WEST FALMOUTH NITROGEN-REDUCING SEPTIC SYSTEM DEMONSTRATION PROJECT

MAY 2017 **STATUS REPORT**

PROJECT PARTNERS

This project brought together the town of Falmouth, the Buzzards Bay Coalition, the West Falmouth Village Association, and the Barnstable County Department of Health and the Environment. Funding came from a U.S. EPA grant from the Southeast New England Coastal Watershed Restoration Program.

PROJECT OVERVIEW

For the past 20 years, West Falmouth residents have watched the health of their harbor decline due to nitrogen pollution. The harbor's health became so bad that, in 2002, it was listed on the federal "dirty waters" list as polluted with too much nitrogen.

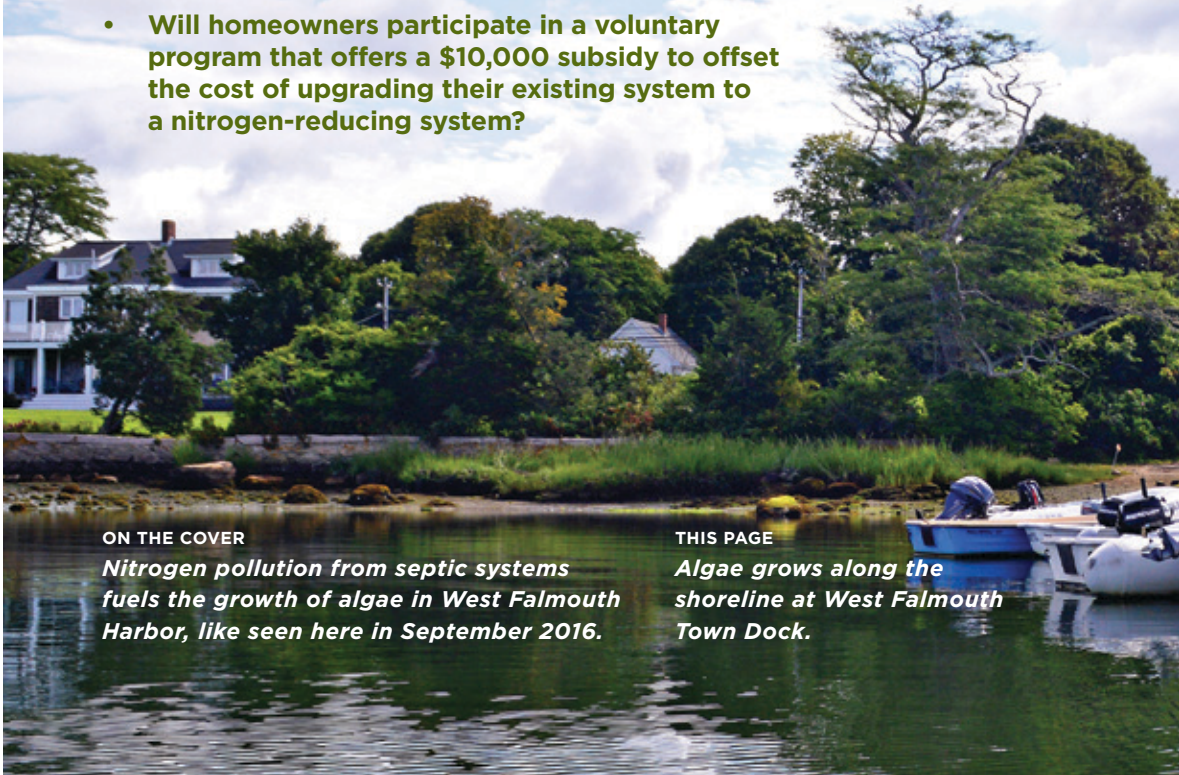
In 2008, the U.S. Environmental Protection Agency approved a federal pollution limit called a Total Maximum Daily Load (TMDL) for West Falmouth Harbor. The TMDL required the town of Falmouth to take action to reduce the amount of nitrogen being discharged into this ecologically sensitive harbor.

At that time, the largest source of nitrogen was the town's wastewater treatment facility on Blacksmith Shop Road. After the Coalition and local residents advocated for pollution reductions to the harbor, the Massachusetts Department of Environmental Protection set strict permit limits and the town upgraded that facility.

