Watershed Nitrogen Management Plan

Town of Mashpee, Popponesset Bay, & Waquoit Bay East Watersheds

Technology Screening Report

Final Report
November 2007

STEARNS & WHELER LLC

Prepared for Town of Mashpee Sewer Commission

WATERSHED NITROGEN MANAGEMENT PLAN
TECHNOLOGY SCREENING REPORT

TOWN OF MASHPEE, POPPONESSET BAY, & WAQUOIT BAY EAST WATERSHEDS

Prepared for
MASHPEE SEWER COMMISSION

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EXECUTIVE SUMMARY

ES.1 REPORT AND PROJECT BACKGROUND

The Technology Screening Report is the second phase of the Watershed Nitrogen Management Plan (WNMP), which is being prepared to provide a comprehensive strategy for nitrogen removal in the Town of Mashpee, Popponesset Bay, and Waquoit Bay East Watersheds over the next 20 years.

The purpose of the Technology Screening Report is to identify and screen alternative wastewater collection, treatment, and disposal technologies, which will form the basis for the development of the Scenario Evaluation Report in the next phase of work. The Scenario Evaluation Report will identify a group of alternative wastewater management plans developed to meet the Project Planning Area's wastewater treatment and disposal needs. Information developed for this report will be combined with the Development and Evaluation of Alternatives to create the Alternative Screening Analysis Report required as part of the Project's Massachusetts Environmental Policy Act (MEPA) review process.

The report identifies specific technologies associated with:

- Decentralized technologies including:
  - Individual innovative and alternative (I/A) septic systems
  - Cluster systems
    - Those serving flows less than 10,000 gallons per day (gpd)
    - Those requiring a groundwater discharge permit (small wastewater treatment plants)
- Centralized facilities
  - Those facilities serving large areas of Town. These facilities are often municipally run and typically treat wastewater flows greater than 150,000 gpd.

Some additional components that are associated with cluster systems and centralized facilities are evaluated in this report. Those components include:

- Collection system
- Disinfection technologies
- Effluent disposal
- Water reuse technologies

Although described in Chapter 5, water reuse technologies are not considered part of traditional wastewater treatment. Therefore, they are presented for informational purposes and no recommendations are made on the use of these technologies. These technologies are often very costly and would require extensive piloting prior to implementation as part of any alternative.

In addition, the report examines other methods of reducing nitrogen through stormwater control, fertilizer management, oyster propagation, and groundwater treatment. All of these methods can provide a positive means of reducing nitrogen (to varying degrees), but they would be difficult to rely on for consistent, widespread performance. It is important to state that a number of these nitrogen reduction measures will vary in their nitrogen removal performance because of their reliance on natural systems and highly variable loadings. Many are not currently credited with nitrogen removal by regulatory agencies and therefore additional public education, management structure, and enforcement would be required in order for them to be considered a reliable, long-term means of nitrogen removal.

ES.2 TECHNOLOGY SCREENING CRITERIA

In addition to describing the various technologies that are included in this screening report, the advantages and disadvantages of each technology are presented. The screened technologies have system characteristics summarized with respect to a set of standard criteria to allow a side-by-side comparison. The standard criteria that are used for comparison are as follows.

A. **Suitability –** General technical ability to achieve improvements under local conditions.

B. **Implementability –** The ability to construct, operate, monitor, and manage.

C. **Performance –** The effectiveness and reliability in similar soils and environments, effects of seasonal population changes, and performance data from the 2007 Barnstable County Report on I/A technologies, where available.

D. **Long-term Maintenance –** This criterion is related to the complexity and number of mechanical components of each treatment process. Long-term track record (reliability) and the level of skill needed to maintain a technology are considered.

E. **Land Use –** Efficiency of land use (amount of land used).

F. **Aesthetics –** Visual impacts and potential odor emissions.

G. **Public Acceptance/Political Feasibility –** This criterion involves how the public may react to a specific type of treatment system.

H. **Institutional Concerns –** This includes permitting issues and state approval.

I. **Cost –** The relative costs of the various alternatives.

Costs can be influenced by any number of factors, including the construction bidding climate during the year of the project, material costs, level of treatment, location of facility, site specific conditions (i.e. high groundwater, abutters, drinking water protection, sensitive habitats and receptors, etc.), and permit/regulatory requirements. As a result, the costs are presented as "relative costs," and they eliminate some of these cost escalators that may not be specific to a technology and are often unknown.

However, during preliminary and final design cost estimates will be revised and factors that are specific to a technology or proposed location will be more readily identifiable.

ES.3 RECOMMENDATIONS OF THE TECHNOLOGY SCREENING REPORT

A. **Decentralized Treatment Alternatives.** Decentralized treatment technologies are systems that are not connected to a central, municipal treatment plant. They often include individual and multiple-home systems that have total flows less than 10,000 gpd and do not require a groundwater discharge permit. The multiple-home systems require a small wastewater collection system and are often called cluster systems. Cluster systems can exceed 10,000 gpd; however, they would then require a groundwater discharge permit and a small wastewater treatment facility rather than a large Title 5 or Innovative/Alternative system. The decentralized technologies that are evaluated and discussed in Chapter 4 are included in the list below.

- Title 5 systems
- Peat systems
- Glendon biofilter
- JET aerobic treatment systems
- Orenco system sand filter
- Tight tanks
- Waterless toilets
- Recirculating sand filter (non-proprietary)
- RUCK
- Bioclere
- Micro-, Nitri-, High-Strength, and Modular FAST
- Amphidrome
- Waterloo biofilter
- AdvanTex
- NitrexTM
- OAR
- RUCK CFT
- Cromaglass
- Norweco Singulair
- Omni Recirculating Sand Filter
- SeptiTech

Each technology is reviewed as part of the evaluation process in the report. The technologies that are recommended for further consideration are summarized in the following table. The table provides relative ranking for three categories – cost, performance, and other considerations. Performance refers to a technology's nitrogen removal ability. The other considerations include the screening criteria that are discussed in greater detail in Chapter 3.

Technology	Cost [1]	Performance [2]	Other Considerations [3]
FAST	Lower	Good	Highly Favorable
Bioclere	Moderate	Good	Highly Favorable
Nitrex™/Omni RSF	Higher	Good [5]	Highly Favorable
RSF	Moderate	Moderate	Highly Favorable
Norweco Singulair	Moderate	Good	Moderately Favorable
RUCK	Higher	Moderate	Highly Favorable
Amphidrome	Higher	Moderate [5]	Highly Favorable
Waterloo Biofilter	Higher	NA[4,5]	Highly Favorable
Advantex	Lower	NA[4,5]	Highly Favorable
SeptiTech	Moderate	Low	Highly Favorable
RUCK CFT	Higher	NA[4]	Less Favorable
Cromaglass	Moderate	Low	Less Favorable
OAR	Moderate	Low	Less Favorable

Notes:

(1) Lower Cost Ranking = <$5,000; Moderate Cost Ranking = $5,000 - $10,000; Higher Cost Ranking = >$10,000. Refer to Table 4-1 for a more detailed breakdown of costs.

(2) Performance ranking is in reference to the number of systems that had median nitrogen concentrations below 19 mg/L, as documented in the County report. Good refers to systems with more than 50% achieving 19 mg/L; moderate refers to systems with between 25% and 50% achieving 19 mg/L; low refers to systems with less than 25% achieving 19 mg/L.

(3) Other considerations include a relative ranking of the screening criteria discussed in Chapter 3, including aesthetics, land use, and long term maintenance.

(4) NA indicates technologies with limited performance data as summarized in the County report.

(5) Data based on five or less systems as summarized in the County report.

All of the technologies identified in the above table are allowed by MassDEP and are approved for use (whether Pilot, Provisional, or General Use). Although none of these technologies are ruled out completely, some of these technologies have shown better performance (based on the Barnstable County report) on Cape Cod. The following technologies are considered more favorable for nitrogen removal applications within the Project Planning Area:

- FAST
- Recirculating Sand Filters (RSF)
- Bioclere
- Nitrex/Omni RSF
- RUCK
- Amphidrome
- Waterloo Biofilter
- Norweco Singulair

Other technologies either have very limited performance data or other considerations that make them less favorable.

B. **Small Wastewater Treatment Facilities.** Small wastewater treatment facilities, similar to a number of facilities found in Mashpee, utilize biological nitrogen removal (BNR) processes that are compact in size and are generally more mechanized than the individual and multiple-home, on-site-type systems presented in Chapter 4. These facilities can produce a treated effluent that meets the permitted standards of 30 mg/L BOD_5, 30 mg/L TSS, and 10 mg/L nitrate-N. Small wastewater treatment facilities typically serving less than 50,000 gpd are discussed in the first part of Chapter 5. The small facilities, or package plants, that are discussed include:

- Rotating biological contactors (RBC)
- Sequencing batch reactors (SBR)
- Amphidrome
- Membrane bioreactors (primarily Zenon)
- Micro-FAST and Modular FAST
- Bioclere

The following summarizes the criteria that are considered in evaluating the small wastewater treatment (package) plants.

Technology	Cost (1)	Performance (2)	Other Considerations (3)
SBR	Higher	Good	Highly Favorable
Amphidrome	Lower	Moderate	Highly Favorable
Zenon	Higher	Good	Moderately Favorable
RBC	Lower	Moderate	Moderately Favorable
FAST	Lower	Moderate	Moderately Favorable
Bioclere	Higher	Moderate	Moderately Favorable

Notes:

(1) Lower Cost Ranking = <$60/gallon; Higher Cost Ranking = >$60/gallon. Refer to Table 5-2 for a more detailed breakdown of costs.

(2) Moderate Performance ranking indicates that it is capable of treating nitrogen to less than 10 mg/L. Good Performance ranking indicates that it is capable of treating nitrogen to less than 6 mg/L.

(3) Other considerations include a relative ranking of the screening criteria discussed in Chapter 3, including aesthetics, land use, and long term maintenance.

RBCs, SBRs, Amphidrome and Zenon are recommended for further consideration due to the flexibility in relation to providing treatment for relatively small wastewater flows and their current use throughout Mashpee. Sequencing Batch Reactors (SBRs) are often more expensive for smaller flows but become more cost effective as the flows increase due to the change from precast structures to cast-in-place concrete; they also remain fairly compact and have other process advantages over some of the more package type systems like Bioclere, Amphidrome, and FAST systems. Those package type systems are more cost effective at lower flows but are less flexible when it comes to any potential expansion.

Bioclere and FAST systems would not be recommended for use in the Project Planning Area as they would be introducing another technology into a planning area that already has a variety of systems. If the Town of Mashpee (or a future sewer district) were to take over management of the existing facilities, the best option would be to minimize the number of different systems and maximize common components, spare parts, and operational requirements to simplify the operations and maintenance activities for multiple wastewater treatment facilities.

C. **Centralized Treatment Facilities.** Centralized facilities capable of treating larger wastewater flows (typically greater than 150,000 gpd) are discussed separately from the package plants. Chapter 5 discusses the following technologies:

- Activated Sludge/ Modified Ludzack-Ettinger Process
- Activated Sludge/ Extended Aeration
- RBC
- SBR
- Activated Sludge/ Plug Flow Systems
- Membrane Biological Reactor
- Biological aerated filters
- Denitrification filters
- Constructed wetlands
- Solar Aquatics

Of the previously mentioned technologies, the following list summarizes those that are recommended for further consideration as the Watershed Nitrogen Management Plan process continues.

- Activated Sludge/Extended Aeration
- Sequencing Batch Reactor
- Membrane Biological Reactor
- Denitrification Filters (in combination with other centralized technologies)

RBCs, although very common in Mashpee, may become cost prohibitive for a large scale wastewater treatment facility (as flows exceed 0.5 mgd) because of the large structure required to house such a facility and to shelter components in winter conditions. On the other hand, the recommended technologies can have large open tanks or, in the case of MBRs, a smaller footprint, reducing the cost of structures. Therefore, RBCs would not be considered for a centralized facility.

D. **Water Reuse Technologies.** Conventional wastewater treatment systems typically achieve levels of 6 to 10 mg/L total nitrogen; they can be upgraded for enhanced nitrogen removal and achieve an average of 3 mg/L total nitrogen. However, additional (non-conventional) wastewater treatment can be provided downstream from most of the centralized treatment technologies discussed in order to obtain an effluent quality suitable for a variety of water reuse options. Chapter 5 discusses technologies that may be considered for water reuse applications. The technologies are described, and advantages and disadvantages are presented. As identified previously, these are often costly additions with minimal increase in performance. The technologies that can achieve less than 3 mg/L total nitrogen (the current accepted limit of wastewater treatment technology) are identified and discussed, but they are unlikely to be recommended and are presented for informational purposes. These technologies include:

- Reverse osmosis
- Ultrafiltration
- Electrodialysis
- Adsorption
- Advanced oxidation technologies
- Precipitation
- Ion exchange
- Break point chlorination
- Membrane filtration

E. **Disinfection Alternatives.** It is very likely that any treatment facilities constructed in the Project Planning Area will be required to provide disinfection. Therefore, alternative technologies to provide suitable disinfection are discussed in Chapter 5. The technologies considered are:

- Chlorination
- Ozonation
- Ultraviolet (UV) radiation

Based on the higher costs and safety concerns associated with chlorination and ozonation, UV disinfection is the only technology that is recommended.

F. **Collection System Technologies.** Prior to reaching a treatment facility, wastewater flows through a collection system. The following collection system technologies are discussed in Chapter 6:

- Gravity sewers and lift stations
- Pressure sewers and grinder pumps
- Septic tank effluent sewers (pump and gravity systems)

- Vacuum sewers
- Combination of technologies

Many collection systems involve a combination of the various technologies. The most likely combination that will be practical for use in the Project Planning Area involves gravity and low pressure systems, as discussed in the Sewer Modeling and Preliminary Design Evaluations Guidance Document and Case Study Report prepared for Barnstable County.

When a project area consists of rolling terrain and large numbers of properties located in low areas along ponds, wetland, rivers and estuaries, a combination of technologies is typically most cost effective. The most common technology combination is gravity and pressure sewers.

Gravity systems can be more expensive to install but have lower operations and maintenance costs. Pressure sewers allow much shallower excavations and provide an easier means of serving low elevation properties; however, they require power at each property served. While vacuum sewers do not have the power requirements of pressure sewers, they are limited in length and are difficult to expand. Although vacuum sewer costs are similar to that of a gravity system, the limited flexibility makes these a less favorable option.

G. **Effluent Discharge Technologies.** All wastewater treatment facilities require a means of discharging and/or reusing treated effluent. The technology selected for effluent disposal needs to be specific to the discharge site to minimize the impacts of treated effluent on nearby surface waters and groundwater, while utilizing any potential site's unique features. Land availability, nearby land use, discharge technology, and distance from the treatment plant also play a role in determining suitable effluent discharge sites. Chapter 6 describes available effluent discharge/recharge technologies and provides advantages and disadvantages for each in order to screen the technologies. The alternatives considered include:

- Sand infiltration beds
- Subsurface infiltration
- Spray irrigation
- Well injection
- Wick well
- Drip irrigation
- Ocean outfall
- Wetland restoration

The alternatives that are recommended for further consideration include:

- Wetland restoration
- Sand beds
- Subsurface infiltration
- Spray/drip irrigation

Wetland restoration is a highly favorable alternative because construction costs will typically be low due to the smaller amount of excavation and site work involved. Operation and maintenance costs are also low for wetland restoration. An added advantage to wetland restoration is the additional nitrogen removal that is possible as treated effluent flows through the wetland system. It should be noted that although wetland restoration has many advantages, it will likely not be sufficient to handle all of the effluent recharge needs of the Project Planning Area. It should still be considered as a part of the solution to handling effluent recharge. Permitting and approval issues also complicate their use and can increase the cost associated with implementing these types of systems.

Sand beds are typically a cost-effective alternative because of the higher loading rates that are allowed. Although the loading rate is site-specific, it will usually be higher than any of the other alternatives. The disadvantages of sand beds include the lack of opportunity for secondary use of the land and limited additional nitrogen removal.

Subsurface infiltration has the advantage of allowing a secondary use of the land. The disadvantages include the high construction costs that result from extensive excavation, piping, and equipment. Limited additional nitrogen removal may be achieved through the leaching area.

The two irrigation alternatives (spray and drip) have the advantage of providing additional nitrogen removal by means of vegetation. Construction costs may be lower than subsurface infiltration because excavation primarily involves laying a small diameter water pipe. The disadvantages include the need for alternative methods of disposal during winter months, the lower loading rates allowed, and the need for a higher level of treatment (typically).

Ocean outfalls are currently prohibited by the Ocean Sanctuaries Act and therefore will not be considered. Wick wells and injection wells have advantages of small footprints; however, they are not recommended due to limited performance data and issues associated with the fouling of the wells and the resultant maintenance needed for these systems. Although still being considered, spray and drip irrigation systems may be limited by the large area requirements. In addition, MassDEP may restrict their use during the winter months, which would require a secondary effluent disposal system.

H. **Stormwater Treatment Technologies.** Stormwater runoff is typically a significant nitrogen source, although this depends on the amount of impervious area (roofs, driveways, roads, parking lots, etc.) in a planning zone. Reduction of impervious areas can reduce the resulting pollutant loads. Town bylaws can be used to encourage Low Impact Development (LID), to regulate amounts of impervious areas, and to reduce the amount of runoff that flows to paved roads. However, runoff from paved roads is also a significant contributor to nitrogen loads.

Chapter 7 presents a discussion of various nitrogen removal alternatives that do not involve wastewater management. Included in the discussion is an evaluation of various stormwater technologies. The stormwater management alternatives that are evaluated and screened according to the previously discussed criteria include:

- Dry extended detention basins
- Wet retention ponds
- Infiltration basins
- Stormwater wetlands
- Submerged gravel wetlands
- Bioretention (rain gardens)
- Water quality swales
- Porous pavement
- Infiltration trenches

As presented earlier, the use of other methods of reducing nitrogen through stormwater control, fertilizer management, oyster propagation, and groundwater treatment has its limitations when trying to achieve a regulated limit. Best management practices for stormwater control, fertilizer management, and other innovative non-wastewater approaches can provide a positive means of reducing nitrogen but are difficult to rely on for consistent performance. It is important to identify that a number of these nitrogen control measures will vary in their nitrogen removal performance because of their reliance on natural systems and highly variable loadings. Many are not currently credited with nitrogen removal by regulatory agencies and would therefore require additional public education, management structure, and enforcement to be considered a reliable/long term means of nitrogen removal.

TOWN OF MASHPEE
TECHNOLOGY SCREENING REPORT
WATERSHED NITROGEN MANAGEMENT PLAN

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GLOSSARY OF COMMON ACRONYMS

AOT	Advanced Oxidation Technologies
BAF	Biological Aerated Filter
BOD	Biochemical Oxygen Demand
BNR	Biological Nitrogen Removal
CCC	Cape Cod Commission
CMR	Code of Massachusetts Regulations
DO	Dissolved Oxygen
ENF	Environmental Notification Form
FAST	Fixed Activated Sludge Treatment
FFL	Falmouth Friendly Lawns
GAC	Granular Activated Carbon
gpd	Gallons per Day
gpd/ft^2	Gallons per day per square foot
GWDP	Groundwater Discharge Permit
I/A	Innovative/Alternative
LID	Low Impact Development
LOT	Limit of Technology
MassDEP	Massachusetts Department of Environmental Protection
MBR	Membrane Bioreactor
MEP	Massachusetts Estuaries Project
MEPA	Massachusetts Environmental Policy Act
mgd	Million Gallons per Day
mg/L	milligrams per liter
MLE	Modified Ludzack-Ettinger
MLSS	Mixed Liquor Suspended Solids
NAR	Needs Assessment Report
NH_3-N	Ammonia Nitrogen
NO_3-N	Nitrate Nitrogen
NPC	Notice of Project Change
O&M	Operations and Maintenance
PAC	Powdered Activated Carbon
PPA	Project Planning Area
PRB	Permeable Reactive Barrier
RBC	Rotating Biological Contactor
RO	Reverse Osmosis
RSF	Recirculating Sand Filter
SBR	Sequencing Batch Reactor
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TSS	Total Suspended Solids
USGS	United States Geological Survey

GLOSSARY OF COMMON ACRONYMS
(continued)

USEPA	United States Environmental Protection Agency
WNMP	Watershed Nitrogen Management Plan
WWTF	Wastewater Treatment Facility

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

1.1 REPORT AND PROJECT BACKGROUND

This Technology Screening Report is the second report that will be produced as part of the Watershed Nitrogen Management Plan (WNMP) Project. This report follows the Needs Assessment Report dated April 2007, which documented the Project Planning Area's (PPA) wastewater needs and related issues. Figure 1-1 depicts the PPA.

The purpose of the Technology Screening Report is to identify and screen alternative wastewater collection, treatment, and disposal technologies and to form part of the basis for the development of the Scenario Evaluation Report (in the next phase of work), which will identify a group of alternative wastewater management plans that will be formulated to meet the PPA's wastewater treatment and disposal needs. Information developed as part of this report will be combined with the Development and Evaluation of Alternatives to create the Alternative Screening Analysis Report.

The WNMP is being prepared to provide a comprehensive strategy for nitrogen removal in the Town of Mashpee, Popponesset Bay and Waquoit Bay East Watersheds over the next 20 years.

1.2 ORGANIZATION OF THE TECHNOLOGY SCREENING REPORT

The report is divided into the following seven chapters: Chapter 1 presents the general introductory information about the WNMP Project and the Alternatives Screening Analysis Report. Chapter 2 reviews the identified Priority Areas and their wastewater needs. Chapter 3 describes the approach and criteria used for screening alternative treatment and disposal technologies. Chapters 4 through 6 identify and screen collection, treatment, and discharge technologies for centralized and decentralized technologies. Chapter 7 identifies and screens methods of nitrogen reduction other than wastewater treatment.

Chapter 2

Delineation of Wastewater Priority Areas

CHAPTER 2

DELINEATION OF WASTEWATER PRIORITY AREAS

2.1 INTRODUCTION

The Needs Assessment Report (NAR) identified Priority Areas in the Project Planning Area (PPA). Prioritization was based on the nitrogen loading per acre, estimated year round and seasonal occupancy, Massachusetts Estuaries Project (MEP) findings and other related issues in those areas. Prioritization was assigned as either Primary, Secondary, or Tertiary priority for nitrogen loading concerns. This Chapter briefly reviews each of these Priority Areas and summarizes their needs as developed in the NAR. These areas are identified on Figure 2-1.

2.2 PRIORITY AREAS

The primary, secondary, and tertiary Priority Areas are identified below. The reasons for the respective classifications are also summarized. Table 2-1 (9-1 from NAR) shows the various criteria considered in grouping such areas.

A. **Primary Priority Areas.** These Areas are identified in red on Figure 2-1:

Area M-1 "Johns Pond" – this Priority Area is located on the western side of Mashpee and includes planning zones 1511, 1611, 1621, 1622, 1632, 1641, 1651, 1652, 1661, 1671, 1672, 1673, 1681, 1682, 2111, 2121, and 2131. The following factors resulted in the classification of this as a primary Priority Area:

- Within the Waquoit Bay watershed
- Large number of planning zones with moderately high to high nitrogen loading rates
- Relatively high concentration of year round residents and businesses
- There is an existing wastewater treatment facility (WWTF) within this priority area (Southport), which may be suitable for expansion

- A portion of a public supply well watershed/groundwater protection district is within the priority area

Area M-2 "Mashpee Central" – this Priority Area is located in the center of Mashpee, including the Mashpee rotary and Mashpee Commons, and includes planning zones 1522, 1531, 1541, 1542, 1551, 1552, 1571, 2211, 2221, 2231, 2241, 2242, 2243, 2251, 2252, 2271, 2272, and 2421. The following factors resulted in the classification of this as a primary Priority Area:

- Within the Popponesset Bay watershed; relatively far downstream in the watershed
- The majority of planning zones have moderately high or high nitrogen loading rates
- Relatively high concentration of year round residents and businesses
- There are three existing WWTFs in this priority area (Mashpee Commons, Southcape Village, and Windchime Point), some of which may be suitable for expansion

Area M-3 "Shoestring Bay" – this Priority Area is located on the eastern side of Mashpee and includes planning zones 1432, 1442, 1451, 2501, 2511, 2521, 2522, 2531, 2532, 2533, 2541, 2542, 2543, 2544, 2551, 2552, 2561, 2562, 2563, 2564, 2571, 2572, 2581, 2582, 2591, and 2592. The following factors resulted in the classification of this as a primary Priority Area:

- Within the Popponesset Bay watershed; relatively far downstream in the watershed
- Many of the planning zones have moderately high or high nitrogen loading rates
- Many of the planning zones consist of year round residences
- A portion of a public supply well watershed/groundwater protection district is within the priority area
- There is an existing WWTF in this priority area (Willowbend), which may be considered suitable for expansion after further evaluation

B. **Secondary Priority Areas.** These Areas are shown in blue on Figure 2-1:

Area M-4 "Santuit Pond" – this area is located on the northeastern corner of Mashpee, including Santuit Pond, and includes planning zones 1311, 1321, 1322, 1331, 1332, 1341, 1351, 1352, 1361, 1371, 1372, 1381, and 1382. The following factors were considered in prioritization:

- The majority of the planning zones have moderately high nitrogen loading rates
- The Town of Mashpee has identified phosphorous loading issues in Santuit Pond

- The planning zones are all predominantly year round residences
- The watershed for a public supply well/groundwater protection district falls within this area

Area M-5 "Mashpee River" – this Priority Area is in the north-central part of Mashpee and includes much of the Mashpee River and its recharge area. This Priority Area includes planning zones 1213, 1221, 1222, 1223, 1241, 1251, 1252, 1253, 1261, 1271, 1411, 1431, 1441, 1521, 1561, and 1562. The following factors were considered in prioritization:

- Within the Popponesset Bay watershed
- The planning zones within this area are predominantly year round residences
- The Mashpee zoning bylaws have established a Mashpee River Protection District to protect the water resources
- A portion of a public supply well watershed/groundwater protection district is within the priority area

Area M-6 "Jehu Pond" – located on the southwestern side of Mashpee, this Priority Area includes Jehu Pond and Hamblin Pond. It includes planning zones 2321, 3421, 3422, 3431, 3441, 3511, 3512, 3521, 3531, and 3541. The following factors were considered in classifying this as a secondary Priority Area:

- Moderately high nitrogen loading in most of the planning zones in the area
- Located in the lower portions of the Waquoit Bay watershed
- A small portion of a public supply well watershed/groundwater protection district is within the priority area

Area M-7 "Popponesset Creek" – this Priority Area is located around Popponesset Bay and Popponesset Creek and includes planning zones 3111, 3121, 3131, and 3141. The following were considered:

- Located in the furthest downstream section of the Popponesset Bay watershed
- All planning zones in this area have moderately high nitrogen loading per acre

Area F-1 "Red Brook" – this area consists of the Falmouth portion of the PPA that is within the Red Brook subwatershed. This Priority Area was identified based on the following criteria:

- Located far downstream in the Waquoit Bay East watershed
- Has moderate nitrogen loading rates (high existing rates)
- A small portion of a public supply well watershed is within the priority area

Area S-4 "Sandwich Quashnet" – this portion of Sandwich is not in a freshwater subwatershed; groundwater flows directly into the Quashnet River subwatershed. This was identified as a secondary Priority Area based on:

- Moderately high nitrogen loading rates
- Most residences are year round
- Located in a Zone II area

C. **Tertiary Priority Areas.** These Areas are shown as yellow on Figure 2-1:

Area M-8 "Mashpee-Wakeby Pond" – this area is located at the very northern tip of Mashpee and includes planning zones 1111, 1112, 1113, 1121, 1122, 1131, 1141, 1151, 1211, 1212, and 1231. The factors resulting in tertiary prioritization include:

- Far upstream in the Popponesset Bay watershed (a large portion of the nitrogen load is naturally attenuated as groundwater flows through the Mashpee-Wakeby Pond)
- Low nitrogen loading per acre
- A portion of a public supply well watershed/groundwater protection district is within the priority area

Area M-9 "MMR" – this area consists of the portion of the Massachusetts Military Reservation within Mashpee (planning zone 4111) and planning zone 1631. The factors resulting in tertiary prioritization include:

- Far upstream in the Waquoit Bay watershed
- Low nitrogen loading per acre
- Majority of the area is open space
- Connected to treatment plant with discharge outside the PPA

- A small portion of a public supply well watershed/groundwater protection district is within the priority area

Area M-10 "Mashpee East" – this Priority Area is located on the eastern edge of Mashpee, bordering the village of Cotuit (Town of Barnstable). It includes planning zones 1412, 1421, and 1422. The factors resulting in tertiary prioritization include:

- Low nitrogen loading per acre
- The existing WWTF in this priority area (Stratford Ponds) may have minimal potential for expansion
- A portion of a public supply well watershed/groundwater protection district is within the priority area

Area M-11 "Quashnet River" – this area lies in the Quashnet River and Red Brook watersheds in Mashpee and includes planning zones 2141, 2151, 2161, 2261, 2281, and 2291. The reasons for its tertiary prioritization include:

- Located somewhat upstream in the Waquoit Bay watershed
- Low to moderate nitrogen loading per acre
- Large portions are open space
- There is an existing WWTF in this priority area (Mashpee High School), which may be suitable for expansion
- A public supply well watershed/groundwater protection district is within the priority area

Area M-12 "Mashpee South" – this area lies in the Mashpee River, Ockway Bay, Hamblin Pond, and Jehu Pond watershed in Mashpee and includes planning zones 2311, 2411, 2422, 2431, 2432, 2441, 2442, 2443, 2451, and 3411. The reasons for its tertiary prioritization include:

- Located somewhat upstream in the Waquoit Bay watershed
- Mostly low nitrogen loading per acre
- Large portions are open space
- A portion of a public supply well watershed/groundwater protection district is within the priority area

Area M-13 "New Seabury" – this area consists mostly of properties considered part of the New Seabury development. This includes planning zones 3211, 3221, 3222, 3223, 3224, 3225, 3231, 3232, 3241, 3242, 3311, 3312, 3321, 3331, 3341, 3342, 3343, 3344, 3351, 3361, 3362, 3371, and 3372. Although most of the area has relatively high nitrogen loading rates, the reasons for its tertiary prioritization include:

- Not located in either Waquoit Bay or Popponesset Bay watersheds
- Predominantly seasonal residences
- There is an existing WWTF (New Seabury) in this priority area, which may be suitable for expansion
- A portion of a public supply well watershed/groundwater protection district is within the priority area

Area F-2 "Falmouth Quashnet" – this area consists of the Falmouth portion of the PPA that is within the Quashnet River subwatershed. The following considerations resulted in this tertiary prioritization:

- Predominantly seasonal residences
- Relatively low nitrogen loading rates

Area F-3 "Falmouth North" – this area of Falmouth is within the subwatershed that flows through Ashumet Pond. The following considerations resulted in this tertiary prioritization:

- Located high up in the Waquoit Bay East watershed
- Relatively low nitrogen loading rates
- A portion of a public supply well watershed is within the priority area

Area S-1 "Sandwich West" – this is the portion of Sandwich that flows through freshwater ponds in Mashpee prior to flowing into the Quashnet River subwatershed. The following considerations resulted in this tertiary prioritization:

- Located high up in the Waquoit Bay East watershed
- Relatively low nitrogen loading rates
- A portion of a public supply well watershed is within the priority area

Area S-2 "J Well" – this small portion of Sandwich is the subwatershed to a public water supply well. This was considered a tertiary Priority Area based on the following considerations:

- Located high up in the Waquoit Bay East watershed
- Moderately high nitrogen loading rates
- A public supply well watershed is within the priority area

Area S-3 "Snake Pond" – groundwater in this portion of Sandwich flows through Snake Pond in Sandwich prior to flowing into the Quashnet River subwatershed. The following criteria were considered for this Priority Area:

- Located high up in the Waquoit Bay East watershed
- Moderate nitrogen loading rates
- Located in a Zone II area

Area S-5 "Sandwich Popponesset" – this is the portion of Sandwich that contributes to the Popponesset Bay watershed. All of the groundwater in this priority area flows through a freshwater pond. This was classified as a tertiary Priority Area based on the following considerations:

- Located high up in the Popponesset Bay watershed
- Relatively low nitrogen loading rates
- Located in a Zone II area

Area B-1 "Barnstable Freshwater" – this is the portion of Barnstable that contributes to Popponesset Bay's freshwater subwatershed. Following are some of the characteristics of this Priority Area:

- Located high up in the Popponesset Bay watershed
- Relatively low nitrogen loading rates
- A portion of a public supply well watershed is within the priority area

Area B-2 "Shoestring Bay Barnstable" – this area of Barnstable is part of the Shoestring Bay subwatershed.

- Moderate nitrogen loading rates
- A portion of a public supply well watershed is within the priority area

Area B-3 "Pinquickset Cove" – this part of Barnstable makes up the entire Pinquickset Cove subwatershed.

- Relatively low nitrogen loading rates
- Primarily seasonal residences

Area B-4 "Popponesset Bay" – this is the portion of the Popponesset Bay subwatershed that is contributed by parcels in Barnstable.

- Relatively low nitrogen loading rates
- Primarily seasonal residences

Mashpee planning zones 3451 and 3381 were not included in the Priority Areas due to the lack of wastewater nitrogen loads. These areas are predominantly beach area.

The 2007 Needs Assessment Report summarized the nitrogen loads by town and by planning area. Table 2-2 (Table 7-9 from the NAR) summarizes the total nitrogen load per town. Table 2-3 (Table 8-2 from the NAR) summarizes these loads by planning area. Following submittal of the 2007 NAR, it was determined that the infiltration load on golf courses was overestimated and therefore Table 2-3 is a revised version of Table 8-2 from the NAR reflecting this change. This information will become the basis of alternative scenario development in the next phase of this project and technologies identified in this report will be considered as a means to reduce these nitrogen levels to achieve Total Maximum Daily Loads (TMDLs).

Chapter 3

Screening Approach and Criteria

CHAPTER 3

SCREENING APPROACH AND CRITERIA

3.1 INTRODUCTION

The purpose of this report is to identify and screen alternative technologies to be used in evaluations in the next phase of this study. Technologies for nitrogen reduction will be classified as wastewater treatment options, stormwater treatment options, and other options. This chapter describes the approach and criteria for identifying and screening alternative technologies.

3.2 METHODOLOGY FOR IDENTIFICATION AND SCREENING OF ALTERNATIVE WASTEWATER TREATMENT TECHNOLOGIES

The following groups of nitrogen reduction options will be identified and screened:

1. Decentralized wastewater treatment technologies.

2. Centralized wastewater treatment technologies.

3. Collection system technologies.

4. Effluent discharge technologies.

5. Stormwater treatment technologies.

6. Other nitrogen reduction alternatives.

Each of these groups is identified and discussed on the following pages.

A. **Decentralized Treatment Technologies.** Decentralized treatment technologies are described for this report (detailed in Chapter 4) as technologies that are regulated under both 310 CMR 15.000 (Title 5) regulations for flows less than 10,000 gallons per day (gpd), and by 314 CMR 5.000 (the Ground Water Discharge Permit Program) regulations for flows greater than 10,000 gpd. Decentralized alternatives are typically used for individual units or cluster systems (which may include small wastewater treatment systems or package plants), which are typically privately owned or only serve specific areas of a Town. The following decentralized treatment and discharge technologies will be identified and screened (this list is based on the Massachusetts Department of Environmental Protection's (MassDEP) summary of innovative and alternative (I/A) technologies approved for use in Massachusetts as of January 2007):

1. **Individual and Multiple Unit Systems (Flows Less Than 10,000 gpd).** The following technologies are discussed in Chapter 4. There are three basic types: those not credited by MassDEP for nitrogen removal, non-discharge systems, and those credited for nitrogen removal.

a. On-site systems that are not considered nitrogen-reducing technologies are discussed in two general categories, as follows:

- General systems, which include some I/A technologies that have not yet been approved for general use as of January 2007, including:
  - Title 5 septic systems
  - Peat systems
  - Glendon Biofilter

- I/A systems that have been approved for general use by MassDEP as of January 2007 (these systems do provide some degree of nitrogen removal, but are not approved for nitrogen removal credits in nitrogen sensitive areas)
  - JET aerobic wastewater treatment
  - Orenco intermittent sand filter

b. Non-discharge systems:

- Tight tanks
- Waterless toilets

c. On-site nitrogen removal systems, also called I/A technologies, can be grouped into three categories:

- Nitrogen removal systems approved for general use by MassDEP in nitrogen-sensitive areas as of January 2007, including:
  - recirculating sand filters that comply with Title 5
  - RUCK® systems (for flows less than 2,000 gpd)

- Nitrogen removal systems approved for provisional use by MassDEP in nitrogen-sensitive areas as of January 2007, including:
  - Bioclere
  - MircoFAST, High Strength FAST, NitriFAST, and Modular FAST
  - Amphidrome
  - Waterloo Biofilter
  - AdvanTex
  - Nitrex™

- Nitrogen removal systems approved for piloting use by MassDEP in nitrogen-sensitive areas as of January 2007, including:
  - OAR
  - RUCK® CFT
  - Cromaglass WWT System
  - Amphidrome Process
  - Norweco Singulair
  - Omni Recirculating Sand Filter
  - SeptiTech

2. **Cluster Systems (Flows Greater Than 10,000 gpd).** The following technologies are discussed in Chapter 5 because of their larger scale in comparison to individual on-site systems.

a. Rotating biological contactors (RBCs)
b. Sequencing batch reactors (SBRs)
c. Amphidrome systems
d. Zenon systems
e. Fixed activated sludge treatment (FAST) systems
f. Bioclere systems

These technologies will be screened based on their suitability in the PPA for individual unit applications, for cluster systems, and for small wastewater treatment facilities based on the criteria described in this chapter.

B. **Centralized Treatment Technologies.** Centralized wastewater collection, treatment, and discharge technologies are defined as technologies associated with new and existing wastewater treatment facilities and designed to handle flows from various locations/watersheds in the PPA or serve the PPA on a watershed basis. Standard centralized treatment system components include preliminary and primary treatment, secondary/advanced treatment, and effluent discharge. Systems may also include flow equalization, effluent filtration, and effluent disinfection depending on the type of treatment process, the facility location, and permitting requirements as set by MassDEP. The following list summarizes the centralized treatment and discharge technologies which will be evaluated and screened in this report – the treatment technologies are discussed in Chapter 5 and collection and discharge in Chapter 6:

1. **Secondary/Advanced Treatment (Small Wastewater Treatment Facilities).**

a. RBCs
b. SBR process
c. Amphidrome
d. Zenon membrane technology
e. FAST systems
g. Bioclere
h. Wetlands
i. Effluent filters

2. **Secondary/Advanced Treatment (Centralized Facilities).**

a. Moderate Level of Performance (6 – 10 mg/L Total Nitrogen [TN])

- Modified Ludzack-Ettinger (MLE) activated sludge process
- Activated Sludge/Extended Aeration
- RBCs
- SBR process

b. Higher Level of Performance (3 – 6 mg/L TN)

- Activated Sludge/Plug Flow
- SBR process
- Activated Sludge/Extended Aeration
- Membrane Bioreactor
- Fixed Film systems

b. Variable Nitrogen Removal (Natural Systems)

- Constructed Wetlands
- Solar Aquatics

c. Reuse Technologies

- Reverse Osmosis (RO)
- Ultrafiltration
- Electrodialysis

3. **Advanced Nitrogen Removal (<3 mg/L TN)**

a. Adsorption
b. Advanced Oxidation Technologies
c. Precipitation
d. Ion Exchange
e. Breakpoint Chlorination
f. Membrane Filtration

4. **Disinfection**

a. Chlorination
b. Ozone
c. Ultraviolet

5. **Collection**

a. Gravity
b. Pressure
c. Vacuum

6. **Effluent Discharge Technologies**.

a. Sand infiltration beds
b. Subsurface infiltration
c. Spray irrigation
d. Well injection
e. Wick wells
f. Drip irrigation
g. Ocean outfall
h. Wetland restoration

C. **Screening of Technologies.** Each of the wastewater management technologies will be described to allow the reader to understand the technology and related process. Advantages and disadvantages will be presented. The screened technologies will then have system characteristics summarized with respect to a set of standard criteria to allow a side-by-side comparison. The summary will be presented as a matrix followed by a recommendation on the technology being evaluated.

