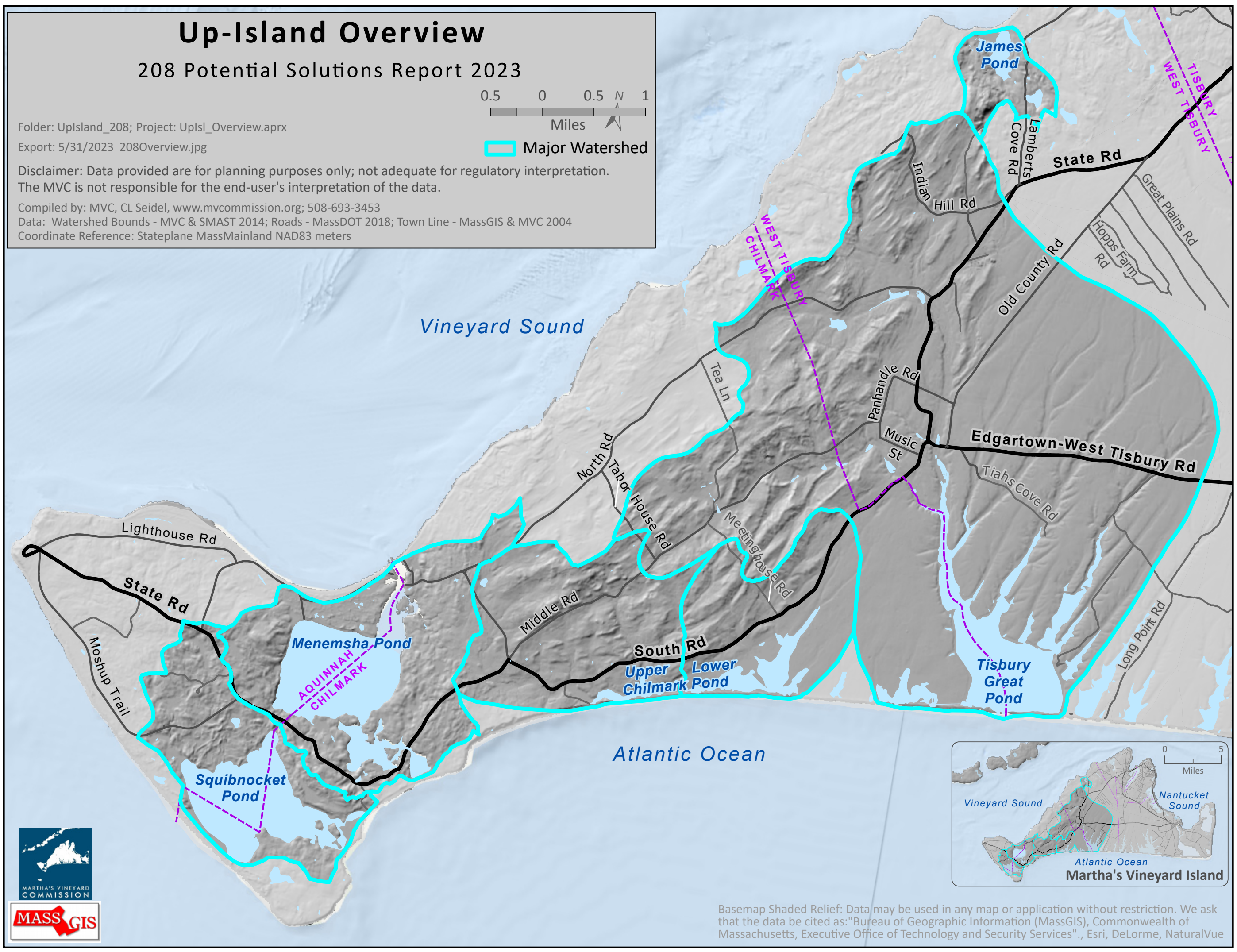
POTENTIAL SOLUTIONS

UP-ISLAND WATERSHED MANAGEMENT PLAN (208 EQUIVALENCY REPORT)



UP-ISLAND WATERSHED MAP. MARTHA'S VINEYARD COMMISSION. JUNE 2023

June 2023

Martha's Vineyard Commission

RJS Development Solutions

Wright-Pierce

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MassDEP

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RELEASE NOTES

Potential Solutions

The "Potential Solutions" chapter, presented here, represents Act II of the Up-Island Management Plan (208 Report) project. This chapter identifies and describes a variety of technologies and approaches for mitigating impaired waters and habitats.

In this chapter, the Martha's Vineyard Commission presents a "menu" of potential solutions to be considered by town administrators, stakeholders, and community members as they approach management strategies for impaired watersheds and their habitats. In addition to technology and/or approach descriptions, we include brief summaries of the advantages and disadvantages associated with each option as well as additional evaluation criteria that decision makers may review as they develop nitrogen mitigation and water quality improvement strategies to restore Up-Island ponds.

Act III will focus quantifying the estimated impact of each technology/approach and how employing the technology/approach contributes to achieving established nitrogen Total Maximum Daily Loads (TMDL) in each watershed. As stated in previous sections of the report the final act will result in a management plan recommendations for how to clean our up-island ponds. Each technology/approach process will be articulated alongside permitting requirements, cost/benefit analyses, and potential funding sources for each option.

For reference to the Individual System Assessments for all five Up-Island watersheds (Chilmark Pond, James Pond, Menemsha Pond, Squibnocket Pond, and Tisbury Great Pond) please find links on the following page.

Up-Island Watershed Management (208 Report) "Acts"

- **Act I – Individual System Assessment (see links below)**
- **Act II – Water quality mitigation technology and options**
- **Act III – Quantification of most appropriate technology for each unique challenge**
- **Act IV – Implementation strategies**

This report was developed by MVC staff, an independent contractor from RJS Development Solutions, and the environmental consulting firm Wright-Pierce. The draft was extensively peer reviewed by a variety of experts prior to release. We look forward to sharing the Acts II and IV with you. If you have questions or comments, please direct them to: Rachel Sorrentino or Sheri Caseau.

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Up-Island Watershed Management Plan (208 Report) Important Links

Chilmark Pond Individual System Assessment Report:
https://bit.ly/208chilmarkreport

James Pond Individual System Assessment Report:
https://bit.ly/208jamesreport

Menemsha Pond Individual System Assessment Report:
https://bit.ly/208menemshareport

Squibnocket Pond Individual System Assessment Report:
https://bit.ly/208squibnocketreport

Tisbury Great Pond Individual System Assessment Report:
https://bit.ly/208tisburygreatreport

INTRODUCTION

The up-island watersheds and ponds on Martha's Vineyard have all experienced some level of degraded coastal water quality due to nutrient loading. This section of the Up-Island Watershed Management Plan (208 Equivalency Report) has been prepared to provide a "toolbox" of nutrient management approaches intended to support town administrators and stakeholders in their work to reduce, remediate and restore watersheds and their coastal estuary systems.

Martha's Vineyard is home to six towns; three of these towns (Aquinnah, Chilmark, and West Tisbury) are collectively referred to as "Up-Island" towns. These three towns are differentiated from other areas on the island, in part, due to their rural nature. The relatively sparse development setting of these three towns requires water resource planning solutions that are unique from the more densely populated towns on the island. As described in the Existing Conditions documents for each of the five main up-island watersheds, the character and needs of each watershed are different from one another, and in some cases, the physical characteristics of the ponds vary within the same estuary system.

Without question, there is no single "magic bullet" for addressing excess nitrogen in our watersheds. Furthermore, watersheds are complex areas that include freshwater streams, wetlands and upstream ponds that impact estuary water. To manage all elements of the watershed, a comprehensive set of nitrogen control options must include methods to control both current and future loads. In the following sections of this document, you will find several management technologies and approaches along with descriptive information and basic evaluative criteria for nitrogen and phosphorus management. In addition to information offered for these categories, the last section of this document offers a brief discussion of additional evaluation criteria to be considered during the decision-making process.

POTENTIAL SOLUTIONS

TECHNOLOGIES & APPROACHES

Many Southeastern Massachusetts embayments suffer from a variety of pollutants and excess nutrients in their watersheds. While there is reason to have concern about a wide range of pollutants impacting our watersheds, for coastal estuary systems with brackish water, nitrogen is most often targeted for management. For estuary systems with compromised water quality, existing nitrogen loads must be reduced. But equally important is the control of future nitrogen loads. While water quality in a typical embayment might be restored by removing 40% of existing nitrogen loads (through remediation or restoration efforts), these actions must be accompanied by removing or preventing 100% of future loads (reduction technology/approach).

Up-island, most of the excess controllable nitrogen originates from onsite wastewater treatment systems (see existing conditions links for watershed specific sources of nitrogen) . In a typical up-island watershed where homes and businesses are served by onsite Title V septic systems, nitrogen originating from septic systems range from 40% - 81% of controllable nitrogen loads .

Up-island, controllable nitrogen sources include:

- Wastewater disposal (onsite septic systems)
- Fertilized lawns and gardens
- Agriculture
- Runoff from impervious surfaces (stormwater)

This section of the Watershed Management Report identifies 11 potential technologies/approaches that address excess nitrogen in up-island watersheds, our “toolbox”. This list of tools has been compiled based on watershed Best Management Practices and with the conditions unique to each up-island watershed in mind. Where applicable, this section includes examples of the options that have been implemented on Martha’s Vineyard and some locations on Cape Cod. The Cape Cod Commission has created an excellent resource for many of the technologies/approaches included in this report. The Martha’s Vineyard Commission (MVC) is grateful for the Cape Cod Commission’s support and their permission to use information it has made public regarding descriptions, advantages and disadvantages associated with these technologies. For detailed information provided by the Cape Cod Commission, please see: https://www.capecodcommission.org/our-work/technologies-matrix/.

In general, the most effective approaches for managing excess nitrogen specifically address a source or location of nitrogen loading. For example, an onsite wastewater treatment system prevents some of the household nitrogen load from reaching the groundwater. A Permeable Reactive Barrier (PRB) does not address nitrogen at its source, instead it removes some of the nitrogen in groundwater as it flows toward the receiving water. Likewise, shellfish harvesting does not address nitrogen at its source or in the groundwater but can remove some nitrogen from the receiving water column within the embayment. Therefore, when evaluating management opportunities, one can begin by addressing:

- Nitrogen loading at its source (most often onsite wastewater systems) - source **reduction** techniques/ approaches,
- Nitrogen loading that has reached the groundwater – groundwater **remediation**, or
- Nitrogen existing within the receiving water – watershed/ waterbody **restoration**.

In the following pages, you will find technology/approach descriptions, advantages, and disadvantages. Where possible, the type of technology (reduction, remediation, or restoration) has been noted.

Finally, each technology/approach described below is subject to various levels of risk associated with climate change. Among those discussed in this report, several technologies/ approaches could be associated with risks depending on the physical characteristics of their locations. Risk assessments must be analyzed in terms of the proposed location for a particular approach or technology and how that approach or technology may experience performance challenges associated with climate change conditions. For example, exposure to saltwater from floods or sea level rise could damage wastewater treatment equipment or cause plants in a “rain garden” that do not tolerate brackish water to expire. In each case, technologies and/or approaches adopted for nitrogen reduction, remediation or restoration must be designed and located to minimize risks from potential sea-level rise, flooding, or drought conditions.