But even with these improvements, the harbor's nitrogen limit will not be met without reducing nitrogen from neighborhood septic systems, which are now the main source of nitrogen pollution to the harbor.

The West Falmouth Nitrogen-Reducing Septic System Demonstration Project illustrates how nitrogen can be reduced by upgrading on-site septic systems. The project set out to answer two major questions:

- **Can existing nearshore homes with on-site septic systems be successfully retrofitted with the best available technology to reduce nitrogen?**
- **Will homeowners participate in a voluntary program that offers a $10,000 subsidy to offset the cost of upgrading their existing system to a nitrogen-reducing system?**



ON THE COVER
Nitrogen pollution from septic systems fuels the growth of algae in West Falmouth Harbor, like seen here in September 2016.

THIS PAGE
Algae grows along the shoreline at West Falmouth Town Dock.

SUMMARY CONCLUSION

West Falmouth homeowners responded enthusiastically to this program. Twenty properties around West Falmouth Harbor were identified in spring 2016, and new septic systems were installed at the homes by the end of the year.

Project partners set out to reduce nitrogen from on-site septic systems at these 20 homes by at least 67%. Data collected to date indicates that nitrogen from these 20 systems has been reduced by at least 78%. The average cost to add on to a conventional Title 5 system was $20,417, while full upgrades from old cesspools cost an average of $33,225.

This project made it clear that it is possible to retrofit on-site septic systems with state-of-the-art nitrogen-reducing septic technology. The availability of septic technology was not a limiting factor – there are many types of systems available that can achieve a treatment level of 12 mg/L or less (about one-third of the nitrogen that's discharged from a conventional system).

Cost was the driving factor in homeowner decision-making, with willingness to pay estimated at $10,000-$15,000 to add on nitrogen-reducing technology to existing systems. Through this demonstration project, each homeowner was offered a $10,000 subsidy, which was sufficient to encourage participation in this neighborhood.

The long-term success of this demonstration project will be determined by how well these nitrogen-reducing systems operate over time and how many additional homeowners choose to follow the lead of these 20 homes. Each system will be sampled monthly for a full year to measure the amount of nitrogen being discharged.

The success of this program has led to a Phase II project, which will upgrade septic systems at an additional 10 homes in 2017 with a reduced $7,500 subsidy.

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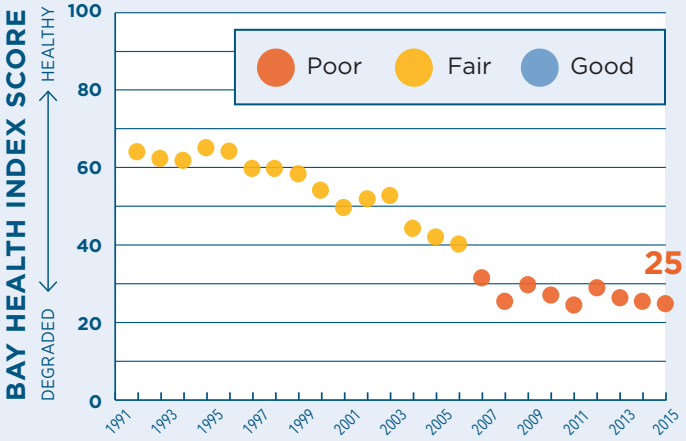
How does nitrogen pollution harm West Falmouth Harbor?

Water quality declines when too much nitrogen gets into the water. Nitrogen fuels the growth of algae that makes the harbor's waters look cloudy and murky. Beaches and boats can become covered with slimy green algae. Over time, underwater eelgrass beds die and fish and shellfish slowly disappear.

Data collected through the Coalition's Baywatchers program clearly tell the story of West Falmouth Harbor's declining health. The Bay Health score for portions of West Falmouth Harbor, such as Snug Harbor, have steadily fallen over time and are now considered "poor," with too much nitrogen pollution for the waterway to function as a viable ecosystem (see graph above right).

