoral budget, nourishment sand budget/source	What is the appropriate sand budget?
Maintaining the road and infrastructure	Erosion is bringing the bluff edge closer to the road.	The Town is legally responsible to provide utilities (water, sewer, and access)	How can we address the need to keep the road in its current location for access? Is the road in the right location?
Tax/economic assessment and implications	Who pays for what?	The relocation of infrastructure is expensive	What are the public and private costs?
Designation of Pre-1978 Structures	Policies in the Wetlands Protection Act (WPA) and Nantucket By-laws about coastal protection	Related to “substantial improvement” renovations defined in the Bylaw regulations as cumulative expansion of habitable space greater than 20%.	How can we determine which improvements are substantial?

It is challenging to find common desires within the diverse vision for a pathway forward. An “Adaptation Pathways’[17] exercise with polling was completed during the second road of meetings. It was centered around short-, mid-, and long-term desired outcomes. The Magenta group preferred geotube removal and planning for retreat as soon as possible. They were open to nearshore breakwaters as a potential solution to reduce beach erosion. The Orange group wanted to shift to adaptive dune nourishment and to expand the existing system. By 2050, they wanted to see nearshore breakwaters installed and to start planning a removal, retreat and road relocation which would occur in 2070.

Figure 4 shows the preferred pathway of each group.

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[17] Werners, Saskia E., et al. "Adaptation pathways: A review of approaches and a learning framework." Environmental Science & Policy 116 (2021): 266-275. View HERE

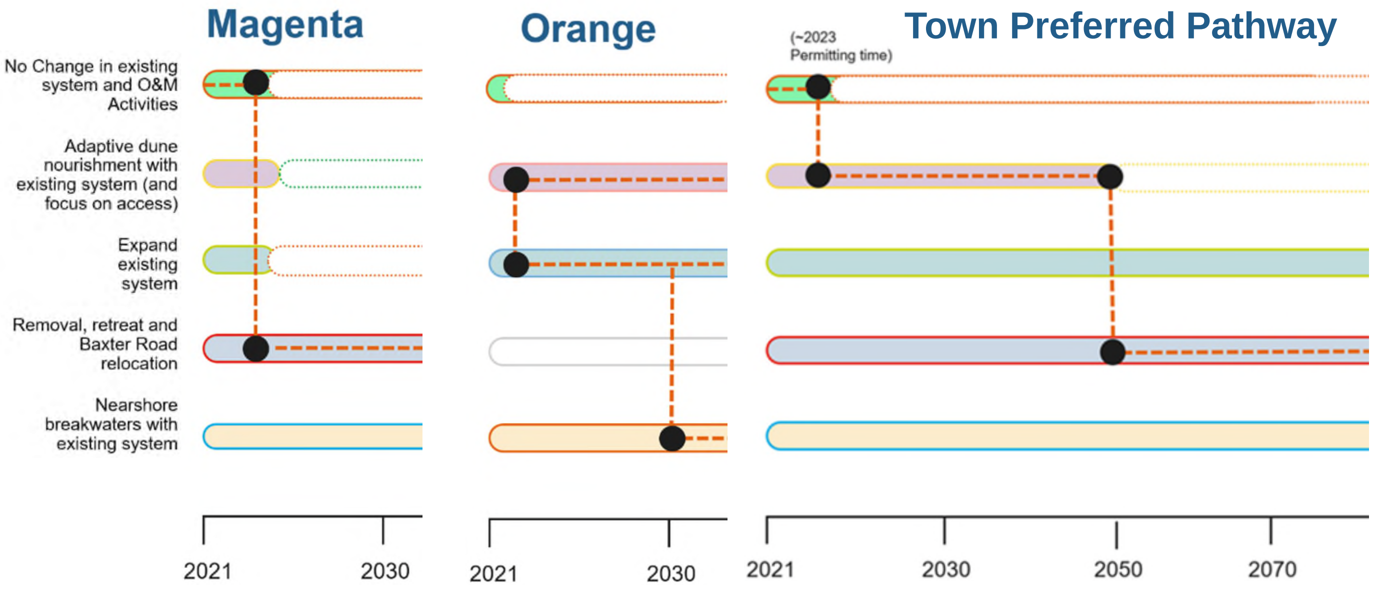

Figure 4 Adaptation Pathways exercise results for each group, with the Magenta and Orange group's preference from 2030 continuing out to 2100.

On September 14, there was a final meeting with all stakeholder groups. The Arcadis team proposed which tipping points are key for assessing potential scenarios and presented recommendations, and these are outlined in Section 5.1. It was stressed that the immediate removal of the current geotube system would likely lead to road failure in the near term. Even replacement with a softer form of toe stabilization would not provide sufficient protection to ensure sufficient time to plan for retreat. It will take time for the system to establish a new dynamic equilibrium. In the meantime, the Town and community are exposed to a range of risks including damage to roadways and utilities, emergency and public access limitations, and environmental impacts from damage to residential properties. It was recommended that the existing system remain in place and that it continues to be maintained and monitored. Stakeholders were encouraged to understand that the key concern is with the stronger storms eroding the bluff toe and causing rapid, catastrophic bluff failure.

Ideally, recommendations for toe stabilization measures would be intended to address storms with higher water levels and larger waves. The Arcadis team explained that if effectiveness were the only criterion, expanding toe protection along more of the bluff would have been recommended. However, the team was charged with identifying potentially feasible solutions based on a technical review, including the ability of the alternative to be issued permits under existing regulations, and taking stakeholder feedback into consideration. For these reasons, the recommendations focus on long-term removal and retreat, with exploration of interim measures to buy some time for the retreat process. A recommended plan with short-, mid-, and long-term actions was proposed and discussed. This memo provides more on the recommendations in Section 5.

Despite the strong caution against immediate removal of the geotubes, there was still the same feedback from the magenta group about their negative impacts and concerns about downdrift erosion. Stakeholders felt that they were perpetually stuck discussing the same issues. In general, there was agreement on the key tipping points. However, there was still a resistance to come together and plan for a workable relocation strategy.

4. Alternatives Analysis

4.1 Coastal Zone Background

The shoreline fronting Baxter Road on Nantucket Island is a unique coastal environment; it can be described as a drowned glacial erosional coast and is a product of glacial movement (USACE, 2006). The bluffs are consolidated material from glacial overburden and differ from dune back beaches by not having a mechanism for replenishment or rebuild. In a typical dune backed beach (Figure 5), sediments may migrate from the backshore and foreshore seaward to nearshore and offshore areas from storms and more energetic wave conditions. During more quiescent and lower wave energy conditions such as the summer, sediment migrate back onshore. The bluffs do not have the same regeneration abilities since they were formed from glacial movement and once eroded, cannot rebuild. Figure 5 schematizes coastal definitions on different types of coasts including typical dune backed beach, typical bluff beach and a typical overwash profile. All three types of coasts may be present at different areas of Nantucket however for the purposes of Sconset/Baxter Road area, this document will focus on bluff beaches.

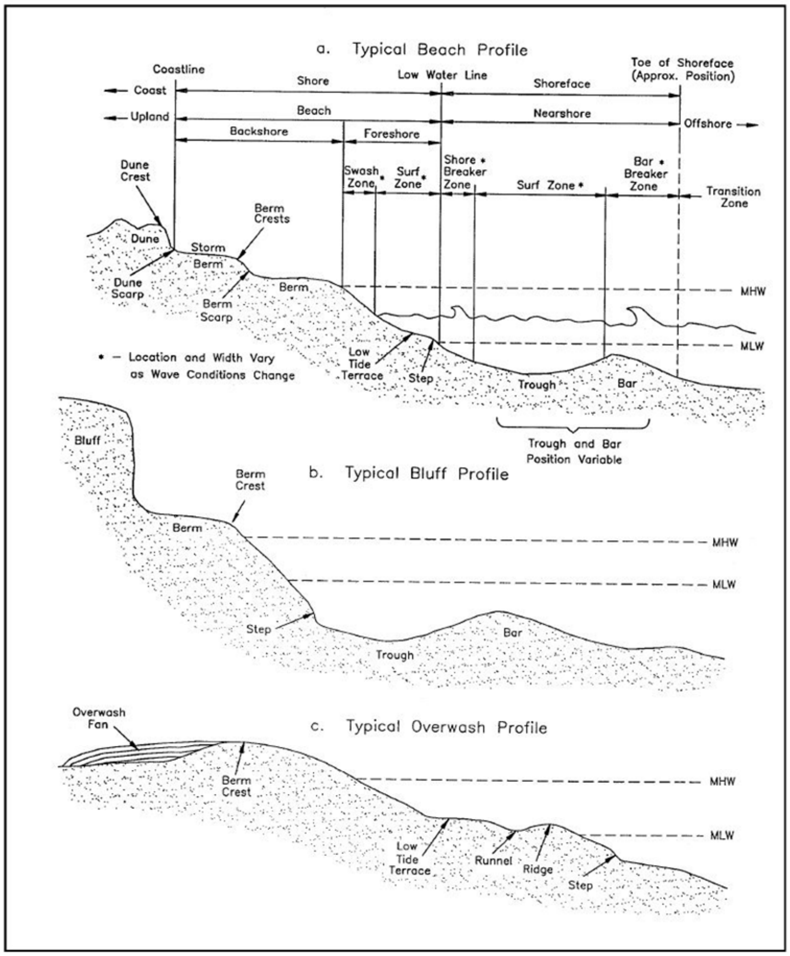

Figure 5. Definition of coastal terms and features in the coastal zone (USACE, 2006).

4.1.1 Coastal Sedimentary Processes

Sediment is in constant motion at the shore and beyond. This movement is generally evaluated as longshore and cross shore movements. Longshore or alongshore refers to sediment moving parallel to and near the shoreline

(USACE, 2003). Cross shore refers to sediment moving perpendicular to the shoreline. Wind driven transport is generally referred to as aeolian transport. Bluffs are an important feature for the Baxter Road location. “Slope instability produced by cliff-base wave erosion gives rise to mass movement…” (Komar, 1983). The following sections further describe coastal structures and coastal processes pertinent to this work.

4.1.2 Types and Functions of Coastal Structures

Several coastal structures and approaches are discussed in this section. They are described here for readers’ convenience and are detailed further in USACE, 2006.

4.1.2.1 Groins

Groins are shore parallel structures intended to increase sediment on the beach from the longshore drift. These structures are generally built of rubble mound but historically have been constructed of timber. Groins are typically constructed as a series along an eroded shoreline. Sediment will typically deposit on the updrift side and erosion occurs on the downdrift side. Erosion and accretion impacts will be observable at a distance from the structure. Figure 6 Figure 6 presents a schematic of a typical beach configuration with groins including the erosion and accretion areas adjacent to the structure in response to the net longshore transport direction. The figure also provides two typical cross sections of the structure looking both onshore (B-B) and alongshore (A-A). There are several groin fields on north shore of Nantucket where these effects of groin fields are evident. Groins would not provide direct toe protection for a coastal bluff, but could provide additional beach width, indirectly reducing the potential for bluff erosion. However, given the potential to impact longshore sediment transport, and limited ability to reduce bluff erosion, groins were not included as a feasible solution.

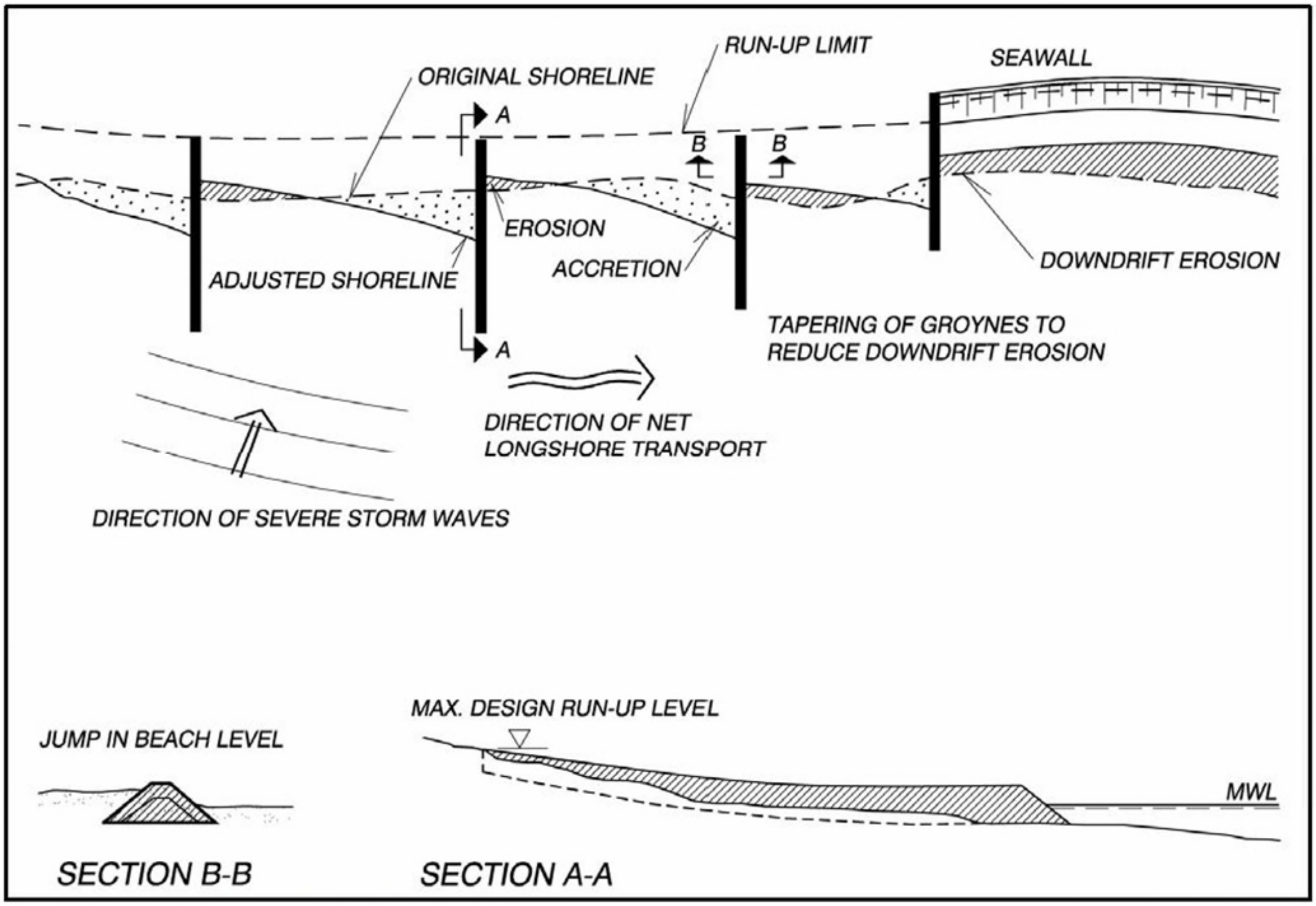

Figure VI-2-8. Typical beach configuration with groins

Figure 6. Typical beach configuration with groins (USACE, 2006).

4.1.2.2 Nearshore Breakwaters

Nearshore breakwaters or detached breakwaters are shore parallel structures with the principal function of reducing the wave energy impacting the shoreline behind the structure and encouraging sediment deposition from the longshore drift. Key components of their design and siting include wave height and length, breaker location, and gap distance. Specific configuration of these types of structures would be determined in a formal design process to determine these parameters iteratively for the desired shoreline response. One of the benefits of this approach is the ability to maintain longshore drift in the lee or land side of the structures. However, a potential limitation of this approach is the nearshore bottom topography immediately offshore of Baxter Road has a steep slope. As water depth increases, the structure cost will increase. The structures will also need to be built to survive a storm to minimize failure in this energetic wave climate. While offshore breakwaters are effective in helping to reduce beach erosion and build the beach, they have limited ability to prevent bluff erosion. In order to reduce waves during storm surge conditions, they would need to extend above the normal high-water line, increasing costs and potentially increasing aesthetic impacts. Figure 7 is a schematic of potential nearshore breakwater configurations and the likely shoreline response.

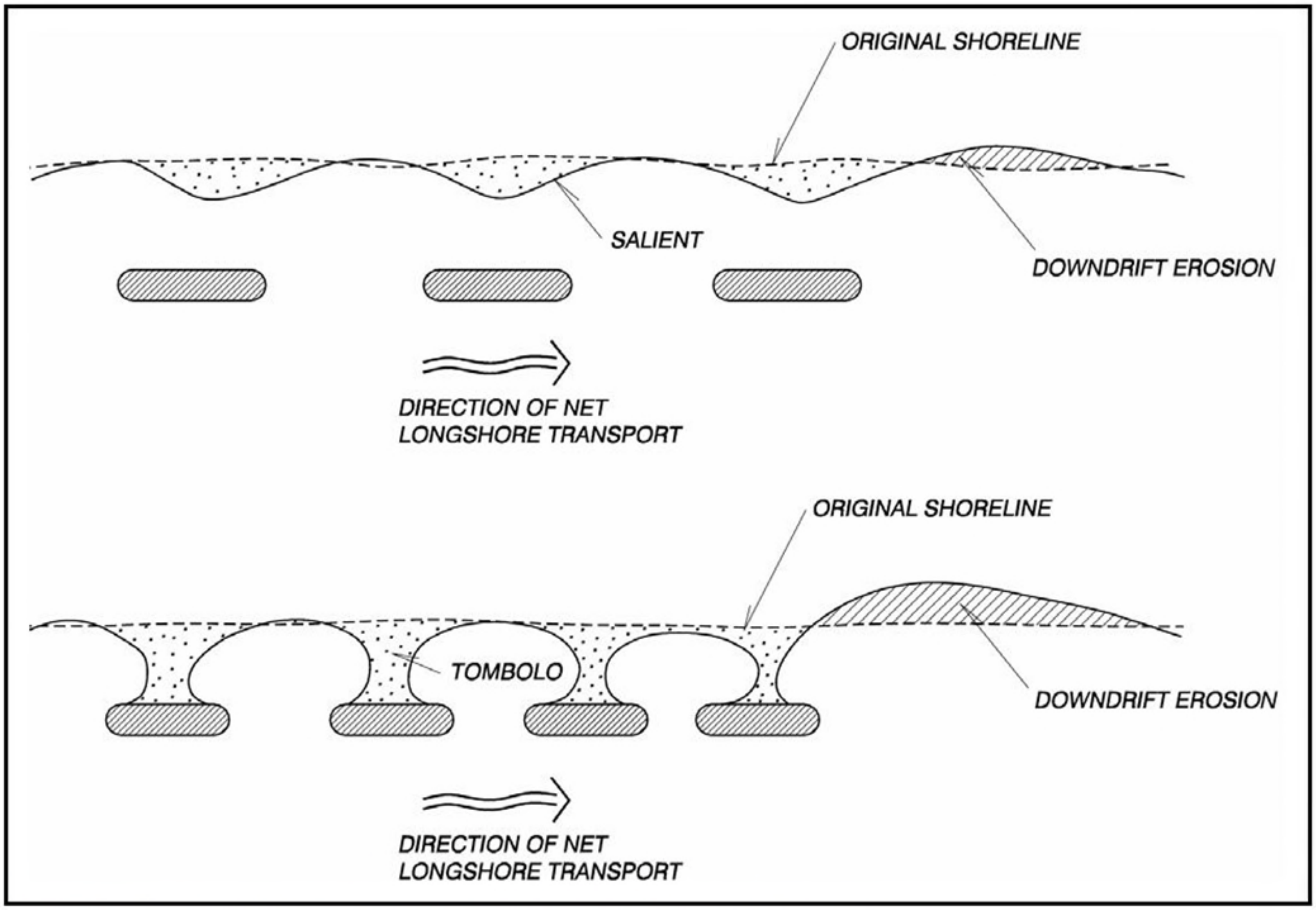

Figure VI-2-10. Typical beach configurations with detached nearshore breakwaters

Figure 7. Typical beach configurations with detached nearshore breakwaters (USACE, 2006).

4.1.2.3 Beach nourishment and dune construction

This approach is intended to reduce beach erosion and protect again flooding through an "…artificial infill of beach and dune material to be eroded by waves and currents in lieu of natural supply" (USACE, 2006). Beach nourishment is considered a soft structure solution to address shoreline erosion. Material is brought in from an outside source either from an upland mine or an offshore source such as a borrow pit or other coastal dredging project. Sediment compatibility to existing material is assessed for color, grain size and minerology. Dune construction can be described as "…piling up of beach quality sand to form protective dune fields to replace…" (USACE,2006) dunes that have washed away or damaged from intense storms. Constructed dunes can act as sacrificial dunes to add material to the littoral system during storms. "Maintenance of coastal dune systems is an important component of coastal protection and management" (Masselink, 2003). Dune construction is typically combined with planting of dune vegetation, netting or snow fencing to assist in retaining material moved by wind. Mature vegetation is effective at trapping wind-blown sand and should be incorporated. Figure 8 shows an example of mature vegetation trapping wind-blown sand on Indialantic, FL beach. Predominant wind direction during this time is from north (right) to south (left). The vegetation is trapping wind-blown sand creating an elevated feature compared to the surrounding beach surface. Beach nourishment has some limitations to preventing bluff erosion; during larger storm surge events, the storm surge may be higher than the beach elevation, allowing waves to reach and erode the bluff. Dunes can be used to protect a bluff toe, but the protection is provided by allowing the dune to erode sacrificially during storm conditions. As such, the volume of sand above the storm surge elevation needs to be sufficient for a specified design storm condition.

Figure 8. Vegetation trapping wind-blown sand (Indialantic, FL., I. Watts).

4.1.2.4 Nearshore Berm or Nearshore Placement

A nearshore berm is a sand berm that is constructed parallel to the shore and can act as either a feeder berm or a stable berm. A feeder berm is intended to provide a source of sand to a beach and migrates onshore through wave action. One of the advantages of this approach to beach nourishment is avoiding constructing directly on the beach which in some environments may have a negative impact on sensitive bird species and turtle nesting. In this sense, nearshore berms have the potential to expand the construction window. Research is ongoing to update and further refine design guidance for this method of shore protection. Aerial imagery and nearshore berm bathymetry of a field example at Ft. Meyers, FL are shown in Figure 9. Aerial imagery of the nearshore berm is shown in the left panel where the berm can be observed by shallower areas offshore from the beach. The right panel included the original constructed berm area (red) and nearshore bathymetry. Warmer colors indicate shallower water depths and cooler colors indicate deeper water depths. Gaps in the berm were included to examine the effect of water quality on the lee (land) side of the berm. Research and monitoring is ongoing for this pilot project including its morphology and sediment partitioning. Stable berms help build the beach by slowing longshore transport and reducing normal (non-storm) waves, performing a similar function to offshore breakwaters.