Management Technology and Approach Categories

- Land preservation
- Growth control
- Fertilizer management
- Management of agricultural practices
- Stormwater management
- Individual onsite wastewater treatment systems
- Public sewers and package facility systems
- Permeable reactive barriers
- Aquaculture
- Habitat alteration and restoration
- Green infrastructure

Cape Cod Commission. Technology Matrix (2020).
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Accessed June 20, 20203

Land Preservation Approaches

Increased Conservation Land

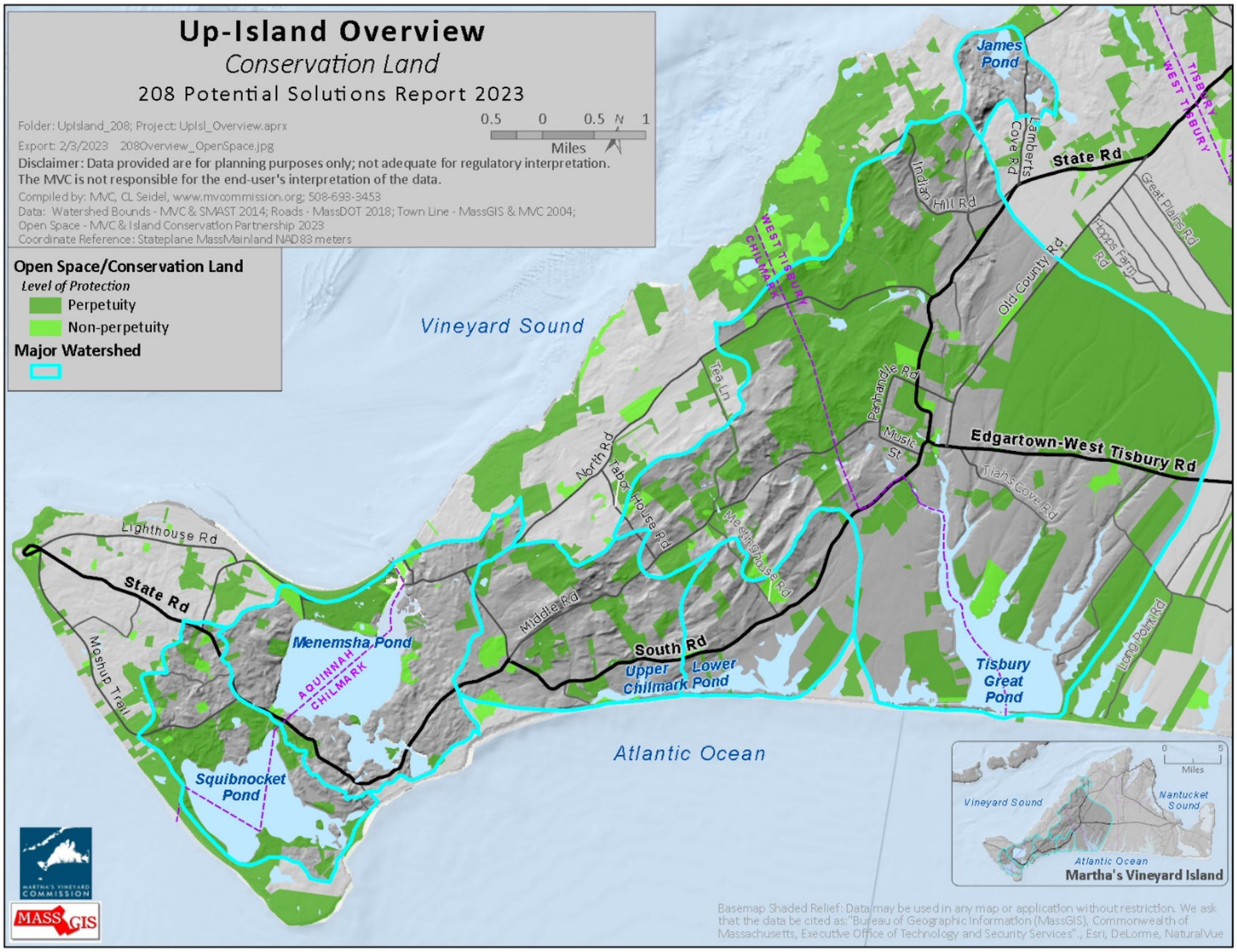
When undeveloped land is set aside for open space use, historic preservation, or protection of natural habitat, future nitrogen loads that could result from residential, commercial, or agricultural use of undeveloped land is avoided. Land preservation has occurred for many decades in the Commonwealth, and the steps necessary to set aside land are well documented. Although current nitrogen loads are not addressed, land preservation can be a useful tool for limiting future loads. Martha's Vineyard is home to several well-established conservation organizations that work to preserve land.

The principal benefit of land preservation is the nearly complete elimination of future nitrogen loads from protected parcels. Even when some development is allowed on the parcel, such as recreational fields, the prevention of future septic loads is significant. Although the cost of preserving land is high, this is a nitrogen management approach that carries little or no ongoing operational expense. Grants and donations can offset the land cost, and landowners may be motivated to support historic preservation and habitat protection with nitrogen avoidance as a secondary benefit. This option is considered a "reduction approach" and ranks highly for avoidance of environmental impact, public acceptability, and climate resiliency.

Martha's Vineyard Conservation Groups

- Martha's Vineyard Land Bank (https://www.mvlandbank.com/)
- Sheriff's Meadow Foundation (https://sheriffsmeadow.org/)
- The Trustees (https://thetrustees.org/)
- Vineyard Conservation Society (https://vineyardconservation.org/)
- Vineyard Open Land Foundation (https://vineyardopenlandfoundation.org/mission.html)

Up-Island Conservation Land



Up-Island Conservation Land Map. Martha's Vineyard Commission. June 2023

*Note: Levels of protection for Open Space/Conservation land depicted on this map reference two categories of land protection.

- Perpetuity -- Legally protected in perpetuity and recorded as such in a deed or other official document. This land cannot be developed in the future.
- Non-Perpetuity – Land that is protected for less than perpetuity. These lands have a potential possibility to be developed at some time in the future.

Transferring Development Rights

Transferring development rights refers to a regulatory strategy that shifts development rights from one property (sending area) to another (receiving area) in order to direct growth and associated nutrient loading away from sensitive watersheds or water bodies. The primary requirement of this strategy is that a separate, undeveloped property outside the sending area watershed is available for deed restriction to ensure that no additional development occurs within the sensitive watershed in the future.

Transferring development rights is an approach that requires complex administrative structures, and it can present significant costly and time-consuming challenges. Unlike growth control regulations, which are discussed in the following section, transferring development rights requires establishing a marketplace for "nitrogen credits," extensive valuations and long-term administrative oversight. This is a source reduction approach.

Advantages:

- Shifts nitrogen loads away from more environmentally sensitive areas.

Disadvantages:

- In order to establish this policy, administrators must develop a commodity marketplace and a valuation system that allows for transferred rights that are associated with financial and/or regulatory incentive to transfer development potential from one location to another.
- May require adopting zoning bylaw amendments that authorize landowners to transfer development rights. Availability of receiving areas, watersheds without excessive nitrogen levels, may be limited. Furthermore, to establish that an area is capable of receiving nitrogen loads offset from sensitive areas, MassDEP modeling may be required to demonstrate hydrodynamics and attenuation capabilities of receiving areas.

Growth Control Regulation Approaches

Put simply, this approach is intended to control growth in a way that reduces future nitrogen loads associated with buildout. In this case, watershed nitrogen loads are managed through targeted regulatory measures in which communities elect to limit new nitrogen loads by restricting the amount of nitrogen-creating development growth permitted on certain parcels. Like land preservation, this basic approach has no impact on existing nitrogen loads, instead, this approach limits nitrogen originating from future development.

Zoning policies that stipulate minimum lot sizes in residential settings are also considered growth control regulations; these policies can be found in all three up-island towns. By introducing minimum lot size zoning, the expectation is that there will be fewer residential developments and therefore a lower concentration of onsite septic systems, reduced lawn and garden fertilization, and less stormwater runoff. West Tisbury and Chilmark have designated a 3-acre minimum lot size for most residential/ agricultural zoned lots; Aquinnah has designated a 2-acre lot size. Other, more draconian examples of growth control policies could be temporary or permanent growth moratoriums.

"Offset" policies are formal restrictions that focus on shifting the impact of nitrogen loads from one area of a watershed to another, within the same watershed. "Offsets" limit future nitrogen loads when developers use them to limit the overall impact of watershed nitrogen loads associated with new developments by preventing the development of potential loads elsewhere in the watershed. This policy would require the owner of a new residential development to place another comparable parcel located within the same watershed into conservation (or other permanent legal restriction). One example would be if a town grants a nitrogen "offset" for one residential parcel and requires a public use facility like a playground to be built on another comparable parcel. It is also possible for a community to ask for an offset that is larger than the new load, thus affecting some net removal of future capacity.

The Martha's Vineyard Commission has nitrogen offset policies that apply to Developments of Regional Impact (DRIs); The MVC Water Quality Policy states that offsets may be achieved by either permanently reducing nitrogen at an alternate site within the same watershed or diverting wastewater from another parcel within the watershed to a sewer system . The "offset" policy has been applied in the Tisbury Tashmoo Watershed.

Another example of a growth control policy is MassDEP's practice regarding residential or commercial developments which process more than 10,000 gallons of wastewater per day , . This practice suggests that a nitrogen load offset equal to “new” nitrogen from developments be diverted from groundwater and/or sent to an equivalent wastewater treatment facility serving that development. Applying this nitrogen offset approach to smaller developments (that is, those below the thresholds for groundwater discharge permits or DRIs) can broaden the benefits.

The principal advantages of growth control regulations are low management costs and the potential for managing growth control regulations with existing administrative processes. Once regulations are in place, there are no costs to the community and no ongoing operational costs. However, new limitations on growth can represent a cost to landowners in terms of changed land value.

Advantages:

- Limits development potential along with associated nitrogen loading.

Disadvantages:

- Impact is dependent on the type of wastewater system in use and the number of individuals utilizing the parcel.
- Clear documentation must be put in place to ensure that conserved land (land protected from development) is not viewed as potential source of nitrogen “credits” for future development projects.

Fertilizer Management Approaches

NON-AGRICULTURAL FERTILIZER

Chemical or organic fertilizers are most commonly formulated using a combination of nitrogen, phosphorus, and potassium. Unlike soil amendments (e.g., compost) the primary purpose of fertilizer is to deliver nutrients to plants. Fertilizer application to lawns, gardens, and open space can result in nitrogen leaching into the groundwater, particularly if fertilizer application is not controlled with respect to the amount applied and growing season timing.

Understanding the potential impact of fertilizer use on water quality, all six Martha’s Vineyard towns adopted the District of Critical Planning Concern (DCPC) Martha’s Vineyard Lawn Fertilizer Control District in 2014. The intent of the agreement is to manage the quantity and timing of fertilizer application to reduce fertilizer impact on island watersheds. For more information about the Lawn Fertilizer Control District DCPC see: https://www.mvcommission.org/sites/default/files/docs/DCPC%20Decision%20M%20V%20Lawn%20Fertilizer%20Control.pdf. By implementing fertilizer control bylaws and regulations, towns reduced their fertilizer load from residential lawns and gardens. While residential watershed fertilizer loads often represent less than 10% of the total watershed nitrogen loads up-island, residential loading rates could be further reduced. A similar, yet more comprehensive measure has been proposed by the towns of Nantucket, Orleans, and Harwich, in which complete bans on non-agricultural fertilizer use have been proposed.

Public outreach and education programs that promote "Vineyard Lawns," advocating for replacing turf areas with native vegetation, and establishing and maintaining vegetated buffer strips on waterfront lots are additional ways to minimize the impact of fertilizer application on watershed nitrogen loads and are often required by Conservation Commissions. This option has the principal benefit of being a low cost, general public acceptability, and low environmental impact. This is a source reduction approach.

Advantages:

- Minimal implementation cost.
- Reduced fertilizer costs to homeowners/landowners due to reduced use.

Disadvantages:

- Resulting nutrient removal rates are highly dependent on homeowner/landowner behavior and participation in the program.
- Site-specific assessments are needed to estimate load reductions.
- The burden of enforcing fertilizer bans falls on towns, who must ensure that fertilizer is not being provided from outside sources.

Mark Lovewell. *Water quality protection is the rationale behind Islandwide plan to control fertilizer use. (2014). Martha's Vineyard Gazette.* [https://vineyardgazette.com/sites/default/files/styles/medium/public/article-assets/main-photos/2015/aof_fertilizer_farm_neck.jpg?itok=Q1Rartyi] Accessed June 20, 2023.

COMPOSTING

Compost is decomposed organic material that can be used as a soil amendment, one that often contains nutrients that contribute to plant growth. However, unlike fertilizer, the addition of organic material found in compost can improve water and nutrient retention in soil. In addition to reducing potential for soil erosion, compost can also reduce the need for chemical or organic fertilizers that impact watershed nitrogen loads.

Composting is a process in which biodegradable material is decomposed by aerobic microorganisms in a controlled environment. The heat generated in composting pasteurizes the product, significantly reducing pathogens. The heat generated also drives off water vapor, further de-watering the product and reducing volume. Composting that is performed according to regulatory guidelines produces Class A Biosolids. Composting that is performed properly produces a nuisance-free humus like material. The three different methods of composting typically used are aerated static pile, windrow, and in-vessel composting. The desired temperature required for optimal operation and end quality vary based on the method of composting and desired use of the end product. After the "active composting" period is complete, the material is cured and distributed.