The following is a summary of the standard criteria that will be used for screening alternative technologies:

1. **Suitability.** General technical ability to achieve improvements under local conditions will be considered.

2. **Implementability.** The ability to construct and operate will be considered. Also considered will be parties responsible for implementation and any necessary regulatory changes. Implementation issues will be discussed, such as methods the Towns or a wastewater management district could use to monitor and operate on-site systems or treatment plants over the expected lifetime of the treatment system. Management issues to be discussed include public or private ownership of treatment facilities, obtaining land for multiple home treatment sites, and Town

regulations needed to address the potential administrative issues.

3. **Performance.** The real world effectiveness and reliability in similar soils and environments will be evaluated. Effects of seasonal population changes will also be considered. Where available, performance data from the 2007 Barnstable County Report on I/A technologies will be included in the evaluation.

4. **Long-term Maintenance.** This criterion is related to the complexity and number of mechanical components of each treatment process. Long-term track record (reliability) and the level of skill needed to maintain a technology will be considered. Reliability and technical feasibility of a process or plan is a function of how consistently it is expected to function and to achieve required effluent limits. In general, long-term reliability decreases as the complexity of mechanical equipment increases.

5. **Land Use.** Efficiency of land use (amount of land used) will be a factor.

6. **Aesthetics.** Visual impacts and potential odor emissions will be considered.

7. **Public Acceptance/Political Feasibility.** This criterion involves how the public may react to a specific type of treatment system. Relative costs, aesthetics, and perceived impacts will all be included.

8. **Institutional Concerns.** This includes permitting issues and state approval.

9. **Cost.** The relative costs of the various alternatives will be considered. How the costs can be distributed to taxpayers, developers, and individual property owner/customer will be evaluated as part of later phases as costs for specific alternatives are developed.

D. **Stormwater Treatment Technologies.** Stormwater treatment is intended to reduce flooding, prevent runoff from discharging into water bodies, and remove pollutants from runoff. The following technologies will be discussed:

- Dry extended detention basins
- Wet retention ponds
- Stormwater wetlands
- Water quality swales

- Infiltration trenches
- Infiltration basins
- Bioretention (Rain gardens)
- On-lot treatment

E. **Other Nitrogen Reduction Alternatives.** Although nitrogen comes predominantly from wastewater and stormwater, there are other sources. Management of these sources through alternative means will provide additional benefit to the PPA. However, management of nitrogen to meet TMDLs will not likely rely solely on these methods because of the variability in nitrogen concentration and treatment/removal performance. The following alternative nitrogen reduction options will be considered:

- Fertilizer education and management
- Landscape design practices
- Animal waste management
- Green rooftops
- Open space acquisition
- Public education

F. **Nitrogen Mitigation Alternatives.** The ongoing research into cultivating oysters and seeding them in heavily nitrogen-loaded embayments for nitrogen removal will be reviewed and discussed. Additionally, the use of groundwater treatment filters and vegetative systems will be discussed in relation to nitrogen reduction from various sources.

Chapter 4

Decentralized Treatment Alternatives

CHAPTER 4

DECENTRALIZED TREATMENT ALTERNATIVES

4.1 INTRODUCTION

A. **Purpose.** The purpose of this Chapter is to identify and screen decentralized wastewater treatment technologies that could be used to address nitrogen loading issues that were identified in the Needs Assessment Report and summarized in Chapter 2 of this Report.

Decentralized treatment technologies are systems that are not connected to a central, municipal treatment plant. They often include individual and multiple-home systems that have total flows less than 10,000 gpd and do not require a groundwater discharge permit (GWDP). The multiple-home systems require a small wastewater collection system and are often called cluster systems. Decentralized treatment technologies also include small wastewater treatment facilities that treat and discharge flows greater than 10,000 gpd and therefore require a GWDP. Cluster systems and small wastewater treatment systems are typically designed for greater performance because they treat larger flows and are usually regulated by GWDP limits or other local, regional, or state constraints. Discharge/recharge technologies are discussed in Chapter 6.

The treatment technologies are identified and screened based on their ability to mitigate and prevent impacts to human health or the environment and to address existing nitrogen problems within a project area. The ability of these technologies to remove nitrogen from wastewater is an important factor for consideration within nitrogen sensitive areas. Advantages and disadvantages of these systems for use in the PPA are provided. Decentralized treatment alternatives selected for further consideration will be included in the scenario development phase (the next phase of this project).

B. **Comparison with Centralized Collection and Treatment.** The decentralized technologies in this Chapter are presented as an alternative to centralized wastewater collection and treatment. Technologies suitable for centralized collection and treatment of wastewater are described and evaluated in detail in Chapters 5 through 7. The most appropriate decentralized technologies will be selected for further evaluation at the end of this chapter.

In order to properly evaluate decentralized treatment system alternatives, it is important to understand some of the general advantages and disadvantages of centralized collection and treatment systems. The following lists present a summary of advantages and disadvantages of centralized collection and treatment.

Centralized collection and treatment has the following advantages:

- The wastewater is removed from a project area, minimizing any health threat and nitrogen load to the project area.
- Individual property owners do not have the burden of operating their own on-site wastewater treatment system.
- An "economy of scale" to treat and discharge the wastewater at one location can reduce capital and operations & maintenance (O&M) costs.
- Fewer resources are required for a Town or Wastewater Management District to operate one facility.
- The ability to achieve TMDL limits is greatly improved because of the level of treatment provided by these facilities.

Centralized collection and treatment has the following disadvantages:

- Alternate means of discharge may need to be identified, including sending treated effluent back to the areas where the flow originated for effluent disposal.
- Sewer construction in the areas to be connected to a central facility would be disruptive to traffic flow.
- Potential impacts on groundwater quality and elevation and on embayment water quality need to be carefully considered before siting and constructing an effluent disposal system for a centralized treatment facility.

4.2 INDIVIDUAL ON-SITE SYSTEMS

A. **Introduction.** Although centralized wastewater treatment technologies offer many advantages over individual on-site systems, it is likely that some of the existing and anticipated future wastewater management problems in the PPA could be managed using on-site systems. However, as shown in the Massachusetts Estuaries Project (MEP) model run for use of I/A's, these individual technologies applied across the watersheds are not sufficient to address the TMDLs alone.

On-site systems are used to treat wastewater from individual lots and may utilize one of several innovative/alternative (I/A) technologies. Wastewater flows less than 10,000 gpd are regulated by the Title 5 code, 310 CMR 15.000. Flows greater than 10,000 gpd require a state-issued groundwater discharge permit per 314 CMR 5.00. The following is the definition of I/A technologies in accordance with Title 5 Regulations (310 CMR 15.002):

> "Alternative Systems – Systems designed to provide or enhance on-site sewage disposal which either do not contain all of the components of an on-site disposal system constructed in accordance with 310 CMR 15.100 through 15.255 or which contain components in addition to those specified in 310 CMR 15.100 through 15.255 and which are proposed to the local Approving Authority and/or the Department for remedial, pilot, provisional, or general use approval pursuant to 310 CMR 15.280 through 15.289."

MassDEP has identified the allowable uses for each approved I/A system and has assigned each into one of four categories: remedial, pilot, provisional, and general use. Each of these categories is defined below.

> "The purpose of a **Piloting Approval** is to provide field testing and technical demonstration that an I/A technology can or can not function effectively under relevant physical and climatological conditions at one or more pilot facilities. Although information obtained during piloting is likely to be relevant to long term operation and maintenance concerns about a particular alternative system, approval for piloting is not intended, in and by itself, to provide a full evaluation of these issues."

Technologies approved for piloting use are permitted 15 installation sites, which must be monitored for a minimum of 18 months to determine if the expected treatment level is achieved. Successful piloting is achieved when at least 75percent of the pilot sites achieve the expected treatment level for at least 12 months.

> "**Provisional Approval** is intended to designate alternative systems that appear technically capable of providing levels of protection at least equivalent to those of standard on-site disposal systems and to determine whether, under actual field conditions in Massachusetts with broader usage than a controlled pilot setting, general use of the alternative system will provide such protection, and whether any additional conditions addressing long-term operation and maintenance and monitoring considerations are necessary to ensure that such protection will be provided."

Technologies approved for provisional use are installed at a minimum of 50 sites and are monitored for at least 3 years. Provisional use is considered successful when 90 percent of the installations achieve performance levels at least equivalent to a conventional Title 5 system.

> "Certification for **General Use** is intended to facilitate the use, under appropriate conditions, of alternative systems that have been demonstrated to provide levels of environmental protection at least equivalent to those of standard on-site systems."

> "The purpose of approval for **Remedial Use** is to allow for the rapid approval of an alternative system that is likely to improve existing conditions at a particular facility or facilities currently served by a failed, failing or nonconforming system."

MassDEP has also identified I/A systems (as of January 2007 for this report) that are approved for general use and receive nitrogen reduction credits in nitrogen-sensitive areas. For the purposes of this evaluation, the various on-site treatment system technologies are grouped as follows:

1. Non-nitrogen removal systems. These systems remove nitrogen to varying degrees. However, these systems are NOT credited for nitrogen removal by MassDEP in nitrogen sensitive areas. The non-nitrogen removal systems vary from Title 5 septic systems, to I/A systems that do not have General Use approval, to I/A systems that are approved for General Use.

a. The general non-nitrogen removal systems include:

- Title 5 septic systems
- Peat systems
- Glendon Biofilter

b. The I/A systems that are approved for General Use include:

- JET aerobic wastewater treatment
- Orenco intermittent sand filter

c. The non-discharge systems include:

- Tight tanks
- Waterless toilets

2. On-site nitrogen removal systems approved for nitrogen sensitive areas are grouped by their current MassDEP approval level (general, provisional, or pilot);

a. Nitrogen removal systems approved for **general use** by MassDEP in nitrogen-sensitive areas include:

- recirculating sand filters that comply with Title 5
- RUCK® systems (for flows less than 2,000 gpd)

b. Nitrogen removal systems approved for **provisional use** by MassDEP in nitrogen-sensitive areas include:

- Bioclere
- Mirco-FAST, High Strength-FAST, Nitri-FAST, and Modular-FAST
- Amphidrome
- Waterloo Biofilter
- AdvanTex
- Nitrex™

c. Nitrogen removal systems approved for **piloting use** by MassDEP in nitrogen-sensitive areas include:

- OAR
- RUCK® CFT
- Cromaglass WWT System
- Amphidrome Process
- Norweco Singulair
- Omni Recirculating Sand Filter
- SeptiTech

All of the above listed technologies will be discussed below. The costs for the various technologies will be described in relative terms. All systems approved for I/A use by MassDEP are expected to have an operational cost for sampling and analysis of $1,200 to $1,500 per year (not including inflation), above and beyond any other operational or maintenance costs. For a detailed cost comparison of the various technologies, see Section 4.2.G of this chapter.

B. **On-Site Systems Not Credited for Nitrogen Removal.**

1. **Title 5 Systems.** Title 5 systems consist of a septic tank, a distribution box, and a leaching area, as shown in Figure 4-1. Wastewater is discharged to the septic tank, as shown in Figure 4-2, where settleable solids sink to the bottom of the tank and floatables (like oil and grease) rise to the surface, forming a scum layer. Natural bacterial decomposition of organic matter occurs in the anaerobic conditions of the septic tank and produces ammonia. The liquid effluent is then discharged via the distribution box to a leaching area, where it percolates through stone bedding and the soil (receiving some additional treatment) before reaching the groundwater. A typical leaching chamber and leaching trench are shown in Figures 4-3 and 4-4, respectively.

Septic tank effluent ammonia-nitrogen levels are generally in the range of 20 to 60 mg/L. Septic tank effluent concentrations of biochemical oxygen demand (BOD) and total suspended solids (TSS) are approximately 140 to 200 mg/L and 50 to 90 mg/L, respectively. In addition to pollutant removal in the septic tank, treatment in a Title 5 system also occurs in the stone and soil interface through the action of a biological mat. Title 5 systems reduce bacterial contamination primarily via filtration of effluent through the mat and soils beneath the leaching area. If the leaching area is designed to promote aerobic conditions, nitrification can occur, converting the ammonia-nitrogen (NH_3-N) to nitrate-nitrogen (NO_3-N). Once the nitrogen is in the nitrate form, it can be converted to nitrogen gas and released to the environment. Nitrogen removal rates can range from 10 to 40 percent, depending on the leaching area, system design, and loading. Nitrogen removal is not usually significant in a Title 5 system due to limited opportunities for denitrification (conversion of NO_3-N to N_2 [gas]) under typical aerobic conditions. MEP findings estimate this reduction to be approximately 25 percent (reducing influent TN from 35mg/L to 26.25mg/L).

Soil characteristics are an important consideration for on-site systems, and many soils are not suitable for use as leaching areas. Those consisting of clay and silt (tight soils) do not percolate easily and may force the septic tank effluent to come to the surface, causing human health concerns, contaminated surface runoff, and possible shellfish bed closures.

Title 5 systems have the following advantages:

- Relatively low installation and maintenance cost compared to other systems.
- No moving parts unless pumps are required for discharge.

They have the following disadvantages:

- Require pumping the septic tank every two to three years (as do all individual on-site systems).
- The effluent from the system is of a comparatively low quality, and it is high in nitrogen, which may impact drinking water supplies or coastal embayments. These systems do not provide advanced nitrogen removal.

2. **Peat Systems.** Peat systems were originally developed in the late 1970s in Maine and have been designed to take advantage of the natural properties of peat. The vast majority of peat systems in the United States are installed in Maine, and peat system manufacturers have received limited approval from other states, including New Jersey, Maryland, Virginia, Ohio, North Carolina, Kentucky, and Alabama. A peat bed is installed following the septic tank and can function both as a filter and leaching area. The septic tank effluent is distributed via perforated pipes to the peat bed, where the wastewater moves through the peat and is treated by a combination of physical filtration, microbial activity, and chemical adsorption. A typical cross-section of a peat system is shown in Figure 4-5.

The nitrogen removal that has been reported with this system is assumed to involve nitrification (NH_3-N to NO_3-N) occurring in the aerobic portions of the peat bed, followed by denitrification [NO_3-N to N_2 (gas)] occurring within anaerobic microsites. The N_2 gas is then lost to the atmosphere, resulting in an overall net loss of nitrogen. Reported nitrogen removal rates in Maine vary from 60 percent to greater than 90 percent, with fecal coliform removal of 99.9 percent and effluent BOD and TSS concentrations of 10 mg/L. Test sites on Cape Cod report inconsistent nitrogen removal, often ranging between 30 to 40 percent. The low nitrogen removal rates on Cape Cod may be caused by the naturally acidic water on Cape Cod (often as low as pH 5.5), which may inhibit the nitrification and denitrification processes. As a result, the peat system is not considered a nitrogen removal alternative at this time.

This alternative requires very little maintenance and has no moving parts, unless site conditions make a pump necessary. For most installations, the top surface of the peat bed is exposed at ground level; therefore, traffic and parking must be prevented from occurring over the system. Grass is slow to establish on the surface, often taking more than one growing season to become established. Recommended design specifications, peat type, and compaction specifications must be followed to obtain an effective peat system.

Peat systems have the following advantages:

- It is an accepted technology in the northeast (Maine).
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The basic system requires no pump.
- Bacterial removal rates range from 90 percent to greater than 99.9 percent.
- It requires no special skill or knowledge for routine O&M.
- Septage pumping requirements are similar to those of a standard septic system.

They have the following disadvantages:

- MassDEP has only approved these systems for remedial use.
- Costs are typically higher than those of a standard septic system (see Cost Comparison in Table 4-1).
- Transportation cost of the peat can be expensive.
- Vehicles cannot be driven on top of a peat system.
- Low nitrogen removal rates have been recorded at test sites on Cape Cod.

3. **Glendon Biofilter.** The Glendon Biofilter is an upflow filter that consists of a septic tank, a pump tank, and the filter unit. A distribution tube is installed upright through the unit and layers of different material (sand and gravel) are laid horizontally up to the top of the filter unit. The top of the system is covered with soil. Septic tank effluent enters the filter at the bottom of the distribution tube, where it travels by hydrostatic pressure though the different layers. After the effluent surfaces at the top of the unit, it is either transported across the interface by a wicking action, or allowed to flow by gravity to collection piping and subsequent discharge to the leaching system. A diagram of the Glendon Biofilter is included as Figure 4-6. It is noted that the manufacturer of this technology has declined to pursue MassDEP approval based on the extensive permitting process. It is therefore not recommended that this technology be considered for further evaluation.

4. **JET Aerobic Treatment System**. This is an aerobic treatment system designed to achieve limits of 30 mg/L BOD and 30 mg/L TSS. Flow enters a primary settling chamber to remove solids, and then enters an aerated chamber where BOD and TSS removal is achieved. Aeration is provided by a mechanical aspirator that mixes the chamber and entrains air. The system uses both suspended growth and fixed-film bacteria to achieve the above stated removals. It is possible that these systems can accomplish nitrogen removal if a timer is used to control the aerator, thus switching the chamber from aerobic to anoxic conditions. However, this system has not been credited by MassDEP for nitrogen removal.

Regular maintenance is required, as this is a mechanical system. Massachusetts requires that a quarterly preventative maintenance schedule be maintained for this system. A diagram of the JET Aerobic Treatment System is included in Figure 4-7.

JET systems have the following advantages:

- High effluent quality (BOD and TSS less than 30 mg/L).
- Allows for variances for reduction in leaching area or separation to groundwater.
- Approved for General Use in Massachusetts.

They have the following disadvantages:

- Higher capital cost and operation and maintenance costs than standard Title 5 systems (see Cost Comparison in Table 4-1).
- Requires routine maintenance, beyond the typical pumping of a septic tank.

- Currently only designed to handle flows up to 1,500 gpd.

5. **Orenco Systems Sand Filters.** Orenco Systems, Inc. manufactures an intermittent sand filter and a recirculating trickling filter, which can be installed either as a component of a new septic system or retrofitted into an existing septic tank. Intermittent sand filters are designed to disperse daily septic tank effluent flow over a distribution area throughout the course of a 24-hour period. The even distribution provides for a higher quality final effluent because it allows for more efficient use of the soil absorption system. In a recirculating trickling filter, the septic tank is fitted with a small trickling filter on top of the tank and a PVC pump vault inside the tank. The pump vault houses both a recirculation pump and an effluent pump. Inlet holes in the pump vault allow septic tank liquid to enter the vault, where it is either recirculated to the trickling filter or pumped to a leaching area. Nitrification occurs in the trickling filter, and with a recirculation ratio of 15 to 1, the effluent is denitrified after returning to the septic tank. A diagram of the Orenco intermittent sand and trickling filters is included in Figure 4-8.

The Orenco filters have the following advantages:

- Better treatment than a Title 5 system can be attained and the leaching size can be reduced through variance.
- Total nitrogen levels in the septic tank effluent have been shown to be reduced by 84 percent (from 68 to 11 mg/L, with an average of 10 to 15 mg/L total nitrogen discharged to the leaching area) if maintained properly, according to their literature.
- Septage pumping requirements are similar to those of a standard septic system.
- Proven technology.
- Both systems are approved for General Use in Massachusetts (not for nitrogen removal).
- Can be retrofit into an existing system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process operation is flexible, with the ability to adjust cycle times.

The Orenco systems have the following disadvantages:

- Costs are typically higher than those of a standard septic system due to filters and pumps.
- Temperature sensitive in winter.

- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used which must be maintained and periodically replaced.

C. **Non-Discharge Systems.**

1. **Tight Tanks.** Tight tanks are non-discharge systems which collect and store the wastewater until it can be removed by a septage hauler. All the wastewater generated by the household or business goes directly into the tight tank. The storage tank typically has a level indicator with an alarm, and a signal is transmitted when the liquid level reaches a certain height. When the tank is full, a septage hauler empties the tank and transports the contents to a treatment facility. This type of system has high transportation and disposal cost. The system can generate odors during pumping. Land requirements are lower for a tight tank than for a septic system because a leaching system is not used.

Tight tanks have the following advantages:

- Simple technology.
- No significant environmental concerns when they are properly sited and designed.
- Wastewater is not discharged to the ground; therefore groundwater mounding or nitrogen loading is not a concern.
- Require less land area than a septic system.
- Water conservation is encouraged because most water used must be transported and disposed off site at a high cost.

They have the following disadvantages:

- MassDEP does not consider tight tanks an adequate long-term solution, and will only allow use under certain conditions.
- Tanks provide only short-term storage.
- High operational costs due to frequent pumping.
- Potential for frequent pump truck traffic and odors that occur during pumping.
- Wastewater treatment and disposal issues are transferred to another location.

2. **Waterless Toilets.** Water consumption, wastewater flow, and pollutant loading can be reduced using waterless toilets. Waterless toilet systems operate by separating black wastewater and gray wastewater. Black wastewater is toilet waste and gray wastewater is generated from non-sanitary sources, such as washing clothes or dishes and bathtub, sink, or shower use. Black wastewater is treated in the waterless toilet unit, and gray wastewater is discharged to a septic system, resulting in potential system size reductions. The two most common wastewater toilet systems are composting toilets and incinerating toilets.

Composting toilets recirculate the black wastewater over remaining solids to promote a natural decomposition process. Incinerating toilets burn black wastewater and generate a small quantity of ash and gas. Composted material and ash are periodically removed from the respective systems; air filters and exhaust units are used to minimize odors. Public acceptance of waterless toilet systems is often low due to the composting, incinerating, and handling of human waste within living spaces. A potential use of waterless toilets is in public restrooms and convenience stations. This option eliminates the need for individual users to handle human waste, and would remove the composting process, odors, and incinerating process from residential areas. Diagrams of composting and incinerating toilets are included as Figures 4-9 and 4-10, respectively.

Waterless toilets have the following advantages:

- Wastewater flows and loads are reduced if properly designed and installed.
- Water consumption is significantly reduced.
- Minimal environmental concerns occur when properly sited and designed.
- Composting toilets require minimal energy use.
- Size of standard septic system can be reduced to treat only gray wastewater.
- Routine maintenance is minimal and requires no special training.

Waterless toilets have the following disadvantages:

- Public acceptance is generally low.
- Incinerating toilets generally require high energy use.
- Handling of composting toilet contents can be objectionable.
- Incineration units are likely to generate odors if not vented properly.
- Not well suited to high seasonal peak loading.

D. **On-Site Nitrogen Removal Systems (Approved for General Use in Nitrogen-Sensitive Areas).**

1. **Recirculating Sand Filters (Non-Proprietary Filters).** Sand, rock, or mixed media recirculating filters are non-proprietary systems with a recirculation tank and filter. Effluent flows from the septic tank to the recirculation tank where it is pumped to the top of the filter and over the media. A portion of the flow is recirculated back to the recirculation tank and the remaining flow is discharged to the leaching area. A diagram of a typical recirculating sand filter is shown in Figure 4-11.

Anaerobic decomposition occurs in the septic tank, changing organic matter to ammonia. The ammonia is then converted to nitrate in the aerobic filter media. The recirculated effluent then undergoes denitrification in the recirculation tank, and nitrates are converted to nitrogen gas. The nitrogen gas is then lost to the atmosphere, yielding a net loss of nitrogen from the wastewater. The Massachusetts Alternative Septic System Test Center reports nitrogen removal efficiency in the range of 40 percent (final effluent of 21 mg/L), although additional data provides estimates in the 60-90 percent (3-14 mg/L TN in the effluent) range. However, actual performance units installed on Cape Cod show only about 50 percent of the units are able to achieve a median value of less than 19 mg/L. Many variations on the basic system are available to handle specific needs of a project or site.

Maintenance includes backwashing or periodic removal and replacement of the upper layers of media. Pumps must be maintained and replaced on a schedule. In emergencies, such as power loss, the system can be designed to function as a flow-through system, with treatment equal to a standard Title 5 system.

Recirculating sand, rock, or mixed media filters have the following advantages:

- Approved for General Use in nitrogen-sensitive areas by MassDEP.
- Septage pumping requirements are similar to those of a standard septic system.
- Well proven technology with operating history since the 1970s.
- Do not require a high level of technical skill to operate when designed and installed correctly.
- Better treatment can be attained and the leaching size can be reduced.

- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process has operational flexibility, with capability to adjust cycle times.

They have the following disadvantages:

- More maintenance is required than for a standard septic system due to mechanical and electrical components.
- Generally require a larger land area (for recirculation tank and controls) than a standard septic system. Land surface may be occupied by the filter unit and not available for other use.
- Systems are sensitive to low temperature and must be protected from freezing.
- Installation costs are typically $5,000 higher than those of a standard septic system; inspection and maintenance costs are $700 annually or higher.

2. **RUCK® System.** The RUCK® system is designed to divide the black (toilet wastes) and gray (non-toilet wastes) wastewater and treat each in separate septic tanks. The two flows are typically piped separately from a home (or group of homes) and divided to either a black water or gray water septic tank. Black water flows through the RUCK® filter constructed of sand or other media in which nitrification occurs. The effluent is then returned to an anaerobic tank and mixed with the gray water to promote denitrification, using the gray water as a carbon source. The gray wastewater septic tank effluent is discharged through a distribution box to a standard leaching area. These systems are used primarily for nitrogen removal. Figure 4-12 presents a diagram of the RUCK® system. The basic components of a Title 5 system are required for a RUCK® system, and the additional components, including design services, cost $15,000 above and beyond the Title 5 components and installation. If a RUCK® system is installed within a Zone II, quarterly sampling is required for the first year, which averages $400 per quarter. After the first year, annual inspection is required (which is the only requirement if the system is *not* in a Zone II).

Nitrogen removal performance is variable. Based on the County's study of these systems on Cape Cod, only about 45 percent were able to achieve a median value of less than 19 mg/L.

The RUCK® system has the following advantages:

- Approved for General Use in nitrogen-sensitive areas (for flows less than 2,000 gpd).
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Low operational and maintenance costs.
- Effluent quality of BOD and TSS of 20 and 30 mg/L, respectively.
- Routine maintenance requires no special training.

The RUCK® system has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Requires more space than a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used, which must be maintained and periodically replaced.
- Retrofitting the plumbing to separate black and gray wastewater flows can be difficult and expensive.

E. **On-Site Nitrogen Removal Systems (Approved for Provisional Use in Nitrogen-Sensitive Areas).** The remaining nitrogen removal systems are considered recirculating treatment technologies. Recirculating treatment technologies are a category of alternative treatment systems which are used in combination with standard septic systems. These systems typically include a recirculation chamber and a media to support microbial growth, which biologically treats the wastewater prior to discharge through a leaching system. A percentage of the wastewater is recirculated through the system, depending on influent quality, required effluent quality, and system design.

Recirculating treatment technologies vary in the type of media used, the wastewater pumping arrangement, and the overall system configuration. Some of these systems are produced by a specific manufacturer and are commonly referred to by their trade names. This section identifies and describes many of the recirculating treatment technologies and respective manufacturers which are currently approved for use in Massachusetts. The main disadvantage of these systems is the six- to eight-week startup period for biomass development. Summer residences are typically used only over a three-month period; therefore, these systems do not provide the maximum performance during the first half of the residence use. Recirculating treatment technologies are further grouped as those approved for "Pilot" or "Provisional Use" in nitrogen-sensitive areas and those that are not.

1. **Bioclere.** Bioclere is a trickling filter and pump unit in one manufactured unit, designed to treat the anaerobic effluent from a septic tank, which is high in ammonia. The filter media is PVC or polypropylene. Effluent from the septic tank is pumped to a distributor, which spreads the wastewater over the top of the media, where aerobic conditions allow nitrification to occur (conversion of ammonia to nitrate). In the media, anaerobic microsites also form where some limited denitrification (NO_3-N to N_2 [gas]) can take place. However, the majority of denitrification occurs when the effluent is collected at the base of the filter, and about 70 percent of the flow is recirculated back to the anaerobic septic tank. The rest of the effluent is discharged to a leaching area. A diagram of a Bioclere treatment unit is shown in Figure 4-13.

Installation of the Bioclere tank is relatively simple. One treatment unit contains a pump, distributor, and filter media. The treatment unit can either be retrofitted into existing septic systems by reusing the septic tank, piping, and leaching area, or it can be installed into new systems. The sealed double wall of the treatment unit provides insulation to minimize cold weather impacts. Nitrogen reductions of 70 to 85 percent (effluent nitrogen concentrations of 7-11 mg/L) have been achieved according to their literature. Performance on Cape Cod as shown by the County's study indicates about 65-70 percent can achieve a median value of 19 mg/L TN. The system can handle flow variations by varying the recirculation rates, and the units can handle increased flow by inserting additional media into the unit.

The Bioclere system has the following advantages:

- Well proven technology in Massachusetts.
- Approved for General Use in Massachusetts in non-nitrogen sensitive areas.
- No significant environmental or public acceptance concerns when properly sited and designed.
- The process operation is flexible, with ability to adjust cycle times and add additional media.
- The basic system has low operation and maintenance costs (see Cost Comparison in Table 4-1). The pump contained in the unit is easily accessible for replacement, when required.
- Septage pumping requirements are similar to those of a standard septic system.
- Better treatment can be attained and the leaching size can be reduced.

They have the following disadvantages:

- Capital costs are typically higher than those of a standard Title 5 system (see Cost Comparison in Table 4-1).
- Maintenance agreements are required and have an associated cost.
- More maintenance is required than a standard Title 5 system due to mechanical and electrical components.
- Generally require a larger area (for treatment tank) than a standard Title 5 system.
- Tops of Bioclere tanks extend above ground.

2. **Micro-, High Strength-, Nitri-, and Modular-FAST.** The modular fixed activated sludge treatment (FAST) systems are constructed using a submerged filter unit installed below ground in a configuration similar to that of a standard septic tank. Wastewater enters the primary settling zone of the tank, where primary solids removal is achieved. Flow is then recirculated by means of a centrally located draft tube through the submerged FAST filter, which is located at the effluent end of the tank. A small portion of the recirculated wastewater flow is periodically discharged to a leaching area. An enclosed blower supplies air to the system in order to support bacterial growth on the filter media. Nitrification and denitrification are achieved as part of the FAST system design and result in a total nitrogen removal rate of 70 percent (effluent nitrogen of 11 mg/L) or greater (performance data from the Massachusetts Alternative Septic System Test Center indicated nitrogen removal rates of 50 percent (18 mg/L) over a two year monitoring period).

The Barnstable County evaluation of installations on Cape Cod showed about 70 percent of these systems were able to achieve a median value of 19 mg/L TN. A diagram of the FAST system is included as Figure 4-14. The Micro-FAST system is incorporated into the design of a standard Title 5 system and costs $4,100 above and beyond a standard Title 5 septic system. This is the cost of the components only – an additional $400 is required for delivery and setup in the septic tank.

The FAST system has the following advantages:

- Proven technology in Massachusetts.
- Septage pumping requirements are similar to those of a standard septic system.
- The basic system uses a small mechanical aerator, which is accessible for service or replacement.

- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Generally requires same land area as a standard septic system.

The FAST system has the following disadvantages:

- Costs are typically higher than those of a standard Title 5 system (see Cost Comparison in Table 4-1).
- More maintenance is required than a standard Title 5 system due to mechanical and electrical components.
- Pumps and/or fans are used which must be maintained and periodically replaced, and require a backup power source.
- The blower can be relatively noisy in a quiet residential area and therefore must be enclosed.

3. **Amphidrome.** The Amphidrome process combines filter technology with a biofilter, an equalization tank, a clearwell, and the common components of a septic system. Wastewater flows by gravity from an equalization/septic (anoxic) tank through the biofilter into a clearwell. Wastewater is then pumped in reverse through the biofilter to the anoxic tank. The biofilter alternates between aerobic and anoxic conditions, providing nitrification and denitrification as the cycle is repeated. Wastewater is allowed to cycle through the system several times before it is discharged. A diagram of the Amphidrome system is included as Figure 4-15.

The Amphidrome process has the following advantages:

- Utilizes deep bed filter technology, which has a good historic performance record.
- Septage pumping requirements are similar to those of a standard septic system.
- It has demonstrated very good nitrogen removal (average effluent concentrations of 11 mg/L TN) in several cluster and commercial installations on Cape Cod as well as at the Massachusetts Alternative Septic System Test Center.

The Amphidrome process has the following disadvantages:

- Installation costs are typically higher than those of a standard septic system (see Cost Comparison in Table 4-1).

- Pumping requirements are high due to internal treatment configuration. Nitrogen removal ability is sensitive to sludge accumulation.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used which must be maintained and periodically replaced; these also incur operating costs.
- Startup time can be as long as 12 weeks, depending on ambient temperature, so it may not be suitable for seasonal homes.
- Very limited data on existing individual home installation as evaluated by the County.

4. **Waterloo Biofilter.** The Waterloo Biofilter consists of a 6-foot by 6-foot by 4-foot enclosure which includes filter media, an air ventilation system, and a wastewater distribution system. The distribution system pumps effluent from the septic tank and sprays it over the surface of the media. Wastewater trickles through the media while air is blown through the system. The system uses a small ventilation fan and an effluent pump timed via a control panel to dose effluent at frequent intervals over a 24-hour period. The effluent is collected at the base of the biofilter and a portion is recirculated back through the media, while the rest is discharged to a leaching area. The mechanism for nitrogen removal is similar to the recirculating filters described earlier. The Massachusetts Alternative Septic System Test Center reported a 60 percent nitrogen removal efficiency (an average of 14 mg/L TN in the effluent) after a year of testing. However, there was only limited data on existing systems on Cape Cod. A diagram of the Waterloo Biofilter is included as Figure 4-16.

The Waterloo Biofilter has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process operation is flexible, with the ability to adjust cycle times.
- The basic system uses a small pump, which has low operational and maintenance costs. The pump is easily accessible for service or replacement.
- Although the design hydraulic loading rate is 10 gallons per day per square foot (gpd/ft^2), it can handle surges of up to 49 gpd/ft^2 for several days with little effect on effluent quality.
- Better treatment can be attained and the leaching size can be reduced.
- Removal rates for nitrogen range from 60 percent to greater than 90 percent (60

percent nitrogen removal observed at Massachusetts Alternative Septic System Test Center), depending upon the system and site. Effluent BOD and TSS are expected to be <10 mg/L in the winter and often <5 mg/L at other times of the year. Fecal coliform removal ranges from 99.0 to 99.5 percent.

They have the following disadvantages:

- Installation costs are typically higher than those of a standard septic system (see Cost Comparison in Table 4-1).
- Systems are sensitive to the temperature of the septic tank effluent entering the system from the septic tank. Insulation of the septic tank is recommended.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used which must be maintained and periodically replaced.
- Denitrification unit periodically requires recharging with material like sawdust or leaves to serve as a carbon source for denitrification.
- Unit may need to be installed above ground depending on depth to groundwater.

5. **AdvanTex®.** The AdvanTex® system is a textile filter technology. The main components are a control panel, a filter pod, a recirculating splitter valve, a pumping package, and a processing tank. The filter material consists of an engineered textile that has greater surface area than sand or gravel, allowing greater volumes of wastewater treatment in less space. After initial settling in the first compartment of the processing tank, effluent is pumped to the filter pod. As effluent percolates through the filter media, a biological film develops, providing additional BOD, TSS, and nitrate removal.

The splitter valve directs a portion of the flow to the effluent discharge and a portion back to the processing tank. The splitter valve also maintains a minimum water level in the processing tank; therefore, all of the treated effluent is recycled back to the processing tank when there is no influent. Effluent discharge is controlled by a timer, which discharges in “microdoses.” The microdoses occur for relatively short intervals, typically 72 times per day. Testing in New Zealand and Oregon has shown reliable performance in achieving an effluent TN concentration less than 15 mg/L. Very limited data on Cape Cod is available based on the County’s evaluations. A process diagram is shown in Figure 4-17.

AdvanTex® systems have the following advantages:

- The system can be installed within a small footprint (filter box has an area of 8 feet by 3 feet).
- High quality effluent (5 mg/L BOD and TSS) can be used for drip irrigation.
- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process operation is flexible, with the ability to adjust cycle times.
- The basic system uses a small pump, which has low operational and maintenance costs.

AdvanTex® systems have the following disadvantages:

- Costs are typically higher than those of a standard septic system due to additional mechanical components.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used which must be maintained and periodically replaced.
- May require media replacement at a higher cost than a system with sand or gravel media.

6. **Nitrex™ System.** This system is a filter unit that can be added to the end of an I/A system. The system requires a nitrified effluent for the unit to work; therefore a treatment process beyond a normal septic system is required prior to this system, such as a recirculating sand filter. The filter media is contained in a tank and is a gravity flow through system. The media is comprised of wood chips and cellulose. Costs for the Nitrex™ filter (not including shipping and installation) are approximately $4,000. It should be noted that this does not include costs for the treatment system required prior to the Nitrex™ filter. See Figure 4-18. Currently, Nitrex™ is marketed with an Omni Recirculating Sand Filter as the pretreatment system. Costs for a typical package, including both treatment components, range between $12,000 and $14,000.

The Nitrex^{TM} system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Better treatment can be attained and the leaching size can be reduced.
- Does not require system pumping.
- Reduces nitrogen by as much as 95 percent, or 2 mg/L in the effluent although there is very limited data available on this system.
- No supplemental carbon required.

They have the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Requires pretreatment (use of another technology) to provide a nitrified effluent to the system.
- Media life is unknown, but it is guaranteed for 10 years.

F. **On-Site Nitrogen Removal Systems (Approved for Piloting Use in Nitrogen-Sensitive Areas).**

1. **OAR System.** The OAR system (illustrated in Figure 4-19) is comprised of two tanks. The first tank is aerated using compressed air to provide aerobic conditions for the reduction of BOD and TSS and to nitrify ammonia. The aerobic tank is also heated to provide suitable conditions for these biological processes and to aid in nitrification during the winter months. The effluent from this tank enters the anoxic or denitrification tank where nitrate-nitrogen is converted into nitrogen gas. This process requires a supplemental carbon source to aid in the denitrification process. Denitrifying bacteria are also added to this tank to aid in the nitrogen removal process.

The OAR system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly located and designed.

- Can achieve better treatment than a Title 5 system and the leaching size can be reduced.

They have the following disadvantages:

- Costs are typically higher than those of a standard septic system due to the additional tanks, mechanical components, and bacteria.
- System requires supplemental carbon and denitrifying bacteria.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Chemical storage is required.

2. **RUCK® CFT.** The CFT model is similar to the traditional RUCK® system. However, all of the wastewater flows through the filter. A supplemental carbon source (soapy water) is added to the effluent in the mixing chamber. Denitrification takes place in the mixing chamber. A schematic of the RUCK® CFT is shown in Figure 4-20.

The RUCK® CFT system has the following advantages:

- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Nitrogen removal rates to as high as 90 percent, depending upon the system and site.
- Routine maintenance requires no special training.

The RUCK® CFT system has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Requires more space than a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used, which must be maintained and periodically replaced.