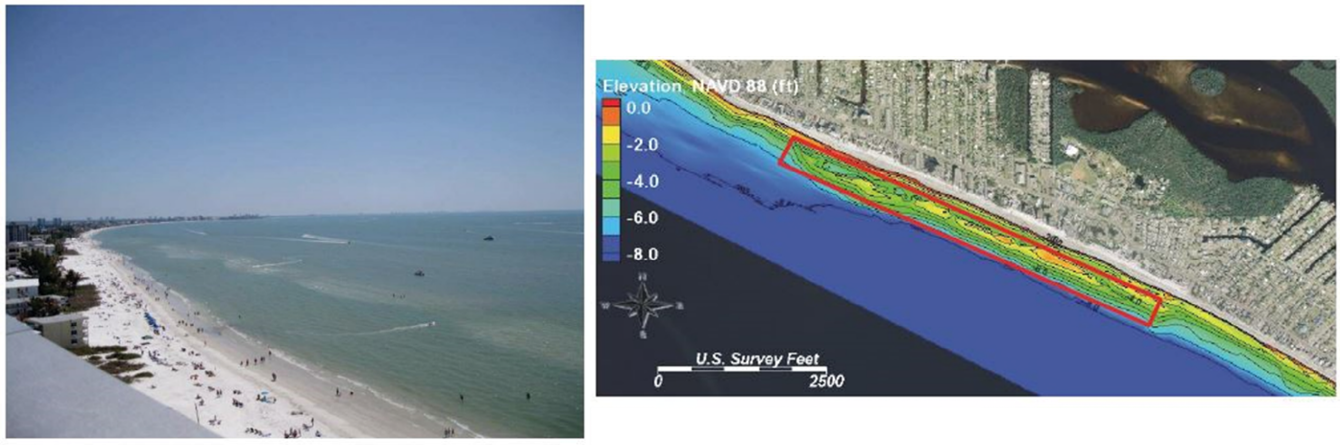

Figure 9. Nearshore berm field example, Ft. Meyers (a, left; aerial image, Brutsche, 2019; b, right; bottom topography contours, Wang, 2013).

4.1.3 Additional Coastal Tools and Techniques

4.1.3.1 Sand Fencing

Sand fencing is "…frequently used to enhance sand accumulation but recommendations for the most effective sand fence configurations vary among sites" (Miller, 2001). A conceptual model of how sand fencing works on a beach is shown in Figure 10. In this instance, the sand fence is placed seaward of the natural dune and results in a foredune building behind the fence in the sheltered area between the fence and the natural dune. Sand fence is effective in areas above high tide levels where aeolian transport (blowing sand) is prevalent.

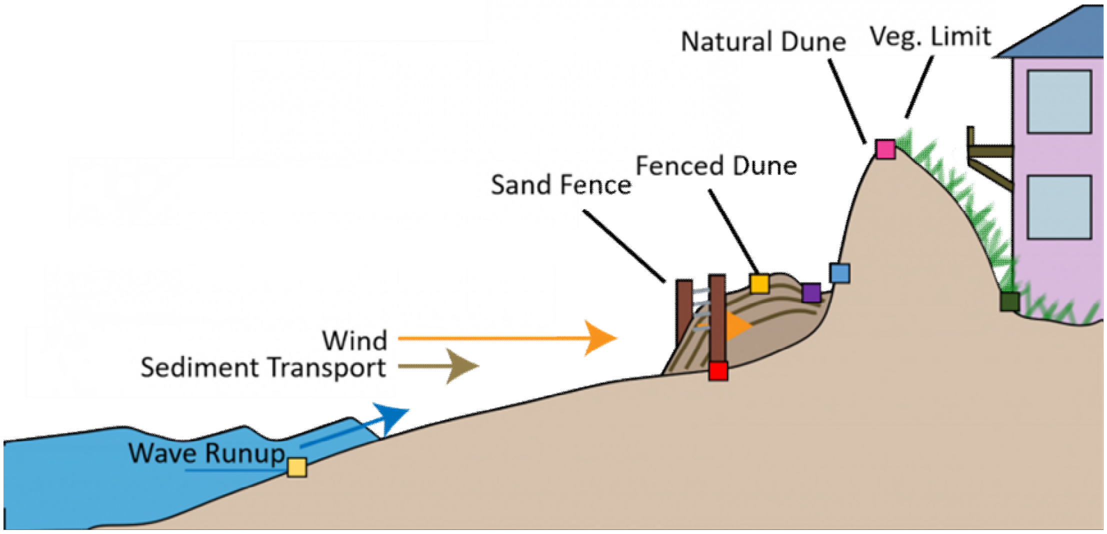

Figure 10. Conceptual model of sand fencing (NOAA, 2020).

Recent studies indicate that while sand fencing can trap sand and increase the dune width at the base, sand fencing can also "…prevent sand deposition to the natural dune behind the fence reducing vertical growth" (NOAA, 2020). Sand fencing should be considered as part of a series of management actions and their performance in the field monitored.

4.1.3.2 Natural Fiber Materials for Toe Protection

There is an interest by the stakeholders to consider natural fibers for toe and dune protection. Presently, design guidance for use of these type of materials in a coastal (wave) environment is very limited. It is anticipated that these materials are not as resilient as geotextile materials and are more appropriate in lower energy environments such as stream banks, marshes and embayments rather than shorelines with direct exposure to the open ocean. These materials are not anticipated to provide significant wave protection; however, they can serve a beneficial role in certain types of shorelines and environments. These materials have been placed in shoreline areas adjacent to the Baxter Road coastal protection system however their performance has not been quantified.

4.2 Alternative Development

Alternative analysis was performed from both an engineering and coastal process perspective. Bluff protection cannot be achieved without toe stabilization. Bluff erosion and collapse is a primary risk factor for Baxter Road structures, roadway and utilities. Therefore, all alternatives that provide bluff protection include toe stabilization. It should also be noted that alternative development assumes the existing system will be brought back into compliance.

Other forms of innovative protection methods that are common on other coasts were investigated as part of this effort. However, most of these protection methods do not provide toe protection to a bluff and some methods are not appropriate for this energetic wave climate. This speaks to the unique challenge of Nantucket bluff shoreline.

Removal of the present system and replacement with another form of toe protection would also have environmental and cost impacts. Any change to the shoreline area will require the system to establish a new dynamic equilibrium. Dynamic equilibrium of beaches can be described as "…the tendency for beach geometry to fluctuate about an equilibrium that also changes with time but much more slowly" (Dean, 2005). This analysis assumes that the present system and alternative scenarios would be fully functional and matching the project design.

With these considerations, analysis was completed with the existing system in place for most alternatives with a single variable changing each time. High level evaluation criteria included identifying the functional coastal processes, defining the environmental, ecological and habitat considerations, and identifying cost and structural considerations. Cost considerations are limited to an anticipated relative cost rather than cost estimates that would be a product of more advanced design stages.

This approach helps to identify which tools or methods can be adapted to the Baxter Road site and which options may not be applicable. All shore protection tools and approaches were evaluated based on a synthesis of the findings from the document review and stakeholder engagement sessions. The methodology of the application of these coastal tools and approaches are diagrammed as mind maps. These mind maps are diagrams that document the reasoning behind the alternative analysis and are meant to be read from left to right and top to bottom.

4.2.1 Longshore Transport

Longshore transport refers to sediment migrating parallel to the shoreline. This sediment transport mechanism is driven primarily by waves approaching the shoreline at an angle creating currents. The selection process for shore protection tools that address longshore transport is diagrammed in Figure 11. The diagram identifies three shore protection approaches that are intended to address longshore transport. Groins, nearshore breakwaters, and nearshore berms were evaluated in a qualitative manner as to whether or not they were feasible options given the discussion with stakeholders and review of documents. Groins were not identified as feasible alternative since they provide limited bluff toe protection and can have significant downdrift impacts. Nearshore berms were also considered not feasible in this location due to concerns regarding covering cobble habitat.

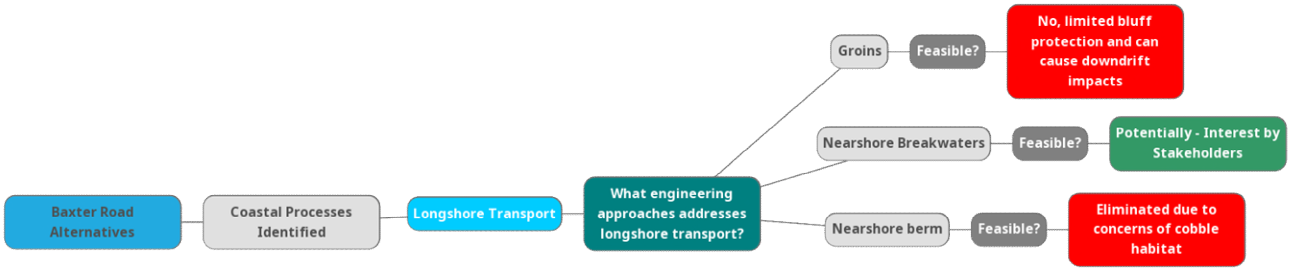

Figure 11. Longshore Transport Mind Map.

4.2.2 Cross Shore Transport

Sediments moving perpendicular to shore can be described as cross shore transport (Figure 12). This method is driven by "…the combined action of tides, wind and waves and the shore-perpendicular currents produced by them" (Seymour, 2005). Cross shore beach morphology has a seasonal fluctuation due to changes in energy levels of incoming waves. In response to storms and high wave energy, sediment moves offshore and is deposited in bars or other deposition features. This material is still in the active zone and during lower energy periods (summer) sediment migrates back onshore to form a summer beach profile. The intent of the cross shore transport alternative analysis is to explore methods or structures that may address cross shore transport of material. Structures such as nearshore breakwaters address cross shore processes by attenuating wave energy that alters the waves and currents behind them. Beach and dune nourishment projects also address cross shore processes by adding material into the system.

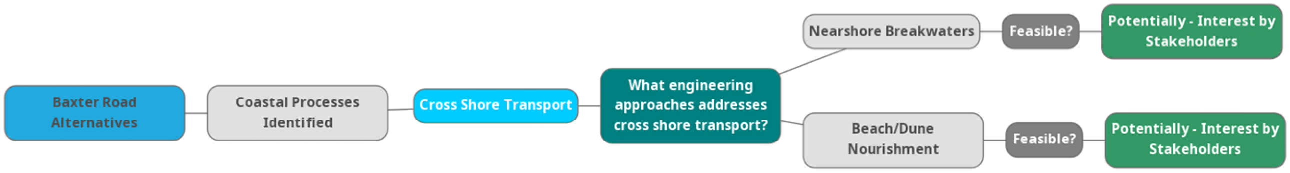

Figure 12. Cross Shore Transport Mind Map.

4.2.3 Aeolian Transport

Aeolian or wind transport refers to material that is transported primarily by winds. Bluff stabilization through native vegetation and geotextiles attempts to address the movement of sand by winds. Sand fencing can help trap sands to build a fronting dune but should be applied with the complex coastal system in mind to avoid preventing sand deposition on the natural dunes (NOAA, 2020). All three coastal sediment transport processes were discussed by the stakeholder groups and incorporated into the alternatives analysis.

4.2.4 Bluff Erosion

A wide spectrum of coastal tools and structures were evaluated related to bluff erosion. The approaches were separated by toe and slope protection. Toe protection addresses bluff erosion by preventing wave action from eroding the base of the bluff contributing to collapse. Bluff faces can erode from wind, precipitation, stormwater runoff and potentially groundwater runoff. Erosion can be greater with a steeper slope and potential solutions could include flattening the slope, vegetation, and stormwater management at the top.

Toe protection alternatives included the entire available spectrum including seawalls, engineered dune, armoring and geotubes. Hardened structures such as seawall, engineered dune and armoring were eliminated due to hardened structures not desired by the stakeholder community and have significant regulatory restrictions. Geotubes were identified as a potential an option since there is an existing installation and an interest by the stakeholders. Slope protection options such as geotextiles and vegetation were identified as potential alternatives by the stakeholders. The methodology of bluff erosion alternatives is diagrammed in Figure 13.

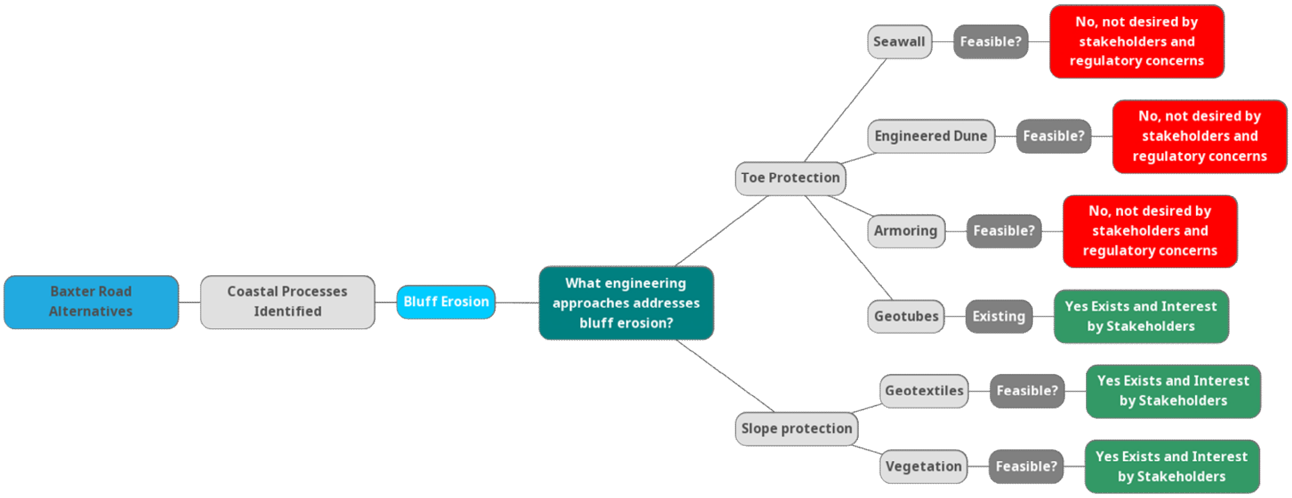

Figure 13. Bluff Erosion Mind Map.

4.2.5 Storm Return Period

A storm return period is an expression of storm intensity and its probability for recurrence. Storms with greater intensity that happen less frequently have larger storm return periods in years (50, 100). While more frequent lower intensity storms have a lower return period in years (1, 5). It should be noted that return period does not necessarily mean that a 100-year storm might not happen each year. The 100-year storm is the same as a 1% annual change of occurrence storm. There have been recent advances in the coastal community of practice in response base modeling and moving towards a more probabilistic approach to quantify risk from coastal storms. It should also be acknowledged that storm intensity and occurrence are expected to increase in response to climate change (IPCC, 2014). For the purposes of this work, we will simply express that higher intensity storms occur less frequently while lower intensity storms occur more frequently. Figure 14 diagrams the relationship between storm intensity and the suite of toe protection.

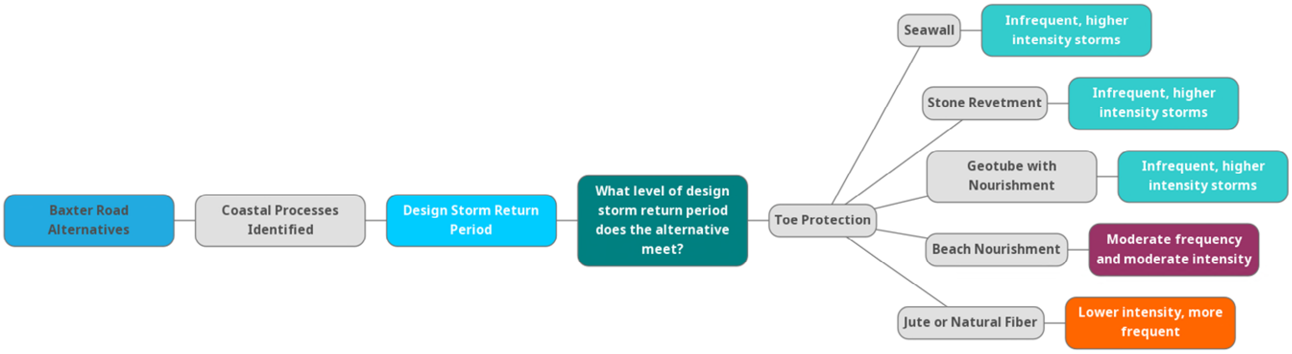

Figure 14. Design Storm Return Period Mind Map.

4.3 Environmental, Ecological and Habitat Considerations

A broad range of environmental, ecological and habitat considerations were evaluated as part of this alternatives analysis. Each element was discussed during stakeholder engagement sessions and the teams' analysis. This section details the methodology applied to these considerations across the selected alternatives.

4.3.1 Nearshore Cobble Habitat

During stakeholder engagement, an interest in nearshore cobble habitat was identified and incorporated into the alternatives analysis. Nearshore cobble habitat is important in the New England coastal waters for supporting a variety of communities including lobster. Each alternative was evaluated for the potential interaction to the nearshore cobble habitat and diagrammed in Figure 15. The existing system with toe protection and nourishment is not presently impacting nearshore cobble habitat as indicated by ongoing monitoring. Therefore, an adaptive approach to nourishment with the existing system is not anticipated to negatively impact nearshore cobble by burial. Expanding the existing system alongshore would add additional sediment to the system and monitoring of the cobble habitat should continue to ensure the nearshore cobble would not be buried. Removal, retreat, and Baxter Road relocation would not be expected negatively impact the nearshore cobble habitat since additional sediment is not being added and any erosion of the bluff is assumed to be less than what is currently being added by the nourishment program. Nearshore breakwaters would need to be evaluated for any potential impacts to the nearshore cobble habitat. It may be possible to locate the breakwaters so the footprint of the breakwaters does not overlap with the habitat. Modeling and monitoring would be required to determine if the breakwaters would cause for sedimentation over the cobble habitat by lowering the existing wave climate. It should be noted that rubble mound breakwaters, may provide similar habitat functions to nearshore cobble habitat and as such, could potentially increase the amount of available habitat.

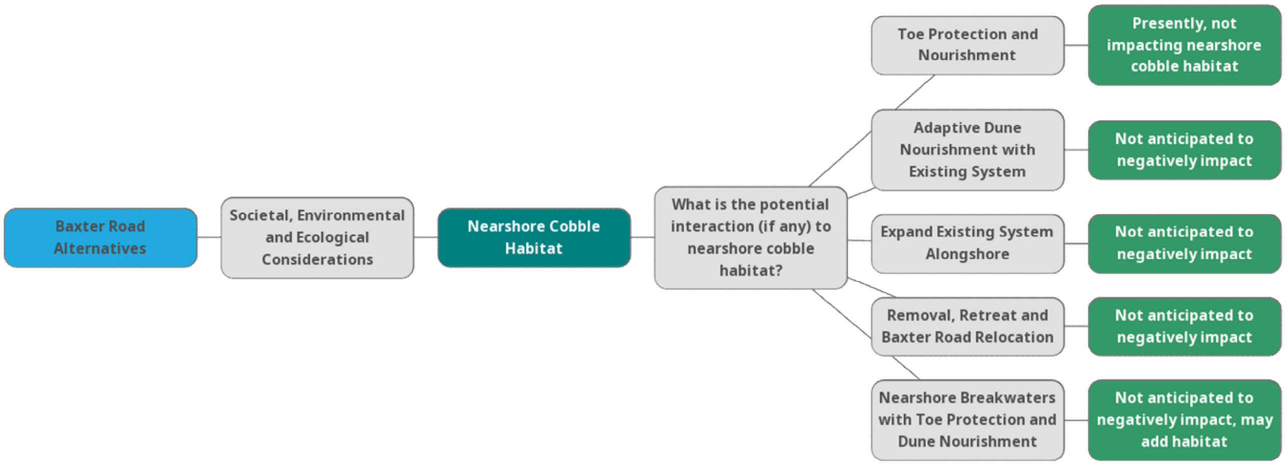

Figure 15. Nearshore Cobble Habitat Mind Map.

4.3.2 Promote Native Vegetation

Native vegetation is an important component in supporting a robust habitat. Each alternative was evaluated for their ability to promote or support the incorporation of native vegetation and is diagrammed in Figure 16 .

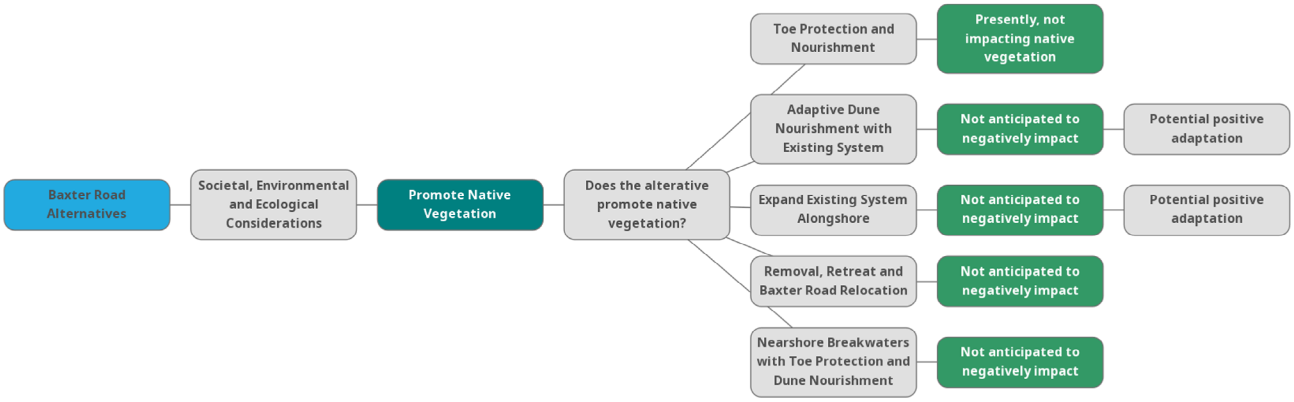

Figure 16. Promote Native Vegetation Mind Map.

No adverse impacts to native vegetation were anticipated for the suite of alternatives. All alternatives can support the incorporation of native vegetation and in the case of expanding the geotube system and adaptive dune nourishment or dune toe protection, there can be a potential for expansion of native vegetation. Adaptive dune nourishment may support native vegetation by optimizing placement volumes and preventing existing vegetation from being buried.

4.3.3 Nesting Birds

The team has assumed that alternatives that extend the beach and/or the dunes would have a positive impact on birds. Habitat requirements are very species specific so the assessment may not be directly applicable for all species that might use the beach habitat. It is also assumed that any project would have permit conditions intended to protect nesting bird populations with appropriate seasonal restrictions on construction activities. The methodology of this analysis is diagrammed in Figure 17.

