Nature-Based Solutions for Atlantic Highlands

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Introduction

The previous report, the Atlantic Highlands Flooding Vulnerabilities Assessment, highlighted several environmental hazards and risks associated with those hazards. This report serves as a follow-up by providing and prioritizing nature-based solutions to mitigate those risks. Nature-based solutions address climate and environmental hazards by building upon natural processes to create resilient, multi-functional ecosystems that are mutually beneficial to humans and their environment. These approaches capitalize on nature's intrinsic resilience, or ability to bounce back, resulting in longer-lasting, often less expensive, and more holistic solutions. The primary hazards identified in the previous report were coastal and riverine floods, coastal erosion, and shallow landslides (slumps). Additionally, water quality emerged as a highly relevant issue in Atlantic Highlands, and is therefore also addressed here. Several potential solutions are described in the following sections and prioritized in Appendix A.

Atlantic Highlands' previous natural infrastructure studies have been reviewed for this report. From past studies, this report examines available tools to prioritize opportunities for the enhancement of natural infrastructure. Previously, the Army Corps of Engineers (USACE) proposed a suite of projects for Many Mind Creek, but the solutions proved to be too expensive for the municipality. Also, any work at Many Mind Creek is pending New Jersey Natural Gas's final phase of coal-tar remediation which is ongoing through May 2022 and should open future opportunities. Additionally, in 2008, the Borough pursued a wetlands restoration project along Wagner Creek to help it drain into the bay. However, after several years, continued maintenance became a challenge, reducing the effectiveness of the wetland at flood reduction. Due to obstacles like COVID-19, no other progress has been reached on natural infrastructure projects. This report aims to give the municipality tools that are feasible and fit the community's needs. Feasibility is assessed in terms of cost, ease of planning and implementation, and required operation and maintenance.

Opportunities for nature-based solutions

1. Coastline erosion protection and improved water quality

According to several existing studies, the shoreline of Atlantic Highlands is at risk for erosion and flooding during storm events. Two key areas at risk include the outlet of Many Mind Creek and the shoreline along the Henry Hudson Trail. Many Mind Creek has a shallow outlet that feeds into Sandy Hook Bay. This outlet structure results in constrained flow during storm events which contributes to flooding in Atlantic Highlands via runoff. Approximately 1.25 miles of the Henry Hudson Trail is located adjacent to Sandy Hook Bay such that the path is no more than 250 feet away from the water at any point along this stretch of trail. This coastline is prone to flooding and is one of the town's first lines of defense in protecting the steep coastal bluffs in the area.

The goals for nature-based solutions to mitigate the impacts of erosion and flooding in these areas include:

- Stabilize the shoreline and attenuate wave energy using a combination of structural and organic materials (*e.g.,* strategically placed plants, stone, sand etc.).
- Utilize organic materials that will generate improvements in local water quality (*e.g.,* mussels).
- Create habitats that will support biodiversity and bring native flora and fauna to the area without contributing excessive nutrients to the region.
- Improve the visual appeal of the coastline to foster increased tourism and recreation in the area.

Thus, our team recommends completing the **Many Mind Creek Beach Restoration** and **Henry Hudson Trail Shoreline Protection** projects assessed in the 2019 Raritan/Sandy Hook Bay Coastal Resiliency Planning Study (Michael Baker International 2019) with some additional nature-based considerations that could improve water quality.

Many Mind Creek Beach Restoration

The proposed beach restoration initiative at the mouth of Many Mind Creek consists of clearing the existing outlet, replenishing the beach bordering the outlet to maintain the outlet's integrity, and conducting upland dune restoration to help protect the surrounding infrastructure from flooding and storm damage (Figure 1). The entire project is estimated to require 7,888 cubic yards of dredged sand for the beach replenishment that will consist of a berm at 2.5 feet with respect to the NAVD88 level, 388 cubic yards of dredged sand for maintenance dredging to -2 feet to with respect to the NAVD88 level, and the following materials for the upland dune restoration: 4,872 cubic yards of dredged sand/silt, 102 #2 containers of morella pensylvanica, and 16,458 *Ammophila breviligulata* seedlings. Our team did not develop this plan, but would like to highlight several considerations that were likely discussed when choosing this location and solution that could be applied when considering beach restoration in other locations: determine the natural habitat at the site; determine the extent of erosion; identify the slope, orientation, bathymetry, and currents in the area; identify any other hard shoreline stabilization efforts nearby to see if those can be tied into this effort; who owns the land; how much boat traffic is along the shoreline; is the site suitable for planting vegetation; what would be the result if nothing was done.

Henry Hudson Trail Shoreline Protection

The proposed shoreline protection efforts along the Henry Hudson trail would consist of the installation of breakwaters along the coastline in combination with beach replenishment (Figure 2). In this location, the beach replenishment would be higher than that at the mouth of Many Mind Creek: it is recommended the berm be at 3 feet with respect to NAVD88 which would require 60,360 cubic yards of dredged sand as well as 21,840 concrete blocks (12 feet x 8 feet).

The breakwater installation would span from -2 feet to +2 feet with respect to NAVD88. Beach replenishment would occur behind and in-front of the breakwater to maximize shoreline protection.

Natural enhancements- living shoreline

In addition to the previously recommended restoration efforts, this beach replenishment in front of the breakwater could become a living shoreline. Living shorelines are a shoreline stabilization practice that addresses erosion and attenuates wave energy. Beaches combined with sand dunes reduce the risks of storm surge/wave attack and flooding. Both beach nourishment and dune building are significant parts of the USACE's strategy to reduce coastal risk. The costs of this kind of project depend upon the size and location, placement of materials, transport, renourishment requirements and how the cost evolves. According to the USACE report in 2013, the costs of beach restoration to reduce flooding risk to 1 percent annual chance is estimated as $18 million per mile ($11 million per km), and $6.3 million per mile ($3.9million per km) for renourishment projects. However, many beach nourishment projects are designed lower to this level due to their lower costs. Adding native flora to the beach restoration area may prolong the success of the breakwater structure by providing an additional layer of defense against high energy storm events.

Figure 1. Schematic of the proposed beach restoration initiative at the mouth of Many Mind Creek proposed by Michael Baker International (2019).

The **major advantage** of beach nourishment and dune building projects are in reducing damage against moderate-energy hurricanes as proven through historical cases of Hurricanes Dennis and Floyd in 1999 and also Hurricane Sandy in 2012 (National Research Council 2014). Additional environmental benefits of nourishment projects are the ability to provide important ecological functions such as the offering of natural habitats and enhancing dune formation. However, one of

the **challenges** of beach restoration projects is the immediate increase in mortality of sand-dwelling organisms and decrease in total biomass, which usually appear in the short term. Restrictions on the timing of dredge and fill operations in winter months can be a critical strategy (Peterson et al., as cited in National Research Council 2014). The long term implications of repeated renourishment projects are still unknown: the ecological recovery in the long term will be dependent on factors such as sediment quantity and quality, the size and placement of nourishment, as well as the nourishment technique. Our team ranks these projects as having moderate feasibility in that the plans already exist, making planning and implementation highly feasible, but the cost is high, which weighs down the feasibility to a moderate standing.