Septic systems are the largest source of nitrogen pollution to Buzzards Bay. Even properly functioning Title 5 septic systems cause pollution problems. When you add up all the homes that use septic systems around places like West Falmouth Harbor, they amount to the largest source of pollution.

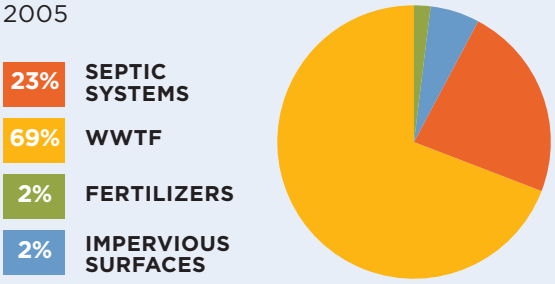
West Falmouth Snug Harbor



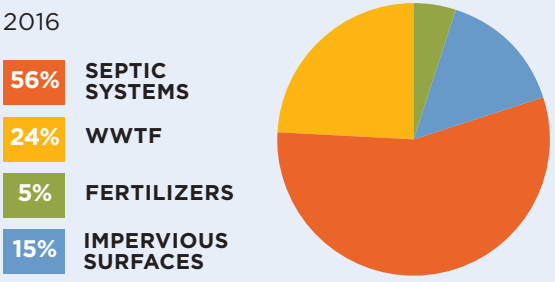
Septic Systems + Nitrogen

Prior to Falmouth's wastewater treatment facility upgrade in 2005 (top), 69% of the nitrogen in West Falmouth Harbor came from the sewage plant. Today (bottom), the primary source of nitrogen to West Falmouth Harbor is septic systems.