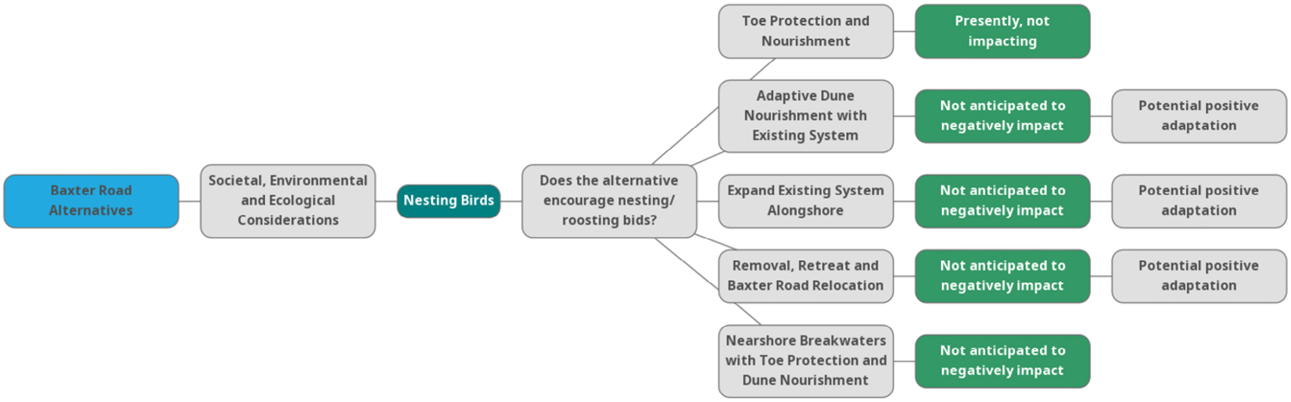

Figure 17. Nesting Birds Mind Map.

4.3.4 Beach Access

Concern regarding beach access was expressed during the stakeholder engagement sessions and was incorporated into the alternatives analysis. Beaches are considered a public resource in the Commonwealth of Massachusetts and access must be maintained. Figure 18 provides a diagram of the evaluation of the potential impact of each alternative may have on beach access.

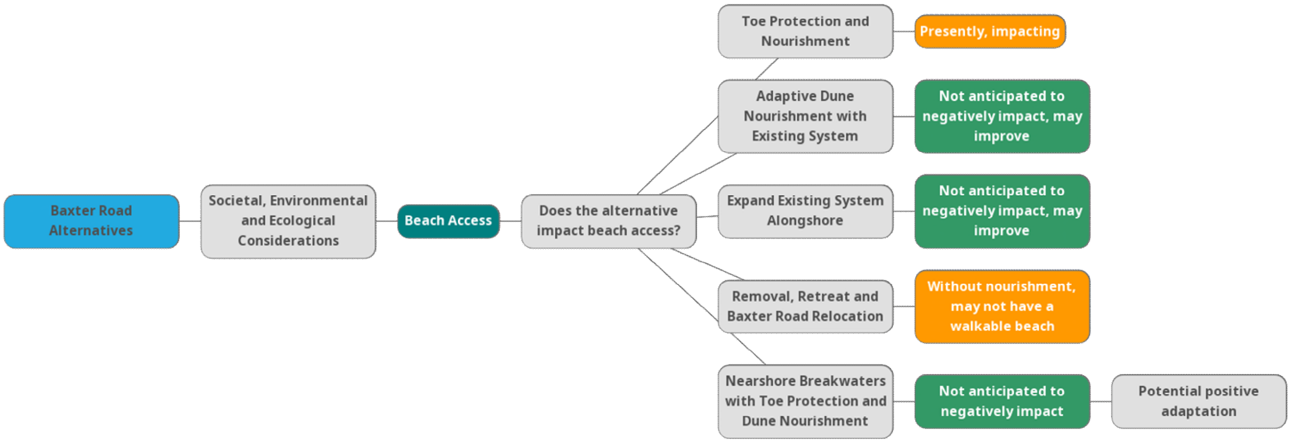

Figure 18. Beach Access Mind Map.

From stakeholder engagement sessions, the present system of toe protection and nourishment is thought to be presently impacting the beach access. It is possible that if the dune nourishment ends with the removal of the geotube system, the beach may narrow. While the unprotected bluff would provide some material to the beach, it is uncertain if this volume would maintain the beach at the same level as dune nourishment.

The other alternatives are not anticipated to negatively impact beach access.

4.3.5 Tourism and Aesthetics

Tourism is an important component in the Nantucket economy. Aesthetics and interpretation by both the local community and visitors is also an important consideration for any proposed solution. The mind map for the tourism and aesthetics category is shown in Figure 19.

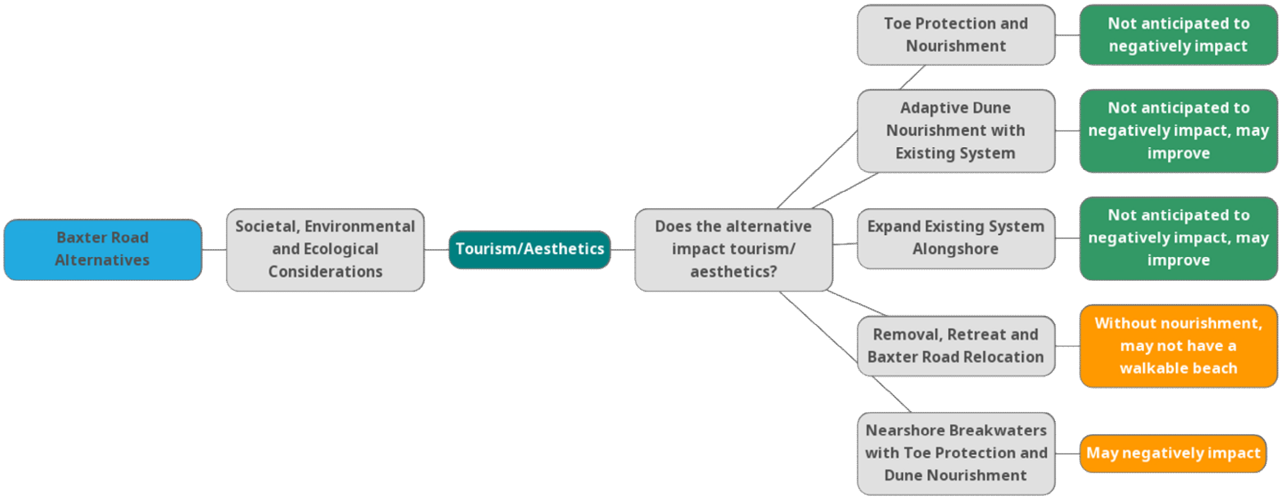

Figure 19. Tourism and Aesthetics Mind Map.

Both nearshore breakwaters and removal were identified as potentially having negative consequences to tourism and aesthetics. It is anticipated with the removal of the present system and ending of dune nourishment, the beach may narrow and not be as accessible which in turn, could negatively impact tourism and aesthetics. It is also anticipated that due to high wave energy environment and steep nearshore slope that the nearshore breakwaters may need to be situated close to shore, extend above the high tide level, and have large armor stones. That may have a negative impact on both tourism and aesthetics dependent upon the interpretation of the structure and community outreach. The other alternatives are not anticipated that have a negative impact on tourism or aesthetics because they have a comparatively more subtle change in the coastal environment and may improve tourism and aesthetics of the area.

4.3.6 Emergency Access

Maintaining or improving emergency access to the beach is an important consideration to support safe recreation on the beach. Figure 20 diagrams the approach for evaluating if the suite of alternatives impacts emergency access.

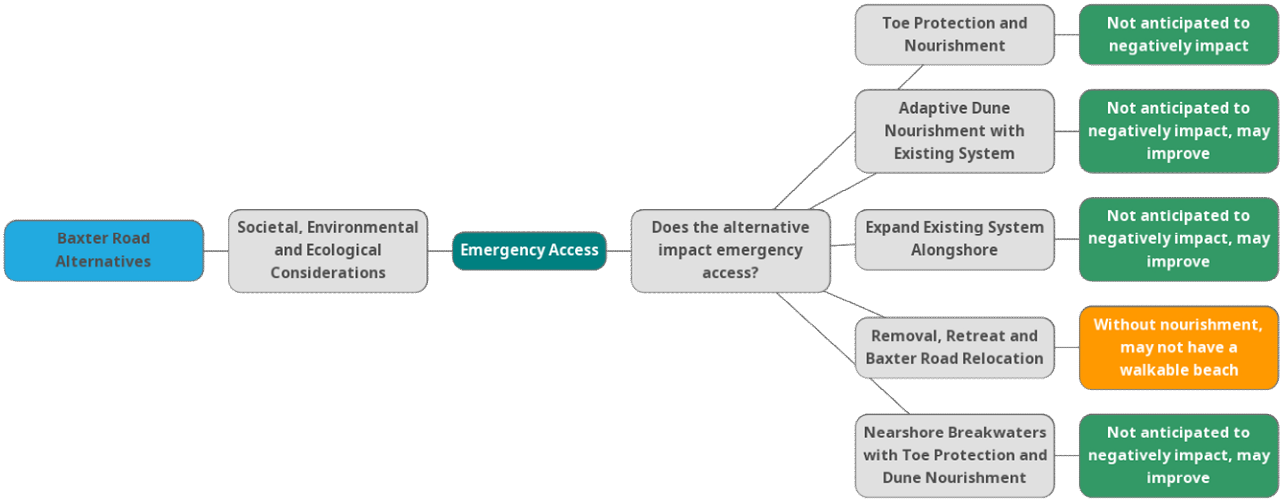

Figure 20. Emergency Access Mind Map.

If the geotube system is removed prior to the road relocation, emergency access from the existing road could be jeopardized. The removal, retreat and relocation alternative may have negative impact to emergency access due to the potential narrowing of the beach with the end of the dune nourishment. The other alternatives are anticipated to either not negatively impact emergency access or may improve beach access by widening the beach. Reliable emergency access should be incorporated into any implemented alternative as part of design.

4.4 Cost and Structural Considerations

This section documents the analysis of alternatives for cost and structural considerations. This category includes both installation and operational costs, design life, funding considerations, utilities, tax implications, maintenance responsibilities and legal agreements. Each subcategory will be discussed in the following sections.

4.4.1 Installation Cost

Relative installation costs at a feasibility level were evaluated for all alternatives and are described in Section 4.8. The existing system of toe protection and nourishment as well as the adaptive dune nourishment is assumed to not have an installation cost since the system is presently in place and the adaptive option simply refines the volume of material placed rather than add a new component. The adaptive dune nourishment alternative has the potential for cost savings by optimizing the dune nourishment volumes. The installation cost for the expanded system is considered to be comparatively moderate to the adaptive dune nourishment. The expanded system will require additional length of geotubes, additional volume of sediment as well as plantings. Construction of nearshore breakwaters will be comparatively high from a mobilization, demobilization, and materials cost.

4.4.2 Operational Cost

Operational costs refer to costs required to maintain and monitor the implemented alternative. The process to evaluate the relative operational costs at a feasibility level are diagrammed in Figure 21.

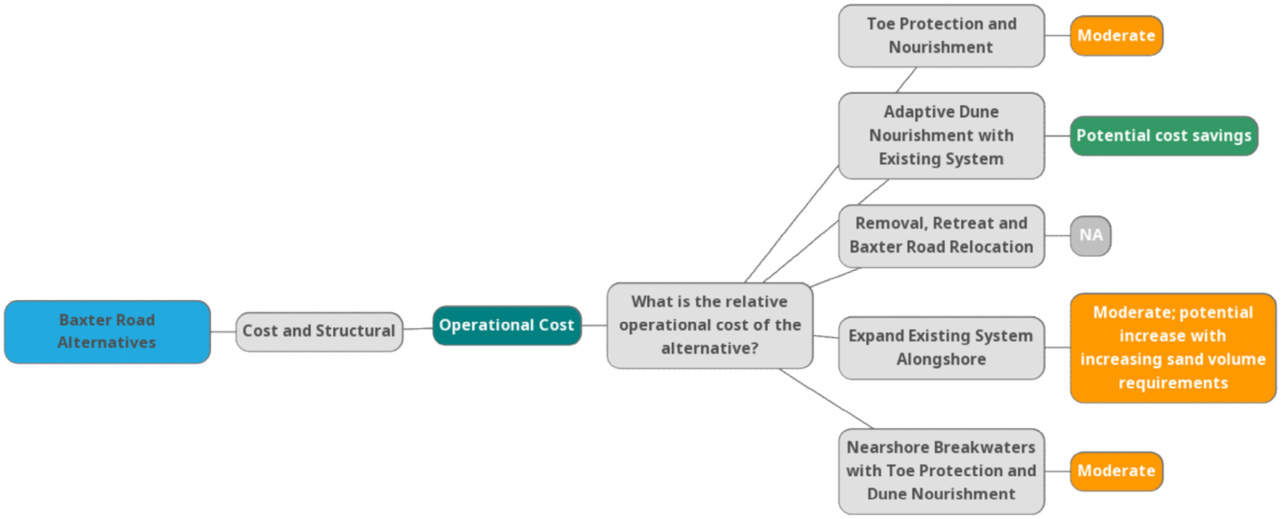

Figure 21. Operational Cost Mind Map.

The adaptive dune nourishment alternative has the potential to provide an operational cost savings by optimizing the material placed. The existing system has a comparatively larger operational cost due to the increased sand requirements. Expanding the toe protection and dune nourishment system along will increase maintenance and monitoring costs by both increasing the volume needed and increasing the area that is monitored. The nearshore breakwaters option is also anticipated to have a moderate operational cost. These structures are designed generally with a 50-year design life and resistance to a return period storm. Nearshore breakwaters do not require maintenance but require monitoring. Repair to the breakwaters is not anticipated during this design life but may be required if they are damaged and need repair. Monitoring costs are likely to increase but can easily be incorporated into the existing field monitoring plan. There is no associated operational cost with the removal, retreat, and relocation alternative.

4.4.3 Design Life

Design life can be described as the intended operational life span of a structure. Probable design life was evaluated as part of this alternative analysis and the methodology is diagrammed in Figure 22.

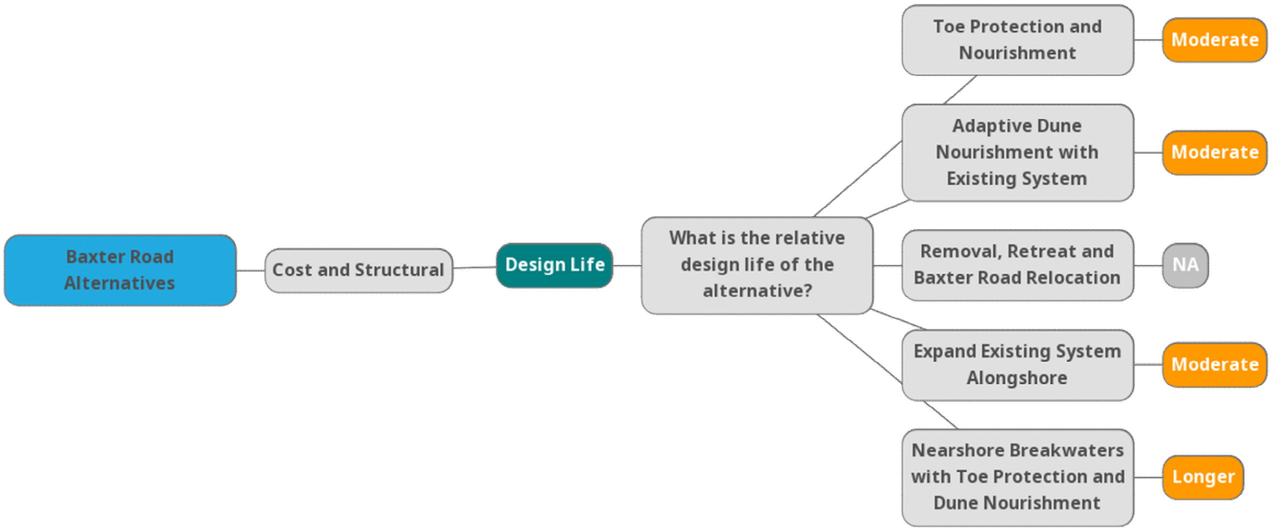

Figure 22. Design Life Mind Map.

It is anticipated that engineered solutions such as the existing toe protection and nourishment system, adaptive dune nourishment, and any expansion of toe protection alongshore would have a comparable moderate design life from a feasibility level assessment. The nearshore breakwaters would have a longer design life as part of its design process. The removal, retreat and relocation alternative would not have a design life.

4.4.4 Funding Considerations

For this feasibility level assessment, funding considerations were evaluated across the suite of alternatives. The assessment of funding considerations per alternative is diagrammed in Figure 23.

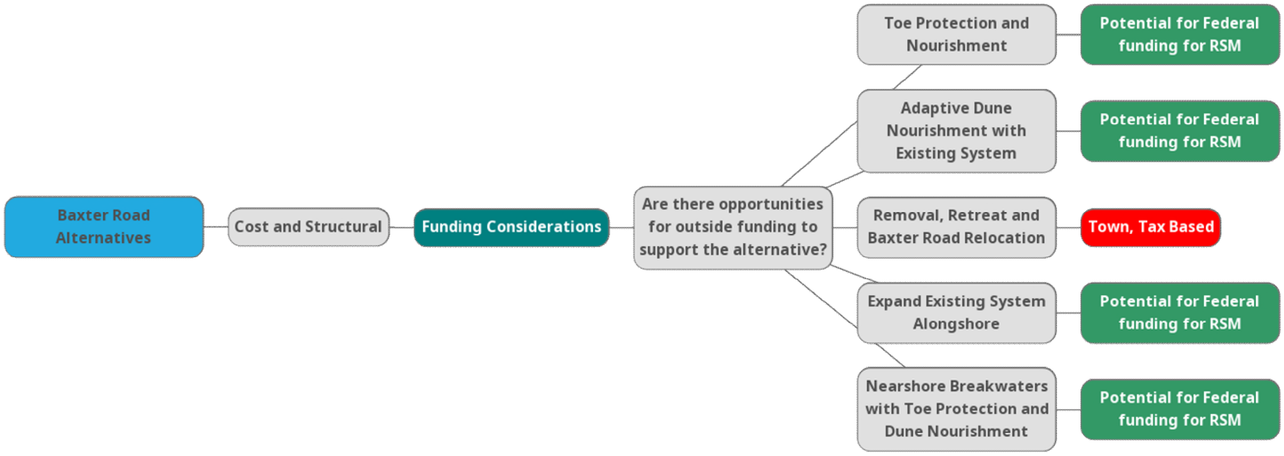

Figure 23. Funding Considerations Mind Map.

The Regional Sediment Management (RSM) program is a federally funded program that promotes a systems approach for management of sediments across coastal, estuarine and inland environments (USACE, 2021). This program would require coordination with local stakeholders as well as the U.S. Army Corps of Engineers New

England District. These funds may be used to reuse sediment from the navigation channel for beach and dune nourishment at Baxter Road and other projects around Nantucket Island. Figure 24 provides a graphic of national RSM program participation across the USACE Districts and Divisions and other federal and non-federal partners. Many funding programs require a positive cost benefit ratio (BCR) in order for a project to be funded. Due to the single-family residential nature of the area, potential benefit costs are likely to be relatively low compared to most structural solutions, and possibly even a substantial dune or beach nourishment program.

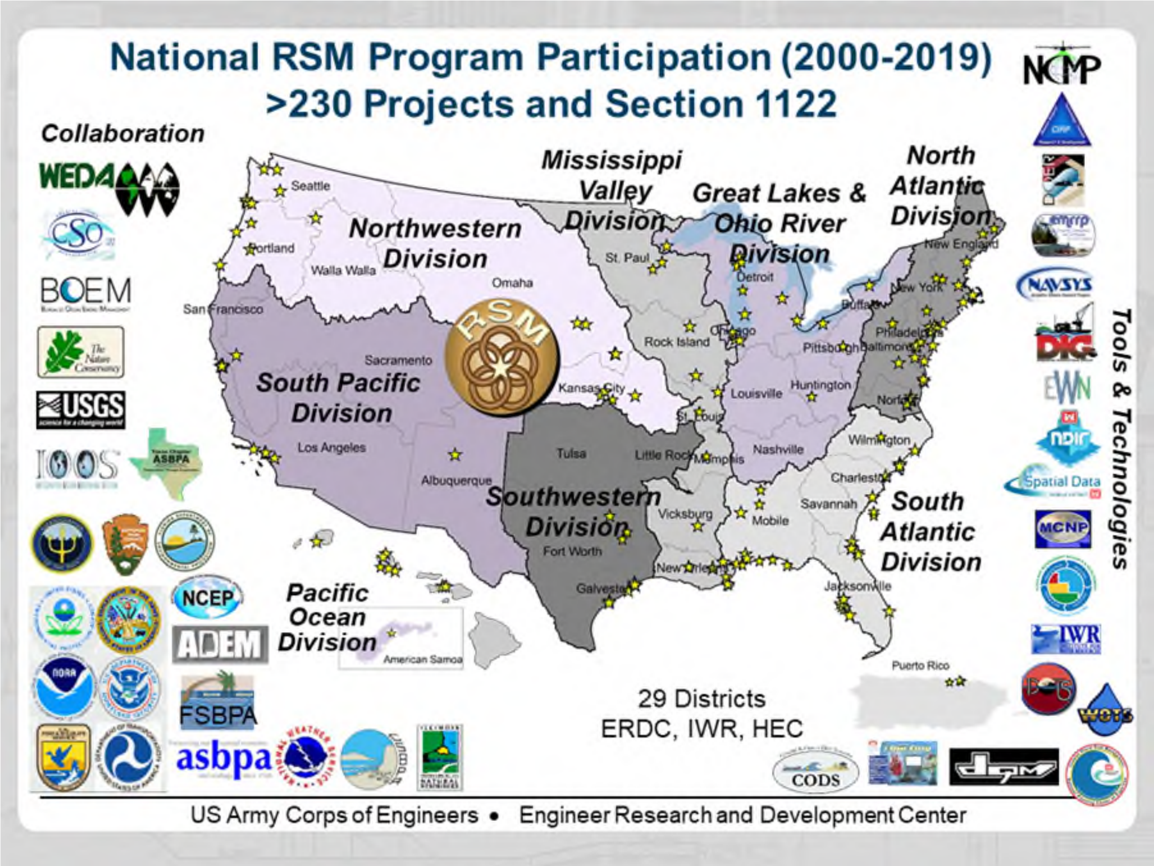

Figure 24. National RSM Program Participation (USACE, 2021).

Yellow stars indicate RSM projects across the USACE mission areas from 2000 to 2019. All alternatives except removal, retreat and relocation of Baxter Road have the potential for RSM or other federal funding programs.

Erosion reduction projects at Baxter Road will likely be eligible for FEMA funding, including Building Resilient Infrastructure and Communities (BRIC) grant and Hazard Mitigation Grant Program (HMGP). For FY2021, $1B will be available through BRIC and in FY2022, $3.46B will be available through HMGP. For these programs, eligibility is for projects which mitigates the risk of natural hazards to infrastructure. There is ample data on erosion rates that will provide documentation for historic losses and the need to increase the level of protection. With a 25% local match, each project can be up to $50M federal share. These FEMA opportunities also provide funding (up to $300k) and technical assistance for planning, project scoping, and studies. Local and private funding can be used for match or to fund an entire project that is scoped. Expansion of the system would likely be funded by private homeowners as well as retreat of private homes.