3. **Cromaglass System.** The Cromaglass system (illustrated in Figure 4-21) is a type of sequencing batch reactor (SBR) treatment process. The system operates in five stages: fill, aeration, denitrification, settling, and discharge. Flow enters the first stage, where solids settle out and the remainder of the flow passes through a non-corrosive screen. After passing through

the screen, the wastewater is aerated and mixed using submersible pumps. The pumps are then shut down to provide an anoxic condition to promote denitrification. Flow is pumped to the clarifiers for final settling, and then flow is pumped from the clarifiers for effluent discharge to the leaching facilities.

The Cromaglass system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Better treatment can be attained and the leaching size can be reduced.

They have the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps are used which must be maintained and periodically replaced.

4. **Norweco Singulair.** This system (illustrated in Figure 4-22) is a type of extended aeration system. The treatment process is contained within a three-chambered tank. The first chamber provides solids settling, the second chamber is the aerobic zone where the wastewater is aerated to promote BOD removal and nitrification, and the third chamber is the final settling chamber. This chamber is equipped with a filtration unit to aid in clarification prior to effluent disposal. The system is followed by a recirculation chamber to pump 10 to 20 percent of the flow back to the first chamber for nitrogen recycle. 60 to 65 percent of systems installed on Cape Cod, according to Barnstable County, are able to achieve (a median value of) 19 mg/L TN.

The Singulair system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Can achieve better treatment than a Title 5 system and the leaching size can be reduced.

They have the following disadvantages:

- Costs are typically higher than those of a standard septic system (see Cost Comparison in Table 4-1).
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps are used which must be maintained and periodically replaced.

5. **Omni Recirculating Sand Filter (RSF).** The Omni RSF is a proprietary recirculating sand filter. The functioning and setup of the system is very similar to the process discussed for RSF in general (see Figure 4-11). Only about 50 percent of these systems on Cape Cod have been shown to achieve a median value less than 19 mg/L TN according to the County.

The Omni RSF has the following advantages:

- Modular design allows for easy installation
- Septage pumping requirements are similar to those of a standard septic system.
- Do not require a high level of technical skill to operate when designed and installed correctly.
- Can achieve better treatment than a Title 5 system and the leaching size can be reduced.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process has operational flexibility, with capability to adjust cycle times.

The following are some disadvantages of the Omni RSF:

- More maintenance is required than for a standard septic system due to mechanical and electrical components.
- Land surface may be occupied by the filter unit and not available for other use.
- Systems are sensitive to temperature and must be protected from freezing.
- Costs are typically higher than those of a standard septic system (see Cost Comparison in Table 4-1).

6. **SeptiTech System.** This system is a fixed-film-type system. The first two tanks or chambers of the system provide solids settling and the anoxic zone for denitrification. The

second chamber contains trickling filter media and wastewater is recirculated within this chamber for treatment. Flow is also recirculated back to the anoxic zone to promote denitrification. A diagram of the SeptiTech system is included as Figure 4-23. Only about 10-25 percent of these systems on Cape Cod have achieved a median value less than 19 mg/L TN according to the Barnstable County study.

The SeptiTech system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Can achieve better treatment than a Title 5 system and the leaching size can be reduced.
- No supplemental carbon required.

They have the following disadvantages:

- Costs are typically higher than those of a standard septic system (see Cost Comparison in Table 4-1).
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps are used which must be maintained and periodically replaced.

G. **Cost Comparison of Individual On-Site Systems.** The technologies discussed above were further compared on a cost basis in order to provide a cost-benefit analysis related to nitrogen removal performance. The following conditions and assumptions were made in order to compare the technologies on an equivalent basis:

- Equipment manufacturers were contacted and cost information from those who responded is included in Table 4-1.
- Costs are based on a single-family, three bedroom home with an estimated daily wastewater generation of 330 gpd.
- Technologies were assumed to replace existing, traditional Title 5 septic systems, making use of the existing 1500-gallon septic tank and the leaching system.
- Costs for any associated permitting (building, health, conservation) are not included.

- Construction costs for installation and additional equipment not included unless specifically stated.
- Excavations are not below the groundwater table.
- Performance is based on data available from the Barnstable County 2007 report titled, "Performance of Innovative Alternative Onsite Septic Systems for the Removal of Nitrogen in Barnstable County, Massachusetts 1999-2007"
- Only technologies where either cost or performance data or both were available are presented.

The information provided in the Table 4-1 is intended for basic comparison purposes only and the County has done an excellent job in identifying the statistical nuances of using the performance data associated with these technologies. The limitations identified by Barnstable County on the information used for their study is identified in their report. Costs are based on manufacturer's provided information and therefore may not reflect the total cost of the project, which may be influenced by site constraints, owner constraints, optional features, state and local requirements, etc. Barnstable County's general finding was that 60 to 70 percent of the I/A technologies listed in their report produce a median effluent quality that meets a regulatory discharge standard of 19 mg/L or less of TN.

Additional costs associated with design, permitting, installation, site restoration, and additional O&M (for those technologies where information was not provided by the manufacturer) were not provided. These costs will all vary based on site conditions, locations within any of the Towns of the PPA, local rules and regulations and expected property use. In May of 2007, the Barnstable County Department of Health and the Environment issued a report titled "Projected Use of Innovative/Alternative On-site Sewage Treatment Systems in Eastham, Under Current Regulations and Policies". This report documented estimates on capital and O&M costs associated with I/A technologies. Because of the similarity in costs of I/A system equipment, an average present worth cost for these systems was estimated over a 20 year design life:

- $35,000 per I/A (without additional Title 5 components: septic tank, leaching facilities. $10,000 capital cost for entire system, $1,550 annual maintenance costs).
- $45,000 per I/A (including Title 5 components. $20,000 capital cost for entire system, $1,550 annual maintenance costs.)

Site specific conditions will dictate actual costs associated with the installation of these systems; however, these costs provide a reasonable approximation of what could be expected.

4.3 CLUSTER TREATMENT SYSTEMS

Cluster treatment systems are systems that fall between individual on-site systems and large municipal facilities designed to serve large areas of a town. These systems are typically designed to treat and discharge wastewater generated within the bounds of a certain planning area. The Towns of Mashpee, Sandwich, and Barnstable have a varying number of these types of systems. The main difference between cluster systems and centralized wastewater treatment facilities is the location of the treatment and effluent disposal. For the purpose of this project, centralized wastewater facilities are those which collect wastewater from various planning areas and discharge them at the facility site or remote sites that may or may not be located within the planning area from which the wastewater was generated.

Cluster systems can range in size from serving small groups of homes or businesses to an entire planning area. Cluster treatment systems may utilize any one of the on-site technologies described previously in this chapter, or could be served by a small wastewater treatment system (as described in Chapter 5) for flows over 10,000 gpd. Because cluster systems are designed to handle "clusters" of properties, they require a collection system to transport the wastewater from the properties to the treatment facility. Collection system technologies are discussed in Chapter 6.

Cluster treatment systems require greater land area for effluent disposal than individual on-site systems due to the larger wastewater flows. A potential alternative for reducing land area requirements for effluent disposal is to pump the treated effluent back to the properties where the wastewater was generated. This concept could also mitigate potential groundwater mounding impacts associated with discharging large volumes of treated effluent at one site. At the same time, this concept might not be possible if the property generating the wastewater currently has limited space, high groundwater, or poor soil conditions that make it difficult to discharge effluent now or in the future. Pumping treated effluent back to the point of generation would be more expensive and would create a very complex system of effluent disposal.

4.4 SCREENING OF ALTERNATIVE DECENTRALIZED TECHNOLOGIES

A. **Summary of Screening.** Table 4-2 summarizes key information for each technology alternative with respect to each screening criteria discussed in Chapter 3. All the wastewater treatment technologies require review and approval by MassDEP and/or the local Board of Health. Additional technologies may be approved in the future.

B. **Technology Review.** Septic systems are a reliable, simple, feasible technology with relatively low capital costs and minimal operations and maintenance requirements. Land requirements for septic systems are relatively low and can be further reduced according to local variance guidelines established in the 310 CMR 15.000 (Title 5) regulations. Typical variances to septic system design requirements include a reduction in the distance between process equipment and property lines (commonly referred to as the setback distance), a reduction in the allowable groundwater separation distance, or a reduction in leaching area. Septic systems typically provide moderate treatment of wastewater and are primarily designed for TSS and BOD removal. Nitrogen removal rates in septic systems are quite low.

Although innovative and alternative (I/A) technologies (as defined by MassDEP) do not provide a significant advantage in land area requirements when compared to septic systems, the potential to design I/A systems with reduced groundwater separation may be desirable for areas of the PPA that may have high groundwater elevations. Recirculating I/A treatment technologies provide high levels of treatment for BOD, TSS, and nitrogen removal. Nitrogen removal rates typically range between 40 and 90 percent, depending on the technology used, and could be important in addressing nitrogen loading concerns. However, for nitrogen loading analyses, I/A technologies are assumed to remove only about 50-percent TN, or down to 19 mg/L TN.

The technologies evaluated in this Chapter provide a broad range of nitrogen removal rates. This range can be attributed to system technology. It can also be attributed to installation under varying site conditions, including flow rate, pollutant loading, environmental conditions, the manner in which the system was installed, and operation and maintenance that it has received.

In cases where a site requires pumping of effluent to a leaching area, energy use increases and the reliability of the system is lowered. The more moving parts the system requires, the lower the reliability. If a site does not require pumping, then most systems are considered flow-through, and have reliability similar to a standard certified Title 5 system. Recirculating filter systems require recirculating pumps in most cases. The pumps used are typically in the small (¼ hp) range with low power use. In addition to this, some systems may require a fan or blower to provide ventilation and/or aeration.

Reuse of existing facilities, such as septic tank, piping, distribution box, and leaching area, is possible with most on-site or cluster alternative treatment systems. The existing facilities and tanks must be inspected to be sure they do not leak the contents to the environment, or allow groundwater into the tank. The existing septic tank can often be used as a pumping and anaerobic chamber in many of the recirculating filter systems. Often, additional tanks that contain the additional treatment processes to achieve a higher quality effluent are required. Any additional tanks or structures will require more land area and add cost to the system. An exception is the Orenco Trickling Filter system, which places the aerobic treatment chamber on top of the existing septic tank as part of its design.

Design considerations and treatment levels for small cluster system technologies are similar to those for individual unit technologies and include effluent quality, tank configuration, and general design requirements. Land requirements for a full cluster septic system are relatively high due to a large leaching area, and can range between 3,500 and 25,000 square feet for wastewater flows of 1,000 and 10,000 gpd, respectively. However, variances commonly sought with the use of I/A technologies include: possible reduction in leaching area, property line setbacks or separation from groundwater if allowed by the local approving authority. These variances have the potential to reduce the size of these systems.

Design considerations and treatment levels for small wastewater treatment technologies are greater than those for individual unit and cluster system technologies. For this evaluation, small wastewater treatment facilities for cluster systems are defined as systems that treat greater than 10,000 gpd but less than 200,000 gpd. The treatment technologies associated with these systems are discussed in Chapter 5 under both "Small Wastewater Treatment Facilities" and "Centralized Treatment Facilities". Centralized treatment technologies (discussed in Chapter 5) should be considered for flows greater than 200,000 gpd.

C. **Findings.**

1. **General**. Key information on the wastewater technologies has been summarized in Table 4-2 to allow a side-by-side comparison with respect to a set of standard criteria. Because I/A technologies are regulated by MassDEP, selection of any I/A technology should be made by the individual property owner. The selection process will depend on the particular application (i.e. for repair, nitrogen removal, variance, etc.), the current MassDEP status of the technology, and each Town's Board of Health.

The difficulty with individual I/A systems is the maintenance requirements and costs. Improper maintenance, significant down times due to seasonal use, and owner inexperience all contribute to poor performance and possible system failures. If properly operated and maintained, those systems approved by MassDEP can achieve higher effluent quality and provide a significant improvement over standard Title 5 septic systems. Broad application of these technologies to address the needs of planning areas could severely tax a Town's resources, requiring increased accounting of systems, inspections, and routine operations and maintenance and monitoring to ensure that the systems are performing properly and achieving the goals associated with large-scale implementation to meet the MEP nitrogen loading thresholds. MEP model results have shown the application of I/A technologies (at 19 mg/L TN) at all properties will not achieve the nitrogen thresholds, therefore will be unable to meet the TMDL's. These systems may be better suited to addressing localized problem areas, where other alternative may be more costly. An excellent example of the vast range of performance is shown in the Barnstable County Report titled "Performance of Innovative Alternative Onsite Septic Systems for the Removal of Nitrogen in Barnstable County, MA 1999-2007".

These systems have advantages and may be necessary to address specific site conditions and issues (i.e., high groundwater, setback requirements, repair or replacement of existing systems, or limited nitrogen removal in sensitive watersheds). However, each application should be evaluated on a site-by-site basis for those areas not considered for cluster systems or sewers.

2. **Technologies.** Tight tanks are considered a short-term, or "band-aid," solution to overcome an immediate problem and are recommended for use only on a temporary basis until a long-term solution is found. This was recognized by the MassDEP some time ago and has resulted in restrictions of their use. Allowable uses include keeping a primary residence open to habitation while a permanent system is installed. Another use applies to specialized situations, such as boat pumpout facilities that typically are seasonal in nature and may have site conditions that make construction of a standard septic system impossible. There is also a significant concern that widespread approval of tight tanks would allow development in areas that should not be developed.

Composting and incinerating toilets are non-traditional wastewater disposal systems and public acceptance is expected to be limited. Composting systems may not be well suited to handle seasonal flows and loadings. The physical handling of composted or incinerated wastes may be objectionable to the public. Low public acceptance due to odors is also an issue with these systems. These systems would be best suited for use at comfort stations or other public facilities where the general public would not be responsible for the routine system maintenance.

The MEP team ran several scenarios for the Pilot Project for the Popponesset Bay System in 2006. One of those scenarios was the use of denitrifying I/A systems for all users (including build-out) to meet the threshold values for that estuary. The findings, run under two conditions (realistic removal and best case removal), showed that neither one was capable of achieving the threshold values alone and additional nitrogen would need to be removed. Therefore, although an improvement over existing Title 5 systems, these systems would have to be used in conjunction with other means (including sewering) to reduce the nitrogen levels, at least as shown in Popponesset Bay.

In addition, efforts of the Barnstable County Department of Health and the Environment examined the performance of all the I/A systems on Cape Cod, and found in general that only 70 percent were able to achieve a median value of less than 19 mg/L. However, in review of that report and the variability of the data, a significantly smaller percent were able to achieve less than 19 mg/L at all times. Therefore in working to achieve threshold or TMDL limits, the use of these systems on a large scale is not recommended.

It is recommended that the following wastewater treatment alternatives be considered for general use in future planning areas.

- Continued use of individual I/A systems designed and approved for nitrogen removal in limited planning areas (I/A systems already in use in Mashpee include Amphidrome, Bioclere, FAST, Recirculating Sand Filters, RUCK®, Singulair, Nitrex™, SeptiTech, and Waterloo Biofilter) on a limited basis.
- Small wastewater treatment facilities for multiple home communal systems.
- Connection to existing small wastewater treatment facilities already operating in Mashpee.
- Connection to new centralized wastewater treatment facility or facilities.

Chapter 5

Centralized Municipal Wastewater Treatment Facilities

CHAPTER 5

CENTRALIZED MUNICIPAL WASTEWATER TREATMENT FACILITIES

5.1 INTRODUCTION

A. **Purpose**. The purpose of this chapter is to identify technologies that could be implemented within the PPA as part of one or more new wastewater treatment and discharge facilities for use as part of the WNMP. The recommended technologies will be considered for further detailed evaluation as part of the next phase of the project. Wastewater treatment and discharge alternatives are divided into the following groups:

- Small Wastewater Treatment Facilities
- Large Centralized Wastewater Treatment Facilities
- Effluent Reuse/Recharge

Each group of technologies is presented and screened in a separate section of this chapter. Effluent disposal and collection system technology alternatives are discussed in Chapter 6.

5.2 SMALL WASTEWATER TREATMENT FACILITIES INCORPORATING BIOLOGICAL NITROGEN REMOVAL

Small wastewater treatment facilities incorporating biological nitrogen removal are designed to treat and discharge wastewater flows greater than 10,000 gpd. These treatment systems serve many properties and require a wastewater collection system. For the purpose of this report, these systems are being considered for cluster systems as discussed in Chapter 4.

Small wastewater treatment facilities utilize biological nitrogen removal (BNR) processes that are compact in size and are generally more mechanized than the individual and multiple-home, on-site-type systems previously presented. These facilities can produce a treated effluent that meets the permitted standards of 30 mg/L BOD_5, 30 mg/L TSS, and 10 mg/L nitrate-N. When properly designed and operated, they can provide even better treatment. The following BNR processes will be identified and screened as part of this alternative: rotating biological contactors (RBCs); sequencing batch reactors (SBRs); Amphidrome system; Bioclere; Zenon; and Fixed Activated Sludge Treatment (FAST) systems.

A. **Regulatory Impacts and Treatment Standards.** Wastewater discharges greater than 10,000 gpd require a groundwater discharge permit (GWDP) as required by the Massachusetts Discharge Permit Program and Groundwater Quality Standards described in 314 CMR 5.00 and 6.00, respectively. Mashpee Board of Health regulations and bylaws typically require that new development and redevelopment with anticipated wastewater flows greater than 600 gpd meet a 10 mg/L nitrogen discharge limit. The Planning Board Special Permit Regulations require the following:

> "Private sewage treatment facilities designed to generate effluent with an annual average total nitrogen concentration of 5 mg/L or less, and not to exceed 10 mg/L at any time, shall be constructed for any project for which a special permit is approved by the Board which is expected to generate more than 5,000 gpd of wastewater based on the Massachusetts State Environmental Code, Title 5, unless prohibited by the Massachusetts Department of Environmental Protection, the Mashpee Board of Health, or the Mashpee Zoning By-Law."

If a project requires Cape Cod Commission review, similar nitrogen limits may be necessary to meet the No Net Nitrogen policy of the CCC.

The groundwater beneath the PPA is designated as a sole source of drinking water and, as such, most is classified as Class I. Discharges to a Class I groundwater require a high level of treatment, including nitrogen removal, allowing a maximum concentration of 10 mg/L total nitrogen and nitrate-nitrogen, which is the current drinking water standard. Any treatment facility with a GWDP as issued by MassDEP is REQUIRED to meet a minimum of <10 mg/L nitrate and <10 mg/L TN in its effluent. All technologies presented here can be designed to achieve these limits, however performance varies.

Technical Report #16 Guides for the Design of Wastewater Treatment Works (TR-16) and the MassDEP guidelines entitled *Guidelines for the Construction, Operation, and Maintenance of Small Treatment Facilities with Land Disposal* have been published by MassDEP specifically governing these types of treatment facilities. These guidelines provide detailed design criteria for treatment and discharge facilities.

B. **System Components for Small Wastewater Treatment Facilities.** Several system components are common to most small wastewater treatment facilities. The main components of a small wastewater treatment facility are presented in Figure 5-1 and described below.

1. **Primary Clarifiers.** Primary clarifiers are settling tanks that reduce the organic loading to the biological nitrogen removal process by removing the settleable solids and the floatables. The raw wastewater flows through the clarifier (often large septic tanks) and the solids settle to the bottom, where they are collected and removed for disposal. MassDEP's design guidelines require the installation of primary clarifiers on all small wastewater treatment facilities, though they are not generally used for SBR processes.

2. **Flow Equalization.** Flow equalization is required to equalize the daily variations of wastewater flows and associated loadings that are conveyed to a small wastewater treatment facility. A flow equalization tank stores the variable flows that occur periodically during the day, and equalization pumps convey a relatively constant flow from the equalization tank to the biological treatment process.

3. **Biological Nitrogen Removal Process.** This process utilizes a large concentrated population of microorganisms to treat the wastewater. The microorganisms are mixed with (or brought into contact with) the wastewater in an aerobic environment; biodegradable waste is metabolized by the microorganisms to new cell mass and carbon dioxide. This first step is commonly called carbonaceous (or BOD) removal. The second step is nitrification, during which ammonia in the wastewater is converted to nitrate-nitrogen under aerobic conditions. Both steps are aerobic and generally occur at the same time. When nitrogen removal is incorporated with biological treatment, a third step is required, in which the amount of oxygen entering the process is limited and the microorganism environment becomes anoxic. The anoxic environment causes the microorganisms to obtain oxygen from nitrate, thereby converting the nitrate-nitrogen to nitrogen gas, which is released from the wastewater to the atmosphere. A carbon source such as methanol may need to be added to the process to support the conversion of

nitrate-nitrogen to nitrogen gas. This third step is called "denitrification." A variety of BNR processes are described in the next section.

4. **Secondary Clarifiers.** Secondary clarifiers are an integral component of the RBC and FAST nitrogen removal processes. These clarifiers are used to separate the biological solids (sludge) from the treated wastewater, and they operate similarly to the previously described primary clarifiers.

5. **Effluent Filtration.** This is typically required by MassDEP following the biological nitrogen removal process or in areas discharging within a designated drinking water supply Zone II. This process filters the effluent to remove most remaining particulate matter. The facilities include sand or other media filters along with the necessary pumps and reservoirs to periodically backwash the filters and pump the dirty backwash water to the biological treatment process. Effluent filtration is provided in the Amphidrome and Zenon processes as part of the standard design.

6. **Disinfection.** Disinfection may be required prior to recharging the treated effluent to the groundwater. Disinfection can be accomplished by adding small quantities of sodium hypochlorite to the effluent or by exposing the effluent to ultraviolet light, which inactivates the bacteria in the effluent. Disinfection is not typically required when subsurface leaching fields are used for effluent recharge unless the discharge occurs within a Zone II. Disinfection may be required when sand infiltration beds (open to the atmosphere), well injection, or discharge to a surface water body are used.

7. **Effluent Recharge Facilities.** These facilities are required to discharge and distribute the treated effluent to the ground. Two methods are commonly used, including sand infiltration beds and subsurface leaching fields, although there are other options which are discussed in detail in Chapter 6. When sand infiltration beds are used, the effluent is piped to a sand bed and percolates into the ground through the open sand surface. Maintenance of the beds is relatively easy and solids can be removed from the top of the sand beds. The sand beds are usually sized based on a hydraulic loading rate of 5 gpd/ft^2 of bed area for sandy soils, but this loading rate must be verified with soil analysis and hydrogeologic investigations. When subsurface leaching fields are used, the effluent is piped to a subsurface perforated drain field, where the effluent percolates into the ground. Maintenance of these systems is more difficult because the leaching field is not exposed to the surface and solids cannot be easily removed. The

leaching fields are generally sized based on a hydraulic loading rate of 2.5 gpd/ft^2 of leaching area. Leaching fields have the advantage that they can be located under a parking lot or other large open area that may have another use; therefore, it could require little or no additional space. The selection of effluent disposal facilities must be performed on a site-by-site basis.

8. **Support Structures.** An operation building and possibly other support structures are required to shelter process equipment, store chemicals and supplies, and operate and maintain the various treatment processes.

C. Biological Nitrogen Removal Processes (6 to 10 mg/l TN performance typical).

1. **General.** BNR processes are divided into two general classifications: suspended growth processes and attached growth (film) processes. Suspended growth processes use the concentrated microorganism population suspended in the wastewater via mechanical mixing or injection of compressed air. BOD removal, nitrification, and denitrification are accomplished in one or more tank compartments during the process, and the microorganisms are settled from the wastewater to be reused or processed for disposal.

Attached growth processes utilize a concentrated microbial population, which adheres to a supporting media. The wastewater is circulated through tank compartments containing the media coated with the microorganisms. At the end of the process, the wastewater is typically settled or filtered to remove any micro-organisms that have sloughed from the media.

Although performance is listed as 6 to 10 mg/l TN, some technologies like SBRs and Zenon can achieve less than 6 mg/l without additional processes if the influent characteristics are favorable.

2. **Rotating Biological Contactors (RBC).** RBCs are an attached growth process that utilizes disc-shaped plastic media mounted to a rotating shaft. The plastic media is partially submerged in a tank and provides a growing surface for microorganisms. The rotating shaft brings the microorganisms in contact with both the organic matter in the wastewater and oxygen in the atmosphere. As a result, aerobic bacteria metabolize solids and nutrients in the wastewater. Additional microorganisms are produced and removed from the treated effluent in a settling tank.

When RBCs are used for nitrogen removal, a separate submerged (anoxic) RBC follows the partially submerged (aerobic) RBC to provide denitrification. Methanol may be added to the anoxic RBC to assist nitrogen removal. The anoxic RBC is not aerated and is completely submerged to maintain anoxic conditions. Both the aerobic and anoxic RBCs produce sludge that must be settled and removed from the effluent in secondary clarifiers. A process diagram of an RBC is included as Figure 5-2.

RBCs have the following advantages:

- The technology is used extensively and is well accepted by MassDEP
- Energy requirements are low
- Operational requirements are low
- Can reliably achieve less than 10 mg/L total nitrogen when an anoxic RBC or denitrifying filters are used

They have the following disadvantages:

- Must be preceded by primary treatment
- Capital costs are high
- Cold weather performance is a concern and the tanks must be covered or enclosed in a building
- There is minimal process control
- Generally require a larger land area than the SBR processes

3. **Sequencing Batch Reactors.** SBRs are batch-type suspended growth type treatment processes. Aeration, anoxic reaction (for nitrogen removal), and settling are accomplished in a single basin, though parallel treatment paths are provided. The phases of the SBR process include fill, react, settle, draw, and idle. Wastewater is added during the fill cycle. During the react phase, BOD removal, nitrification, and denitrification reactions are completed by alternating the aeration cycle. The next phase is settling, followed by decanting of clarified effluent in the draw phase. Sludge is collected and removed during the idle phase. A process diagram of an SBR is included as Figure 5-3.

Nitrogen removal with SBRs can be enhanced by modifying the length of the cycle times and monitoring the reactor contents to achieve the desired degree of treatment.

SBRs have the following advantages:

- Batch operation allows reactor contents to be retained until desired effluent quality is achieved, typically between 6 and 10 mg/L TN without additional processes
- Return sludge pumping and internal recycle equipment are not required
- Settling occurs under totally quiescent conditions with no influent flow
- All phases are provided in a single basin, reducing the need for additional tanks
- Highly flexible operation with ability to adjust cycle times
- The technology is well accepted and used extensively

They have the following disadvantages:

- A sophisticated control system with valves, timers, probes, and level sensors is required to control intermittent feeding, cycle times, phases, and process performance
- The reactor volume is increased to allow for cycle times and use of the basin for settling
- Flow equalization typically required downstream of SBRs for efficient operation of disinfection and filtration systems
- Screenings and grit removal can be an issue

4. **Amphidrome.** The Amphidrome process is a fixed-film, sequencing batch-type process designed for nitrogen removal. It combines filter technology with a biofilter, an anoxic/equalization tank, and a clearwell. Wastewater flows by gravity from the anoxic/equalization tank through the biofilter into a clearwell. Wastewater is then pumped in reverse up through the biofilter to the equalization tank. The Amphidrome biofilter alternates between aerobic and anoxic treatment as the cycle is repeated. Wastewater cycles through the system before it is discharged. The Amphidrome system is capable of nitrogen removal without modifications or additions; however, it often requires a supplemental carbon source. A diagram of an Amphidrome system is included in Chapter 4, Figure 4-15.

The Amphidrome process has the following advantages:

- Tanks are typically below ground, minimizing visual impacts
- Allows secondary treatment and nitrogen removal in a single reactor

- Potential for air emissions is minimal, as filters are enclosed and below ground
- The process also provides physical filtering, as well as biological nitrogen removal

The Amphidrome process has the following disadvantages:

- Difficult to service as all equipment (except blowers) are below grade
- Large headloss and below-grade installation requires effluent pumping
- Performance has been variable

5. **Zenon.** The Zenon treatment system (a membrane bioreactor, MBR, process) is an activated sludge process (Modified Ludzack-Ettinger process) packaged reactor tank that is typically divided into multiple chambers. Wastewater flows first to an anoxic chamber where nitrogen removal takes place. The mixture then flows to aerobic chambers where organic material is metabolized and the treated effluent is separated from the mixture using a polymer membrane ultrafiltration system. The filter material is capable of isolating organic matter, bacteria, and viruses from the effluent flow. These pollutants are retained in the biological process tanks and are recycled back to the anoxic chamber. Treated effluent passing through the filter membrane (permeate) is well filtered and can be used as non-potable water for toilet flushing or irrigation. The Zenon process does not require any additions or modifications for nitrogen removal. A diagram of the Zenon reactor tank is included as Figure 5-4.

The Zenon process has the following advantages:

- Small foot print required and can be retrofit in existing processes
- Process can be automated
- Effluent can be reused for non-potable applications and is suitable for Reverse Osmosis treatment
- High level of virus removal
- Can achieve between 3 and 10 mg/L TN in the effluent

The Zenon process has the following disadvantages:

- Capital costs are high (but decreasing)
- Membrane replacement costs are high
- Few installations in Massachusetts to verify performance

- Significant membrane cleaning requirements
- High degree of pretreatment (screening) required

6. **MicroFAST and Modular FAST Systems.** Two standard fixed activated sludge treatment systems -- the MicroFAST and modular FAST -- are manufactured as fixed-film, aerobic processes that can be modified for nitrogen removal. MicroFAST systems are designed for flows up to approximately 40,000 gpd and include individual units that can each treat up to 9,000 gpd. For flows greater than 40,000 gpd, the modular FAST system is used, which includes a large tank packed with submerged fixed media. Wastewater flows from the primary treatment process through the FAST media and is recirculated through a distribution system. A small portion of the recirculated wastewater flows through a clarifier and is periodically discharged to a leaching area. Nitrification and denitrification are achieved using two anoxic tanks and a reaeration tank. These additional process tanks are part of the Modular FAST treatment facility for flows over 40,000 gpd. The Modular FAST system can be designed with additional septic tanks to achieve necessary anoxic and reaeration zones, and because it is modular, it allows the system to be designed around the owner's needs. Blowers supply air to the system to support bacterial growth on the filter media. A diagram of a MicroFAST system is shown on Figure 5-5.

The FAST system has the following advantages:

- Relatively low space requirements
- Shown effective for nitrogen removal as well as secondary treatment

They have the following disadvantages:

- Requires skilled operation
- Higher energy costs for aeration
- High process control requirements to optimize performance
- May require filtration to consistently achieve less than 10 mg/L TN

7. **Bioclere.** Bioclere is a trickling filter and clarifier in one manufactured unit, designed to treat the anaerobic effluent from a septic tank, which is high in ammonia. The filter media is PVC or polypropylene. Effluent from the septic tank is pumped to a distributor that spreads the wastewater over the top of the media, where aerobic conditions allow nitrification (conversion of ammonia to nitrate) to occur. In the media, anaerobic micro-sites may also form

where some limited denitrification (NO_3-N to N_2 [gas]) can take place. However, the majority of denitrification occurs either when the effluent is recollected at the base of the filter, and about 70 percent of the flow is recirculated back to the anaerobic septic tank or through the use of an anoxic-zone tank following the Biocleres (which is the most common application). Supplemental carbon is required in the Bioclere treatment process. The rest of the effluent is discharged to a leaching area. Bioclere systems treating flows greater than 10,000 gpd often incorporate denitrification filters for nitrogen removal. A diagram of a Bioclere treatment unit is shown in Chapter 4, Figure 4-13.

Installation of the Bioclere is relatively simple. One treatment unit contains a pump, a distributor, and filter media. The sealed double wall of the treatment unit provides insulation to minimize cold weather impacts. The Bioclere can be used year-round or seasonally. However, it takes approximately six weeks for the microbial layer (biomass) to be established on the filter media before full treatment is achieved. Nitrogen reductions of 70 to 85 percent have been achieved. The system can handle flow variations by varying the recirculation rates, and the units can handle increased flow by inserting additional media into the unit.

The Bioclere system has the following advantages:

- Well proven technology in Massachusetts.
- No significant environmental or public acceptance concerns when the system is sited and designed.
- The process operation is flexible, with ability to adjust cycle times and to add additional media.
- The basic system has low operation and maintenance costs. The pump contained in the unit is easily accessible for replacement, when required.

The Bioclere system has the following disadvantages:

- The Bioclere units extend above the ground and may require additional vegetative landscaping to reduce aesthetic impacts.
- Pumps and/or fans are used which must be maintained and periodically replaced.
- Requires supplemental carbon source.
- Requires skilled operator.
- Requires filtration and anoxic reactor to achieve less than 10 mg/L TN consistently.

D. **Wetland-Based Treatment Processes.** There are two main types of natural or wetland-based treatment processes that could be considered for cluster systems: (1) constructed wetlands, and (2) solar aquatics. However, because of their large land area requirements, these processes are to be considered only under the centralized wastewater treatment facilities options.

E. **Filtration.** For many small wastewater treatment facilities there is a need for additional effluent polishing which may include additional denitrification and/or solids removal. This is often accomplished using an effluent filter, typically a granular media type (sand and/or anthracite). Depending on the effluent quality required, supplemental carbon may be necessary for denitrification. The following describes two common technologies used to accomplish filtration.

1. **Slow Sand Filtration.** Slow sand filters are a type of treatment process that is very effective in removing total suspended solids, turbidity, and organics from wastewater. Recent research has also shown that simultaneous nitrification and denitrification occur in slow sand filters. The size of the sand media ranges from 0.15 mm to 0.35 mm, with an effective size of 0.2 mm. The filtration rates of slow sand filters usually range from 2.5 – 6 m^3/m^2/day. Filtration rate and sand size are the key factors to nitrification, denitrification, and total nitrogen removal efficiency. Nitrification efficiency is most sensitive to filtration rate and sand size. A diagram of a slow sand filter is presented in Figure 5-6.

Advantages of slow sand filters:

- Lower unit costs for filtering, operation, and maintenance than rapid sand filters
- Highly effective in removing bacterial contaminants
- Reduction in iron, manganese, nitrate, and turbidity are achieved

Disadvantages of slow sand filters:

- Higher construction costs than rapid sand filters
- Large land requirements

2. **Rapid Sand Filtration.** The major difference between a rapid sand filter and a slow sand filter is the sand size. The size of rapid sand filter media ranges from 0.35 mm – 1.0 mm. Filtration rates range from 100 – 300 m^3/m^2/day – approximately 50 times the rate of slow sand filters. Figure 5-7 shows a picture of a rapid sand filter.

Advantages of rapid sand filters:

- Effective in treating higher solids loadings than slow sand filters
- Process water faster than slow sand filters
- Less land is required
- Commonly applied to small wastewater treatment facilities

Disadvantages of Rapid Sand Filtration

- Complicated to operate
- Pretreatment is often required
- Higher unit costs for filtering, operation, and maintenance than slow sand filters
- Ineffective in nitrogen removal

F. **Sizing and Land Area Considerations for Cluster Systems.** The land area required for a small wastewater treatment facility is often determined by three primary factors:

1. Land area needed for process equipment and operations building.

2. Land area needed for effluent disposal facilities, such as sand infiltration beds or leaching beds.

3. The necessary buffer area to visually screen neighboring properties.

The land area of the process equipment and operations buildings is approximately the same for the different BNR processes identified. The RBC process may require slightly more area and the SBR process may require slightly less area, but these incremental increases are small when compared to the land area requirements for effluent disposal facilities and buffer area. Effluent disposal area requirements for this evaluation are based on the use of sand infiltration beds that require the least space and are the easiest to maintain. As previously mentioned, subsurface leaching fields have a larger area requirement, but may have an advantage if they can be located under a parking area or other open space that has a multiple use. The buffer areas required for a particular small wastewater treatment facility will depend on the site selected and the neighboring properties. The buffer areas estimated are based on a separation distance of 100 feet between the property boundary and the process facilities. This separation distance is greater than the distances presented in MassDEP guidelines, but would allow space for driveway access and sufficient planting to provide a visual screen from adjoining properties.

Typical land area requirements for small wastewater treatment facilities to treat wastewater flows of 10,000, 35,000, and 110,000 gpd (typical flows that might be expected for cluster systems in planning areas) are 1.8, 2.8, and 3.7 acres, respectively. Diagrams indicating a typical plan view of small wastewater treatment systems for flows of 10,000, 35,000, and 110,000 gpd are included as Figures 5-8, 5-9, and 5-10, respectively.

G. **Screening of Cluster Systems.** Cluster wastewater treatment systems incorporating RBCs, SBRs, Amphidrome, Zenon, FAST, and Bioclere treatment components provide a variety of treatment alternatives with excellent levels of treatment. These systems allow for greater operator control and flexibility, typically take up a small area for the treatment process (not including the effluent discharge area), and can handle a range of flows. Because most of the tanks can be prefabricated, these systems provide good treatment with reduced capital costs and land requirements.

These wastewater technology alternatives are evaluated and compared in terms of the criteria presented in Chapter 3 to determine which would receive further detailed evaluation. Table 5-1 summarizes the evaluation of the small wastewater treatment systems. Based on this evaluation and as discussed in the text, the wetland-based treatment systems have high land area requirements and there is concern regarding effluent quality for year-round application. As a result, wetland-based systems are not being considered for use in cluster systems. The small wastewater treatment systems are all considered viable options for cluster systems, with smaller footprints and proven effluent quality, and will be carried forward in the evaluations. However, as flows increase beyond 20,000 to 30,000 gpd, RBC and SBR technologies are more common and have a longer track record and historical performance in treating larger flows.

Costs for these types of systems can vary based on many conditions but in general for "cluster" type systems with flows between 15,000 gpd and 150,000 gpd, the amounts shown in Table 5-2 could be expected. Costs for land acquisition, design, engineering, construction administration, extensive site work and other factors and conditions that might impact costs are not identified here. These values are presented to provide a "relative" comparison and will also be dependant on the bidding climate and Town requirements and constraints that are placed upon a project. Table 5-2 presents examples of costs for these types of systems for flows between 20,000 and 60,000 gpd, similar to many of the existing small facilities in Mashpee.

Because of the associated tanks with SBR units, these systems become more cost effective for larger flows. Conversely, Bioclere and Amphidrome systems over 50,000 gpd are much less common and there is no appreciable cost savings with these larger systems as they are mainly constructed of prefabricated units.

5.3 CENTRALIZED TREATMENT FACILITIES

A. **Introduction.** Centralized wastewater treatment processes include the following system components:

- Preliminary treatment
- Primary Treatment
- Flow Equalization
- Secondary/Advanced Treatment Alternatives
- Effluent Polishing
- Disinfection

These system components are described in the following sections, and each secondary/advanced treatment alternative is described in detail, evaluated and screened.

1. **Preliminary Treatment.** Preliminary treatment is designed to remove large and abrasive objects and solids from wastewater, and it is usually the first process of a centralized treatment facility. The removal of these objects prevents damage to treatment equipment such as pumps, valves, and pipelines.

Bar screens are used to remove large objects at the beginning of the wastewater treatment process, and the material removed is referred to as screenings. Preliminary treatment may include grit removal facilities to remove sand, gravel, and other abrasive materials from the wastewater to prevent excessive wear on moving equipment and minimize heavy deposits in pipelines and channels. Grit removal equipment consists of tanks which allow grit and heavy solids to settle as wastewater flows through the tank. In an aerated grit chamber, aeration is used to keep organic materials in suspension to be treated in subsequent treatment processes. Other types of grit removal may involve velocity control or centrifugal force to achieve grit separation.

2. **Primary Treatment.** Primary treatment is a process to remove settleable solids from the wastewater flow. The solids are removed by gravity settling and can be collected using mechanical equipment or by pumping. Primary treatment methods include primary clarification and primary treatment in septic tanks.

Primary clarification typically utilizes large circular or rectangular tanks with mechanical equipment for collection and removal of solids and scum. As wastewater flows through the tank, solids settle to the bottom of the tank and the scum floats to the top of the tank; both are then collected and removed by mechanical equipment.

