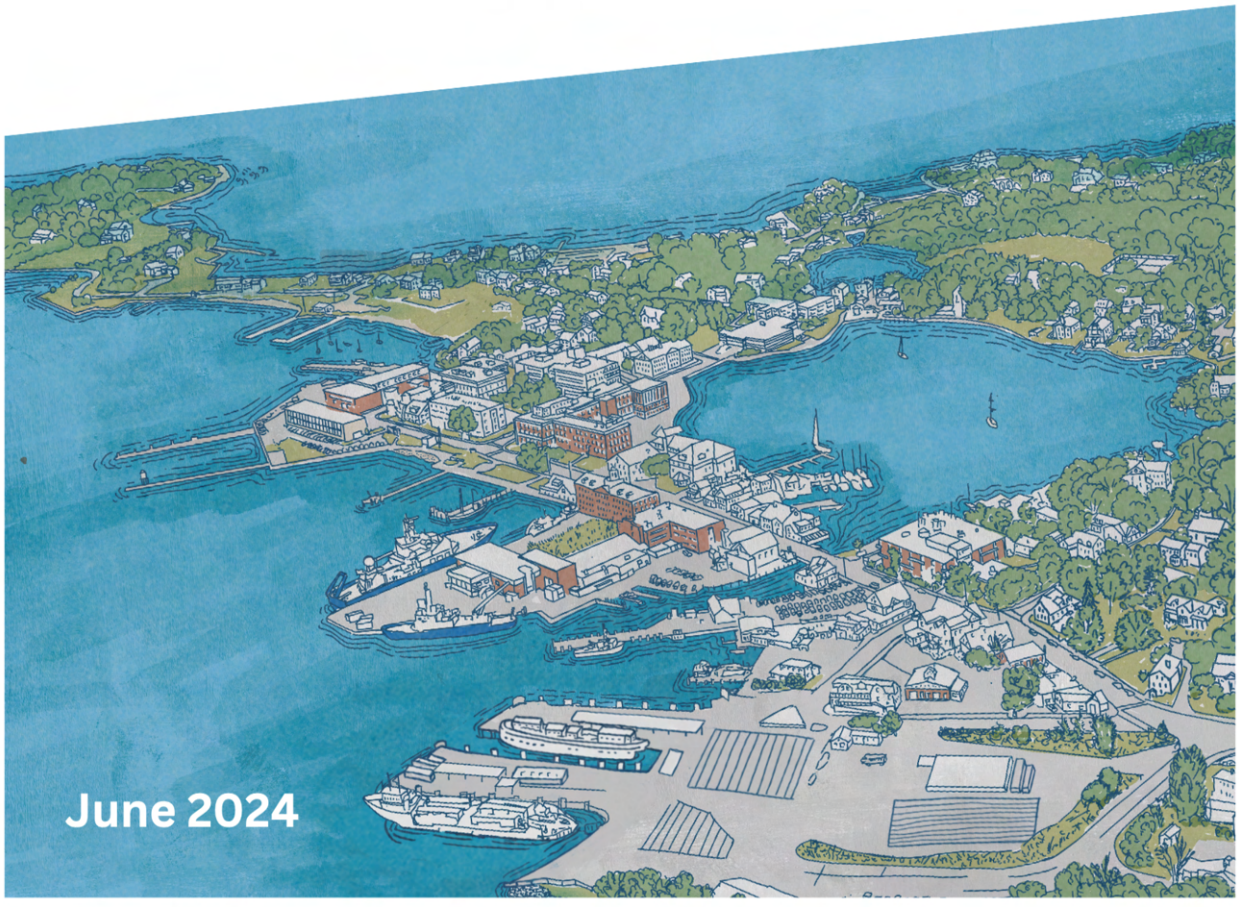
RESILIENT WOODS HOLE

Phase 4 Report

Funded by the Massachusetts Office of Coastal Zone Management (CZM) Coastal Resilience Grant



June 2024

ResilientWoodsHole Phase 4 Report

June 2024

Prepared by:
Woods Hole Oceanographic Institution
86 Water Street
Woods Hole, MA
02543

In Collaboration with:
Marine Biological Laboratory
7 MBL Street
Woods Hole, MA
02543
&
NOAA Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA
02543

Table of Contents

INDEX OF TABLES

INDEX OF FIGURES

Overview

ResilientWoodsHole (*RWH*) is a private-public initiative that includes Woods Hole Oceanographic Institution (WHOI), Marine Biological Laboratory (MBL), National Oceanographic and Atmospheric Administration (NOAA), Town of Falmouth, as well as the Woods Hole Village businesses, organizations, and community members. Organizations that sit on the *RWH*'s Steering Committee include the Woods Hole Community Association, Woods Hole Business Association, Woodwell Climate Research Center, the USGS Coastal and Marine Science Center, Sea Education Association, US Coast Guard Sector Southeastern New England, and the Woods Hole Steamship Authority. The goal of the initiative is to develop a long-range, comprehensive, phased strategy for increasing climate resiliency in Woods Hole Village, including development of Village-wide design concepts and planning. The initiative is a cooperative effort to assess climate threats and jointly develop solutions for institutional, private, and municipal infrastructure, as well as for natural habitat features and waterways. The initiative is in its 4th Phase, funded by the Massachusetts Office of Coastal Zone Management (CZM) Coastal Resilience Grant. Phase 1 and 2 evaluated risks and vulnerabilities of different assets, including buildings, docks, parking lots, natural features and lifelines, at the three institutions and Woods Hole Village, which were self-funded. Phase 3, funded by CZM, developed adaptation solutions to climate risks and vulnerabilities identified in *RWH* Phase 1 and 2. Phase 3 also introduced a robust community outreach initiative, including community workshops, interactive maps, and other engagement opportunities. Phase 4 of *RWH* has three main pillars: near-term flood protection demonstration projects at the three institutions, medium-term feasibility study to evaluate better flood protection by improved dune systems at Stoney Beach, and long-term outreach and engagement initiatives. Within the outreach and engagement pillar, *ResilientWoodsHole* has four community engagement projects: Neighborhood Working Groups, social media, self-guided walking tour, and other outreach and engagement opportunities.

Introduction and Project Need

With roots in whaling, shipping, and fishing, Woods Hole has been a hub for marine commerce and a significant working waterfront in the Commonwealth for centuries. Since 1871 with the establishment of the U.S. Commission of Fish and Fisheries, Woods Hole has transitioned to its current identity as a center for marine science, management, and education. Currently, three major ocean research organizations – Woods Hole Oceanographic Institution (WHOI), the Marine Biological Laboratory (MBL), and NOAA's Northeast Fisheries Science Center (NOAA) – base their marine operations (as well as other research, operational, and educational functions) out of Woods Hole (Figure 1).

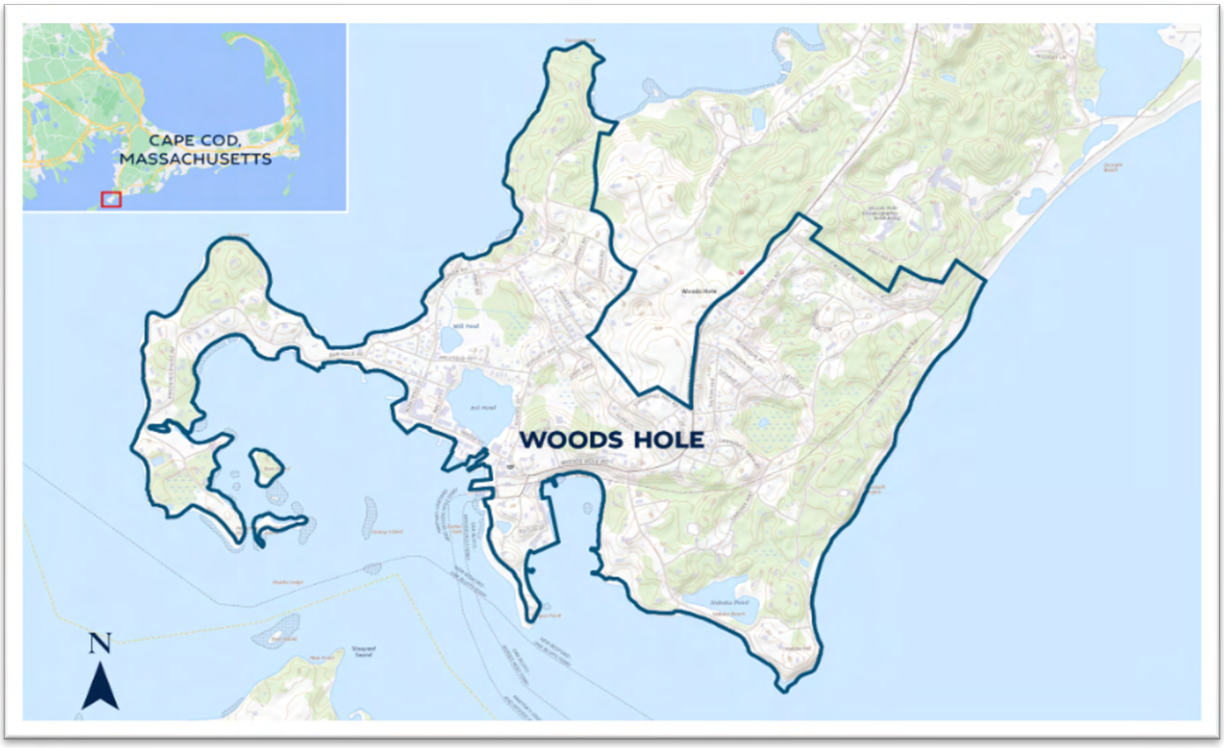


Figure 1. ResilientWoodsHole Study Area

As global greenhouse gas emissions have risen since the industrial revolution (on a timescale like the existence of the scientific community in Woods Hole), sea level rise and climate change have now become significant drivers of scientific investigation for WHOI, MBL, and NOAA, as well as existential threats to these same organizations, and to Woods Hole Village. Woods Hole Village has experienced sea level rise of about 1.01 ft from 1932-2023, and this trend is predicted to accelerate, as seen in the Massachusetts Executive Office of Energy and Environmental Affairs (MA EOEEA) official state sea level rise projections in Figure 2**.** The Village is also highly vulnerable to coastal storm flooding. It is projected that the low-lying parts of the Village could be impacted by flooding on an annual basis as soon as 2070.

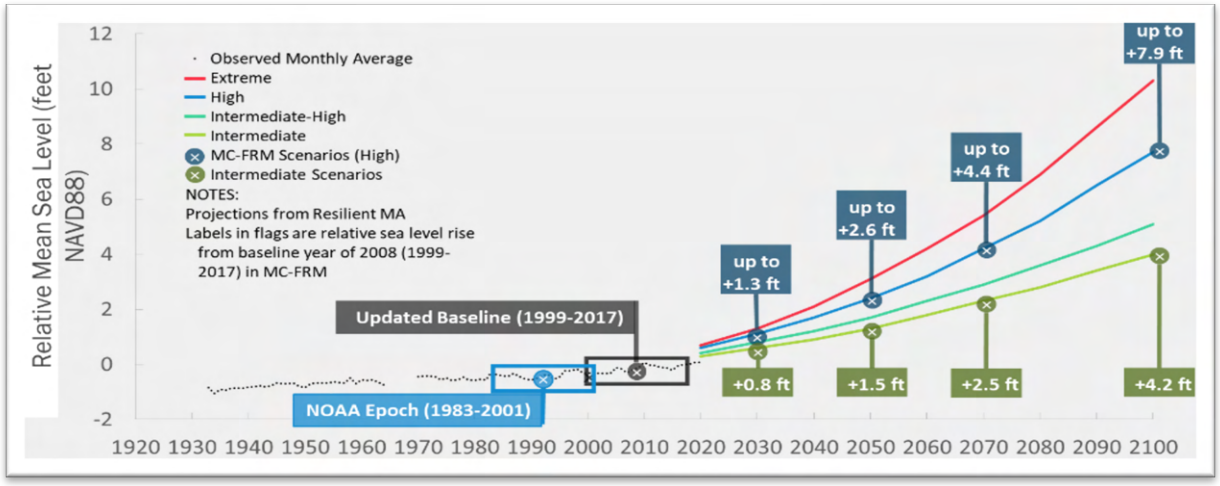


Figure 2. Probabilistic Sea Level Rise Projections from the MA EOEEA.

ResilientWoodsHole Phase 4 builds upon prior work conducted by the project partners, including WHOI, MBL, NOAA, and Town of Falmouth, including institutional vulnerability assessments (Phase 1), Woods Hole and town of Falmouth vulnerability assessments (Phase 2 and Falmouth Climate Change Vulnerability Assessment), adaptation solution assessments (Phase 3), and community engagement (Phase 3). Each institutional member of the *ResilientWoodsHole* initiative, specifically WHOI, MBL, and NOAA, has invested in the previous Phases 1 and 2 with internal funds and external grant support. Phase 3 was supported by a grant through the Massachusetts Zone of Coastal Management (CZM) Coastal Resilience Grant. This current phase is also funded by a second CZM Coastal Resilience Grant.

Phase 4 has enabled the continuation of coastal resiliency planning and execution, as well as robust community engagement plan for collective action. Phase 4 was designed to be multifaceted, with investments in the near-term, medium-term, and long-term. Specifically, *ResilientWoodsHole*, with the support of the CZM Coastal Resilience Grant and matching funds, achieved the following objectives in Phase 4 of the initiative:

- Design, procure and deploy flood protection systems for critical high risk publicly accessible facilities on WHOI, MBL, and NOAA campuses that serve as community adaptation demonstration projects (**Scope 1**)
- Begin the process of addressing a significant flood pathway affecting the Woods Hole community using nature-based solutions by conducting a feasibility and alternatives assessment for dune restoration at Stoney Beach (**Scope 2**)

- Continue conversations with the Woods Hole business and residential community on vulnerability and adaptation, including full -and part-time residents, visitors, students, and organizations (**Scope 3**)

Scope 1 - Demonstration Resiliency Projects

As a short-term climate resiliency project, *ResilientWoodsHole* collaborated with its technical consultant Woods Hole Group (WHG), WHOI, MBL, and NOAA Fisheries to implement flood proofing measures for specific spaces with critical mechanical and building systems equipment at each institution. This includes the aquarium basement at NOAA, the boiler/chiller room in WHOI's Bigelow Laboratory, and the boiler/chiller and electrical spaces in MBL's Lillie Laboratory. All contain critical systems that are vulnerable to flooding from storms and sea level rise and can pose a significant risk on the operations of the facility (Figure 3). To address this issue, *ResilientWoodsHole* set out to design, procure, and construct flood proofing solutions in vulnerable rooms at each institution, assessing these innovative technologies to demonstrate efficacy for future floodproofing projects. For MBL and WHOI, *RWH* worked with floodproofing professionals in identifying and implementing dry flood proofing solutions for each facility. For the NOAA aquarium, NOAA procured floodproofing interventions from a local contractor through a public bid process and was a cash match for the project.