In addition to these existing plans, our team also recommends introducing Atlantic ribbed mussels (*Geukensia demissa*) to the region. The Atlantic ribbed mussel is a bivalve that can grow up to four inches long and can be found naturally elsewhere in Sandy Hook Bay (Khan and Prezant, 2018). Atlantic ribbed mussels are suspension feeders which means they are able to improve water quality by removing particulate matter from the water column as they feed. Mussels could be planted in a fringing salt marsh environment, introduced to living reef breakwater, or hung from a floating raft in shallow water depending on the goals of the site (Hudson et al. 2016). Planting mussels on the former two scenarios would assist in shoreline stabilization and water quality improvement, while the latter would be focused solely on local water quality improvement. These shellfish are tolerant to wide swings in salinity which makes them the ideal organism for this region which may be subject to extreme low salinity conditions during storm events. The water regions surrounding Atlantic Highlands have not been meeting their designated uses for shellfish or total coliform levels, as reported in 2016. As such, any improvements to water quality move towards meeting the Clean Water Act section 101(a) goal to "restore and maintain the chemical, physical and biological integrity of the Nation's waters."

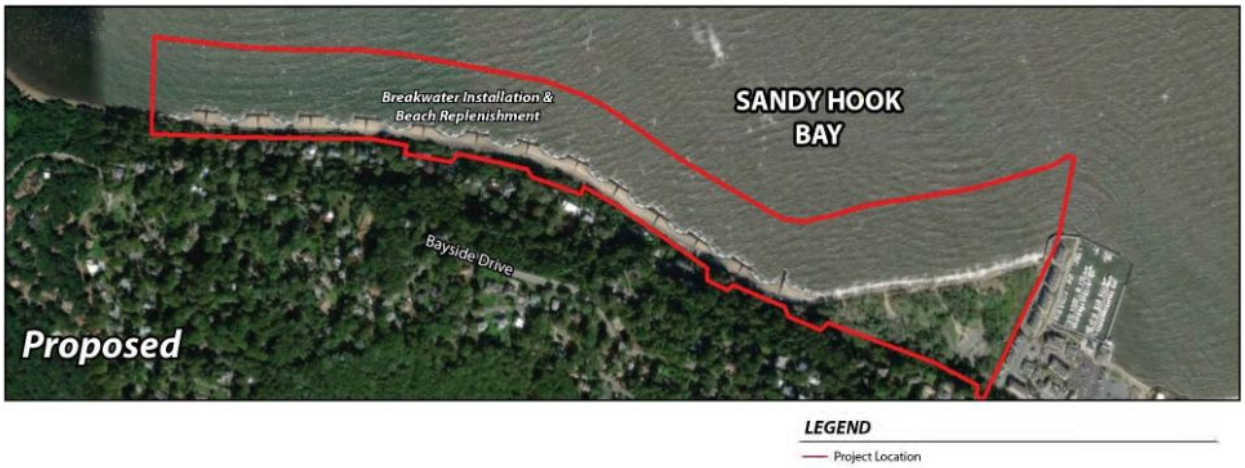

Figure 2. Schematic of the proposed shoreline protection efforts proposed by Michael Baker International (2019).

New Jersey's Department of Environmental Protection (NJDEP) has regulations that preclude the planting of shellfish for human consumption in areas where consumption may be harmful to human health (*e.g.,* the Raritan Bay and Sandy Hook Bay area). As such, it is important to note that the coastline of Atlantic Highlands is currently listed as both prohibited and restricted Atlantic Shellfish Growing Waters (NJDEP Shellfish Growing Water Classification). This challenge is easily overcome by completing a simple permit (*i.e.,* Permit for Shellfish Restoration and/or Enhancement in Waters Other Than Approved) with instructions on how to complete the permit on page two of NJDEP's Consolidated Permit Application (NJDEP 2017). Furthermore, because Atlantic ribbed mussels are not commonly eaten (Curtis 2015), they may be exempt from regulations restricting the planting of shellfish for human consumption in these areas, but this would need to be confirmed with permitting points of contact in NJDEP (NJDEP 2020). All of NJDEP's regulations regarding shellfish growing can be found at New Jersey Administrative Code 7:12 (NJAC 2016). The team considers the planting of Atlantic ribbed mussels to be highly feasible, given its inexpensive and easy to implement nature.

2. Vegetation restoration for slope stabilization

Starting in 1782, several landslides have occurred in the steep coastal bluffs in the Atlantic Highlands and Highlands municipalities (United States Geological Survey [USGS], 2017). According to studies by the USGS, these shallow mass movements of soil, termed slumps, have occurred with increasing frequency since the 1970s, and even more so since the 2000s (USGS, 2016). Atlantic Highlands has previously addressed this issue with a municipal ordinance, Municipal code art. VII § 150-78, requiring special permitting for any land changes in the affected areas with slopes greater than 15%. Additionally, gabion walls have been installed along some sloped areas to strengthen the base of the slopes and foster infiltration at the base. Ongoing and previous studies indicate that intense precipitation, particularly during hurricanes and Nor'easters, combined with inadequate tree canopy cover, a high groundwater table, and homeowner land alterations have led to landslide conditions (Ashland *et al*. 2017; TRC, 2014). In their studies, USGS and TRC Engineering provided nature-based recommendations to prevent slumps by increasing canopy cover and slowing groundwater infiltration during heavy precipitation events. This section offers insight into methods to implement these control measures.

The goals of the nature-based approach to slope stabilization in the coastal bluffs are as follows:

- Slow infiltration of stormwater in the steep slope areas
- Reduce excess runoff being directed downslope to the lower lying areas
- Stabilize slope soils with extensive root systems
- Restore the ecosystems, providing new habitats and increasing carbon sequestration
- Engage the community in these efforts to "Stabilize Our Slopes and Our Climate"

Towards these goals, the team recommends **s**trategic **conventional vegetated planting** and **soil bioengineering** with live staking with live fascines to stabilize the slopes.

Conventional re-vegetation, planting on the slopes

Vegetation with well-established and varied root systems stabilizes soils by providing strength against forces, such as water and wind, that put pressure on and move otherwise loose soils. Additionally, fully grown vegetation increases canopy cover in forested areas, catching rainwater as it falls, slowing infiltration into the high water table, and reducing runoff volumes downslope. Further, trees and other vegetation, such as grasses and shrubs, provide habitat to birds and other animals, and pull carbon out of the atmosphere, making them beneficial to the community and the world beyond the immediate benefits of slope stability. The species recommended here for conventional vegetated planting consider the following traits: native New Jersey species, low height (to avoid blocking homeowner's bay view), deep or laterally spread root system, adequate canopy cover (including some pine species for year-round protection), suitable for low pH and sandy soils, and tolerance of salt sprays. **Recommended species include**: *trees/shrubs*- Pussywillow, Southern arrowwood, Nannyberry, Silky dogwood, Mountain laurel, Pitch pine, Eastern red cedar, Indigobush; *grasses*- Little bluestem, Big bluestem, Switchgrass (Lower Passaic River Project Plant Resource Document 2008).