Septic tanks are typically used for decentralized wastewater treatment. However, several tanks can be arranged in series to provide primary treatment at larger centralized treatment facilities. Septic tanks at a centralized treatment facility require periodic pumping, but typically do not require moving parts such as those used in primary clarifiers.

3. **Flow Equalization.** Flow equalization is used to even out the flow peaks at a treatment facility. Most of the wastewater is produced during two to three hours in the morning and evening when water usage is at its highest. Flow equalization utilizes one or more aerated storage tanks to store the wastewater during the hourly peaks and feed it into the treatment process evenly throughout the day.

4. **Secondary/Advanced Treatment Concepts and Configurations.** Secondary treatment processes are designed to remove solids from wastewater, reducing the biochemical oxygen demand (BOD) and total suspended solids (TSS) concentrations. Advanced treatment processes typically remove nutrients such as nitrogen and phosphorous.

Biological treatment of wastewater utilizes microorganisms to transform solids and organic matter into biological cell mass, carbon dioxide, and/or nitrogen gas. Biological processes provide an environment for microbial growth using nutrients, BOD, and TSS in the wastewater as a food source. Microorganisms are removed from the wastewater as settled sludge, and the carbon dioxide and nitrogen gas are released to the atmosphere.

Biological processes are classified as aerobic, anoxic, or anaerobic processes. Aerobic processes are those which occur only in the presence of oxygen; anoxic processes occur when there is minimal oxygen but sufficient nitrate nitrogen to act as an oxygen source; and anaerobic processes occur when there is no oxygen or nitrate present.

Biological processes are also classified by the physical configuration used for promoting microbial growth. The following sections provide a brief description of the three major types of biological processes:

a. **Attached Growth Processes.** Attached growth processes utilize an inert media of plastic, stone, sand or other material on which the microorganisms grow and multiply. The wastewater is brought in contact with the microorganisms (also called biomass) on the media, and the biomass consumes the solids and organic material to produce more biomass. Attached growth processes (also known as fixed-film processes) include trickling filters, rotating biological contactors (RBCs), aerated biological filters, packed beds, and fluidized beds. These process names identify the configuration of the support media.

b. **Suspended Growth Processes.** Suspended growth processes are biological processes that maintain a concentrated supply of microorganisms suspended in the wastewater. The supply of microorganisms and organic solids are collectively referred to as mixed liquor suspended solids (MLSS). Decomposition of solids and organic matter is achieved by combining untreated wastewater and MLSS in a contact tank. The microorganisms grow and consume the solids and organic material. The microorganisms multiply and are later separated from the treated water to be reused in the process. Excess biological growth is wasted as sludge. A hybrid to this type of system is the "membrane bioreactor," in which a traditional suspended growth process is modified with membrane filtration to allow increased MLSS and elimination of clarifiers or additional filtration.

c. **Natural Treatment Systems.** Natural treatment systems are considered emerging technologies and have not been widely applied for nitrogen removal. They are not as well defined in terms of predictable performance and design criteria as are more conventional systems, and they have large land area requirements. These systems are generally regarded as experimental technology and may require pilot testing. Natural treatment systems include hydroponic systems (like Solar Aquatics) and constructed wetlands. These systems rely on naturally occurring plants, aquatic life, fish, and sunlight to remove contaminants.

B. **Centralized Treatment Technologies.** The following is a summary of biological processes which can be used for treatment and discharge of centralized wastewater flows. The presentation of alternatives is organized on the basis of the level of nitrogen removal performance that can be typically expected from each process. Table 5-3 presents a general summary and a relative cost comparison of the technologies evaluated to obtain 3-10 mg/L TN. The various technologies are discussed in greater detail below.

1. **Moderate Level of Performance (6 – 10 mg/L TN).**

a. **Activated Sludge/Modified Ludzack-Ettinger (MLE) Process.** The activated sludge process is a suspended growth biological treatment process that utilizes a high concentration of microorganisms suspended in the wastewater flow. An aerobic environment is maintained in the reactor tank through either diffused or mechanical aeration. In addition to supplying oxygen, aeration provides mixing of the suspended solids and microorganisms. The mixture of wastewater and microorganisms passes from the reactor tank to a settling tank where the microorganisms are settled from the treated effluent. The settled microorganisms are then recycled and combined with influent wastewater to maintain the desired concentration in the activated sludge basin. A portion of the settled microorganisms are periodically wasted as sludge.

The oxidation of organic matter and the conversion of ammonia to nitrates (nitrification) are aerobic processes, and the activated sludge process can accomplish both within the same basin. Activated sludge processes can also be modified to achieve nitrogen removal by creating anoxic zones in the reactor tank, which force microorganisms to use nitrates as an oxygen source. With an adequate supply of carbon, the nitrogen is removed as nitrogen gas that is released to the atmosphere in a process known as denitrification. The MLE process is a proven activated sludge process used for nitrogen removal that can remove nitrogen to the 6 to 10 mg/L range. A diagram of an activated sludge/MLE process is included as Figure 5-11.

Activated sludge/MLE processes have the following advantages:

- Relatively low capital and O&M costs
- Does not need to be preceded by primary treatment
- Shown to be highly effective for nitrogen removal as well as secondary treatment
- Provides flexibility in operation and process control

They have the following disadvantages:

- Requires final settling tanks
- Requires skilled operation
- Higher energy costs (for aeration) than other treatment options
- High process control requirements to optimize performance

b. **Activated Sludge / Extended Aeration**. The extended aeration type of activated sludge process simply refers to an activated sludge process with a longer hydraulic retention time as compared to a conventional complete-mix or plug-flow type activated sludge processes. There are a number of versions of this type of process but they are generally able to achieve a high level of treatment and to incorporate nitrogen removal. Three different types of extended aeration processes will be presented because of their common application in the field.

The extended aeration processes are described as follows:

1) Oxidation Ditch. The activated sludge basin is configured in a circular or oblong track that is sometimes referred to as a continuous-loop reactor. Aeration and mixing is typically provided by brush, disk, or mechanical aerators, but diffused aeration with submerged mixers can also be utilized. An oxidation ditch can be operated for biological nitrogen removal by controlling the dissolved oxygen level such that at some point downstream of the aerators the system becomes anoxic, thus promoting denitrification. The system uses very high recirculation rates and can be quite efficient at denitrification when

the system is nitrifying. See Figure 5-12. An oxidation ditch can also be set up in a conventional MLE configuration as discussed above.

Carrousel® and Orbal® are two types of oxidation ditches that are capable of achieving TN concentrations in the range of 6-10 mg/L. Both of these processes will be discussed in further detail in a later section of this chapter.

2) Biolac Lagoon. This is a patented process that maintains an activated sludge in a lagoon with either internal or external final clarifiers. A "wave oxidation" system is used to create alternating periods of aerobic and anoxic treatment, thus achieving both nitrification and denitrification. The process is capable of meeting permit limits more stringent than 6-10 mg/L TN, depending on the characteristics of the wastewater and the design criteria. See Figure 5-13.

3) Schreiber. The Schreiber process is an activated sludge system built in a circular tank with counter current aeration. This aeration system operates with fine bubble diffusers mounted on a bridge that rotates around the tank. This method separates the functions of mixing and oxygen transfer, and it creates alternating periods of aerobic and anoxic conditions to achieve nitrification and denitrification. The systems can be optimized for even greater levels of treatment efficiency. See Figure 5-14.

Activated Sludge / Extended Aeration processes have the following advantages:

- Reliable and flexible operation
- Low level of operator attention required
- Reduced quantity of sludge production

They have the following disadvantages:

- Large land area requirements
- Higher costs associated with large tank volume
- Increased oxygen consumption
- Require final settling tanks

c. **Rotating Biological Contactors (RBC).** RBCs are attached growth processes that utilize disc-shaped plastic media mounted to a rotating shaft. The plastic media is partially submerged in a tank and provides a growing surface for microorganisms. The rotating shaft brings the microorganisms in contact with both the organic matter in the wastewater and oxygen in the atmosphere. As a result, aerobic bacteria metabolize solids and nutrients in the wastewater. Additional microorganisms are produced and are removed from the treated effluent in a settling tank.

When RBCs are used for nitrogen removal, a separate submerged (anoxic) RBC follows the partially submerged (aerobic) RBC to provide denitrification and achieve nitrogen concentrations in the 6 to 10 mg/L range. Methanol must be added to the anoxic RBC to assist nitrogen removal. A process diagram of an RBC is included as Figure 5-2.

RBCs have the following advantages:

- The technology is used extensively and is well accepted by MassDEP
- Energy requirements are low
- Operational requirements are low

They have the following disadvantages:

- Must be preceded by primary treatment
- Must be followed by final settling tank(s)
- Capital costs are high
- Cold weather performance is a concern and the tanks must be covered
- There is minimal process control and flexibility for seasonal flows
- Limited application in denitrifying systems for large flows due to large land area required

d. **Sequencing Batch Reactors (SBR).** Sequencing batch reactors are batch-type treatment processes. Aerobic and anoxic reactions and settling are accomplished in a single basin. Parallel treatment units can be provided. The phases of the SBR process include fill, react, settle, draw, and idle. Wastewater is added during the fill cycle. During the react phase, which alternates between aerobic and anoxic, nitrogen removal will occur. The next phase is settling, followed by decanting of clarified effluent in the draw phase.

Sludge is collected and removed during the idle phase. A process diagram of an SBR is included as Figure 5-3.

Nitrogen removal with SBRs can be enhanced by modifying the length of the cycle times, monitoring the reactor contents to achieve the desired degree of treatment, and adding methanol. SBRs can achieve nitrogen concentrations in the 5 to 10 mg/L range.

SBRs have the following advantages:

- Batch operation allows reactor contents to be retained until desired effluent quality is achieved
- Return sludge pumping and internal recycle equipment are not required
- Settling occurs under totally quiescent conditions with no influent flow
- All phases are provided in a single basin, reducing the need for additional tanks
- Highly flexible operation with ability to adjust cycle times
- The technology is now well accepted and used extensively

They have the following disadvantages:

- A sophisticated control system with valves, timers, probes, and level sensors is required to control intermittent feeding, cycle times, phases, and process performance
- The reactor volume is increased to allow for cycle times and use of the basin for settling
- Flow equalization typically required downstream of SBRs for efficient operation of disinfection and filtration systems

2. **Higher Level of Performance (3 – 6 mg/L TN).** The systems described previously can be upgraded and incorporated with additional treatment units to achieve higher levels of treatment. However, there are other processes that would be considered if the required level of treatment approached 3 mg/L TN, which is considered the Limit of Technology (LOT) for nitrogen removal. This level of treatment is obtainable using proven technologies but typically requires greater safety factors in the design to ensure reliable performance. In addition, the systems are more expensive to build and operate. The processes to be considered for this level of nitrogen removal are discussed below.

a. **Activated Sludge – Plug Flow Systems.** The MLE process discussed previously can be upgraded for higher levels of treatment by adding a post-denitrification zone just downstream of the MLE process. In this zone, which would operate anoxically, most of the remaining nitrates passing through the MLE would be denitrified. However, methanol addition would be required since the wastewater carbon has already been consumed. Re-aeration would need to follow the second anoxic zone in order to release the nitrogen gas. An effluent filter would be necessary for reliable treatment to a level of 3 mg/L TN.

The Bardenpho system is another activated sludge system capable of producing very low levels of effluent nitrogen. It basically resembles an MLE process with a downstream denitrification zone. However, with the Bardenpho process, the second or post anoxic zone is sized to use endogenous carbon rather than relying on an external carbon source. The detention times and reactor sizes therefore are greater than with an MLE with post-denitrification using methanol. However, the Bardenpho would have a lower operating cost. Re-aeration and an effluent filter would most likely be necessary to consistently achieve a level of 3 mg/L TN.

Advantages and disadvantages are similar to those previously identified for activated sludge/MLE processes.

b. **Sequencing Batch Reactor (SBR).** An SBR can be sized to treat to a level of 3 mg/L TN. An external carbon source would be required during a portion of the anoxic react phase. Effluent filtration would be required, requiring flow equalization after the SBR and before the filters. Advantages and disadvantages of SBRs were discussed previously.

c. **Activated Sludge – Extended Aeration.** Extended aeration activated sludge processes were discussed previously. However, there are several extended aeration processes that are capable of achieving LOT treatment. These include the Carrousel® process and Orbal® process as discussed below.

1) <u>Carrousel®.</u> The Carrousel® process by Eimco is a multi-stage continuous loop reactor. Carbon removal and nitrification occurs in the main loop reactor. A sidestream from the loop reactor is diverted into a pre-anoxic zone for denitrification. Very high recycle rates are achieved with this system.

Downstream of the loop reactor is a post anoxic zone which can use either endogenous carbon or an external source of carbon to denitrify the remaining nitrates. Re-aeration allows the release of nitrogen gas. See Figure 5-15.

2) Orbal®. The Orbal® process by USFilter is comprised of three concentric ditches that flow in series. A very low DO is maintained in the first ditch, and the DO increases toward the effluent. Aeration and mixing energy is provided by disc aerators. Nitrification and denitrification occur simultaneously at the minimal DO levels maintained in the process. See Figure 5-16.

Both of these extended aeration activated sludge processes can produce effluent with TN concentrations between 4-6 mg/L, but require a filter at the end of the process to reliably achieve effluent concentrations of 3 mg/L of TN. Advantages and disadvantages were discussed previously.

d. **Membrane Bioreactor (MBR).** With an MBR, the final clarifiers are replaced by a membrane filtration system. Both microfiltration and ultrafiltration type membranes have been used and they are installed either directly in the mixed liquor of an activated sludge system or are installed as an external part of the system. If installed within the mixed liquor, the clarified effluent is pulled through the membrane (outside –in) by a vacuum pump. If installed externally, then the mixed liquor is pumped to the membranes under pressure and the clarified effluent flows through the membrane inside-out. There is no return activated sludge since the mixed liquor suspended solids are retained within the process. Sludge wasting is directly from the mixed liquor. The systems typically operate at very elevated MLSS concentrations (8 to10 g/L) and are thus able to operate at very high sludge ages. The high level of performance is obtained through the operation at high sludge ages plus the ability of the membranes to remove essentially all of the solids. An MBR can be configured in most different types of activated sludge flow schemes such as are typically used for nitrogen removal. There are a number of equipment manufacturers offering MBR systems; a few are discussed below.

1) Zenon MBR. The Zenon process utilizes hollow-fiber ultrafiltration membranes mounted in modules. The modules are immersed in the mixed liquor and operate under a vacuum. A diagram of the vertically mounted Zenon reactor tank is included as Figure 5-4.

2) Enviroquip MBR. The MBR manufactured by Enviroquip utilizes Kubota flat plate microfiltration membranes. In most other respects, the system is similar to Zenon. The membranes are installed within the mixed liquor and operate under a slight vacuum. See Figure 5-17.

The MBR processes have the following advantages:

- Small foot print required and can be retrofit in existing processes
- Process can be automated
- Effluent can be reused for non-potable applications and is suitable for Reverse Osmosis treatment
- High level of virus removal

MBR processes have the following disadvantages:

- Capital costs are high (but decreasing)
- Membrane replacement costs are high
- Few installations in Massachusetts to verify performance
- Significant membrane cleaning requirements
- High degree of pretreatment (screening) required

e. **Fixed Film Systems.**

1) Biological Aerated Filters (BAFs). BAFs are a fixed film system where biomass is grown on a granular media such as sand. The wastewater flows either upward or downward through the media bed. The BAFs are high rate systems and can achieve a high level of treatment with some degree of solids filtration. The Biofor BAF by Infilco Degremont, Inc. is an upflow system that uses a non-buoyant media. Wastewater and air are introduced at the bottom of the filter and flow upward. The Biostyr BAF by Kruger is another upflow filter that utilizes a floating media. The systems can be designed for BOD removal, nitrification, and denitrification (denitrification involves the addition of an anoxic filter). See Figure 5-18.

2) Denitrification Filters. Denitrification filters can be added downstream of any process that is capable of complete nitrification. Because denitrification filters can only denitrify effluent that has already been nitrified, a high level of nitrification is required prior to the filters to achieve a low total nitrogen level in the effluent. Two general types of denitrifying filters are available: downflow packed bed systems and upflow fluidized beds. Downflow packed bed systems are deep bed sand filters operated to encourage attached microorganisms to denitrify. Methanol is added to provide a carbon source for denitrification. Packed beds provide adequate detention time and surface area to maintain the anoxic conditions needed for denitrification to occur. The packed beds also act as effluent filters to remove suspended solids and improve effluent quality. Periodically, the beds must be backwashed and "bumped" with backwash water for a few seconds to release nitrogen gas which accumulates in the filter media and increases headloss through the media. Figure 5-19 presents a schematic for denitrifying filters.

   Denitrifying filters are a proven technology and are capable of achieving a high level of nitrogen removal to meet a total nitrogen limit of 3 to 6 mg/L, provided a high level of nitrification is provided in preceding steps.

   Upflow fluidized beds consisting of columns containing sand have been used for denitrification. Denitrifying microorganisms attach to the sand as nitrified effluent flows upward through the column. This type of process is considered an attached growth and suspended growth process. Fluidized beds have seen limited applications and have been used mostly for industrial wastewater treatment.

Biological Aerated Filters and Denitrifying Filters have the following advantages:

- Well-proven and reliable technology to meet a total nitrogen limit of 3 to 6 mg/L.
- Familiar technology, as it is similar to deep bed filters.
- No significant environmental or public acceptance concerns.
- Potential for air emissions is minimal, as filters are enclosed in a building.

They have the following disadvantages:

- Moderate capital costs for new facilities and building enclosure.
- High O& M Costs.
- Effluent pumping is typically required due to large headlosses associated with the process.
- Methanol addition is required.

3. **Variable Nitrogen Removal (Natural Systems).**

a. **Constructed Wetlands.** Constructed wetlands consist of an artificial receiving water body with vegetation to treat surface and subsurface water flow. Vegetation must be harvested on a regular basis to effectively manage the system, and disposal of wetlands vegetation is a significant consideration in the design and operation of wetlands systems. Treatment performance in northern climates may be subject to seasonal weather variations, and large storage basins may be required to effectively manage wastewater flow. Nitrogen removal is typically accomplished through plant uptake and denitrification which can occur in anoxic regions of the wetland. These systems are generally regarded as emerging technology and may require pilot testing prior to being approved by MassDEP for installation. They may best be utilized as a polishing step to remove some of the remaining nitrogen. A diagram of a constructed wetland system is shown on Figure 5-20.

Constructed wetlands systems have the following advantages:

- Require little operational control
- Relies on use of natural systems

Wetlands treatment systems have the following disadvantages:

- Large land area requirements due to long wastewater retention times
- Cold weather performance is questionable
- Systems have limited number of full-scale installations, particularly for nitrogen removal
- Design information and performance data are limited
- Removal efficiency is not readily predictable or controllable

- Harvesting and disposal of vegetation is required
- May require an additional treatment process prior to or following the system to achieve permit limits

b. **Solar Aquatics.** A variety of solar aquatics systems are available ranging from homemade greenhouses to systems located inside living space where plant material is used for decoration. Some systems use only plants, while others utilize organisms such as snails and fish. Wastewater is first allowed to settle to remove large solids. The wastewater is then treated by a series of stages with different types of living organisms, usually plants or algae. The effluent then moves to a unit that uses wastewater nutrients as a food source. Sunlight is required to supply light to the plants and heat for the overall system. The final effluent is then discharged to a leaching area. Again, these systems may best be utilized as a final polishing step for nitrogen removal. A diagram of a solar aquatics system for large wastewater flows is included as Figure 5-21.

Solar aquatics systems have the following advantages:

- Process operations can be flexible, with ability to adjust cycle times
- Pumping requirements are minimal
- The process is very interesting and can be a tourist attraction

They have the following disadvantages:

- The process is very labor intensive
- Performance data is limited for larger installations (greater than 1 mgd)
- The system has a large space requirement due to the long wastewater retention time required for proper treatment
- Requires frequent maintenance and knowledge of biological and ecological systems for proper operation
- Requires energy to maintain relatively high operating temperatures
- Requires disposal of accumulated biomass generated in the system
- Plant death and low treatment rates may occur during low-temperature months, impacting effluent quality

5.4 WATER REUSE TECHNOLOGIES

Additional treatment can be provided downstream of most of the technologies discussed previously, to obtain an effluent quality suitable for a variety of water reuse options.

A. **Reverse Osmosis (RO).** Reverse osmosis, also known as hyperfiltration, is a process to remove dissolved salts and small particles from a solution. During the reverse osmosis process, only the fluid to be purified will pass through the semi-permeable membrane, while the undesired contaminants, such as dissolved organics, bacteria, salts, sugar, and proteins, will be rejected. Larger particles are more likely to be rejected by the membrane. The driving force required to push fluid through the membrane increases as the concentration of rejected items increases. Figure 5-22 presents the schematics of a reverse osmosis unit and the membrane mechanism.

Advantages of Reverse Osmosis:

- Effective in particulate nitrogen and phosphorus removal and, to a minor degree, the removal of some large organic soluble forms
- Able to remove dissolved organics that are less selectively removed by other demineralization methods
- Able to meet stringent water quality standards

Disadvantages of Reverse Osmosis:

- High capital costs
- Limited applications in domestic wastewater treatment
- Demands a high degree of pretreatment to avoid excessive backwashing requirements

B. **Ultrafiltration.** Ultrafiltration is used to remove dissolved and colloidal materials and large molecules. It utilizes a porous membrane driven by relatively low pressure. Ultrafiltration can be applied alone or can serve as a pretreatment step to RO. The disadvantage of ultrafiltration is the high capital cost. The mechanism of ultrafiltration is similar to reverse osmosis as presented in Figure 5-22.

C. **Electrodialysis.** Electrodialysis is another membrane technology. The membranes used in electrodialysis are semi-permeable and ion-selective. During the electrodialysis process, electrical potential is applied to the two electrodes; as a result, electrical current is produced and passed through the solution. Cations migrate toward the negative electrode while anions move towards the positive electrode. Since the cation- and anion-permeable membranes are arranged in an alternate manner, regions of concentrated and dilute salts are formed. A diagram of electrodialysis membranes is shown in Figure 5-23.

Advantages of Electrodialysis:

- 100% of suspended organic nitrogen can be removed
- Certain levels of ammonia and nitrate can be removed

Disadvantages of Electrodialysis:

- Occurrence of chemical precipitation of salts with low solubility on membrane surface
- Clogging of membrane by residual colloidal organic matter in wastewater treatment effluent
- Activated carbon pretreatment may be needed to reduce membrane fouling

5.5 ADVANCED NITROGEN REMOVAL

A. **Introduction.** There is a significant amount of experience with removing nitrogen to levels below 8 – 10 mg/L, and there is increasing experience with treatment to the Limit of Technology (3 mg/L TN). The need to treat to levels below 3 mg/L is rare and thus there is little experience with full scale municipal systems in the application of the appropriate technologies. Technologies available will be discussed below.

First, it is important to understand why the task of removing nitrogen to levels below 3 mg/L is so difficult. The nitrogen that remains in the effluent following biological treatment through any of the systems discussed previously consists of one of three forms—ammonia, oxidized nitrogen (nitrate), and organic nitrogen. In a system that is fully nitrifying, the ammonia will be less than 1 mg/L, perhaps as low as 0.2 – 0.5 mg/L. If the system has performed very well with denitrification, there will still be a small amount of nitrate in the effluent, again less than 1 mg/L.

Both ammonia and nitrate are soluble so filtration will not reduce them further. Organic nitrogen consists of both a soluble and a particulate form. The particulate form is associated with any microorganisms that escape in the effluent and is generally proportional to the level of suspended solids in the effluent. The soluble organic nitrogen is generally less than 1 mg/L but can be higher in treatment plants that receive waste from industries such as textile or dye plants or that receive a significant amount of septage. Thus, if the various forms of nitrogen in the effluent are added together, the concentration approaches 3 mg/L as a limit unless some additional, more unusual treatment steps are taken to remove them.

B. **Technologies used to achieve less than 3 mg/L TN.** The technologies described below reduce the effluent Total Nitrogen by removing, in one of several ways, one of the three remaining fractions of nitrogen in the effluent.

1. **Adsorption.** Activated carbon may be used to adsorb soluble organics including both carbon and nitrogen compounds. There are several processes to accomplish this. Granular Activated Carbon (GAC) filters are available as either downflow gravity filters or pressure filters. Powdered Activated Carbon (PAC) is typically added to a stage of the activated sludge process to adsorb the organics while also retaining them in the process for possible further biological treatment. The Zimpro PACT system is an example of this type of process.

2. **Advanced Oxidation Technologies**. Advanced Oxidation Technologies (AOT) work on the principle of breaking down the bonds in the organic nitrogen (and other organic compounds as well) that make it difficult for the compound to be oxidized biologically. Once these bonds are broken down, the nitrogen compound may be further metabolized by natural biological processes. There are two basic AOT technologies. One relies strictly on UV light and is referred to as direct photolysis. The organic compound would absorb the energy provided by the UV light, which causes the bonds to disassociate. The second type, which would be more applicable, utilizes a combination of UV light and some type of oxidant, such as hydrogen peroxide or ozone. The UV light and oxidant produce hydroxyl (OH^-) radicals, which are very strong oxidants and will attack the bonds.

3. **Precipitation.** Chemical precipitation may be used to remove additional ammonia. If magnesium and phosphorus salts are added, the ammonia will be precipitated as a form of struvite.

4. **Ion Exchange.** Zeolite media has been used to remove the ammonium cation (NH_4^+). The media can be added as a slurry or can be used in a packed column. There are several commercial applications of this technology. The media is regenerated with a caustic salt water solution.

5. **Break Point Chlorination.** Break point chlorination chemistry is well known and was applied early in the industry as a physical chemical process for nitrogen removal. The process was found to be expensive and difficult to operate as the main process for removing all of the ammonia from a waste stream. However, it is more practical when treating only the ammonia remaining in the effluent of a biological treatment plant.

6. **Membrane Filtration.** Reverse Osmosis (RO) membrane filtration was discussed previously. It is somewhat effective in removing additional organic nitrogen because the membranes are capable of blocking some of the higher molecular weight organic compounds. The system would also remove any nitrogen associated with effluent particulate solids.

5.6 DISINFECTION ALTERNATIVES

A. **Introduction.** For any new wastewater treatment facility it is likely that disinfection in some form will be required. Several of the existing WWTFs have disinfection facilities that use ultraviolet (UV) disinfection to perform this task. MassDEP typically requires disinfection for new or upgraded WWTFs, and may require it for any new facility in the PPA. This section will review the most common types of disinfection and their advantages and disadvantages.

The three most common methods used for disinfection include:

- Chlorination (using sodium hypochlorite)
- Ozone
- Ultraviolet (UV) Radiation

B. **Chlorination.** Chlorination can be provided by the addition of a number of chemicals, including sodium hypochlorite, calcium hypochlorite, gaseous chlorine, bromine chloride, and chlorine dioxide.

Use of either sodium hypochlorite or calcium hypochlorite for disinfection is very similar and involves storage and feeding of hypochlorites in solution form. Calcium hypochlorite is available in solid form and sodium hypochlorite is in liquid form. The disinfection mechanism and potential adverse environmental impacts are the same as those with gaseous chlorine. Hypochlorites are hazardous and corrosive, but provide more safety in the storage and handling of chemicals than gaseous chlorine in the storage and handling of chemicals.

Gaseous or liquid chlorine is another form of chlorination, but would involve increased safety issues and public acceptance concerns. It should not be considered due to the storage and safety concerns.

Chlorine dioxide can be used for disinfection and is highly effective, but its use has been very limited. Chlorine dioxide is unstable and potentially explosive; therefore, it cannot be transported. It must be generated on site with chlorine and sodium chlorite, both of which can be dangerous. The environmental impacts of disinfection with chlorine dioxide are not well known.

Bromine chloride has also been shown to be effective in providing disinfection. One advantage of bromine chloride compared to chlorine and hypochlorite is that a shorter contact time is required for disinfection. Bromine chloride is hazardous and corrosive and requires special transportation, storage, and handling requirements. Bromine chloride is very similar to chlorine in terms of its requirements for chemical feed systems, handling, and precautions. The use of bromine chloride has been limited, and extensive data is not available.

All chlorine compounds can combine with organic material and produce trihalomethanes (THM), which have been proven to be carcinogenic in small quantities. The United States Environmental Protection Agency (USEPA) and MassDEP have established a drinking water standard of 0.1 mg/L for THM. Testing of treatment plant effluent on Cape Cod disinfected with sodium hypochlorite does not indicate the formation of THM above 0.1 mg/L.

Sodium hypochlorite (NaOCl) is the preferred method of chlorination and has the following advantages:

- Process can be controlled for feed dosages and chlorine residual
- Minimal energy use is required
- Low O&M costs, depending on the cost of NaOCl

It has the following disadvantages:

- A large chlorine contact tank is needed
- Potential perception of groundwater contamination with trihalomethanes (THM)
- Storage and handling of sodium hypochlorite can be a safety hazard
- Limited shelf life of NaOCl

C. **Ozone.** Ozone has been found to be highly effective in disinfection and has fewer potential adverse environmental impacts on receiving waters and water supplies. Ozone must be generated on site, which normally involves the use of high voltage electrodes and pure oxygen. Ozone is then transferred from the gas phase to the liquid phase with diffusers and closed contactors. The off-gases from the contactor must be treated thermally to destroy excess ozone, which is toxic.

Ozone presents less environmental concern than chlorination because ozone dissipates rapidly to oxygen after application, leaving no ozone residual and adding dissolved oxygen to the treated effluent. Ozone, however, can produce toxic mutagenic and/or carcinogenic compounds. Unlike chlorine, ozone does not produce a residual concentration which can be measured and used as an instantaneous indication of satisfactory disinfection.

The cost to produce ozone on site is high, resulting from the high capital cost of generation equipment and the high energy requirements. Ozonation is labor intensive because the system is complex and difficult to operate and maintain.

Disinfection with ozone has the following advantages:

- Ozone dissipates rapidly to oxygen, leaving no ozone residual
- Ozone adds dissolved oxygen to the treated effluent
- Fewer adverse environmental impacts compared to chlorination
- Process is well demonstrated

It has the following disadvantages:

- Ozone is toxic, even though it rapidly dissipates to oxygen
- High capital costs associated with generating equipment
- High energy usage to generate ozone
- Complex operation and maintenance
- High O&M costs
- Can produce toxic mutagenic and/or carcinogenic compounds
- Destruction of off-gases from contactors required to destroy ozone
- Does not produce a residual that can be monitored like chlorination to verify performance

D. **Ultraviolet (UV) Radiation.** Unlike the previous alternatives, UV radiation provides disinfection without the use of chemicals. UV light provides radiation which penetrates the bacterial cell walls and destroys the cell. No toxic residuals are produced due to the lack of chemicals in the treatment process. The UV bulbs are contained in racks or modules that are submerged in channels. Required contact time with the bulbs is short. Effluent suspended solids can interfere with disinfection efficiency by preventing penetration of the cell wall and by absorbing radiation; therefore, a high quality effluent is required prior to the UV disinfection. The UV bulbs do foul and must be periodically removed and cleaned, which is normally accomplished chemically by dipping the rack of bulbs in a bath. The bulbs must be replaced periodically, which adds to the O&M costs; however, UV disinfection has been found to be cost competitive with chlorination.

UV disinfection has the following advantages:

- No adverse environmental impacts
- Minimal space requirements with short contact time
- Ease of operation and maintenance
- Cost competitive with other disinfection techniques
- Well-proven effectiveness

It has the following disadvantages:

- Suspended solids, turbidity, and color can interfere with the effectiveness of disinfection
- High quality effluent required prior to UV disinfection, which impacts overall costs
- Periodic cleaning and replacement of bulbs is required
- Does not produce a residual that can be monitored like chlorination to verify performance

Table 5-4 presents a matrix summary of the screening criteria for each of the disinfection alternatives, and the findings of the screening process are briefly summarized below.

Sodium hypochlorite is not recommended due to potential liabilities associated with the transportation and storage of hypochlorite, which is corrosive and toxic, and it has the potential to produce trihalomethanes in the treated effluent.

Ozonation is not recommended for further evaluation due to its high costs, complex operation, and the fact that it may potentially produce toxic compounds.

Ultraviolet (UV) is currently the most common disinfection technology. Its costs (capital and O&M), reliability, simplicity, and minimal chemical requirements (cleaning solutions), make this the most favorable of the technologies and therefore is the recommended technology.

5.7 SCREENING OF SECONDARY/ADVANCED TREATMENT TECHNOLOGIES

The screening of secondary/advanced treatment technologies is based upon a description of each technology, their respective advantages and disadvantages, and the screening criteria established in Chapter 3 of this Report. A summary of secondary/advanced treatment technologies with respect to the screening criteria is included in Tables 5-1 and 5-3. More detailed costs for these technologies will be developed as part of the scenario development in the next phases of the project; therefore, they are only presented in relative terms here.

The activated sludge/MLE process is a proven and reliable technology with moderate capital and O&M costs. Land area requirements for activated sludge process tanks and equipment are relatively low. Primary treatment equipment would not be required, but effluent clarification with final settling tanks would be required. This process would have higher capital costs than an SBR, which will yield the same or better effluent quality.

RBCs are less desirable due to their requirement for primary treatment, necessity to cover equipment due to cold weather, higher capital costs, and limited process control. Thus, this process is not considered for further evaluation.

SBRs perform all treatment phases in a single basin, are highly flexible in operation, and can achieve consistent nitrogen removal to the range 5 to 10 mg/L. SBRs should be evaluated in detail.

MBRs, like the Zenon system, are commonly used for small wastewater treatment plants or as a retrofit to an existing system, but there are a limited number of large installations in Massachusetts; therefore, large-scale performance data is limited. These processes are typically used for smaller installations; however, they will be considered for further evaluation for centralized facilities in addition to being considered for cluster systems, as described in Chapter 4, especially because of their benefits for use within Zone IIs.

Oxidation ditches provide good nitrogen removal when using additional pre- or post-anoxic tanks designed for additional nitrogen removal. They can achieve nitrogen removal to the range of 5 to 10 mg/L. The system provides relatively easy operation, but the large tank requirements have higher capital costs than other processes. Use of oxidation ditches is a traditional process that is more than capable of achieving the treatment requirements; however, land area requirements and capital costs likely make this less attainable for the PPA. Also, it is likely that a new facility will only serve part of the PPA, which may be more efficiently addressed using other technologies like SBRs and MBRs.

Solar aquatics have high land area requirements and would be unsuitable for use in the PPA due to the high maintenance requirements, low process control, minimal operational data for large installations, and cold weather performance. Solar aquatics should not be considered for further evaluation.

Constructed wetlands would potentially require an extensive area, depending on centralized wastewater flow volumes, and may not provide consistently reliable effluent quality. Also, the performance may be limited in cold weather. This process has been shown in studies to perform denitrification, although a pilot study may be necessary to prove its effectiveness in cold weather. Constructed wetlands should not be considered for further evaluation as a wastewater treatment process; however, their use as a mitigation measure for treating groundwater or stormwater in watersheds should be further examined.

Biological aerated filters are typically used to provide BOD and TSS removal and nitrification of the ammonia in the wastewater. Depending on the type of BAF used, it may need to be followed by a denitrification filter to denitrify the full nitrogen loading (approximately 30 mg/L of nitrate nitrogen) because minimal denitrification is achieved in some BAFs. This technology takes up minimal space and is useful at treatment plant sites that have no room for expansion or where only nitrification is needed. BAFs also have high capital and O&M costs.

Denitrification filters provide denitrification and filtering of a previously nitrified effluent. They can be used to denitrify most of the full nitrogen loading (approximately 30 mg/L of nitrate nitrogen) when they are preceded by a BAF or an activated sludge extended aeration process. They can also be used to denitrify (polish) a greatly reduced nitrogen loading (approximately 5 to 10 mg/L of nitrate nitrogen) when they are preceded by one of the nitrification and denitrification processes previously described. They can be sized smaller (and have lower capital costs) and will use less methanol when they are used to polish a previously nitrified and denitrified effluent. This process should be evaluated further for effluent polishing only.

The following technologies will be evaluated further for new WWTFs:

- Sequencing batch reactors
- MBRs
- Effluent polishing with denitrification filters
- Extended aeration processes (as site condition allows)

5.8 IDENTIFICATION OF AVAILABLE WASTEWATER TREATMENT FACILITY SITES FOR PRIORITY AREAS

Site identification and screening for decentralized facilities for cluster systems, small wastewater treatment facilities, and effluent discharge locations within the PPA will be performed as part of the next phase of work – Development of Alternative Scenarios.

Chapter 6

Effluent Discharge Technologies and Alternatives

CHAPTER 6

SEWAGE COLLECTION AND EFFLUENT DISCHARGE TECHNOLOGIES

6.1 INTRODUCTION

Centralized wastewater processes, whether neighborhood cluster systems or centralized municipal systems, require sewage collection infrastructure to convey raw sewage and effluent discharge facilities designed to minimize the impacts of effluent discharge on nearby surface waters and/or groundwater. Potential impacts of large effluent discharge flows include groundwater mounding and an increase in pollutant concentrations in receiving water bodies.

This Chapter will identify and screen sewage collection technologies and effluent discharge technologies for more detailed evaluation.

6.2 SEWAGE COLLECTION TECHNOLOGIES

Several types of sanitary sewer collection systems are in use throughout the United States, each with advantages and disadvantages. Each system is designed to transport sewage from individual buildings to a treatment and disposal facility. This is normally accomplished with a combination of simple gravity flow, pumps and force mains, and may include a vacuum system. Careful analysis of the area being sewered must be performed during planning and design to determine the feasibility of a particular collection system.

This section presents several different types of collection systems and the associated advantages and disadvantages of each. Each technology is described in terms of operating principle, design considerations, and suitability in given conditions.

A. **Gravity Sewers and Lift Stations.** The most prevalent type of sewer system is a traditional gravity sewer. This type of system involves the installation of sewers at a constant downhill slope that is capable of maintaining a sufficient velocity within the sewer line that will keep solids suspended within the waste stream, rather than settling to the bottom of the pipe.

The minimum size of a sanitary sewer is typically 8 inches. The pipe size increases proportionally with the expected wastewater flow. The sewer is installed at a constant slope until its depth becomes so great that a sewage pumping station (lift station) is needed to "lift" the flow to a wastewater treatment plant or to another gravity sewer. In flat terrain, several lift stations may be required before the flow is pumped to a treatment facility.

In most situations, homes along a gravity sewer connect into the system with gravity service connections from the building to the collector sewer (the main). Houses that are below the street elevation may have to use small pumps for discharging to the main.

The installation cost and ease of construction of a gravity sewer depend greatly upon the topography within a particular area and on the specific soil types. In areas where topography is consistently increasing or decreasing, the sewers can be installed close to minimum depth. In very hilly areas, deeper sewers and/or lift stations may be required. This can significantly increase construction costs when compared with other options.

Advantages of gravity sewers include the following:

- A properly designed and installed gravity sewer requires little maintenance.
- A gravity system can be easily expanded to serve additional areas.
- The potential for odors in a properly designed gravity sewer is low.
- A gravity sewer system is reliable because it is not dependent upon electrical power for operation. When lift stations are used on collector sewers, electrical generators are provided to supply power during a power outage.

Disadvantages of gravity sewers include:

- Gravity sewers are installed at a constant slope, and thus can require deep excavations as the topography changes. Construction of gravity sewers with trenchless technologies is generally difficult due to the necessity of constant slopes. Construction is generally disruptive to traffic patterns and surface infrastructure, as they are often located along the centerline of roads.