4.4.5 Utilities

There are both town-owned and private utilities located within Baxter Road. Among the town-owned utilities are the physical roadway as well as the water and sewer service. Privately owned and maintained utilities include the overhead electric lines as well as buried internet & communication lines. This portion of the alternative analysis included examining if the alternative would support utility resiliency. This process is diagrammed in Figure 25 as a mind map.

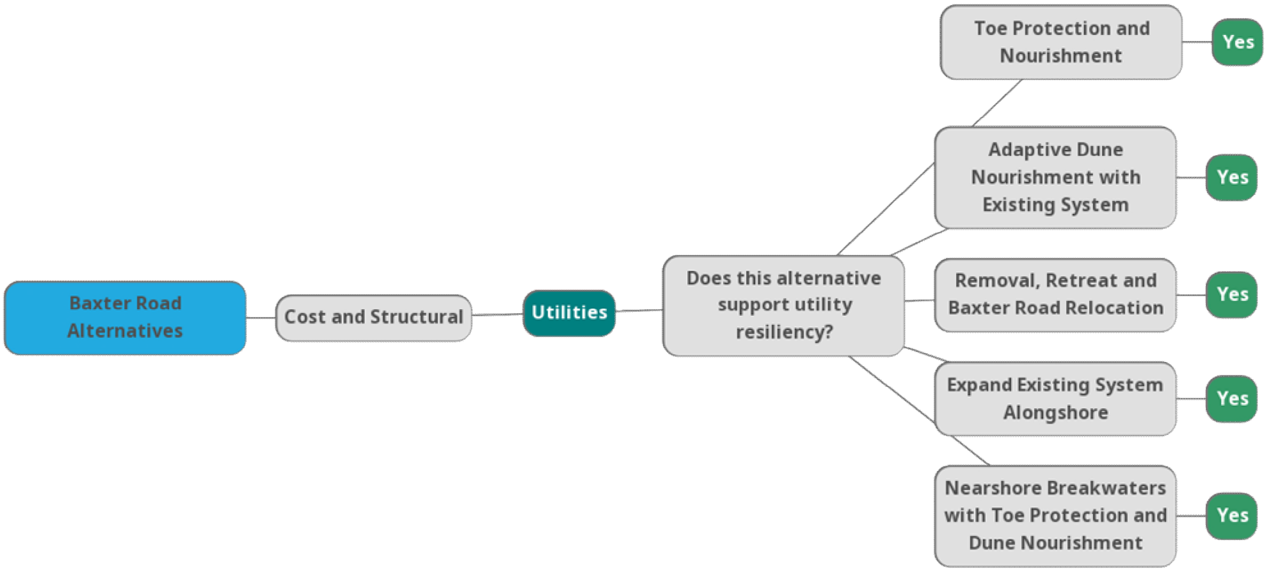

Figure 25. Utilities Mind Map.

4.4.6 Tax Implications

Town revenue from property taxes may be affected by the loss of privately owned property through erosion. Therefore, any alternative which has a positive (mitigating) effect on erosion may be considered to positively maintain the town's revenue from property taxes along Baxter Road. However, analyses of Nantucket's property tax loss for anticipated property loss for years 2030, 2050, 2100 was reviewed and is included in Appendix C. The analysis utilized the assessor's data for the current assessed land/and property values from 2021 and shows that any loss in revenue due to loss of property on Baxter Road would result in only modestly higher property taxes across the whole island. By 2100 it is anticipated that a total of $531,000 in tax revenue will be lost this represents less than 1% of the tax base for the island. Thus, many suggest any loss in property tax would be absorbed by the remaining property owners within Nantucket.

4.4.7 Maintenance Responsibilities

Any implemented system will need to be maintained by an entity. Toe protection is presently maintained by the SBPF including periodic dune nourishment. Any existing or new roadway as well as utility infrastructure would be maintained by the Town, private utility companies, and private property owners, as applicable based on maintenance agreements set forth during the planning and construction of the roadway. Maintenance of other components would need to be determined as part of the implementation process.

4.5 Description of Alternatives

The purpose of this work is to present a suite of options for the stakeholder community to consider. The decision of which pathway to choose is the responsibility of the local community.

4.5.1 No Change in Project and Operation and Maintenance Activities

This alternative serves as baseline for analysis. It is also an opportunity to define the individual components of the system and the linkage to the coastal processes. The existing system provides toe protection, artificial or sacrificial dune nourishment and bluff stabilization over a portion of the study area (approximately 950 feet). Toe protection is achieved by geotubes placed at the toe or base of the bluff protecting it from erosion due to wave action. Erosion at the base of the bluff can lead to episodic collapse. Dune nourishment is compatible sand that is placed on top of the geotubes to provide a buffer to the geotubes and add material to the littoral system. Presently, compatible sand is added to the template by heavy machinery. Bluff stabilization includes vegetation and promoting best management practices to manage surface drainage. Surface drainage can exacerbate erosion of material from the bluff face. This alternative assumes that the system is brought back into compliance with the existing permit.

Feedback received during stakeholder outreach and documents in the background information files have conflicting information on the geotubes and current nourishment program with regard to downdrift beach erosion. While a detailed analysis of the substantial available beach and bluff monitoring data was beyond the scope of this study, a preliminary review of several reports suggesting downdrift impacts indicated that the analysis was based on selective data analysis as opposed to a more comprehensive analysis. Changes in beach position occur on multiple time scales, from hours to decades with significant variability over those time frames, and as such, a more comprehensive review is more likely to accurately capture long-term trends. One of the more comprehensive analyses reviewed for this study noted:

> Long term shoreline change plots are presented for continued insight into beach response. Although there is substantial variability, no post-geotube changes have yet been observed that deviate substantially from past observations. The present shoreline is at a similar location as more than ~10 years ago at many profiles and no significant accelerated erosion has been noted.(Woods Hole Group, 2021)

4.5.2 Adaptive Dune Nourishment with Existing System

Adaptive dune nourishment refers to incorporating an adaptive or optimized nourishment strategy. A potential method of implementation is to determine the sacrificial sand volume necessary to refill the template to design specifications after the springtime survey. A topographic and bathymetric survey should be done twice annually to capture both the quiescent (summer) configuration and the resulting profile after the energetic (winter). This survey approach is used at other locations with active adaptive management approaches to beach nourishment (Zarillo, et al., 2016). The motivation behind this alternative is efficient use of sand resources and prevent overfilling the template documented by Epsilon, 2020. This adaptive technique minimizes potential to impact nearshore cobble habitat and fishing industry. Adaptive mitigation optimizes sediment requirements by only placing the material needed on the beach. This approach may reduce the volumes of sand necessary for maintenance, however greater volumes of sand may be needed if more erosion is observed. Optimizing sand resources may become more necessary in the future with sand becoming a more in-demand commodity around the island. It should be noted that throughout the monitoring efforts, nearshore cobble habitats were not found to be impacted by sediment burial. This optimization technique for sediment management addresses annual variations in erosion and accretion which is more in line with natural variability in coastal processes.

4.5.3 Expand Existing System Alongshore

This alternative leverages previous work investigating expanding toe protection and dune nourishment alongshore to approximately 2,800 feet. This proposed alternative includes four tiers of geotubes (similar to the existing system) to provide resiliency to the 100 to 200-year storm. This alternative also includes vegetation of the bluff face with American beachgrass or other native vegetation. The dune nourishment to cover the geotubes for the longer length of the system is also included in this analysis. With the expanded system, the monitoring program would also need to be expanded. A variation on this alternative would be to design expanded toe protection to a lower level of return-period storm, such as 25- or 50-year storm, to be more aligned with providing protection over a time-period appropriate to allow for a retreat strategy to be implemented. Figure 26 depicts the alongshore extent of the proposed system.

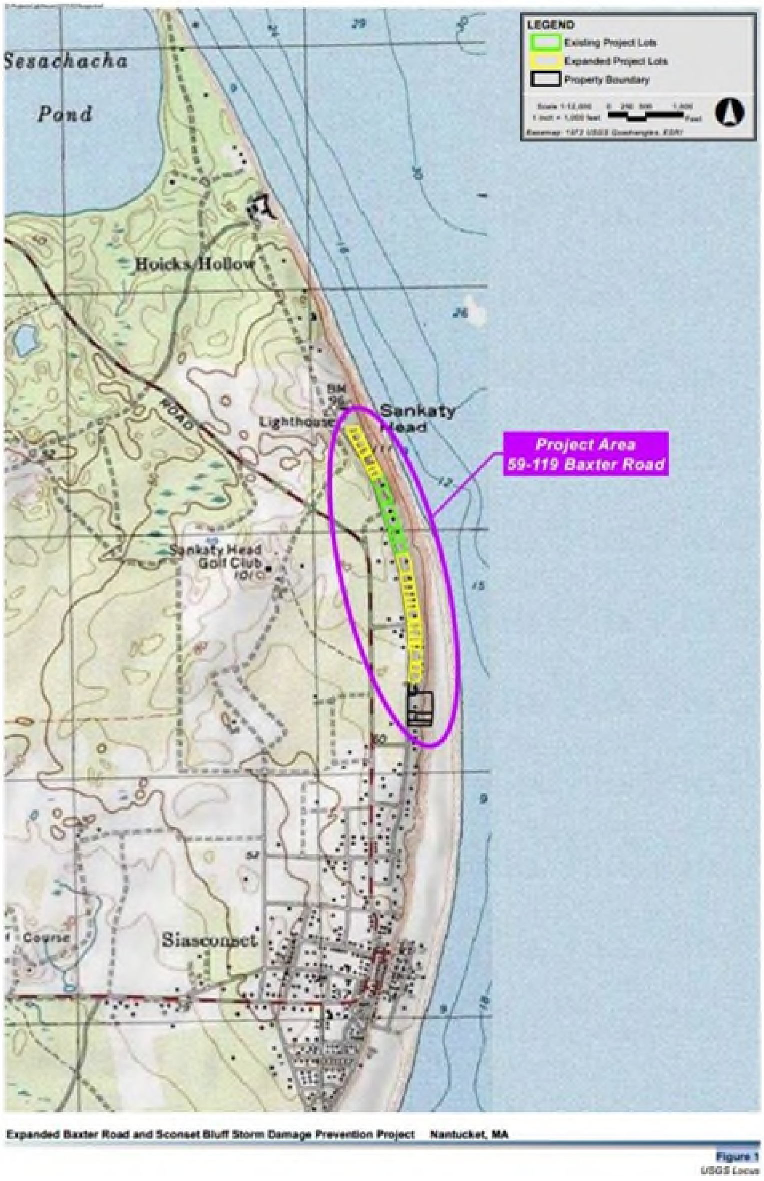

Figure 26. Approximate Alongshore Coverage of Expanded Toe Protection and Dune Nourishment System (Epsilon, 2018).

4.5.4 Removal, Retreat and Baxter Road relocation

The removal, retreat and Baxter Road relocation includes the removal of the existing structures including geotubes and associated components. This alternative would also include ceasing artificial dune nourishment activities including truck traffic on roadways and heavy machinery on the beach. and begin the retreat process to remove homes and relocate utilities. No additional bluff stabilization measures would be implemented. Removal of the geotubes would occur after relocation activities is complete.

4.5.5 Nearshore Breakwaters with Existing System

This alternative explores the feasibility of adding nearshore breakwaters directly seaward of the existing system to provide wave attenuation. Nearshore breakwaters can assist in maintaining dune nourishment and encourage sediment deposition on the lee (shore) side of the structures. A conceptual sketch is shown in Figure 27 with potential nearshore breakwaters locations indicated as wire frame rectangles.

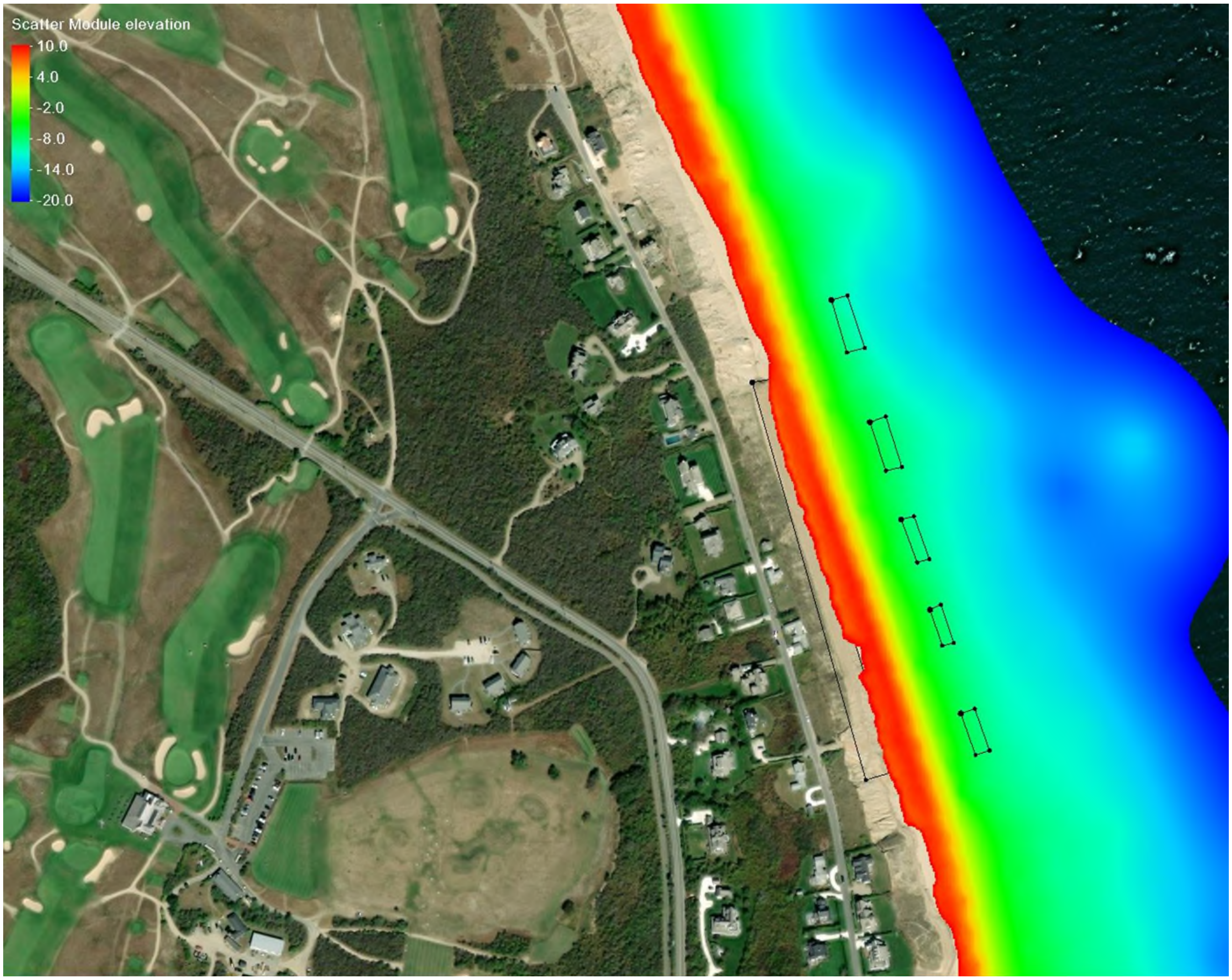

Figure 27. Nearshore breakwaters conceptual configuration.

The lateral extent of the existing project is represented by a wire frame on the shoreline. Bottom topography is included and deeper depths are indicated by cooler colors and shallower water depths are represented by warmer colors. Design specifications such as distance from shore, gap width and number of breakwaters would be defined during later design phases.

4.6 Evaluation of Alternatives

4.6.1 Definition of Purpose

The purpose of the existing project includes the following: provide toe protection to the bluff, add sediment to the littoral system via dune nourishment, and bluff stabilization through vegetation and best management practices for managing surface drainage. Toe protection in the form of a geotube protects the base or toe of the bluff from wave action which can erode the bluff leading to episodic collapse. The dune nourishment covers the geotubes and provides a buffer to the toe protection against storms in addition to adding sediment to littoral system. Bluff stabilization through vegetative cover seeks to address aeolian or sediment transport from wind. The alternative selection process was designed around augmenting one element of the system or one specific coastal process to evaluate the response of the system. Responses by changing a single parameter between each alternative are observed.

4.6.2 Service Life

Coastal erosion mitigation measures have certain service life based on their ability to resist storm events and/or when materials begin to lose strength. A typical design / service life for harder coastal protection structures is 50-years, but softer solutions typically have a lower design life or require more frequent maintenance to maintain a specified level of protection. While many coastal protection projects in the US utilize a typical 100-year return period design storm, it is often better to match the design storm to the desired service life. For instance, if an alternative is designed for a service life of 25 years, the cumulative probability of exceedance is 34% if the design storm is a 100-year event. Figure 28 diagrams toe protection alternatives and the appropriate storm and wave intensity for that approach.

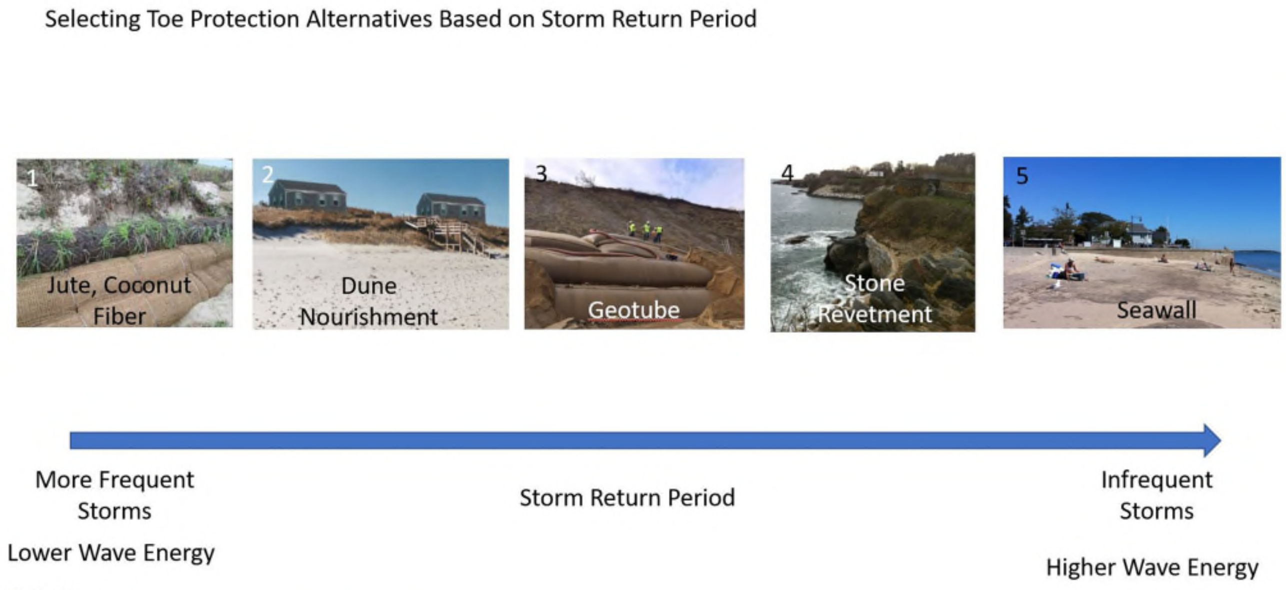

Image Citations:
1: MA, 2017, Applying the Massachusetts Coastal Wetland Regulations
2: https://climateactiontool.org/content/restore-natural-coastal-buffers-beach-and-dune-nourishment-and-restoration
3: http://sconsetbeach.org/wp-content/gallery/geotubes/GeoInstallation_Construction-4.jpg
4: Field Photos, Newport, RI, 2012
5: Field Photos, Revere, MA 2011

Figure 28. Toe Protection Alternatives and Storm Return Period.

4.6.3 Initial Construction Cost

To facilitate a relative comparison of initial construction costs between the alternatives, the following assumptions are made.

It should be noted that sand costs are highly variable and are likely to change in the future.

The nearshore breakwaters with existing system alternative have the largest initial construction cost. The value listed in Table 3 is derived from previous experience with these structures in similar environments. The next alternative with the largest cost is the removal, retreat and Baxter Road relocation as discussed in 4.7 Removal, Relocation of Baxter Road and Utilities, Retreat section. The expand the system alongshore is estimated at $6M from previous documentation. Adaptive nourishment and existing alternatives are not included because they do not have an initial construction component.

Table 3. Estimated Initial Construction Costs.

Parameter	Cost ($)
Expand System Alongshore	$6M (Includes initial sand template)
Removal, Retreat and Baxter Road Relocation	$30M
Nearshore Breakwaters with Existing System	$100M

4.6.4 Operations and Maintenance

Potential downdrift impacts of any proposed solution are possible and the recommended method to address these impacts is through sand mitigation. If expanded dune nourishment is implemented, a similar adaptive management monitoring and maintenance approach should be taken. In addition to annual filling to a design template, emergency replenishment may be needed after significant storm events.

It should be noted that Nantucket has identified the need for a comprehensive island-wide approach to sediment management. The CRP recommends a comprehensive approach to sediment management across the island as well as priority data collection and analysis steps including performing a Sediment Transport Study and developing an operational sand budget, or Sediment Budget. These projects will be beneficial to implementation (or continued implementation) of the alternatives discussed in this Summary of Findings.

Other maintenance activities associated with bluff best management practices include installation, monitoring and repair of sand fencing, vegetation, or other slope erosion reduction measures. Diversion of storm water runoff away from the bluff face should continue and irrigation of lawn areas should be avoided. Homeowner Best Management Practices are discussed in more detail in Section 4.9 and in Appendix B.

The performance of any alternative needs comprehensive monitoring to support informed management. Monitoring activities should have a comprehensive system wide approach and resolve coastal processes acting on the system and the response of the system to coastal forcing. Specifically, monitoring should capture sediment changes in the constructed system, beach, and adjacent areas. Other components that should be included in a monitoring effort is any plantings or habitat elements. Conditions of any other system components such as sand fencing should also be included in the monitoring efforts. Presently, the ongoing monitoring program provides a basis for analysis however can be improved by expanding the surveys and leveraging new survey techniques and technologies.

Previously, changes in the shore and shoreface were observed with a combination of land based cross shore transects via GPS RTK to wading depth and single beam survey via boat. The most recent survey performed by Woods Hole Group on June 16th, 2021, included drone based Light Detection And Ranging (LIDAR) that captures the beach, dunes and bluff. This approach enables the development of a 3D topographic map and move towards a surface based evaluation of sediment movement rather than cross shore profiles. It should be recognized that cross shore profiles have been industry standard approach for quantifying changes in beaches however, the Baxter Road site poses some unique challenges to traditional survey techniques with the bluff and geotube project. The incorporation of drone based LIDAR represents a significant step forward in evaluating sediment movement in a comprehensive manner by capturing the majority of the system in a single survey. Depending on laser penetration depth, these surveys will likely need to be combined with traditional boat based surveys to capture deeper water depths. Costs associated with surveys include mobilization, demobilization, survey time and post processing time. Incorporating remote sensing techniques such as LIDAR may save survey time. However, post processing of LIDAR data may increase as compared to traditional survey methods however it is dependent upon software, scripting and computational capabilities.