Brittany Bowker. *400 yards of "black gold." (2019). Creating a compost culture.* MVTimes.com. *[*https://www.mvtimes.com/mvt/uploads/2019/04/BB_Thimble-Farm_Composting_04.jpg*]* Accessed June 16, 2023.

One can find examples of residential, commercial, and agricultural composting on Martha's Vineyard. The Island Grown Initiative (https://www.igimv.org/) manages a 45' in-vessel composter to process food waste that is sourced from local restaurants, farms, and other food establishments. Composting programs are also in place at several local businesses that process landscaping and some types of agricultural waste materials that originate from multiple watersheds island wide.

The impact of residential composting on estuary water quality is unclear. However, there is potential for commercial and agricultural compost processors to contribute to nitrogen loads if run-off from large operations is not effectively managed. Commercial and agricultural composters often process large quantities of organic material, as a result, there is potential for nutrient runoff at the process locations. Furthermore, material from multiple watersheds could be collected and processed at one commercial facility, in these cases, nitrogen loads from multiple watersheds is deposited in the groundwater of the watershed in which the compost processing facility is located. Therefore, watershed management policies could benefit from recommending that all commercial and agricultural composters utilize Best Management Practices in their operations. These practices include mechanisms that capture nutrient-rich runoff to ensure that the nutrients discharged from the compost piles do not infiltrate groundwater.

Advantages:

- Composted material contributes to soil health and water retention.
- Potential income source for commercial producers.
- Produces a Class A product that is more marketable than other types of biosolids.
- Generally simple process that is relatively easy to operate and maintain.
- Well proven technology.
- Minor regulatory requirements.

Disadvantages:

- Relatively high operations and management cost.
- Many systems are labor intensive.
- Market study needed to ensure reliance on demand for end product.
- Runoff from the composting location must be diverted from direct infiltration into groundwater.
- Winter months impact distribution and marketing, wintertime storage is typically required.
- Potential for odors and vermin that requires careful management.

Management of Agricultural Practices Approaches

Some agricultural practices can have a high potential for nitrogen loading to the groundwater and, in some cases, may have high potential for increasing stormwater nitrogen loads. Good agricultural practices that also reduce nitrogen loading should not impose undue costs on farmers, and Best Management Practices for guidance are well defined in this field, particularly those related to manure storage and application.

Agricultural fertilizer application rates, storage volumes and timing of application are important aspects of most farming practices. Guidelines for agricultural use of fertilizers are outlined by the Natural Resource Conservation Service. Although many Martha's Vineyard commercial farmers do not rely heavily on synthetic fertilizers, the Massachusetts Department of Agricultural Resources regulates the type of products used by farmers as well as application rates and procedures. Additionally, the United States Environmental Protection Agency (EPA) regulates agricultural fertilizer use.

Farm generated nutrients are a valuable resource and should be managed to minimize their loss to the groundwater. On farm composting is an important way to better utilize crop and animal waste as a source of nutrients and increase soil organic matter. However, if improperly managed, at scale farm generated nutrients can become a concentrated source of substantial nutrient loading to the groundwater. Large compost piles should be situated on an impervious

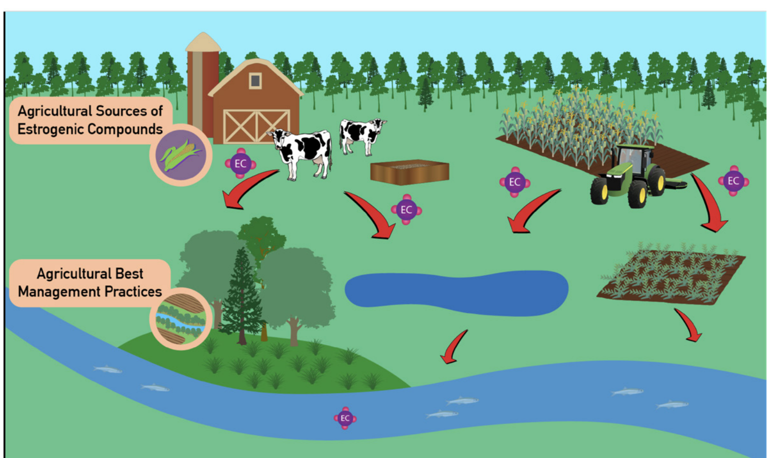


Figure 1. Agricultural sources of estrogenically active compounds typically include animal waste and pesticides. These compounds can be reduced by using agricultural Best Management Practices (BMPs) such as riparian buffers retention ponds

Chesapeake Bay Best Management Practices Conceptual Diagram. 2022. [https://www.usgs.gov/media/images/chesapeake-bay-best-management-practices-conceptual-diagram].
Accessed June 20, 20203

surface with runoff captured and distributed appropriately or directed into a vegetated filter strip where nutrients can be incorporated into the vegetation. On farm animal waste piles can also leach nutrients and should be managed in a similar fashion.

Martha's Vineyard farmers are encouraged to adhere to Best Management Practices for agricultural fertilizer to ensure that nutrient and livestock management limit impact on the environment and water quality. These practices include: analyzing soil before planting and side-dressing crops to determine appropriate application rates and locations, incorporating organic matter like compost or biochar materials to improve nutrient and water retention, no-till field management, practicing rotational livestock grazing areas and stocking rates prescribed by the USDA Natural Resource Conservation Service (NRCS) farm plan, establishing permanent vegetated buffers, grass filter strips or swales to separate farm fields from wetlands, and minimizing leachate from manure storage areas. Finally, the addition of nitrogen fixing legumes in both hay and pasture plantings will allow near zero synthetic nitrogen application to those fields. Managing agricultural practices is considered a nitrogen reduction approach.

Advantages:

- The principal advantages of this option are low cost to the community and well-established Best Management Practices in the industry.

Disadvantages:

- Like fertilizer controls, nitrogen load reductions are difficult to measure, so expected removal information is limited to estimations only. Estimate-based measurements present a challenge for predicting and quantifying nitrogen removal.

Stormwater Management Approaches and Technologies

Runoff from impervious surfaces contains nitrogen at the same concentration as rainfall, which in New England is attributed to upwind air pollution sources. Runoff from any impervious surface, including rooftops, paved parking areas and roadways carries nitrogen to groundwater. It is estimated that runoff from these impervious surfaces may be responsible for 10% to 15% of the total watershed nitrogen load . Estimates are based on EPA studies and do not reflect local environmental conditions. Despite this, it is clear that runoff from impervious surfaces contains nitrogen as well as a variety of other pollutants including those from vehicles, soil-based pollutants, and animal waste. Best management practices (BMPs) and strategies are well developed for controlling runoff volume and the nitrogen and phosphorus in runoff.

The Cape Cod Commission has suggested that an effective stormwater management program could reduce stormwater nitrogen loads by 25%. However, recent studies in the Pleasant Bay watershed have shown that while many stormwater BMPs are effective in routing runoff nitrogen to groundwater (through infiltration), pollutants in groundwater are still deposited into the embayment, therefore, the realistic estimates of net removal from diverted stormwater may be smaller. Most of the nitrogen removal from stormwater BMPs occur through vegetative uptake, so vegetated approaches are most effective, provided they are adequately maintained.

Stormwater Solutions for Homeowners Fact Sheet: Swale with stone base. (2023). Massachusetts Office of Coastal Management (CZM). *[*https://www.mass.gov/doc/stormwater-solutions-for-homeowners-fact-sheet-vegetated-swales/download*]* Accessed June 16, 2023.

Mitigation measures using Best Management Practices (BMPs) approaches can be installed on town runoff sources (such as roadways and parking lots) and can also be mandated for all new development. Because it is difficult to measure nitrogen removal via stormwater management, performance curves must be employed to estimate removal. Documentation of stormwater removals that cannot be field monitored and rely on estimated values cannot be awarded formal Watershed Permit credits. Implementing stormwater BMPs may not be cost-effective for nitrogen removal alone, yet one reason to implement stormwater BMPs is their effectiveness for removing a range of pollutants in addition to nitrogen.

It is important to note that Best Management Practices for stormwater may become more valuable if frequent heavy rainfalls associated with climate change increase. It is also important to note that care must be taken to ensure the chosen stormwater systems are climate-resilient because stormwater BMP systems are typically located in low-lying areas subject to flooding.

One example of stormwater mitigation in a low-lying area can be found in the rain garden installed and maintained by Tisbury Waterways Inc in the town of Tisbury. This rain garden, updated in 2022, mitigates stormwater at the end of Owen Little Way. Also, in 2018, Friends of Sunset Lake installed a stormwater system and a walkway surrounding Sunset Lake in Oak Bluffs. Another project of note is the partnership between the Town of Tisbury, MVC and the University of New Hampshire (UNH) Stormwater Center to mitigate stormwater at the "Five Corners" intersection in Vineyard Haven and at the end of Grove Avenue in Tisbury. The UNH partnership is funded through a 5-year watershed grant from EPA. Each of these projects demonstrate catchment systems that are applicable for comparable sites around the island.

STORMWATER BMP – PHYTOBUFFER

This approach is a stormwater treatment mechanism that relies on a buffer that is at least 35 feet wide and includes plants to remove nutrients and other contaminants. Fast growing vegetation including trees, shrubberies and/or grass are typically required.

Advantages:

- Potentially a good strategy for areas where more runoff is generated during the summer (plant growing season).

Disadvantages:

- For tree systems, it takes several years before plants are mature enough to uptake the maximum number of gallons per day.

STORMWATER BMP – VEGETATIVE SWALE

Vegetated swales, such as a grassed channel, dry swale, wet swale or biofilter, are open channels used to convey stormwater runoff. Vegetated swales typically do not reach pond water for a long period of time and induce infiltration. These swales typically have a trapezoidal or parabolic shape with relatively flat side slopes. The width of the swale will be dependent, in part, on the slope and soil type of the surrounding area.

Individual vegetated swales generally treat small drainage areas (five acres or less).

Advantages:

- Very easily scalable.

Disadvantages:

- Requires the creation and enforcement of stormwater regulations and policies.

Stormwater Solutions for Homeowners Fact Sheet: Vegetated Swales. *(2023). Massachusetts Office of Coastal Management (CZM). [*https://www.mass.gov/doc/stormwater-solutions-for-homeowners-fact-sheet-vegetated-swales/download*]* Accessed June 16, 2023.

STORMWATER BMP – GRAVEL WETLAND

Sub-surface gravel wetlands typically have a high pollutant removal efficiency. They filter stormwater as it flows horizontally through a sediment forebay and a series of gravel-bottomed wetland cells. The wetland cells consist of a thin layer of wetland soil which supports a thick vegetative cover; below which is a thick layer of gravel where algae and microbes grow in abundance. Treatment occurs through physical, biological, and natural chemical reactions in the wetland soil and gravel layers. Water flows through the series of cells via sub-surface pipes and is discharged to a receiving waterway or additional system through a submerged pipe in the final cell. These systems are designed to maintain constant saturation of the wetland soils. Existing dry ponds can be retrofitted into a gravel wetland to treat stormwater runoff more effectively and may require less excavation than new construction.

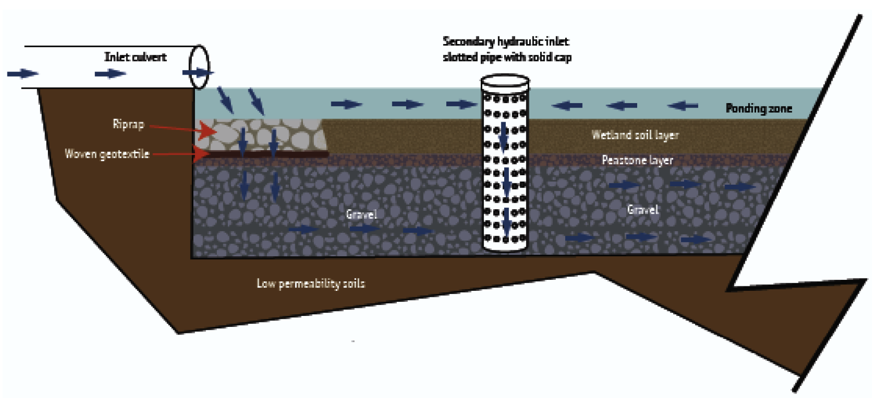
An example of a stormwater BMP utilizing a gravel wetland can be found in Vineyard Haven in the park located under the drawbridge. There is also an installation across the street from the Tashmoo Overlook.