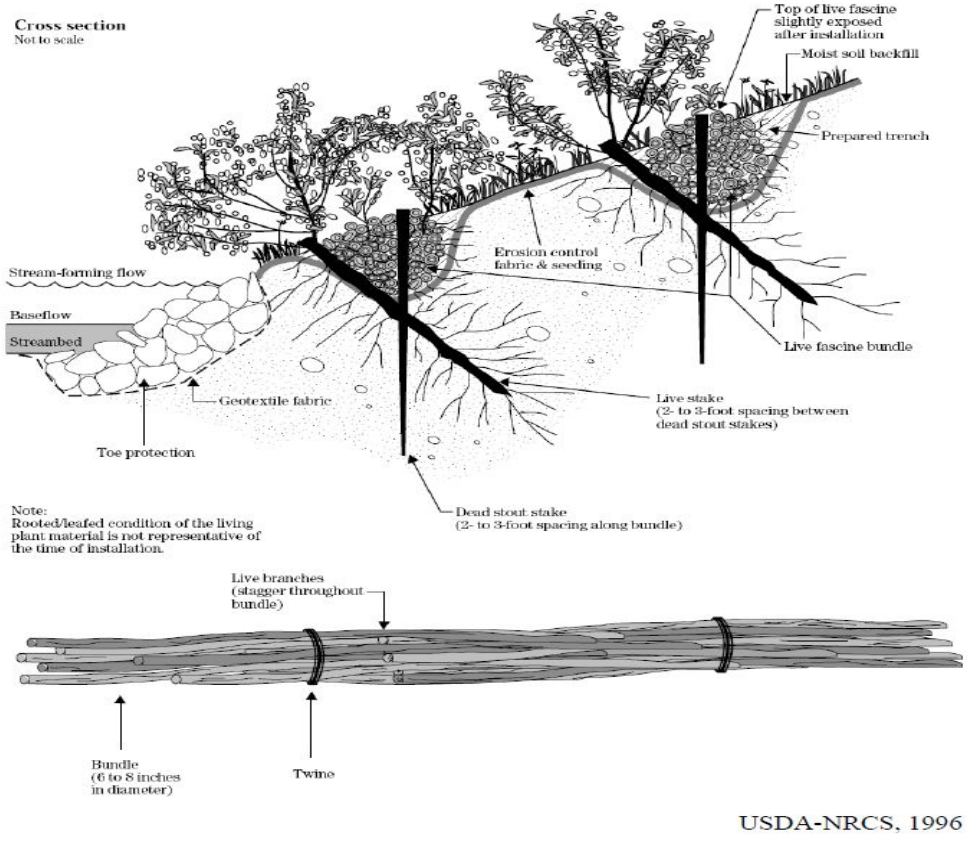

Figure 3. Live fascine and live stake installation schematic. Image source: Lower Passaic River Restoration Project Plant Resource Document (2008)

Encouraging residents in the sloped areas of town to participate in the revegetating process presents the Atlantic Highlands Shade Tree and Environmental Commissions an opportunity to collaborate. Together, these commissions can encourage homeowners to plant vegetation on their private properties through an outreach campaign to "Stabilize Our Slopes and Our Climate." This builds off of the current mission of these commissions, allows for greater community engagement, and highlights the mutual benefit of this vegetation-focused approach. By leveraging the resources of the existing commissions, conventional revegetation work can begin immediately and within current budget constraints. Based on the low cost (approximately $180/tree, all things included), existing $10,000 Shade Tree Commission budget, and ease of implementation, this project is highly feasible.

The advantages to this approach include ease of implementation in terms of cost and municipal skillset, as well as the co-benefits of slope stabilization, reduced downslope flooding, habitat creation, carbon sequestration, community engagement, and aesthetic improvements. **The challenge** to this approach is community outreach and resident buy-in, as private property owners will need to participate in this program on their own property. However, with a targeted outreach campaign and clear explanation of the co-benefits (ie., reduced danger and property loss, habitat restoration, carbon sequestration, and aesthetic improvements), this challenge can be addressed head-on.

Soil bioengineering with live stakes and fascines

While reintroduction of vegetation as described above is suitable for any location in the sloped areas of Atlantic Highlands, larger sensitive areas may be better stabilized with a more complete bioengineering strategy. Live staking is another method of introducing vegetation into a sloped area by planting live cuttings of tree or shrub pieces (at least 3 years of age) into the ground during the dormant season that establish roots over time, stabilizing the soils. This method is most effective when done in conjunction with additional stabilization methods. Thus, the team recommends installation of live stakes in conjunction with live fascines, or bundles of live branches placed horizontally along the slope in shallow trenches, staked into the ground (Figure 3). These methods work together to prevent surface soil erosion and to strengthen the subsurface by establishing root systems that grow out of live stakes and fascines. This method has been used to stabilize steep slopes along roadsides (Figure 4). **Recommended species for the live stakes include:** Black willow, Southern arrowwood, Nannyberry, Silky dogwood, and Ninebark. This method is relatively inexpensive compared to other slope stabilization methods. Live stakes cost approximately $1-5 per three-foot stake, live fascines cost $4-10 per linear foot, and natural fiber geotextiles, laid beneath the installation for surface erosion control, cost approximately $150-200 per 600 sq. feet. The US Army Corps of Engineers (USACE) estimates that, accounting for all installation costs combined, live fascines cost approximately $10-30 per linear foot (Sotir and Fischenich, 2000). To put this in context, for a 300-ft long plot with three rows of live fascine bundles, the estimated cost on the high end of the spectrum is approximately $27,500 (cost adjusted for inflation). These systems should be installed during the dormant season between

November and March, and root systems and vegetation can take 1-2 years to fully establish, at which point they can stabilize the soil from 1-3 feet below the surface. This type of project is considered highly feasible in terms of low cost and complexity of implementation as well as operation and maintenance. One factor that makes this not immediately implementable, however, is the need for site selection and project design, making it overall moderately feasible. The team recommends considering this strategy uphill from the gabions that were previously installed. This could build on efforts already undertaken, and increase the capacity of the installed system to withstand future landslide pressures.

Advantages of this method include the lack of heavy equipment and maintenance required to provide meaningful structural support. **Challenges** associated with installation of live stakes and fascines include the proper handling of live materials prior to and in early stages of planting (i.e. they must be kept wet and will fail if dried), the necessity of planting in the dormant season, and the time required to fully establish strong root systems. An additional challenge in Atlantic Highlands is finding an appropriate and necessary location for this system that either (a) does not involve private property or (b) involves private property with an owner who is interested in participation.