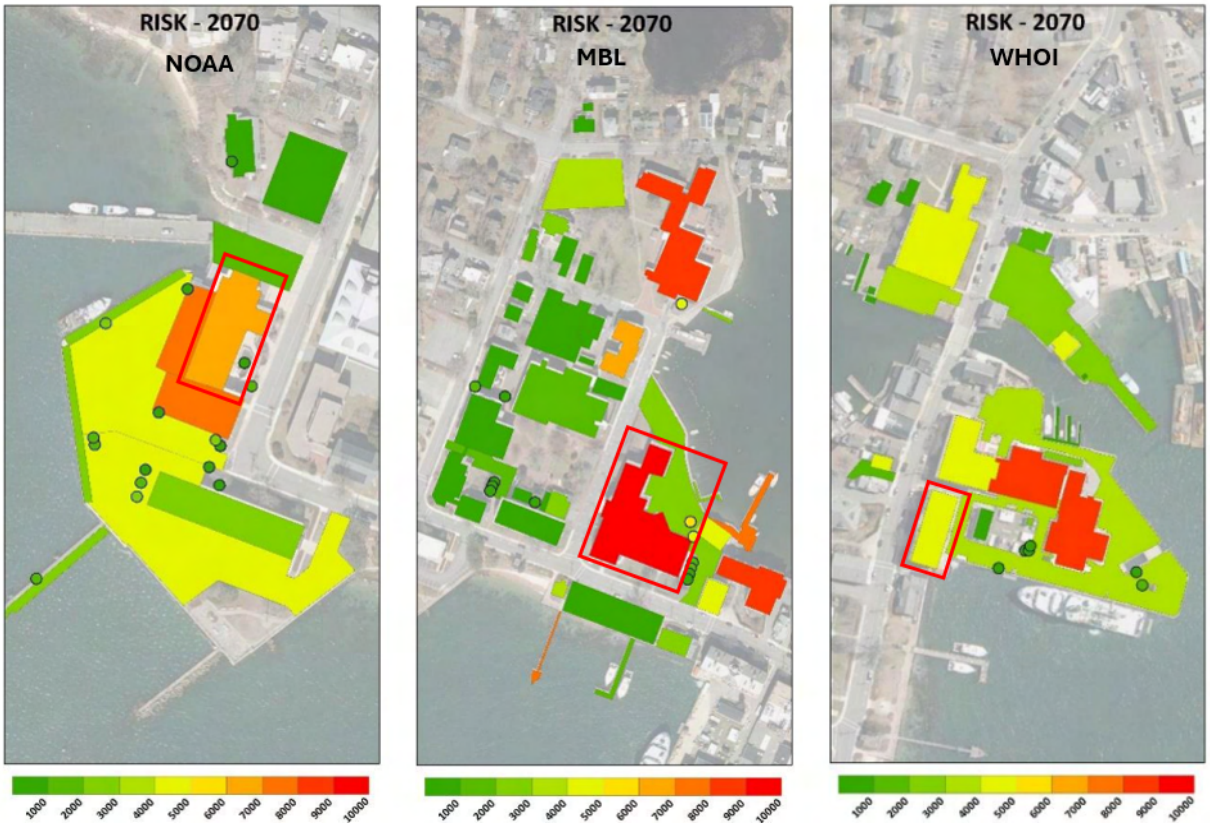


Figure 3. Risk assessment charts (2070) assets at NOAA (left), MBL (middle), and WHOI (right). Each building of interest for the present study is outlined in red. Details and methods on the risk assessment can be found in the RWH Phase 1 Report found on the RWH Website.

The demonstration projects built on previous work conducted by *ResilientWoodsHole*, including facility-level flood vulnerability and risk assessment conducted in *RWH* Phase 1 study, and top priority facility adaptations identified in *RWH* Phase 2 study. The goals of the demonstration resiliency projects were to implement near-term floodproofing measures for vulnerable rooms at each institution and demonstrate progress in local climate impacts preparedness by providing the residential and business community local examples of immediate resilience methods.

Scope 1 Methods

NOAA

NOAA completed their demonstration project in the aquarium basement as a match for this project. NOAA developed a request for quote (RFQ) document for an unsealed vent shaft located in the aquarium basement. NOAA then collaborated directly with a local contractor to procure, remove, and replace the aquarium ventilation shaft and sealant membrane.

WHOI and MBL

ResilientWoodsHole worked with WHG and floodproofing professionals at Floodproofing.com to design, procure, and construct floodproofing solutions at MBL and WHOI. During the two-year duration period, *ResilientWoodsHole* completed two objectives:

1. Design and Select Immediate Flood Proofing Measures
2. Procure and Construct Flood Proofing Measures

To design and select immediate flood proofing measures, an internal meeting was conducted at both institutions, WHOI and MBL, which included both leadership and facilities staff to discuss goals and establish design flood elevations. Each organization then hosted an on-site meeting with the floodproofing professionals, floodproofing.com, to tour the facilities, discuss adaptation options (Figure 4), take measurements, and develop an initial suite of adaptation solutions. *RWH* evaluated and discussed different approaches and products with each institution's facilities staff and took any additional measurements and site condition notes as necessary. After the on-site visit, floodproofing.com developed a series of initial quotes based on a variety of potential configurations. *RWH* worked with the institutions' facilities staff to evaluate each adaptation option for feasibility of implementation and home in on the best alternatives. When several alternatives were vetted, floodproofing.com quoted three draft configurations for each facility at WHOI and MBL, using various products, configurations, and, in some cases, building modifications. The quotes were developed based on preferred products and configurations that were developed by WHG and WHOI/MBL staff in consultation with floodproofing.com, then WHG recommended review by structural engineers. Reinforcement and alternative configurations relying on exterior and/or load bearing walls were developed, approved, and submitted for final quote to floodproofing.com for WHOI and MBL.

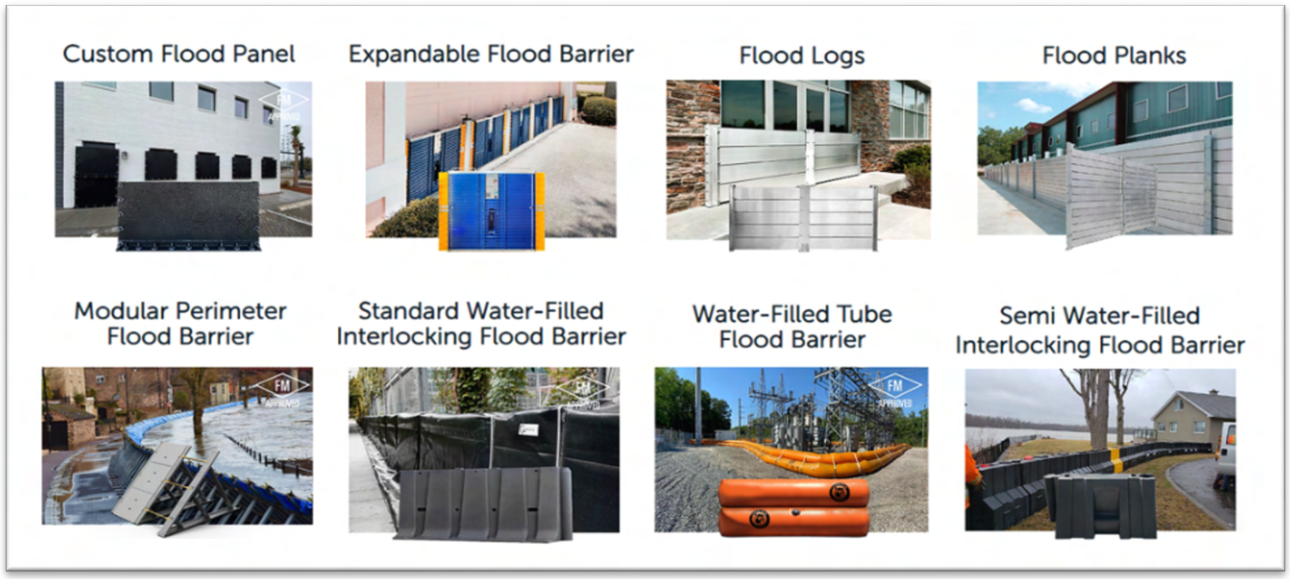


Figure 4. Figure 4. Some dry floodproofing alternatives considered by ResilientWoodsHole (source: https://www.floodproofing.com/dry-floodproofing)

To procure and construct near-term floodproofing measures, *RWH* worked with floodproofing professionals to commence the procurement process by securing contracts to purchase and install materials for the selected floodproofing solutions. The institution's facilities staff worked with the flood proofing installation team and *RWH* to outline project logistics, schedule, and installation. During installation, the process was photo-documented, along with maps, plans, and narratives, and shared the demonstration project progress and results with the community via social media and print.

Scope 1 Results

Three demonstration projects that constructed near-term floodproofing measures to protect critical rooms at NOAA's aquarium Basement, MBL's Lillie Laboratory, and WHOI's Bigelow Laboratory, were concluded by the end of *ResilientWoodsHole* Phase 4.

NOAA's aquarium

As part of the project's funding match, NOAA designed, procured, and constructed flood proofing measures to protect the aquarium basement, which contains critical water filtration/treatment systems for facility tanks. An unsealed ventilation shaft in the NOAA Gear Shed connected to the aquarium basement was identified by NOAA facilities as the primary pathway for flooding to the basement. NOAA collaborated with a local contractor to remove and replace the aquarium

ventilation shaft. The contractor then removed all components of the existing aquarium basement ventilation shaft assembly and installed the new ventilation shaft, including the ductwork, fans, louvers, dampers, and hardware. The new ventilation shaft is completely water-tight, protecting the aquarium basement from external flooding (Figure 5).

Figure 5. The aquarium basement ventilation system before floodproofing measures (left top and bottom pictures) and after floodproofing measures were implemented (right picture).

Floodproofing professionals at floodproofing.com visited NOAA during the on-site meetings for WHOI and MBL on January 30th, 2023, to discuss potential adaptation solutions for other NOAA infrastructure, such as the gear shed, maintenance shed, seawater pump house and hazardous material storage sheds, which are also vulnerable to coastal storm flooding (Figure 6).

Figure 6. On-site meeting between WHG, floodproofing.com, and NOAA about other vulnerable NOAA infrastructure on January 30, 2023 (source: Woods Hole Group)

MBL's Lillie Laboratory

For MBL's Lillie Laboratory, an on-site meeting was conducted with WHG, MBL facilities and leadership, floodproofing professionals on January 30th, 2023 (Figure 7).

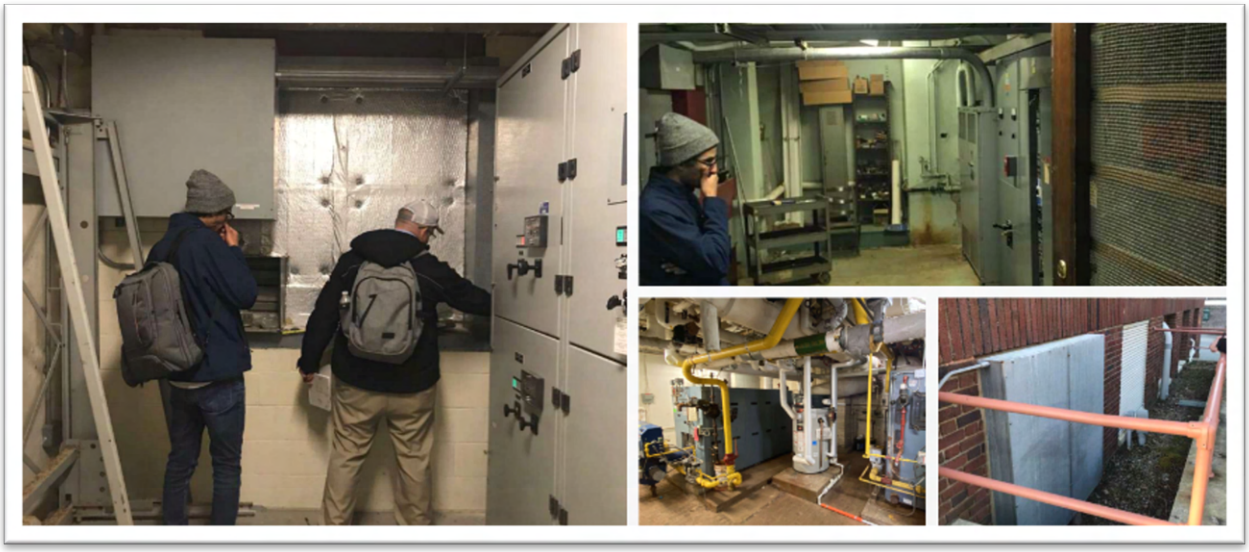


Figure 7. On-site meeting between WHG, floodproofing.com, and MBL about the Lillie Laboratory on January 30, 2023 (source: Woods Hole Group)

Prior to the on-site visit, MBL leadership and facilities identified several priority mechanical and electrical equipment rooms in the basement level of the building that were vulnerable to water during flood events. These rooms include a boiler room, mechanical room, electrical switchgear room, and electrical switching room. The floor plan of the Lillie Laboratory can be seen in Figure 8. During the on-site assessment, MBL, *RWH*, and floodproofing professionals identified and measured the vulnerable windows and doors in each of the priority mechanical and electrical rooms to determine the best floodproofing solution.

Figure 8. Floorplan of Lillie Laboratory with vulnerable rooms highlighted in yellow.

During initial assessments, deployable flood panels and stacking flood logs were considered as floodproofing solutions to cover the windows and doors in the four rooms highlighted in Figure 8. Floodproofing.com developed initial quotes, and *RWH* discussed the quotes, products, and configurations with the MBL facilities and on-call structural engineers for each of the vulnerable rooms. During this process, on-call structural engineers expressed concern that interior masonry walls did not have sufficient structural support/reinforcement to withstand hydrostatic loads and could, therefore, lead to structural failures. Additionally, there were concerns that the walls surrounding the rooms of concern are not waterproof, and not impermeable to water seepage and leakage into the rooms.

Following the structural engineering assessment, *RWH* worked with floodproofing professionals and MBL to identify an alternative floodproofing configuration that would rely on exterior load bearing walls, rather than internal masonry. The new solution utilizes deployable GeoDesign barriers that span from the southeast corner of the Lillie Laboratory (Area 1) to the Plant Operations and Maintenance (POM) area, using an attachment wall construction as reinforcement (Figure 9).