2005



2016

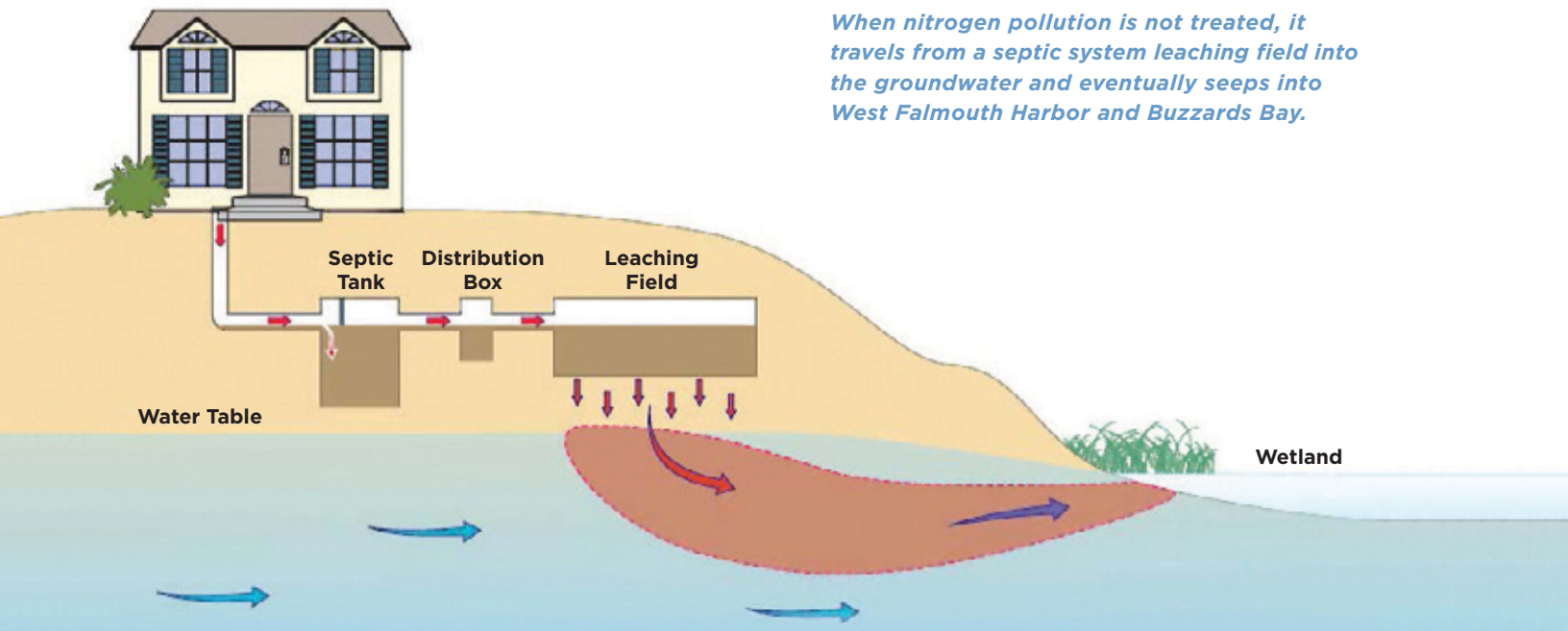


Sources: Massachusetts Estuaries Project (2005), Buzzards Bay Coalition (2016)

THE VALUE OF NITROGEN-REDUCING SEPTIC SYSTEMS

Although centralized sewer systems are highly effective at reducing nitrogen, they can be costly to expand to low-density residential areas. Affordable on-site septic systems that can remove a significant percentage of nitrogen are an important alternative to solve the nitrogen pollution problem, not only in West Falmouth Harbor but in coastal waters throughout southeastern Massachusetts.

Each home on a conventional Title 5 septic system around West Falmouth Harbor contributes an estimated 13.23 pounds of nitrogen to the harbor per year. The nitrogen-reducing septic systems installed through this project were required to reduce that amount of nitrogen to 4 pounds per house per year – slashing the overall nitrogen load from 20 homes by 68%, from approximately 265 pounds per year to 90 pounds per year.



When nitrogen pollution is not treated, it travels from a septic system leaching field into the groundwater and eventually seeps into West Falmouth Harbor and Buzzards Bay.

Participating Properties

Any home within 300 feet of mean high water was considered a potential site for a septic system upgrade. These 170 eligible properties were ranked based on four factors: how close the home was to the water, how close the home was to the Total Maximum Daily Load (TMDL) target water quality station, the type and age of their system, and how frequently the system was used.

Old systems on year-round homes that were very close to the water became the highest priority targets. The Buzzards Bay Coalition and the West Falmouth Village Association approached these homeowners about participating in the project. Support from community leaders also helped catalyze homeowner participation.