Other monitoring that may be included and can be performed concurrently with drone based survey is aerial imagery. Aerial imagery of conditions can assist in communicating with the public and monitoring habitat such as vegetative cover that might not be reflected in the LIDAR. Another type of aerial imagery is hyperspectral imagery which can assist in delineation of vegetation types to quantitatively measure cover and density. Vegetation has been shown to be an important component in the performance of rehabilitated coastal dunes. Aerial imagery can also best capture other system components such as the condition of sand fencing, presence of debris or location of wrack line.

Additional monitoring components such as nearshore wave and current monitoring would be advantageous to closely link response of the system to coastal forcing however likely beyond the scope of this effort. If offshore breakwaters are proposed, then collecting this information would be needed to establish baseline conditions and monitor changes due to the breakwaters. Oceanographic instrumentation such as acoustic doppler current profilers (ADCP) and directional wave buoys requires substantial capital cost, regular servicing and rapid response should a surface buoy move outside its defined watch circle. Nearshore waves and currents can be observed remotely through the use of high frequency (HF) radar and could provide the added benefit of providing near real time surface currents, waves and tidal current predictions.

Comprehensive monitoring will support the development of an operational sand budget. "Budgets allow estimates to be made of the volume of volume rate of sediment entering and existing a defined region of the coast and the surplus or deficit remaining in that region" (Rosati, 2005). A sediment budget is an engineering tool that accounts for the sediments sources and sinks in a local or regional area with specified boundaries and time interval. This approach can be used to examine short-term conditions (seasonal) or longer term such as a previous or existing conditions. "Sediment budgets are a fundamental tool for project management and they often serve as a common framework for discussions with colleagues and sponsors…" (Rosati, 2005). A previous effort to develop a sediment budget could serve as a starting point and updated with recent field data. An operational sediment budget would be one of the primary products of an island wide sediment study. "Understanding the boundaries of littoral cells, rates, and direction of net sediment transport should be the basis for science-based coastal management" (UMASS Boston, 2021).

Monitoring activities will also provide field data necessary to support an adaptive nourishment approach. Presently, the annual nourishment volume is set at a single, non-adaptive value. This approach does not allow for natural variability in sediment movement. Sediment transport can vary from season to season as well as longer time scales. An adaptive approach to refill the constructed template once a year rather than a single value may present a cost savings by optimizing sand needs. Previous reporting by Epsilon indicates that the design template is being overfilled beyond its design due to the requirements of the single renourishment value.

Maintenance of nearshore breakwaters may include resetting the armor stone layer or concrete units after an intense storm. In some instances, these stones may need to be replaced. These structures are typically designed to withstand a storm with a larger return interval. Costs associated with maintenance of nearshore breakwaters include materials, mobilization, demobilization and constructions costs.

Relative operations and maintenance costs are detailed below to compare the array of alternatives and listed in Table 4. The price of sand needed for nourishment varies based on current sand availability. Costs assume that 22 cubic yards per linear foot would be required for nourishment. Costs assume sand at $50 per cubic yard (CY) which includes transport and placement onsite with procurement by a private entity. This approximate unit cost of sand was provided by the Sconset Beach Preservation Fund based on existing system costs and is considered a scalable unit cost that may be adjusted as sand prices change.

Table 4. Estimated Annual Operations and Maintenance Costs (Sand Only).

Alternative	O&M Cost
Existing System (947 LF)	$1M per year
Expanded System (2680 LF)	$3M per year
Nearshore Breakwaters	Monitoring + Stone Repair costs

While the expanded system has a higher operation and maintenance cost from a sand nourishment perspective, the additional costs should be contrasted by increased longshore distance of protection and additional infrastructure. A comprehensive benefit cost comparison is beyond the scope of this work.

For the Removal, Retreat and Baxter Road Relocation alterative, operation and maintenance costs for the relocated road and utilities (for example plowing, repaving, drainage maintenance) are expected to be similar to the existing roadway and utilities. Since no appreciable change in costs are anticipated, these costs are not included in the assessment.

4.6.5 Constructability

An important consideration in any project is the constructability of the project and its potential impact to the surrounding community. Any construction project will impact the surrounding community albeit temporarily. Access to the beach may be temporarily limited or eliminated for safety requirements during construction for any of the alternatives. For land-based construction, repeated heavy truck traffic on residential roadways can damage roadways, increase congestion, and pose a noise concern. A traffic survey during maintenance could be considered to understand the present number of trucks during maintenance and its overall contribution to traffic conditions. Sand is typically trucked to the site from offsite, upland sources, and then moved to the beach and placed using beach-based heavy equipment. For both new construction and maintenance activities involving sand placement (geotube construction, dune construction, dune maintenance, beach nourishment), local truck traffic will increase, and beach access will be somewhat restricted for safety. Sand is a commodity, and prices may fluctuate, and availability vary over time. While current trends show a significant increase in sand costs, and the need for sand is expanding island-wide, at this time we do not believe sand availability restricts the constructability or viability of any alternatives. Water based construction has a limited season and operable weather windows with additional cost. Timing of construction activities may also be restricted due to environmental requirements. Nesting birds may limit when certain onshore construction activities take place and fish species spawning may limit times of the year when in-water work can be completed. While some of the alternatives are more challenging to construct than others, none of the solutions were deemed not feasible to move to construction. All alternatives presented have been implemented previously either onsite, or in similar conditions elsewhere.

4.6.6 Other Issues and Considerations

Regulatory Considerations

Solutions that would be implanted on the beach or further offshore require Conservation Commission review and approval under the Wetlands Protection Act. Additionally, USACE, CZM, and other Federal agencies also play a regulatory role for alternatives that are constructed below the high water line.

4.7 Removal, Relocation of Baxter Road and Utilities, Retreat

Allowing the natural process of erosion to continue unchanged is of interest to certain stakeholders. This alternative will involve the loss of private homes as well as existing easements that the town possesses and will require the Town to obtain new easements for the building of new utilities for the remaining homes on Baxter Road.

Removal

The removal of the existing toe protection involves unearthing the geotubes, emptying of the sand contents, and disposal of the fabric. Similar heavy machinery used during the installation of the geotubes would be utilized for the removal. The excess sand from the geotubes' contents would be graded into a dune adjacent to the toe of the bluff. This excess sand would erode as coastal processes continue and expose the toe of the bluff, leaving it vulnerable to the same coastal erosion over time. Our understanding is that there are funds in escrow devoted for the removal of the geotubes. It needs to be determined if the funds are sufficient for system removal.

Retreat

Following the removal of the geotubes, the unprotected shoreline would begin to retreat landward as the coastal processes continue unmitigated. It is difficult to predict how the shoreline would adjust to this change, as it depends on the intensity of the following storm seasons, as well as several other factors. The best prediction of how the shoreline might realign itself comes from the FEMA hazard areas for 2030, 2050, and the 2100 years, as shown in Figure 3: The 70 buildings which are projected to be at risk by 2100 are shown in blue based on FEMA Coastal Erosion Hazard Maps from July of 2019 (Source: https://arcg.is/1fuXXD0).

There is the potential for the shoreline realignment to be rapid and dramatic, so it is important that homeowners, the Town, and all residents of Nantucket have a strategic plan before removal of the geotubes. The Arcadis team will be recommending a plan below.

Relocation

The relocation of Baxter Road involves the relocating of utilities, roadways, and private property inland away from the 2030, 2050, and 2100 erosion hazard areas.

Maintaining both access and water/sewer service to residents will require advanced planning and implementation. As previously studied and recommended by Milone & MacBroom, the integrity of the roadway is likely to become compromised when the top of the bluff is within 25ft of the roadway. It is important that Town has a shovel-ready plan in place to address continued access and utility service well before the 25ft threshold is reached. Table 5 shows the most recent measurements taken by the town during August 2021 and Figure 29 provides an aerial image of the monitoring locations.

Table 5. Baxter Road Bluff Monitoring

Baxter Road Top of Bank to Edge of Pavement Measurements (In feet)							
Location	**Street Address**	**6/2/2018**	**10/4/2018**	**1/30/2019**	**8/24/2020**	**3/3/2021**	***8/9/2021**
A	109		67	67	67	67	67
1	105	39	39	39	38	38	37
2	101	35	35	35	35	35	35
3	91	56	56	56	56	56	56
4	87/Way	66	66	66	66	65	65
5	85	63	63	63	63	57	57
6	71/Way		144	144	144	144	144
7	67		192	192	191	191	191
8	61/Way		163	163	163	163	163

August 2021 Measurements in ft[1]

[1] Measuring tape was used, these numbers are subject to variations in measuring methods.

* Not associated with any storm event.

Figure 29. Locations of Baxter Road Bluff Monitoring.

Considerations

The team considered several factors in the design of the relocation. Included in these considerations are the following:

1. Location of existing town owned parcels and easements
2. Proximity of FEMA Hazard areas
3. Continued Access to Sankaty Head Lighthouse
4. Maintaining utilities (both public and private utilities) and access to homes
5. Minimizing impact to sensitive environmental areas
6. Dimensional requirements for roadway (e.g. width requirements for Fire Department)

The relocation of Baxter Road is considered for affected areas up to the year 2100 according to the FEMA erosion lines. Because of the breadth of the affected area as well as the imminence of the years 2030 and 2050, the relocation is broken up into two phases.

Phase 1 (through year 2050)

Phase 1 includes the previously executed Alternative access MOU[18] and utility relocation route with an extension to provide additional at risk properties access and utilities through year 2050. The extension is planned to be a one-way gravel access route while the original MOU pathway will be a two-way gravel access route. Gravel will allow the absence of required roadway drainage for impervious asphalt, while the one-way extension will limit the width of required easement acquisition. Figure 30 below shows the locations of easements involved in the Phase 1 plan in blue. Also, note the red highlighted parcel within this area which shows the shortest bluff edge to pavement edge measurement (35') within the Baxter Road area.

Phase 2

Phase 2 considers the impact of the 2100 FEMA erosion area on all assets, access, and private property. As such, it is not as imperative to begin further design of this concept plan when compared to the Phase 1 area. Included in Phase 2 is a short Sankaty Road re-routing where the road bends northwesterly. This will require the associated water utility within the roadway to be rerouted within the new roadway alignment. Within Baxter Road, several more private homes and utilities are affected and therefore easements for utilities (water and sewer) and maintenance of the road will need to be acquired behind the landward houses of Baxter Road. As with Phase 1, costs associated with Phase 2 sewer incorporate pricing to reflect a low-pressure HDPE sewer system with grinder pumps located at each residence. Both water and sewer utilities will continue to travel south within this easement, until the 2100 FEMA line moves seaward away from the Baxter Road properties, at which point the proposed water and sewer utilities will reconnect with existing Baxter Road infrastructure. This occurs just south of 55 Baxter Road. The areas in Phase 2 with proposed easement acquisition and new utility routes are shown below in yellow in Figure 31.

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[18] This is the 2015 Memorandum Of Understanding (MOU) detailing Alternative Access plans for Baxter Road.

Figure 30 Phase 1 Relocation

Figure 31 Phase 2 Relocation

4.8 Cost Estimate

4.8.1 Capital Cost of Retreat

Costs for the various items involved in both Phase 1 and Phase 2 are shown in Table 6. Arcadis utilized unit rates for prior contracts for estimating the different items. For easements, assessed land value from the fiscal year of 2021 were averaged and used in the estimate. Easement widths of 40 feet were assumed to be large enough to cover the temporary construction requirements. Permanent easements were assumed to be 20 ft. Currently prices in the table are based on the payment for permanent easements only. Costs do not include the relocation of the electrical or communication utilities as it is assumed these costs would be part of the utility company ownership requirements and spread over a different base of users. All costs are in 2021 dollars.

In addition, the cost of hardened drainage infrastructure was not included as it assumed property owners will mitigate any needed drainage on site. The new roads are mostly gravel and assumed to not need drainage infrastructure.

Both the subtotal and total costs for each phase of work are included, as well as a grand total representing the cost for both phases of work. This grand total should be considered a ballpark estimate to relocate the roadway and infrastructure away from the FEMA erosion area projections through the year 2100.

Table 6. Road Relocation Costs

Item	Unit Prices	Unit	Phase 1 Quantity	Phase 2 Quantity	Phase 1 Cost	Phase 2 Cost
Sewer pipe (4" HDPE Force Main)	$150	/LF	3,200	5,100	$480,000	$765,000
Low Pressure Grinder Pumps	$25,000	EA	19	30	$475,000	$750,000
Water Main (8" DIP)	$175	/LF	3,200	2,600	$560,000	$455,000
Fire Hydrants	$7,260	EA	8	22	$58,000	$159,000
Service Connections	$3,000	EA	8	22	$24,000	$66,000
Paved Road	$60	/Sq. Ft	0	22,200	-	$1,332,000
Gravel Road	$40	/Sq. Ft	63,400	0	$2,536,000	-
Police Details	$2,200	/week	8	12	$17,600	$26,400
Easements					$1,540,000	$2,475,000
Temporary Facilities (Travel Expenses)	$3,000	/week	10	14	$30,000	$72,000
Environmental Controls					$50,000	$75,000
SUBTOTAL					**$5,800,000**	**$6,200,000**
Contractor's General Conditions	10%				$580,000	$620,000
Engineering % Construction Management	20%				$1,160,000	$1,240,000
Mobilization & Demobilization	30%				$1,740,000	$1,860,000
Permits & Survey	15%				$870,000	$930,000
Legal Fees & Documentation	15%				$870,000	$930,000
Contingency	40%				$2,320,000	$2,480,000
TOTAL					**$13,340,000**	**$14,260,000**
GRAND TOTAL					**$27,600,000**	

Immediate Next Steps for Retreat Planning

The following immediate next steps should begin for planning for retreat:

- Continue public education and outreach throughout Nantucket to gain consensus on the funding needed for utility and road relocation.
- Appropriate dedicated funding ($2-4 million) to begin the work to solidify utility and road relocation route.
- Proceed to field surveys (including sensitive receptor surveys) and discussion with homeowners on possible routing.

Project Cost Recovery

Arcadis reviewed several potential options for recovering the cost of the Phase 1 and Phase 2 improvements. The following provides a brief overview of the options; however, it is noted that some of the options have specific requirements per Massachusetts statutes and the Town should consult its legal counsel to determine the best course of action.

- User Fees – In Arcadis' experience, it is common for sewer and water utilities to include utility relocation and sewer main replacement work as part of ongoing capital budgets. In this instance, the Town is planning for the eventual relocation of utilities to maintain service that is threatened by the onset of natural circumstances beyond the control of the existing customers. The cost of the improvements could be paid via borrowing, with the annual debt service principal and interest recovered from all customers via the Town's existing sewer user fee (for the sewer portion of the relocation cost). The respective cost of relocating the water and other utilities such as electricity or cable would likewise be recovered from the corresponding utility's customers.
- One advantage of using this option for cost recovery includes the establishment of a relatively easy to understand method for recovering utility costs related to future natural disasters or pre-disaster mitigation projects. As future projects are required to restore or enhance the resilience of existing service connections, the cost would be recovered across the customers of the service area. From a financial standpoint, using the user fee for recovery of costs provides greater economies of scale resulting in less overall impact to existing customers.
- It is also noted that the Massachusetts Division of Local Services (DLS) provides a guide for betterments and special assessments. The guide notes that local communities could also potentially recover capital costs via user fees, or a user fee surcharge. In this instance a surcharge would be applied to specific customers that benefit from a project in addition to the general user fees charged to all customers. In this instance, the user fee surcharge would shield all other customers from contributing to a specific project.
- Betterments – Betterments would recover all or a portion of the project costs from parcels impacted by the project based on a formal vote of the Town. A betterment is a special property tax "that is permitted by general or special law where real property within a limited and determinable area receives a special benefit or advantage, other than the general advantage to the community, from the construction of a public improvement." In general, betterments must show special benefit, i.e., an enhancement of the use or value of the property due to the construction of the improvement. A special benefit is measured by how much the particular improvement has increased the fair market value of the property considering all present and future uses to which the property is or may be reasonably adapted in the hands of any owner.[19]
- Within the realm of sewer or water utilities, betterments can occur when a utility is looking to initiate service or extend a water or sewer line to provide service to new customers. In these instances, the receipt of quality will let you save as public water or sewer service compared to reliance on a well or septic system can be seen as adding value to a customer's property. The enhanced value provides the basis for establishing a betterment

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[19] From Informational Guideline Release for Betterments and Special Assessments Assessment and Collection Procedures published by the Massachusetts Department of Revenue Division of Local Services, February 2021.

assessment that recovers the cost of the project from benefiting customers over time. The existing customers of the system are thus shielded from paying for the capital costs of extending service to new customers. The relocation of utilities provided in this report essentially leave the customers with the same or similar service, thus, it may be difficult to reflect that the proposed project provides an enhancement of value to the existing properties as they have service or access to the utilities currently located in Baxter Road.

- Special Assessments – These are similar to betterments but focused primarily on sewer or water improvements. Like betterments, the assessment is a special property tax, and is backed by a lien on the property that benefits. The project must provide a special benefit, which includes enhancement of value or use of the property. As noted above, it is difficult to discern the special benefit or use those customers would derive from the project, as relocating the utilities would essentially restore the same or existing service to the customers that they currently have. In addition to special assessments, the Massachusetts statutes also note the ability of Towns to charge customers for “permanent privilege” of connecting to a system. This is a one-time charge usually collected when a customer has connected to the main that abuts the property. They recover capital costs that have not been previously recovered via a special assessment. Thus, they typically recover, additional or incremental costs above and beyond what existing or new customers have already been charged via special assessments or other means.

As seen, utilities have several options for recovering certain capital improvements to sewer or water systems. There are certain requirements that are necessary for a Town to use a betterment or special assessment as a means for recovering capital project costs. This includes determining the special benefit that properties receive from the project. Arcadis recommends that the Town consult with its legal counsel to ensure what is possible from a legal standpoint. From a ratemaking standpoint, Arcadis recommends that the Town consider the project in light of similar existing, or potential future capital projects across its service area. If the proposed project is of a one-time nature, other similar projects are not expected, and it is determined to be legally feasible, then the special assessment option should be considered more fully. If the proposed project is similar to potential future projects that may deal with rising sea levels or recovery from natural disasters, then recovery of capital costs through user fees should be considered more fully.

4.9 Best Management Practices (BMPS)

Poorly controlled rainwater drainage can affect bluff erosion negatively. Rainwater that drains over the bluff edge can cause sediment erosion at the top of the bluff, further exacerbating the toe erosion occurring from wave action. In addition, lack of appropriate vegetation or the presence of partially impervious vegetation such as manicured lawns may create a suboptimal top-of-bluff interface. Planting the appropriate types of vegetation with stabilizing roots near the edge of the bluff may delay erosion further. Irrigation of lawn areas should be avoided.

There are several Best Management Practices (BMPs) like vegetation selection and planting and runoff control which homeowners can implement to mitigate bluff erosion.

Best Management Practices (BMPs) are simple protocols that can be implemented to reduce factors which contribute to erosion on an individual property owner basis. Homeowners can implement these practices to mitigate stormwater runoff to prevent erosion of the bluff. These BMPs do not typically require additional permitting and represent the “low-hanging fruit” of reducing the acceleration of erosion along the Baxter Road bluff.

Appendix B includes the full PDF of homeowner BMPs. These were adapted from Massachusetts Coastal Zone Management (CZM) documentation and adapted to only include pertinent BMPs for the Baxter Road area.

5. Recommendations

5.1 Adaptation Pathways

Adaptation Pathways are sequences of actions, which can be implemented progressively, depending on future dynamics. They can be oriented around performance-thresholds, considering the input of multiple-stakeholders. The pathways should indicate flexible options for changes in actions based on appropriate tipping points, which can be planning horizons, increases in sea level, severity or impacts of storm events, changes in policy, maintenance costs, distance to the bluff, or other tipping points. For the pathway exercise described in Section 3, the initial tipping points including planning horizons of 2030, 2050, 2070, and 2100. Based on stakeholder input, Figure 32 shows a refined adaptation pathways graphic which centers around erosion rates and the distance of the bluff to homes, buried infrastructure, and the road.

Identified Tipping Points include:

1. **Baxter Road is determined to be within 25 feet from the bluff.**
2. **Maintenance of an installed system is no longer cost-effective.**
3. **Removal of the Existing System. It is not advisable that the existing toe protection be removed before a comprehensive retreat plan is in place.**
4. **Construction of the Relocated Road and Utilities**

All of the adaptation pathways eventually lead to strategic retreat from the shoreline. However, the retreat must be carefully planned, and the planning must begin now. For example, it is not prudent to remove the geotubes without a plan to prevent the erosion and other impacts that will come with their removal. Time needs to be given to plan for minimizing these potential impacts.

Based on a number of factors, including climate change, increasing construction and maintenance costs, and regulatory policy, indefinitely protecting the bluff from erosion is no longer a practicable solution. However, we do not recommend a policy of retreat without a plan to manage anticipated impacts, and adequate time to implement the retreat plan.

As seen in Figure 34, the *Adaptation Pathways* are split into Adaptation Alternatives shown in orange which include the alternatives evaluated to slow bluff erosion and maintain the beach and *Recommended Short-Term Actions* shown in blue which center around planning for eventual Retreat (shown in pink). Provisions for monitoring and maintenance are shown in gold, tipping points indicated with a scale symbol, and cautionary steps with a caution symbol.

Monitoring and maintenance should continue during this process to support informed management of the system until retreat is complete. Continuing routine surveys of the system provides valuable information to support continued sand placement and can inform adaptive management approaches if incorporated. In turn, this information may also inform other sediment management activities at other locations with similar shoreline characteristics and wave energy.

If effectiveness were the only evaluation criterion, Expansion of the Existing System would be the recommended Adaptation Alternative for the short term. This would provide the greatest level of risk reduction to Baxter Road, the utilities, and private properties and human safety. A variation on this alternative would be to design toe protection to a lower level of return-period storm, such as 25- or 50-year storm, to be more aligned with providing protection over a time-period appropriate to allow for a retreat strategy to be implemented. The work of this project was to identify potentially feasible solutions based on a technical review, including the ability of the alternative to be issued permits under existing regulations, and taking stakeholder feedback into consideration. Based on stakeholder engagement and the current regulatory landscape, it is understood that expansion of the system may not be possible. **At a minimum, it is recommended that the existing system remain in place and that it continues to be maintained and monitored.** This provides time for comprehensive retreat planning as discussed in Section 5.2. Such a system could remain in place while retreat planning occurs and the new road and utilities are built, and until such time as maintenance is no longer cost effective, the bluff erodes to within 25 feet of the road, or the existing toe protection fails. If any of these tipping points occur, the Town and private property owners must be ready to move, and the new road must be already built. Therefore, design of the new road and comprehensive retreat planning must be undertaken in the short term.