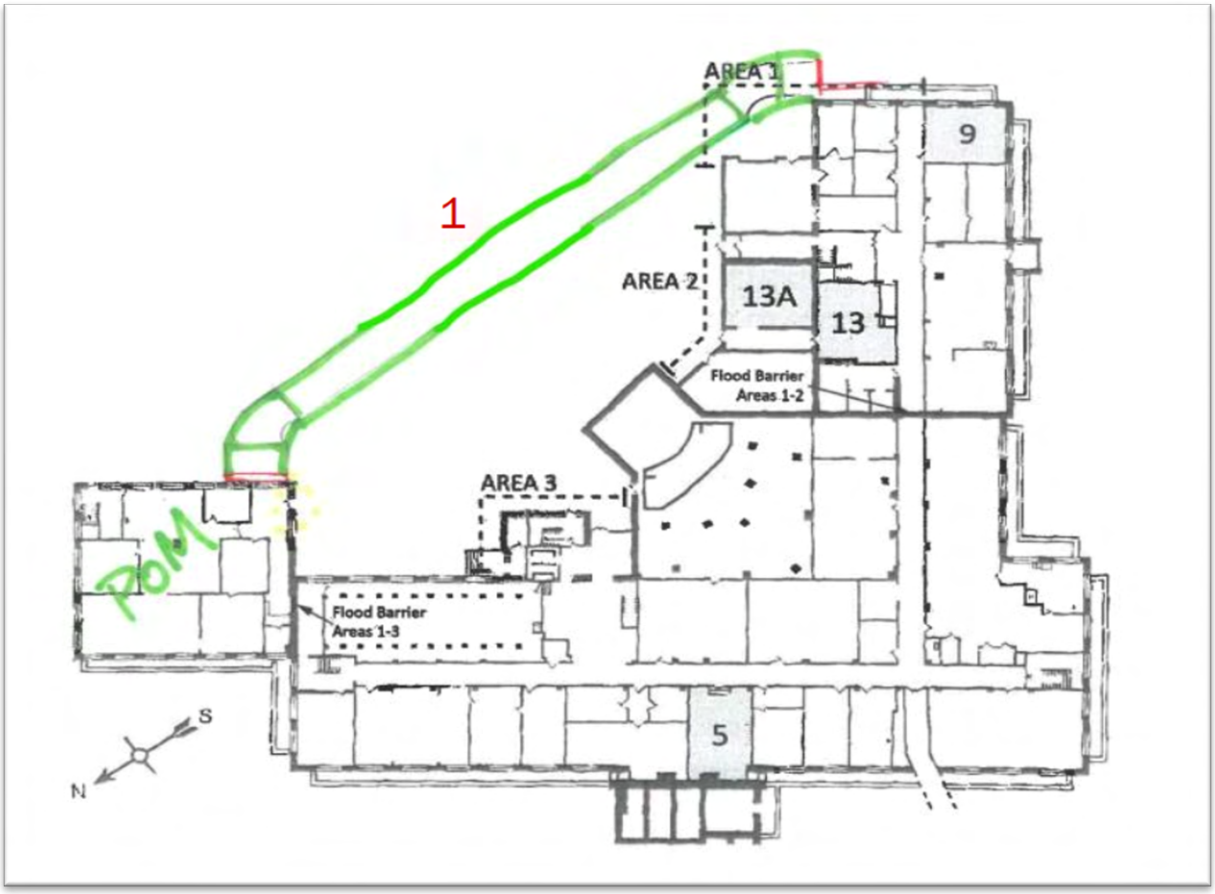


Figure 9. Alternative flood proofing solution using the GeoDesign barriers.

Floodproofing professionals conducted one more on-site meeting in early May 2024 to take final measurements for fabrication of the GeoDesign deployable barriers for Lillie Laboratory. The GeoDesign deployable barriers are made of steel and marine-grade aluminum a-frame barriers, which are lined with a durable PVC coated poly-membrane. To keep everything in place, metal chains are draped over the structure. Installation of the GeoDesign barrier on the exterior of Lillie Laboratory was completed on June 11th, 2024 (Figure 10).

Figure 10. MBL installation team with the GeoDesign barrier in the background.

WHOI's Bigelow Laboratory

For WHOI's Bigelow Laboratory, an on-site meeting was conducted with WHG, WHOI facilities and leadership, floodproofing professionals on January 30th, 2023 (Figure 11).

Figure 11. On-site meeting between WHG, floodproofing.com, and WHOI about Bigelow on January 30, 2023 (source: Woods Hole Group)

Prior to the on-site assessment, WHOI's facilities had identified several vulnerable rooms that require floodproofing, including room G1, room G12 (boxed in red), and door 933 (circled), as seen on Figure 12. Room G1 contains boiler systems essential to the functioning of the building and is surrounded on two sides by windows and an external door. The south-facing entryway, labeled at door 944 in Figure 12 below, is not protected and vulnerable to flooding following storms. Room G12 is an electrical room. Floodproofing.com quoted draft solutions for each vulnerable room, using various products, configurations, and building modifications. This included using flood logs and panels on doors and windows for each room. In evaluation of room G1, facilities and *RWH* evaluated an unused pass-through opening between room G1 and G3. Closing this pass-through was initially in the draft solutions by floodproofing.com, however facilities decided to brick up the pass-through as a cost-saving method, instead of placing floodproofing barriers. At this stage, on-call structural engineers evaluated the alternative configurations and expressed concern for all the interior walls in rooms G1 and G12, as there were structure concerns. G12 was not considered for further floodproofing due to other potential vulnerabilities, and priority was given to floodproofing room G1 and door 933.

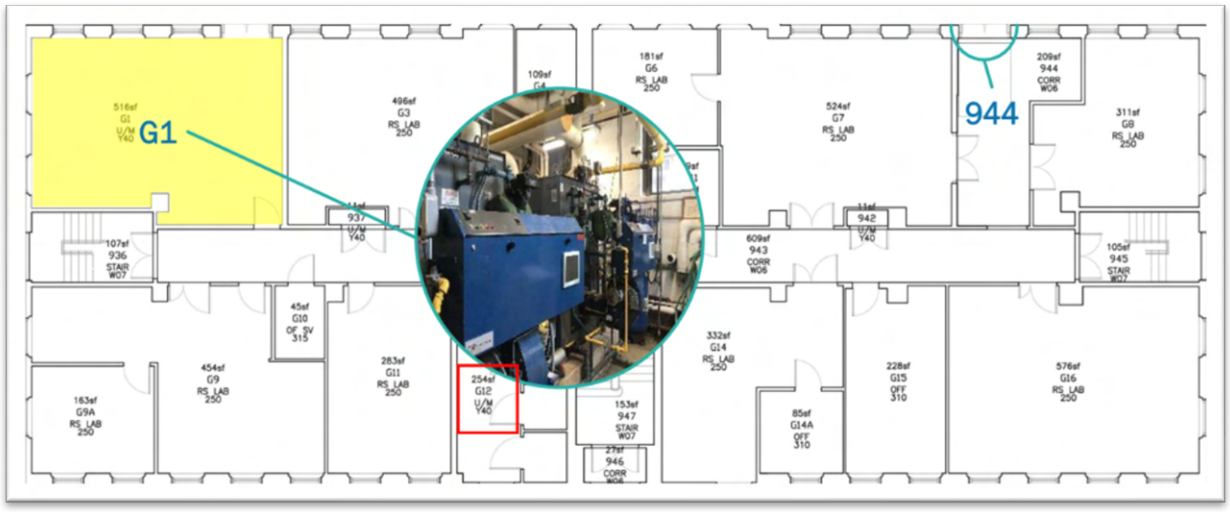


Figure 12. Floorplan of Bigelow with highlighted in yellow vulnerable room G12, circled in blue is door 944, and room G12 outlined in red.

WHOI's facilities staff expressed preference to using deployable barriers to cover windows and doors, including metal flood logs on the doors and flood panels on the windows. Facilities staff preference for deployable barriers was because logs can be stacked incrementally through storm prep phases, which would preserve access to vital utility rooms as long as possible.

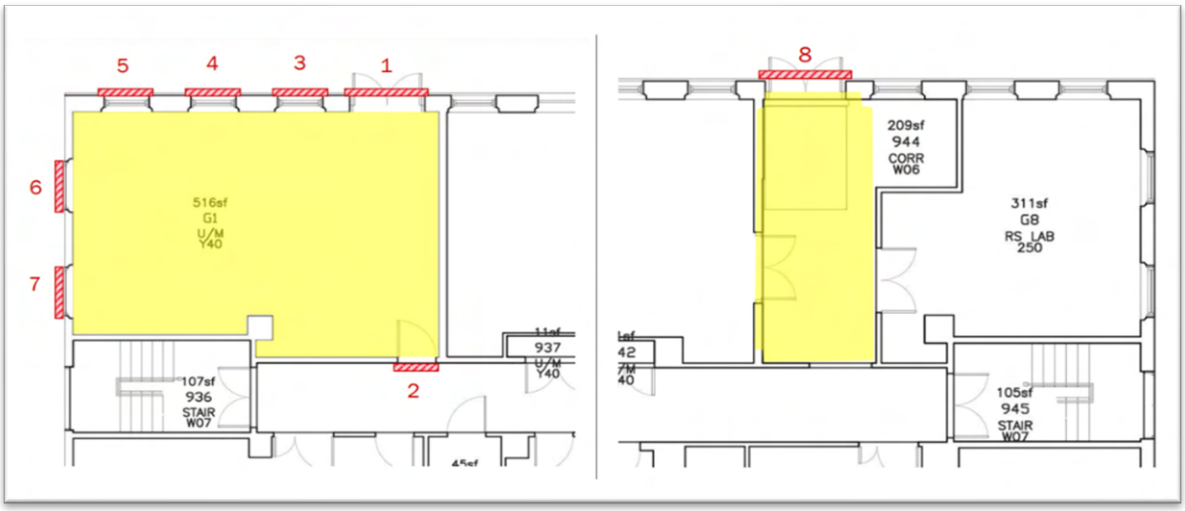


Figure 13. Detailed floor plans of vulnerable rooms and the proposed solutions, including G1 (left) and door 944 (right).

During the structural engineering analysis of the adaptation solutions, there were some concerns about the capacity of interior non-load bearing walls to withstand the hydrostatic pressure exerted on doorways by retained floodwaters. To address this concern, the structural engineer recommended reinforcing these interior masonry walls, however ultimately solutions that

focused on exterior walls were chosen to continue with installation. Final configurations were developed, approved, and submitted for final quote to the floodproofing professionals (Figure 13).

Floodproofing professionals conducted one more on-site meeting in early May 2024 to take final measurements for fabrication of the deployable window and door barriers for Bigelow. These deployable barriers are made of metal and are attached to the exterior masonry. The door barriers are made of metal flood logs that are placed incrementally on top of each other prior to a storm, while the window barriers are one metal flood panel. Installation of the window and door flood panels was completed on June 12th, 2024 (Figure 14).

Figure 14. Bigelow deployable barrier installation on key windows and door.

Lessons Learned

The demonstration projects at WHOI and MBL proved more challenging than anticipated. This is largely because both WHOI and MBL facilities were old buildings with unique design parameters than found at newer facilities.

The first lesson learned is that floodproofing older buildings requires additional considerations. The initial plan was to implement dry floodproofing solutions focused on protecting selected interior spaces that contained critical building systems. However, floodproofing interior spaces leads to hydrostatic loads being placed on a variety of interior (non-structural) walls. As a result, the institutions needed to conduct structural engineering analyses to determine whether those walls could in fact manage the load of water building against them, and if not, what additional steps would need to be taken. In the case of the MBL, those analyses quickly revealed that a straightforward process of floodproofing individual interior spaces would require additional actions be taken to manage the impact of flood water on interior walls. In the end, *RWH* determined that for the case of an older building like MBL's Lillie Laboratory, the best flood proofing solutions would be external ones that kept water off both internal and external walls. As an older building, WHOI's Bigelow Laboratory presented other challenges, including making a smooth seal on the exterior masonry. The installation technicians installed gaskets to fill these exterior gaps, however WHOI plans to further evaluate the longevity of these gaskets or if a better solution can be implemented.

The second lesson learned is challenges associated with planning large-scale demonstration projects with flood proofing professionals. Retrospectively, *RWH* learned that a planning call with the floodproofing professionals and installation technicians would have ensured that both sides were fully prepared and aware of expectations for the training and demonstration of the flood proofing solutions. These two lessons learned will be applied for the successful implementation of future resilience projects.

Scope 2 - Stoney Beach Feasibility Study and Performance Modelling

As a medium-term climate resiliency effort, *ResilientWoodsHole* worked with the MBL and WHG to assess the feasibility and develop conceptual designs for a nature-based improvement project at Stoney Beach. Stoney Beach is owned by the MBL and is available for public use. During the summer season, the town of Falmouth manages public parking and provides lifeguards. Aside from its recreational value, Stoney Beach provides partial protection against storm surge and flooding to the neighborhood right behind the beach. However, Stoney's dune system has eroded over the years which reduces its protective ability, and the remnants of a tennis court act as a

hardscape that inhibits storm flowage and filtration. In fact, the beach is one flood pathway that allows flooding between Buzzards Bay, Eel Pond, and Mill Pond, affecting a large part of the Woods Hole community (Figure 15). The feasibility study evaluated the restoration of dunes on the beach and relocation of the parking lot among other features. This study addressed vulnerable areas including ocean-facing beaches and dunes and assesses the impact of removing hardened areas.

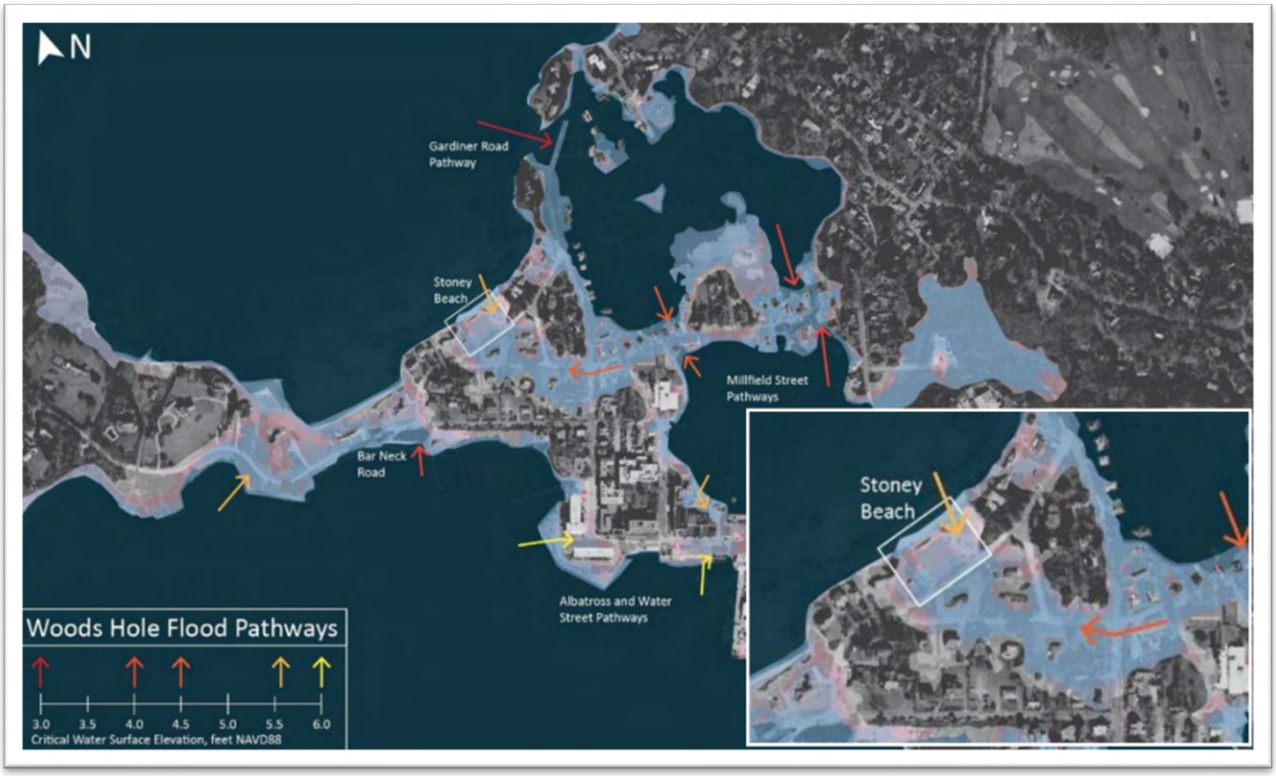


Figure 15. Flood pathways in Woods Hole Village. Stoney Beach is one flood pathway in the Village that impacts the several residential neighborhoods behind it (Source: Woods Hole Group).