Map: Buzzards Bay National Estuary Program


Outer
W. Falmouth
Harbor
Mashapaquit
Creek
Snug
Harbor
Harbor
Head
Oyster
Pond

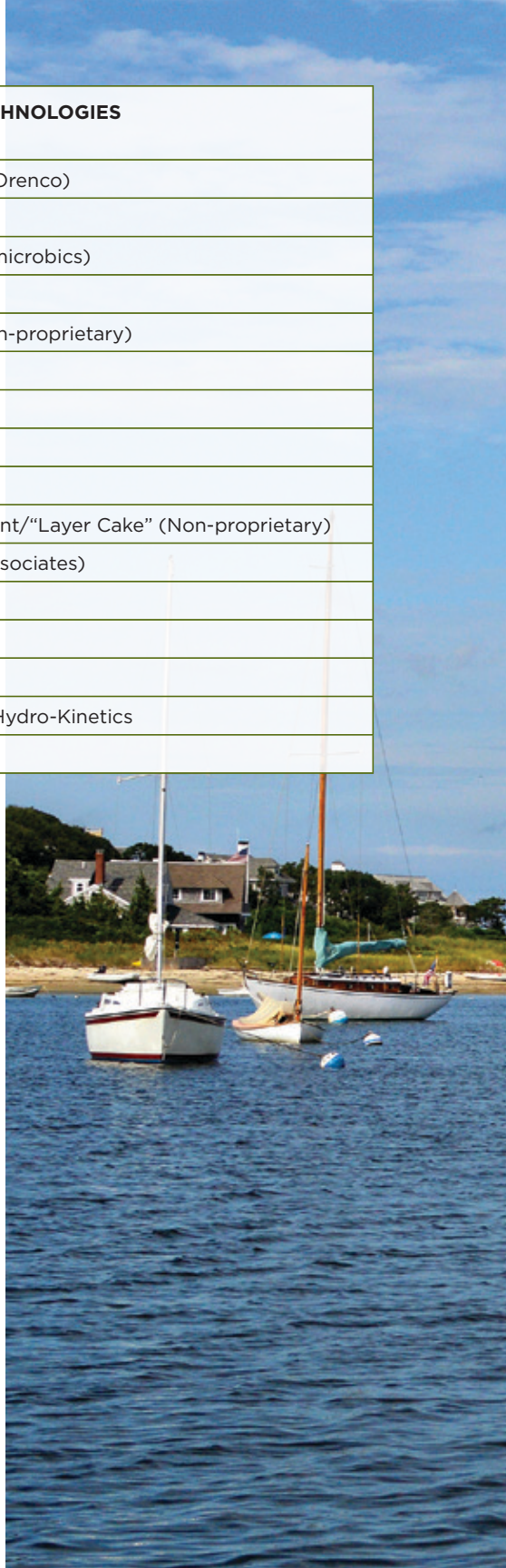
Types of Denitrification Systems

There is a wide range of septic systems on the market that can reduce nitrogen from wastewater. This project considered only the highest-performing systems that could reduce at least 67% of nitrogen compared to conventional systems. Nitrogen-reducing systems that qualified were required to show, through third-party verifiable information, that they were capable of achieving a treatment level of 12mg/L (a conventional system is assumed to discharge nitrogen at 35mg/L). The project team reviewed available technologies and determined that 16 different technologies met this requirement and could be offered to an interested homeowner (see table at right).

SEPTIC SYSTEM TECHNOLOGIES MEETING 12 MG/L
AdvanTex AX20RT (Orenco)
Amphidrome - SBR
Biobarrier MBR (Biomicrobics)
Bioclere (Aquapoint)
Blackwater Tank (Non-proprietary)
BUSSE Green Tech
Eliminite +Puraflo
GPC
Hoot BNR
Layered Soil Treatment/“Layer Cake” (Non-proprietary)
Nitrex (Lombardo Associates)
NJUN Systems
RUCK
SepticNET
SES Environmental: Hydro-Kinetics
Waterloo Biofilter

To understand how different on-site nitrogen-reducing septic systems work, it’s helpful to understand how nitrogen is removed from wastewater. It is a two-step process that involves adding oxygen and then taking it away:

1. Raw wastewater contains ammonia: a form of nitrogen that comes from urine. That ammonia is converted to nitrate by adding oxygen to the raw wastewater. Oxygen promotes the growth of “nitrifying” bacteria that convert ammonia into nitrate.
2. Once the oxygen “nitrifies” the wastewater, the oxygen is taken away by denitrifying the wastewater. There are specific bacteria called “denitrifiers” that convert the nitrate to safe nitrogen gas, which is dissolved into the air we all breathe.



A NOTE ON DATA *– Data collection did not begin on all systems all at the same time. The installations of these systems began in February of 2016 with the last one completed on December 26, 2016. Therefore, the data presented here do not represent a full year of operation for all 20 systems. This report will be supplemented to reflect a fuller data set. It should also be noted that these systems need time to grow the necessary bacteria to remove nitrogen. Therefore, initial samples were taken before nitrogen removal was taking place. Regardless, those data were included.*

WHAT SYSTEMS DID HOMEOWNERS SELECT?

These qualifying technologies varied in complexity, aesthetics, energy use, and cost. To help homeowners rank systems based on their preferences, project partners created a Decision Support Tool. The top qualifying systems were then reviewed to assess how feasible they would be to install at each unique property. Systems were selected that could be tailored to site conditions and the needs of the homeowner.

Generally, homeowners wanted something simple, affordable, reliable, and out of sight – no surprises there. Because the majority of the project participants were seasonal residents, systems that operate well on a seasonal basis were popular.

When the project had 10 interested homeowners, project partners held a vendor presentation at a homeowner's house to showcase the most popular technologies. This presentation gave homeowners an opportunity to meet the vendors, learn more about each technology, and ask questions.

Ultimately, of the 14 systems offered, homeowners selected four: two proprietary systems, Eliminite and Hoot, and two non-proprietary, layer cake and blackwater systems. All systems required an operation and maintenance contract and compliance sampling throughout the year.