Figure 4. Newly installed live fascine on roadside (Image source: Western Transportation Institute by G. Keller, 2011)

If no action is taken to revegetate and stabilize the slopes in Atlantic Highlands, there is a growing risk of shallow slumps, which may damage property and endanger human lives. As precipitation intensity increases and severe storms occur more frequently, an increased occurrence of these landslides is expected (Runkel *et al.* 2017; Ashland *et al*. 2017). Therefore, it is in the interest of the residents to begin with this effort to preserve property and ensure safety through a combination of revegetation and soil bioengineering. Further, these approaches will enhance the ecosystems in the sloped areas, improve aesthetics in areas of historical slumps, reduce downslope flooding, and contribute to carbon sequestration. Additional resources towards implementing these solutions are below:

State standards:

- Standards for soil erosion and sediment control- New Jersey
- Soil bioengineering for upland slope protection and erosion reduction- USDA-NRCS

About examples & materials:

- Examples: Washington State DOT Report on Soil Bioengineering for Upland Slope Stabilization
- Materials: Lower Passaic River Restoration Project Plant Resource Document ; https://www.jerseyyards.org/plant ; https://www.ernstseed.com/products/bioengineering-materials/

3. Stormwater management on Many Mind Creek

The Many Mind Creek, which is vulnerable to storm surge flooding, sits behind Atlantic Highlands' historic downtown and is crucial to the borough's stormwater management. A primary watershed for the region, the creek drains into Sandy Hook Bay and directly impacts its water quality and ecosystem health. At the same time, stormwater projects for the Many Mind Creek face the unique challenges of the borough's steep slopes, coal tar contamination in the streambed and associated ongoing remediation efforts, and contamination of coliform (bacteria) from animal waste in the creek and greater watershed.

The goals for nature-based solutions for stormwater in Many Mind Creek are as follows:

- Slow infiltration rates around the creek
- Reduce influx of runoff from higher ground in the watershed
- Assist soil stabilization in slopes throughout borough
- Maximize space for recreation and bike-pedestrian transportation on the long-planned creek greenway
- Discourage attraction of animals, which may exacerbate coliform issues and suffer adverse health impacts from exposure to lingering coal-tar contamination
- Utilize native plants for USDA Temperate Zone 7 with appropriate cold hardiness and heat tolerance

Thus, our team recommends both **rain gardens** and **increased tree canopy cover** to address stormwater flooding and pollution concerns on the Many Mind Creek. Additionally, **collaborative management of the creek watershed** with upstream neighbors will increase the efficacy of all strategies to improve conditions in Many Mind Creek.

Implement Rain Gardens

Rain gardens, a low-tech bioretention system, are shallow depressions and short-term water storage tanks planted with species that thrive on water, mainly grasses. The strategy has been used extensively in Hoboken to mitigate flooding in infiltration and retention areas with an ambitious plan to reduce stormwater and control combined sewer overflows. It has also been used at smaller scales, including a town hall parking lot situated on steep slopes in Mars Hill, North Carolina. Rain gardens are positioned downhill of impervious surfaces, and work to slow

rain infiltration and filter out pollutants. They can either be fitted with underdrains or designed to filtrate water into the subsoil, and are well-suited to be incorporated into the Many Mind Creek Greenway design. Given space constraints around the creek, underground water collection may help prevent creek overflow and maximize recreational use, while providing a more manicured appearance than a planned wetland. Rain gardens should not attract mosquitoes.

Recommended species for rain gardens in wetlands and moist upland soil include: Marsh Mallow, Soft Rush, Common Threesquare, Sweetflag, Blueflag Iris, Buttonbush, Swamp Milkweed, Green Bulrush, Arrow Arum

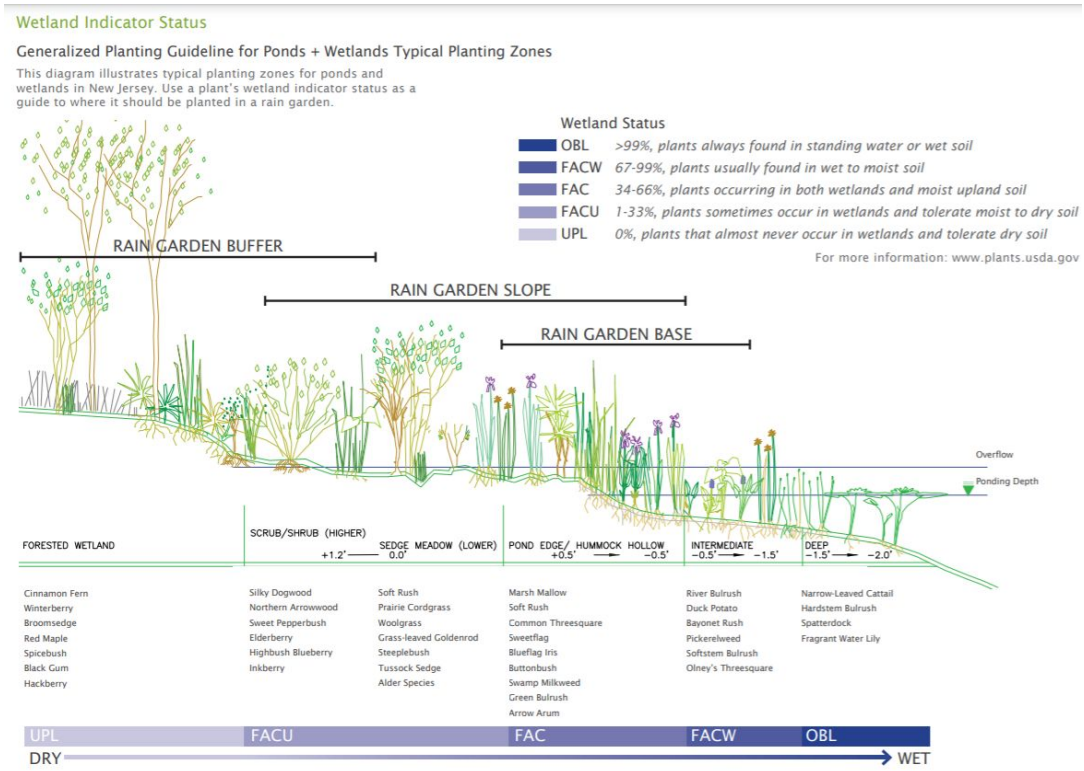

Figure 5. Planting zones and species for rain gardens in New Jersey. Image source: Native Plant Society of NJ Rain Garden Manual

The **advantages** of rain gardens include their effectiveness in capturing and filtering stormwater and slowing infiltration, as well as their aesthetic and habitat enhancements. Cost and maintenance may **challenge** rain gardens' implementation, although they require less maintenance than traditional garden landscaping. They also require soil testing and cannot be planted where the seasonal high water table is within 24 inches of soil surface, although the borough could experiment with bioswales or stormwater planters, which follow similar principles with an altered design. State engineering guidelines for bioretention structures can be found at https://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.1.pdf.