This feasibility study built upon previous work, including Massachusetts Coast Flood Risk Model (MC-FRM) probabilistic sea level rise and storm surge projections for Woods Hole as discussed in the Phase 1 report, flood pathways developed in *RWH* Phase 2, and one of the targeted adaptations that was assessed for *RWH* Phase 3. The feasibility study assessed dune restoration to provide protection against flooding and increase storm-resilience in an area of high public use and near threatened neighborhoods in Woods Hole.

Scope 2 Methods

ResilientWoodsHole worked with WHG to complete the Stoney Beach feasibility study and produce a summary report. To complete Scope 3, *ResilientWoodsHole* undertook five tasks:

1. Site Survey & Evaluation of Existing Conditions
2. Alternatives Assessment and Conceptual Designs for Reducing Flood Vulnerability
3. Dune/Beach Performance Modeling
4. Regulatory Feasibility Review
5. Reporting and 3D Renderings of Select Alternatives

To complete the site survey and evaluation of existing conditions, WHG researched the Barnstable County Registry of Deeds to identify a description of the Stoney Beach property boundaries, performed a wetland delineation to locate all resources protected by the local and state wetland regulations, and collected sediment samples for grain size analysis. Additionally, a Massachusetts Registered Land Surveyor performed a topographic survey of the beach and located all existing infrastructure, wetland flagging, and property monuments. An existing conditions plan for Stoney Beach was developed that showed property boundaries, existing infrastructure, wetland resources, and vegetated areas.

WHG examined the restoration of the beach's existing dunes with several proposed alternatives, including dune crest elevations, dune widths, dune locations, and beach nourishment. Beach nourishment is used to enhance the longevity of a protective dune and add to the recreational value of the beach. Along with identifying the different dune alternatives, WHG also evaluated the feasibility of reconfiguring the beach’s hardscape, the tennis courts, and the beach's amenities, such as parking lot, picnic tables, and bathrooms. Several conceptual designs were prepared for the MBL. These included different dune heights, parking lot configurations and related amenities.

To conduct dune performance modeling, WHG utilized numerical modeling to assess the performance of the different dune and beach nourishment alternatives, including existing conditions and a do-nothing alternative. Cross-shore sediment transport models were used to assess the performance of different alternatives. For the numerical model, high frequency storms equivalent to the 1-, 5-, 10-, and 25-yr events were simulated to show the extent of dune/beach erosion and the feasibility of using nature-based solutions to eliminate Stoney Beach as a flood pathway to other parts of Woods Hole. Several different alternatives were assessed for their level of protection and findings were presented to the MBL.

To perform a regulatory feasibility review, WHG collaborated with permitting specialists to review the conceptual designs and identify the local and state permits that would be required for construction. Performance standards for work in coastal dunes and coastal beaches were reviewed to ensure compliance with the regulations.

Finally, WHG prepared a summary report with 3D renderings of the select alternatives to be published on the *RWH* website. The summary report describes the goals of the project, projected flooding if nothing is done, alternatives considered, expected performance of the different alternatives, and regulatory requirements. Costs and a schedule for final design, public outreach, and permitting were also included in the report, along with planning level construction and Operation & Maintenance costs. The summary report of all the tasks was prepared by the WHG. The Marine Biological Laboratory then reviewed the alternatives presented in the summary report and approved one alternative to move forward to design and permitting.

Scope 2 Results

WHG conducted a site survey of Stoney Beach, which was composed of a topographic survey, wetland resource delineation, property research at the Registry of Deeds, and sediment sampling.

The topographic and nearshore bathymetry surveys indicated that the existing dune crest elevation is between 5.0 and 9.0 ft NAVD88, with the public access path to the beach at the lower elevation of approximately 5.0 ft NAVD88. The surveys also indicated the existing features on the site, such as the tennis court, parking area, stone groins, walls/fences on adjacent properties, edge of vegetation, footpaths, stones, trash/recycling receptacles, and wetland resource areas. The two features behind the dune, including the deteriorated tennis court and parking area, slope down from 9.5 to 5.5 ft NAVD88. This information is important for evaluating current vulnerability, feasibility of tie-in elevations, and volumes of nourishment needed to achieve target elevations that will have a protective effect for the beach.

For the wetland resource delineation, the following delineations were made Land Under the Ocean (310 CMR 10.25), Coastal Beach (310 CMR 10.27), Coastal Dune (310 CMR 10.28), Land Subject to Coastal Storm Flowage (310 CMR 10.04). More information on the wetland resource delineation can be found in the Summary Report on page 4. Property research at the Registry of Deeds identified three main results:

1. Stoney Beach property is divided into two parcels, both owned by MBL.

2. Original property markers have been replaced over time, with some new markers on the property not previously documented.
3. A 10 ft easement was identified between Gosnold Rd and the beach, which was established in 1911.

Finally, sediment samples collected from both the coastal dune and the coastal beach are characterized as medium-grained sand with trace percentages of gravel and silt/clay, and coarse to medium-grained sand with some gravel and trace percentages of silt/clay, respectively. This information was used in performance modeling of the beach and nourishment and is likely to inform grain-size matching requirements if either beach nourishment or dune reconstruction is implemented.

Following the site assessment, WHG conducted an alternatives assessment and performance modeling for different dune heights, with and without beach nourishment. Modeling is important for determining the optimal dune height to protect the beach from strong storms. Dune performance modeling was conducted for 8ft, 9ft, and 10ft NAVD88 dune crest elevations (Figure 16), with and without beach nourishment. The 10ft NAVD88 dune crest was chosen as it was the largest elevation that could be built and tied-in to the neighboring properties. The 8ft NAVD88 dune crest would fill in low spots at the access paths, while the 9ft NAVD88 dune crest is an intermediate alternative. Modeling was assessed based on 10-year return period and 5-year return period storm events, with wave heights of 2.4ft, 3.6ft, and 4.9ft.

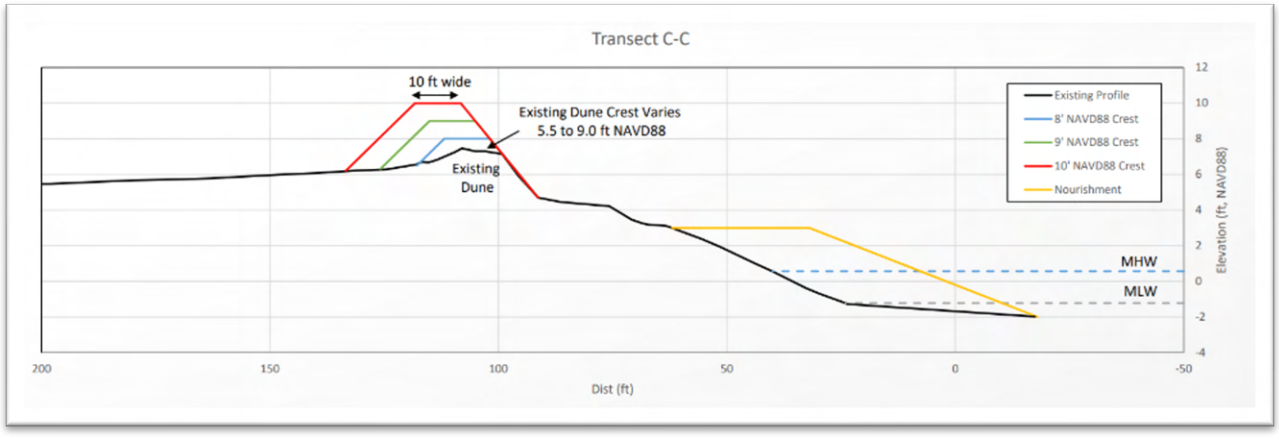


Figure 16. Conceptual model of the dune performance modeling with 8ft, 9ft, and 10 ft NAVD88 crest

The results of the performance modeling indicated that the dune crest at 10 ft NAVD88, with beach nourishment provided protection from storms of 10-year return period with 3.6 ft wave and 5-year return period with 4.9ft wave (Figure 17). While this dune crest elevation did not protect against the 10-year return period with 4.6ft wave, the 10ft crest elevation provided the

most protection overall. It should be noted that the likelihood of waves greater than 3.6 ft that occur at the same time at the 10-year and 5-year return period storms are low, but necessary to evaluate in performance modeling to get a conservative estimate of dune erosion from those high-energy storms. Results of all the dune crest elevations considered for the performance modeling can be found in **Appendix A**.

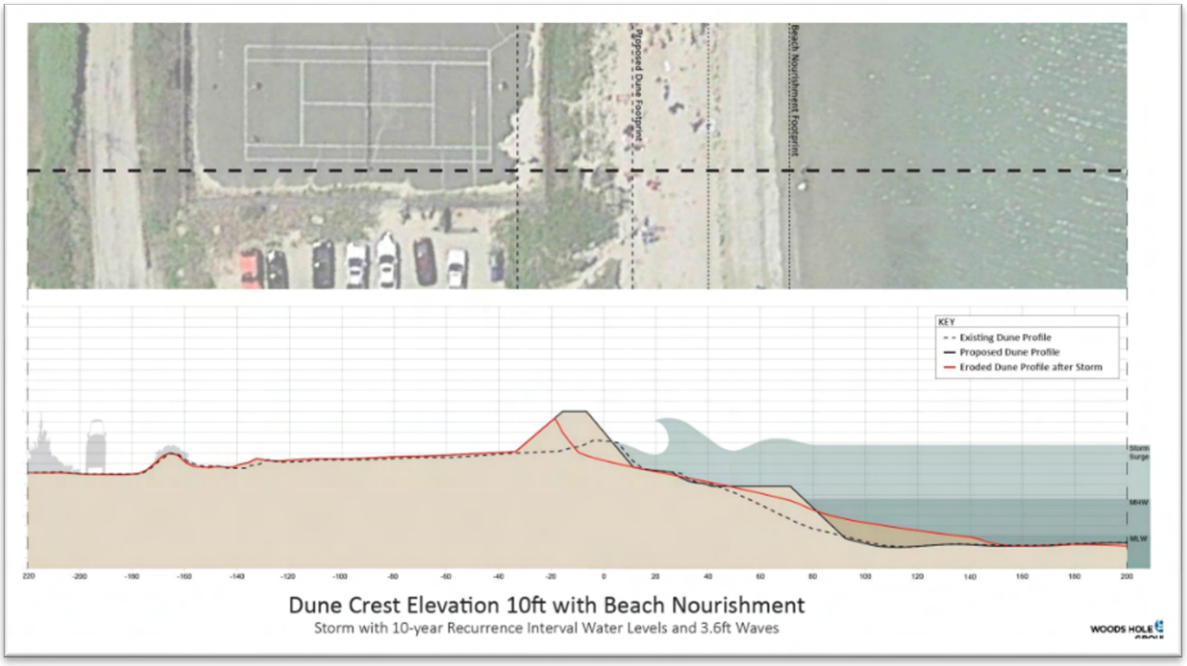


Figure 17. Performance modeling of 10ft dune crest elevation with beach nourishment following 10-year return period with 3.6 ft waves

Aside from dune restoration and dune nourishment, WHG evaluated the configuration of amenities, particularly parking, walkways, restrooms, bike racks, and picnic tables. Current amenities include approximately 30 parking spots, a tennis court and natural area with both native and invasive species (Figure 18).

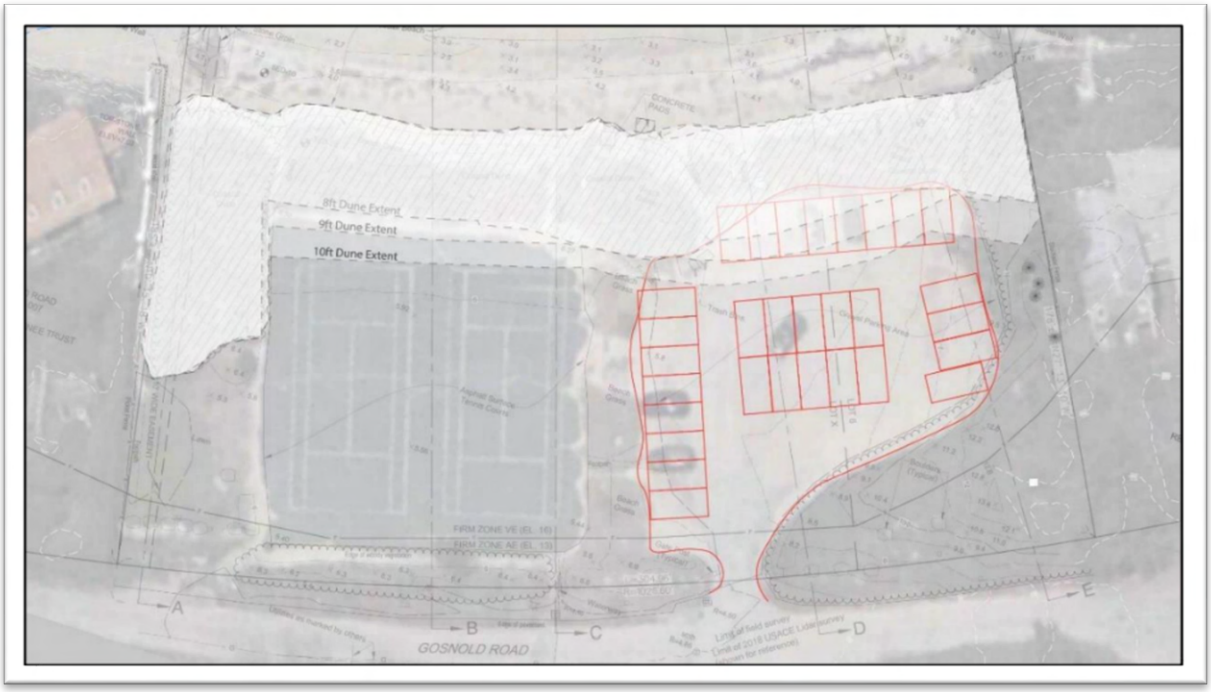


Figure 18. Current amenities, including the tennis court and 30 parking spots.

WHG evaluated three (3) options for reconfigurations of the beach's amenities. The number of parking spots differs between each option, ranging from 21-30. All reconfiguration options consider the removal of the tennis court, and the reconfiguration of parking spaces due to the reclamation of this space. All options also allow for space of the dune to naturally migrate landward to varying degrees. Option 2 can be seen in Figure 19 below, with Option 1 and 3 found in **Appendix A**.