Advantages:

- Very easily scalable.
- Reduces peak stormwater flows and provides local flood control.
- Improves quality of local surface waterways.
- Enhances the beauty of residential, commercial, or industrial sites.
- Provides wildlife habitat.
- Reduces soil erosion.
- Provides effective year-round stormwater treatment in cold climates.

Disadvantages:

- Requires the creation and enforcement of stormwater regulations and policies.



James J. Houle, Ph.D., M.ASCE and Thomas P. Ballestero, Ph.D., P.E., M.ASCE. *Some Performance Characteristics of Subsurface Gravel Wetlands for Stormwater Management. (*2020). World Environmental and Water Resources Congress. [https://scholars.unh.edu/cgi/viewcontent.cgi?article=1069&context=stormwater] Accessed June 20, 2023.

Stormwater: Bioretention / Soil Media Filters - Sandy Soils (no compost)

Bioretention is the process in which contaminants and sedimentation are removed from stormwater runoff through physical and biological processes. Stormwater is collected in the treatment area which consists of a grass buffer strip, sand bed, ponding area, organic or mulch layer, planting soil, and plants.

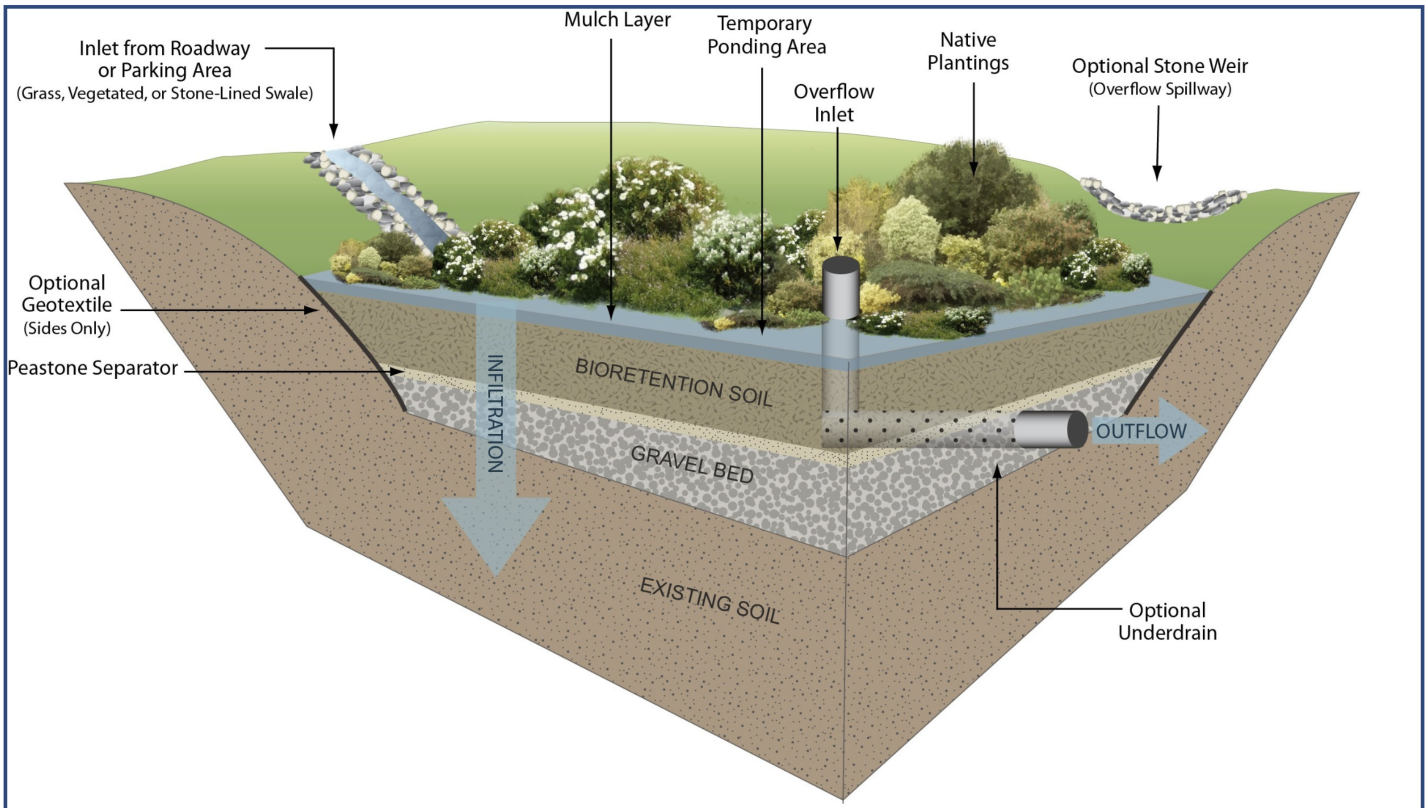
Runoff passes first over or through a sand bed, which slows the runoff's velocity, distributes it evenly along the length of the ponding area, which consists of a surface organic layer and/or ground-cover and the underlying planting soil. The ponding area is graded, its center depressed. Water is ponded and gradually infiltrates the bioretention area or is evapotranspired. Stored water in the bioretention planting soil area exfiltrates over a period of days into the underlying soils.

Advantages:

- Achieves nitrogen removal and phosphorus removal.

Disadvantages:

- Open space is required for construction.



Bioretention areas are similar to rain gardens, but are more highly engineered to include an underdrain, overflow inlet, gravel bed, and engineered soils to promote infiltration.

MassDEP. Massachusetts Clean Water Toolkit: Bioretention Area. [https://megamanual.geosyntec.com/npsmanual/bioretentionareasandraingardens.aspx] Accessed June 20, 2023.

Individual Onsite Wastewater Treatment Technologies

Innovative/Alternative (I/A) Systems

Innovative/Alternative (I/A) onsite de-nitrifying systems typically consist of standard septic system components that are augmented to remove nutrients. As noted previously in this and other reports, it is estimated that approximately 40% to 80% up-island watershed nitrogen loads are associated with onsite wastewater disposal . Individual onsite denitrification systems like I/A systems can address the largest nitrogen load source, septic systems, and could do so without the need for constructing town wastewater facilities. De-nitrifying systems have been termed “innovative/ alternative (I/A) systems” and several proprietary models are in the process of formal approval process conducted by the State of Massachusetts so that the systems can be used more widely.

MassDEP approves innovative/ alternative wastewater treatment technology according to stages of development and documented performance. MassDEP’s approval process includes three levels: Pilot, Provisional Use, and General Use.

Pilot approval processes are applied to new technologies that can be shown to perform as well or better than a traditional Title V system. Piloting requires 18 months of monitoring along with a full technical report of performance and results. If new technology can demonstrate expected performance for at least 75% of pilot sites for 12 months, the approval process moves to the provisional use phase.

Provisional Use is granted to test piloted technology in field conditions and on sites that experience a broad range of environmental conditions; beyond those that occur in the controlled “lab” oriented piloting phase . In order to move forward to General Use, at least 50 systems must be installed and evaluated for no less than three years. If, after three years, 90% of the installed systems perform as well or better than a traditional Title V system, it can be approved for General Use.

General Use certification allows technologies to be installed at any site in which a traditional Title V septic system can be located. Once General Use has been certified, system owners are responsible for submitting inspection and performance testing to MassDEP on a regular basis.

One significant advantage of I/A systems is the ability to control nitrogen loading in low-density residential areas where the cost of installing sewer systems (wastewater treatment facilities) can be high. Although I/A systems have had performance limitations due to homeowner inattention, particularly in seasonal settings, recent advances have resulted in systems with passive nitrogen removal and automated oversight functions.

Recently, attention has been directed toward MassDEP's review of proposed Title V policy revisions. Although the outcome of this review is unclear, it is possible that individual nitrogen-removing treatment systems will be included in future recommendations. In nitrogen sensitive areas without an approved watershed permit, MassDEP is considering the value of recommending that all existing and new septic systems be supplemented by de-nitrifying systems. An alternative to supplemental de-nitrifying systems could be for towns to adopt other nitrogen management actions identified and approved by the MassDEP through the watershed permitting process. It is likely that future policy frameworks will suggest that I/A systems be managed by the town (even with private ownership) or by a Responsible Management Entity (RME). Should this be the case, the town or RME is intended to ensure proper operational oversight and maintenance for these systems in a way that is similar to sewer district management. It is important to note that the RME and required regular effluent monitoring adds to system costs.

One example of how towns implement I/A regulations can be found in the town of Tisbury. Tisbury established a regulatory framework for installing and maintaining onsite de-nitrifying systems in August 2016. The Town of Tisbury Board of Health (BOH) implemented regulations requiring enhanced denitrification technologies within the Lake Tashmoo and Lagoon Pond Watershed Nitrogen Overlay District. This regulation requires an upgrade to a denitrification system for: new construction, failed systems, increased flow, additional bedrooms, or when a property is transferred if deemed necessary by the Board of Health. Note, some property owners who are required to install I/A systems voice concern about the impacts on their yards, the costs, and the possible impact on property values.

Chris Seidel-MVC. (2019). IHT Affordable Housing Cluster Development. Tisbury MA. Martha's Vineyard Commission.

In 2018 the MVC and the Town of Tisbury received a grant to test and monitor ten Nitroe© systems installed in Tisbury. Each of the ten systems were monitored monthly for the first two years and are now monitored quarterly. In a similar program, the Barnstable Clean Water Coalition on Cape Cod has completed 12 I/A septic system installations at Shubael Pond. Monitoring officials report a nitrogen reduction of over 90% for the Shubael Pond installations.

By the Summer of 2022, a total of fifty KleanTu NitROE I/As were expected to be installed in Massachusetts, once these have been monitored for the required amount of time and evaluated, this technology could be approved for General Use by MassDEP. With General Use approval it will be possible for these I/A systems to be installed and maintained with fewer monitoring requirements.

In addition to the NitROE system, other I/A systems produced by different manufacturers have reported comparable results. As additional I/A systems come to the market, these systems have become increasingly cost-effective. This is a source reduction technology.

Advantages:

- Relatively inexpensive.
- Collection system unnecessary.

Disadvantages:

- Generally lower cost effectiveness in terms of nutrient removal than shared systems.
- Lack of research regarding performance of I/A systems over time.
- The current status of provisional approval increases costs associated with required testing.

KleanTu A/I Treatment System. [https://www.kleantu.com/wastewater-treatment-systems/] Accessed June 20, 2023.

“Title 5 Septic System Replacement (Base Line Condition)”

Standard septic systems that comply with Title 5 of the State Environmental Code consist of a septic tank and soil absorption system (leaching field). In 2022 MassDEP proposed revisions to Title V regulations that are intended to address excess nitrogen levels in Nitrogen Sensitive Areas. For more on the current policy and proposed changes see: https://www.mass.gov/regulations/310-CMR-15000-septic-systems-title-5.

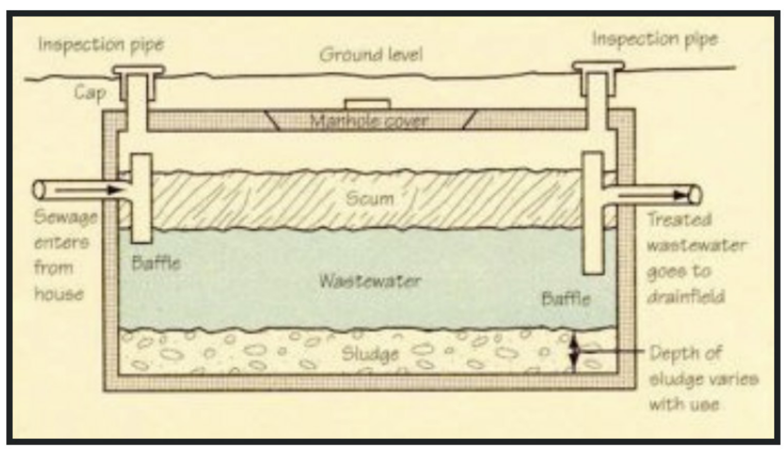
Title V Septic Systems are considered source reduction technology and are highly effective for managing pathogens associated with wastewater. However, the levels of nitrogen reduced by Title V Septic systems are no longer considered adequate for achieving current nitrogen reduction goals.