Increase Tree Canopy Cover

Street trees' **benefits** include increased lag time in the infiltration process, soil stabilization, and absorption of excessive rainwater. Compared to rain gardens, they have a shorter implementation timeline and a less disruptive installation process, which is likely to have community and conservation group support. This can build on the work of Atlantic Highlands' Shade Tree Commission in any efforts to increase tree canopy for stormwater management purposes. Atlantic Highlands already participates in tree planting and is considered a "Tree City USA" community, and therefore this recommendation is simply for an expansion of these efforts. Generally, tree planting strategies are relatively inexpensive. Coordinating with the state forestry program, which occasionally provides free trees, could make the strategy even more cost-effective. Due to the Borough's existing forestry management plan, the Borough is also eligible for the New Jersey Urban and Community Forestry Stewardship Grant, which can be applied to reforestation efforts.

Planting trees throughout the county along the creek could help to offset runoff due to development and higher impervious cover upstream. Sustained maintenance and community caretaking efforts may be a **challenge**, and the borough will need to consider climate impacts on trees' health, choosing species for planting wisely with help from a certified forester.

Recommended species for tree plantings include: Loblolly Pine, Sweetgum, Red Maple, Black Oak, White Oak, Southern Red Oak, Black Cherry, American Beech, Chestnut Oak, and Yellow Poplar.

Both tools have numerous **co-benefits**, including aesthetics, enhanced recreation, and climate adaptation through plant species. Importantly, both stormwater management techniques contribute to clean water and enhancement of water-dependent uses through improved stream and bay health. Rain gardens require more funding, skilled planning, and maintenance, which reduce their feasibility to a moderate level, although they could be incorporated into ongoing landscaping plans on public property. Tree plantings, by contrast, are highly feasible due to comparatively low costs and human resource expenditures.

About examples & materials:

- City of Hoboken Rainfall Flood Mitigation: https://cityofhoboken.maps.arcgis.com/apps/Cascade/index.html?appid=65c107f7e6984c4ca988c84ae406d27f
- Mars Hill Stormwater Demonstration Project: http://www.wncstormwater.org/pdf/MarsHill_TrailMap.pdf
- Native Plant Society of NJ Rain Garden Manual: http://www.npsnj.org/PDFs/2011_rain_gardens/3_Planning_14-31.pdf
- NJ Forest Adapt: https://njforestadapt.rutgers.edu/#/map

Many Mind Creek Watershed Management for Riverine Flooding

As identified in the Flooding Vulnerabilities Report, riverine flooding from Many Mind Creek poses a significant risk to many of Atlantic Highlands' assets. Many Mind Creek is also currently undergoing remediation for contamination related to its historical use as a dumping ground for coal tar waste and other pollutants[1]. Floodwaters from the creek are therefore more dangerous to nearby residents and commercial users since they carry the risk of exposure to contaminants.

In 2017, the US Army Corps of Engineers (USACE) completed the Many Mind Creek Planning Assistance to States (PAS) Study, the goal of which was to "develop flood risk reduction alternatives for Many Mind Creek"[2]. The report identified two primary components to the floods along the banks of Many Mind Creek: coastal flooding from Sandy Hook Bay and riverine flooding of the creek due to rainfall. While the coastal flooding may require hard infrastructure for complete management, the riverine flooding can be mitigated using nature-based solutions and watershed management. Managing the Many Mind Creek watershed can greatly reduce the frequency and intensity of riverine flooding in Atlantic Highlands.

Many Mind Creek originates in Middletown, a borough south of Atlantic Highlands. The creek's watershed is approximately 1.38 square miles, and includes 58% residential land use, 11% deciduous forest, and 9% commercial land use[3]. The commercial land use areas at the mouth of the creek do not have sufficient infiltration and drainage since they were developed during a time without consideration for adequate stormwater management. According to a 2008 study by Weston Solutions, the degradation along the creek's banks "is the result of increases in impervious cover, bank degradation and compaction, sedimentation, nonpoint source (NPS) loading, loss of riparian buffer habitat, and historical fill activities"[4].

Generally, high peak flows in the creek have contributed to its eroded banks and downstream sedimentation. Reducing peak flows and their negative impacts can help improve the riparian habitat overall and reduce the severity of riparian flooding in Atlantic Highlands.

There are three primary strategies to improving the Many Mind Creek Watershed:

1. Reduce erosion by stabilizing stream banks
2. Reduce impact of impervious surface by adding rain gardens
3. Prevent and reverse loss of riparian buffer habitat

[1] Borough of Atlantic Highlands LINK
[2] USACE 2017, p. 1 LINK
[3] USACE 2017, p. 3
[4] USACE 2017 p. 3

Stream banks can be stabilized by reducing the slope of banks, planting riparian edges to reduce erosion, and strategically placing deflectors to encourage more rapid water flow in the center of stream instead of at the edges. These strategies are relatively low cost to implement, but **it is essential to implement throughout the watershed to really see positive effects.** If the Middletown portion of the creek still has eroding banks and excess runoff, the Atlantic Highlands portion will face the negative impacts of the upstream conditions. A large-scale, collaborative and holistic approach is necessary to truly solve the Many Mind Creek issue. This project is rated medium feasibility: the cost is relatively low, implementation is relatively simple, and maintenance is not too burdensome if implemented correctly, but the coordination with Middletown makes the project more challenging.

Additional Resources

- Yochum, Steven E. 2018. Guidance for Stream Restoration. U.S. Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center, Technical Note TN-102.4. Fort Collins, CO. LINK
- North Jersey Resource Conservation & Development. Water Resource Protection: Stream Restoration. LINK

4. Open space as a rainfall runoff solution

In Atlantic Highlands, the shoreline, Many Mind Creek, and Wagner Creek are on the frontlines for coastal and rainfall related flooding as the main areas that collect and overflow with excessive water during flooding events. The prevalence of urban concrete and other impervious surfaces pose human and environmental health concerns with respect to stormwater runoff through increased pollutants (coal and tar), low-lying wastewater discharge backups, and increased mosquito habitat via undrained stagnant water. According to the EPA, a natural ground cover causes only 10% runoff, with 50% infiltration and 40% evapotranspiration. Conversely, impervious cover causes up to 55% runoff, with only 15% infiltration and 30% evapotranspiration. Notably, almost exclusively impervious pavements extend from the commercial district and historic preservation area along Many Mind Creek to the harbor/bay (Figure 6). This section offers insight into additional nature-based solutions to this excessive runoff issue focusing on open spaces.

The goals for rainfall runoff management in Atlantic Highlands using open space are as follow:

- Slow runoff rate
- Increase infiltration of stormwater in the downslope areas
- Improve water quality
- Increase recreational and environmental education opportunities
- Boost biodiversity of native plant species

Figure 6. Impervious pavements extending from the commercial and historic preservation sites along Many Mind Creek to the harbor.

The goals for open space nature-based solutions outlined above focus on planning solutions to managing stormwater and alleviating cascading impacts on health by increasing planned infiltration and drainage to prevent stagnant water accumulation, and improving water quality through soil filtration and plant nutrient uptake. Land and property acquisitions were recommended in the 2015 Getting to Resilience Report (prepared by the Jacques Cousteau National Estuarine Research Reserve) and the 2019 Atlantic Highlands Master Plan to mitigate flooding risk.