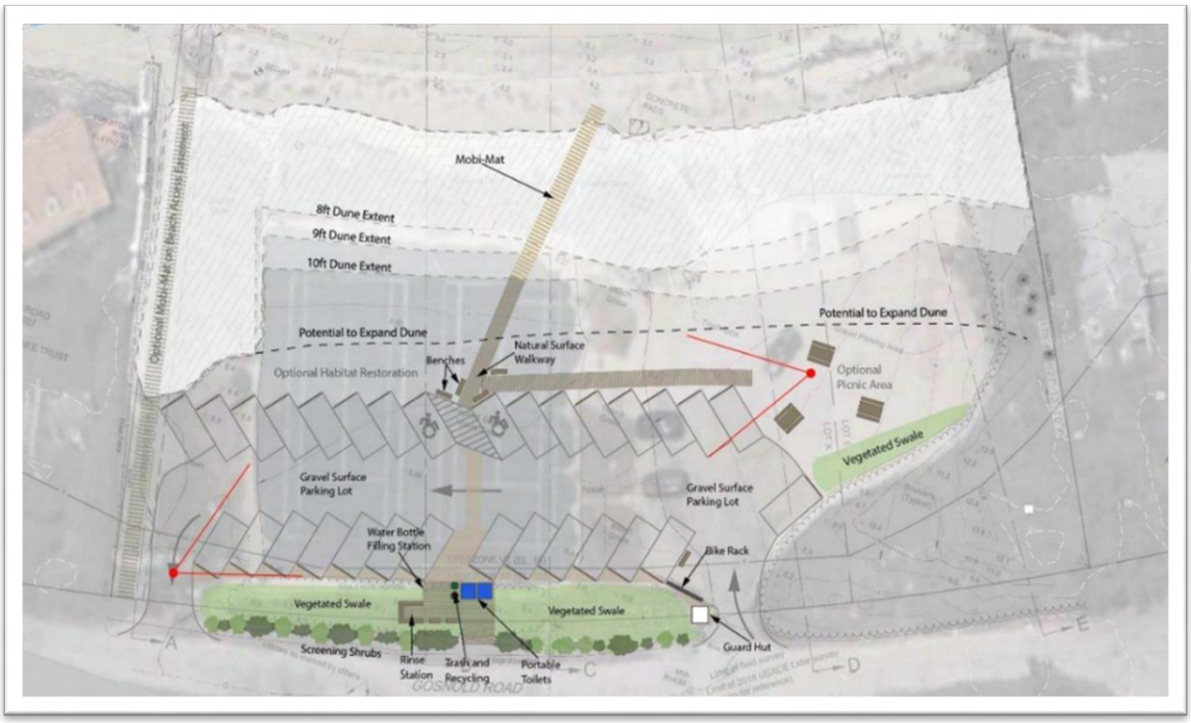


Figure 19. Option 2 for reconfiguration of Stoney Beach, including 30 parking spots, picnic tables, restrooms, and vegetated areas.

WHG also completed 3D renderings for reconfiguration Options 2 and 3. 3D renderings for Option 2 can be seen in Figure 20 and Figure 21 below. 3D renderings for Option 3 can be found in **Appendix A**.

Figure 20. Rendering of Option 2 from middle of the parking lot looking east.

Figure 21. Rendering of Option 2 from the middle of the parking lot looking west.

The reconfiguration options and 3D renderings were presented at the second NWG meeting and third NWG meeting (see "Scope 3 - Task 1") to gather feedback from the community on their preference.

WHG evaluated the regulatory framework as it relates to the Stoney Beach dune restoration. Permitting agencies, types of permits, triggers for regulatory review, and recommendations for moving forward with the permitting were noted. The followings permitting agencies were identified:

- Massachusetts Environmental Policy Act (MEPA) Unit
- Falmouth Conservation Commission
- Mass Department of Environmental Protection Waterways Program
- United States Army Corps of Engineers (USACE)
- Mass Office of Coastal Zone Management

More information about the regulatory framework for the Stoney Beach project can be found in the summary report found on the ResilientWoodsHole Website, starting on page 23.
Finally, WHG prepared a summary report for the Stoney Beach Feasibility Study. WHG recommended the 10ft dune crest elevation, along with beach nourishment, as a design alternative for MBL's Stoney Beach. While the 10ft dune crest provided substantial protective capacity for the beach during high energy storms, the addition of beach nourishment provided an added benefit of minimizing dune erosion. When beach nourishment is added to a 10ft dune crest elevation, there is still erosion along the seaward face of the dune due to storms, however, the crest of the dune is only lowered by 1 ft, as compared to 2ft without nourishment. Furthermore, models show that beach nourishment itself erodes further seaward after storms, however it is expected that this material would be transported back to shore during calmer conditions. Overall, the 10ft dune crest elevation with beach nourishment was considered the best design alternative. Cost estimates for the recommended design alternatives by WHG for Stoney Beach can be seen in Table 1.

Project Component		Cost
Dune Nourishment	10 ft (680 cy)	$56,540
Beach Nourishment	1,290 cy	$76,279
Parking Lot Configuration	Option 2	$95,148
Design & Permitting Costs		$57,500
Total Project Cost Estimate		**$285,467**
Maintenance (10-Year Period)		**$48,205**

Table 1. Cost estimates for recommended design alternative (10ft dune height elevation with beach nourishment, with reconfiguration Option 2) for Stoney Beach.

Scope 3 - Strengthening the Private-Public Alliance

To ensure long-term community buy-in, *ResilientWoodsHole* proposed four outreach and engagement activities that would help mature the initiative and increase community involvement. This scope focused on advancing existing relationships with community members and *RWH* researchers to create a comprehensive public outreach program that engages the community on a deeper level. There were also examples of public outreach and engagement that fell outside of grant-supported outreach and engagement activities. Scope 3 included four main projects: neighborhood working groups, social media, *RWH* Climate Walking Trail, and other outreach and engagement opportunities.

Task 3.1 - Activate Management Area Working Groups to Provide In-Depth Input to Localized Community Resiliency Opportunities

ResilientWoodsHole recruited community members to serve in the Neighborhood Working Groups (NWGs) with the goal of identifying community-preferred coastal resiliency strategies over different time horizons. The groups met with *RWH* staff to discuss detailed coastal impacts to their neighborhoods and potential climate resiliency efforts to alleviate those impacts. NWGs were two-hour meetings, which were held three times over a one-year period. After each meeting, *RWH* produced publicly accessible summary notes of the meeting.

Nine neighborhoods (Figure 22) were identified for the Neighborhood Working Groups.

Figure 22. Study area of Woods Hole with nine neighborhood working groups.

ResilientWoodsHole conducted outreach to community members via email campaigns, social media, mailing posters, and through steering committee outreach. From this initial outreach, approximately 80 community members signed up for the management area groups.

ResilientWoodsHole initially planned to recruit about 5-15 community members per management area. However, some management areas had few sign-ups so *RWH* combined some management areas based on the type of climate change impact the neighborhood would experience. In total, six groups were formed, representing nine neighborhoods:

- Gansett/Fay Rd.
- Eel Pond/School St
- Spencer Baird
- Mill Pond/Woods Hole Park
- Waterfront

- Penzance Point/Juniper Point/Nobska Point

The first set of meetings were held in the spring. The first half of each meeting had an introduction, summary of previous phases of *ResilientWoodsHole*, and the current phase. The second half was spent discussing the initiative, answering questions from community members, and hearing about community members' experiences, their concerns as it relates to climate resilience, and any other feedback. From this meeting, *RWH* heard a lot of personal stories about flooding from community members. Community members also expressed concerns for specific areas in their neighborhoods. For example, most members of the Mill Pond/Woods Hole Park neighborhood working group were extremely concerned about the seawall just north of the park, as this seawall causes issues with drainage after water goes over the wall during coastal storms. Water pools behind the wall and funnels into the park and backyards of community members. Members of the Spencer Baird neighborhood working group were concerned about flooding from MBL's Stoney Beach, as well as from Mill Pond. During these initial meetings, *RWH* identified a gap in community understanding, specifically a need to help community members visualize climate change projections in the context of their own home and community. As a result, *RWH* decided to make a 3D model of Woods Hole with different layers representing flooding and mean high water projections. This 3D model was conceptualized after the first meeting and was unveiled during the launch of the *RWH* Climate Walking Trail (See "3D Model" under "Other Outreach and Engagement Opportunities"). The notes from this first set of meetings are available publicly on the *RWH* website.

The second set of meetings were held during the summer at MBL. The turn-out for the second set of meetings was lower than the first. The outline for this meeting was like the first with the first half spent reviewing background on adaptation strategy maps and the second half focused on community feedback. The goals of the second meeting were to better understand community preference for adaptation solutions, and hear more community needs in relation to the *ResilientWoodsHole* initiative. Community members provided excellent feedback regarding preferred adaptation solutions. For example, several NWGs discussed their concern for Mill Pond and the surrounding wetlands, its water quality, along with its capacity to hold water during flood events. This area is a major flood pathway because of several constraints that prevent flood waters from the pond from quickly draining. Additionally, several NWGs discussed Eel Pond flooding, specifically from coastal storm surge, along with the lack of proper flow between Mill Pond and Eel Pond. The notes from the second set of meetings is publicly available on the *RWH* website.

Figure 23. Final NWG meeting held on August 24, 2023

The third neighborhood working group meeting was a combined open-house style meeting for all six neighborhood working groups held at the end of the summer in the Woods Hole Community Center on Water Street (Figure 23**,** Figure 24 and Table 2). *RWH* held a combined third meeting to allow community members from different working groups to interact and facilitate an interactive approach as opposed to presentation based. During this meeting, *RWH* organized five stations for community members to visit, outlined in the table below:

Station	Goal	Station Materials
1. Whole Village Vulnerabilities	Discuss the climate impact projections for Woods Hole and identify areas of concern for the community.	Phase 2 mean high-water maps, coastal storm flooding charts, and maps of the vulnerability assessment of buildings and roads; interactive posters.
2. Flood Pathways	Educate public on flood pathways and gather feedback on the Stoney Beach Feasibility Study.	Video of flood pathways in the community and information about the Stoney Beach Feasibility Study.

3. Property Owner	Communicate with Barnstable Country Floodplain Coordinator to provide homeowners with advice and resources that evaluates coastal risk to residential homes.	Homeowner resources, including Homeowner Handbook to Prepare for Coastal Hazards.
4. Adaptation	Identify community-preferred adaptation solutions.	Phase 3 adaptation solution charts for each neighborhood in Woods Hole.
5. Community	Create space for community members to discuss coastal resilience with each other.	Chairs, waters, and index cards to leave input for *RWH*.

Table 2. NWG Workshop Stations, August 2023

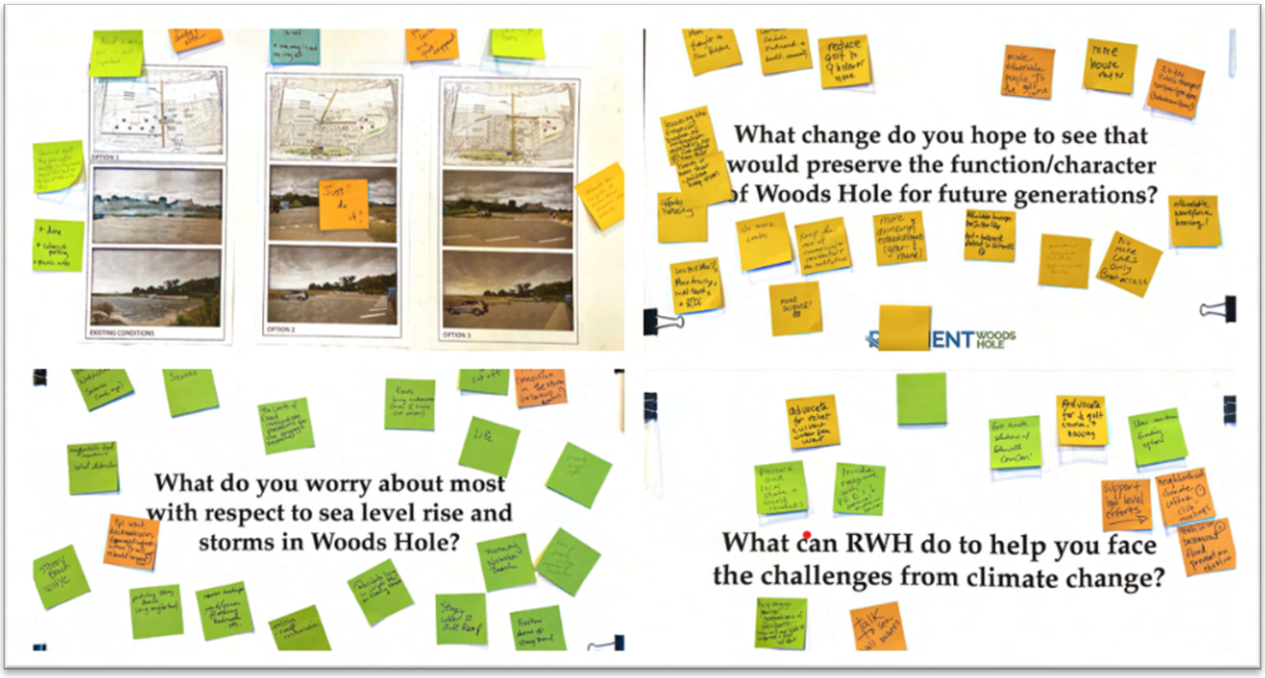


Figure 24. Posters from the third NWG meeting.

After the conclusion of the NWG meetings, a new page was made on the *RWH* website under 'Get Involved' with links to each NWG meeting summary (Figure 25).

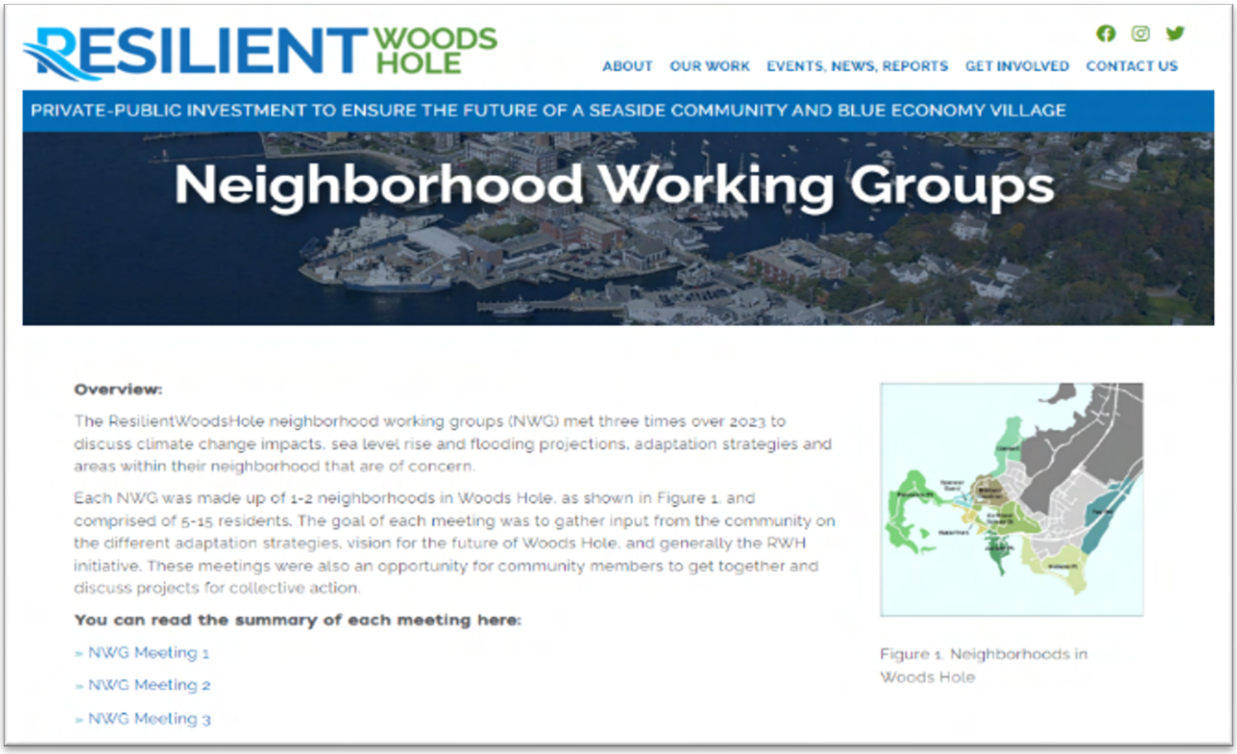


Figure 25. Publicly accessible NWG page on RWH website with available summary notes.