- Lift stations are required to transport the sewage out of low points in topography.
- Capital and operation and maintenance costs increase with each lift station required.
- Lift stations tend to increase the potential for odor emissions.
- If not installed properly, gravity sewers are prone to infiltration from groundwater, which reduces the wastewater-carrying capacity of the pipe, increases pumping costs, and can adversely affect treatment capacity and process effectiveness at the downstream treatment facility.
- If not installed properly, there is a potential for exfiltration of sewage into the surrounding soil if breaks occur in the pipeline.

B. **Pressure Sewers with Grinder Pumps.** A pressure sewer system requires the installation of a grinder pump to serve each building or group of buildings. Wastewater flows by gravity into the pump chamber, where the sewage is shredded and pumped into a pressure sewer. The pressure sewer eventually discharges into a gravity sewer main, lift station, or treatment facility. This type of technology has become more widely used and is particularly suited to areas where there is a need to minimize excavation.

The typical pressure in this type of system is 5 to 40 pounds per square inch (psi). Pressure systems can be expanded to serve additional areas up to a design limit of 60 psi. Typically, systems can be expanded to serve a large number of additional homes, but the overall expansion capability tends to be less than that of a gravity sewer.

Advantages of a pressure sewer include the following:

- The collection main is installed at a relatively shallow depth and is independent of grade changes. This will result in lower construction costs and less overall disruption to the area due to shorter construction periods.
- A pressure sewer can serve areas of hilly terrain or marginal slope.
- The pressure sewer in the street is not subject to infiltration.
- The shredding action of the pump eliminates the need for a larger-size collection system. Pressure sewer pipe diameters range from 1-1/4 inch to 4 inch, depending on expected design flow.
- Portions of pressure sewers can be installed with trenchless technologies, further reducing general disruptions experienced during construction.

Disadvantages of this type of system include the following:

- Each building or group of buildings in the system requires a pump unit, which increases operation and maintenance requirements. Spare parts must be maintained for these units to minimize disruption of service.
- Each pump unit is dependent upon electrical power for proper operation; since the pumps are located at individual homes, municipal backup electrical power is typically not provided. Storage capacity is typically built into each pump chamber (normally 60 gallons). However, in a prolonged power outage, it is possible for the wastewater flow to exceed this capacity and back up into the pipelines within the structures. This can be prevented by providing electrical connections on each pump unit to allow a portable generator to be connected during times of prolonged power outage. Another option is to install a larger capacity unit or a dual tank system, thus providing more storage.
- Pressure systems are more sensitive to seasonal flow conditions than gravity sewers. In areas with extreme seasonal fluctuations, minimum flow conditions must be carefully quantified to be sure the sewage can properly flow through the system without hardening and causing blockages.
- There is a potential for exfiltration of sewage into the surrounding soil if leaks or breaks occur in the pipeline.
- Training is required to familiarize operating staff with maintenance of the pumps and pressure sewers.
- Ownership considerations need to be clearly defined early in the selection and design process. Costs for systems will depend on who owns, operates, and maintains the grinder pump. Easements may also be required to address maintenance and emergency power issues.

C. **Septic Tank Effluent Sewers.** Septic tank effluent sewers incorporate new or existing septic tanks to remove solids from the sewage, and then transport septic tank effluent to a treatment facility. The use of septic tanks in this manner prevents a large portion of solids and grease from entering the sewer.

Septic tank effluent sewer systems require routine pumping and maintenance of the septic tank. Each septic tank needs to be inspected during sewer construction to replace those tanks that provide inadequate service. Inadequate tanks include those which are prone to infiltration, are insufficient in size, or have inappropriate inlets or outlets.

When connecting septic tank effluent into existing gravity systems, odor control systems may be required at the discharge point and downstream pump stations to mitigate odors caused by the hydrogen sulfide content in the effluent. Manholes at the discharge point should be protected from corrosion, which can occur as a result of the high hydrogen sulfide concentrations.

There are two types of septic tank effluent collection systems: (1) septic tank effluent pump systems; and (2) septic tank effluent gravity systems. A discussion of each system is presented below.

1. **Septic Tank Effluent Pump (STEP) System.** The STEP system involves the installation of an effluent pump immediately downstream of (or in) the septic tank, which pumps the effluent to a pressure sewer. Thus, the STEP system is very similar to a pressure system. The STEP system has the following advantages:

- The system can serve in areas of hilly or flat terrain.
- The pumps and piping can be installed at shallow depths, which reduces construction costs and overall disruption associated with excavation.
- The pressure sewer in the street is not subject to infiltration.
- Septic tank effluent pumps tend to be less expensive than grinder pumps because the need for a shredder is eliminated.
- Few solids are transported in the system, which reduces the potential for sewer blockages caused by solids deposition.

The STEP system has the following disadvantages:

- The septage must be periodically pumped from the individual septic tanks.
- The system relies on electrical power to operate the pumps and will not function during power outages. However, the pumps are frequently installed in tanks with relatively large storage capacity.

- A large number of pumps are required, which creates greater maintenance requirements of this system when compared to a gravity sewer.
- Hydrogen sulfide buildup is common within these pipelines, which increases the potential for odors and corrosion.
- There is a potential for exfiltration of sewage into the surrounding soil if leaks or breaks occur in the pipeline.
- Training is required to familiarize operating staff with maintenance of the pumps and pressure sewers.
- A treatment plant that receives flow from this type of system must be carefully designed because it will not receive the higher organic loading that is typically needed for nitrogen removal treatment processes.
- Ownership considerations need to be clearly defined early in the selection and design process. Costs for systems will depend on who owns, operates and maintains the pump in a STEP system. Easements may also be required to address maintenance and emergency power issues.
- Greater levels of site investigations are required to establish the adequacy of existing septic tanks.

2. **Septic Tank Effluent Gravity (STEG) System.** The STEG system can be used to transport effluent from septic tanks to a pumping station or treatment facility. Layout of the system is very similar to a gravity system. Advantages of STEG systems include the following:

- A flatter slope can be maintained in comparison with gravity sewers, because most of the larger solids have been removed in the septic tank. The flatter slope allows for shallower installations.
- The lack of solids allows smaller diameter pipes to be installed. Sizes typically range from 4 to 6 inches versus 8 inches or greater for a typical gravity sewer.
- Cleanouts can be installed instead of manholes, which reduces installation costs.
- Very little maintenance is required on this type of system.

STEG systems have the following disadvantages:

- The septage must be periodically pumped from the individual septic tanks.
- Hydrogen sulfide buildup is common within these pipelines, which increases the potential for odors and corrosion.
- They are not adaptable to hilly terrain.
- A treatment plant that receives flow from this type of system must be carefully designed because it will not receive the higher organic loading that is typically needed for nitrogen removal treatment processes.
- Greater levels of site investigations are required to establish the adequacy of existing septic tanks. Location of existing septic tank may also limit ability to connect to the sewer main by gravity.

D. **Vacuum Sewers.** Vacuum sewers are smaller than traditional gravity sewers and rely upon a vacuum created within the pipeline to draw the sewage towards a lift station. A vacuum pump located at the lift station pumps air out of the sewer, creating a vacuum inside the sewer. Sewage from individual homes flows by gravity to a vacuum valve pit.

As sewage fills a chamber in the bottom of the valve pit, a sensor activates an automatic vacuum valve. When the valve opens, sewage is drawn into the sewer because of the pressure difference between the sewer and atmospheric pressure outside the valve. Each subsequent opening of the valve draws the sewage further downstream until it reaches the lift station, where it is pumped to a gravity sewer or treatment facility.

Advantages of vacuum sewers include:

- Installation at shallow depths is possible, which reduces installation costs and excavation time.
- Because the piping must be airtight to allow proper vacuum operation, the potential for infiltration is low. Infiltration can occur if a pipe leaks or breaks in areas where the line is completely submerged in groundwater; however, leaks are readily identified through vacuum system operation records.
- Vacuum stations can be equipped with emergency generators, which allow the system to remain in operation during power outages. Valve pits and buffer tanks do not

require power and will remain in operation during power outages as long as the vacuum station is operational.

- This technology provides some flexibility to avoid conflicts with existing underground utilities.

A vacuum system has the following disadvantages:

- A vacuum must be constantly maintained in the pipeline for the system to work. Malfunctions (air leaks) in the line or open valves can affect the entire system and must be fixed quickly to keep the system operational. Leaks or malfunctions may also be difficult to locate.
- The potential for odor generation is greater due to the vacuum pump air flow. This air flow must be treated to minimize odors.
- This type of system is not readily adaptable to hilly terrain and it has design limitations on length, elevation change, and headloss.
- The sewage moves at high velocities when the vacuum valve is actuated. Pipe fittings must be designed to withstand the high velocity and possible impact of entrained solids.
- Vacuum sewers are relatively new in the New England States, although Cape Cod has the first two installations in Massachusetts in the towns of Hyannis and Provincetown. Because it is a fairly new technology, specialized training to design, construct, and operate the system is required.

E. **Combination of Technologies.** In most cases, the combination of terrain, soil conditions, and congestion of an area prevents one single type of sewer system from being the most cost effective. In these situations, the combination of two or more methods may achieve an optimum solution. The combination most widely used is a combination of pressure sewers with grinder pumps and gravity sewers.

In some cases, it is not feasible to combine methods due to the inherent characteristics of the specific technology. Septic tank effluent systems are designed to transport only liquids using a small diameter pipe. Thus, any other type of system which carries solids should not be able to connect into this system.

6.3 EVALUATION AND SCREENING OF COLLECTION TECHNOLOGIES

The screening of collection system technologies is based on the description provided for each technology, the respective advantages and disadvantages, and the screening criteria as discussed in Chapter 3. A summary of collection system technologies and a side-by-side comparison of screening criteria are included in Table 6-1 and are briefly reviewed below.

Wastewater collection with gravity sewers and lift stations is a widely used, simple, and reliable technology. Gravity sewers are easily expanded to accommodate additional flows. The relative cost of gravity sewers depends on environmental conditions and increases with the number of lift stations required and depth of excavations.

Pressure sewers with grinder pumps are less widely used than gravity sewers, but have relatively low construction costs and are adaptable to changes in topography. Public acceptance of pressure sewers may be low due to the need for a pump at each individual home or business. In addition, pressure sewers rely on electrical power, and flow backup can occur during power outages.

Septic tank effluent sewers require installation of special pumping equipment and piping at each point of connection to the gravity system. The main advantage of these systems is the reduced amount of solids transported in the collection system and the reduced potential for sewer blockage caused by solids deposition. Unfortunately, the lack of organic solids in the sewage delivered to the treatment plant will make the nitrogen removal process more difficult due to the need for organic carbon to make denitrification possible. These systems also require periodic pumping of the individual septic systems, which adds operational costs and potential for odor generation. They also do not lend themselves to being added to existing collection systems that transport all the wastewater solids. As a result, planning areas that might be served by a WWTF designed for nitrogen removal should not use septic tank effluent systems. However, septic tank effluent systems may be considered for cluster systems outside of nitrogen-sensitive areas.

Vacuum sewers have maintenance requirements similar to those of low pressure systems and require specialized staff training for implementation. Vacuum sewers are not easily expandable and require accurate flow estimates prior to construction. The capital costs of vacuum sewers are typically slightly higher than low pressure systems. Vacuum systems have a greater reliability of continued operation during power outages than low pressure systems because electrical service is not required at the valve pit.

6.4 IDENTIFICATION OF EFFLUENT DISCHARGE TECHNOLOGIES

All wastewater treatment facilities require a means of discharging and/or reusing treated effluent. The technology selected for effluent disposal needs to be specific to the discharge site to minimize the impacts of treated effluent on nearby surface waters and groundwater, while utilizing any potential site's unique features. Land availability, nearby land use, discharge technology, and distance from the treatment plant also play a role in determining suitable effluent discharge sites. This section describes available technologies and provides advantages and disadvantages for each in order to screen the technologies. A comparison of the effluent discharge technologies is summarized on Table 6-2.

A. **Sand Infiltration Beds.** Sand infiltration beds are open basins designed to allow treated effluent to flow across the bottom of the basin and percolate through the sand bed, through the unsaturated zone, and then to the groundwater. Bed maintenance is relatively easy because the bed is exposed at the surface and the sand surface can be raked or replaced if the sand becomes plugged with effluent solids. Hydraulic loading rates of 5 gallons per day per square foot (gpd/ft^2) of bed area are typically allowed by MassDEP for most of the soils found on Cape Cod.

Effluent disposal in sand infiltration beds has the following advantages:

- Bed construction is relatively simple.
- Operation and maintenance (O&M) is relatively easy and O&M costs are lowest.
- Hydraulic loading rates are typically higher than other disposal methods, which allow the beds to take up less area.

Effluent disposal in sand infiltration beds has the following disadvantages:

- Construction of new beds requires the clearing of large areas of land, which may have a visual impact.
- Infiltration beds do not have secondary uses, such as parking lots and recreational areas.

- Extensive site work may be required for construction of new beds at new sites.
- Disinfection is typically required.

B. **Subsurface Infiltration.** Large–scale subsurface infiltration facilities typically utilize pump and piping systems to pressure dose infiltration areas (trenches, beds, or galleys) where the effluent percolates to the groundwater. Maintenance and cleaning of these systems is more difficult because the infiltration area is not exposed to the surface and effluent solids cannot be easily removed. Subsurface infiltration beds can have secondary uses, such as parking lots, lawns, playing fields, and recreational areas. Hydraulic loading rates of 2.5 gpd/ft^2 (to the trench or galley base and side walls) are typically allowed by MassDEP for most of the sandy soils on Cape Cod.

Subsurface infiltration facilities have the following advantages:

- Disinfection is typically not required prior to discharge unless it is in a water supply recharge area.
- Facilities are contained underground and can have a secondary use, such as parking lots and recreational areas.

They have the following disadvantages:

- Large land areas are required (larger than sand infiltration beds) due to lower hydraulic application rates.
- Pressure dosing is typically required for large systems, which adds capital and O&M costs.
- Extensive site work may be required for construction, particularly if the site is forested.
- Limited access for cleaning and maintenance.

C. **Spray Irrigation**. Spray irrigation facilities are typically comprised of effluent pumps, distribution piping, and a spraying system consisting of risers and spray nozzles. Treated effluent is pumped through various distribution lines and discharged via spray nozzles to the surrounding area. Spray irrigation systems have often been used at golf courses and in large remote fields. Application rates for non-golf course areas are typically 2 inches per acre per week. Application rates for golf courses are typically based on the turf management needs.

Effluent disposal using spray irrigation has the following advantages.

- Allows for secondary use of land (i.e., golf courses) as regulated by MassDEP.
- Provides inexpensive means of irrigation, reducing clean water demands.
- Provides nitrogen uptake by plant life and also reduced nitrogen application for fertilization at golf courses.
- Evapotranspiration reduces infiltration volume, thereby creating less potential for groundwater mounding.

Effluent disposal using spray irrigation has the following disadvantages:

- Difficult to find locations suitable or willing to use spray irrigation.
- Limited cold weather use due to potential freezing problems.
- Spray nozzles may be subject to clogging.
- Requires secondary means of effluent disposal or storage during winter months.
- Must meet more stringent MassDEP requirements for reclaimed water use, including disinfection.
- Large areas are needed.

D. **Well Injection.** Well injection involves the discharge of treated effluent to groundwater below the land surface. The discharge is accomplished by pumping the effluent through wells that extend into permeable, saturated, and unsaturated geologic strata. When discharged into saturated strata, this type of discharge can be compared to the reverse of extracting water from a well.

Wells can be designed to discharge a range of wastewater flows depending on site conditions, such as depth to groundwater and geological conditions. A potential concern of well injection is the mounding of groundwater in low elevation areas. As a result, well injection requires extensive testing prior to design and construction. This would include hydraulic conductivity tests, hydrogeologic surveys, and pilot testing.

Well injection for effluent disposal has been implemented on a limited basis throughout the United States, and there are limited regulatory standards on the siting, design, construction, and operation of the wells. A Pilot test for this technology was completed at the Hyannis Water

Pollution Control Facility that indicated injection wells can become plugged with biological growth if the effluent is not chlorinated. Discussions with MassDEP indicate minimal support for the development of this technology because it requires chlorination, which can create secondary impacts to the groundwater. For example, the formation of disinfection byproducts may provide health risks.

Effluent disposal with well injection has the following advantages:

- The land area required would be much less than the area required for infiltration beds, subsurface infiltration, and spray irrigation. The effluent discharge would occur below the surface, and the surface would have minimal disruption.
- Discharge points (wells) could be spread over a large area to minimize groundwater mounding.

It has the following disadvantages:

- Effluent filtration is needed to provide a high level of nutrient and solids removal to minimize plugging in the wells.
- Relatively unproven technology in Massachusetts.
- Limited performance data is available.
- Chlorination is needed, which conflicts with guidance from MassDEP.

E. **Wick Well Technology.** Wick technology is a relatively new and innovative approach to treated wastewater disposal. Wick technology entails the use of larger (3 to 6 foot) wells which extend to the water table. The wells are filled with stone; treated wastewater is discharged over the stone to infiltrate via gravity flow into the underlying aquifer. There are two wick well installations in southeastern Massachusetts.

Effluent disposal with wick wells has similar advantages and disadvantages to injection wells. Advantages include:

- The land area required would be much less than the area required for infiltration beds, subsurface infiltration, and spray irrigation. The effluent discharge would occur below the surface, and the surface would have minimal disruption.

- Discharge points (wells) could be spread over a large area to minimize groundwater mounding.
- High public acceptance.

Disadvantages include:

- Effluent filtration is needed to provide a high level of nutrient and solids removal to minimize plugging in the wells.
- Relatively unproven technology in Massachusetts. Limited performance data is available.

F. **Drip Irrigation.** Drip irrigation is a subsurface version of spray irrigation. Treated wastewater is used to irrigate agricultural land or other open land (parks, ballfields, etc.).Subsurface piping is laid out approximately 6 to 12 inches below the surface in areas to be irrigated. Discharge of wastewater is through emitters that are spaced 12 to 24 inches apart; the laterals are spaced at 12 to 24 inch intervals. Water is pumped through the lines under pressure but is discharged slowly through the emitters. The intent of the system is to discharge the water into the root zones of the plants.

Advantages include:

- Can be used in adverse terrain conditions.
- Is associated with water reuse because water is discharged into root zone of plants or crops.
- Ease of construction.
- Low human exposure to wastewater.
- Low delivery rate to minimize water table impacts.
- High public acceptance.

Disadvantages include:

- Effluent must be highly treated to minimize plugging.
- Difficult to monitor emitter performance.
- Periodic backflushing is required.

- May not operate in very cold conditions, or redundant facilities may be required by MassDEP due to restrictions on irrigation during the winter/non-growing season months.
- Will likely be subject to the MassDEP Interim Guidelines for Reclaimed Water Use and therefore have additional treatment requirements and discharge location restrictions in order to be used.

G. **Ocean Outfall.** This alternative would involve the siting, construction, and operation of an ocean outfall for effluent disposal into Nantucket Sound. The Massachusetts Ocean Sanctuaries Act prohibits the discharge of any municipal wastewater into an ocean sanctuary. Waters off the coast of Mashpee, Barnstable and Falmouth within the PPA fall into the Cape and Islands Ocean Sanctuary. The legislation is strictly imposed and a variance is only available to communities that have an existing municipal wastewater discharge to an ocean sanctuary. Since there are no existing outfalls, the PPA would not be eligible to apply for a variance.

Effluent disposal using an ocean outfall has the following advantages:

- No large land area requirements
- Protects the groundwater and coastal embayments

It has the following disadvantages:

- Special legislation, possibly at the Federal level required
- Extensive design and permitting requirements depending on the location of the discharge
- Low public acceptance
- Potential reduction in aquifer recharge

H. **Wetland Restoration.** In recent years an innovative technology/management concept has been considered. It is the conversion of abandoned cranberry bogs or previously modified wetlands to more diverse wetland settings that can accommodate and will benefit from increased hydrologic flow. It has the primary purpose of improving water quality of the groundwater flowing through the wetland and restoring hydrologic balance to areas that have been impacted by drinking water withdrawals. It can provide natural nitrogen attenuation and thereby protect downgradient marine waters. It can also provide improved wildlife habitat and improved open-space and recreational areas.

This concept has significant regulatory permitting challenges due to national, State, regional and local wetland protection regulations that have been written to stop any modifications in wetlands. However, many regulators, municipalities, and citizen groups are recognizing the water-quality and wildlife habitat benefits of converting previously disturbed, monoculture cranberry bogs to more diverse wetland settings.

The concept has been developed and promoted by the Massachusetts Estuaries Project (MEP) as a way to increase natural nitrogen attenuation in the watershed. It is also being considered as a way to reintroduce highly treated wastewater into watersheds that have been impacted by water withdrawals.

One application of this innovative approach of wetland restoration is being investigated by the towns of Barnstable and Yarmouth. The towns are considering the feasibility of introducing a well treated water (with minimal nitrogen and phosphorous) into the subsurface through a leaching area that is adjacent to a long constructed wetland/pond. The constructed wetland/pond is adjacent to a cranberry bog or natural wetland. The subsurface flow will make its way through the wetland/pond and then into the bog/natural wetland. This approach may be effective at restoring hydrologic flow to a watershed that is currently impacted by high water withdrawals (as high as 1.3 million gallons per day). A general schematic of this process is shown in Figure 6-7.

The benefits of wetland restoration include the following:

- Clearing of land is minimal; no change in land use would result.
- Significant nitrogen attenuation.
- High public acceptance.
- Potentially high ecosystem benefits.

The disadvantages include:

- Regulatory hurdles are likely.
- Disinfection of effluent is likely required.

I. **Technology Summary.** Sand infiltration beds are a simple and reliable effluent discharge technology with relatively low operating costs.

Subsurface infiltration facilities are simple and reliable. These facilities are constructed below ground and therefore have minimal visual impacts, have reduced potential for odors, and can provide secondary use of the land. Effluent discharge in subsurface infiltration facilities has higher land area requirements. Subsurface infiltration facilities are not easily cleaned. Therefore, the life of the facilities will be dependent on the quality of the effluent.

Spray irrigation and drip irrigation are simple and reliable effluent discharge technologies with relatively low construction costs. They can provide additional nitrogen uptake and removal. Irrigation uses are limited to growing seasons and both types of irrigation may be restricted in accordance with the MassDEP Interim Guidelines on Reclaimed Water Use.

Effluent discharge through well injection has relatively low land requirements and relatively low construction costs. Well injection has the potential of plugging at the injection point due to build-up of fine solids and biofouling; effluent would require chlorination. This method does provide a means of effluent disposal at multiple potential sites with minimal land requirements; however, MassDEP resistance to support and permit this technology eliminates it from further consideration.

Ocean outfalls have minimal land requirements and groundwater impacts. However, legislation would not allow an outfall to be constructed.

Effluent discharge through wick well is a variation of well injection and has similar advantages and disadvantages. It is attaining limited regulatory acceptance, and more complete acceptance is contingent on long-term demonstration of effectiveness.

Wetland restoration and nitrogen attenuation concepts are being evaluated on Cape Cod and include evaluation and modeling of very site-specific considerations. If they prove to be feasible and acceptable to the regulatory community, they could be low cost methods to discharge highly treated effluent, recharge impacted portions of the watershed, and attenuate nitrogen in the groundwater.

Costs for effluent discharge technologies will ultimately depend on the site conditions and therefore costs will vary significantly between technologies. Factors such as amount of land available, land purchase costs, abutters, loading rates, and distance from the wastewater treatment facility will all impact costs. The most critical of these is the loading rate allowed by the technology and the site because higher allowable loading rates allow for more water to be discharged within a smaller footprint. As a result, higher loading rates result in significantly reduced costs.

Table 6-3 summarizes some of the ranges of costs based on recent projects related to these technologies. For technologies where limited construction cost information was available, engineering estimates have been provided.

Open sand beds can be the most cost effective when loading rates of 5 or more gpd/ft^2 can be achieved. These higher rates are dependant on site conditions and in some cases rates higher than 5 gpd/ft^2 may be negotiated with MassDEP. The higher loading rates would allow up to five times the loading capacity for the same costs as identified on the Table 6.3.

No costs for wetlands restoration were developed as this will be very dependant on regulatory approval, permitting, and other site specific conditions.

The following effluent discharge technologies are recommended for further evaluation:

- Sand infiltration beds.
- Subsurface leaching.
- Spray irrigation (in conjunction with other technologies for winter discharge).
- Drip irrigation (in conjunction with other technologies for winter discharge).
- Wetland restoration (if appropriate sites are available).

6.5 WASTEWATER TREATMENT ISSUES AND REQUIREMENTS FOR EFFLUENT DISCHARGE AT NEW REMOTE SITES

As the PPA and sewer commission considers developing new effluent discharge sites, potential future discharge limits must be considered.

A. Effluent that is discharged into subsurface leaching or irrigation facilities must have low suspended solids to avoid plugging the soil infiltration system and requiring costly repairs. Effluent filtration would reduce this potential.

B. Effluent discharges upgradient of freshwater ponds and lakes would likely need phosphorus removal to avoid the creation of a phosphorus plume that could migrate to the freshwater body and cause eutrophication. The Otis Air Force Base wastewater treatment facility discharge and the eutrophication of Ashumet Pond in Falmouth and Mashpee is a recent Cape Cod example of this issue. This case study is described in the 2003 report by the U.S. Geological Survey (USGS) entitled *"Reactive-Transport Simulation of Phosphorus in the Sewage Plume at the Massachusetts Military Reservation, Cape Cod, Massachusetts."* Groundwater modeling as developed by USGS (as part of the MEP work) will need to be evaluated when considering whether effluent discharge at the proposed sites would recharge into freshwater bodies and therefore require phosphorus removal.

C. Effluent discharge into Zone II areas will need to meet the MassDEP *"Interim Guidelines on Reclaimed Water"* dated January 2000. These guidelines are currently being revised and may become more stringent in the future. Effluent limits for this type of discharge would need to meet, at a minimum, the following treatment and design standards for areas within Zone II's with greater than a 2 year time of travel:

- pH: 6 to 9
- BOD concentration: <30 mg/L
- Turbidity: ≤5 Nephelometric turbidity units (NTU)
- Fecal coliform content: <200 colonies/100 mL
- TSS concentration: <10 mg/L
- TN concentration: <10 mg/L

Effluent discharges in a Zone II area with less than a two-year travel time to a public water supply would need to meet, at a minimum, the following, more stringent treatment and design standards:

- pH: 6 to 9
- BOD concentration: ≤10 mg/L
- Turbidity: ≤2 NTU

- Fecal coliform content: median of no detectable colonies/100 mL and no single sample to exceed 14 colonies/100 mL
- TSS concentration: $\leq$5 mg/L
- TN concentration: <10 mg/L

These standards are typically met by microfiltration and disinfection.

D. MassDEP may not allow discharge of a chlorinated effluent into a Zone II area due to the possible formation of disinfection byproducts. In this case, ultraviolet radiation disinfection would be needed.

These requirements and issues will need to be incorporated into the individual site evaluations and should be reviewed with MassDEP to discuss potential permitting requirements as part of the next phase of this project.

6.6 SUMMARY AND RECOMMENDATIONS

The sewage collection system technologies were narrowed down to the following technologies for further consideration:

- Gravity sewer and lift stations
- Low pressure sewers and grinding pumps

The effluent recharge alternatives discussed in this chapter were narrowed down to the following for further evaluation:

- Sand infiltration beds.
- Subsurface leaching.
- Spray irrigation (combined with sand infiltration or subsurface leaching for winter use).
- Drip irrigation (combined with sand infiltration or subsurface leaching for winter use).
- Wetland restoration.

The next phase of the WNMP includes development of various alternative scenarios to manage wastewater nitrogen.

Chapter 7

Non-Wastewater Nitrogen Reduction Alternatives

CHAPTER 7

NON-WASTEWATER NITROGEN REDUCTION ALTERNATIVES

7.1 INTRODUCTION

The WNMP Needs Assessment Report and the MEP reports showed that wastewater is the primary source of nitrogen to each of the Town's watersheds. However, there are other sources that contribute nitrogen. The percent of non-wastewater nitrogen varies depending on the characteristics of the individual planning zones. The previous chapters have focused on nitrogen reduction by means of wastewater treatment; this chapter will discuss alternative nitrogen reduction methods.

Although these technologies will not be the "backbone" of the approach to achieve TMDL's set for the PPA, they are a significant part and any effort to reduce nutrients and pollutants from reaching groundwater and estuaries is important.

7.2 STORMWATER NITROGEN REDUCTION

Stormwater runoff is typically a significant nitrogen source, although this depends on the amount of impervious area (roofs, driveways, roads, parking lots, etc.) in a planning zone. Reduction of impervious areas can reduce the resulting pollutant loads. Town bylaws can be used to encourage Low Impact Development (LID), to regulate amounts of impervious areas, and to reduce the amount of runoff that flows to paved roads. However, runoff from paved roads is also a significant contributor to nitrogen loads.

The most common method of controlling stormwater runoff is infiltration in various types of leaching facilities; however, studies have shown that this provides little or no nitrogen removal. Stormwater treatment for nitrogen typically involves using constructed wetland systems, or some other vegetative system, to biologically denitrify the oxidized nitrogen in the stormwater. This type of treatment requires a large land area to construct. In addition, the nitrogen removal performance of these types of systems for treatment of stormwater is highly variable and dependent on several factors including nitrogen concentration, climate, season, vegetation types, and surrounding land use. Some of the applicable technologies are summarized below.

Regionally, the University of New Hampshire has done extensive research on Stormwater systems and information on these efforts can be found at www.unh.edu/erg/cstev.

A. **Dry Extended Detention Basins.** Detention basins are designed to contain stormwater for a minimum of 24 hours in order to allow solids to settle out of the water. The basin, which is planted with vegetation, collects runoff and releases it slowly over the course of 24 hours; the basin is dry between storms. Fairly large land areas are needed and nitrogen removal is relatively low (20%-30% of total nitrogen), unless the nitrogen is tied up with sediments. Figure 7-1 illustrates a typical detention basin cross-section. Maintenance activities include litter and debris removal, mowing, restoration of dead or damaged ground cover, and sediment removal.

Advantages of dry extended detention basins include:

- Relatively high nitrogen removal rates
- Suitable for use in the PPA
- Suitable for most soils and geology

The disadvantages of detention basins include:

- Requires a large land area
- Difficult to construct in developed areas (best on sites with a minimum of 10 acres)
- Sediment removal is required more often in colder climates
- Can be an aesthetic detraction from adjacent properties
- Does not provide groundwater recharge

B. **Wet Retention Ponds.** Retention ponds are designed to have a permanent pool of water for a significant portion of the year (the wet season at a minimum). Solids settle out of the water in a forebay; nutrients, including nitrogen, are removed by means of algae and other biological activity in the larger basin. During precipitation events, water is discharged from the permanent pool as stormwater runoff enters the pond (minimal decrease in runoff volume is provided). For areas with permeable soils (such as sand), an impermeable layer will need to be included in the design in order to maintain a permanent pool of water. Average total nitrogen removal is around 30%, and construction cost estimates (as of 2005) are upwards of $13,000 per acre of contributing drainage area. A typical retention pond is shown in Figure 7-2. Maintenance activities include litter and debris removal, management of wetland plants, mowing, erosion monitoring and repair, and sediment removal.

Advantages of retention ponds include:

- Suitable for application in the PPA
- Relatively high, consistent pollutant removal rates

Disadvantages include:

- Potential drowning hazards
- Can become a mosquito breeding ground if improperly designed
- Large land requirements make it difficult to fit into already developed areas
- Large drainage area is needed in order to maintain a permanent pool of water (25 acres+)
- High salt concentrations and sediment loads (from winter road maintenance) can impact pond vegetation and reduce storage capacity
- May cause loss of wetlands or forest if improperly located
- Does not provide groundwater recharge

C. **Infiltration Basins.** Infiltration basins are shallow reservoirs that are designed for stormwater infiltration. These basins are similar to extended detention basins except that stormwater is infiltrated into the ground rather than being released as surface runoff. The bottoms of the basins need to be completely flat. Soils cannot drain either too fast or too slow – they should be in the range of 0.5 to 3 inches per hour. The bottoms and sides of infiltration basins are vegetated. These are maintenance-intensive facilities (requiring mowing, aeration of bottom, de-thatching basin bottom, maintenance of ground cover, and sediment removal) and pretreatment is critical. Properly designed and maintained basins can achieve more than 60% total nitrogen removal.

Advantages of infiltration basins include the following:

- Relatively high nitrogen removal rates
- Suitable for application in the PPA
- Provides groundwater recharge

Disadvantages of infiltration basins include the following:

- Require relatively large areas of continuous, flat space
- Difficult to retrofit
- Not aesthetically pleasing
- High maintenance
- High rate of failure due to clogging
- Multiple pretreatment practices are recommended to prevent excessive sediment buildup

D. **Stormwater Wetlands.** Stormwater wetlands are similar to the retention ponds discussed previously. The difference is that wetland plants are included in the design of the pond/wet areas. These plants are tolerant of saturated soil conditions and provide for natural pollutant removal. See Figure 7-3 for a typical stormwater wetland diagram. There are four basic types of stormwater wetlands, varying in the number and size of pools as well as land requirements. Sedimentation and microbial activity are the primary means of nitrogen removal, which varies from 20% to 50% removal depending on the type of stormwater wetland used. Stormwater wetlands have moderate maintenance requirements, including removal of invasive species, sediment and debris removal, mowing, and plant replacement as necessary.

Advantages of stormwater wetlands include:

- Applicable for use in the PPA
- Suitable for large drainage areas (25 acres and more)
- Suitable in areas with high ground water
- Provides aesthetic appeal
- Can provide wildlife habitat

Stormwater wetlands have the following disadvantages:

- Not suitable for use in densely developed areas
- Large land area is consumed
- Freezing may occur, reducing the effectiveness of pollutant removal
- Road salting and road sanding may cause high salt and sediment concentrations that can impact wetland vegetation
- Mosquito breeding can occur if improperly designed
- Does not provide groundwater recharge
- Creation of wetlands may restrict adjacent property usage through setback restrictions.

E. **Submerged Gravel Wetlands.** These are a type of stormwater wetlands in which runoff flows through a submerged gravel filter that has wetland plants at the surface. Biological activity on the surface of the rocks and uptake by the plants are the primary means of pollutant removal. Gravel wetlands have the same advantages and disadvantages of other types of stormwater wetlands. They are separated for the means of this discussion because of the significantly higher reported nitrogen removal rates. Figure 7-4 illustrates a typical gravel wetland. Nitrate removal is in the range of 80-99% and 2005 construction costs were over $22,000 per acre of contributing drainage area.

F **Bioretention (Rain Gardens).** Rain gardens are landscaping features that provide stormwater treatment. Runoff flows over a sand bed into a shallow depression. The sand bed slows the velocity and evenly distributes flow. After the sand bed is a ponding area, where woody and herbaceous plants provide evapotranspiration or biological uptake of pollutants. Microbial activity contributes to removal of soluble pollutants, such as nitrates. Excess runoff is infiltrated into the soils or flows to an underdrain in areas with less pervious soils. Vegetation selection is important to the functioning of rain gardens because of varying wet and dry conditions that are experienced. Rain gardens are well-suited for parking lots or residential areas. USEPA reports total nitrogen reduction efficiencies in rain gardens to be approximately 50%. The maintenance activities required include mulching, mowing, watering, treating diseased vegetation, and litter and debris removal. Figure 7-6 is a typical bioretention design. Initial construction costs are relatively high – approximately $25,000 to $30,000 per acre of contributing drainage area.

Some of the advantages of rain gardens are:

- Suitable for application in the PPA
- Suitable for urban/developed areas such as parking lots
- Easy to retrofit
- Maintenance requirements can be performed by landscaping contractor
- Aesthetic benefit (shade and wind breaks, noise absorption, visual improvements)
- Provides groundwater recharge

The disadvantages include:

- Not suitable for large drainage areas
- Initially require intense maintenance, which decreases over time
- Frozen soil can prevent infiltration

G. **Water Quality Swales.** Swales are broad, shallow channels with dense vegetation along the sides and bottom. Swales are designed at slopes sufficient to slow down stormwater runoff (slopes should be between 0.5% and 5%), allowing sedimentation, filtration, and infiltration. Swales are especially well suited to treat runoff from roadways because of the linear nature of the design. Various estimates of nitrogen removal efficiencies have been reported, ranging from 40% to nearly 100%. Maintenance activities for swales include trash and debris removal, sediment removal, mowing, and plant maintenance. See Figure 7-5 for a water quality swale diagram.

Advantages of water quality swales include:

- Suitable for use in the PPA
- Suitable for a variety of soil conditions
- Can serve as snow storage area during winter months
- Provides groundwater recharge

The disadvantages include:

- Cannot accommodate a large drainage area (5 acres and more)
- Require relatively flat sites

H. **Porous Pavement.** Traditional pavement can be replaced with porous pavement, which is a permeable paving surface that often has an underlying stone reservoir to store surface runoff before infiltration. Porous pavement includes porous asphalt, pervious concrete, and permeable pavers. Porous asphalt and pervious concrete contain fewer fine materials than traditional pavement, making it highly permeable. Permeable pavers consist of either concrete blocks or fibrous grids, each containing open areas through which grass can grow or in which sand or gravel can be placed. Maintenance activities include vacuum sweeping, debris and sediment removal, and mowing and seeding upland areas. Porous pavement is illustrated in Figure 7-8. Construction cost estimates vary, ranging from 50% more than traditional paving to 4 times more than traditional paving.

The advantages of porous pavement include:

- Reduces amount of runoff that needs to be treated by means of other treatment practices
- Land area can have additional uses, rather than being solely used for stormwater treatment
- Can reduce hydroplaning
- Easy to retrofit in parking areas
- Provides groundwater recharge
- Can improve site appearance

The disadvantages include:

- USEPA does not recommend use of porous pavement near groundwater drinking supplies due to the pollutants that are not treated, such as nitrates and chlorides
- Areas of high commercial traffic and truck loading are inappropriate
- Road salt can clog the filtration area
- Pavers are easily damaged by snow plows
- Frost heave can result when runoff freezes below the pavement
- Requires frequent maintenance
- High rate of failure due to clogging
- Vehicles can leak fuel or other toxic chemicals, which will eventually reach the groundwater with no treatment
- Construction costs are higher than traditional paving

I. **Infiltration Trenches.** Infiltration trenches are shallow excavations filled with stone, providing a storage area for stormwater runoff. The runoff is filtered as it flows through the stone and then into the underlying soils. Infiltration trenches require pretreatment by means of other best management practices in order to function properly. Maintenance of infiltration trenches includes sediment removal, debris removal, and prevention of large vegetation close to the trench. A typical diagram of an infiltration trench is shown in Figure 7-9.

Advantages of infiltration trenches include:

- Suitable for application in the PPA
- Adaptable to small sites due to the narrow profile
- Provides groundwater recharge

Disadvantages of infiltration trenches include:

- No appreciable nitrogen removal
- Larger sites generally cause clogging, which results in high maintenance
- Multiple pretreatment practices are recommended
- Upland drainage area needs to be stabilized to prevent high sediment loads
- Road salting can speed clogging, prompting failure
- Pretreatment is necessary to increase effectiveness and life of the trench
- Trench may freeze, preventing runoff from entering the trench

J. **On-Lot Treatment.** Several practices are considered on-lot treatment, ranging from rain barrels to diverting runoff to pervious areas. Many of the on-lot treatment systems are similar to methods discussed previously; however, they are on a smaller scale and are the responsibility of individual homeowners. The goal of on-lot treatment is to minimize the amount of stormwater runoff that reaches paved roads and enters the drainage system. One of the easiest methods to implement is the rain barrel. A rain barrel collects rooftop runoff and stores it for landscaping use or other use by the homeowner. Rain barrels reduce the gross impervious area of a watershed. In addition, when the stored runoff is used for landscaping, additional nitrogen uptake is provided by the plants being watered. Rain barrel maintenance involves annual cleaning, cistern inspection, and mosquito breeding prevention. Surface treatments require sediment removal and vegetation maintenance. Costs for on-lot treatment are highly variable, but rain barrels can be as inexpensive as $100.