Advantages:

- Relatively inexpensive.
- Collection system unnecessary.

Disadvantages:

- Negligible nutrient removal.
- Replacement system may be costly depending on the design of the original system, land limitations, and Board of Health regulations.



Rich Vetstein. Massachusetts Title V Septic Regulations Frequently Asked Questions *(FAQ).* [https://www.mvbuyeragents.com/title-5-septic-systems-faq] Accessed June 16, 2023.

Waste Reduction Toilets - COMPOSTING

Composting toilets use no or minimal amounts of water. The human waste captured by composting toilets is decomposed and turned into compost. The compost generated from composting toilets can be used as fertilizer to replace synthetic fertilizers or can be removed from the site. Composting toilets require the installation of a separate toilet(s) and room in the basement for a container to capture and compost the human waste. Household water use (i.e., sink and shower uses) continues to flow to the septic system. This is a source reduction technology.

Advantages:

- Targets pollutants at the source.
- If composted material from the system is used as fertilizer, there can be associated environmental impacts.

Disadvantages:

- Require ongoing maintenance to function correctly.
- Resulting nutrient removal rates are highly dependent on homeowner/landowner behavior and participation in the program.
- Requires a significant number of citizens to participate to be effective.
- Requires independent citizens to change systems to be cost effective.

Photo courtesy of Clivus New England. (2012). *Potty Talk: Wastewater treatment techniques promote win-win*. MVTimes.com. [https://www.mvtimes.com/mvt/uploads/2012/04/foamflush.resi_.jpg?x82607] Accessed June 16, 2023.

Waste Reduction Toilets - INCINERATING

Incinerating toilets are self-contained waterless systems that do not require being hooked-up to a sewer system or in-ground septic system (except to dispose of gray water). They rely on electric power or natural or propane gas to incinerate human waste to sterile clean ash. When properly installed these systems are simple to use, safe, clean, and relatively easy to maintain. This is a source reduction technology.

Advantages:

- Targets pollutants at the source.
- Incinerating toilets do not use water, resulting in no waste of water. The ash left behind after incineration is sterile, and safe for disposal. They are portable, easy to install and use, and work no matter how cold the weather. They are ideal for isolated locations, where there may be no water, sewage lines, or power.

Disadvantages:

- The incineration process demolishes any nutrients found in human waste - meaning it cannot be used for nourishing soil.
- These systems save water but use energy and emit CO_2.
- Resulting nutrient removal rates are highly dependent on homeowner/landowner behavior and participation in the program.
- Requires a significant number of citizens to participate to be effective.
- Still requires septic tank and leaching field for gray water.

The proprietary nature of this technology will impose high fees for waste removal and maintenance, prompting concerns with waste management and collection.

Cinderella Eco Group: Incinerating Toilet. [https://www.cinderellaeco.com/us-en/articles/228/what-is-an-incineration-toilet?] Accessed June 20, 2023.

Waste Reduction Toilets - PACKAGING

A packaging toilet encapsulates human waste in a durable material for removal from the site. The package is stored beneath the toilet and removed and taken away when full. The nutrients can be recycled by the servicing company that picks up the packages. Household water use (i.e., sink and shower uses) continues to flow to the septic system. This is a source reduction technology.

Advantages:

- Targets pollutants at the source.

Disadvantages:

- Resulting nutrient removal rates are highly dependent on homeowner/landowner behavior and participation in the program.
- Requires a considerable number of citizens to participate to be effective.
- Still requires septic tank and leaching field for gray water.
- The proprietary nature of this technology will impose high fees for waste removal and maintenance prompting concerns with waste management and collection.
- Not approved for general use, the permitting process could be lengthy and/or costly.

Waste Reduction Toilets – URINE DIVERTING

Urine diversion systems divert urine into a holding tank where it is stored and periodically collected by a servicing company. The servicing company empties the tank for disposal or conversion to fertilizer. Through these means, the nitrogen is removed from the watershed. With urine diverting toilets, the remainder of human waste and all other water uses (sink and shower) continue to go to the septic system. This is a source reduction technology.

Advantages:

- Targets pollutants at the source.

Disadvantages:

- Resulting nutrient removal rates are highly dependent on homeowner/landowner behavior and participation in the program.
- Requires a considerable number of citizens to participate to be effective.
- Still requires septic tank and leaching field for gray water.
- Requires a company infrastructure to pick up package.
- Tight tank for urine storage required. In general, the plastic storage tank is designed to hold 600 liters.

EFFLUENT DISPOSAL – DRIP IRRIGATION

Drip irrigation uses small diameter, porous tubing to discharge the effluent from primary, secondary, or tertiary quality wastewater within a foot of the ground surface and within the root zone of vegetation. The plants uptake a portion of the discharge including nitrogen and phosphorus, lowering nitrogen and phosphorus concentration before reaching the water table.

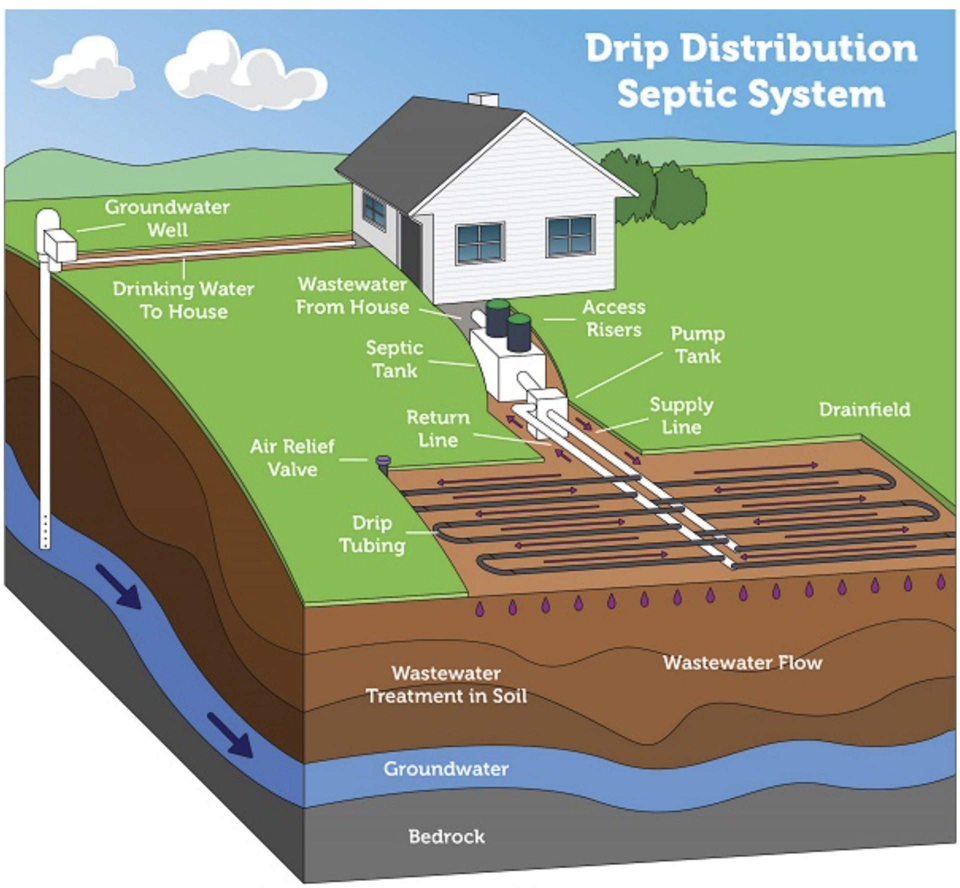
Drip irrigation can potentially be used with septic systems and I/A septic systems to further the uptake of nitrogen and phosphorus discharge concentrations. There are several examples of drip irrigation systems in use on Martha's Vineyard, the most notable is found at Station Menemsha in Chilmark.

Advantages:

- Can be used in areas in which traditional septic leaching fields are not appropriate.
- Potential cost savings associated with installing drip irrigation instead of traditional leach fields or soil absorption systems.

Disadvantages:

- None Documented



Please note: Septic systems vary. Diagram is not to scale.

US Environmental Protection Agency: Drip Distribution System. [https://www.epa.gov/septic/types-septic-systems] Accessed June 20, 2023.

Public Sewers and Package Facility Treatment Technologies

Sewers and package facility treatment systems are the workhorses of traditional nitrogen management and can provide complete removal of septic nitrogen loads in the areas they serve when the treated effluent is disposed of outside the watershed. These two types of wastewater treatment systems are commonly referred to as "traditional" systems. These options have been used for many years in a variety of locations and environments and the performance and cost of sewer systems and package facilities are relatively predictable. Town sewers are more commonly used to manage wastewater from larger and/or more densely populated areas with "centralized" systems. Alternatively, areas in which there are a small number of parcels utilize "package facilities."

To date (2023) the vast majority of up-island communities are serviced by individual wastewater treatment systems (i.e., Title V Septic Systems, I/A Systems, and Waste Reduction Toilets). The exception to this is the package treatment plant that is owned and operated by the Wampanoag Tribal Housing Authority in Aquinnah.

Compared to other options, traditional systems typically carry a large capital cost, and relatively low operational and maintenance costs. Package facilities (small scale, neighborhood-sized systems) are typically owned and operated privately, while centralized systems are publicly developed and operated. Grants and low-interest loans are often available for centralized systems. Towns are directly responsible for deciding how to recover local capital costs, weighing property taxation and betterment assessment depending on the benefits of the program.

With the aggregation of wastewater that occurs when using a traditional

Nelson Wastewater Treatment Facility improvements funded by EPA loan. (2022). [https://www.jocogov.org/newsroom/nelson-wastewater-treatment-facility-improvements-funded-epa-loan] Accessed June 20, 2023.

system, issues associated with seasonal variability do not present significant challenges and towns can hire staff or contractors to provide cost-effective operation maintenance and monitoring. Once such a town system is installed, its performance is very predictable.

While these facilities substantially reduce the nitrogen load in their service areas, it is important to note that a portion of the nitrogen may be returned to the watershed at the effluent disposal location. If the levels of nitrogen from facilities are more than what is targeted for nitrogen reduction goals, communities may consider additional mitigation measures that specifically address excess nitrogen in the effluent discharged from the wastewater treatment facility.

A co-benefit of traditional treatment is that in addition to nitrogen reduction there is potential to use treated wastewater for irrigation and other non-potable purposes. For example, if the treatment facility provides a high level of treatment, the effluent may be suitable for reuse in applications such as golf course irrigation.

There are several disadvantages to employing traditional sewer systems or package facilities up-island. The cost-effectiveness of these systems depends on the development density of the location served. The cost of wastewater collection increases sharply in areas that are not densely developed and those with relatively large parcel size. Another significant disadvantage of these systems is the need to disrupt roadways to install sewers as well as locating appropriate land for pump stations and treatment plants. Installing traditional effluent disposal systems can be a challenge in rural areas.

There are three town centralized wastewater systems located on Martha's Vineyard (Tisbury, Oak Bluffs and Edgartown) and five on Cape Cod. The small treatment plants located at the Dukes County airport and at the Tribal Housing Authority Wastewater Facility provide good examples of how package facilities function and are installed, maintained, and monitored. Furthermore, as has been done in other Southeastern Massachusetts communities, it may be possible to develop a town wastewater system that can be shared by adjacent communities. In areas where town treatment systems already exist, costs can be less than in new systems, particularly if reserve capacity at an existing facility is available.

Properly sited and designed, these systems can be made relatively immune to sea level rise or storm damage, however, the mechanical pumping and treatment systems are generally energy intensive, with a large carbon footprint.

Public acceptability varies across the spectrum; some residents expect public sewers to be a modern necessity. Others fear the potential for uncontrolled growth that may ensue.

CENTRALIZED PUBLIC SEWERS

A traditional public sewer wastewater treatment facility typically treats wastewater communities with more than 1,000 homes. Wastewater flows are generally between 330,000 and 1,000,000 gallons per day. This is a source reduction technology.

Advantages:

- Higher treatment efficiency than individual systems.

Disadvantages:

- Requires the installation of a collection system increasing costs and disruption within roadways.
- Significantly higher maintenance, monitoring, and reporting costs than individual or package facilities.
- Requires large land areas for facilities and disposal.