The next page describes the operation, installation, costs, and performance of these four systems.

Constructing a new septic system on an existing home site presents unique challenges. Partners were able to work with homeowners to find the best solutions that could be tailored to their specific needs and site conditions, such as this Hoot system installed under a small area of yard.

BLACKWATER SYSTEMS

The non-proprietary **blackwater system** was selected for many of West Falmouth's summer homes, which are typically only occupied 8-10 weeks a year. The blackwater system works by adding a 1,500-2,000 gallon concrete storage tank to a standard Title 5 septic system to store blackwater (wastewater from toilets). Because summer cottages often aren't insulated, it's relatively easy to re-plumb interior toilets to a new holding tank. The blackwater holding tank is sized to require only one or two pumpouts per season. An alarmed float meter alerts homeowners and property managers when the blackwater tank is two-thirds full, and a counter tracks the number of times the alarm is triggered.

How Blackwater Systems Remove Nitrogen

Blackwater systems prevent wastewater from entering the harbor by storing it in a tank until a septage hauler pumps out the tank and takes the contents to the Falmouth Wastewater Treatment Facility, where they are treated and then discharged. All other water from the home (sinks, showers, washers) goes to a 1,500-gallon greywater tank, which is discharged to a leach field.

Operating and Maintaining Blackwater Systems

The current estimated annual cost for operating and maintaining a blackwater system is $700. This includes at least two pumpouts per year ($300 per pumpout) and $100 for the annual inspection and total nitrogen sample, which is taken to a lab to confirm performance.

BLACKWATER SYSTEMS INSTALLED	9
AVERAGE INSTALLATION COST FOR FULL UPGRADE FROM CESSPOOL	$25,799
AVERAGE INSTALLATION COST FOR ADD-ON TO CURRENT TITLE 5 SYSTEM	$14,52O
AVERAGE NITROGEN CONCENTRATION BEFORE UPGRADE	95 MG/L
AVERAGE NITROGEN CONCENTRATION AFTER UPGRADE	8 MG/L
REDUCTION IN NITROGEN FROM THESE HOMES	92%

ELIMINITE SYSTEMS

Eliminite is a denitrifying septic system developed in Bozeman, Montana. Two 1,500-gallon concrete tanks treat all household wastewater (both blackwater and greywater) for nitrogen. No interior plumbing changes are required, but this system does require a pump and electricity. Eliminite systems worked well for homes with an existing Title 5 septic system and a 1,500-gallon septic tank. Only one additional treatment tank was needed, which reduced the cost for these installations.

How Eliminite Systems Remove Nitrogen

The Eliminite system uses patented, proprietary treatment media called MetaRocks to remove nitrogen from wastewater. The MetaRocks provide a surface area for the nitrifying and denitrifying bacteria to grow. The first 1,500-gallon tank serves as a settling tank, and the second tank is a two-chamber tank which houses the MetaRocks and a pump. The MetaRocks treat the wastewater, and then the pump chamber pumps the treated wastewater out to the leach field.

Operating and Maintaining Eliminite Systems

Eliminites are new to Massachusetts, and the Massachusetts Department of Environmental Protection requires a robust inspection and sampling schedule for new technologies. At this time, annual operation and maintenance costs are $1,319.20. These costs and requirements will go down as data continue to show how the systems perform.

ELIMINITE SYSTEMS INSTALLED	3
AVERAGE INSTALLATION COST FOR ADD-ON TO CURRENT TITLE 5 SYSTEM	$21,040
AVERAGE NITROGEN CONCENTRATION BEFORE UPGRADE	78 MG/L
AVERAGE NITROGEN CONCENTRATION AFTER UPGRADE	30 MG/L
REDUCTION IN NITROGEN* FROM THESE HOMES	62%

These results may not be representative. One of the three homes sampled was under construction during sampling, and total nitrogen results were likely affected by construction constituents (paint thinners, etc.) being washed down drains. However, the results were included here to show the real-life impacts of on-site systems – sometimes bad stuff gets dumped down drains. If that result was removed from the data,* ***the total nitrogen reduction from these systems would be 85%.*

HOOT SYSTEMS

The **Hoot system** is a proprietary two-tank denitrifying system built by Hoot Systems, LLC of Lake Charles, Louisiana. Each tank is divided into two chambers, and all household wastewater (both blackwater and greywater) is treated for nitrogen. Hoot systems require a pump, compressor, and electricity. With several Hoot systems already in the ground and operating across Cape Cod, this locally distributed system was popular due to its track record in the region.