Some of the advantages of on-lot treatment are:

- Reduces the total imperviousness of a watershed
- Broad application potential
- Useful for water conservation when runoff is used for irrigation
- Minimal maintenance
- Provides groundwater recharge

On-lot treatment has the following disadvantages:

- Rooftop runoff generally has lower pollutant concentrations than other sources
- Homeowners need to perform basic maintenance

K. **Recommendations.** The Towns within the PPA should promote the use of vegetated swales, basins, and wetlands as the preferred way to reduce nitrogen loading from stormwater sources. In addition to the ability of these facilities to reduce nitrogen, they also are easier to maintain than catchbasins and leaching pits (the traditional type of stormwater management) and they can be the least expensive. Their main disadvantage is that they require a greater land area than a typical catchbasin and leaching pit. The best ways to promote these methods include:

- Initiate collaboration between the Conservation Commission, Highway Department, and Building Department to develop the public understanding that recharge of stormwater adjacent and/or into a natural wetland is a beneficial way to manage stormwater as long as it is introduced without promoting erosion or sedimentation.
- Provide Highway Department budget to remediate all surface stormwater discharges to this type of Best Management Practice.

The key characteristics of the stormwater treatment technologies discussed above are summarized in Table 7-1.

7.3 OTHER NITROGEN REDUCTION OPTIONS

A. **Fertilizer Education and Management.** The possible reduction of nitrogen leaching into the ground from fertilized areas is difficult to predict due to the popular desire of growing green lawns with minimal effort. Education on proper fertilizer types, application techniques, and frequency of use can help reduce over-fertilization, which is the most common cause of fertilizer leaching into the groundwater system.

Although nitrogen from fertilizer only makes up a small percentage of the overall nitrogen impacting an embayment, any effort to actively reduce nitrogen inputs will assist in preserving and restoring impacted embayments.

Public participation programs have been initiated in other Cape Cod Towns, most notably Falmouth, where the Preserve Falmouth's Bays and Ponds and the Falmouth Friendly Lawn (FFL) programs have been initiated. The Preserve Falmouth's Bays and Ponds is a public outreach program designed to educate people on the uses of fertilizers and was developed as part of the Nitrogen Offset Program for Bournes, Green, and Great Ponds. The FFL program, approved in July 2003, has created a means of rewarding those organizations and individuals who volunteer to limit their use of fertilizer nitrogen, and signifying those products considered Falmouth Friendly. Although the program is voluntary, it is recommended that other Towns, including Mashpee, look to implement similar programs.

In Dennis, the Comprehensive Wastewater Management Task Force's Public Outreach Subcommittee, working with the Cape Cod Collaborative Extension, developed a *Clean-Green Lawn Program*, which is patterned after Falmouth's Friendly Lawn program. A flyer was produced for distribution to the public (attached in Appendix B). The purpose of this program is to make the public aware of the potential damage improper use of lawn fertilizers can do to our estuaries and groundwater. It also provides them with a simple program from soil preparation to proper fertilizer application, maintenance, watering, and weeding to help them have a healthier lawn, avoid over fertilization, and reduce nitrogen leaching into our groundwater.

B. **Landscape Design Practices.** Although the majority of the population does not realize it, landscaping practices have a significant impact on water quality. Education to inform homeowners of ways to minimize negative impacts can reduce the effect that landscaping has on water quality. Certain landscape design practices can reduce fertilizer needs, reduce impervious area, and increase runoff control. One program initiated to promote the use of landscape practices that maintain and/or improve water quality is the 2006 Greenscapes program (http://www.nsrwa.org/greenscapes/default.asp). This program is an effort by several non-profit groups and southeastern Massachusetts towns. The program provides workshops and guidebooks to educate consumers on environmentally-conscious landscape designs. One such guidebook is attached as Appendix C. Landscape practices recommended in the guidebook include pesticide and fertilizer alternatives, composting, and low maintenance plants. Programs such as this are voluntary and therefore will rely on thorough public education. However, each Town's cost could be as low as a few cents per resident reached. Therefore, public education is important to obtain support for these practices from homeowners and lawn care providers.

C. **Animal Waste Management.** In addition to being a source of bacterial contamination, nutrients from animal waste can result in eutrophication of lakes and ponds or algal blooms. Several options should be considered to encourage pet owners to control animal waste.

- Ordinances and associated fines can be implemented requiring removal of pet waste from public areas (roads, beaches, parks, etc.) and other peoples' property. Reminders of the ordinance in public parks along with supplies for waste removal may improve compliance.
- Dog parks can be created where pets are allowed off the leash. Parks can include reminder signs and waste removal supplies. Dog parks should be designed to minimize stormwater runoff. Additionally, dogs tend to defecate in areas with longer grass. If certain areas are maintained with slightly longer grass, natural disintegration of feces will be promoted.
- Public education programs can be used to educate pet owners on the link between animal waste and water quality, thereby making it more likely that owners will clean up after their animals.

D. **Open Space Acquisition.** Open space can be acquired to serve as an aquatic buffer near waterbodies or wetlands. These buffers serve to reduce the amount of runoff reaching surface waters. Buffers can be natural or engineered. Natural buffers minimize runoff and increase infiltration. Engineered buffers use constructed wetlands or similar designs to provide treatment of stormwater runoff. A distance of 100 feet is typically what is required for adequate protection of surface water. Acquiring the land needed for buffer areas can be cost prohibitive for Towns. Implementation of zoning bylaws restricting activities within buffer zones is an alternative method of obtaining similar benefits at less cost to each Town. An additional consideration when developing buffer zones is the increased property values resulting from aesthetic improvements.

Open space acquisition also serves to prevent development and the associated wastewater generation and disposal (i.e. septic systems). To date, towns in the PPA have been able to prevent large numbers of residences by means of open space acquisition. It is highly recommended that support of these efforts continues. As large tracts of developable land become scarce, a trend has arisen in which development of any significant parcel is sought under the provisions of 40B. Acquisition of open space can prevent these larger developments from occurring in environmentally sensitive areas, further adding to nitrogen loading issues within the PPA.

E. **Public Education.** According to the National Environmental Education and Training Foundation, Americans' comprehension of pollution sources and environmental issues is significantly less than believed. The Northeast was the 3rd least-educated region (of 4 regions) regarding environmental issues. Public education can increase awareness of everyday activities that contribute nitrogen to the watershed. Public education campaigns can target several homeowner activities to reduce nitrogen loads, such as encouraging use of grass clippings as fertilizer and promoting use of native, drought-resistant vegetation for landscaping.

The Massachusetts Bays Estuaries Association has initiated the "Think Again. Think Blue." campaign. This campaign provides many homeowner tips to improve water quality. Additionally, they provide posters designed to raise awareness of the effects of lawn fertilizer and pet wastes on local waters. Samples of the ads are contained in Appendix D. More information on this campaign is available at http://www.thinkagainthinkblue.org/index.html.

On a more local basis, the Cape Keepers program has been developed to educate Cape Cod homeowners about the impacts of septic systems on water quality and to encourage owners to take responsibility for the health of local ponds and estuaries. Posters, educational flyers, education kits, and public service announcements have been developed to aid in informing the local population of the nitrogen loading problems and the part that each individual plays in both the problem and the solution. Some of the flyers and posters are contained in Appendix E of this report. For more information on the Cape Keepers, visit www.capekeepers.org.

Some important guidelines to keep in mind when developing a public education program are:

- Develop a strong connection between the yard, the storm, and the water resource to emphasize the undesirable effects that can result

- Consider regional media campaigns to maximize effectiveness and minimize costs
- Use television wisely – community cable access channels are typically less effective than commercial or public television channels
- Keep the message simple, direct, and humorous
- Information packets are most effective if they are attention-grabbing (colorful), small, and durable. Handy references can be posted around the home or workbench – be sure to include contact information for additional detail
- Consider any unique demographics of a watershed – other languages, church groups, etc.

F. **Recommendation.** These items should be promoted to reduce nitrogen loading to the groundwater and to the estuaries. They may represent a small step toward the goal of restoring the estuaries, but they are all Best Management Practices and should be promoted by each Town in the PPA, its volunteer boards, and its departmental structure.

7.4 NITROGEN MITIGATION ALTERNATIVES

A. **Oyster Propagation.** Wastewater treatment is understood to provide the most reliable long-term solution to nitrogen loading problems in the estuaries in Mashpee. However, implementation of a planning area-wide solution is, at best, several years away. Additionally, some of the groundwater in the watershed is at such a distance that it takes over 20 years to reach surface waters. This would indicate that wastewater treatment facilities will have a somewhat delayed effect on the estuaries.

With the nitrogen loading and eutrophication problems in mind, the Town of Mashpee's Shellfish Department is currently investigating the possibility of using oysters to mitigate existing impacts in the waters of the Mashpee River – one of the most impacted embayments in Mashpee. Discussions with the Mashpee Shellfish Department indicated that the ultimate goal is to remove 500 kilograms of nitrogen from the Mashpee River with oyster fisheries. The oysters harvest the algae and nitrogen, thereby improving the quality of the water. Once the oysters are harvested, that nitrogen is removed from the system.

Oyster fisheries in the Mashpee River were depleted by disease and lack of habitat in the 1980s. With funding from shellfish permit fees, the MA Division of Marine Fisheries, and the Barnstable County Cooperative Extension's shellfishing program, oysters have been reintroduced to the Mashpee River. In 2004, 200 bags of oyster seeds were obtained from an aquaculture facility. The first year of harvesting (January through March of 2006) resulted in collection of approximately 160,000 oysters, containing about 50 kg of nitrogen. By 2006, 400 bags of oyster seeds from both the aquaculture facility and one million seeds from the Town's propagation program were seeded in the Mashpee River. Seeding will continue with the goal of harvesting one million oysters, thereby providing removal of 500 kg of nitrogen – 10% of the necessary nitrogen removal as determined by MEP.

Some researchers believe that oyster beds can promote the growth of denitrifying bacteria. More research is necessary to determine the reliability of this theory, but if it proves feasible, the benefits of oyster propagation can be significant.

Despite the success of the ongoing oyster propagation, wastewater treatment infrastructure will still be necessary for long-term reliability. Oysters are susceptible to diseases and habitat impacts. As a result, they cannot be counted on as the primary means of removing nitrogen from an estuary. However, they should still be used as a highly effective, immediate solution to increased nitrogen loads. Re-establishment of shellfish growing habitats provides multiple environmental benefits. Funding and support for this program is highly recommended, not only for the long-term environmental benefits in general, but also as an interim means of reducing nitrogen concentrations until wastewater facilities can be constructed.

B. **Groundwater Treatment.** The oyster propagation discussed above is one means of addressing the nitrogen loads already existing in the estuaries. The manufacturers of the Nitrex™ I/A system have developed a method to treat groundwater plumes, which can provide an immediate improvement to water quality (in comparison to Town-wide sewering). The groundwater treatment is performed by using the Nitrex™ media to create a Permeable Reactive Barrier (PRB) within a pollution plume or within contaminated groundwater. Denitrification occurs as the groundwater flows through the filter media. Some test projects were recently installed near the shores of Childs River and Waquoit Bay in Falmouth. Preliminary results have shown some success in removing nitrate from the groundwater before it flows to the estuaries.

It is unclear whether this application is suitable for large scale groundwater treatment. It appears to have some success in treating discrete plumes. However, the problem facing the PPA is the level of nitrogen reaching the groundwater and flowing to the estuaries. Because of the broad use of septic systems, nitrogen does not originate from localized areas. Therefore, it would not seem feasible to rely on this technology for achieving significant reduction of nitrogen levels. If nitrate plumes are identified and can be channeled effectively to maximize performance while reducing impacts to property owners, this is likely a potential solution. An additional obstacle to large scale implementation of this technology is that the most benefit is achieved when the PRB is installed close to the edge of water bodies (where no septic systems are located downstream of the groundwater flow). Large portions of the waterfront of the impacted estuaries are already developed, minimizing the potential locations to construct the PRBs. There may also be minimal public acceptance or aesthetic appeal if construction is required in public shorefronts.

Report Tables

TABLE 2-1

PRIORITY AREA CRITERIA SUMMARY

Watershed Nitrogen Management Plan
Mashpee Sewer Commission

Priority Area Name	MEP Removal Rate	Nitrogen Loading Rates	Year Round	Other Town Considerations	Zone II
Primary Priority Areas					
M-1 – Johns Pond	√	√	√		
M-2 – Mashpee Central	√	√	√		
M-3 – Shoestring Bay	√	√	√		√
Secondary Priority Areas					
M-4 – Santuit Pond		√	√	√	√
M-5 – Mashpee River			√	√	√
M-6 – Jehu Pond	√	√			
M-7 – Popponesset Creek	√	√			
S-4 – Sandwich Quashnet		√	√		√
F-1 – Red Brook	√	√			
Tertiary Priority Areas					
M-8 – Mashpee-Wakeby Pond			√		
M-9 – MMR			√		
M-10 – Mashpee East			√		√
M-11 – Quashnet River			√		√
M-12 – Mashpee South			√		√
M-13 – New Seabury		√			√
B-1 – Barnstable Fresh Water			√		√
B-2 – Shoestring Bay (Barnstable)	√		√		√
B-3 – Pinquickset Cove					
B-4 – Popponesset Bay	√				
S-1 – Sandwich West			√		√
S-2 – J Well			√		√
S-3 – Snake Pond			√		√
S-5 – Sandwich Popponesset			√		√
F-2 – Falmouth Quashnet	√				
F-3 – Falmouth North			√		√
Note: Prioritization is based on build-out conditions.					

TABLE 2-2

SUMMARY OF TOTAL NITROGEN LOADS PER TOWN[(1)]

Watershed Nitrogen Management Plan
Mashpee Sewer Commission

Town	Wastewater Nitrogen Load (kg/yr)		Non-Wastewater Nitrogen Load (kg/yr)		Total Nitrogen Load (kg/yr)		% Wastewater Nitrogen Load[(2)]	
	Existing	**Future**	**Existing**	**Future**	**Existing**	**Future**	**Existing**	**Future**
Mashpee								
Waquoit Bay East	14,000	29,000	5,600	5,900	20,000	35,000	70%	83%
Popponesset Bay	28,000	41,000	**8,900**	**9,300**	**37,000**	**51,000**	78%	82%
Other	9,000	16,000	1,800	1,900	11,000	18,000	82%	89%
Total	51,000	86,000	**16,000**	**17,000**	**68,000**	100,000	76%	87%
Falmouth								
Waquoit Bay East	3,200	5,800	800	1,000	4,100	6,800	78%	85%
Sandwich								
Waquoit Bay East	4,500	5,400	1,200	1,300	5,700	6,700	79%	81%
Popponesset Bay	12,000	14,000	2,300	2,500	14,000	16,000	86%	88%
Barnstable								
Popponesset Bay	5,700	8,500	1,200	1,300	7,000	9,800	81%	87%
PLANNING AREA TOTAL	76,000	120,000	22,000	23,000	99,000	140,000		

Notes:

1. The nitrogen loads presented in this table do not assume any natural attenuation. Wastewater nitrogen loads are based on septic system nitrogen concentrations of 35 mg/L. All numbers are rounded to two significant figures.
2. Percent of total nitrogen load that comes from wastewater sources.
3. Nitrogen loads were calculated as discussed in this chapter.
4. Non-wastewater nitrogen loads were recalculated to include golf course fertilizer loads.
5. Numbers in **bold** have changed from the original Table 7-9.

TABLE 2-3

SUMMARY OF NITROGEN LOADS BY PLANNING AREA

Watershed Nitrogen Management Plan
Mashpee Sewer Commission

Priority Area	Wastewater Flow (gpd)		WW Nitrogen Load (kg/yr)		Non-Wastewater Nitrogen Load (kg/yr)		Total Nitrogen Load (kg/yr)	
	Existing	Future	Existing	Future	Existing	Future	Existing	Future
Mashpee								
M-1 Johns Pond	140,000	380,000	6,600	15,000	**1,600**	**1,700**	**8,200**	**16,000**
M-2 Mashpee Central	94,000	210,000	4,700	10,000	**960**	**1,000**	**5,700**	**11,000**
M-3 Shoestring Bay	150,000	240,000	7,800	12,000	**2,000**	**2,200**	**9,700**	**14,000**
M-4 Santuit Pond	110,000	140,000	5,100	6,900	**1,100**	**1,500**	**6,200**	**8,300**
M-5 Mashpee River	76,000	160,000	3,600	7,000	**890**	**1,000**	**4,500**	**8,000**
M-6 Jehu Pond	95,000	150,000	4,600	7,200	980	1,100	5,600	8,300
M-7 Popponesset Creek	57,000	83,000	2,800	4,000	490	520	3,300	4,500
M-8 Mashpee-Wakeby Pond	44,000	99,000	2,100	4,800	690	750	2,800	5,500
M-9 MMR	0	140	0	7	350	350	350	360
M-10 Mashpee East	20,000	45,000	880	1,200	250	260	1,100	1,500
M-11 Quashnet River	45,000	78,000	2,200	3,600	640	700	2,900	4,300
M-12 Mashpee South	25,000	42,000	1,200	2,100	480	500	1,700	2,600
M-13 New Seabury	190,000	380,000	9,100	18,000	**2,100**	**2,200**	**11,000**	**20,000**
TOTAL	1,000,000	2,000,000	51,000	92,000	13,000	14,000	63,000	104,000
Barnstable								
B-1 Barnstable Fresh Water	0	560	30	30	30	30	30	60
B-2 Shoestring Bay	110,000	140,000	5,400	6,700	1,000	1,100	6,400	7,800
B-3 Pinquickset Cove	5,100	9,300	250	450	150	160	400	620
B-4 Popponesset Bay	3,900	5,900	190	290	80	85	270	370
TOTAL	120,000	160,000	5,900	7,500	1,300	1,400	7,100	8,900
Sandwich								
S-1 Sandwich West	48,000	61,000	2,300	3,000	750	800	3,100	3,700
S-2 J Well	19,000	22,000	920	1,100	170	180	1,100	1,300
S-3 Snake Pond	2,700	3,600	130	170	40	40	170	220
S-4 Sandwich Quashnet	22,000	25,000	1,100	1,200	190	190	1,300	1,400
S-5 Sandwich Popponesset	240,000	280,000	12,000	14,000	3,300	3,500	15,000	17,000
TOTAL	330,000	390,000	16,000	19,000	4,500	4,700	21,000	24,000
Falmouth								
F-1 Red Brook	23,000	58,000	1,100	2,800	310	380	1,400	3,200
F-2 Falmouth Quashnet	42,000	59,000	2,000	2,900	310	390	2,400	3,300
F-3 Falmouth North	1,700	1,700	80	80	30	30	120	120
TOTAL	67,000	120,000	3,200	5,800	670	800	3,900	6,600
PLANNING AREA TOTAL	1,500,000	2,700,000	76,000	120,000	19,000	21,000	95,000	140,000

Figures in **bold indicate figures that changed as a result of recalculation of golf course nitrogen loads.

TABLE 4-1

TECHNOLOGY COST COMPARISON

Watershed Nitrogen Management Plan
Mashpee Sewer Commission

Technology	Typical Effluent Nitrogen Concentration Range (Median Values) Mg/L [12]	Percent Of Median Values Below 19 Mg/L [14]	Equipment Capital Cost (March 2007)	Manufacturer's Estimated O&M [2] Cost
Peat System	NA [1]	-	$16,100 [10]	NA
JET	NA	-	$6,270 [5]	NA
RUCK	10 to 42	43	$15,000 [7]	$1,600 [6]
Bioclere	2 to 57	66	$8,000 [3]	NA
FAST	2 to 64	70	$4,500 [3]	NA
Amphidrome	1 to 68 [11]	-	$10,000 [8]	$1,150 [9]
Waterloo Biofilter	12 to 48 [11]	-	$11,255 [3]	$1,500 [6]
AdvanTex	9 to 32 [11]	-	NA	NA
Nitrex™	1 to 7 [11]	-	$4,000 [3, 13]	NA
Nitrex™/Omni	NA	-	$12,000-$14,000	NA
Norweco Singulair	2 to 62	60	$6,500 [3]	$2,125 [4]
Omni RSF	2 to 62	48	NA	NA
SeptiTech	8 to 76	13	$12,000 [8]	NA

Notes:

1. Systems where data was not available are identified as "NA"
2. O&M = operation and maintenance
3. Equipment Only, no installation
4. Includes O&M, sampling, and electricity
5. Includes 2 years O&M and setup for plumber and electrician
6. O&M includes sampling and inspection only
7. Equipment cost, including system design
8. Includes estimated equipment and tank costs
9. $2 per month per occupant (assuming 3 people), including sampling and analysis
10. Equipment cost, including installation
11. Limited number of sites (less than 6)
12. Based on the 2007 Barnstable County Report
13. Does not include any of the costs associated with the additional technology necessary to denitrify the wastewater from the system to perform properly
14. Technologies with "Percent of Median Values Below 19 mg/L" with no data listed were either not reported in the County study or had an insufficient number of data points to accurately report.

TABLE 4-2

SUMMARY OF DECENTRALIZED TREATMENT TECHNOLOGIES
Watershed Nitrogen Management Plan
Mashpee Sewer Commission

NON-NITROGEN REMOVAL [(1)] SYSTEMS

Alternative	Regulatory Requirements	Suitability	Implementability	Performance	Long Term Maintenance	Land Use	Aesthetic Appeal	Public Acceptance/Political Feasibility	Relative Capital Costs	Relative O&M Costs	Selected for Further Evaluation
General Systems											
Septic system (Certified Title 5)	In accordance with 310 CMR 15.00, Title 5 regulations.	Primary means of wastewater disposal in Mashpee – will not result in improved conditions.	Well known technology; no regulatory changes necessary.	Nitrogen removal range 10 to 40 percent (typically assumed to be 25 percent)	Does not require energy for operation; may require effluent pump.	Moderate compared to other systems. Not allowed for use with reduced leaching area.	High, although high groundwater areas may require less appealing raised leaching fields.	Well-known technology with minimal potential problems.	Low, no filters are required and usually no pumps are required.	Low; no training or equipment operation required. Tank must be pumped every few years.	No, due to lack of nitrogen removal.
Peat system	MassDEP may require additional full-scale testing before General Use approval. Only approved for Remedial Use.	May not be suitable for naturally acidic waters of Cape Cod.	Long track record in Maine. Simple system, no moving parts.	Test sites on Cape Cod have low nitrogen removal rates (30-40%). Good BOD and TSS removals.	Does not require energy if site does not require pumping.	Similar to other I/A systems, may allow for reduction in leaching area.	High.	Known technology in Maine.	Moderate to High, will be more expensive than a standard Title 5 system.	Low; minimal training requirements. Tank must be pumped every few years.	No, due to inconsistent performance data on Cape Cod.
Glendon Upflow Filter	MassDEP may require additional full-scale testing. Not an approved I/A technology.	May not result in any improvement over existing conditions.	Not listed as I/A technology by MassDEP.	Minimal data available	Requires a small pump.	Higher than septic system	High.	Low because it is a relatively new technology with no New England applications. Requires further testing.	Moderate, will be more expensive than a standard Title 5 system.	Low; no training or equipment operation required. Tank must be pumped every few years.	No, due to lack of data, potential lack of public acceptance, and lack of MassDEP permitting approval.
MassDEP-Approved I/A Systems											
JET aerobic wastewater systems	Approved for General Use. Not Credited for Nitrogen Removal.	High quality effluent (BOD and TSS); currently only suitable for flows less than 1,500 gpd.	More complicated system than typical Title 5 due to numerous moving parts. Would require maintenance agreement.	Nitrogen removal information not available for this technology.	Moderate energy use due to pumps and other mechanical equipment.	Similar to other I/A systems, may allow for reduction in leaching area.	High.	Similar to Title 5 systems, although will be more expensive.	Moderate to High, will be more expensive than a standard Title 5 system.	Pumping requirements, maintenance of equipment, and additional electrical requirement add to moderate O&M costs.	No.
Orenco intermittent sand filter	Approved for General Use. Not Credited for Nitrogen Removal.	May achieve nitrogen reduction when properly maintained.	Can be installed in new septic system or retrofit into existing one.	Flexible operation; may reduce nitrogen; may be sensitive to winter temperatures	Moderate energy use due to pumps and other mechanical equipment.	Similar to other I/A systems, may allow for reduction in leaching area.	High.	Similar to Title 5 systems, although will be more expensive.	Moderate to High, will be more expensive than a standard Title 5 system.	Pumping requirements, maintenance of equipment, and additional electrical requirement add to moderate O&M costs.	No.

Note (1): These systems remove nitrogen to varying degrees. However, none of them are credited by MassDEP for nitrogen removal in nitrogen sensitive areas.

NON-DISCHARGE SYSTEMS

Alternative	Regulatory Requirements	Suitability	Implementability	Performance	Long Term Maintenance	Land Use	Aesthetic Appeal	Public Acceptance/Political Feasibility	Relative Capital Costs	Relative O&M Costs	Selected for Further Evaluation
Tight Tanks	MassDEP will only approve as a short-term solution.	Suitable as a short-term solution.	Simple installation; regulatory approval required.	Moves problem to a different location.	Tanks may leak after many years.	Minimal, leaching system is not used.	Low; high potential for odors due to frequent pumping.	Poor to moderate acceptance due to odors, frequent pumping requirements, and lack of MassDEP approval.	Low installation costs.	High pumping and disposal costs.	No, typically this would only be approved by MassDEP as a short-term solution.
Waterless Toilets	May require BOH approval	High nutrient removal for black water only.	Requires some repiping and remodeling for existing homes or structures.	Reduces wastewater flows and loads.	High energy use for incinerating type.	Land required for gray water disposal systems are less than a standard Title 5 system.	Low; high potential for odors; requires contact with composted waste.	Poor to moderate, since it is a non-traditional system.	Low installation cost, but must handle gray water separately.	Moderate; weekly maintenance and removal of solids required.	No.

TABLE 4-2 (Continued)

NITROGEN REMOVAL SYSTEMS

Alternative	Regulatory Requirements	Suitability	Implementability	Performance	Long Term Maintenance	Land Use	Aesthetic Appeal	Public Acceptance/Political Feasibility	Capital Costs Beyond Title 5 System (2)	O&M Costs	Selected for Further Evaluation
Recirculating Sand Filter (non-proprietary)	Certified for use in nitrogen sensitive areas when designed in accordance with MassDEP guidelines.	Capable of nitrogen removal, already in use in the PPA.	Most have moderate to long track records and are used in the PPA already.	Nitrogen removal ranges from 40 to 90 percent. Good BOD and TSS removals. Sensitive to winter temperatures.	Require energy for pump operation.	Land requirements are slightly more than for Title 5.	High.	High, proven technology.	Moderate due to additional components including filters and pumps.	Moderate; pumping requirements and replacement and maintenance of filter media add costs.	Yes.
RUCK® System	Certified for use in nitrogen sensitive areas when designed in accordance with MassDEP guidelines.	Capable of nitrogen removal, already in use in the PPA. Approved for flows less than 2,000 gpd.	Most have moderate to long track records and are used in the PPA already.	Nitrogen removal ranges from 40 to 80 percent. Good BOD and TSS removals.	Require energy for pump operation.	Land requirements are slightly greater than Title 5.	High.	High, proven technology.	$15,000	Moderate; pumping requirements and replacement and maintenance of filter media add costs. Required annual inspection adds cost of $250. Additional monitoring required for systems located in a Zone II.	Yes.
APPROVED FOR PROVISIONAL USE IN NITROGEN SENSITIVE AREAS											
Bioclere	O&M Agreement, quarterly monitoring. 50 system limit has been reached.	Capable of nitrogen removal, already in use in the PPA.	Well established, reliable technology.	70-85% nitrogen removal. Good BOD and TSS removals.	Energy for pumping; maintenance contract	Similar to Title 5. Eligible for reduced leaching area outside nitrogen sensitive areas.	Tops of tanks are above ground, blowers can be noisy.	High.	$8,000	Moderate; similar to other I/A systems.	Yes.
FAST	O&M Agreement, quarterly monitoring, limit of 50 systems.	Capable of nitrogen removal, already in use in the PPA.	Well established, reliable technology.	50-70% nitrogen removal. Good BOD and TSS removals.			Tops of tanks are above ground, blowers can be noisy.	High.	$4,100-$4,500	Energy costs for pumps and blowers, maintenance contract	Yes.
Amphidrome	O&M Agreement, quarterly monitoring, limit of 50 systems.	Capable of nitrogen removal, already in use in the PPA.	Has General, Provisional, and Remedial use approvals.	Up to 75% nitrogen removal.			Blowers can be noisy.	High.	$8,000 (assuming standard Title 5 tank is 2,000 gallons)	$1,100 per year for inspection and monitoring, energy costs estimated to be $2 per month per occupant.	Yes.
Waterloo	O&M Agreement, quarterly monitoring, limit of 50 systems.	Capable of nitrogen removal, already in use in the PPA.	Well established, reliable technology. Approaching Provisional Use installation limit.	60-90% nitrogen removal rates. Good BOD and TSS removals.			Blowers can be noisy.	High.	$11,255 (includes technician to oversee installation)	$1,500 per year for inspection and monitoring, energy costs for pumps, control panel, etc.	Yes.
Advantex	O&M Agreement, quarterly monitoring, limit of 50 systems.	Capable of nitrogen removal.	Established technology.				Filter lid is at ground level.	High.		An average of $2 per month for electricity.	Yes, but less favorable due to limited local performance data.
Nitrex™	O&M Agreement, quarterly monitoring, limit of 50 systems.	Capable of nitrogen removal, already in use in the PPA.	Established technology.	Up to 95% nitrogen removal. Good BOD and TSS removals.			High.	High.	$4,000 for Nitrex™ components.	Maintenance contract	Yes.
APPROVED FOR PILOT USE IN NITROGEN SENSITIVE AREAS											
OAR	O&M Agreement, monthly monitoring for first 6 months, then quarterly monitoring, limit of 15 systems.	Capable of nitrogen removal	Established technologies; MassDEP-recognized technologies, although still in the piloting phase, which limits the number of systems until provisional use is obtained.	Limited performance data for local applications.	Energy for pumping and other equipment; maintenance contract	Similar to Title 5. Eligible for reduced leaching area outside nitrogen sensitive areas.	Blowers can be noisy.	High.	Moderate due to additional components including filters and pumps.	High; pumping requirements and replacement and maintenance of filter media add costs. Additional bacteria required.	Yes, but less favorable due to limited local performance data.
RUCK® CFT	O&M Agreement, monthly monitoring for first 6 months, then quarterly monitoring, limit of 15 systems.	Capable of nitrogen removal		Reportedly as high as 90% nitrogen removal.		More than Title 5.	Blowers can be noisy.	High.		High; pumping requirements and replacement and maintenance of filter media add costs. Supplemental carbon source required.	
Cromaglass	O&M Agreement, monthly monitoring for first 3 months, then quarterly monitoring, limit of 15 systems.	Capable of nitrogen removal		Limited performance data for local applications.		Similar to Title 5. Eligible for reduced leaching area outside nitrogen sensitive areas.	Blowers can be noisy.	High.		Moderate. Similar to other I/A systems.	
Norweco Singulair	O&M Agreement, monthly monitoring for first 3 months, then quarterly monitoring, limit of 15 systems.	Capable of nitrogen removal, already in use in the PPA.		40-70% nitrogen removal.		Similar to Title 5. Eligible for reduced leaching area outside nitrogen sensitive areas.	Blowers can be noisy.	High.	$6,500	$2,125 annually.	Yes.
Omni	O&M Agreement, monthly monitoring for first 3 months, then quarterly monitoring, limit of 15 systems.	Capable of nitrogen removal		40-90% nitrogen removal.		Similar to Title 5. Eligible for reduced leaching area outside nitrogen sensitive areas.	High.	High.	Moderate due to additional components including filters and pumps.	Moderate. Similar to other I/A systems.	Yes, but less favorable due to limited local performance data.
SeptiTech	O&M Agreement, monthly monitoring for first 3 months, then quarterly monitoring, limit of 15 systems.	Capable of nitrogen removal, already in use in the PPA.		40-60% nitrogen removal.		Similar to Title 5. Eligible for reduced leaching area outside nitrogen sensitive areas.	High.	High.	$12,000	Moderate. Similar to other I/A systems.	

Note (2): Dollar values provided when available from manufacturers.

TABLE 5-1

SMALL WASTEWATER TREATMENT FACILITIES (PACKAGE PLANTS)

Watershed Nitrogen Management Plan
Town of Mashpee Sewer Commission

<table>
<tr><th>Alternative</th><th>Regulatory Requirements(1)</th><th>Suitability</th><th>Implementability</th><th>Performance</th><th>Long Term Maintenance</th><th>Land Use</th><th>Aesthetic Appeal</th><th>Public Acceptance/Political Feasibility</th><th>Relative Capital Costs</th><th>Relative O&M (2) Costs (annually)</th><th>Selected for Further Evaluation</th></tr>
<tr><td>Rotating Biological Contactor</td><td rowspan="3">Needs MassDEP and BOH approval. Requires typical effluent discharge permit. These technologies are in use in MA and are well-accepted technologies.</td><td>Good reliability and proven performance. Many existing facilities in the PPA use this technology.</td><td rowspan="6">Easy to construct, most systems are modular or are designed using prefabricated tanks.</td><td>6-10 mg/L TN</td><td>Low; simple system.</td><td>Highest of package treatment plants; may require building or tank covers.</td><td>Moderate – system is enclosed in a building.</td><td rowspan="3">Moderate – many existing facilities with these technologies in the PPA; additional site location may be difficult.</td><td>More cost effective for lower flows due to requirements for covering tanks.</td><td rowspan="3">No major difference between RBC, SBR, Amphidrome, FAST, and Bioclere.</td><td rowspan="4">Yes. Town of Mashpee currently has or will have these types of technologies.</td></tr>
<tr><td>Sequencing Batch Reactor (3)</td><td>Good reliability and proven performance. Can achieve high nitrogen removal. One existing facility in the PPA uses this technology.</td><td>6-10 mg/L TN (<6 mg/L TN possible without additional processes)</td><td>Operator control of processes allows flexibility. Aeration and pumping requirements.</td><td>Lowest of package treatment plants; no final settling required.</td><td>Moderate.</td><td>In general, more expensive at lower flows due to cost of pre-cast concrete vs. cast-in-place concrete.</td></tr>
<tr><td>Amphidrome</td><td>Good reliability and proven performance. Some existing facilities in the PPA use this technology.</td><td>6-10 mg/L TN</td><td rowspan="4">More complex systems; typically based on proprietary equipment, making replacement parts and costs dependent on manufacturers.</td><td>Moderate, but all below grade.</td><td>High – tanks can be below ground, allowing secondary use of land.</td><td>At larger flows, tank costs become prohibitive.</td></tr>
<tr><td>Zenon (Membrane Bioreactor) (3)</td><td>Needs MassDEP and BOH approval. Requires typical effluent discharge permit. Relatively new technology with few local, large-scale facilities.</td><td>Can achieve high nitrogen removal. Effluent is typically of a high quality. One of the existing facilities in the PPA will likely be switching to an MBR.</td><td>6-10 mg/L TN (<6 mg/L TN possible without additional processes)</td><td>Lower than some of the package treatment plants; no final settling required.</td><td>Moderate – system is often enclosed in a building.</td><td>Moderate – effluent can be re-used for irrigation or other purposes, increasing its appeal.</td><td>Technology costs are typically more expensive than other technologies.</td><td>Higher O&M based on operating complexity and membrane replacement.</td></tr>
<tr><td>FAST</td><td rowspan="2">Needs MassDEP and BOH approval. Requires typical effluent discharge permit. These technologies are in use in MA and are well-accepted technologies.</td><td rowspan="2">Moderate reliability and performance.</td><td>6-10 mg/L TN</td><td>Moderate; requires final settling, which can be located below grade.</td><td>Moderate – can be located below grade.</td><td rowspan="2">Moderate – siting facilities may be difficult.</td><td rowspan="2">Technology is more cost effective at lower flows due to the "prefabrication" components.</td><td rowspan="2">No major difference between RBC, SBR, Amphidrome, FAST, and Bioclere.</td><td rowspan="2">No major advantage of these over other technologies currently used in Mashpee.</td></tr>
<tr><td>Bioclere</td><td>6-10 mg/L TN</td><td>Moderate; most located below grade.</td><td>Moderate – top of tanks may be above ground.</td></tr>
</table>

Notes:

(1) Additional permit requirements will be necessary for discharge within a Zone II.
(2) O&M = operation and maintenance.
(3) Can achieve less than the 6 mg/L TN without additional processes.

TABLE 5-2

TECHNOLOGY COMPARISON

Watershed Nitrogen Management Plan
Mashpee Sewer Commission

TECHNOLOGY	APPROX. FLOW (mgd)	ESTIMATED CONSTRUCTION COST (IN MILLIONS)	EST. $/GAL FOR FLOW RANGES AS PRESENTED ONLY	ESTIMATED O&M ($/GAL)
Amphidrome w/ Effluent Disposal [(1)]	0.03	$1.3 M	$ 45.00	$1 -$5
Bioclere w/ Effluent Disposal [(1)]	0.02	$1.2 M	$ 60.00	$1 -$5
SBR with Effluent Disposal [(1)]	0.06	$4.2 M	$ 70.00	$1 -$2.5
RBC with Effluent Disposal [(2)]	0.04	$1.8 M	$ 45.00	$1 -$2.0
Zenon with Effluent Disposal [(2)]	0.04	$2.4 M	$ 61.00	$1 -$3.5

Notes:
1. Costs are based on actual construction costs for these projects.
2. Costs are based on proposals of costs for similar sized facilities.