Open spaces serve multiple functions and **advantages** such as mitigating effects of climate change (i.e., cooling), managing flood control and stormwater, providing recreational opportunities, and improving aesthetics (Kabisch et al., 2017; Volkan Oral et al., 2020). By increasing the connectivity of open spaces, Atlantic Highlands can magnify its multi-functional purpose. Open spaces are defined as green spaces ranging from small scale residential yards (0.25 acre) to large scale parks (ranging 3-30 acres). In relation to flood control and stormwater management, open spaces are used to decrease runoff rate and increase infiltration of water through soil (Kabisch et al., 2017; Volkan Oral et al., 2020). Open space mechanisms used for

flood control include: increasing the percentage of green spaces at grey areas, diversifying types of green spaces to serve different functions, and preserving current green spaces at multiple scales and various land use types (Green Infrastructure Resources).

The type of open space preserved or created depends on the intensity and purpose of human activities. Hubs of open spaces such as gardens and community parks can be installed at new development or redevelopment, commercial, and industrial sites with active uses. This type of open space is proposed to be implemented at the commercial district along Hennessy Boulevard and residential neighborhoods. In large patches of open space, such as riverfront parks, wetlands are often constructed or preserved close to the natural environment with passive activities. This type of open space is suggested along Many Mind Creek, in the shoreline (along Sutton Walk), and already partially exists along Wagner Creek. Corridors such as trails and greenways act as linkages connecting hubs to the large patches. Atlantic Highlands has already collaborated with Monmouth County's Open Space Plan on maintaining the Henry Hudson Trail and devising a comprehensive plan for a Many Mind Creek Greenway.

Mixed use open space (Case study- The Gowanus Canal)

An advantage of open space solutions is the potential for enhanced recreational spaces. Here, the team presents case studies on this topic that showcase how recreational opportunities align with this mitigation approach. A case study of the Gowanus Canal Sponge Park was done in Brooklyn, NY with the goals of reducing the rate of stormwater runoff, increasing water quality, and marrying recreational and educational opportunities. This project incorporated a waterfront park and wetlands as buffer zones of the Gowanus Canal (Figure 7). The U.S. EPA had put Gowanus Canal on the Superfund National Priority List, enabling the site to access at least $1 million in grant funding to clean the canal for future use. The 11.4 acres was later converted into a waterfront park, with 7.4 acres used for greenways and recreational open space and 3.5 acres dedicated as wetland basins to remediate polluted landscapes and waterways. Phytoremediation, a process in which selected plants metabolize hazardous substances in the contaminated water, was involved. Though plants cannot act as the only method to enhance water quality, they efficiently screen pollutants, preventing further flushes into the waterway. Maintenance on a seasonal basis was recommended, which requires professionals that may need to be outsourced. Lastly, underground storage tanks were built to capture and hold dirty water that was then gradually released. This project parallels potential projects that could be constructed around Many Mind Creek or Wagner Creek. The team acknowledges that there was a wetland project constructed by the USACE at Wagner Creek. Here we are not proposing to construct another wetland, but to implement potential plantings and encourage human-environment interaction possibilities.

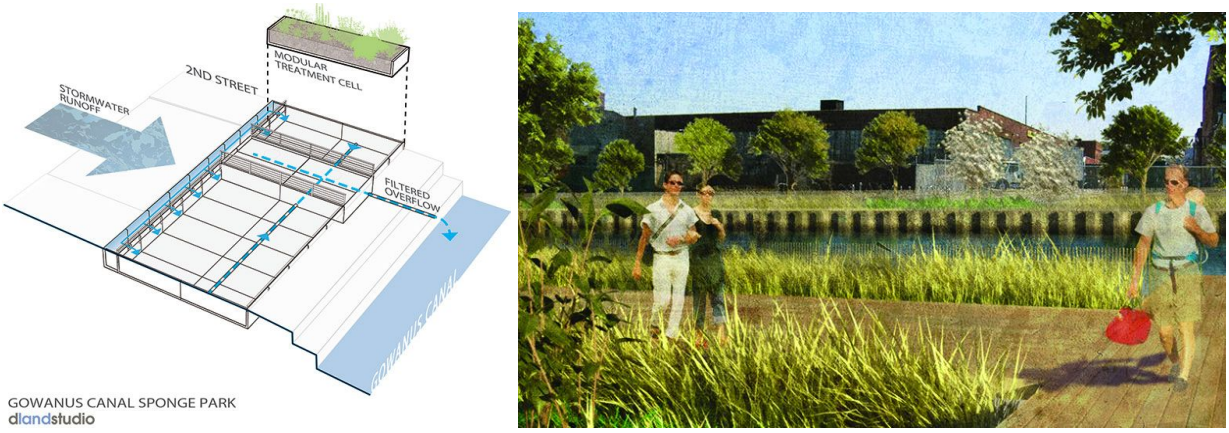

Figure 7. Water treatment (left) and recreational walkway use of riverfront park at Gowanus Canal (right). Source: https://www.asla.org/sustainablelandscapes/gowanus.html

Increased connectivity of open spaces- green roofs (Case study- Washington Mutual Center)
Increased connectivity includes building green roofs on institutional and commercial buildings, installing rain gardens, bioswales, detention ponds along sidewalks and in parking lots. While rain gardens have been mentioned in detail in previous sections, here we focus on the green roof. Buildings along the Many Mind Creek are mostly flat compared to the tilted rooftops of residential housing. This flat topology on roofs makes buildings suitable to install green roofs, or rooftop gardens, on top. A rule of thumb when choosing vegetation is to avoid trees or large brush species so as to prevent damage under strong windy weather or during hurricanes. Also, recreational infrastructure should be light-weighted for roofs to support its weight. Seasonal maintenance of green roof vegetation is recommended while the roof drainage system should be checked twice a year. The Washington Mutual Center Green Roof in Seattle, Washington State is shown below (Figure 8). The vegetation covers two-thirds of the roof, with mainly native and drought resistant plants which require little maintenance. This vegetated area covered with plants and soil absorbs thousands of gallons of rainwater. This reduces pollution to water and saves infrastructure cost by trapping and filtering the water as well as keeping water from entering the sewer system. This space also acts as a social venue for employees to relax and enjoy their lunch, including an outdoor fireplace, a deck, and pathways through the garden. The deck soon became a sightseeing area for employees and visitors.

Figure 8. Recreational use of green roof (left); two-thirds of vegetation planted on the roof (right). Source: https://www.asla.org/sustainablelandscapes/greenroof.html

Additionally, open spaces provide the **advantages** of being aesthetically appealing, reducing urban heat island effect, increasing air quality, and increasing biodiversity. The **challenges** of supporting quality open spaces are maintenance labor, maintenance costs and funding availability. In Atlantic Highlands, recreational activities are mostly directed towards children and the elderly. Open spaces, especially waterfront parks act not only as recreational sites but also as educational venues about the environment. Open spaces also serve as primary stress relief and safe places, as reflected from new reports of the current covid-19 social distancing restrictions. Due to the planning and cost required, as well as the maintenance, green roof projects are considered moderately feasible.