How Hoot Systems Remove Nitrogen

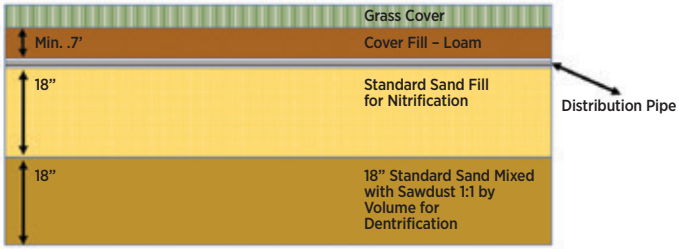
The first chamber acts like a septic tank where the solids and non-biodegradables sink to the bottom. The second chamber adds air to turn ammonia into nitrate. The third chamber takes the air away which promotes denitrification. The final chamber is a pump chamber, which discharges the treated wastewater out to the leach field.

Operating and Maintaining Hoot Systems

At this time, annual operation and maintenance costs are $600.

HOOT SYSTEMS INSTALLED	**7**
AVERAGE INSTALLATION COST FOR FULL UPGRADE FROM CESSPOOL	**$37,726**
AVERAGE INSTALLATION COST FOR ADD-ON TO CURRENT TITLE 5 SYSTEM	**$28,291**
AVERAGE NITROGEN CONCENTRATION BEFORE UPGRADE	**63 MG/L**
AVERAGE NITROGEN CONCENTRATION AFTER UPGRADE	**12 MG/L**
REDUCTION IN NITROGEN FROM THESE HOMES	**81%**

LAYERED SOIL TREATMENT ("LAYER CAKE") SYSTEMS



The **layered soil treatment system**, fondly known as the **"layer cake,"** is a passive, non-proprietary technique that layers sand over a mix of sand and wood cellulose (commonly known as sawdust) in the leach field. Layer cake systems most closely resembles a conventional Title 5 septic system: All wastewater from a house is sent to a typical 1,500-gallon septic tank, with no interior plumbing change required. A pump chamber then sends the wastewater to the modified leach field, where it is evenly distributed over the layered system. For homes that required a completely new septic systems, the simplicity and low maintenance of the layer cake was very popular.

How Layer Cake Systems Remove Nitrogen

As opposed to using treatment tanks like the three other technologies used in this project, layer cakes treat nitrogen in the leach field by passing wastewater through a sand layer (where oxygen converts it to nitrate) and then through a sand/sawdust layer (where there is no oxygen and the nitrate converts to nitrogen gas).

Operating and Maintaining Layer Cake Systems

One of the benefits of the layer cake system is the low operating and maintenance requirements. Other than annual maintenance of a simple pump, this system has no other components that require inspection. Estimated annual costs are $300 or less.

LAYER CAKE SYSTEMS INSTALLED	**1**
AVERAGE NITROGEN CONCENTRATION BEFORE TREATMENT	**56 MG/L**
AVERAGE NITROGEN CONCENTRATION AT BOTTOM OF LEACH FIELD	**29 MG/L**
REDUCTION IN NITROGEN* FROM THIS HOME	**48%**

**This does not include a full year of data. Results from the Massachusetts Alternative Septic System Test Center indicate that layer cake systems can regularly achieve an 88% reduction in nitrogen.*

Engineering, Permitting, Installation & Costs

Site Design & Engineering

In the town of Falmouth, a registered civil engineer must prepare site plans to place a system on a property. A site plan identifies the placement of all system components – including tanks, compressors, plumbing, and electrical – together with site and groundwater elevations. After homeowners selected their desired nitrogen-reducing technology, they engaged a professional site engineer to design the placement of their systems.