PACKAGE FACILITIES

A single-stage package facility operates much like a large I/A system and generally treats wastewater flows greater than 2,000 gallons per day. With this system, a collection of homes or businesses discharge to a shared I/A system where effluent is treated. Two-stage package facilities are similar to single-stage systems but require a separate de-nitrifying process and other facilities to reduce nitrogen levels below that of a single-stage system. Two-stage systems may require chemical systems and an operator to run the system. Disinfection may be required if the discharge is located within a Zone II of a public water supply well. Single-stage and two-stage package facilities are considered source reduction technologies.

Advantages:

- Higher treatment efficiency than individual systems.
- Potentially lower transport costs than wastewater treatment facilities.

Disadvantages:

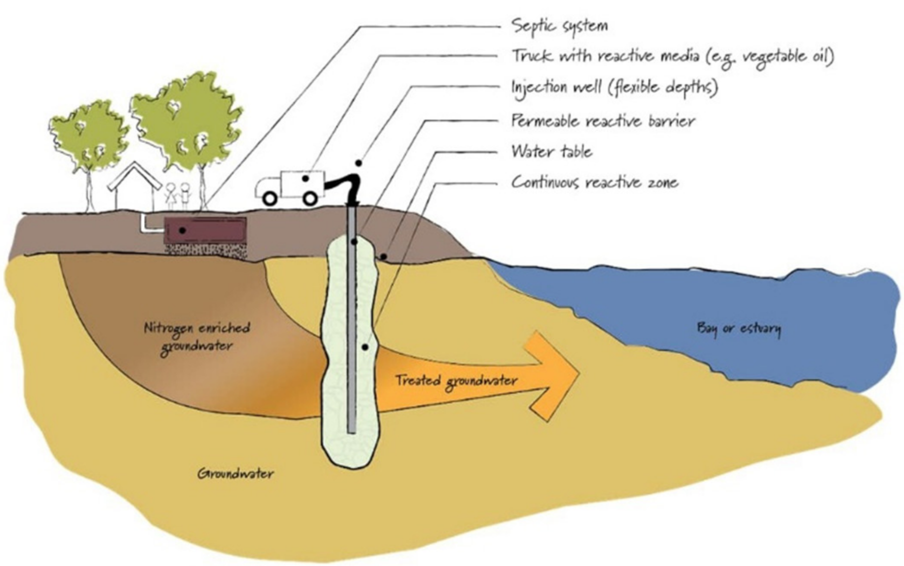
- May require the installation of a collection system.
- Single-stage systems generally have lower treatment efficiencies than traditional wastewater treatment facilities.
- May not meet the nitrogen standards without additional methanol (or other carbon source) and/or alkalinity adjustment requiring a professional operator.
- All systems discharging greater than 2,000 gpd require a dosed leaching field.

Permeable Reactive Barrier Technology

Permeable reactive barriers (PRBs) are in-situ treatment zones designed to intercept nitrogen enriched groundwater. Through the use of a carbon source, naturally occurring bacteria in the groundwater convert nitrogen (as nitrate) to nitrogen gas, a process that effectively de-nitrifies groundwater flowing through the PRB zone. PRBs are particularly useful in areas in which there are multiple sources of nitrogen that have not been fully addressed by other source reduction technologies. This is a groundwater remediation technology.

Atmospheric and other non-point sources of nitrogen, like effluent from septic systems, reach sensitive embayments via surface water and direct deposition on the embayment as well as through groundwater transport. If a below-ground permeable reactive barrier (PRB) is constructed in the appropriate location it can intercept and de-nitrify groundwater flow. PRB technology has been widely used for cleaning contaminated industrial sites since the 1990s, more recently it has been applied to nitrogen removal in other areas. In residential locations, a PRB would remove some of the nitrogen from upgradient septic systems, applied fertilizers, and the stormwater load. Further, a PRB constructed in a roadway right-of-way (i.e., shoulder of the road) can “serve” not just the homes on that street, but properties on other upgradient streets. It must be noted that identifying the proper location for a PRB is critical for realizing maximum performance of this technology.

Several Cape Cod and Martha’s Vineyard communities have investigated this technology using a trench filled with a carbon source



Woods Hole Oceanographic Institute. [https://www2.whoi.edu/site/groundwater/projects/barriers/] Accessed June 20, 2023.

of woodchips or an injection system using emulsified vegetable oil. As groundwater flows through the carbon source, the medium provides food for bacteria living in the groundwater. The bacteria consume the carbon source (food) as well as oxygen, developing an anaerobic environment that allows for the conversion of nitrate into nitrogen gas, which is ultimately released to the atmosphere. This process effectively reduces the groundwater nitrogen load before it reaches the estuary.

A liquid (emulsified vegetable oil) injection PRB system typically uses a series of injection points to introduce the carbon source into groundwater. Liquid injection PRBs can be installed to reach groundwater at greater depths than trench PRBs (which commonly rely on woodchips); and are considerably less disruptive to habitats. Liquid injection PRBs could be used in combination with the PRB trenching (woodchip) method if required by existing site conditions. Again, performance results are largely dependent on-site specific conditions. All PRBs must be properly located to maximize their potential for preventing nitrogen from reaching an estuary.

In November 2020, the MVC and the School for Marine Science and Technology at the University of Massachusetts at Dartmouth successfully installed a liquid injection PRB at a site on the West Arm of the Lagoon in Vineyard Haven. The West Arm PRB was monitored monthly and has removed approximately 91-97% of the nitrogen in groundwater that passed through. Another PRB is planned for the Oak Bluffs side of the Lagoon near the Sailing Camp.

It is important to note that identifying the best location to install a permeable reactive barrier can be challenging in terms of the time, labor and cost involved in properly identifying nitrogen plumes to be serviced by the PRB. Siting issues have been a hurdle for PRBs in areas where public roadways do not exist or are filled with buried utility equipment. However, when nitrogen plume(s) have been properly identified, PRBs have proven to be highly effective approaches to preventing nitrogen from reaching estuary water. Once located, PRB nitrogen removal can be seen in a relatively short time when compared to source control measures located farther away from the embayment.

MassDEP classifies PRB technology as one that falls into the “Advanced Pilot” stage of development. With this classification, PRB monitoring costs are a significant unknown. Regular monitoring is required to document characteristics of the groundwater passing through the PRB and the nitrogen load that is removed. Demonstration projects in Southeast Massachusetts have shown the need for multiple monitoring points and frequent analyses to document performance.

When compared to public sewers, PRBs are competitive in certain circumstances such as areas with relatively shallow groundwater. PRB technology is attractive because, in addition to the promising level of nitrogen removal they are capable of achieving, the passive nature of this technology requires no energy. Other than monitoring, the only ongoing operational expense is media replacement (approximately every 5 to 10 years for injection technology or 15 to 25 years for woodchips).

Advantages:

- Relatively low capital and operating costs.
- No above ground structures.
- High removal efficiency.

Disadvantages:

- Siting can be limited by wetlands, public utilities, and abutter concerns.
- Detailed knowledge of local groundwater hydrology is required. Large projects may require hydrogeologic investigation and groundwater modeling to estimate PRB effectiveness.
- Permitting requirements may be extensive and time consuming.
- Projects may require extensive groundwater monitoring near or in the embayment as well as monitoring of vegetation and benthic community where groundwater surfaces in the receiving estuary.

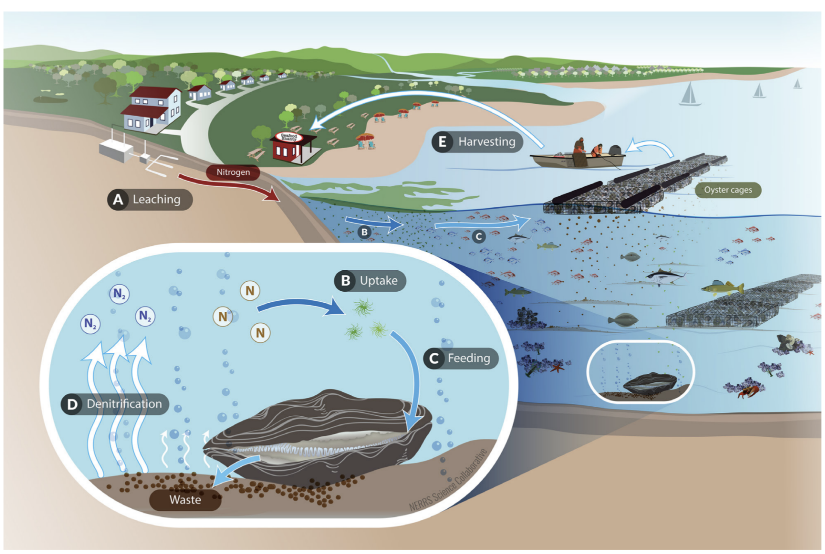
Chris Seidel-MVC. (2020). PRB installation on Lagoon Ave., Tisbury, MA. Martha's Vineyard commission.

Aquaculture Approaches and Technologies

Undesirable nitrogen concentrations within an embayment can be reduced by cultivating and harvesting mature shellfish and/or seaweed. Shellfish remove nitrogen from the water column by storing nutrients, including nitrogen, in their tissue and shells. When shellfish are removed from the system (harvested) the nitrogen they store within is also removed from the estuary. Like shellfish, seaweed also utilizes and stores nitrogen. Improvement in water clarity is often an added benefit. Shellfish harvesting and seaweed cultivation should be considered tools for effective nitrogen removal where sites are available, but not as the principal nitrogen removal technique for an entire watershed.

Several successful demonstrations have shown that nitrogen removal through shellfish harvesting can be a low-cost approach with several ancillary benefits. However, one of the primary risks associated with this approach is the need to guard against catastrophic loss of nitrogen removal capacity resulting from pathogen or storm damage. The potential for natural pathogens to destroy the shellfish population or coastal storm damage to fisheries and equipment are significant risk factors. Therefore, developing a nitrogen management plan that includes heavy reliance on shellfish harvesting is considered "non-traditional" by MassDEP and will require a traditional back-up nitrogen reduction plan.

Although permits are required if commercial sale of the shellfish is planned, program costs can be offset by shellfish commercial activity. While



This graphic helps explain how nitrogen gets into coastal waters, and how oysters can help remove nitrogen by stimulating denitrification in the sediment and through the harvesting of oysters for food.

The National Estuarine Research Reserve System's Science Collaborative. *Evaluating Whether Oyster Aquaculture Can Help Restore Water Quality.* [https://nerrssciencecollaborative.org/sites/default/files/resources/Rogers17_Final_FactSheet.pdf] Accessed June 20, 2023.

the scalable use of this technology will be limited by the availability of suitable sites, some questions have been raised about the impacts of additional shellfish operations on commercial harvesters if widespread use of this technology depresses market prices. It is also important to note that Shellfish Constables on Martha's Vineyard stock public shellfish beds for public harvest which is an existing management practice that contributes to nitrogen removal.

Like Permeable Reactive Barriers, nitrogen removed by shellfish originates from multiple sources. Because nitrogen removal occurs within the embayment, the results can be seen in a relatively short time, compared to source control measures higher in the watershed. Aquaculture includes both water body restoration technologies and approaches.

AQUACULTURE – SHELLFISH HARVESTING

Cultivating shellfish using floating shellfish cages or upwellers above the bottom surface of the estuary can be used in combination with other types of aquaculture as well as alongside floating constructed wetlands designed for brackish water.

Unlike cultivated oyster upwellers, maintaining wild oyster and other types of shellfish beds involves establishing or restoring, and subsequent maintenance. Maintaining wild oyster and other shellfish beds requires that wild shellfish are not harvested, instead, these shellfish support their natural aquatic community.

Advantages:

- Low cost per pound of nitrogen removed.
- Potential positive economic impacts associated with commercial shellfish harvesting.
- One of few approaches that can effectively sink natural nitrogen sources.
- Can help clean water of silt and can improve water quality parameters in addition to reducing nitrogen (when shellfish are removed).
- Increases biodiversity and supports plant life survivability for eelgrass and other species.
- Increases critical commercial and recreational fish populations.

Disadvantages:

- May not be applicable in all watersheds due to growing conditions, aesthetics, or navigation.
- Seasonal nitrogen uptake.
- Requires taking harvested shellfish from the watershed estuary in order to receive watershed permit "credit" for nitrogen removal.
- Shellfish will undergo rapid growth to a marketable size after which they must be harvested. If repeatedly harvesting and marketing is not economically

viable, unsold shellfish must be destroyed.