As previously discussed, the addition of Nearshore Breakwaters to the existing system may reduce wave energy from smaller storms but to be effective for larger storms, they would need to extend above storm tide elevations and, as such, would need to be several feet above normal high tides. This may have visual impacts and would also contribute to higher construction costs. As an added benefit, they would encourage sand deposition on the beach. The cost of such a solution is likely prohibitive given the benefits provided at this location and would face significant regulatory hurdles and evaluation of a range of potential environmental impacts. Nearshore breakwaters in combination with a softer form of toe protection (sand dune or jute fiber) may provide a way to optimize wave reduction from the breakwaters with storm protection for the bluff toe. However, offshore breakwaters, even ones with lower crest elevations, will have cost and regulatory challenges as noted above.

It is not recommended that the existing toe protection be removed until after new infrastructure is in place, and an orderly retreat can be implemented, as there is not anything currently permittable to provide the same level of toe protection and risk reduction to the infrastructure and homes on the bluff. If the toe protection is significantly damaged by a storm and must be removed, other interim measures should be immediately implemented to allow the retreat process to continue; these measures may include sand dunes (with ongoing maintenance) or another temporary toe protection system.

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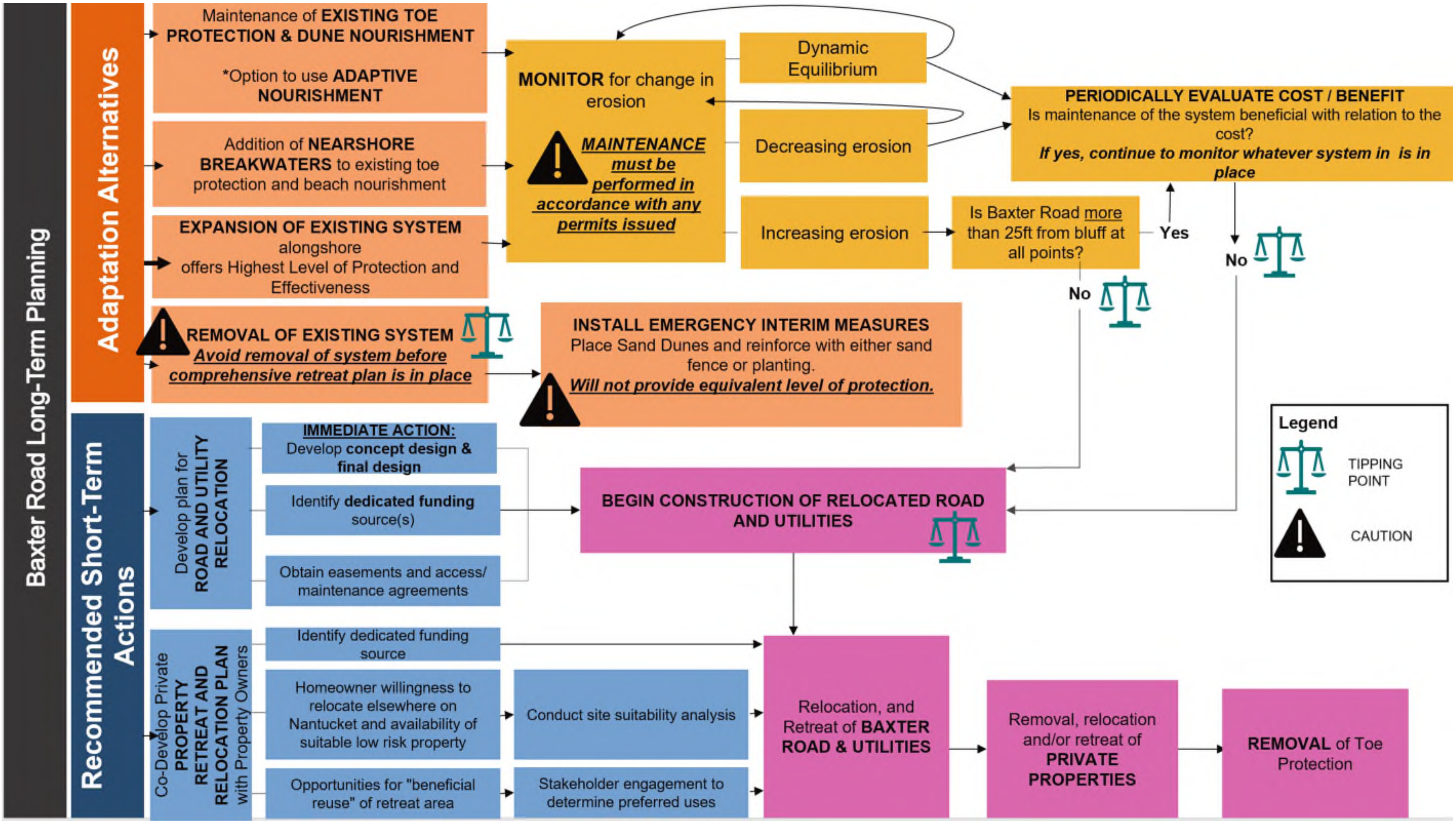

Figure 32 Adaptation Pathways

5.2 Comprehensive Retreat Planning

Given the historic erosion rates in the Baxter Road area and likely increase in erosion due to SLR and increased storm frequency, maintaining the bluff in its current position is not a practical long-term option. There is a need for an alternative approach rather than protecting the bluff, due to:

- Limitations on hard structures,
- Desire to maintain beach access, and
- Likelihood that sand mitigation costs will continue to increase further.

Given these constraints and the input received during this analysis, Arcadis recommends relocation and a return to a more natural bluff system as the most practical long-term solution.

For the short term, it is imperative to maintain and enhance existing measures that can keep the area safe during the retreat process. The appropriate length of time for these protection measures to stay in place depends on the timing for the selected retreat process, on how much erosion increases, and on other tipping points as previously discussed.

The Recommended Short-Term Actions on the Adaptation Pathways figure (Figure 34) have been split into two categories: Road and Utility Relocation, and Private Property Retreat and Relocation. Comprehensive retreat planning for the road relocation includes work to further develop the concept design and final design for road relocation, identification of a dedicated funding source(s), and obtaining easement, access, and maintenance agreements for the road relocation plan. The order of magnitude costs associated with this effort were previously presented.

Comprehensive retreat planning for Private Property retreat and relocation involves co-development of a plan by the Town and property owners including identification of a funding source(s), assessment of homeowner willingness to relocate and availability of suitable low-risk property, as well as identification of acceptable beneficial reuse of the retreat area.

This area will not be the only location on the island facing eventual retreat from the shoreline. This planning effort presents an opportunity for the community to set precedent for retreat island-wide consistent with the CRP, and then apply lessons-learned at Baxter Road in other likely retreat areas.

5.3 Recommended Action Plan

The following summary is intended to serve as the short- and long-term adaptation roadmap for the Baxter Road Long-Term Planning project, including actions that need to be taken by the Town and private property owners.

5.3.1 Short-Term Actions

- Start to apply for funding through FEMA and other applicable programs
- Continue to monitor erosion rates and other indicators
- Plan out the road relocation now. Continue public education and outreach throughout Nantucket to gain consensus on the funding needed for utility and road relocation.
- Appropriate dedicated funding ($2-4 million) to begin the work to solidify utility and road relocation route.
- Hold discussions with homeowners on possible routing. Obtain easements, access and maintenance agreements, locate all sensitive receptors to finalize road alignment, conduct field investigations and survey, get a concept and final design in place (bid-ready documents).
- Removal of the existing toe protection is not recommended until comprehensive retreat planning is complete and use of the new road and utility infrastructure is imminent. Keep existing toe protection in place and perform required maintenance until an agreed upon tipping point. Consider adaptive nourishment.
- The pending enforcement action for removal will likely be appealed. If removal or failure occurs, switch to emergency interim measures.
- Planned private property retreat – begin planning now for the inevitability of strategic removal and relocation. Develop comprehensive retreat plan.
- Plant and stabilize the bluff face and maintain the existing and new planting areas.
- Implement homeowner BMPs to reduce runoff contributing to bluff erosion.
- Develop a feasibility and cost/benefit assessment for nearshore breakwaters.
- Develop a Sediment Budget.
- Work collaboratively with all stakeholders to set a timeline for retreat.

5.3.2 Mid-Term Actions

- Continue to monitor erosion rates and other indicators.
- Install nearshore breakwaters if shown to be feasible.
- Begin Construction of the new road as soon as planning is complete, and funding is in place.
- Continued development of retreat plan
- Relocate homes.

5.3.3 Long-Term Actions

- Continue to monitor erosion rates and other indicators.
- Implement the Retreat Plan fully, support the eventual removal of existing toe protection and relocation of homes.
- Manage the beach/bluff for public access and habitat. This may still involve some nourishment and breakwaters could be beneficial for this purpose.

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APPENDIX A

Abbreviations and Glossary

Acronyms and Abbreviations

AEP – Annual Exceedance Probability. The probability of a flood event occurring in any year. The probability is expressed as a percentage. For example, a large flood which may be calculated to have a 1% chance to occur in any one year, is described as 1% annual chance or commonly the 100-year flood event.

Aeolian transport – The transportation of sediment by wind.

BMPs – Best Management Practices

ASCE – American Society of Civil Engineers

Beach Profile – A cross-section taken perpendicular to a given beach contour; the profile may include the face of a dune or sea wall, extend over the backshore, across the foreshore and seaward underwater into the nearshore zone (USACE, 2003).

Bluff Stabilization – Includes vegetation and promoting best management practices to manage surface drainage.

ConCom – Nantucket Conservation Commission

CRAC – Nantucket Coastal Resiliency Advisory Committee

CRP – Nantucket Coastal Resilience Plan

Cross Shore Transport – The movement of sediment perpendicular to shore.

CZM – Massachusetts Office of Coastal Zone Management

DEP – Massachusetts Department of Environmental Protection

Depth of Closure – The water depth beyond which repetitive or topographic surveys (collected over several years) do not detect vertical sea bed changes, generally considered the seaward limit of littoral transport. The depth can be determined from repeated cross-shore profile surveys or estimated using formulas based on wave statistics. Note that this does NOT imply the lack of sediment motion beyond this depth (USACE, 2003).

Design Life – The length of time during which a capital investment or mitigation strategy is expected to function within its specified parameters. For example, short-term solutions may have a 10-year design life. Long-term solutions may have a 50- or 100-year design life.

Dynamic Equilibrium – Short term morphological changes that do not affect the morphology over a long period (USACE, 2003).

Dune Nourishment – Sand that is placed on top of the geotubes to provide a buffer to the geotubes and add material to the littoral system.

FEMA – Federal Emergency Management Agency, primarily responsible for disaster response and recovery following Federal declared state of emergency.

GIS – Geographic Information System

Longshore – Parallel to and near the shoreline; alongshore (USACE, 2003).

Longshore Drift – Movement of (beach) sediments approximately parallel to the coastline(USACE, 2003).

Morphology – River, estuary, lake, beach, seabed form and its change with time (USACE, 2003).

MOU – Memorandum of Understanding

MSL – Mean Sea Level, The average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly height readings (USACE, 2003).

Nearshore – (1) In beach terminology an indefinite zone extending seaward from the shoreline well beyond the breaker zone. (2) The zone which extends from the swash zone to the position marking the start of the offshore zone, typically at water depths of the order of 20 m (USACE, 2003).

Nourishment – The process of replenishing a beach. It may occur naturally by longshore transport or be brought about artificially by the deposition of dredged materials or of materials trucked in from upland sites (USACE, 2003).

NHESP – Natural Heritage & Endangered Species Program

MORIS – Massachusetts Ocean Resource Information System
http://maps.massgis.state.ma.us/map_ol/moris.php

NOAA – National Oceanic and Atmospheric Administration

NOI – Notice of Intent

RSM – Regional Sediment Management. This program is a federally funded program that promotes a systems approach for management of sediments across coastal, estuarine and inland environments (USACE, 2021).

Sediment Transport – The main agencies by which sedimentary materials are moved are: gravity (gravity transport); running water (rivers and streams); ice (glaciers); wind; the sea (currents and longshore drift). Running water and wind are the most widespread transporting agents. In both cases, three mechanisms operate, although the particle size of the transported material involved is very different, owing to the differences in density and viscosity of air and water. The three processes are; rolling or traction, in which the particle moves along the bed but is too heavy to be lifted from it; saltation; and suspension, in which particles remain permanently above the bed, sustained there by the turbulent flow of the air or water (USACE, 2003).

SBPF – Siasconset Beach Preservation Fund

SLR – Sea Level Rise, the long-term trend in mean sea level (USACE, 2003)

SOOC – Superseding Order of Conditions

Subsidence – Gradual settling or sudden sinking of vertical land surface elevation, exacerbating the effects of sea level rise.

Toe Protection –Protection that is placed at the toe or base of a bluff or cliff to prevent wave erosion during storms. .

USACE – United States Army Corps of Engineers

USGS – United States Geological Survey

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APPENDIX B

Homeowner Best Management Practices

StormSmart Coasts

Controlling Overland Runoff Specific to Coastal Bluffs

The following was adapted from the Massachusetts Coastal Zone Management Storm Smart Coasts initiative. Arcadis gives full credit of this document to Massachusetts CZM.

What Is Runoff and How Does It Cause Coastal Erosion?

Runoff is rainwater, snowmelt, and water from irrigation systems and other sources that does not soak into the ground or evaporate, but instead flows over the ground surface. Runoff causes erosion when water falling on and/or running across bare or sparsely vegetated areas dislodges soil and other sediments. When runoff flows over a coastal bank, dune, or beach, it can erode these landforms from above and exacerbate other coastal erosion problems.

Channels or gullies on the face of a bank or dune are a sign of a runoff problem. As shown in the photograph on the right, sediment carried by runoff is often deposited in a fan-shaped pile at the base of the slope. The channels and fan-shaped deposits are both indicators that runoff is eroding the bank. Similarly, runoff can erode soil from behind concrete seawalls and under rock revetments (i.e., shoreline stabilization structures constructed of sloping rock), causing them to slump or collapse. Indicators that runoff may be contributing to the failure of seawalls and revetments include channels in the bank above the structure or sinkholes behind the structure. If overland sources of runoff are not successfully managed, the effectiveness of other shoreline stabilization techniques can be compromised.

Runoff has eroded a channel in this bank face, exacerbating the coastal erosion problem. Some of the eroded material has been deposited in a fan-shaped mound at the base of the bank. (Photo: CZM)

General Approaches to Runoff Control

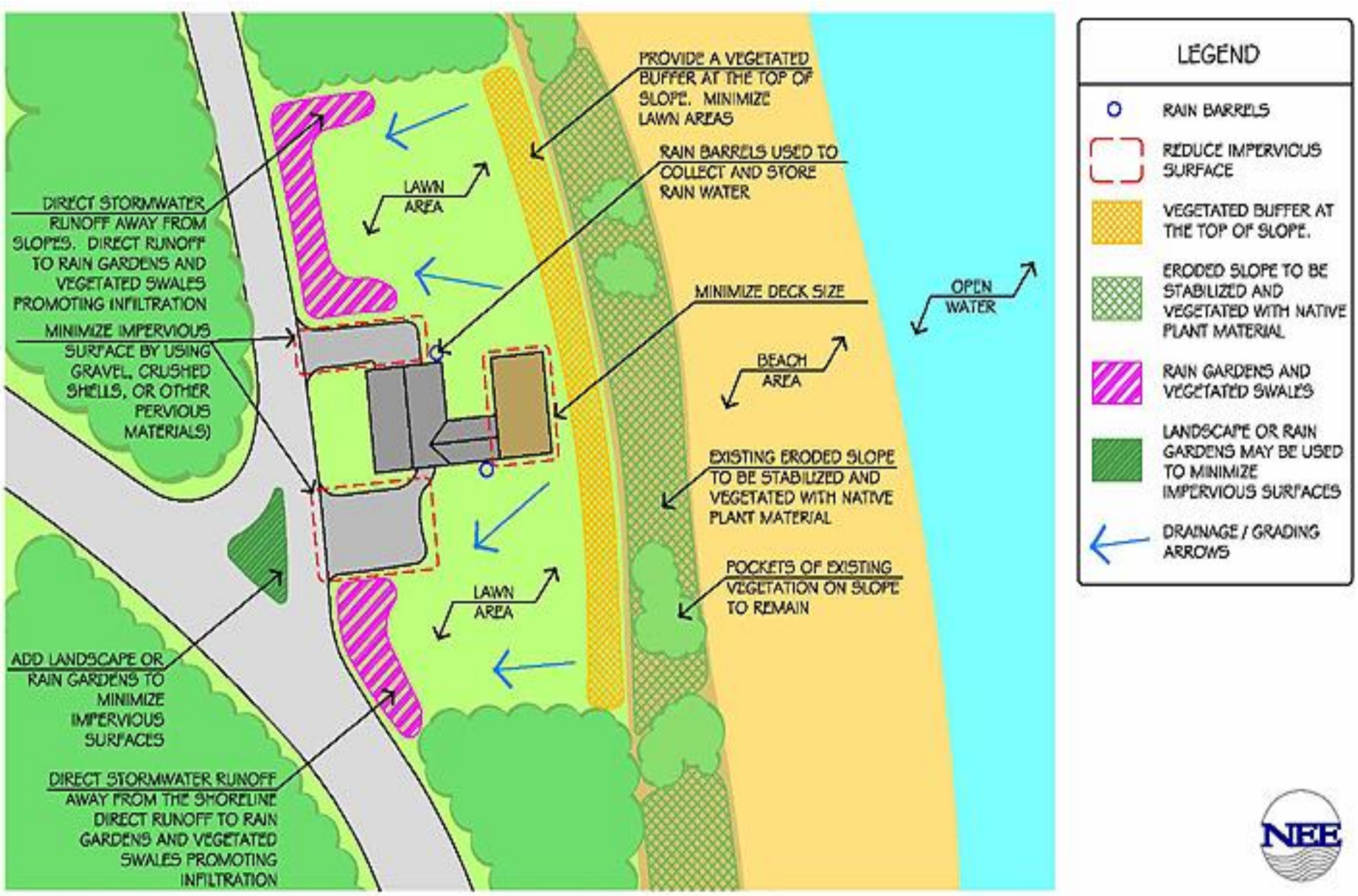
Controlling runoff from upland sources helps reduce a significant cause of erosion on many beaches, dunes, and banks. Efforts to control runoff focus on reducing the quantity and velocity of water flowing across the land surface and changing the direction of flow as necessary to address specific erosion problems. Runoff control approaches include:

- Removing and reducing impervious surfaces (i.e., pavement, concrete, and other impermeable materials) and planting natural vegetation to help slow the flow of runoff and allow the water to naturally seep into the ground. For example, converting asphalt or concrete driveways to grass, crushed-shell, or other surfaces that allow water to soak into the ground is an excellent way to reduce impervious surfaces.
- Capturing runoff so that it can be infiltrated into the ground over a broad area or reused for irrigation.
- Redirecting the flow of water away from erosion-prone areas by regrading the ground surface, constructing a barrier of soil or other sediment (known as a berm), and removing landscaping elements that channel runoff.
- Maintaining the soil's natural capacity to absorb water by preventing saturation from lawn watering and other irrigation.

Runoff control techniques should address the specific patterns and sources of runoff on the site based on a comprehensive evaluation of site conditions. These conditions include the location and extent of impervious and vegetated surfaces, soil types, slope and elevations on the property, and sources and amounts of water coming from both on- and off-site. An experienced professional may need to be consulted for additional guidance regarding project design, and the local Conservation Commission should be contacted about permitting.

Several options are available for installing grass driveways, including this grass and paver system. As with all runoff control options, site conditions and potential impacts should be fully evaluated in project design. **(Photo: CZM)**

This lawn was regraded to slope inland, and a buffer of native shrubs was planted along the top of the bank to stabilize the area and direct runoff away from the bank. These measures reduced runoff flowing over the bank so that a bioengineering project with natural fiber blankets, coir rolls, and vegetation could be successfully installed. **(Photo: CZM)**



This figure demonstrates how a typical coastal property could be modified to reduce runoff and where appropriate runoff control techniques could be sited. (Graphic: New England Environmental, Inc.)

The following factors should be addressed to ensure that the runoff control options selected do not create **unintended negative impacts:**

- **Channelization of Runoff** - Improperly managing runoff can have negative impacts, particularly if the runoff is channelized or redirected onto adjacent properties where it inadvertently increases erosion and flooding issues or where it would impact sensitive environmental resources, such as salt marsh. To avoid these impacts, runoff control options should include components that redirect and spread the flow of water across a broad vegetated area or into a rain garden or vegetated swale (i.e., specially constructed depressions in the ground that are planted with vegetation).
- **Impermeable Soil Layers on Banks** - When there is an impermeable layer of soil (like clay) underlying permeable sediments in a coastal bank, water that infiltrates into the ground may flow along this impermeable layer toward the bank face. This concentration of water flow may exacerbate erosion where the water breaks out onto the bank face. The runoff control techniques described below may address this issue. However, it is not

always obvious that this situation exists and is exacerbating erosion on a bank. Therefore, professional assistance may be needed to identify the problem and determine the most appropriate techniques to address it.

Design Considerations for Common Runoff Control Techniques

The following section describes a variety of techniques that can be used to help control runoff erosion problems. Specific suggestions for proper design, construction, and implementation are listed for each technique.

Reduce Impervious Surfaces

Reducing the area covered by impervious surfaces slows overland flow and allows water to naturally seep into the ground. To reduce impervious cover:

- Construct driveways or patios with pea stone, gravel, crushed shells, or other pervious materials, rather than using impermeable pavement or concrete.
- Avoid the use of dense-graded aggregate, stone dust materials, and other products that prevent water from permeating into the ground on driveways, patios, or walkways. These products are designed to eliminate voids in the compacted surface, which causes these areas to become impervious.
- Minimize the footprints of proposed buildings and impervious surfaces as much as possible.

Additional Benefit - Improved Coastal Water Quality
Contaminants carried in runoff can significantly harm coastal water quality. Oils and greases washed from roadways and driveways and pesticides from lawns can introduce toxins to coastal waters. Bacteria in runoff can lead to closed shellfish beds and swimming areas. Nutrients from fertilizers, pet waste, or septic systems can lead to nuisance plant or algae growth, which can reduce oxygen supplies (leading to fish kills and odors) and shade out eelgrass beds. Runoff control techniques allow the runoff to seep into the ground where some contaminants may be filtered out by the soil or absorbed by plant roots, minimizing contamination of coastal waters.

Replace Lawns with Natural Plantings

Lawns exacerbate runoff issues because water readily runs over mowed grass and the soils under lawns tend to compact to create an impervious surface. Replacing lawn with longer grass, shrubs, and other vegetation can therefore significantly improve runoff problems. Where possible:

- Restrict the use of mowed lawns to areas needed for pathways and recreation.
- Avoid mowing the lawn right up to the edge of the dune, bank, beach, or marsh (which has the added advantage of keeping people back from the edge—foot traffic may exacerbate erosion).