Task 3.2 - Utilize Social Technology to Reach & Franchise Underserved and Diverse Residents and Businesses

In March 2023, *ResilientWoodsHole* hired a social media manager to help manage social media accounts and further develop the social media strategy to build connections with seasonal and year-round residents, resilience-minded people, and organizations. *RWH* opened four social media channels, including Instagram (@resilientwoodshole), Facebook (@resilientwoodshole), Twitter/X (@ResilientWdHole), and LinkedIn (@Resilient Woods Hole). An additional goal for activating *RWH* social media accounts was to ensure that *ResilientWoodsHole* gets established as a local climate resilience initiative. Each social media account serves a separate purpose in engaging and connecting with different individuals, groups, and organizations. Facebook is *RWH*'s primary channel, used for posting news, updates, charts, and information from previous phases. Facebook is also the platform that helps *RWH* connect with community groups. Instagram is used to post pictures, adaptation solution charts, and climate projection maps. Twitter/X is used to connect with different organizations, media outlets, and update followers on any news and updates. LinkedIn is used to interact with businesses and other organizations. Social media posts occurred at least three times a week, and included a variety of information,

including charts, graphs, and photos from the previous phases of the initiative, as well as information about events and outreach opportunities (Figure 26). Along with posting, *RWH* responded to comments, connected with other climate resilience communities, and maintained a positive page engagement.

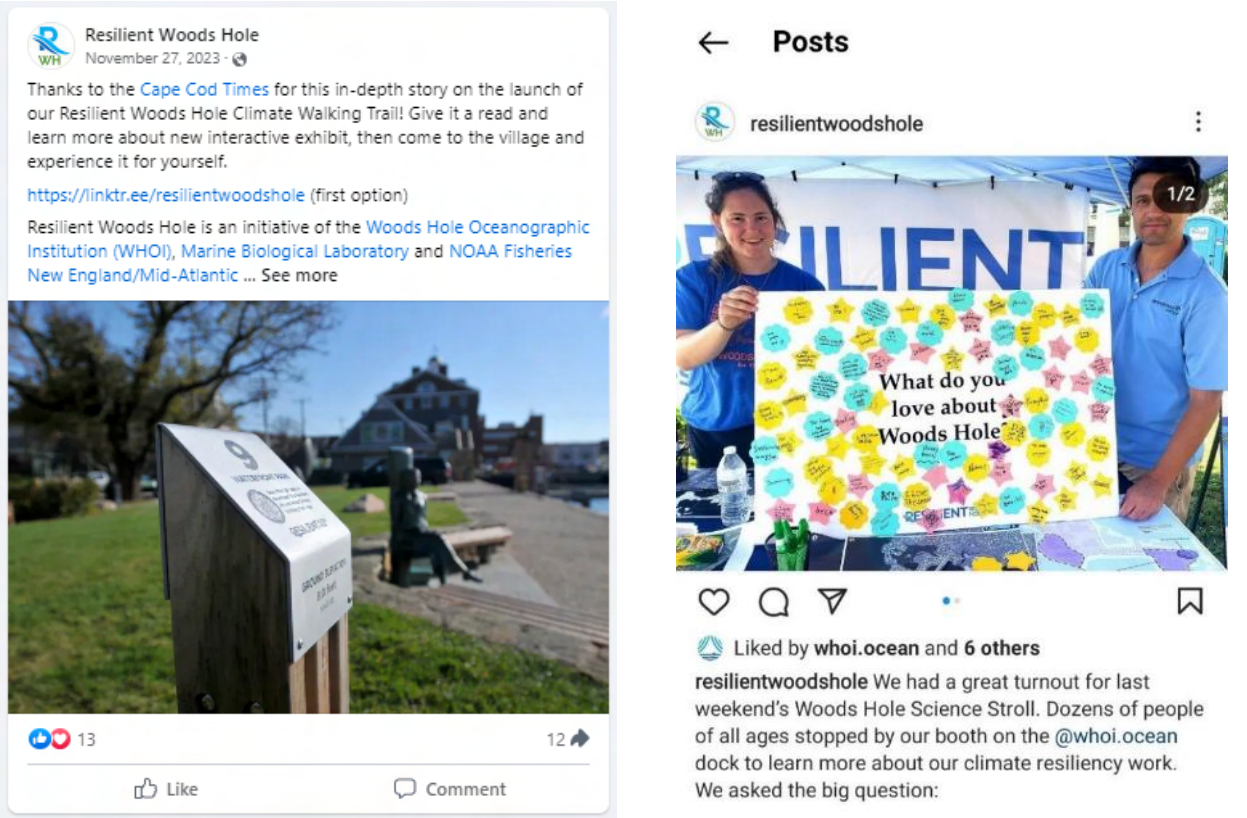


Figure 26. Facebook (left) and Instagram (right) posts on RWH news and updates on outreach, such as hosting an engagement table at the Woods Hole Science Stroll.

From March 2023 to May 2024, *ResilientWoodsHole* increased followers, interactions and reach on all three platforms. In total, across all social media platforms, *RWH* has a total of 525 followers, 1903 interactions, and has reached over 100,000 individuals. Most followers are locals from Falmouth, MA (Figure 27) and women are engaged more than men across all age groups.

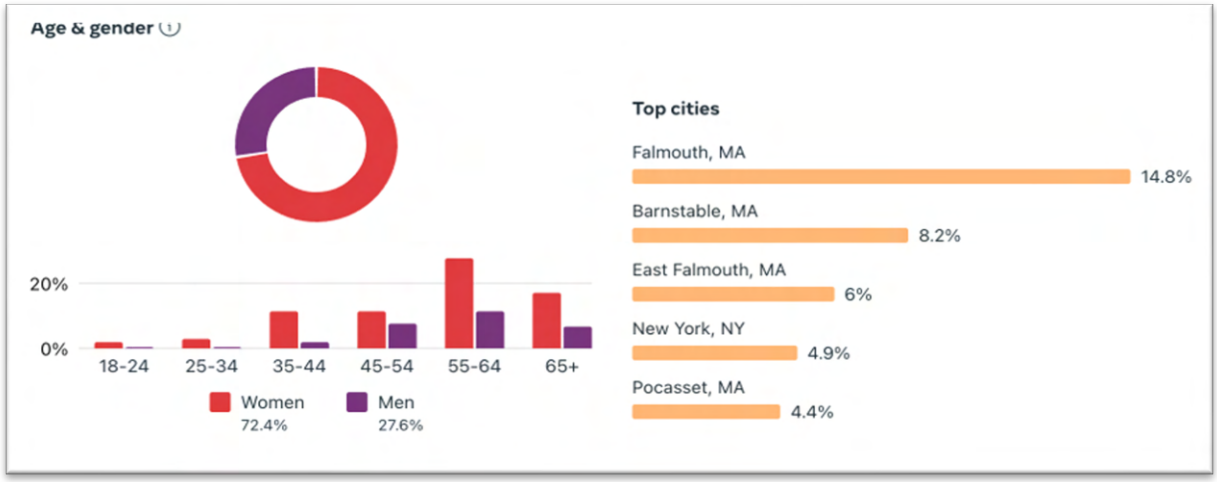


Figure 27. Demographic information across all social media accounts.

Task 3.3 - Develop and Deliver Climate and Climate Resiliency Podcasts to Educate and Engage Stakeholders

In early 2023, *RWH* set out to develop and deliver a climate resilience podcast series. The initial ideas were to develop four podcasts, which are woven into one cohesive narrative. Each podcast episode would have a different general theme, including 'Climate Science,' "Climate Resilience Communities around the country," "Climate Resilience in Woods Hole'', and "Adaptation Solutions." From the initial brainstorms, *RWH* inquired with WBUR and its CityScape Productions team about producing the podcast. After several meetings with the WBUR team and evaluating the proposed budget for the content sheet, *ResilientWoodsHole* determined that the costs of producing the podcasts were outside of the budget considerations and far more complicated than originally understood. With CZM approval, *RWH* reprogrammed funds from the podcast to other, more impactful community engagement and outreach activities, especially considering the increased cost of the podcast relative to the initial estimates. Funds from podcasts were reallocated to funding the development and printing of a 3D model of Woods Hole Village, along with climate change projections and mean high water (see 'Other Outreach and Engagement Opportunities' Section). *RWH* hopes to return to the production of podcasts with future funding.

Task 3.4 - Produce an Accessible Woods Hole Climate Walking Tour for All Visitor Types to Physically Connect with the Urgent Climate Resilience Needs and Opportunities

ResilientWoodsHole worked to develop a Village walking tour, titled the *RWH* Climate Walking Trail. The walking trail is marked in Woods Hole Village by physical posts that have a stop number,

stop name, NAVD88 elevation specific to each location, and a QR code to the *RWH* Climate Walking Trail app (Figure 28).

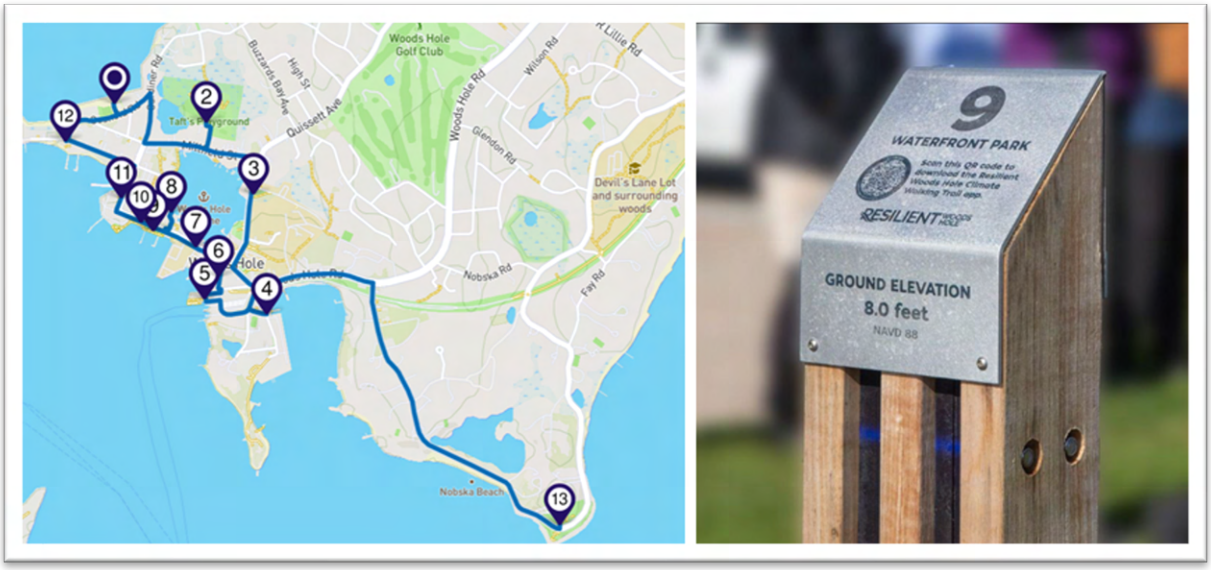


Figure 28. RWH Climate Walking Trail waypoints (left) and post at each location (right)

A self-guided walking trail was developed via the tour platform STQRY, that can be taken remotely online via the platform or in person via the *ResilientWoodsHole* app. The *RWH* Climate Walking Trail includes 13 stops around Woods Hole Village and takes over 90 minutes to complete. The goals of the trail are to demonstrate the vulnerabilities of Woods Hole Village to sea level rise and coastal storm flooding, present town, and institution climate resilience planning, and discuss other adaptation solutions to help protect Woods Hole from climate-related impacts. The climate walking trail includes video interviews with leaders in the *RWH* partner organizations and Woods Hole Village community members, charts of adaptation solutions and climate change projects, and current and historic images (Figure 29). The *RWH* Climate Walking Trail was officially launched on October 24, 2023, at an event attended by community members, leadership from each partner institution, Town of Falmouth leadership and members of the state legislative delegation. Since its launch, the *RWH* Climate Walking Trail has been visited by 1,229 individuals, as quantified by STQRY Analytics. The tour is being continuously improved, with several in-person aspects of the tour still being updated. This includes updating the GPS capabilities, navigation and instruction for the participant taking the tour on the *RWH* app. To learn more about the tour, visit the *ResilientWoodsHole* website or visit the digital platform directly at *RWH*.stqry.app.

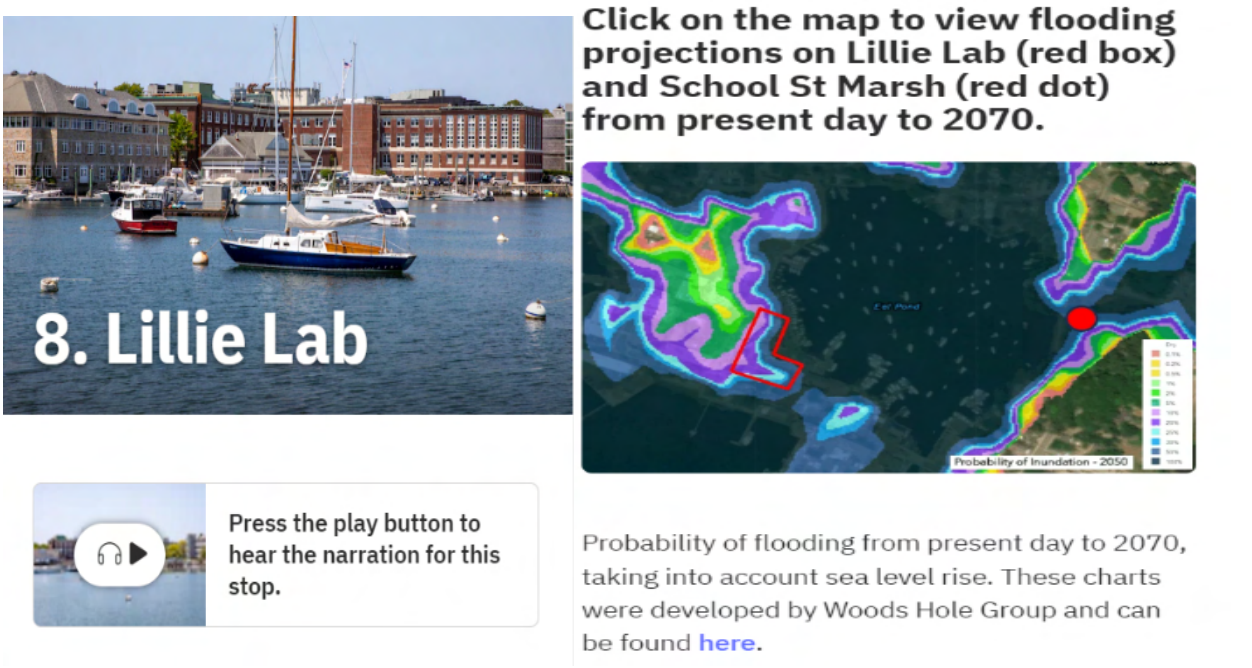


Figure 29. Lillie Lab on the RWH Climate Walking Trail. Most stops include narration, text, historic pictures, current day pictures, flooding projections, and video interviews.