- Nitrogen uptake is subject to possible disruption due to pathogens or population crash.
- Population monitoring is important to maintain benefits.
- Can require large areas to gain significant nitrogen removal.
- Large concentrations of shellfish can generate waste products, reduce dissolved oxygen levels, and possibly generate ammonia.
- If the waterbody is closed for shell fishing, management of the shellfish by the town (or other) will be required to prevent the shellfish from getting into the food supply.

AQUACULTURE – SEAWEED CULTIVATION

Seaweed and other marine vegetation remove nitrogen from their environment. Cultivating and removing marine vegetation can remove nitrogen from an estuary, reducing the estuary's nitrogen load. Like shellfish cultivation, mariculture can become a dual-purpose process in which seaweed is both harvested and sold and nitrogen within the estuary is removed from the overlying water column during the growth and maturation of the seaweed.

Also, like shellfish cultivation, mariculture can be used in combination with other types of aquaculture such as floating constructed wetlands designed for brackish water. This is a water body restoration approach.

Advantages:

- Low cost per pound of nitrogen removed.
- Potential positive economic impacts associated with commercial shellfish harvesting.
- One of few approaches that can effectively sink natural nitrogen sources.
- Can improve multiple water quality parameters in addition to nitrogen reduction.
- Increases biodiversity and supports plant life survivability for eelgrass and other species.
- Increases critical commercial and recreational fish populations.

Disadvantages:

- May not be applicable in all watersheds due to growing conditions, aesthetics, or navigation.
- Seasonal nitrogen uptake.
- Requires removal of vegetation to remove nitrogen.
- Nitrogen uptake is subject to possible disruption due to pathogens or other.
- Can require large areas to gain significant nitrogen removal.

Habitat Alteration and Restoration Approaches

Inlet Management and Estuary Dredging

For the purposes of this report, inlet management is understood as pond opening or culvert management/ widening. Dredging refers to removing sediment for the purposes of removing nitrogen and other pollutants that may be found in the sediment on the bottom of an estuary. Channel widening refers to removing sediment in specific locations that will increase waterflow during pond openings.

Embayments that are most susceptible to nitrogen overloading are those with limited flushing or tidal exchange with the ocean. Pond opening or culvert widening address limited flushing when embayment inlets are constricted. Successful pond openings that occur on a regular basis can improve estuary environments for its inhabitants when adequate tidal exchange is achieved. However, pond opening is temporary and not considered a sole solution for managing excess nitrogen, particularly if source reduction technologies are not employed.

Dredging lakes, ponds, streams, and estuaries can remove nutrients that are stored within waterbody sediments. Sediments tend to accumulate over time; nitrogen within sediment can be released in the overlying water column. Removing sediment by dredging material from the bottom surface of the water body removes nutrients stored in dredged material from the estuary and, if sediment is transported to another location, outside the watershed.

Channel widening, like culvert widening or pond opening is a practice that can result in improved water circulation and flushing when adequate tidal exchange is achieved. As noted by William Wilcox, “periodic dredging of a channel(s) through the in-pond tidal flats to facilitate tidal flow in the great ponds should be part of their maintenance program. Dredging a channel(s) is not intended to contribute to the initial opening but to prolong the tidal period so that the required exchange and nutrient removal can occur.”

While pond opening, culvert widening, dredging and channel widening are actions that can reduce excess nitrogen loads within an estuary, the biggest challenge to this approach is maintaining the improvements over time in the face of normal coastal processes and extreme storm events. Also, reduced rainfall accompanied by higher temperatures during summer months may prevent sufficient pond levels to build to a “head” and allow for a successful pond opening. Finally, the timing of openings must be taken into consideration to ensure successful flushing. For example, Spring openings that do not close withing 14 days may impact the success of summer openings if pond water volume has not increased to the point at which a sufficient head will support a successful opening.

INLET MANAGEMENT (POND OPENING AND CULVERT WIDENING)

Advantages:

- Low incremental operation and management costs.
- Increased tidal flushing decreases nitrogen residence time and average concentrations in estuaries and tidal marshes.
- Larger openings provide for debris passage and thus reduce the potential for snags and clogging. This reduces maintenance costs.
- Depending on the size of the culvert the increased size could allow for public access via boat and/or kayak to the upstream estuary or from the estuary to the downstream creek or beach.

Disadvantages:

- Disruption of coastal processes and existing habitats must be considered.
- Permitting requirements may be costly and time consuming.
- Will only "return an estuary to a more natural hydrologic regime" if the original opening has been restricted.

DREDGING AND CHANNEL WIDENING

Advantages:

- Removes nutrients from pond or estuary that can leach out over time when sediments are relocated/moved outside the watershed.

Disadvantages:

- Dredging can be highly disruptive to biological communities.
- Permitting requirements may be costly and time consuming.

Sediment testing is required to ensure contaminated sediment is disposed of properly. Depending on the type of contaminants present in the sediments, disposal of the sediments may be costly.

COASTAL HABITAT RESTORATION

Restoring coastal habitats (wetlands) includes establishing and/or enhancing estuary salt marshes, eelgrass beds and shellfish beds as an ecosystem. Habitat restoration should focus on creating or rehabilitating natural communities native to the area. The installation of riparian buffer zones and floating islands and/or constructed wetlands should be considered when restoring coastal habitats. This is a restoration approach.

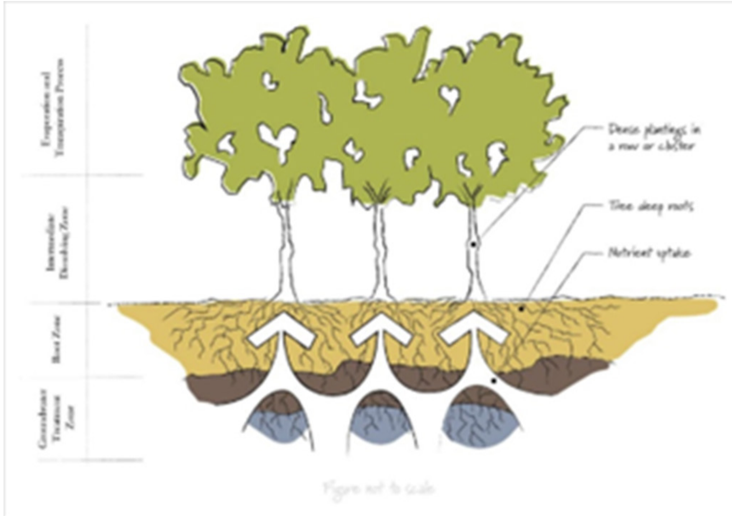
Advantages:

- Generally, less scour
- Low incremental operations and management costs.
- Sustainable technology.
- Allows for native species growth as well as increased biodiversity.
- Provides pH buffer through carbon sequestration.
- Allows for sediment accretion.
- Provides water filtration resulting in less turbidity and better water quality.

Disadvantages:

- Sufficient nitrogen removal using this approach is context dependent. Removal requirements in the watershed and/or sub-watershed may limit the effectiveness of this restorative practice.
- While this approach *may* address coastal water quality issues, it could leave issues like algal booms in freshwater ponds unanswered.

Rich Saltzberg (2016). *Menemsha dredge converts impediment into beach nourishment*. MVTimes.com. [https://www.mvtimes.com/mvt/uploads/2016/01/dredging021.jpg?x82607] Accessed June 16, 2023.



Cape Cod Commission. Technology Matrix. (2020). [https://www.capecodcommission.org/our-work/technologies-matrix] Accessed June 20, 20203

Green Infrastructure Approaches and Technologies

PHYTOREMEDIATION

Phyto-remediation uses plants to extract contaminants from surface waters or shallow groundwater. Nitrogen is removed when plants are periodically harvested and the contaminants accumulated in plant material are taken out of the system, nitrogen is also removed through bacterial action occurring in the plant root system.

Plant removals are seasonal and may be difficult to predict; providing for the appropriate reuse or disposal of harvested vegetation is also necessary for success. Like other alternative technology, phytoremediation is a nitrogen removal approach that requires a traditional back-up plan. In southern United States locations, floating constructed wetlands have been used to take up nitrogen in sensitive receiving waters, but this approach has not been widely used in the northeast where design and performance data are lacking.

Practical applications of this technology are unlikely to provide enough nitrogen removal to be the principal part of a nitrogen control plan for a threatened embayment but can be considered as part of an overall plan. Benefits of this option are low cost and public acceptability due to its “green” nature.

Responsibility for the system will require land ownership or easement. Care must be taken to ensure climate resiliency because these systems are often located in low-lying areas that are subject to flooding and storm damage.

PHYTOREMEDIATION – PHRAGMITIES

Existing phragmities stands have been identified as ideal tools for bioextraction due to their well-known role as a component in alternative wastewater treatment plants, storm drains and agricultural buffer zones.

The Martha's Vineyard Shellfish Group (MVSG) has studied the use of invasive phragmities stands and identified mid-late July as the optimal time to harvest and remove vegetation (and the nitrogen it stores) from the estuary. An additional study will be conducted in the Lagoon Pond watershed in conjunction with the UNH Stormwater Grant in 2024. It is anticipated that a July phragmities harvest will contain an average of 65 – 100 pounds of nitrogen per acre. A second fall cutting may be ideal for use as livestock feed and is expected to promote increased biomass in the following season.

Although phytoremediation approaches are likely to remove nitrogen from groundwater, nitrogen removal rates and final impacts are unknown. Should phragmities prove to be a reliable source of nitrogen mitigation, there is a co-benefit opportunity for economic development if a local market for harvesting and processing can be established.

Advantages:

- TBD

Disadvantages:

- TBD

Martha's Vineyard Shellfish Group. Research project to quantify nitrogen reduction potential associated with harvesting phragmitie reeds. Lagoon Pond Road, Vineyard Haven, MA. 2015.

CONSTRUCTED WETLANDS – SUB-SURFACE FLOW

After treatment in a septic tank or wastewater treatment facility, discharged wastewater is treated by pumping it slowly through subsurface gravel beds where it is filtered through plant root zones and soil media. Most often, these systems are used as secondary treatment approaches to address nitrogen that remains in effluent after treatment.

These systems are designed so that water flows 3-8” under the surface to prevent public exposure to wastewater and mosquito breeding. A combination of horizontal and vertical flow subsurface systems must be utilized to achieve total nitrogen removal. The treated water is generally discharged into a leach field or similar system to infiltrate into the groundwater. Treated water can also be discharged into a water body or used for open space irrigation. However, strict permitting and water quality standards must be met if treated water does not discharge directly into groundwater. This is a source reduction technology.

Advantages:

- Very efficient and requires less land area than Free Water Surface wetlands.
- Water stays below the surface so may not require disinfection. Lower capital, annual operations, and management cost than secondary and tertiary treatment.
- Proven Technology.

Disadvantages:

- Higher maintenance than other approaches in the first few years.
- May require carbon source initially.
- Can become clogged over time.
- Phosphorous removal may decline over time.
- May require fencing and security measures.
- May attract waterfowl which could aggravate nitrogen issue.
- In addition, physical characteristics may require that these systems be lined to prevent complete infiltration and allow time for nitrogen removal rather than just putting nitrogen into groundwater.

CONSTRUCTED WETLANDS – FLOATING CONSTRUCTED WETLANDS

Manufactured "islands" serve as floating wetlands that treat pond and estuary water. Vegetated islands are made of recycled materials that float on ponds or estuaries and plant root-zones are exposed to the pond and estuarine waters. Plant roots provide habitat for fish and microorganisms while reducing nitrogen and phosphorus levels. Floating islands can also be designed to culture shellfish and seaweed, which can be harvested, offsetting some of the systems costs.

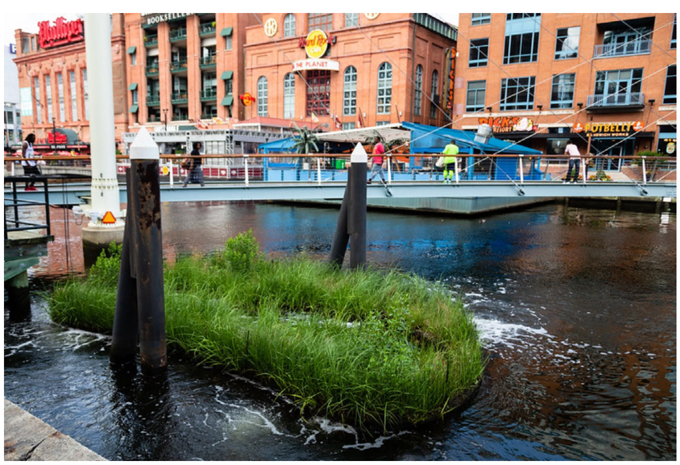
Some systems circulate surface water through the island, exposing the water to the root zones of the plants. The islands can be installed with shellfish beds and/or salt marsh grasses potentially assisting with their establishment. The islands are generally stationary and can be installed with walkways to access and maintain the plants growing on the islands. The islands require little operation and management resources and do not need to be removed during the winter months, even if freezing water is a concern. Floating constructed wetlands are not a commonly used technology/ approach found in New England. This is a restoration technology.