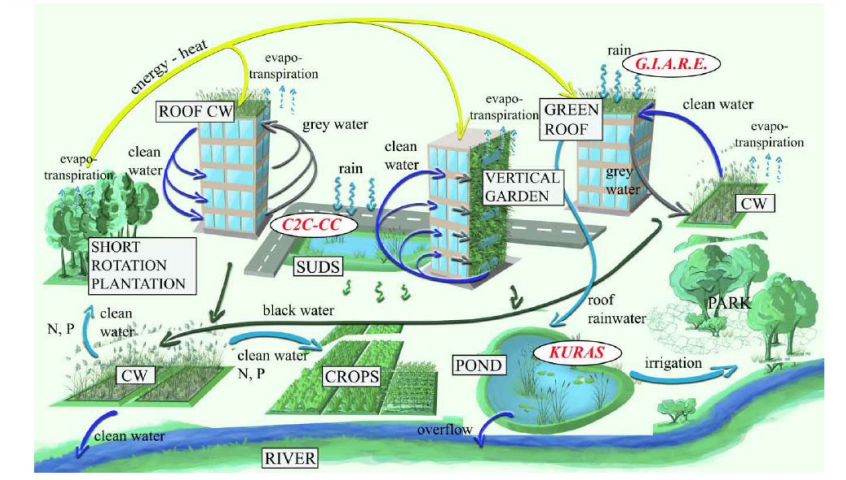

Figure 7 | Advisable scheme of decentralised and integrated, sustainable water management in an urban settlement with the contributions of the case studies C2C-CC, KURAS and G.I.A.R.E. highlighted (SUDS: sustainable drainage systems, CW: constructed wetlands) (adapted from Masi *et al.* 2018).

Figure 9. Advantages created in the urban living environment from the multifunctional nature of open spaces. Source: A review of nature-based solutions for urban water management in European circular cities: a critical assessment based on case studies and literature

Funding options

1. **National Fish and Wildlife Foundation in partnership with NOAA**
   The National Fish and Wildlife Foundation in partnership with NOAA strengthens natural systems that can help communities increase preparedness and improve coastal resiliency. NFWF will award up to $30 million in grants to create, expand and restore natural systems in areas that will both increase protection for communities from coastal storms, sea and lake level changes, flooding, and coastal erosion and improve valuable habitats for fish and wildlife species.
2. **United States Fish & Wildlife Service's Coastal Program**
   The United States Fish & Wildlife Service's Coastal Program utilizes tax revenue from hunting, boating, and fishing. A primary goal of the program is centered on seeking to help mitigate flooding and increase water quality. USFWS recently awarded nearly $19 million to 22 projects in 13 coastal states to protect, restore or enhance more than 30,000 acres of coastal wetlands and adjacent upland habitats under the National Coastal Wetlands Conservation Grant Program.
3. **New Jersey Water Resources Research Institute (NJWRRI)**
   NJWRRI offers grants primarily to academic researchers to study water related issues in New Jersey. Possible collaboration opportunities exist with the Haskin Shellfish Research Lab (affiliated with Rutgers University) to study water quality enhancement provided by bivalves in Atlantic Highlands' coastal waters. Check the NJWRRI website here (**https://njwrri.rutgers.edu/njwrri_funding.htm**) periodically for funding updates.
4. **New Jersey Department of Environmental Protection Water Quality Restoration Grants**
   NJ DEP offers grants to "reduce water quality impairment through implementation of nonpoint source (NPS) pollution control projects." Natural infrastructure solutions for Many Mind Creek would be eligible for this grant. A previous grant recipient used funds to stabilize streambank erosion and plant a 35-foot forested buffer on either side of a wetland of the Middlebrush Brook tributary in northern New Jersey.
5. **New Jersey Urban and Community Forestry Program Stewardship Grant**
   With their existing Community Forestry Management Plan (CFMP), Atlantic Highlands is eligible for grant opportunities through the NJ Forest Service specifically for resilience planning through the NJ Urban & Community Forestry (NJUCF) Stewardship Grant. The NJUCF Stewardship Grants are $10,000-$30,000, and provide funding for projects such as tree risk assessments, storm assessments, and tree planting/ reforestation. Information for the NJUCF Stewardship Grant information can be found here.

6. **Conserve Wildlife Matching Grant Program**
   With funding from the Conserve Wildlife License Plate renewal fund, the NJDEP Division of Fish and Wildlife's Endangered and Nongame Species Program (ENSP) offers small matching grants for one-year projects that advance endangered, threatened, and nongame wildlife conservation and education. Approved projects are funded on a reimbursement basis and must be located in New Jersey. Grants are awarded every other year. To be added to their notification list, please e-mail MacKenzie.Hall@dep.nj.gov.
7. **The Monmouth County Municipal Open Space Grant Program**
   Note: Atlantic Highlands had successfully applied for this grant previously, and is now waiting for its 2020 application approval.
   The Monmouth County Municipal Open Space Grant Program was authorized by the Monmouth County Board of Chosen Freeholders in 2003. Since then, an allocation of a $2 million fund has been granted every year to selected areas. The goal is to assist municipalities on local land acquisition to create and preserve open spaces under recreation and conservation purposes. The projects approved by the grant were to enhance daily recreation needs of local residents. Types of projects include but are not limited to: open space acquisition, indoor recreation, development or redevelopment of recreation, historic preservation, conservation resources, and cooperative projects, etc. For example, selected projects in 2019 include recreational infrastructure aspects: boardwalk improvements at Bradley Beach and coast trail extension in Township of Howell. The project can also be proposed into phases. **Effort involved:** Local government must have a Green Acres-approved Open Space and Recreation Plan (OSRP) as well as an open space tax to apply for the Monmouth County Municipal Open Space Grant Program. Efforts of local government include: engaging environmental consultants to create a Preliminary Assessment and Site Inspection (PASI) before grants agreement. After being selected by the Monmouth County Board of Chosen Freeholders, the project has to be implemented within a 30-month timeframe. Starting from 2019, plans have to include a regional analysis when applying. Atlantic Highlands is eligible to apply. Atlantic Highlands participated in a 5-year program in 200 that is similar to the Monmouth County Municipal Open Space Grant Program.
   Additional information: Grants are allocated as 50% covered by Monmouth County and 50% spent by the municipality. Grants are allocated at a regional scale. Monmouth County is divided into 9 regions, Bayshore, Northern, Southern, Western, Panhandle, Coastal North, Coastal North Central, Coastal South Central, Coastal South. Atlantic Highlands is in the Bayshore region, which is a prioritized region for grant allocation. This can be understood through the following quote in Monmouth county's Open Space Plan "the Bayshore, and all of the Coastal Monmouth regions meet and exceed the benchmarks for municipal open space for recreation set forth using both the Balance Land Use Calculation and the per population calculation."