The *RWH* Climate Walking Trail was advertised on the *RWH* website, the *RWH* social media platforms, along with partner organizations networks. The tour was also promoted via different organizations, including the Woods Hole Historical Museum, the Woods Hole Business Association, the Friends of Nobska Museum, and the Museum on the Greens. Through promotions of the walking trail, *RWH* is working to collaborate with different organizations on cross events and exhibitions.

Other Outreach and Engagement Opportunities

Aside from the four Outreach and Engagement projects that *ResilientWoodsHole* expected to complete as part of Phase 4 funded by CZM, *RWH* developed and participated in several other outreach and engagement opportunities. This includes:

- Development of a 3D model of Woods Hole
- Participating in staffing events where *RWH* is represented, such as WaterWorks 2024 at Cape Cod Community College, the 2023 Woods Hole Science Stroll, and Cape Cod Coastal Resilience Week
- Presentations at WH Children's School of Science and other venues
- Collaborating with other organizations

3D Engagement Model of Woods Hole and Project Flooding Impacts

ResilientWoodsHole developed a 3D-printed model of Woods Hole, with 2050 sea level rise and 2050 1% coastal storm flooding projections, as an interactive outreach tool. In the first NWG meeting, *ResilientWoodsHole* identified a gap in community members' understanding of their risk from coastal storm flooding and sea level rise. Community members had trouble visualizing the climate change projections on Woods Hole. During the preparation of the second NWG meeting, *ResilientWoodsHole* decided that a 3D model of what Woods Hole would look like with different climate change projections (i.e., 1% flooding and mean high water projections) would benefit the discussion and help contextualize the projections. Funds were diverted from Scope 3 Task 3.3, climate resilience podcasts with CZM permission, to fund the modeling, development, and printing of the 3D model. Digital modeling and development of the 3D model was done by WHG and WHOI's DunkWorks. The 3D model was also printed at WHOI's DunkWorks, along with the 2050 sea level rise and 2050 1% coastal storm flooding projections. The 3D model was officially unveiled at the *RWH* Climate Walking Trail launch on October 24th, 2023.

Figure 30. 3D model at the RWH Climate Walking Trail Launch (right) and updated model (right) at RWH's exhibit at the Nobska Lighthouse and Maritime Museum.

Since its unveiling, the 3D model has been updated to include painted water and land, markers on the model to help with orienting the viewer, an acrylic cover to prevent breakage, and more interpretive information on side panels that will allow the model to be stand-alone. The 3D model currently sits at the Nobska Lighthouse and Maritime Museum, where it is part of the seasonal *ResilientWoodsHole's* exhibit running from April-November 2024 (Figure 30).

Staffing Events with RWH Representatives

ResilientWoodsHole participated in several events over the course of Phase 4, including at the Woods Hole Science Stroll in August 2023 WaterWorks event in January 2024, and the Cape Cod Coastal Resilience Week in June 2024. During the Woods Hole Science Stroll in August 2023, *ResilientWoodsHole* brought coastal storm flooding projections and adaptation solutions charts to display on the table. *RWH* also produced an interactive poster that asked, "What do you love about Woods Hole?," along with some coloring pages and crayons for young children. The table was popular among attendees of the event. *RWH* had many responses on the poster board, ranging from "scientific institutions" to "the beach" (Figure 31). Furthermore, *RWH*, WHG, and leadership from MBL and NOAA all participated at the event and were heavily engaged in discussion about climate change projections, *ResilientWoodsHole* activities, and continued efforts of community engagement.

Figure 31. Interactive poster (left) and the table (right) during the Woods Hole Science Stroll

ResilientWoodsHole also hosted an engagement table at the WaterWorks event in January 2024. This event was a job-fair style event attended by over 300 high school students from the Cape and was held at the Cape Cod Community College in Barnstable. For this event, *RWH* brought climate change projection charts and adaptation solutions for the Waterfront area of Woods Hole, along with an interactive poster "How has climate change affected your community?" (Figure 32). During this event, *RWH* talked with over 30 students, and had 10 volunteer sign-ups.

The volunteer sign-ups will be used in future activities by *RWH*, hopefully providing help in other outreach opportunities and events where we can host engagement.

Figure 32. Table (left) and interactive poster (right) during the WaterWorks event.

ResilientWoodsHole also participated during two days at the Cape Cod Coastal Resilience Week in June 2024. This event highlighted coastal resilience on the Cape. *RWH* participated with a table at the kickoff event and at the screening of the film 'Inundation District,' where *RWH* spoke with many community members on Woods Hole's vulnerability to coastal impacts. *RWH* also lead community members around the *RWH* Climate Walking Trail and engaged in discussions about *RWH*'s recent and future resilient projects. Some community members that spoke with us during the film event happened to see the floodproofing efforts at MBL the next morning and were quite excited to see solutions actively implemented in their community.

Presentations

ResilientWoodsHole has presented in many forums. In August 2023, *RWH* presented at the Woods Hole Children's School of Science. This was the second summer that *ResilientWoodsHole* was invited to give a presentation to a class of middle and high school students on climate change and *ResilientWoodsHole*. During this year's talk, *RWH* engaged students in a hands-on presentation. Students were divided into three groups and given a neighborhood in Woods Hole to represent. Since many of the students were from the area, *RWH* split them up (roughly) into the neighborhoods where the students reside. Each group was then given climate change projection maps and vulnerability assessments from Phase 1 and 2 to look through and decide which areas in their neighborhood were at risk and in what time frames. After each group presented their evaluations, *RWH* then gave each group the adaptation solution charts for their

neighborhoods. Each group was tasked to identify which solutions were best to undertake and when, along with deciding on pros/cons to each solution they chose. Overall, the students were very engaged in the discussion. *RWH* received feedback from the WH Children's School of Science teachers that the students were extremely interested in the exercise, and that several students chose to complete a climate resilience-related project for their final project for the class.

RWH researchers have also presented on *RWH*'s work at different events/organizations, including:

- Woods Hole Community Association, August 2023
- Falmouth Select Board meeting, February 2024
- Williams College, Center for Environmental Studies, April 2024
- MBL, NACSETAC Annual Meeting, April 2024
- West Falmouth Public Library, May 2024
- MBL, Logan Science Journalism Program, May 2024
- Williams College, June 2024
- WHOI, Marine Policy Center, June 2024

Collaborations

ResilientWoodsHole has been actively searching for potential collaborations with different organizations. During the promotion of the *RWH* Climate Walking Trail, *RWH* connected with several organizations in Woods Hole, including Woods Hole Historical Society, Nobska Lighthouse and Maritime Museum, Museum on the Greens, and Woods Hole Business Association. Several organizations also reached out to *RWH* about collaborating opportunities.

For example, the Nobska Lighthouse and Maritime Museum reached out to *RWH* about a space available in their museum for their revolving exhibit running from April 2024 to November 2024. The museum space is a room-wide space on the first floor of the museum. In May 2024, *RWH* unveiled the new *RWH* exhibit at Nobska, which includes an updated 3D model, a post for the *RWH* Climate Walking Trail, historic and current photographs, and charts in the exhibit space of the museum (Figure 33). For this exhibit, *RWH* also developed a 13th stop for the *RWH* Climate Walking Trail, which includes information about the Nobska neighborhood and vulnerability of the two low access roads to the museum. This stop also includes a video interview of the Nobska Lighthouse and Maritime Museum president.

Figure 33. RWH exhibit at the Nobska Lighthouse and Maritime Museum

Additionally, the Woods Hole Historical Museum has reached out about a potential space in their permanent "History of Woods Hole" exhibit room. The museum and *RWH* have discussed putting up storm photos provided by the museum, climate change projection charts, adaptation solution charts, and text about *ResilientWoodsHole* in the exhibit space. Development of this exhibit is still evolving.

Next Steps

Looking forward the future, *ResilientWoodsHole* aims to shore up participation and planning efforts with the Town of Falmouth and continue community engagement to gather support for the *RWH* initiative. Additionally, *RWH* plans to identify and apply to funding sources that support several projects and grow the *RWH* initiative:

- Applying as the next logical follow-on grant to the Massachusetts Office of Coastal Zone Management Coastal Resilience Grant Program to continue permitting, dune restoration, and reconfiguration of amenities at Stoney Beach (see "Scope 2 – Stoney Beach Feasibility Study").
- Apply to the National Fish and Wildlife Foundation (NFWF) Coastal Resiliency Grant Program to fund a community-based project in evaluating potential solutions that can address the major flood pathways in the Mill Pond Neighborhood. *RWH* applied to NFWF

in June 2023 with this project but was not awarded funding. After meeting with NFWF reviewers and hearing constructive feedback, *RWH* is re-applying for the opportunity in June 2024.

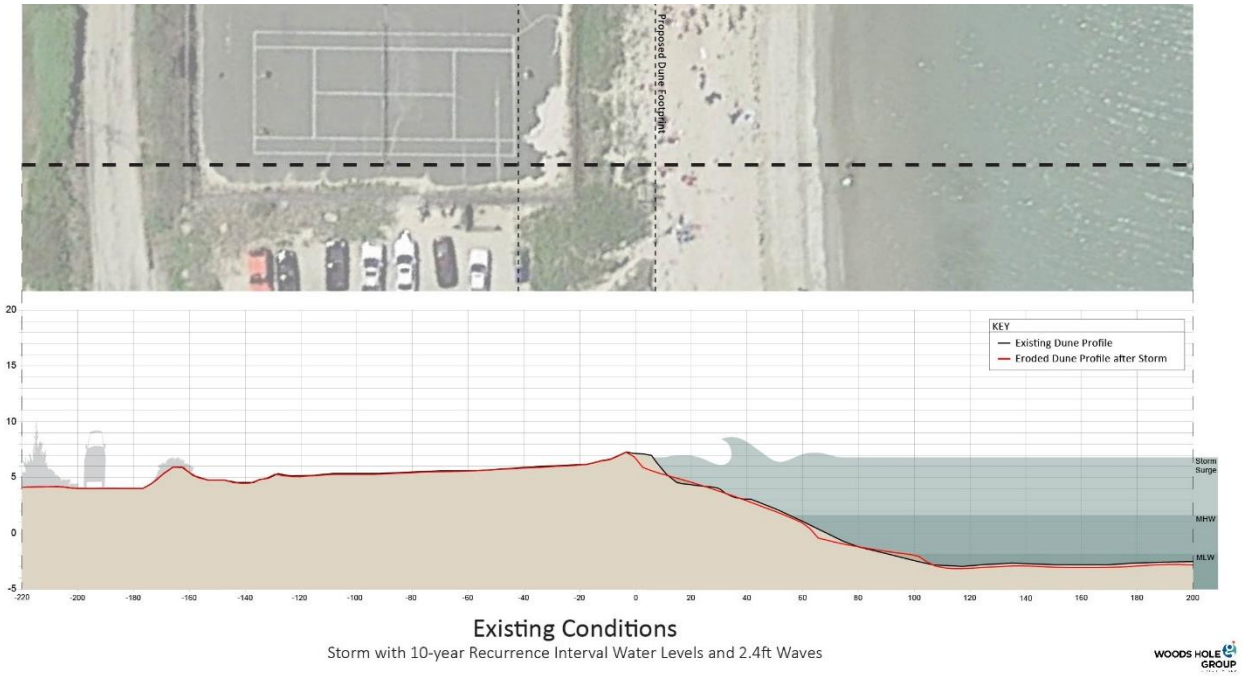
- Applying to National Science Foundation's CIVIC Innovation Challenge, to fund a project that combines all major stakeholders, including *RWH*, the community, and the town of Falmouth and looks at bringing lessons learned about flood proofing during this grant to Water Street property owners and small businesses.

ResilientWoodsHole has moved beyond simply 'admiring the problem' and is beginning to implement solutions based on technical analysis and community feedback, and share our lessons learned with other coastal communities.