<u>TABLE 5-3</u>

SUMMARY OF SECONDARY/ADVANCED TREATMENT TECHNOLOGIES

Watershed Nitrogen Management Plan
Mashpee Sewer Commission

Alternative	Regulatory Requirements [1]	Suitability	Implementability	Performance (TN)	Long Term Maintenance	Land Use	Aesthetic Appeal	Public Acceptance/Political Feasibility	Relative Capital Costs	Relative O&M [2] Costs (annually)	Selected for Further Evaluation
Activated Sludge MLE Process/Extended Aeration	All these processes need MassDEP approval and require an effluent discharge permit.	Good reliability and proven performance.	Requires construction of new facilities.	Effluent N, 3 to 10 mg/l (Carrousel and Orbal oxidation ditches can meet 3-6 mg/L TN)	Moderately complex; high flexibility with good process control.	Moderate due to tank sizes and building requirements.	Moderate/low due to open tanks.	Moderate.	Moderate to other technologies due to large tank requirements.	Aeration costs are higher than RBCs.	Yes, but will be highly dependent on site size constraints and chosen performance.
Rotating Biological Contactor (RBC)			Several package plants in Town use this technology.	Effluent N, 6 to 10 mg/L.	Relatively easy operations; minimal process control.	High for large covered process.	Moderate – can be hidden by buildings.	Moderate.	High capital costs due to requirement to cover tanks.	Lower O&M costs due to minimal aeration and pumping requirements.	No; same performance with smaller structures can be achieved with other technologies for larger facilities.
Sequencing Batch Reactor (SBR)			Requires construction of new facilities.	Can meet 3 to 10 mg/L total nitrogen.	High reliability and proven performance at limited number of facilities. Good process control allows adjustable performance.	Relatively small; no final settling required.	Moderate/low due to open tanks.	Moderate.	Often less than others due to smaller tank requirement.	Higher due to operational considerations.	Yes; small footprint and high nitrogen removal performance.
Membrane Bioreactors (Zenon, Enviroquip)			Requires construction of new facilities.	Effluent N, 3 to 6 mg/L.	Need to clean membrane filters. More complex operations.	Relatively small; no final settling required.	Moderate.	Moderate.	Higher costs associated with membrane technology.	Higher due to membrane replacement costs and operational considerations.	Yes; small footprint and high nitrogen removal performance.
Aerated Biological Filter (Biofor, Biostyr)			Requires construction of new facilities.	Typically provides nitrification but not denitrification without additional process tanks.	Relatively simple filter operations and maintenance; less flexibility and process control.	Relatively small.	Moderate.	Moderate.	Moderate capital costs.	Moderate.	No.
Denitrification Filter		Can be added to end of various treatment trains easily.	Requires construction of new facilities.	Process can meet 3 to 5 mg/L total nitrogen (and reduce BOD and TSS) with methanol feed and upstream nitrification.	High reliability and proven performance. Relatively simple operations.	Relatively small, but is only a process component of a larger facility.	Moderate.	Moderate.	Moderate capital costs when used in conjunction with other nitrogen removal processes.	Moderate for methanol feed.	Yes. Denitrifying filters can reliably produce an effluent of 3 to 5 mg/L total nitrogen and should be considered for effluent polishing.
Constructed Wetlands	These processes need MassDEP approval and require an effluent discharge permit. They may also need pilot testing.	Likely to have lower quality effluent in winter. Extensive sitework required to accommodate all the area needed.	Requires construction of new facilities.	Not expected to reliably produce a high quality effluent year-round.	Simple system with minimal process control; can be expanded for additional flows.	Very high compared to other centralized alternatives.	Odors are possible.	Moderate; systems are typically popular because they use natural processes, but have high capital costs.	High costs for site work and facility construction.	Low due to low energy requirements and vegetation harvesting.	No, due to high land requirements, siting issues, and the inability of process to provide consistent effluent quality year-round.
Solar Aquatics		Likely to have lower quality effluent in winter. Extensive sitework required to accommodate all the area needed.	Requires construction of new facilities.	Not expected to reliably produce a high quality effluent year-round.	High operations and maintenance requirements.	High compared to other centralized alternatives.	Odors are possible.	Moderate; systems are typically popular because they use natural processes, but have high capital costs.	High costs for site work and facility construction.	Moderate due to energy use and high maintenance requirements.	No, due to high land requirements, siting issues, and the inability of process to provide consistent effluent quality year-round.

Notes:
1. Additional permit requirements will be necessary for discharge within a Zone II.
2. O&M = operation and maintenance.
3. Can achieve less than the 6 mg/L TN without additional processes.

TABLE 5-4

SUMMARY OF DISINFECTION TECHNOLOGIES

Watershed Nitrogen Management Plan
Mashpee Sewer Commission

Alternative	Regulatory Requirements	Suitability	Implementability	Performance [1]	Long Term Maintenance	Land Use	Aesthetic Appeal	Public Acceptance/Political Feasibility	Estimated Capital Costs [2]	Estimated O&M Costs [2, 3] (annually)	Selected for Further Evaluation
Chlorination using Sodium Hypochlorite	Chemical storage requirements	Not suitable for treating water that will be discharged in a Zone II area.	Will require MassDEP approval.	<200 cfu/100 mL. Can produce trihalomethanes.	Chemical storage; equipment and tank maintenance.	Requires chlorine contact tank.	High, if sufficient precautions are taken in case of chemical release.	Low – risk of groundwater contamination; risk of chemical spills.	$800,000 - $1,000,000 (contact tanks and feed equipment)	$60,000 - $70,000	No.
Disinfection with ozone	Chemical storage requirements	Suitable for achieving disinfection.	Will require MassDEP approval.	<200 cfu/100 mL. Can produce toxic and/or carcinogenic compounds.	Chemical storage; equipment maintenance.	Minimal.	High, if sufficient precautions are taken in case of chemical release.	Low – risk of groundwater contamination; risk of chemical spills.	$500,000 - $600,000 (ozone equipment)	$20,000 - $30,000	No.
Disinfection with UV radiation	None	Suitable for all discharge areas.	This technology is most favorable to MassDEP.	<200 cfu/100 mL.	Bulb cleaning and replacement; equipment maintenance.	Minimal.	High public acceptance.	High.	$500,000 - $600,000 (UV radiation equipment)	$20,000 - $30,000	Yes.

Notes:
1. cfu = colony forming units
2. Based on typical costs for an estimated wastewater flow of 1 mgd (for comparison purposes only).
3. O&M = operations and maintenance.

TABLE 6-1

SUMMARY OF SEWER SYSTEM TECHNOLOGIES

Watershed Nitrogen Management Plan
Mashpee Sewer Commission

Alternative	Suitability	Implementability	Performance	Long Term Maintenance	Land Use	Aesthetic Appeal	Public Acceptance/Political Feasibility	Relative Capital Costs [1]	Relative O&M [2,3] Costs (annually)	Selected for Further Evaluation
Gravity sewers and pumping stations	Can be expanded to serve additional areas. Initial flows not critical.	Most difficult implementation due to deeper excavations and the need for constant slope.	Not applicable – collection systems do not perform nitrogen removal.	Pumping stations require energy and typically have emergency generators to keep system operational.	Sewer typically located in street. Land may be required for pumping stations. Easements may be required for sewers.	High; low chance of backups into structures; pumping stations can be undesirable.	Well-known technology. Deep excavations can cause traffic disruption.	$200 - $450	$20 - $30	Yes, due to wide use, simplicity, reliability of technology, and low maintenance requirements.
Pressure sewers and grinder pumps	Can be expanded. Initial flows not critical.	Easier installation due to shallower excavations and less critical slopes.		Pumps require energy for operation. System cannot be operated during power failures unless each pump has standby power.	Sewers typically located in street or road ROWs. No land requirements. Easements may be required for sewers.	Moderate; each home or group must have a pump.	Power outage can cause backup into structures and reduce potential public acceptance.	$280 - $350	$20 - $25	Yes, due to adaptability in areas of varying topography and low construction costs.
Septic tank effluent pump system	They are not suitable for nitrogen removal treatment systems that require organic solids to attain denitrification.	Easier installation due to shallower excavations and less critical slopes. May impact nitrogen removal at a treatment plant.	Not applicable – collection systems do not perform nitrogen removal, although these two technologies can have a negative impact on the nitrogen removal processes at a treatment plant.	Pumps require energy for operation. System cannot be operated during power failure unless each pumping station has standby power.	Sewers typically in street. Land requirements for septic tanks and pumps may be on individual properties. Easements may be required for sewers.		Each home must have a pump and septic tank. Odor potential may reduce public acceptance.	Similar to pressure sewer; however, additional money is required for septic tank improvements.	Similar to pressure sewer with additional costs related to septic tank pumping.	No, due to poor compatibility with nitrogen removal treatment systems as required on Cape Cod.
Septic tank effluent gravity system	They are not suitable for nitrogen removal treatment systems that require organic solids to attain denitrification.	Easier installation due to shallower excavations, but constant slopes must be maintained. Not feasible where septic tank elevations are low. May impact nitrogen removal at a treatment plant.		Sewers do not require energy. Pumping stations require energy and typically have generators to keep system operational.	Sewers typically in street. Land requirements for septic tanks and pumps may be on individual properties. Easements may be required for sewers.		Each home must have a septic tank. Odor potential may lower acceptance. Chance of backup is minimal.	Similar to gravity sewer, but on the lower end as pipes are smaller.	Similar to gravity sewer with additional costs related to septic tank pumping.	No, due to poor compatibility with nitrogen removal treatment systems as required on Cape Cod.
Vacuum sewers	Difficult to expand. Initial flows must be accurately estimated and expansion is limited. More difficult to make future connections if not planned ahead.	Shallower excavations than gravity sewers; however, more complex system with critical design features that must be installed properly for the system to function properly. High level of testing required during sewer installation.	Not applicable – collection systems do not perform nitrogen removal.	Energy is required to maintain vacuum. Power typically supplied by generator during outages. Otherwise no power needed at the valve pits.	Sewers in street or road rights-of-way. Land will be required for vacuum station. Easements required for sewers.	Moderate; each home or group must have a valve pit.	Requires large number of easements. Valve pits are required at each property and vents are required on each gravity lateral reducing public acceptance.	$310 - $400	$35 - $50	No, due to its limitations for existing developed areas.

Notes:
1. Average cost per linear foot of sewer. Construction costs only.
2. O&M = operations and maintenance.
3. Average annual cost per linear foot of sewer.

TABLE 6-2

SUMMARY OF EFFLUENT DISCHARGE TECHNOLOGIES

Watershed Nitrogen Management Plan
Mashpee Sewer Commission

Alternative	Regulatory Requirements	Suitability	Implementability	Performance	Long Term Maintenance	Land Use	Aesthetic Appeal	Public Acceptance/Political Feasibility	Capital Costs (per mgd) [1]	Annual O&M Costs [2, 3]	Selected for Further Evaluation
Sand infiltration beds	Permitting and monitoring of effluent discharges. Disinfection may be required by MassDEP.	Flexibility is possible with multiple beds. Low energy requirements.	Relatively simple to implement.	Effluent is already treated and sand beds provide some additional treatment.	Effluent discharge is reliable throughout the year and easy to maintain.	Moderate at large wastewater flows when compared to subsurface leaching.	Moderate due to large areas of land that may require clearing.	Potential for low acceptance from residents who are impacted by bed siting and construction.	Relatively low due to low land area and easier construction.	Low due to low energy requirements and minimal maintenance.	Yes; the technology is simple and reliable. O&M requirements are minimal.
Subsurface infiltration	Disinfection is not required prior to discharge, unless required to meet the Interim Guidelines for Reclaimed Water Use.	Accepted, proven technology.	Relatively simple to implement.	Effluent is already treated and infiltration facilities provide additional treatment. Effluent should be filtered before discharge.	Repair of the beds would be difficult because they are below the surface.	Relatively high. Land surface above the infiltration system can be used for other purposes	High; secondary use of land adds to appeal.	Acceptance should be high due to minimal visual impacts and potential reuse of land area.	Relatively high due to high land area requirements.	High due to pumping requirements and potentially higher repair/cleaning costs.	Yes; technology is reliable and provides secondary use of discharge area.
Spray irrigation	Permitting and monitoring of effluent discharges and design requirements. Disinfection may be required by MassDEP.	May be suitable to handle additional summer flows.	Must have redundant back-up facilities for winter discharge.	Spray irrigation provides further uptake of nitrogen in the effluent.	Moderate maintenance to maintain piping. Spray irrigation cannot be used in freezing weather.	Relatively high. Land above system can be used for other purposes when spray irrigation is turned off.	High; secondary use of land adds to appeal.	The public will want to see recycling of the effluent though they may be concerned about possible health threats.	Relatively low due to minimal excavation, and minimal need to reshape the land. May require additional money for winter facilities.	Moderate due to maintenance and pumping requirements.	Yes; it provides additional nitrogen uptake and reuse of the effluent.
Drip irrigation	Permitting and monitoring of effluent discharges and design requirements. Disinfection may be required by MassDEP.	May be suitable to handle additional summer flows.	May require redundant back-up facilities for winter discharge.	Potential for further uptake of nitrogen.	Moderate maintenance to maintain piping. Spray irrigation cannot be used in freezing weather.	Can be used for fields or open space.	High; secondary use of land adds to appeal.	The public will want to see recycling of the effluent though they may be concerned about possible health threats.	Relatively higher due to low application rates.	Moderate due to maintenance and pumping requirements.	Yes; it provides additional nitrogen uptake and reuse of the effluent.
Deep well injection and wick wells	Permitting and monitoring of effluent discharges and design requirements. MassDEP is not supportive of this technology.	Not suitable, due to MassDEP's position on technology.	Difficult due to MassDEP's position on technology.	Effluent must be well treated (filtered and chlorinated) before discharge.	Uncertain reliability due to few operating installations and increased maintenance due to the potential of plugging of injection point with solids.	Relatively low compared to sand infiltration beds and subsurface leaching.	High.	Land area requirements and visual impacts are minimal.	Relatively low due to minimal excavation, and minimal need to reshape the land.	Moderate due to pumping requirements and maintenance needs.	No; MassDEP is resistant to support the technology due to the need to chlorinate the effluent.
Ocean Outfall	The Massachusetts Ocean Sanctuaries Act prohibits discharge of municipal wastewater into an ocean sanctuary.	Prohibited by the Ocean Sanctuaries Act.	Only possible as last resort.	Disinfection may be required for the outfall.	Maintenance similar to a large force main.	Minimal.	Low.	Low, based on the opposition to the Deer Island outfall and the Ocean Sanctuaries Act.	Relatively high due to extensive permitting and pumping requirements and potential pipe construction.	Moderate due to pumping requirements.	No.
Wetland Restoration	Possible extensive wetland permitting depending on the type of restoration. Permitting and monitoring of effluent discharges.	Could provide additional nitrogen removal.	MassDEP regards this as an innovative technology, which may effects its ability to be implemented.	Effluent must be well treated (phosphorus removal in addition to standard nitrogen removal, disinfection before discharge)	Very low maintenance requirements and low operations complexity.	Would make use of an existing extensive land area. The restoration efforts would occur in specific flow control and infiltration areas.	Moderate, due to perceived potential contact with wastewater.	Could be favorable due to understanding that the technology/concept is a restoration effort and the project could restore proper hydraulic balance to the watershed.	Relatively low due to minimal excavation, and minimal need to reshape the land.	Moderate due to pumping requirements and maintenance needs.	Yes, possibly in relation to the Pilot Project.

Notes:

1. Based on *Effluent Disposal and Reuse Planning Guidance Document and Case Study Report, February 2005*, Table 3-1.
2. Based on *Effluent Disposal and Reuse Planning Guidance Document and Case Study Report, February 2005*, Table 3-1. Various flow ranges are included.
3. O&M = operations and maintenance.

TABLE 6-3

EFFLUENT DISCHARGE TECHNOLOGY COST COMPARISON

Watershed Nitrogen Management Plan
Mashpee Sewer Commission

Technology	Approx. Loading Rate (Gpd/Ft^2)	Approximate Flow (Mgd)	Estimated Construction Cost (In Millions)
Open Sand Beds (1)	1.1	0.16 to 0.35	\$0.8 to \$2.0
Subsurface Leaching (1)	2.0	0.06 to 0.7	\$0.2 to \$1.2
Spray Irrigation	0.3	0.5	\$0.5
Drip Irrigation	0.3	0.05	\$0.2
Well Injection/Wick Wells	N/A	0.5	\$0.9

Notes:
1. Based on actual project costs for the associated loading rates presented.

TABLE 7-1

SUMMARY OF STORMWATER TREATMENT TECHNOLOGIES

Watershed Nitrogen Management Plan
Mashpee Sewer Commission

Alternative	Total Nitrogen Reduction (1,2)	Nitrate Reduction (1,2)	Maintenance (3)	Land Use	Aesthetic Appeal	Costs per Acre of Catchment Area (4)	Other Advantages	Other Disadvantages
Dry Detention Pond	5-30%	10-40%	High	High	Low	$25,000	Long lived facility	Tendency to fail by clogging
Wet Retention Pond	30-35%	25-60%	High	High	High	$14,000	May increase property values Long lived facility	May pose drowning risks Possible mosquito breeding ground Freezing can present problems
Infiltration Basins	55-60%		High	High	Low	Moderate	Simple system	High rate of failure
Gravel Wetlands	20%	80-99%	Low	High	Low	$22,300	Suitable in high groundwater areas	Maintenance of vegetation
Stormwater Wetlands	20-50%	40-70%	Low	High	High	Involves extensive sitework and vegetation maintenance		Freezing can present problems Possible mosquito breeding ground
Rain Gardens	50%	15-40%	Moderate	Low	High	$25,000	Ideal for urban areas and parking lots	Freezing can present problems
Vegetated Swales	10-90%	40-90%	Moderate	Low	Moderate	Low	Provides groundwater recharge	Proper slope is critical to pollutant removal ability
Porous Pavement	80%		High	Low	Moderate	More expensive than traditional paving, with additional maintenance costs	Replaces otherwise completely impervious areas	High rate of failure Not appropriate for areas with high commercial traffic Freezing can present problems
Infiltration Trenches	30-60%	10%	High	Low	Moderate	$12,500	Adaptable to a variety of sites	Requires pretreatment High rate of failure
On Lot Treatment	Varies	Varies	Moderate	Low	Moderate	Varies depending on treatment alternative, although homeowner bears the costs	Reduces amount of stormwater runoff	Requires education of homeowners Relatively small portion of impervious area treatment

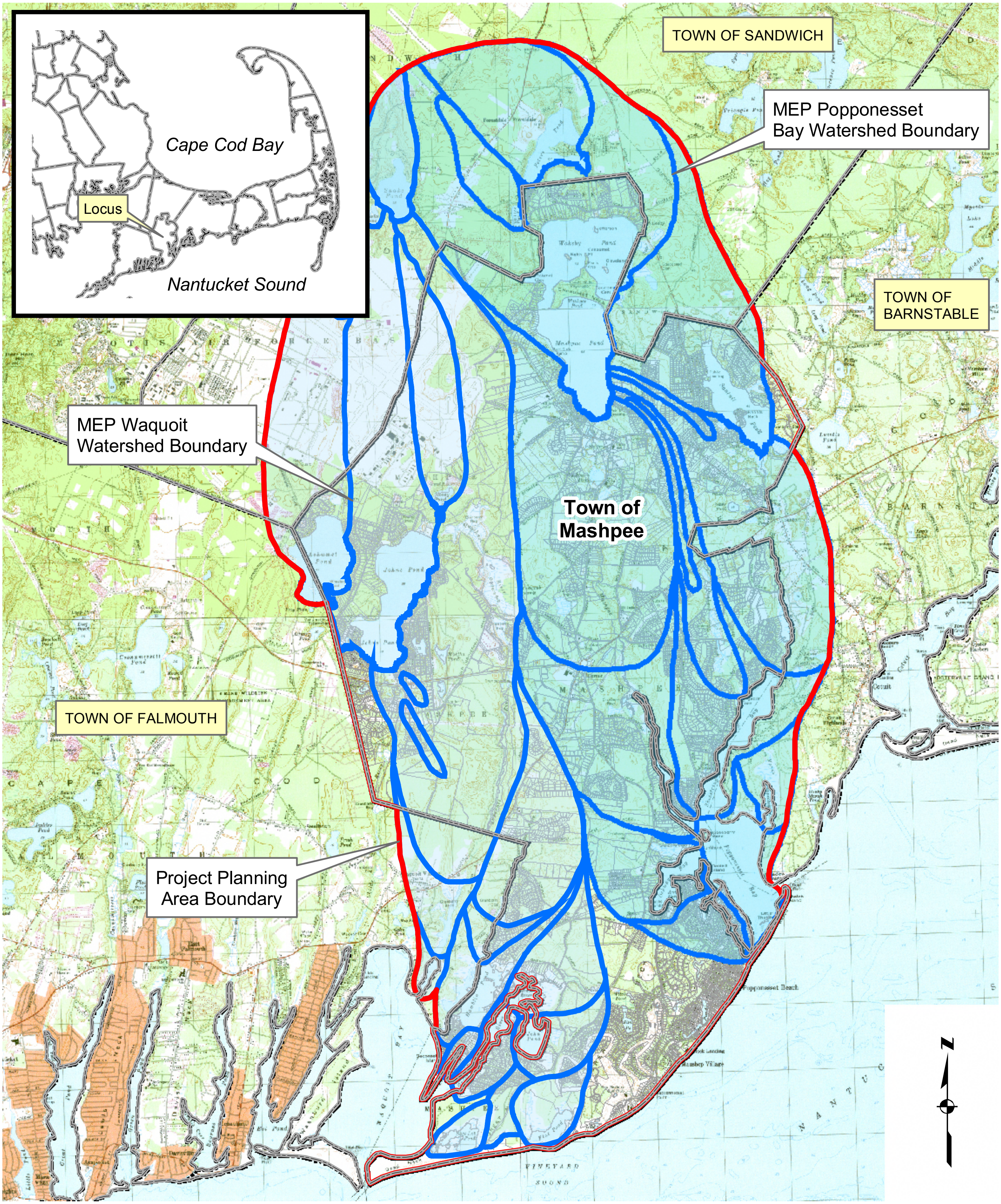
Sources:

Stormwater Management Volume Two: Stormwater Technical Handbook (MADEP, 1997)
2005 Data Report – University of New Hampshire Stormwater Center
National Pollutant Removal Performance Database for Stormwater Treatment Practices, March 2000
National Pollutant Discharge Elimination System Stormwater Menu of BMPs (USEPA)
Stormwater Technology Fact Sheet (USEPA)

Notes:

1. Nitrogen and Nitrate reduction values reflect the reduction in runoff reaching surface waters. Many of these practices still allow nitrogen to infiltrate into the groundwater, which will eventually reach the estuaries.
2. Only one information source was available for technologies that do not show pollutant removal rates as a range of values.
3. Specific maintenance items necessary for each alternative are discussed in the text.
4. Technologies with actual costs are based on the UNH Data Report. Other cost considerations are summarizations of required implementation activities.

Report Figures



*The Project Area is the combination of the Town of Mashpee area and the watersheds of Popponesset Bay and Waquoit Bay-East as delineated by the Massachusetts Estuaries Project (MEP)

Data Source: Mass GIS
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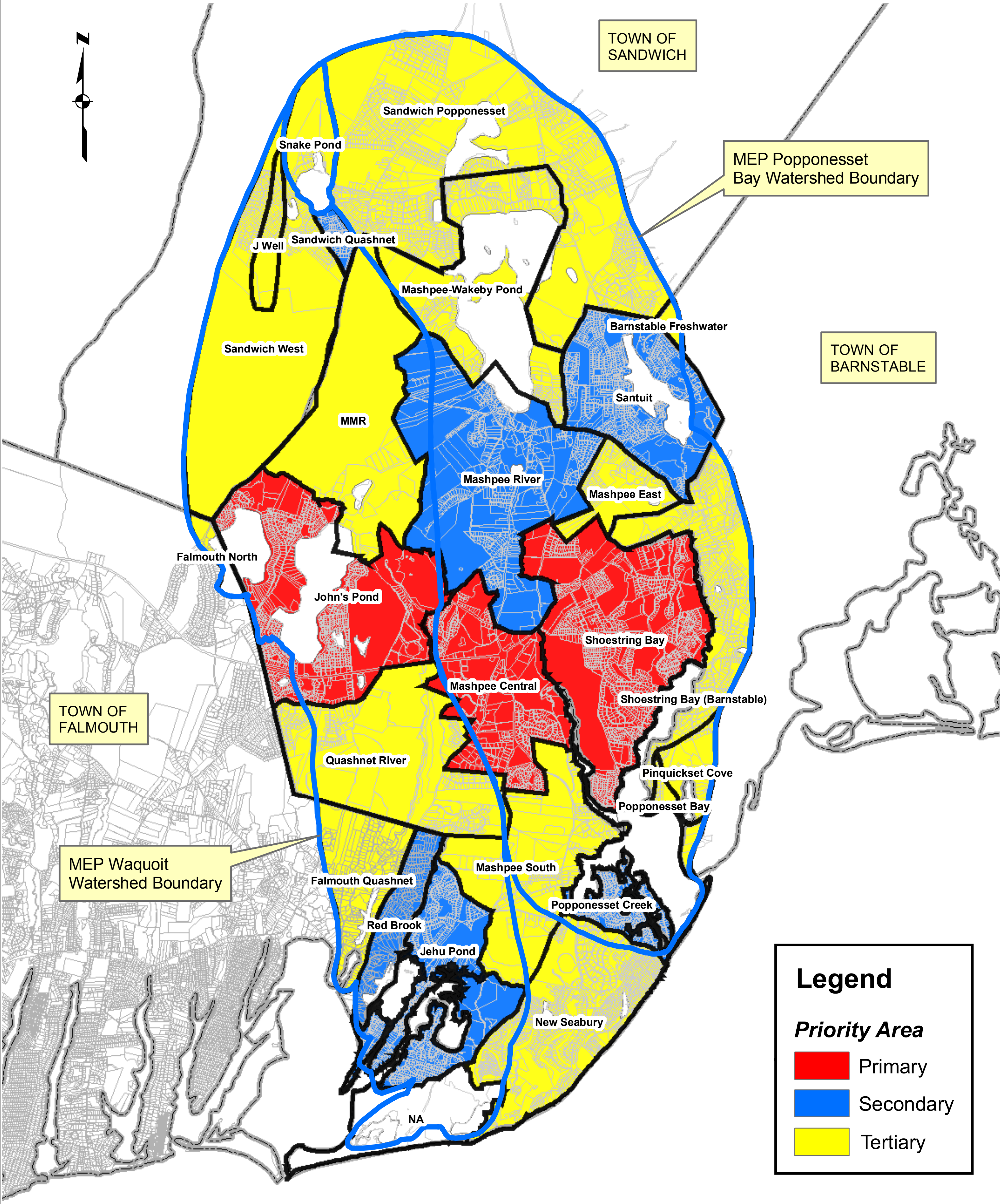
LOCUS MAP

FIGURE 1-1



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PRIORITY AREAS

FIGURE 2-1

Data Source: Mass GIS
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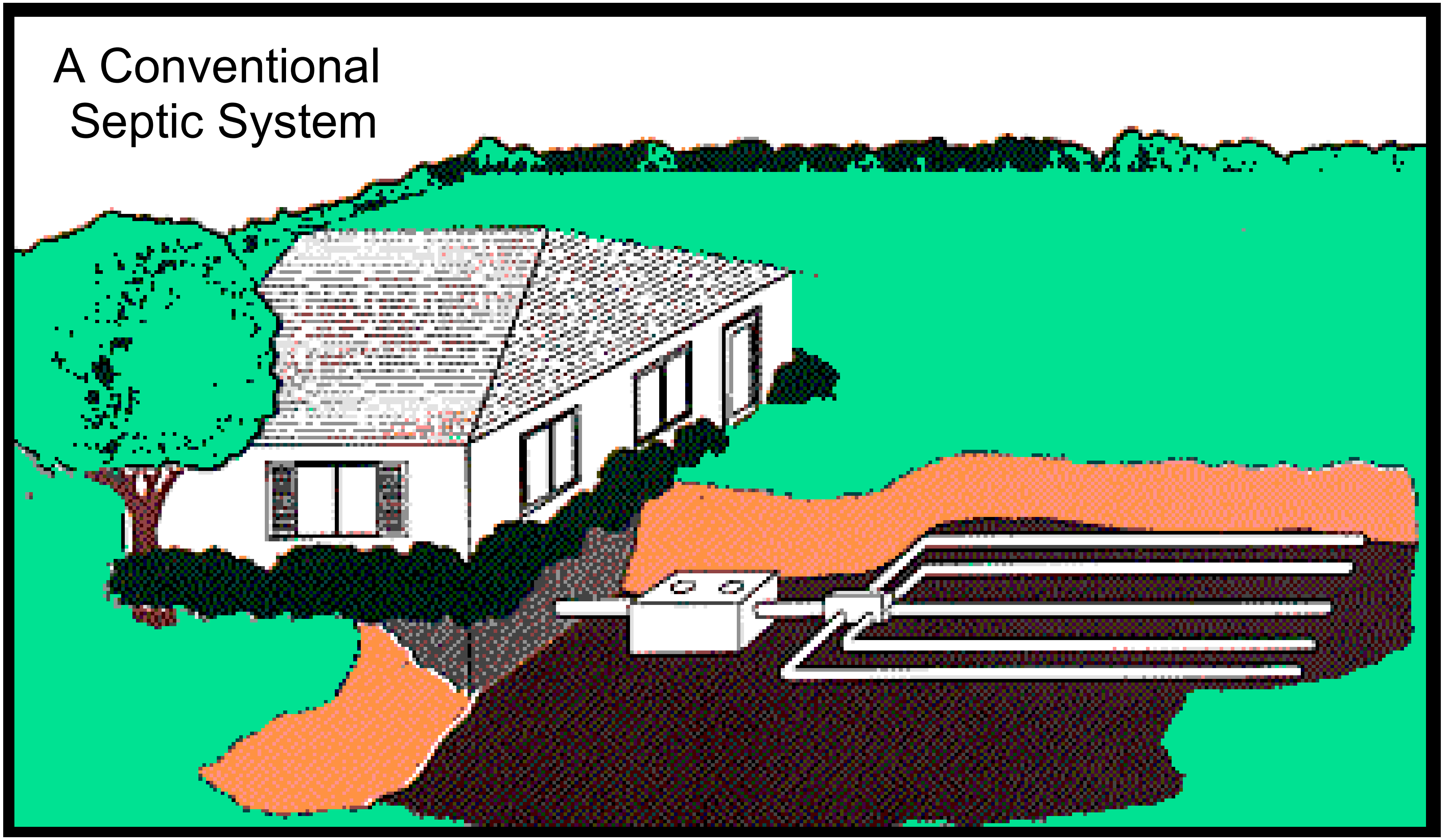

Source: Massachusetts DEP, http://www.mass.gov/dep/water/wastewater/yoursyst.htm

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-1_Septic System Diagram .mxd

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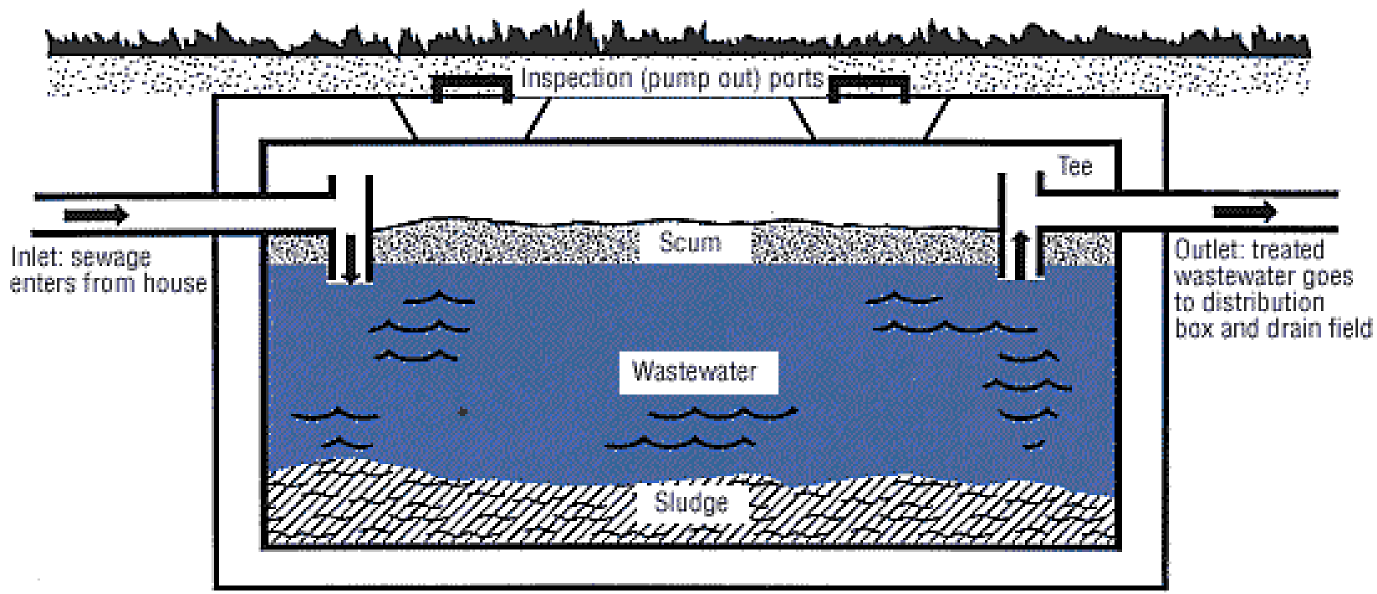
SEPTIC SYSTEM DIAGRAM

FIGURE 4-1



Source: Massachusetts DEP, http://www.mass.gov/dep/water/wastewater/yoursyst.htm

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SEPTIC TANK DIAGRAM

FIGURE 4-2

Data Source: Mass GIS
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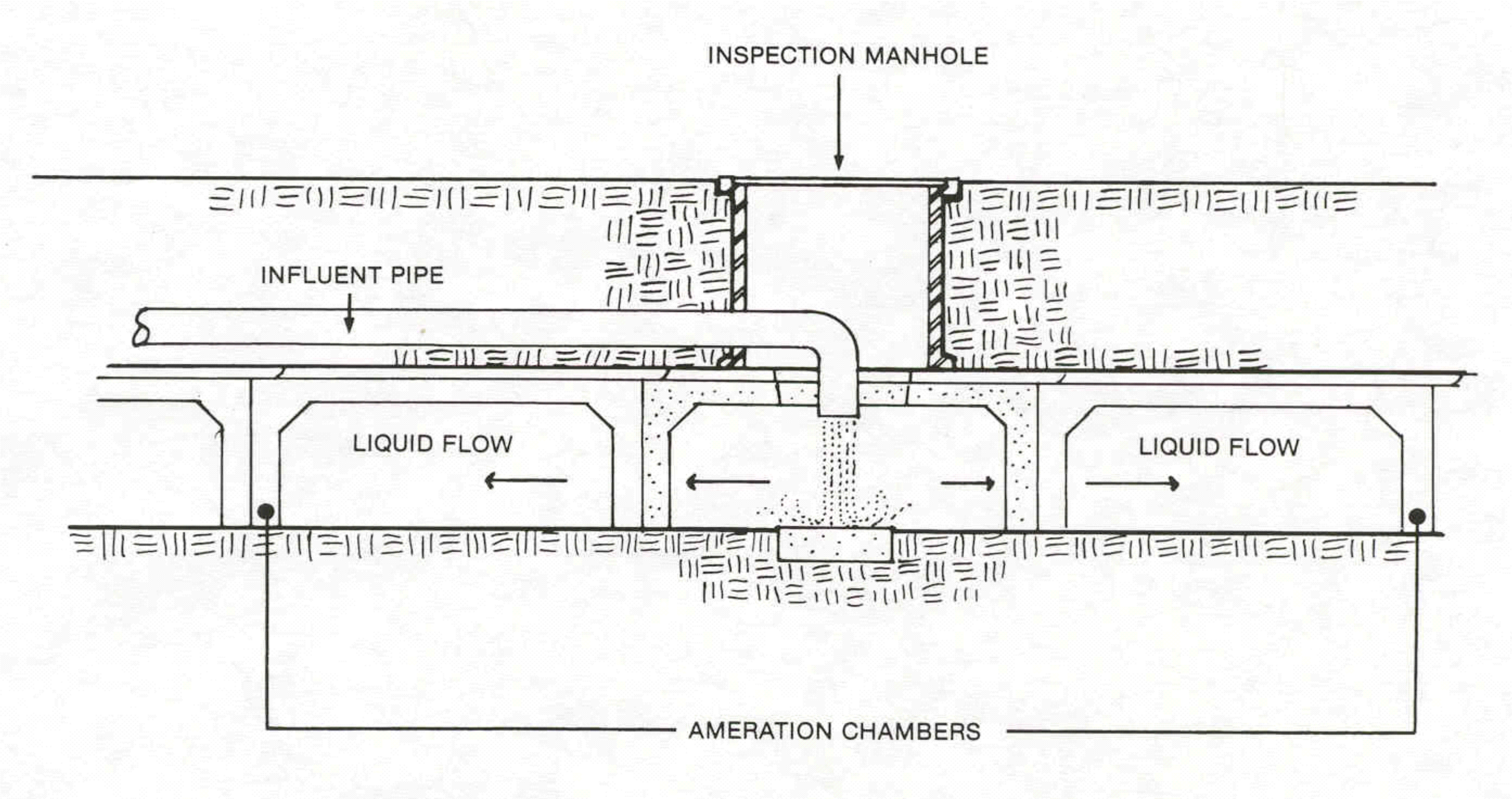

Source: Shorey Precast, 2000

Data Source: Mass GIS
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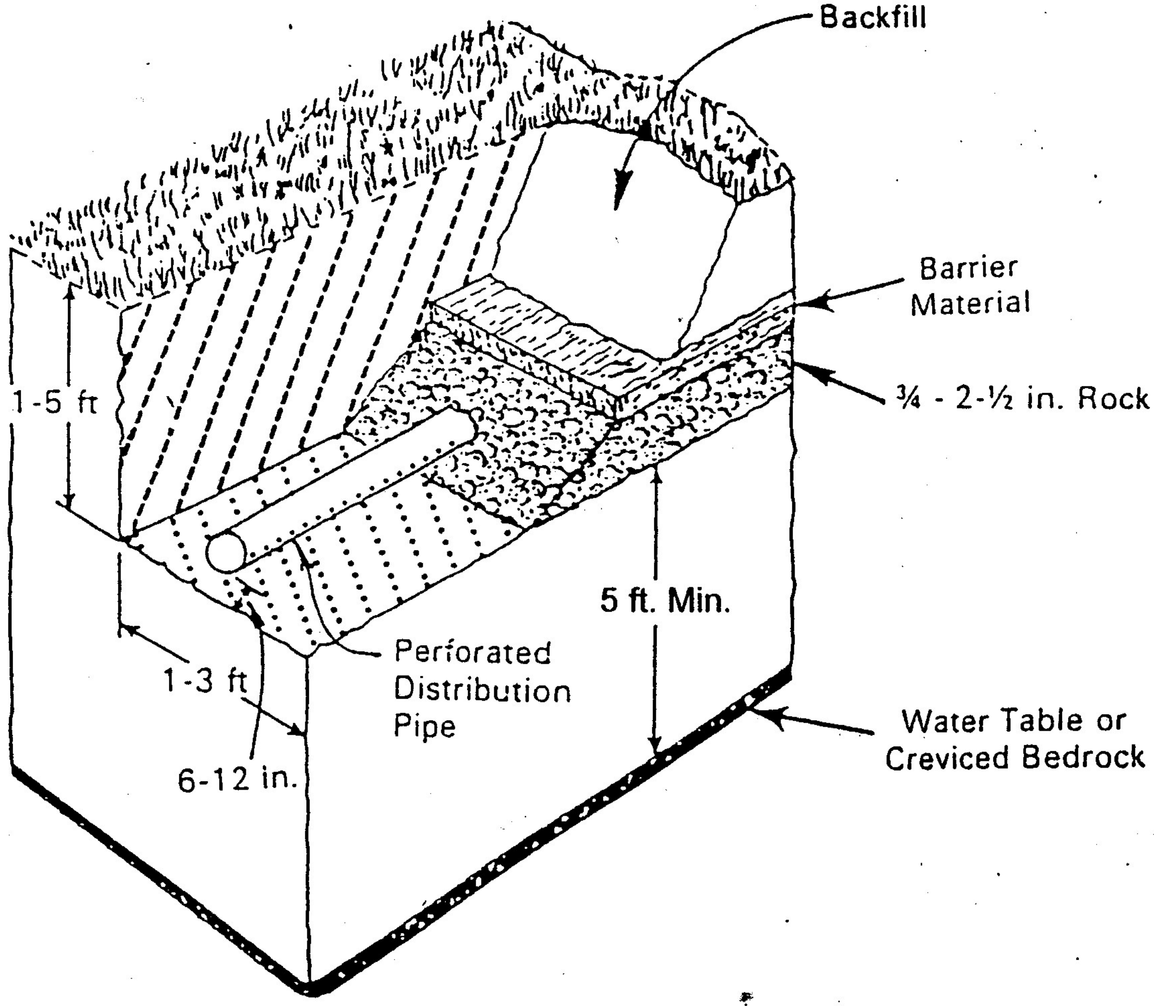
Leaching Chamber System