Approval Process - Permitting

After final plans were completed and approved by the homeowner, project partners worked with the requisite town boards to approve the plans. All plans required approval from the Falmouth Board of Health. In most cases, Falmouth Conservation Commission approval was also required because the system was placed within 100 feet of a wetland resource. Both the Board of Health and the Conservation Commission were extremely supportive of the project and the homeowners who voluntarily took action to improve water quality in West Falmouth Harbor.

Additional state permitting was required for the layer cake and Eliminite systems because they were being installed for the very first time in Massachusetts.

Installation

Whether you're installing a conventional Title 5 system or a nitrogen-reducing system, septic system construction on an existing home site presents many challenges. Working around existing buildings, driveways, utilities, landscaping, and often challenging geology with heavy machinery is vastly more difficult than installing a system for new construction on a vacant lot. Nitrogen-reducing septic systems can be more complicated due to the need for additional tanks, blowers, pipes, and control panels.

For this project, installation required heavy machinery to dig large holes for concrete tanks that were over six feet wide and ten feet long, as well as to dig long trenches for piping to bring wastewater from the home to the treatment tanks. These large concrete tanks were delivered on trailers with large booms, which sometimes required moving landscaping to accommodate delivery.

In cases where homeowners were upgrading from a cesspool, underground utilities were relocated to accommodate the installation of a new leach field. Some installations encountered groundwater, which required the use of special equipment to ensure the stability of the hole and pumps to draw down high groundwater during tank placement.

Costs

Installation costs for any septic system range broadly depending on unique site conditions, such as groundwater elevation, soil type, existing building and landscaping features, and condition of each existing system (conventional system or cesspool). The major cost components for this project included engineering, equipment, installation, and landscaping.

A key learning of this project is that higher costs were related to specific site conditions, not the nitrogen-reducing technology itself.

Costs were higher for upgraded cesspools because a whole new leach field was required in addition to installing treatment tanks. A total of 11 cesspools were upgraded as part of this project.

ITEM	AVERAGE COST	COST RANGE
Equipment (denitrification tanks)	**$8,437**	**$4,146-$10,625**
Engineering	**$2,620**	**$606-$4,200**
Installation (adding a nitrogen-reducing system to an existing Title 5 system)	**$11,096**	**$10,600-$15,350**
Installation (full upgrade from a cesspool)	**$20,675**	**$17,720-$25,600**
Landscaping	**$2,142.97**	VARIABLE

Installing nitrogen-reducing septic system technology on an existing home site presents unique challenges to work around existing buildings, driveways, landscaping, and utilities.

Lessons Learned

1. **West Falmouth homeowners wanted to participate in this project.** They all recognized the negative effects of poor water quality on their homes and were willing to take action when offered a $10,000 subsidy.

2. **Neighborhood outreach was integral to the success of this project.** The West Falmouth Village Association and a local septic system installer became key allies in the effort to encourage homeowners to sign up for the project.

3. **Cost, not technology, is the main factor in successfully upgrading septic systems.** There are many vendors of nitrogen-reducing septic system technologies today. That was not the case even a few years ago. Today, the challenge is finding the cheapest option that works for each site.

4. **Upgrading on-site septic systems is not a one-size-fits-all project.** Each home is unique based on a number of challenges, including soils, utilities, home use, siting additional treatment tanks, and proximity to wetlands.

5. **West Falmouth wants more nitrogen-reducing septic systems.** The success of this program has led to a Phase II project, which will upgrade septic systems at an additional 10 homes in 2017 with a reduced $7,500 subsidy.

6. **The West Falmouth project provides a model that can be used to upgrade septic systems and reduce nitrogen pollution in similar neighborhoods all around Buzzards Bay.** Solving the nitrogen pollution problem in Buzzards Bay will depend on septic system upgrades. This project helps point the way forward for homeowners, town officials, and septic installers in all towns.

Although the installation of nitrogen-reducing septic system technology was invasive during construction (top photo), contractors and homeowners found innovative ways to keep the systems out of sight, but still accessible for monitoring. At this home, the homeowners used landscaping to hide the cover of their new Eliminite system in the driveway garden (inset photos).

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114 Front Street • New Bedford, Massachusetts 02740

(508) 999-6363
info@savebuzzardsbay.org
www.savebuzzardsbay.org

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