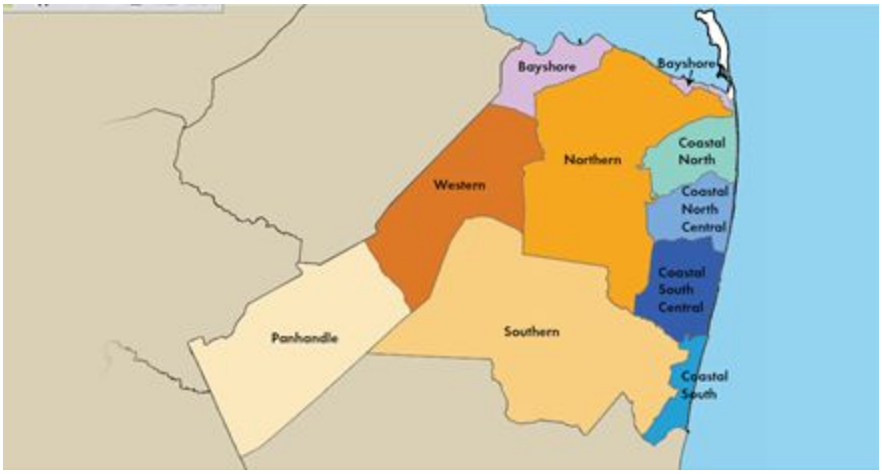

Figure A1. 9 regions in Monmouth County

Source: Monmouth County Open Space Plan

Appendix A. Project priorities

Figure A1. Matrix of priorities organized by impact and feasibility. Note: all included projects have been recommended because they are feasible and important to Atlantic Highlands' resilience, and therefore this organization is working within that context (i.e., even the smallest impact or least feasible projects per this graphic are still impactful, but perhaps less urgent, and moderately feasible due to cost and coordination required). The black icons show where each project can be applied.

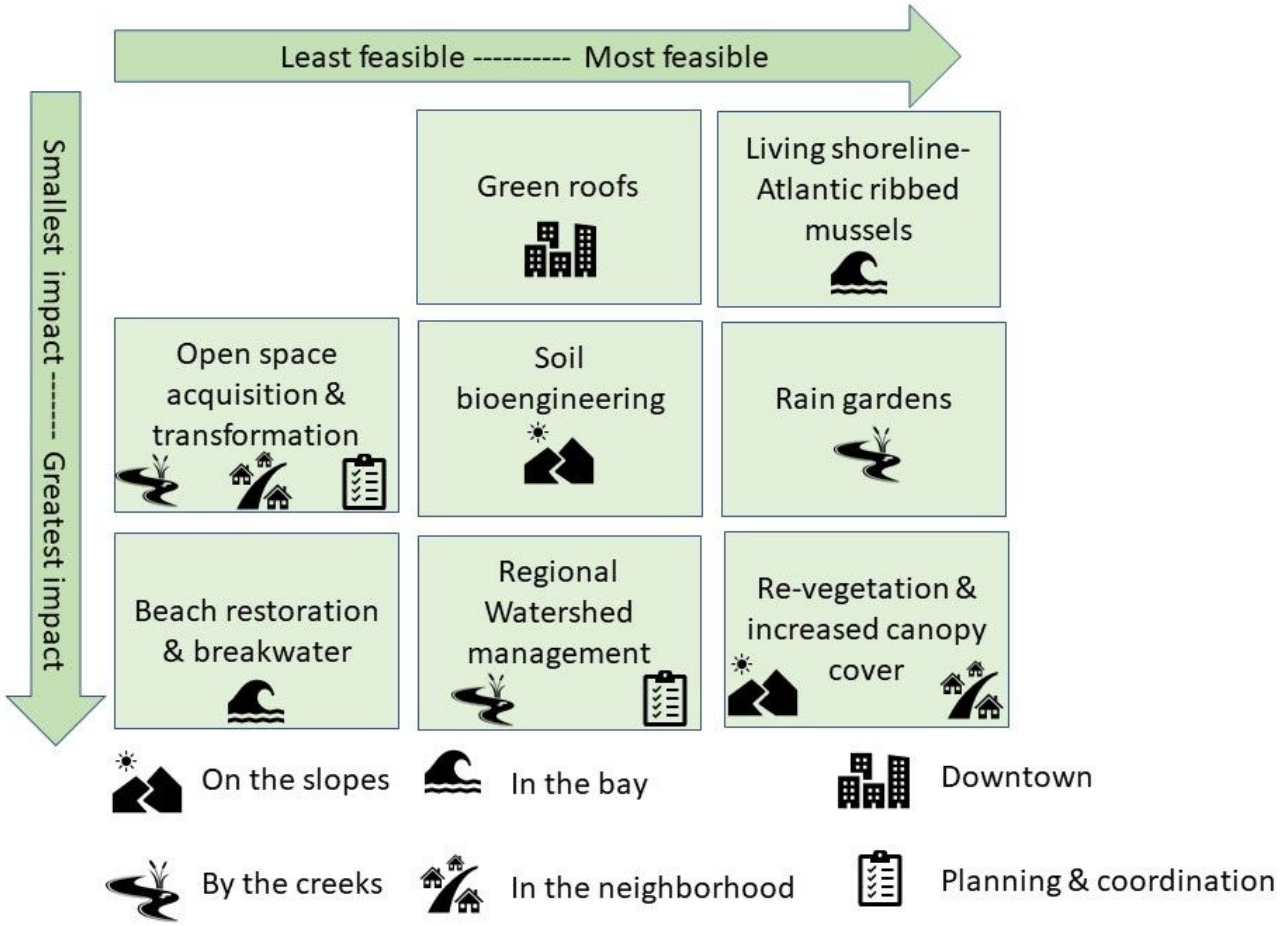

Table A1. Summary of project recommendations and statuses.

Project	Recommended in	Project status
Many Mind Creek beach restoration & Henry Hudson Trail shoreline protection	2015 Getting to Resilience; 2019 Raritan/Sandy Hook Bay Coastal Resilience Planning Study	Preliminary assessments performed
Atlantic ribbed mussel planting-living shoreline	2020 Rutgers Studio Nature-Based Solutions Report	N/A
Conventional re-vegetation of steep sloped areas	2014 TRC Geotechnical Engineering Report; 2017 USGS Study	Not started
Live fascine installation	2020 Rutgers Studio Nature-Based Solutions Report	N/A
Rain garden installation	2020 Rutgers Studio Nature-Based Solutions Report	N/A
Increased canopy cover in downslope areas	2020 Rutgers Studio Nature-Based Solutions Report	Ongoing via Shade Tree Commission
Many Mind Creek regional watershed management	2008 Weston Solutions Many Mind Creek Restoration Plan; 2017 USACE Many Mind Creek Planning Assistance to States Report	Not started
Open space acquisition	2015 Getting to Resilience; 2019 Atlantic Highlands Master Plan	Discussions underway with respect to McConnell Tract; Preliminary planning of Many Mind Creek Greenway
Green roofs to expand open spaces downtown	2020 Rutgers Studio Nature-Based Solutions Report	N/A

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