Extensive irrigated lawns that slope seaward have exacerbated the erosion of this coastal bank. (Photo: CZM)

Plant Vegetated Buffers

Vegetated buffers are strips of high grasses, shrubs, and other plants (other than lawn). These buffers absorb runoff, slow its overland flow, and break the impact of raindrops or wave splash. The plant roots also bind the soils and help improve the stability of the area. See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for additional information on using plants for coastal erosion control. To improve the success of runoff control projects:

- Plant vegetated buffers 5-10 feet in width landward of the top of the bank, dune, or beach to be protected.
- Plant salt-tolerant grasses with extensive root systems to provide more immediate erosion control. Though trees and shrubs may look more stable, grasses can grow more quickly and effectively stabilize large areas and require less maintenance to thrive.
- Plant native and salt-tolerant species that are adapted to local conditions and require less maintenance, watering, and pest control.
- Select appropriate species for site conditions, plant at the appropriate time of year (generally spring or fall), and follow the specific instructions for watering, fertilizing, and general care and maintenance.
- Plant trees far enough back from the top of coastal banks to ensure that their weight does not contribute to bank instability.
- If trees on or near the bank are leaning, they may increase instability of the bank and may need to be pruned or removed.
- Do not place dead plant material, such as lawn clipping, brush, and discarded Christmas trees, on a bank or other coastal area. These dead plant materials limit the natural growth and establishment of plants and do not have roots that help bind soils together. Many municipal landfills accept yard waste for composting.

- **Some of the most effective plants for vegetated buffers in coastal areas include beach plum, bayberry, Virginia or Carolina rose, arrowwood viburnum, sweet fern, and bearberry.**

Fertilizer can cause nuisance plant or algae growth that can degrade water quality. The nitrogen in fertilizer is a particular problem in coastal waters. Consequently, the use of fertilizer on vegetated buffers, as in all coastal areas, should be limited as much as possible. When designed and maintained correctly, vegetated buffers actually filter out nitrogen and other contaminants from inland sources, helping to reduce coastal water contamination.

Install Vegetated Swales and Rain Gardens

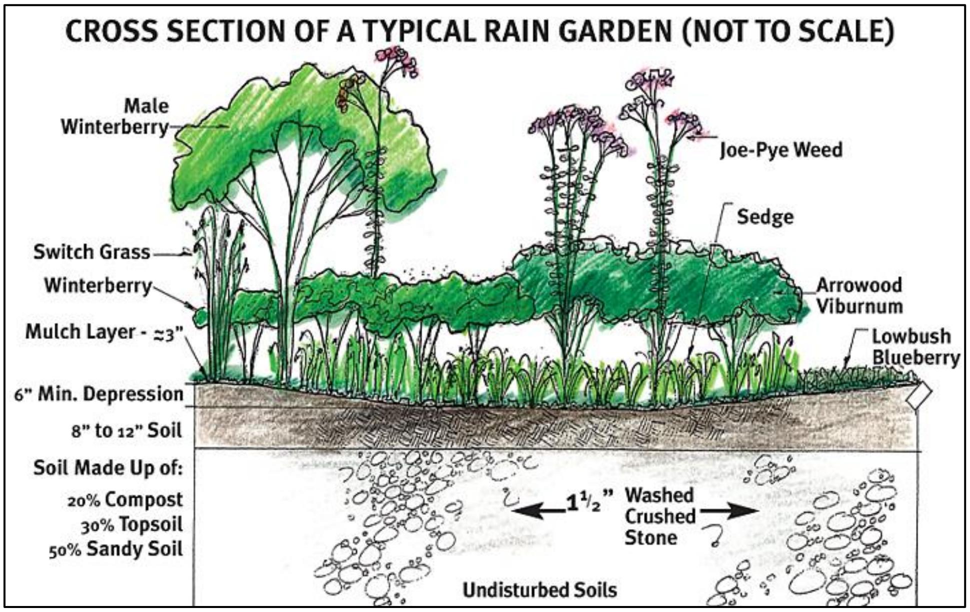
Vegetated swales are channel-like depressions in the ground used to slow, filter, and direct water to another location. Rain gardens are wider and flatter depressions that allow for the maximum collection and infiltration of water. Swales and rain gardens both use plants that tolerate both wet and dry conditions to ensure plant survival (swales often use grasses, while rain gardens are planted with a mix of grasses, perennials, shrubs, and trees).

A large rain garden. **(Photo: Massachusetts Bays National Estuary Program)**

To maximize effectiveness and prevent problems:

- Place swales/rain gardens downslope from a downspout, driveway, or other impervious surface in a relatively flat area (with less than a 5% slope), at least 50 feet away from septic systems, 100 feet away from wells, and 10 feet away from a dwelling foundation. Regrade the area if necessary to create an appropriate location for the swale/rain garden. Consult with your municipal board of health before installing a rain garden or swale near a septic system or well to make sure the proposed setback is sufficient.
- Locate vegetated swales/rain gardens as far away from the top of a bank as possible to reduce the amount of groundwater that may flow toward the bank face and potentially cause erosion.
- Determine the appropriate size of the swale/rain garden needed to effectively capture the runoff based on average yearly rainfall, soil infiltration rates, the size of the area that runoff is draining from, and impervious surface cover. Swales and rain gardens constructed in wetland resource areas will need to meet specifications contained in the *Massachusetts Stormwater Handbook* if a permit is required by the Conservation Commission.
- Plant a series of interconnected swales/rain gardens if one is too small to hold and infiltrate the amount of water flowing into it.
- If necessary, add amendments to clay or poorly drained soils to increase the infiltration capacity of the swale/rain garden. Some of the existing soil may need to be removed and replaced with a layer of gravel, planting soil mix, and mulch.
- To help prevent runoff from washing out the mulch or soil in large storm events, consider installing a temporary erosion-control blanket made of natural fibers over the swale/rain garden to stabilize the soil until the plants become established. (See *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks* for further information.) In addition, if concentrated flow is being introduced from a driveway, downspout, or other source, spread a layer of crushed stone across the entrance point where the water comes into the swale/rain garden to slow the speed of the flow.

As with vegetated buffers, select appropriate plants for site conditions, plant at the appropriate time of year (generally spring or fall), and follow the specific planting and care instructions.


CROSS SECTION OF A TYPICAL RAIN GARDEN (NOT TO SCALE)

Adapted illustration courtesy of Comprehensive Environmental, Inc.

Regrade Site to Direct Water Away from the Shoreline

Regrading the area landward of a bank, dune, or beach can ensure that runoff flows away from the shoreline. With this technique:

- Grade the site to slope toward vegetated swales or rain gardens. As mentioned above, swales/rain gardens should be placed well away from the top of a bank.
- To prevent basement flooding, do not direct the water toward a dwelling.
- To prevent erosion of the regraded area, consider covering exposed soils with a temporary erosion-control blanket and successfully plant the area as soon as possible.
- Avoid regrading work during heavy rains when exposed soils are more vulnerable to erosion.
- Avoid making slopes too steep, which will accelerate the flow of runoff and may cause additional erosion problems. Consult a professional for site-specific assistance in determining the appropriate slope.

Construct a Vegetated Berm

A berm (i.e., a mound of soil or other sediment built as a barrier) can be used as a "speed bump" to slow the flow of runoff. It is important to:

- Strategically construct vegetated berms to address specific runoff problems. For example, place a berm landward of the top of a coastal bank to redirect runoff away from the shoreline, or use a berm as a barrier to block or redirect runoff from roads, other properties, and other offsite sources.
- Determine the height and overall shape of the berm based on site conditions, such as soil characteristics, existing vegetation, site slope, and volume of water flowing toward the berm. The steeper the slope of the site, the faster the water will be flowing, requiring a higher berm to redirect the flow. As for shape, a berm is generally more stable when its base is twice the width of its height.
- Select sediments to construct the berm based on the amount of runoff. For average water flow, a mix of sediments (such as well-drained soil and sand) provides an effective physical barrier while also allowing for infiltration. For higher water flow, coarser materials (such as sand and gravel) provide greater flow-through and infiltration (to avoid the pooling of water behind the berm).
- Cover the berm with a layer of topsoil and plant/seed the area to stabilize the soil
- Consider using a short-term natural fiber blanket to stabilize the berm while the plants get established

Capture Roof Runoff

Significant quantities of rainwater and snowmelt run into roof downspouts. This water can be directed into a rain barrel, where it can be stored for reuse as irrigation water, or into a system designed to immediately infiltrate the water into the ground, such as a drywell or a French drain. When using these techniques:

- Place rain barrels below downspouts (55 gallon drums are the most common size for rain barrels). Cut the downspout to fit directly into the rain barrel. Special adaptations can be used, such as a spigot to attach hoses to reuse the water or an overflow hose to direct any overflow away from the foundation. Rain barrels should have a screen and cover to keep out mosquitoes, leaves, and debris.

- Design the drywells/French drains to channel water away from foundations. For sites directly adjacent to banks, French drains are generally preferred over drywells because they disperse the water infiltration, which helps ensure that the water successfully seeps into the ground and does not flow toward the bank face.
- Base the storage capacity of the drywell/French drain on the quantity of roof runoff, as well as on the depth of the water table. The bottom of the drywell/French drain should be at least two feet (but preferably four feet) above the seasonal high groundwater level.
- Drywells need to be at least 10 feet from building foundations, 50 feet from vegetated wetlands or tops of coastal banks, 50 feet from any component of a septic system, and 100 feet from wells.

Avoid or Reduce Watering of Lawns and Plants

Watering less keeps soils from becoming saturated, allowing them to more effectively soak up rainwater and other runoff. To water less:

- For the first year, if necessary, use a temporary irrigation system (such as drip tubing on a timer) while newly planted vegetation becomes established (see the planting instructions for specific watering requirements). Once the plants are established, watering is only required during extreme drought.
- When nature does not provide enough water to keep a lawn green and growing, allow it to go dormant. Though it may appear dead, this dormant state allows grass to preserve the vital parts of the plant during times of heat and low moisture and revive with the first saturation.
- Avoid cutting grass too short (generally no shorter than 2 inches). Taller grass has a deeper and more extensive root system, which enables the lawn to better withstand heat and drought.
- Plant less lawn grass and more drought-tolerant grasses and vegetation.

Slow the Flow of Water

By allowing water to spread out and flow over a wider vegetated surface, infiltration will increase, erosive forces will decrease, and runoff will be reduced. Specifically:

- Reduce the use of walls, solid fencing, curbs, etc., that concentrate runoff and create channels and gullies.
- Design discharge points for downspouts or other conduits of water to avoid causing scour, gullies, erosion, or alteration to vegetation. Place splash blocks or level spreaders (structures designed to uniformly distribute concentrated flow over a large area), or small amounts of gravel, at these discharge points to minimize erosion.
- Eliminate curbs or small retaining walls for defining the boundaries (such as between a driveway and lawn), which can channelize runoff and concentrate erosive forces. Replace curbs or walls with vegetated swales or rain gardens that promote infiltration and avoid channelization.
- If road runoff is an issue on your property, contact your town or city to determine if there is a drainage easement (an attachment to a property deed which states that access to part of the property is given to a third party, usually a community, for the purpose of maintaining drainage). If there is no easement, consider rain gardens parallel to the roadside to promote infiltration of road runoff. If there is an easement, work with your local officials to address the issue.

Heavy Equipment Use

If heavy equipment is needed for a project to address runoff, equipment access must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, beaches, or other landforms; impacts to wildlife and protected species habitat; and related impacts. When mechanical equipment is being used, contractors should keep hazardous material spill containment kits on-site at all times in case there is a release of oil, gasoline, or other toxic substance.

Additional Information

- CZM's Coastal Landscaping website includes information on landscaping coastal areas with salt-tolerant vegetation to reduce storm damage and erosion.
- CZM's *Landscaping to Protect Your Coastal Property from Storm Damage and Flooding fact sheet* (PDF, 962 KB) gives specific information for homeowners on appropriate plants for erosion control in coastal areas.
- CZM's CZ-Tip - Keep Waterways Clean by Filtering Pollutants with Plants discusses reducing runoff impacts by planting vegetated buffers.
- The Massachusetts Department of Environmental Protection's (MassDEP) Vegetated Buffer Strips: Slow the Flow to Protect Water Quality explains how vegetated buffer strips function and how to create them.
- The U.S. Environmental Protection Agency's (EPA) National Menu of Stormwater Best Management Practices has searchable fact sheets on berms, regrading, swales, and other stormwater control practices.
- EPA's GreenScaping: The Easy Way to a Greener, Healthier Yard provides information on yard maintenance to reduce water usage.
- *Rain Gardens Across Maryland* (PDF, 14 MB) discusses locating, siting, and designing rain gardens and calculating impervious surfaces (rainfall depths and plant species are specific to Maryland).
- CZM's Environmental Permitting in Massachusetts briefly describes major environmental permits required for projects proposed in Massachusetts.
- Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) cover work in wetland resource areas and buffer zones.
- MassDEP's *Erosion & Sedimentation Control Guidelines* (PDF, 4 MB) give best management practices for managing sediment and runoff.
- MassDEP's *Massachusetts Stormwater Handbook* provides design specifications for rain gardens, drywells, and swales.
- The Natural Heritage and Endangered Species Program website provides information on protected species in Massachusetts, habitat maps, and regulatory review for projects in or adjacent to these habitats.
- The Massachusetts Division of Marine Fisheries can provide information on horseshoe crab protection and other fisheries resources.
- The Massachusetts Ocean Resource Information System, or MORIS, is a web-based mapping tool for interactively viewing coastal data. MORIS data layers, such as endangered species habitat and shellfish, can help identify sensitive resource areas within or near the project site.

StormSmart Coasts

StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage

The following was adapted from the Massachusetts Coastal Zone Management Storm Smart Coasts initiative. Arcadis gives full credit of this document to Massachusetts CZM.

How Vegetation Reduces Erosion and Storm Damage

Dunes, banks (also known as bluffs), and other coastal landforms are susceptible to erosion from tides, currents, wind, and coastal storms. Overland runoff, which is the water from rain, snowmelt, sprinklers, and other sources that does not readily soak into the ground or evaporate but instead flows over the ground surface, can also cause erosion by dislodging vegetation, sand, gravel, and other sediments. Salt-tolerant plants with extensive root systems can help address both kinds of coastal erosion problems. First, plant roots hold sediment in place, helping to stabilize the areas where they are planted. Second, by absorbing water, breaking the impact of raindrops or wave-splash, and physically slowing the speed and diffusing the flow of overland runoff, plants reduce runoff erosion. Vegetation also helps trap windblown sand, which is particularly important for building dune volume, increasing the dune's ability to buffer inland areas from storm waves, erosion, and flooding. Finally, high grasses, shrubs, and other vegetation can be planted to limit foot traffic in erosion-prone areas.

Vegetation can be used in conjunction with many other techniques for erosion management. Considering the specific characteristics of Baxter Road, reducing Overland runoff over the Bluff is an important practice.

Beachgrass was planted to stabilize an eroded dune and trap windblown sand to build dune volume. (Photo: CZM)

A variety of salt-tolerant vegetation was planted on the face of this bank to stabilize fill added to address bank erosion. (Photo: CZM)

Shrubs were planted at the top of this bank to slow runoff. On the bank face, natural fiber blankets were installed to hold soils in place until the erosion-control vegetation could get established. **(Photo: CZM)**

Relative Benefits and Impacts Compared to Other Options

The major benefit of vegetation projects is that vegetated areas absorb and dissipate wave energy, rather than reflecting or redirecting waves elsewhere. The design of a hard structure affects how much wave energy is reflected, for example vertical walls reflect more wave energy than sloping rock revetments. These reflected waves erode beaches in front of and next to a hard structure, eventually undermining and reducing the effectiveness of the structure and leading to costly repairs. This erosion also results in a loss of dry beach at high tide, reducing the beach's value for storm damage protection, recreation, and wildlife habitat. Other benefits of vegetation projects are that they preserve the natural character of the coastal environment and provide wildlife habitat.

In general, the impacts of vegetation projects are relatively minor when compared to other options. Vegetation projects in habitat for protected species (i.e., species that are considered endangered, threatened, or of special concern in Massachusetts), however, do have the potential to cause significant impacts, such as removing open sand areas needed for successful nesting of piping plovers and diamond-backed terrapins. Even the planting of native plant species can cause impacts in these areas. See Design Considerations below for information on addressing this issue.

Design Considerations for Vegetation Projects

This section covers a variety of factors that should be considered to minimize adverse impacts and ensure successful design, permitting, construction, and maintenance of vegetation projects.

Appropriate Locations

Vegetation projects are appropriate for virtually any dune or bank along the coast where sand and other sediments are exposed to wind and waves. Because it is relatively difficult to get vegetation established in areas that are regularly inundated or overwashed by tides and waves, however, the longevity and effectiveness of these projects can be limited in certain locations. The techniques discussed in Protecting Plants below can help address this issue.

Protecting Plants

Plants are most vulnerable before their root systems become established. Techniques that can help stabilize dunes and banks while plants get established include:

1) **installing natural fiber blankets** on the ground surface before planting to hold soils in place while roots get established

2) **using temporary baffles** of natural-fiber material to shelter plants from wind

3) **installing sand fencing** to help slow wind, trap sand, and reduce erosion

Combining these techniques is more effective than using only one method. On banks, another method to protect the soil around newly planted live vegetation is to plant a salt-tolerant seed mix on the exposed soil. The plants that grow from seed can quickly stabilize the soil so it is not washed away while the live plants are becoming established.

Another important factor for successful plant establishment and survival is water availability. Since new plants with their smaller root systems have a limited capacity to find water in the surrounding soil, a consistent supplementary source of water should be provided directly to these plants while their root systems and foliage are developing. For large planting projects, the use of a temporary, automated irrigation system may be warranted for up to three summers following planting. See the Watering section below for additional details and cautions on using automated irrigation systems.

To further ensure the success of planting projects, sources of erosion, including upland runoff and waves, should be identified and addressed as part of the site evaluation and design process. Runoff should be reduced or redirected to give the vegetation the best chance of survival. In areas subject to regular erosion from waves, tides, currents, wind, and coastal storms, additional techniques should be considered to improve site protection. For example, beach nourishment can protect vegetation projects by widening beaches in areas with relatively narrow beaches at high tide. For bank projects, dense rolls of natural fiber called coir rolls can protect newly planted areas, hay bales can be staked at the base of the bank to provide a short-term buffer from tide and waves, and artificial dunes can be constructed with sediment from an off-site source to buffer the base of the bank.

In addition, to protect dune and bank vegetation, pedestrian access to the shoreline should be restricted to designated access paths or walkways and the number of access points should be limited as much as possible. Often, multiple properties can use a common access point. The size of access structures should be minimized as much as possible to limit shading impacts to vegetation.

Lightweight, natural-fiber, erosion-control fabric was installed on this bank to protect the plants from wind until the roots could get established. Boards were placed on top of wooden stakes to provide access during construction, which minimized impacts to the bank from foot traffic. The photo on the right was taken one year after planting. **(Photos: New England Environmental, Inc.)**

An Added Consideration on Banks - Establishing a Stable Slope

On banks, a stable slope is essential for project success. If the bottom of the bank has eroded and its slope is steeper than the upper portion of the bank, the bank is likely unstable. Even when heavily planted with erosion-control vegetation, banks with unstable slopes are extremely vulnerable to slumping or collapse that can endanger property landward of the bank. Before planting vegetation, therefore, the bank slope should be stabilized.

Ideally, soil of a similar type to that on the bank or beach is brought in as fill and added to the lower part of the bank to create a slope that matches or is less steep than the upper slope. However, if adding fill brings the toe of the bank within the reach of high tides, the fill will erode quickly and undermine the rest of the bank. In these cases, regrading the bank slope by removing sediment from the top of the bank may be a better option. While removing part of the upper portion of the bank does reduce the land area between the top of the bank and the property, it can be done in a controlled fashion that improves the overall stability and storm-damage prevention capacity of the bank. And if the slope is not stabilized, bank collapse during a storm could cause substantially more loss of land area to the sea. In addition, any investment in vegetation and other methods to prevent erosion on an unstable bank will be lost if the bank collapses. On sites where the top of the bank is well vegetated with mature, salt-tolerant species with extensive roots, the appropriate approach to stabilize the bank should be carefully developed by a professional with extensive experience successfully stabilizing similar sites.

Sediment was added to this eroding bank to create a shallower and more stable slope before the vegetation was planted. The lower bank was planted with grasses and the upper section with mixed grasses and shrubs. (Photo: CZM)

Plant Selection

Specific site conditions—including wind, salt, soil type and quality, moisture, shifting sands, frequency of coastal storms, and exposure to waves and overwash—dictate the plant species that can grow successfully. Native, salt-tolerant species are recommended for coastal use because they are well adapted to the harsh conditions, require less maintenance to grow and thrive, and provide more diverse food and shelter for wildlife. In addition, only plants with extensive root systems should be selected for erosion-control projects.

On dunes or the toe of coastal bluffs (particularly those closest to the beach where wind and wave action are strongest), American beachgrass is the best species to use for initial plantings. Beachgrass quickly establishes a dense root system, rapidly accumulates sand, and is very resilient to being overwashed by waves. For beachgrass to thrive, it should be planted in a location where wind-blown sand will reach the plants. Other plants recommended for use in combination with beachgrass include little bluestem, purple lovegrass, and seaside goldenrod. Further landward in dunes and beyond the reach of regular wave action, shrubs such as beach heather, lowbush blueberry, bayberry, and beach plum can be planted with grasses to add diversity and improve erosion control.

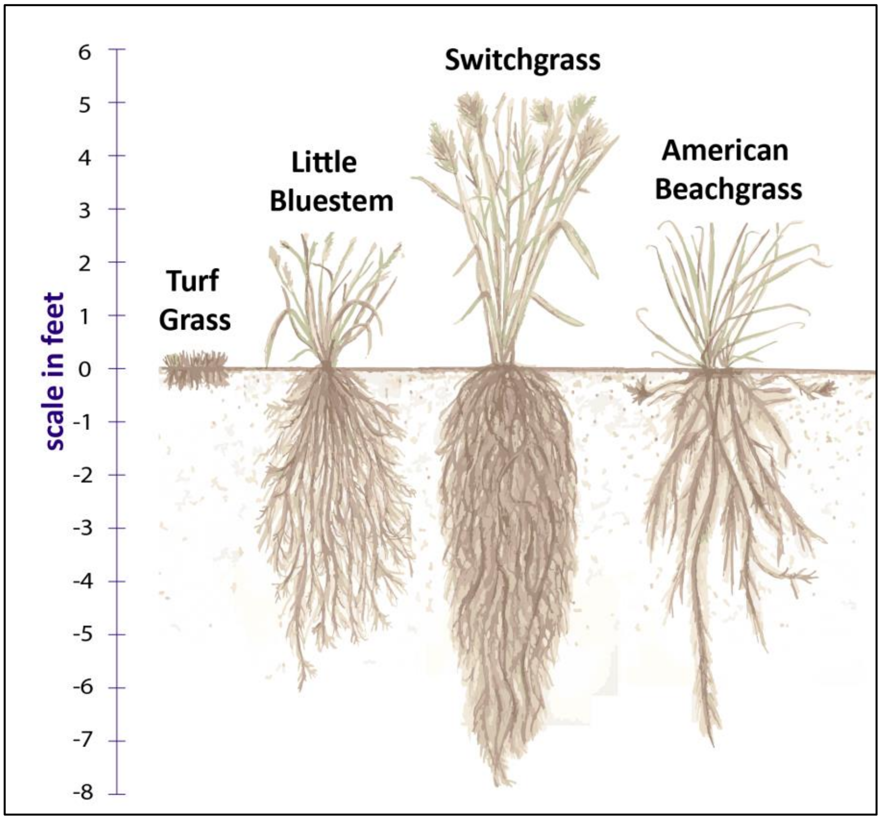
On banks, saltmeadow cordgrass, little bluestem, and other grasses can stabilize exposed areas quickly with their fast-growing, fibrous root systems. While American beachgrass is helpful for initial bank stabilization, it will not thrive on banks that receive little blowing sand. In these areas, it should be planted with other recommended species that will take over as the beachgrass fades. Shrubs, low groundcovers, and perennials that have extensive surface areas and root systems can be used to intercept heavy rainfall and help shelter and stabilize the underlying soils.