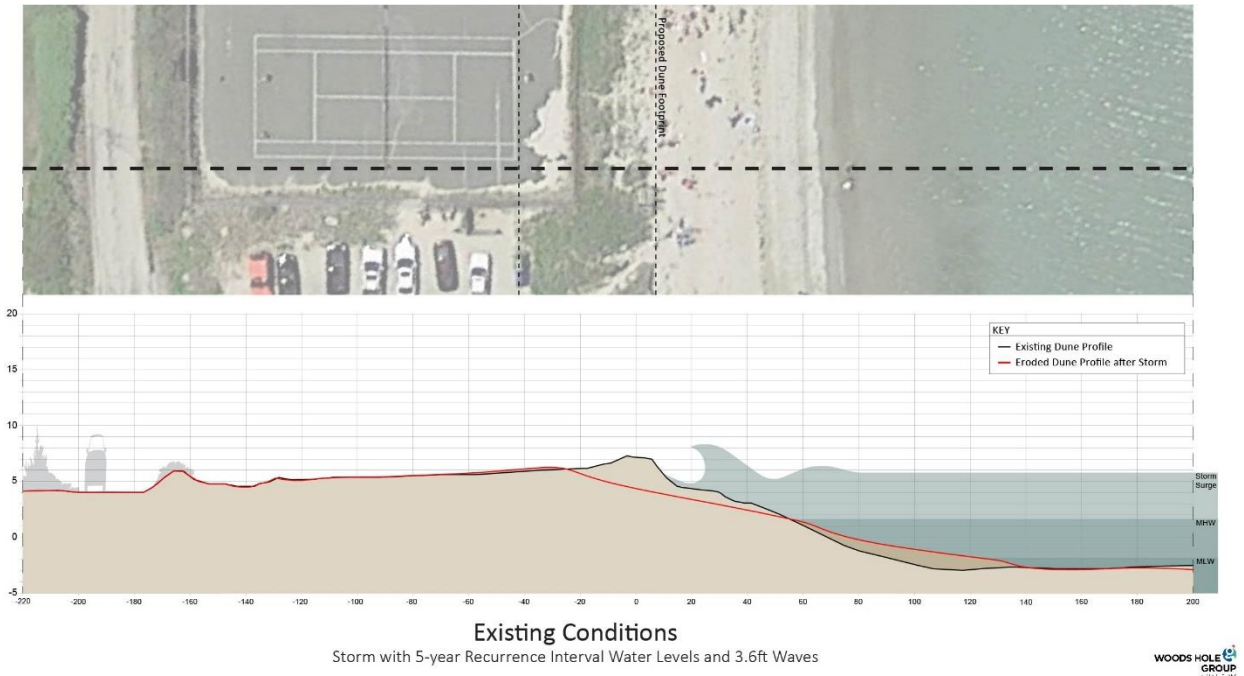
APPENDIX A

***ResilientWoodsHole* Phase 4 Report**
Appendix A:

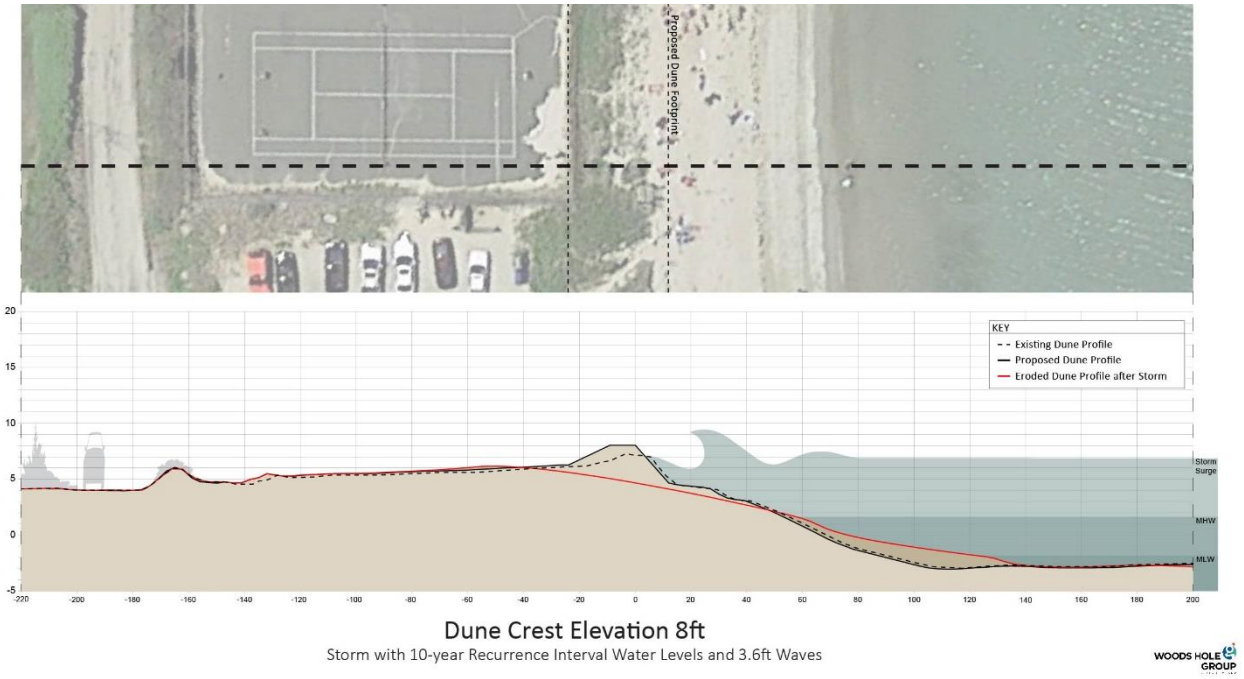
Dune Performance Modeling Results (Scope 2):



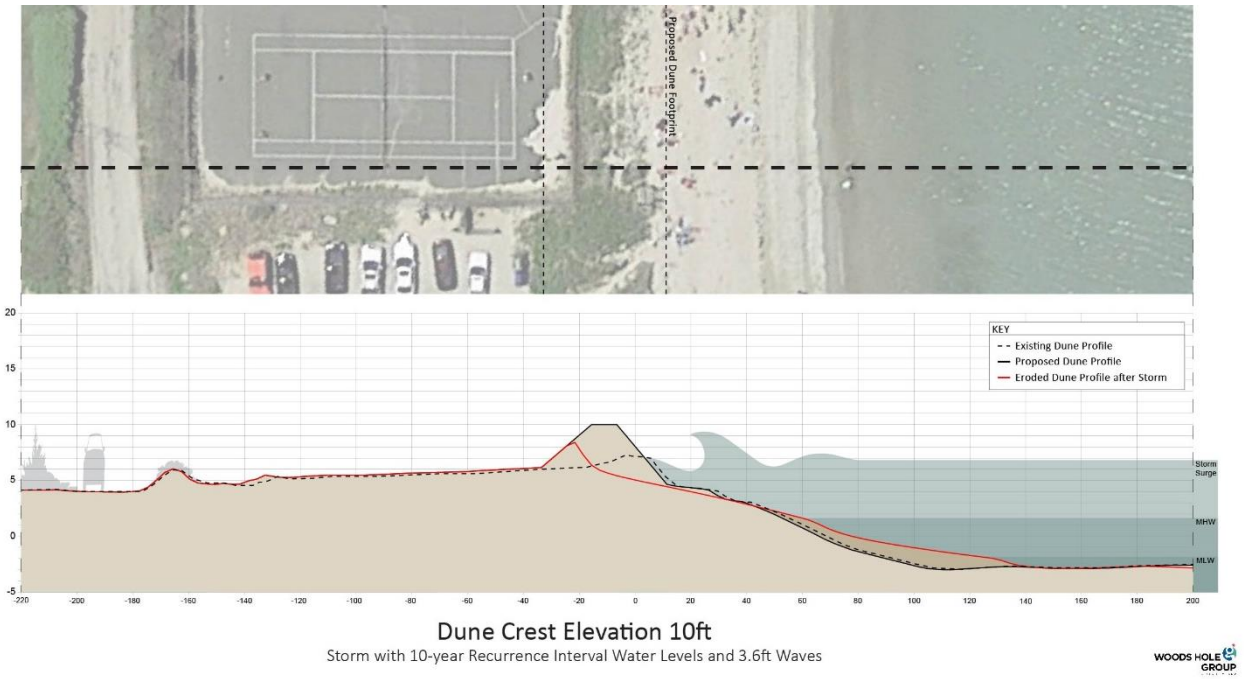
Dune performance modeling of existing dune with 10-year storm and 2.4ft waves.



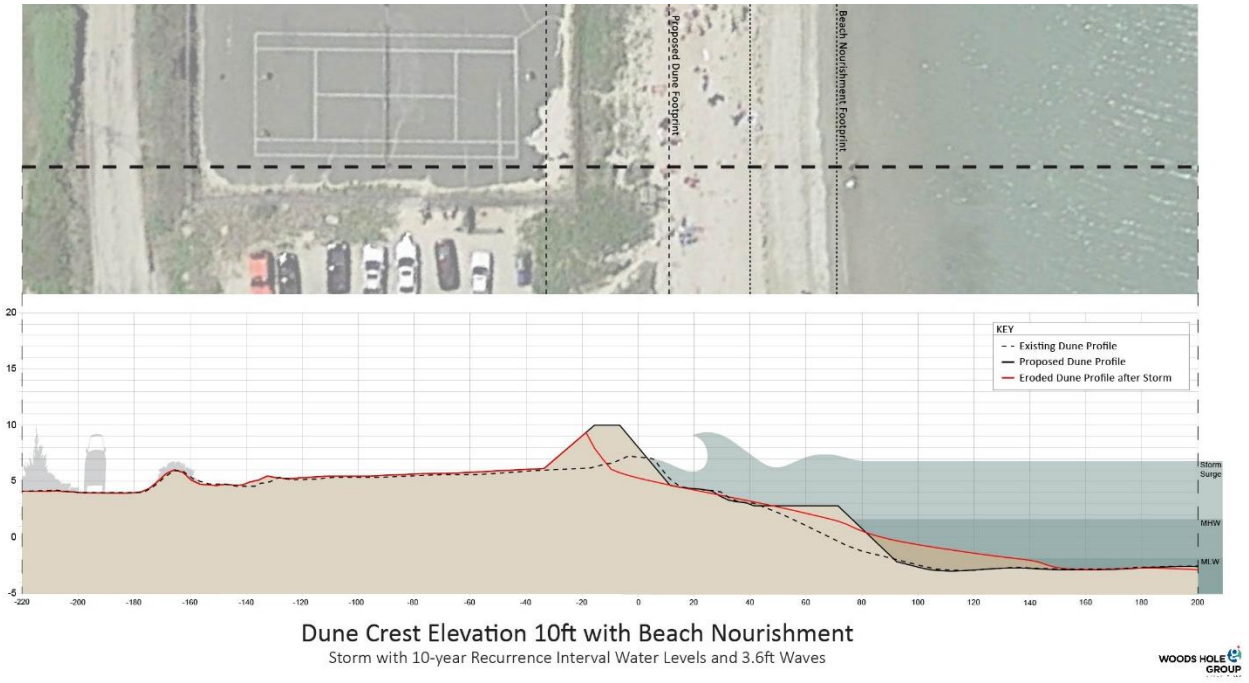
Dune performance modeling of existing dune with 5-year storm and 3.6ft waves.



Dune performance modeling of 8ft NAVD88 dune with 10-year storm and 3.6ft waves.



Dune performance modeling of 10ft NAVD88 dune (no beach nourishment) with 10-year storm and 3.6ft waves.

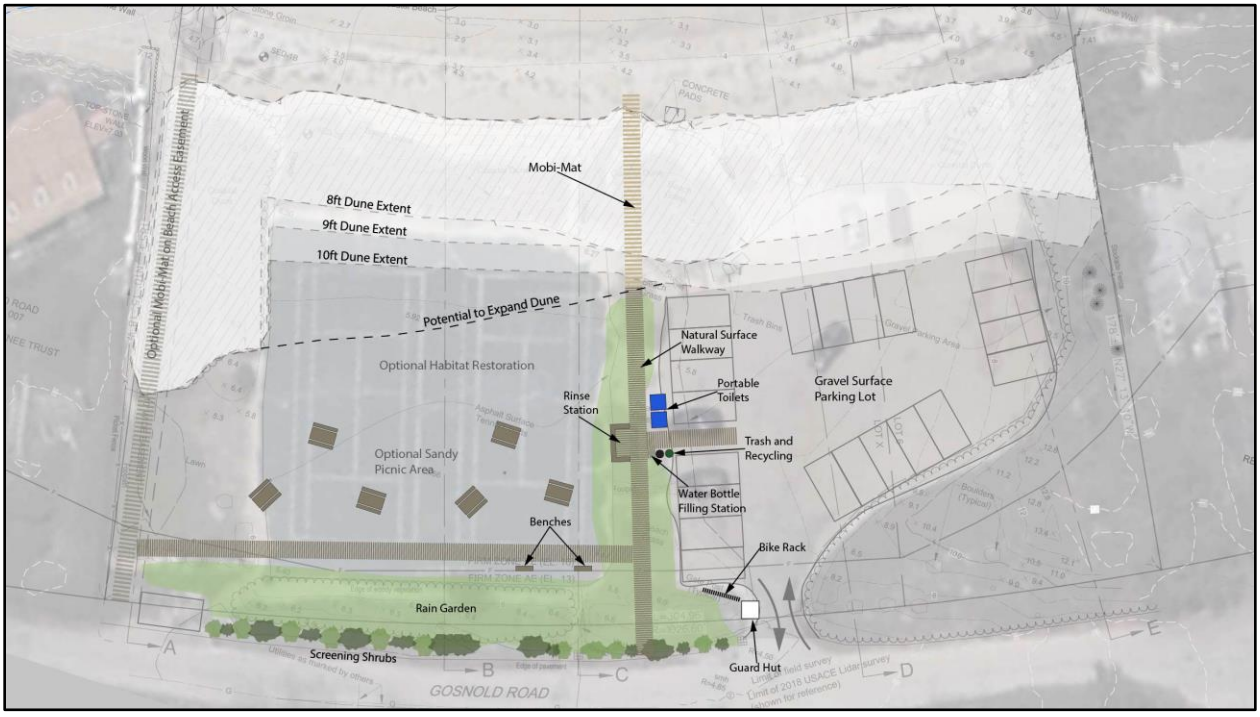


Dune performance modeling of 10ft NAVD88 dune (with beach nourishment) with 10-year storm and 3.6ft waves.

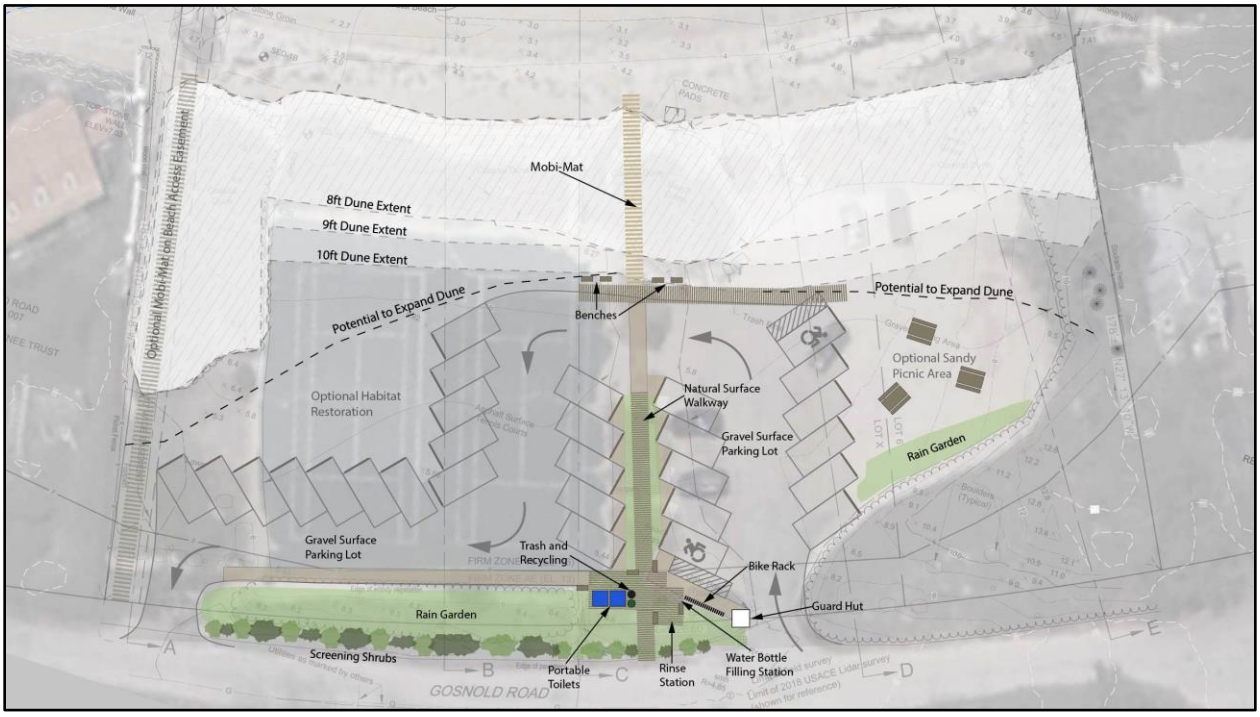
Water Level & Wave Condition	Existing Conditions	Dune Crest at 8 ft NAVD88	Dune Crest at 9 ft NAVD88	Dune Crest at 10 ft NAVD88
5-yr & 2.4 ft	✓	✓	✓	✓
10-yr & 2.4 ft	✓	✓	✓	✓
5-yr & 3.6 ft	✗	✓ (only with nourishment)	✓ (only with nourishment)	✓
10-yr & 3.6 ft	✗	✗	✗	✓ (only with nourishment)
5-yr & 4.9 ft	✗	✗	✗	✓ (only with nourishment)
10-yr & 4.9 ft	✗	✗	✗	✗

Performance modeling results for all three dune crest elevations considered: 8ft, 9ft, and 10ft.

Reconfiguration of Amenities (Scope 2):



Option 1 – reconfiguration of amenities that includes 21 parking spots, one entrance and exit, picnic tables, rain garden, mobi-mat, and other beach amenities.



Option 3 – reconfiguration of amenities that includes 28 parking spots, one entrance and one exit, picnic tables, rain garden, mobi-mat, and other beach amenities.

3D Renderings of Option 3 Configuration (Scope 2):

3D Rendering of Option 3 looking from west of the parking lot to east.

3D Rendering of Option 3 looking from east of the parking lot to west.