Advantages:

- Returns estuary to more natural hydrologic regime.
- Low incremental operations and management costs.
- Sustainable technology.
- Allows for the growth of native species along with biodiversity.
- Provides water filtration resulting in less turbidity and better water quality.

Disadvantages:

- None documented.



Sam Houghton. (2022). *Barnstable to experiment with 'floating wetlands' to address freshwater pond algae blooms*. CAI. [https://www.capeandislands.org/in-this-place/2022-12-01/barnstable-to-experiment-with-floating-treatment-wetlands-to-address-freshwater-pond-algae-blooms] Accessed June 16, 2023.

ADDITIONAL EVALUATION CRITERIA

There are many factors for town administrators and stakeholders to consider when selecting management technologies/approaches to mitigate nitrogen loading up-island. After reviewing relevant criteria from projects taking place or completed in Southeast Massachusetts, the following criteria are suggested for consideration when evaluating the technologies and approaches presented in this report.

ESTIMATED TIME TO IMPROVE ESTUARY WATER QUALITY

Each technology/approach discussed in this section of the watershed management plan will require more or less time to achieve measurable nitrogen load and concentration reductions. Distance from the receiving water as well as the type of mitigation solution selected have the most immediate impact on nitrogen loads in the waterbody. Just as reducing nitrogen at its source has the most direct effect on nitrogen loads in the groundwater and receiving water, removing nitrogen that is in or close to receiving water affords more rapid water quality improvement.

However, focusing on source reduction or areas near waterbodies alone does not address future nitrogen loading. Nitrogen already in the groundwater that is located farther away from the waterbody will take time to reach the estuary that is being tested and evaluated for nitrogen and other environmental benchmarks. Groundwater movement averages one foot per day, therefore, travel time could be many years for upland nitrogen polluted water to reach the estuary/waterbody. Furthermore, the time required for a technology/approach's measurable impact to be realized depends on several additional factors, including existing nitrogen loads in the landscape, seasonal droughts, and extended rainy seasons; each of which impacts the speed of groundwater flow. Finally, as noted in each watershed "existing conditions" report, the physical features (e.g., land cover, geology, and soil type) of parcels also impact groundwater flow dynamics.

COSTS

One of the most important aspects of a nitrogen removal approach is its associated costs, which include: design, construction or implementation, long-term operation, maintenance, and monitoring. Costs are often presented in terms of initial and long-term cost by referring to cost metrics as "life-cycle costs," "present worth," or "equivalent annual costs." In this way, assessments capture situations in which high-initial-capital cost approaches have low annual costs and therefore may be more cost-effective in the long-term than low-first-cost options with high operational costs. Calculating technology costs in terms of near-term capital investments and total cost over the "useful lifetime" of the approach can help communities evaluate and plan for how best to finance nitrogen mitigation projects.

LAND REQUIREMENTS

Some nitrogen removal techniques can be implemented in a small area; others have relatively large geographic footprints. Large land requirements can represent a cost factor, in terms of the land monetary value as well as the opportunity costs associated with taking land away from other important uses. Furthermore, options that have small geographic footprints have the benefit of being less visible.

PREDICTABILITY

Technology like traditional sewer systems, which have been used for decades, have well established nitrogen removal capabilities and costs. Newer approaches, like I/A systems, may offer significant advantages over traditional approaches but limited data surrounding installation, maintenance, and monitoring lead to unpredictable cost estimates. Also, for technologies without fully documented nitrogen removal performance, the lack of predictable results may complicate the permitting process.

MONITORING AND EVALUATION REQUIREMENTS

Routine monitoring is a key component of adaptive management. Progress toward achieving water quality goals can only be definitively determined by measuring the performance of two separate components. Monitoring and evaluation must be applied to the technology or approach used to address nitrogen as well as the impact measured in receiving water.

Routine nitrogen monitoring to establish how much nutrient is processed by a specific technology or approach will enable decision makers to evaluate how the selected technology/approach conforms to its performance criteria. Likewise, well-established water quality indicators must be used to evaluate changes in nutrient levels in the estuary in order to quantify the impact of each technology/approach in the targeted area.

Monitoring bears a cost which is particularly important for emerging technologies, therefore decision makers are urged to consider the costs associated with long term monitoring and evaluation protocols when selecting potential technologies and approaches.

READINESS FOR IMPLEMENTATION

Technologies with long track records can be designed, permitted, and implemented in a straightforward fashion. Newer approaches require more time for implementation, particularly when pilot testing is needed to determine applicability, sizing, and performance, or to demonstrate to regulatory agencies that the technology can work in the chosen setting. Funding agencies may require demonstration testing to confirm that the technology is cost-effective and thus eligible for funding. As various technologies are evaluated for how they are best used, it is prudent for decision makers to consider the status of MassDEP approval for each technology as a part of the technology selection process.

CLIMATE RESILIENCE

Attention should be given to how each nitrogen management approach will stand up to climatic extremes, loss of power, coastal storm damage, and sea level rise. Some systems can be physically protected against many extreme events. Other approaches may be vulnerable to sea level rise, flooding, and storm damage if they must be located in or near the embayment.

PERMITTING ISSUES

Some nitrogen control measures are readily permitted under long-term state regulatory programs, one example is the Massachusetts Groundwater Discharge Program which regulates wastewater treatment systems. Other management options require special considerations. MassDEP has categorized technologies as "traditional" and "alternative" and has stated that a watershed permit must be in place if alternative technologies are to be used. MassDEP policy also states that alternative technologies must have a traditional back-up plan (e.g., wastewater treatment facility like a sewer system) that can be put in place if the alternative system does not perform as expected.

Furthermore, approaches that involve destruction of critical habitat, impact state roads and/or bridges, or encroach on historical/archaeological resources often require extensive, time consuming, and costly permitting processes. Technologies that are not categorized as "general use" by MassDEP also have specific permitting processes which can be costly and time consuming. Non-traditional

GREENHOUSE GAS EMISSIONS AND ENERGY USE

Some communities find that considering the "carbon footprint" of each technology is an important part of their decision-making process. While many options are nature-based and have low "carbon footprints," other options emit greenhouse gases directly or through component manufacture and transport. Energy use should be minimized if possible due to the cost associated with providing energy for technology use and to avoid indirect carbon emission at the point of power generation.

OWNERSHIP

Some technologies are traditionally owned and implemented by the town, others are best owned and managed privately. Private ownership may avoid the need for town meeting approval for appropriations, however, private ownership can also create challenges in permitting and oversight. Funding programs typically will not support privately-owned infrastructure.

POTENTIAL FOR GRANTS AND LOANS

There are often state and/or federal grant and loan programs available to offset the costs of certain nitrogen removal technologies and projects. Numerous eligibility criteria, including demonstration that the selected approach is cost-effective compared to other options and that the environmental impacts are manageable are considered by loan and grant offering organizations.

ENVIRONMENTAL IMPACT

There are always environmental impacts associated with constructing and operating nitrogen removal approaches. Impacts can be from the technology itself or may be indirect as is the case with energy use. While the technologies and approaches considered in this report provide the significant environmental benefit of nitrogen management, approaches that significantly offset environmental benefits must be avoided. Furthermore, it is essential that towns understand and consider Massachusetts Environmental Policy Act (MEPA) threshold triggers and associated requirements for submitting projects or plans for MEPA review.

PUBLIC ACCEPTABILITY

Public acceptability is a critical component of nitrogen management plans. Acceptance of costs, aesthetics, etc. should not be underestimated. Sufficient public support is needed to allow town meeting appropriations of local costs and public acceptance of the method by which these expenses will be recovered (e.g., user fees, betterment assessments and property taxes). The public must also be consulted about local regulatory requirements related to these technologies, such as growth restrictions.

ADAPTABILITY TO GROWTH

If anticipated growth in the watershed is expected to increase nitrogen loads over time, then nitrogen removal approaches must accommodate potential growth in order to maintain water quality goals in the future. Some technologies can be easily modified to accommodate growth; others require significant upgrading or expansion.

ENDNOTES

1. Existing Conditions Report links:

- Chilmark Pond (Town of Chilmark): https://indd.adobe.com/view/3dbd6a5b-3ae0-4512-b876-4d1f400353b0 -
- James Pond (Town of West Tisbury): https://indd.adobe.com/view/3cbe33b3-bbdb-4642-9bb0-37ad06b41c5f
- Menemsha Pond (Towns of Aquinnah and Chilmark): https://indd.adobe.com/view/b7f0f855-0ec6-4e07-b3e0-410610e31b6d
- Squibnocket Pond (Towns of Aquinnah and Chilmark): - https://indd.adobe.com/view/769da4fb-e7c1-4740-80dc-84f49f2666d9
- Tisbury Great Pond (Towns of Chilmark and West Tisbury): https://indd.adobe.com/view/3f52c178-ab5a-4995-8f24-7e0f1640c272

2. See appropriate Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold, available for Chilmark Pond, Squibnocket and Menemsha Pond, and Tisbury Great Ponds embayments. Howes B.L., E.M. Eichner, R.I. Samimy, H.E. Ruthven, D.R. Schlezinger, J. S. Ramsey. SMAST/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.

3. See MVC Water Quality Policy for more details about this policy:

- https://www.mvcommission.org/sites/default/files/docs/Water_Quality_Policy_Final_2020-01-13_1.pdf
- https://www.mass.gov/lists/groundwater-discharge-permitting-regulations-policies-guidance
- https://www.mass.gov/regulations/314-CMR-4-the-massachusetts-surface-water-quality-standards

4. See appropriate Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold, available for Chilmark Pond, Squibnocket and Menemsha Pond, and Tisbury Great Ponds embayments. Howes B.L., E.M. Eichner, R.I. Samimy, H.E. Ruthven, D.R. Schlezinger, J. S. Ramsey. SMAST/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.

5. US Environmental Protection Agency. Composting at Home. Available via https://www.epa.gov/recycle/composting-home#:~:text=Adding%20finished%20compost%20to%20your,need%20for%20pesticides%20and%20fertilizers. Accessed 03/03/2023.

6. William Wilcox, email exchange with Rachel Sorrentino in February 2023.

7. Stormwater estimates are generated by the EPA and do not reflect local conditions. For more information on estimating stormwater see: National Stormwater Calculator User's Guide – Version 2.0.0.1, https://www.epa.gov/sites/default/files/2019-04/documents/swc_users_guide_desktop_v1.2.0.3_april_2019.pdf.

8. For more on stormwater best management practices see: https://www.mass.gov/doc/massachusetts-stormwater-handbook-vol-1-ch-1-stormwater-management-standards/download and Coastal Stormwater Management Through Green Infrastructure Handbook for Municipalities. https://www.epa.gov/sites/default/files/2015-09/documents/massbays_handbook_combined_508-opt_1.pdf.

9. See https://www.tisburywaterways.org/happenings/getting-stormwater-into-the-bioswale-rs6z4 for more information.

10. See appropriate Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold, available for Chilmark Pond, Squibnocket and Menemsha Pond, and Tisbury Great Ponds embayments. Howes B.L., E.M. Eichner, R.I. Samimy, H.E. Ruthven, D.R. Schlezinger, J. S. Ramsey. SMAST/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.

11. For more information about approved technology, please see: https://www.mass.gov/doc/summary-table-of-innovativealternative-technologies-approved-for-use-in-massachusetts/download. Website accessed May 30, 2023.

12. William Wilcox, email exchange with Rachel Sorrentino in February 2023.

13. William Wilcox, email exchange with Rachel Sorrentino in February 2023.

14. Emma Green-Beach, Jamie Vaudrey, Richard Karney. (2019). Annual harvest of the invasive reed, Phragmites australis: a potential nitrogen mitigation strategy with widespread application. FINAL REPORT, Healthy Communities Grant Program.