Northern bayberry is an excellent shrubs for protecting underlying soil in coastal areas. Shrubs are best used higher up on the bank where they are not exposed to waves, and planting a mix of grasses around newly planted shrubs can help stabilize the area while the shrubs become established. Trees and large shrubs should not be planted on the face of a bank because their height and weight can destabilize the bank and make them vulnerable to toppling by erosion or high winds. Existing trees on banks can be pruned back to help address this problem.

It is important to plant a diversity of native species because a stand of only one plant is more susceptible to complete die-out from drought, disease, or pests.

CZM's [Coastal Landscaping website]() provides additional detailed information on appropriate plants for storm damage prevention and flood control on dunes and banks.

Use Only Live Plants for Erosion Control



Turf grass has a very shallow root system compared to these other plants recommended for erosion control. **(Figure redrawn from illustration by Dede Christopher of the Tennessee Valley Authority, Benefits of Riparian Zones)**

Only live plants should be used since brush, lawn clippings, and other dead plant materials prevent live plants from getting established and have no roots to bind soils. Discarded Christmas trees are a particular problem because they leave large, destabilizing holes when they are ripped out by waves. Sand fencing is a much more effective option and does not impede the natural growth of live plants.

Never Plant Invasive Plants

Invasive species (i.e., introduced species that thrive at the expense of native plants) should never be planted in coastal areas. Oriental bittersweet, bush honeysuckle, vine honeysuckle, autumn olive, and porcelain berry vine are particularly problematic coastal invasives because they have shallow roots, spread rapidly, and can secrete toxic compounds that prevent the growth of other plants. Japanese knotweed is another common invasive that is a problem on coastal sites. Although knotweed has deep roots, it can easily be torn out of the ground, taking large chunks of the soil with it. Because of these growth characteristics, even dense stands of these six species do little to reduce erosion by storm waves, runoff, and wind.

Removing/Replacing Invasive Plants

Invasive plants should be removed and replaced with appropriate native plants if they are preventing establishment of erosion-control vegetation. Because of their tenacity, successful control of invasive plants can take years to accomplish and may require perpetual monitoring and management. This effort is particularly warranted when bank stability is severely compromised by the invasive plant or when unruly and overgrown invasives can be replaced with lower-growing native species to stabilize the bank and improve coastal views.

INVASIVE PLANTS THAT HINDER EROSION CONTROL

Bush Honeysuckle

(Photo: Leslie J. Mehrhoff, University of Connecticut)

Vine Honeysuckle

(Photo: Chuck Bargeron, University of Georgia)

Oriental Bittersweet

(Photo: James R. Allison, Georgia Department of Natural Resources)

Autumn Olive

(Photo: Leslie J. Mehrhoff, University of Connecticut)

Porcelain Berry Vine

(Photo: Nancy Loewenstein, Auburn University)

Japanese Knotweed

(Photo: Jan Samanek, State Phytosanitary Administration)

All photos courtesy of Bugwood.org with specific acknowledgements given.

The photo on the left shows a densely vegetated bank that looks stable, but isn't. The invasive black locust, Asiatic bittersweet, and autumn olive growing on the bank do not have deep, dense roots that help hold soils in place. The photo on the right shows a close up of the exposed soils and erosion at the site. In addition, the roots of these invasive plants secrete toxic compounds and the thick branches shade the area, both of which inhibit the growth of native plants that could stabilize the soil. (Photos: Wilkinson Ecological Design)

Removing invasive plants to replace them with native species, however, can temporarily destabilize the bank. For sites where bank regrading is not needed, invasive plants should be cut off at ground level, keeping the roots in place to minimize site disturbance. Many invasive plants can be effectively eliminated by applying limited amounts of herbicide to the cut stems, which kills the remaining root material. Herbicides can only be used in areas where they are allowed by local regulations. A direct and targeted application of herbicides, as opposed to spraying, helps to minimize adverse impacts to existing native vegetation, soils, groundwater, and coastal waters. Invasive plants should also be removed by hand when possible, rather than with heavy equipment. For sites where regrading is needed, the roots of invasive plants can be pulled out to minimize resprouting.

Regardless of the method used, when vegetation is cut or removed, the exposed soils will become more vulnerable to erosion from wind, rain, and waves. Proper scheduling and sequencing of invasive species removal and replanting with native species will minimize this problem, as will the use of other soil stabilization techniques. Consultation with a professional experienced in replacing invasives with native plants in erosion-prone areas is recommended, as the techniques and timing vary between plants.

Time of Planting

Although specific timing varies based on the plant species selected, most vegetation should be planted in early-to-mid spring (when the growing season has started and moisture levels are relatively high) to promote root growth and successful plant establishment. Beachgrass, however, typically does best when planted in unfrozen ground from mid-November through early April, except in areas exposed to strong wind or waves, where it should be planted in early spring to reduce the likelihood it will be washed or blown away in winter storms.

Watering

Established native plants typically do not require watering. When planted at the appropriate time of year, some newly planted species, such as American beachgrass planted on dunes, also do not require watering.

In both dune and bank areas, some supplemental irrigation may be necessary to ensure success in certain circumstances. For most newly planted vegetation, it is generally recommended that a temporary, automated irrigation system be used from April through October during the first two to three growing seasons until the roots can effectively find and absorb water from the surrounding soils. These irrigation rates can typically be reduced each year, with only minimal water needed in the third year, if at all. For American beachgrass and other plants that do not typically require initial watering, temporary irrigation (i.e., for 4-6 months) is needed when these species are planted in the hot, dry summer months.

Permanent irrigation systems and heavy watering are unnecessary and are not recommended, not only because established plants do not require watering (with the exception of times of drought), but also because excess water from permanent irrigation systems generally exacerbates dune and bank erosion and can even lead to bank failure. Excess water on dunes can also reduce soil salinity levels and allow plants that will not survive in the long-term to out-compete appropriate erosion-control plants.

Temporary irrigation systems, such as aerial heads, are good for providing water to large areas of plugs and seeds, while soaker hoses and drip tubing are effective for supporting container plantings, such as shrubs. A timer may be appropriate to deliver a sufficient amount of water (enough to infiltrate well into the soil to help plants develop deep roots) at desired times (often early morning when less water is lost to the heat of the day). The temporary irrigation lines should be left at the surface (so soils will not be disturbed when the lines are removed) and the system should be removed at a determined time (such as when a local Conservation Commission issues a Certificate of Compliance for the project around year 3).

Various methods to improve water retention and nutrient content in the plants and soils can also help significantly boost the survival rates of plants, such as the application of wetting agents (e.g., Yucca extract), beneficial microbes, and organic compost. A professional may need to be contacted to help determine the most appropriate watering methods and applications that will ensure plant establishment while avoiding impacts to coastal resource areas.

Fertilizer

Because sandy soils are typically dry and lack nutrients, it may be necessary to add some organic matter such as compost before planting. For coastal settings, it is appropriate to select plants that require little fertilizer. If the plant label indicates that fertilizer is needed the first year, use only the minimum amount necessary and use slow-release fertilizers composed of water-soluble materials to prevent coastal water pollution. On artificial or nourished dunes where sand has been brought in from off-site, a limited application of time-release fertilizer 30 days after planting is often needed.

Wildlife Protection

Because vegetation can alter habitat, care must be taken with vegetation projects in protected species habitat. Selecting appropriate types of vegetation (e.g., grass vs. shrubs) and increasing the spacing between plantings can reduce impacts to nesting habitat for protected shorebirds and turtles. Detailed guidance is available from the Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife.

Heavy Equipment Use

If heavy equipment is needed for a vegetation project, equipment access must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, beaches, or other landforms; impacts to wildlife, particularly nesting habitat for protected shorebirds and turtles; and related impacts. When mechanical equipment is being used, contractors should keep hazardous material spill containment kits on-site at all times in case there is a release of oil, gasoline, or other toxic substances.

APPENDIX C

Property Tax Analysis

Baxter Road Long Term Planning
Appendix C - Tax Analysis
Property Tax Revenue for Homes Expected to be Lost in 2030

Map / Parcel	Address	Owner	Area (Acres)	FY 2021 Assessed Value	FY 2021 Assessed Land Value	Taxes Collected (at FY2020 Rate of 0.345%)
49 35	85 Baxter Road	SIASCONSET BEACH PRESV FUND	0.52	$18,700	$18,700	$64.52
49 8	87 Baxter Road	SIASCONSET BEACH PRESERVATI	0.46	$16,600	$16,600	$57.27
48 22	91 Baxter Road	KORENGOLD DANIEL L TRST	0.3	$10,800	$10,800	$37.26
48 19	97 Baxter Road	MCQUADE LAWRENCE C & MARG	0.59	$207,100	$181,100	$714.50
48 18	99 Baxter Road	SIASCONSET BEACH PRESERVATI	0.57	$37,800	$30,800	$130.41
48 17	101 Baxter Road	SEA FOREVER LLC	0.6	$21,600	$21,600	$74.52
48 15	105 Baxter Road	MATTESON MARILEE B TRST	0.58	$20,900	$20,900	$72.11
48 14.1	107 Baxter Road	GIFFORD WHITNEY A TRST	0.18	$6,500	$6,500	$22.43
48 14	107A Baxter Road	GIFFORD WHITNEY A TRST	0.27	$9,700	$9,700	$33.47
48 9	117 Baxter Road	KELLEY SCOTT	0.33	$400,400	$11,900	$1,381.38
48 7	119 Baxter Road	SCONSET TRUST INC	0.32	$17,000	$17,000	$58.65
48 10	115 Baxter Road	KELLEY SCOTT	0.34	$170,900	$170,900	$589.61
48 11	113 Baxter Road	LATSHAW KYLE L & YODER LORE	0.22	$304,000	$161,000	$1,048.80
48 12	109 Baxter Road	KENNEY JUSTINE M TR	0.54	$1,020,000	$186,000	$3,519.00
48 21	93 Baxter Road	FREEMAN STEVEN T & ERIN P	0.3	$376,200	$169,200	$1,297.89
48 5	122 Baxter Road	SCONSET TRUST INC	9.2	$5,589,000	$5,589,000	$19,282.05
49 34	83 Baxter Road	DOSTALIER MARIE ETAL	0.35	$390,700	$171,400	$1,347.92
49 33	81 Baxter Road	COHAN WILLIAM D & DEBORAH	0.44	$767,700	$175,800	$2,648.57
49 32	79 Baxter Road	WEYMAR F HELMUT & CAROLINE	0.35	$779,800	$171,400	$2,690.31
49 31	77 Baxter Road	POSNER JOSHUA & RUDDEN EILE	0.25	$357,000	$166,600	$1,231.65
49 30	75 Baxter Road	SANKATY BLUFF GROUP LLC	0.27	$481,100	$167,600	$1,659.80
49 27	73 Baxter Road	THOMPSON BRUCE & MARY	0.52	$779,900	$183,600	$2,690.66
49 26.1	71 Baxter Road	HONEY WILLIAM F & MICHELLE D	0.29	$1,100,200	$168,300	$3,795.69
					Total Tax Revenue	**$44,448.42**
					Total Assessed Value Lost	$12,883,600

Baxter Road Long Term Planning
Appendix C - Tax Analysis
Property Tax Revenue for Additional Homes Expected to be Lost by 2050

Map / Parcel	Address	Owner	Area (Acres)	FY 2021 Assessed Value	FY 2021 Assessed Land Value	Taxes Collected (at FY2020 Rate of 0.345%)
49 36	86 Baxter Road	86 BAXTER RO	0.74	$1,002,700	$621,600	$3,459.32
49 5	90 Baxter Road	NIELSEN CARL	0.46	$1,311,200	$588,100	$4,523.64
48 23	92 Baxter Road	KORENGOLD D	0.58	$2,799,100	$749,400	$9,656.90
48 44	96 Baxter Road	WEBB ALEXAN	0.24	$1,285,900	$553,600	$4,436.36
48 43	98 Baxter Road	PISCHDOTCHIA	0.22	$999,400	$672,600	$3,447.93
48 42	100 Baxter Road	BAILEY DAVID	0.48	$1,898,000	$737,000	$6,548.10
48 40	104 Baxter Road	SEA FOREVER	0.44	$1,773,500	$730,700	$6,118.58
48 39	106 Baxter Road	MATTESON MA	0.47	$1,752,900	$736,100	$6,047.51
48 38.1	108 Baxter Road	GIFFORD WHIT	1.82	$2,832,000	$644,600	$9,770.40
48 37	110 Baxter Road	RYAN PATRICK	0.82	$2,723,800	$778,200	$9,397.11
48 36	112 Baxter Road	Furrow Ann	0.25	$2,745,900	$554,800	$9,473.36
48 35	114 Baxter Road	HINCHEY RICK	0.3	$1,236,300	$563,100	$4,265.24
48 34	116 Baxter Road	DELPIDIO LOUI	0.28	$1,178,700	$560,000	$4,066.52
48 33	120 Baxter Road	MACKAY RICH	0.53	$943,100	$596,400	$3,253.70
49 25	69 Baxter Road	MOSCICKI RICH	0.36	$2,020,100	$172,300	$6,969.35
49 24	67 Baxter Road	MORNING LIGH	0.29	$1,726,800	$168,300	$5,957.46
49 23	65 Baxter Road	TUTTLE THOM	0.21	$1,498,800	$351,700	$5,170.86
					Total Additional Tax Revenue	**$102,562.29**
					Cumulative Total (Including 2030)	**$147,010.71**

Cumulative Total Assessed Value Lost	$42,611,800

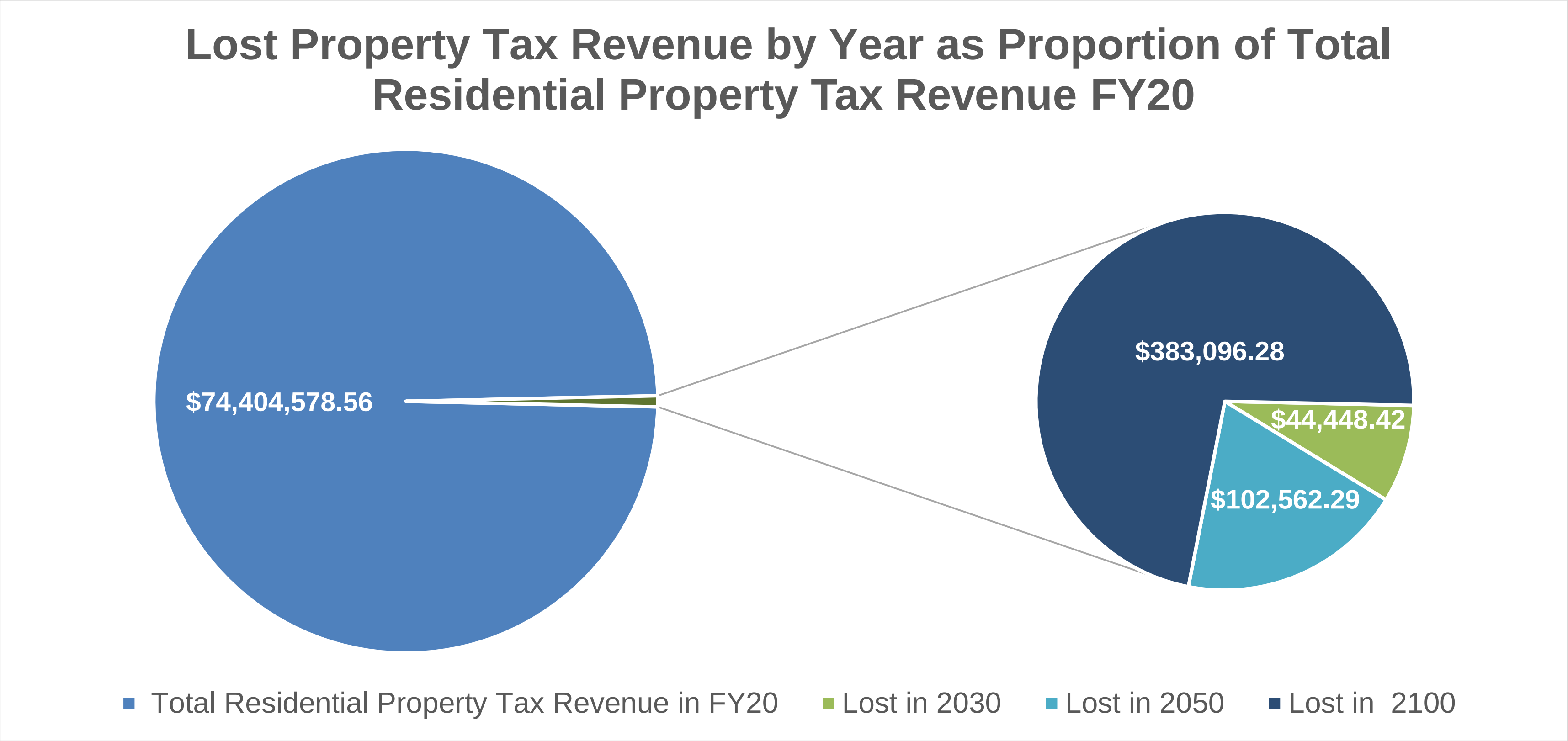
Baxter Road Long Term Planning
Appendix C - Tax Analysis
Property Tax Revenue for Additional Homes Expected to be Lost by 2100

Map / Parcel	Address	Owner	Area (Acres)	FY 2021 Assessed Value	FY 2021 Assessed Land Value	Taxes Collected (at FY2020 Rate of 0.345%)
48 47.1	111 Sankaty Road	GIFFORD WHITNEY	1.51	$3,227,400	$2,537,200	$11,134.53
48 26	115 Sankaty Road	GIFFORD WHITNEY	2.75	$2,214,000	$2,214,000	$7,638.30
49.2.3 14	19 Baxter Road	SIMON MCDUFF LLC	1.24	$9,809,500	$3,808,800	$33,842.78
49.2.3 12	23 Baxter Road	THE BRAES LLC	0.89	$5,777,200	$3,682,800	$19,931.34
49.2.3 9	29 Baxter Road	LAUGHLIN CONAN J	1.01	$5,447,300	$3,373,200	$18,793.19
49.2.3 8	31 Baxter Road	BURKE ROBERT P &	0.51	$4,823,200	$3,193,200	$16,640.04
49.2.3 7	33 Baxter Road	GORSUCH LLC	0.5	$4,393,200	$3,189,600	$15,156.54
49.2.3 6	35 Baxter Road	PRICE MICHAEL F &	0.34	$6,677,000	$3,102,300	$23,035.65
49 10	39 Baxter Road	SAUL ANDREW M &	0.35	$4,535,200	$2,570,000	$15,646.44
49 11	41 Baxter Road	SOROS PAUL TRST	0.37	$4,228,100	$2,586,500	$14,586.95
49 13	45 Baxter Road	SOROS JEFFREY P &	0.21	$4,505,000	$2,377,700	$15,542.25
49 14	47 Baxter Road	SOROS JEFFREY P &	0.3	$4,496,500	$2,537,400	$15,512.93
49 15	49 Baxter Road	JEANNE RICHMOND	0.84	$3,483,000	$2,782,800	$12,016.35
49 16	51 Baxter Road	FIFTY ONE BAXTER	1.19	$5,483,200	$2,908,800	$18,917.04
49 17	53 Baxter Road	KIDDER STEPHEN W	2	$5,679,400	$3,200,400	$19,593.93
49 18	55 Baxter Road	KIDDER STEPHEN W	0.31	$3,702,500	$2,540,700	$12,773.63
49 54	58 Baxter Road	ABCET LLC	1.9	$2,198,900	$1,649,600	$7,586.21
49 20	59 Baxter Road	DALE KEVIN F TRUS	0.46	$2,729,900	$1,764,000	$9,418.16
49 21	61 Baxter Road	HEALEY ANN R TRS	0.25	$2,541,600	$1,668,000	$8,768.52
49 52	62 Baxter Road	HEALEY ANN R TRS	0.18	$875,700	$875,700	$3,021.17
49 22	63 Baxter Road	SINGER ELIZABETH	0.57	$4,345,000	$1,803,600	$14,990.25
49 51	64 Baxter Road	SINGER ELIZABETH	0.51	$1,207,300	$1,182,000	$4,165.19
49 47	68 Baxter Road	ROSEMOOR LLC	0.15	$2,537,400	$1,080,800	$8,754.03
49 45	70 Baxter Road	WILNER SUSAN & G	0.36	$3,639,800	$1,432,500	$12,557.31
49 91.1	83 Sankaty Road	BAILEY DOROTHY	0.9	$1,228,800	$1,228,800	$4,239.36
49 35	85 Baxter Road	SIASCONSET BEACH	0.52	$18,700	$18,700	$64.52
49 95	101 Sankaty Road	ROOSEVELT KERMI	0.83	$3,669,700	$1,220,900	$12,660.47
49 4	103 Sankaty Road	MASSEY CRAIG & P	1.29	$2,650,600	$1,566,300	$9,144.57
48 46	107 Sankaty Road	DIPPELL MARTHA L	0.7	$1,266,300	$1,213,800	$4,368.74
48 27	117 Sankaty Road	GIFFORD WHITNEY	3.14	$3,651,000	$2,260,800	$12,595.95
					Total Additional Tax Revenue	**$383,096.28**
					Cumulative Total (Incl. 2030 and 2050)	**$530,106.99**

Cumulative Total Assessed Value Lost	$153,654,200

Baxter Road Long Term Planning
Appendix C - Tax Analysis
Property Tax Revenue for Homes Expected to be Lost through 2100

Year	Property Tax Revenue	As Percent of Total Residential Property Tax Revenue FY20
Total Residential Property Tax Revenue in FY20	$74,404,578.56	
Lost in 2030	$44,448.42	0.060%
Lost in 2050	$102,562.29	0.138%
Lost in 2100	$383,096.28	0.515%
Sum Lost	$530,106.99	0.712%



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