FIGURE 4-3



Data Source: Mass GIS
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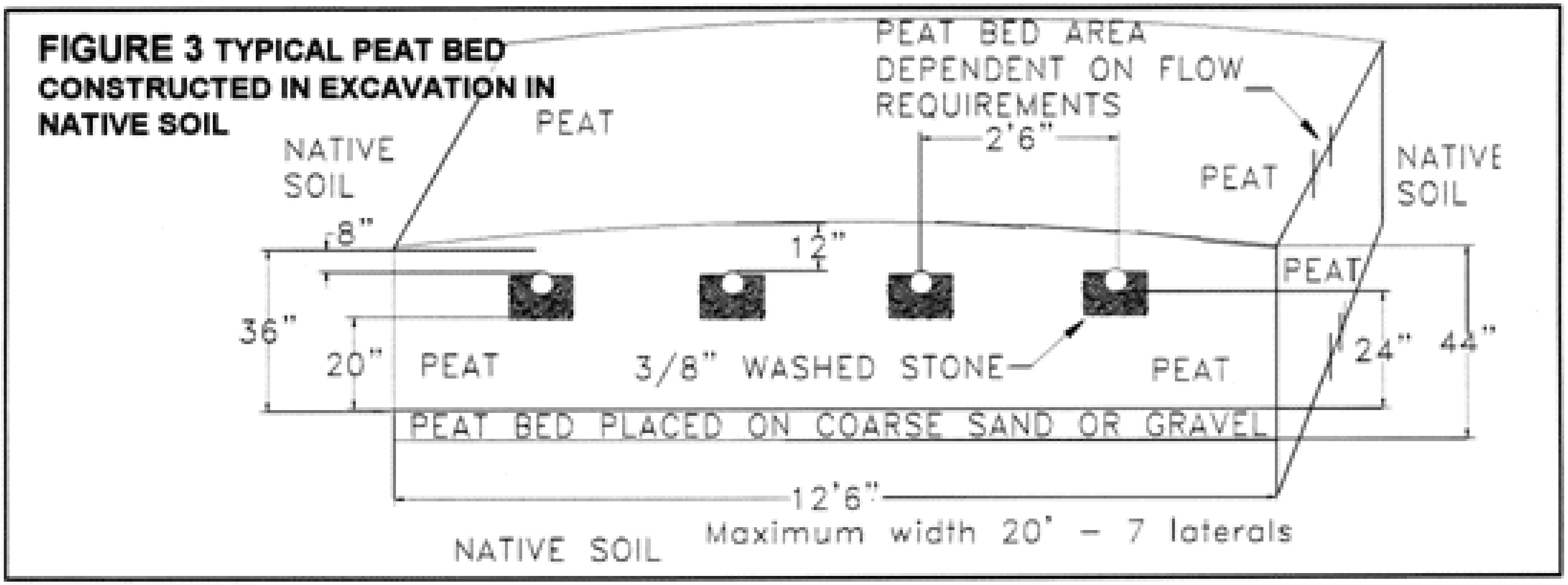
Leaching Trench Diagram

FIGURE 4-4



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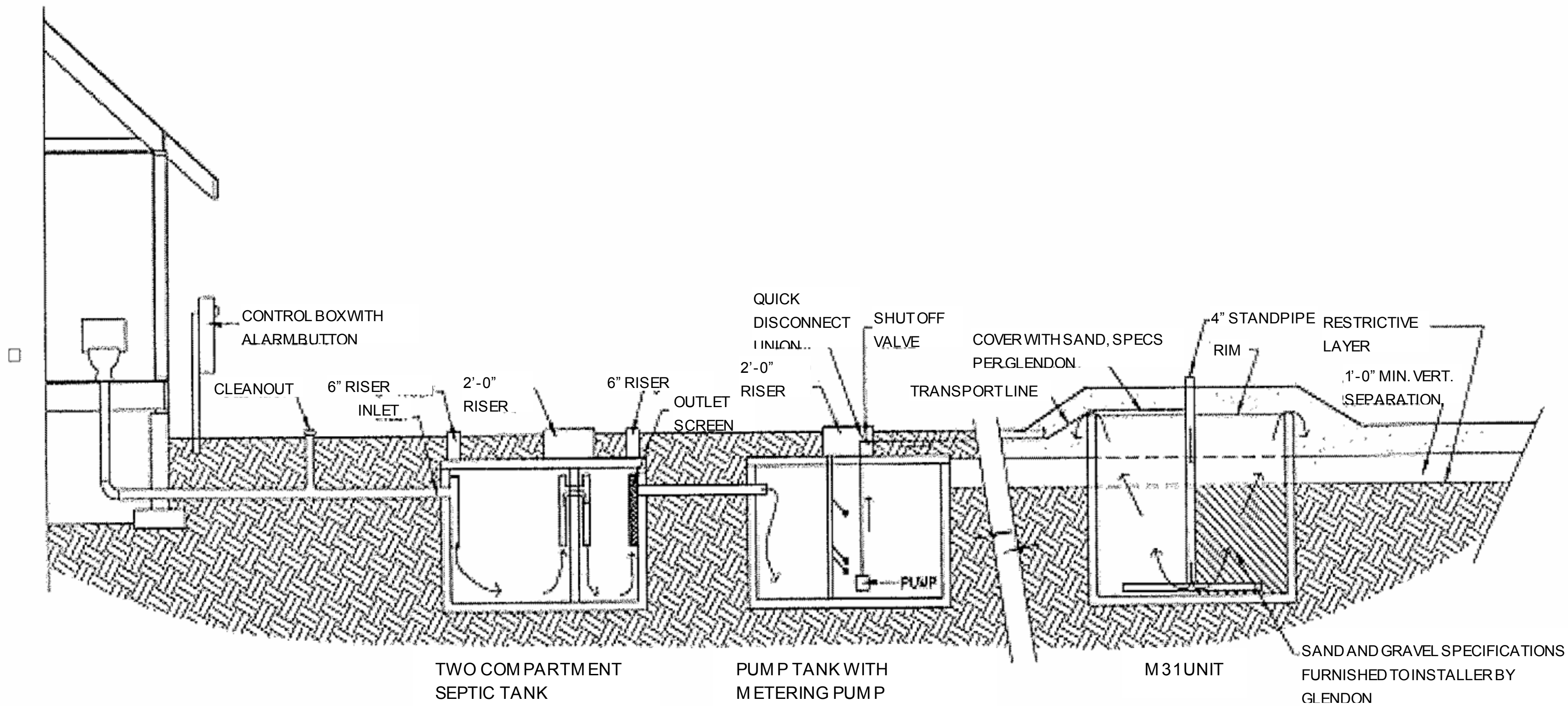
PEAT MOSS SYSTEM CROSS-SECTION

FIGURE 4-5



Source: Glendon Biofilter Technologies

Data Source: Mass GIS
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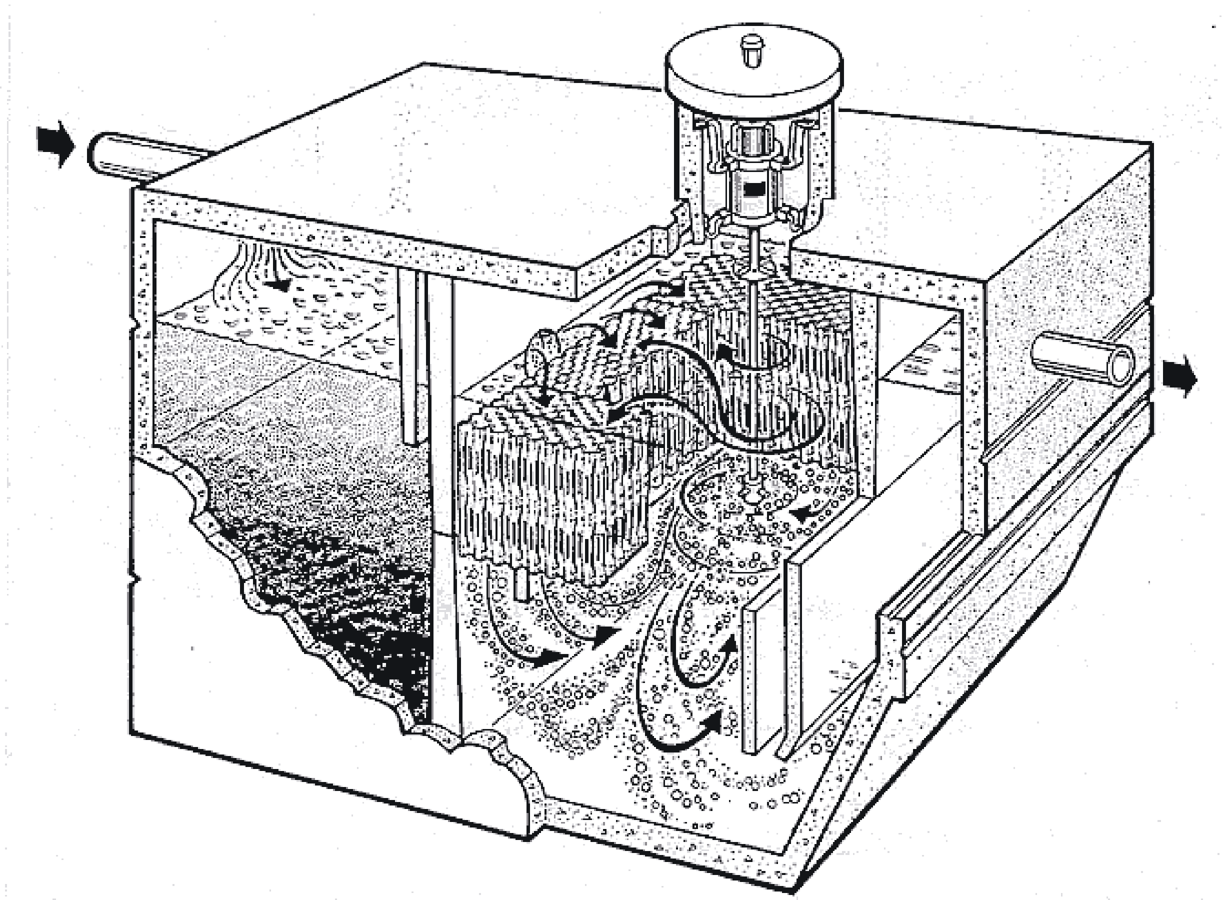
GLENDON BIOFILTER

FIGURE 4-6



Source: USEPA Region 1, January 2007
http://www.epa.gov/ne/assistance/ceitts/wastewater/techs/jetaerobic.html

Data Source: Mass GIS
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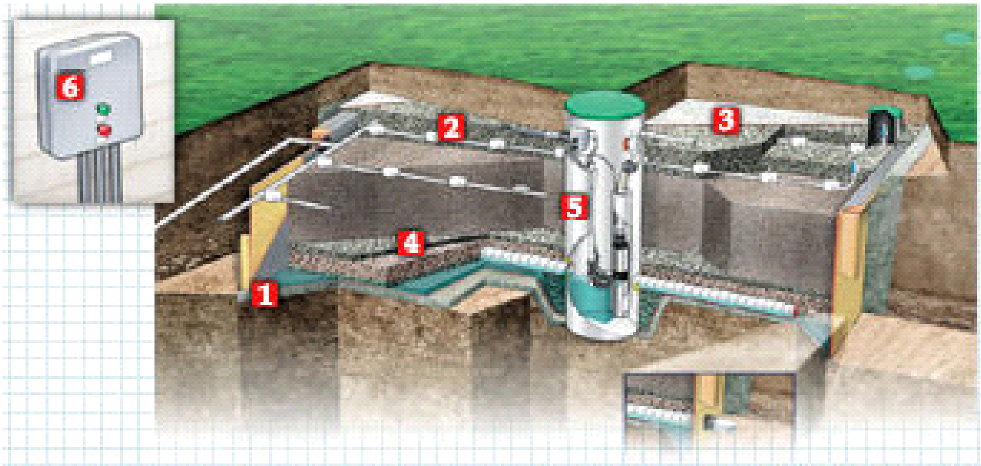
JET Aerobic Treatment System

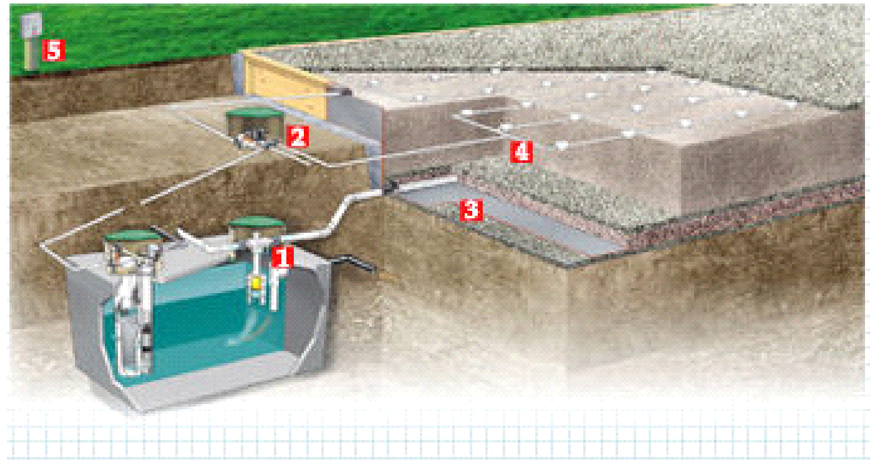
FIGURE 4-7



INTERMITTENT SAND FILTER

1) Liner
2) Manifold kit
3) Filter fabric
4) Air cool kit
5) Pump basin
6) Control Panel

Source: Orenco Systems 2000©



RECIRCULATING SAND FILTER

1) Recirculating splitter valve
2) Distributing valve assembly
3) Liner
4) Manifold kit
5) Control panel

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-8_Orenco .mxd

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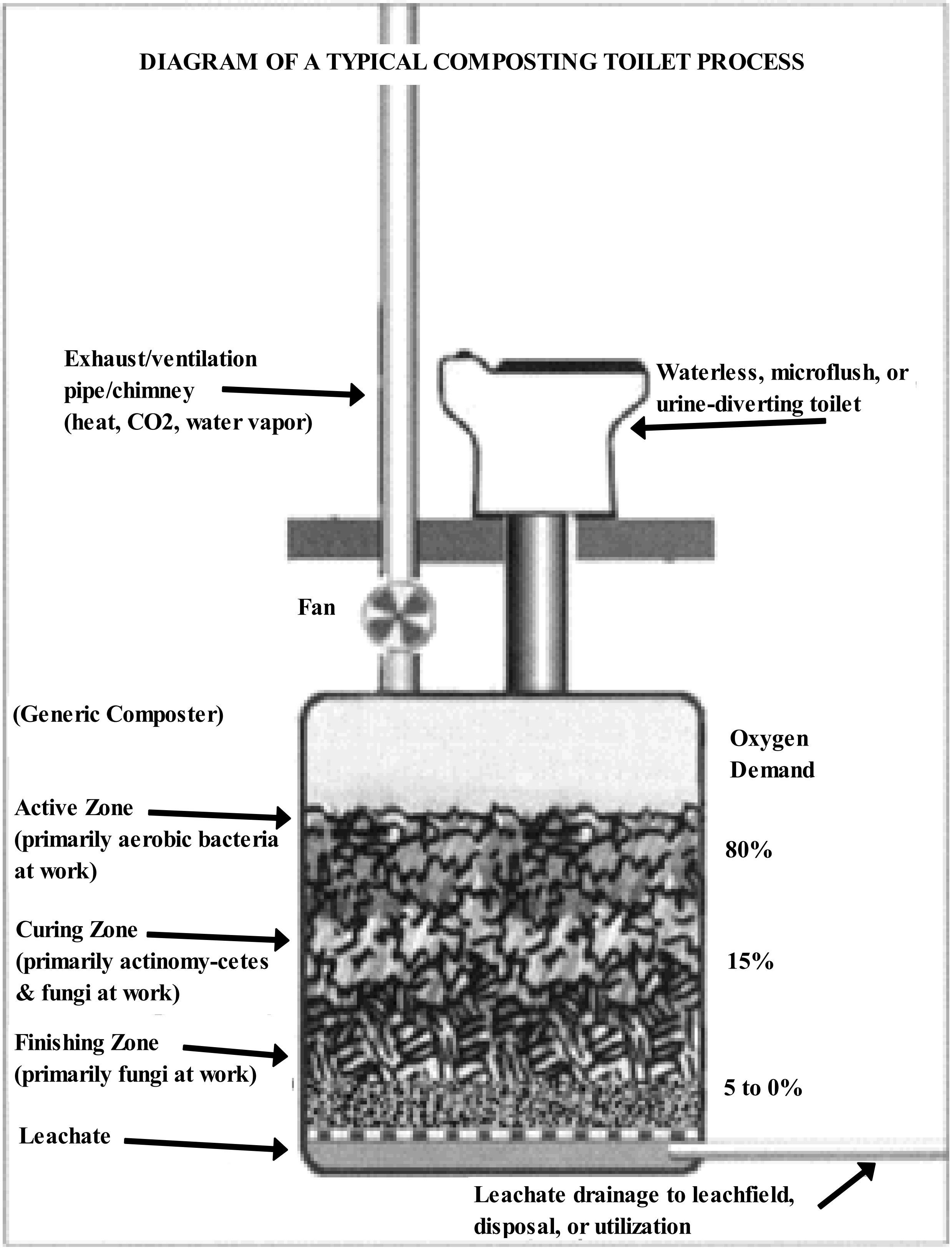
ORENCO INTERMITTENT AND TRICKLING FILTERS

FIGURE 4-8



Source:Oikos®, © 1996-2002

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-9_Compost .mxd

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MASHPEE SEWER COMMISSION

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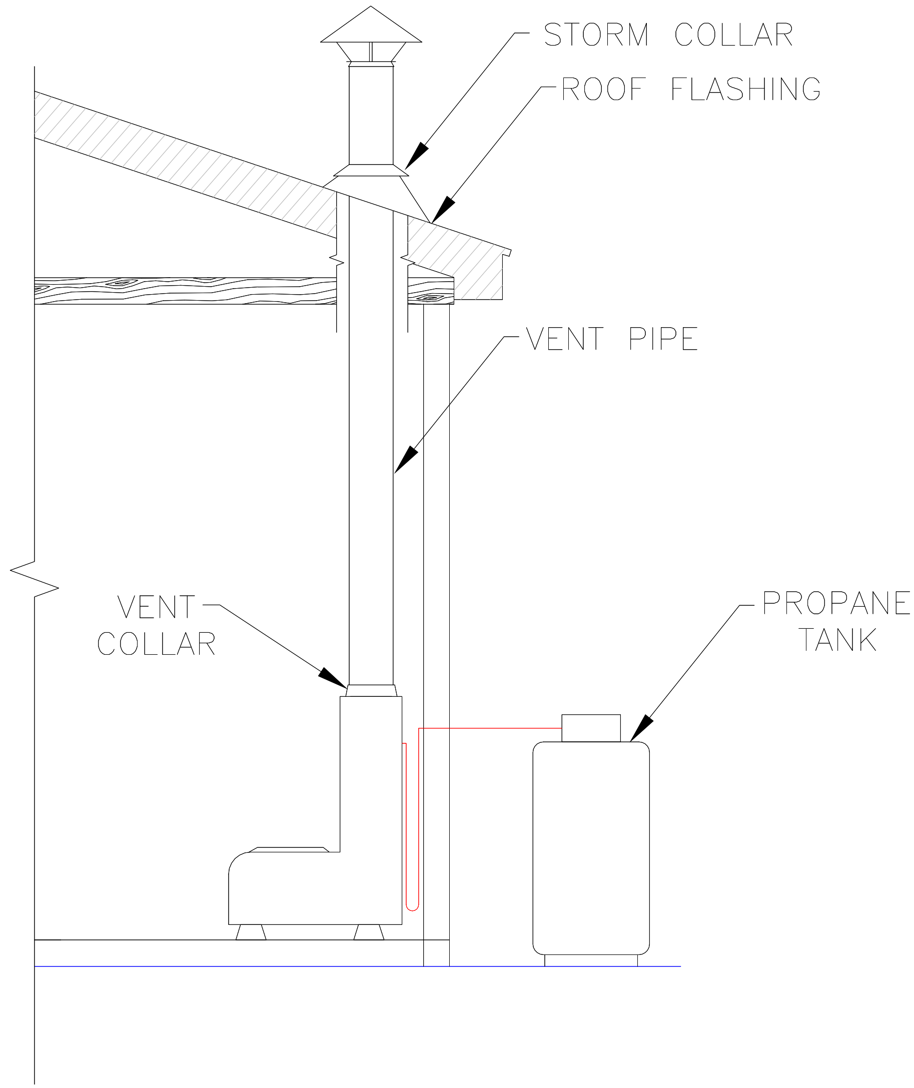
COMPOSTING TOILET DIAGRAM

FIGURE 4-9



Source: Barnstable County Department of Health, June 2003

Data Source: Mass GIS
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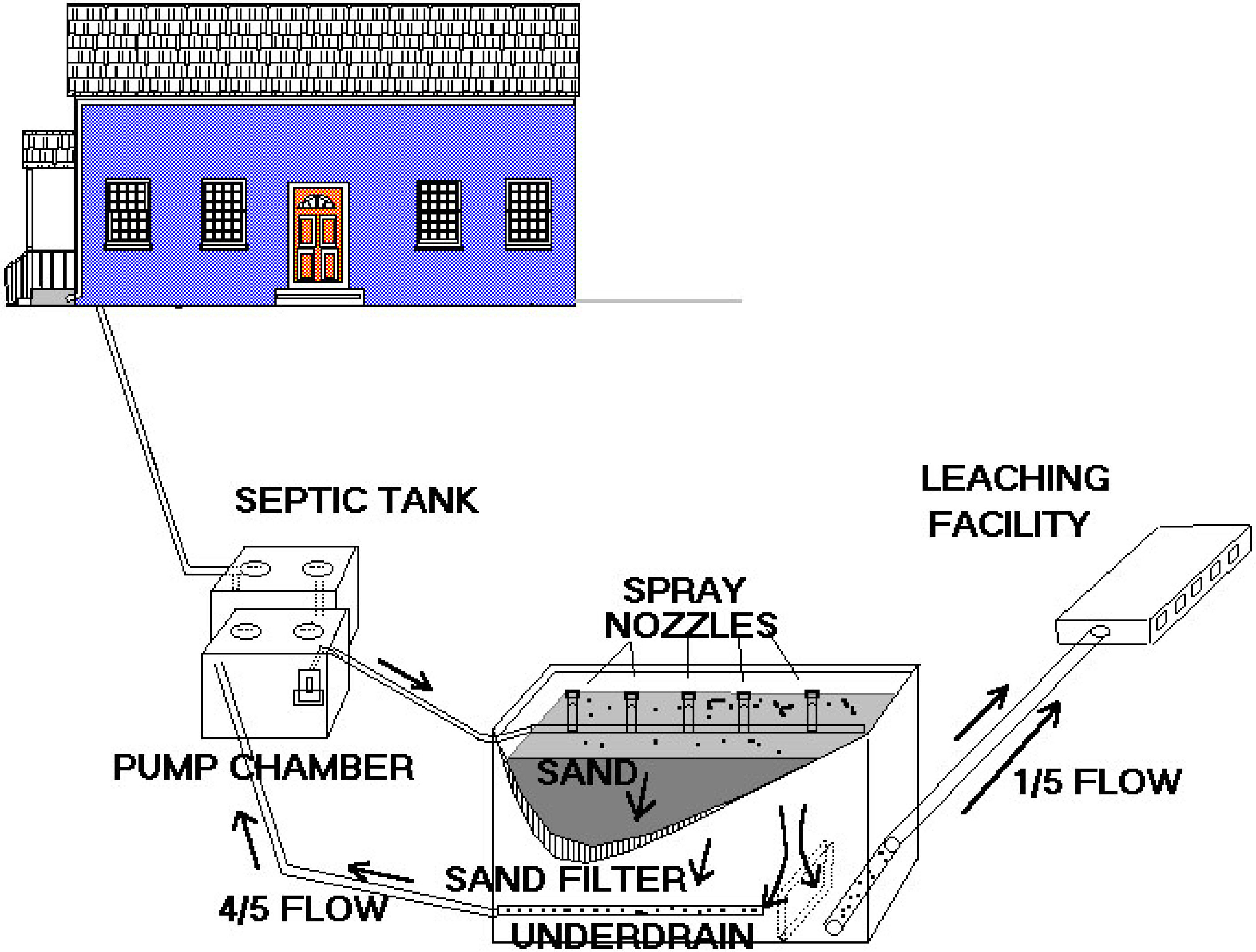
INCINERATING TOILET DIAGRAM

FIGURE 4-10



Source: Barnstable County Department of Health, June 2003

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-11_Sand Filter .mxd

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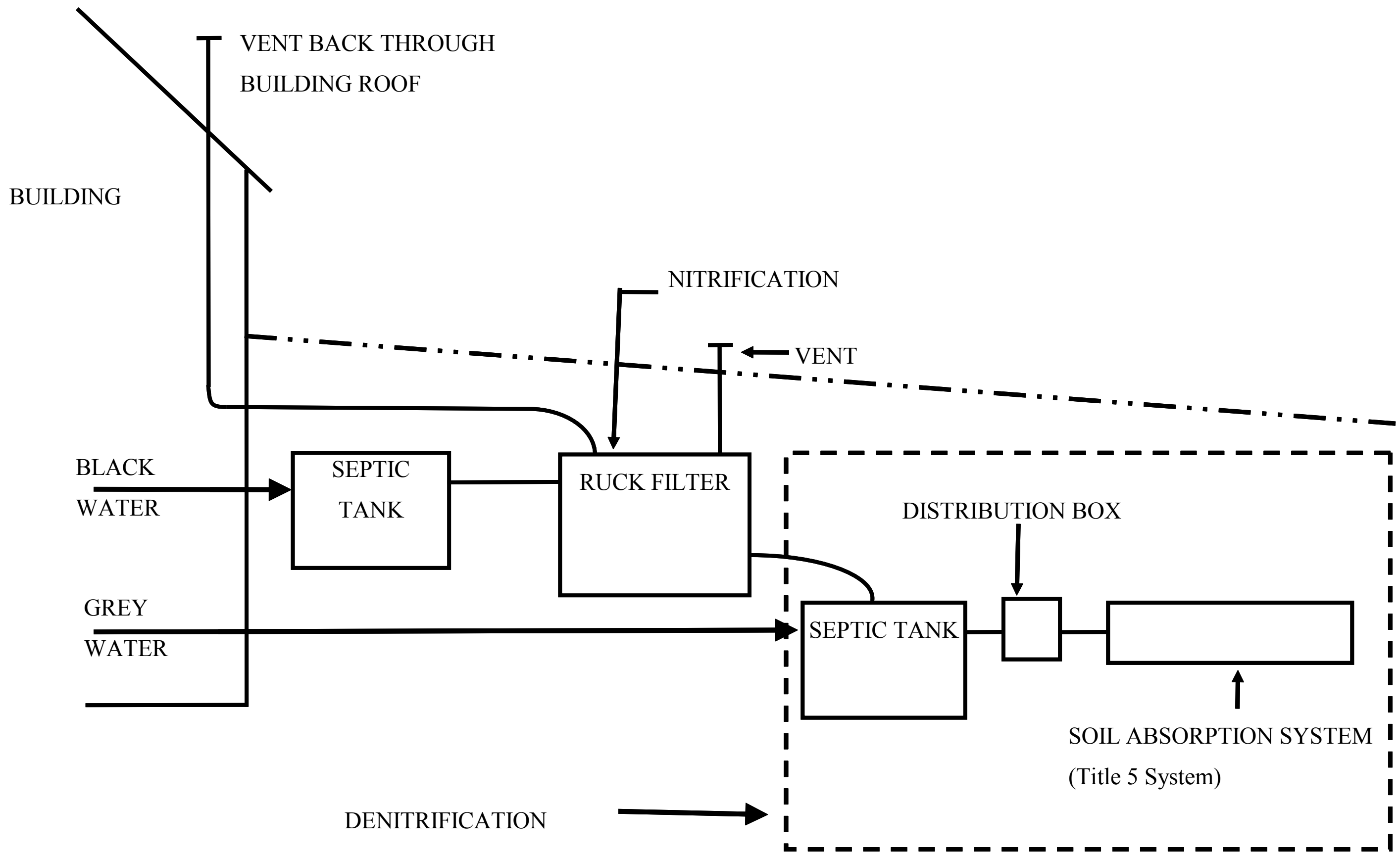
MASHPEE SEWER COMMISSION

WNMP-Technology Screening Report

RECIRCULATING SAND FILTER

FIGURE 4-11



Source: RUCK Systems, Inc., June 2003

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-12_RUCK.mxd

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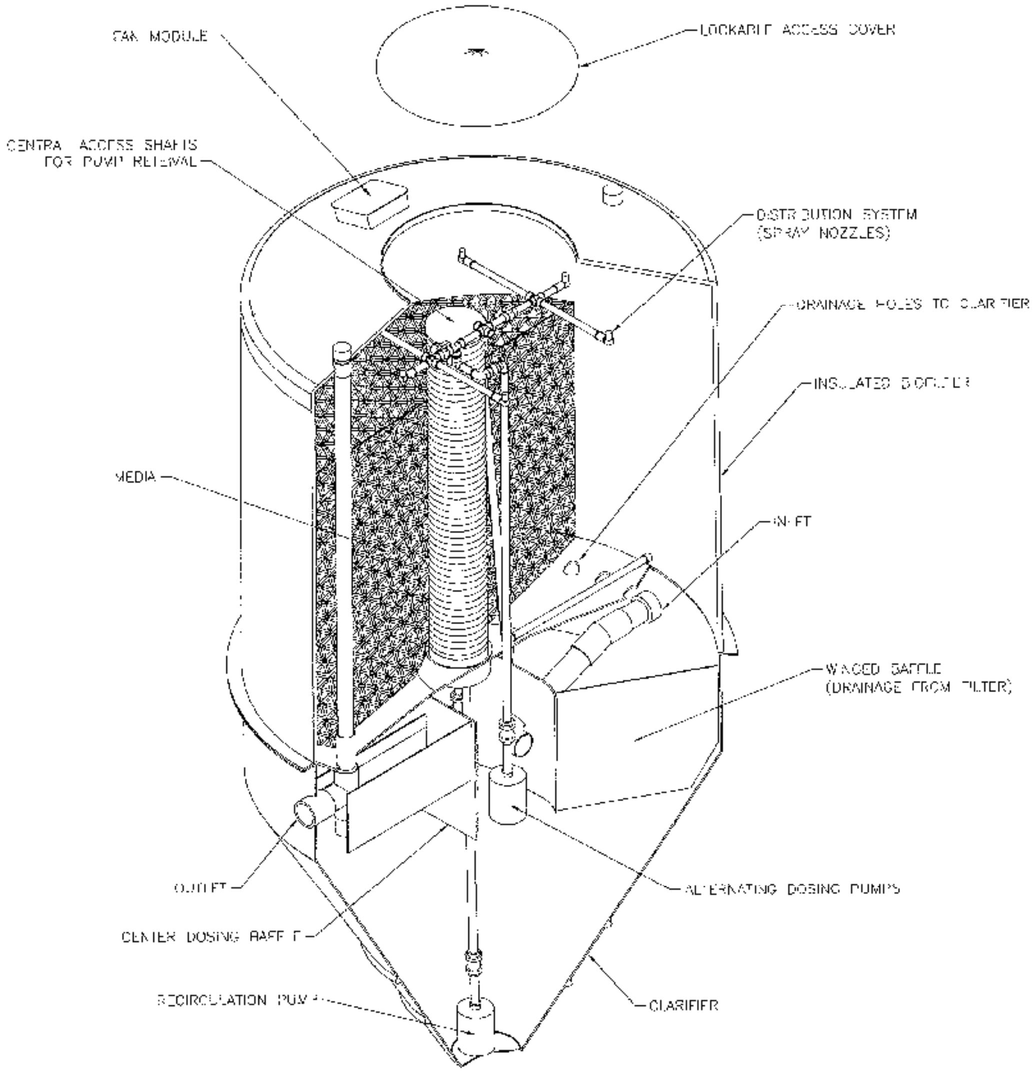
RUCK SYSTEM DIAGRAM

FIGURE 4-12



ISOMETRIC VIEW OF BIOCLERE

Source: AquaPoint

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\ 00074 Mashpee\2006 WWFP\Report Figures \Technology Screening Report\ 00074F4-13 BIOCLERE.mxd

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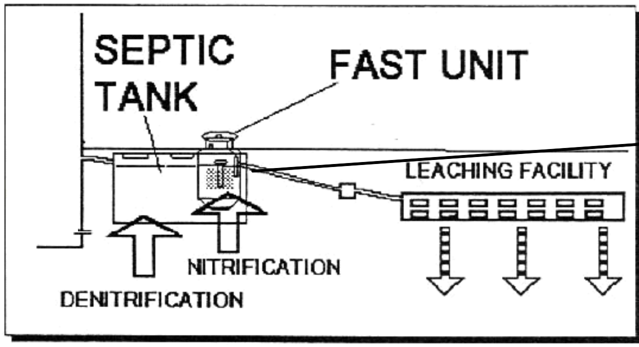
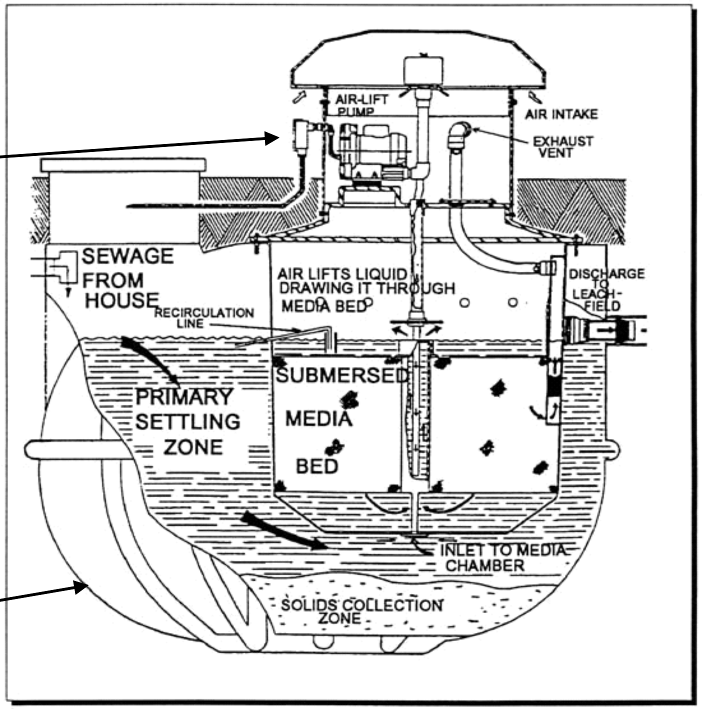
BIOCLERE TREATMENT UNIT
FIGURE 4-13

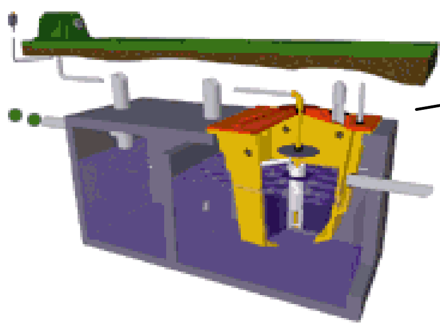


TYPICAL MICROFAST INSTALLATION SCHEMATIC



DETAIL OF MICROFAST UNIT

Source: Barnstable County Department of Health, June 2003



MICROFAST UNIT INSTALLED IN SEPTIC TANK

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-14 FAST SYSTEM.mxd

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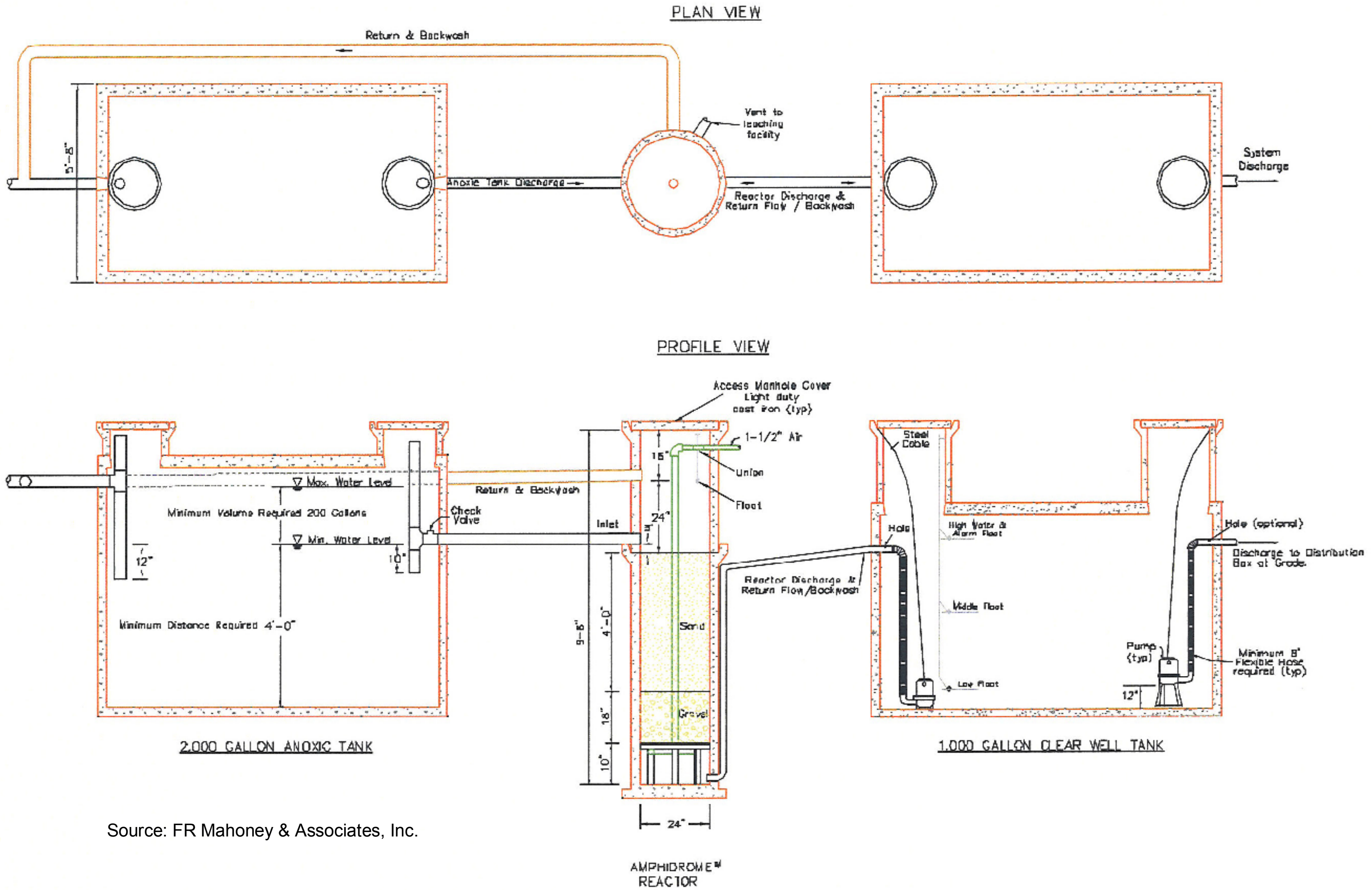
FAST Treatment System (MicroFAST)

FIGURE 4-14



Source: FR Mahoney & Associates, Inc.

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-15 AMPHIDROME SYSTEM.mxd

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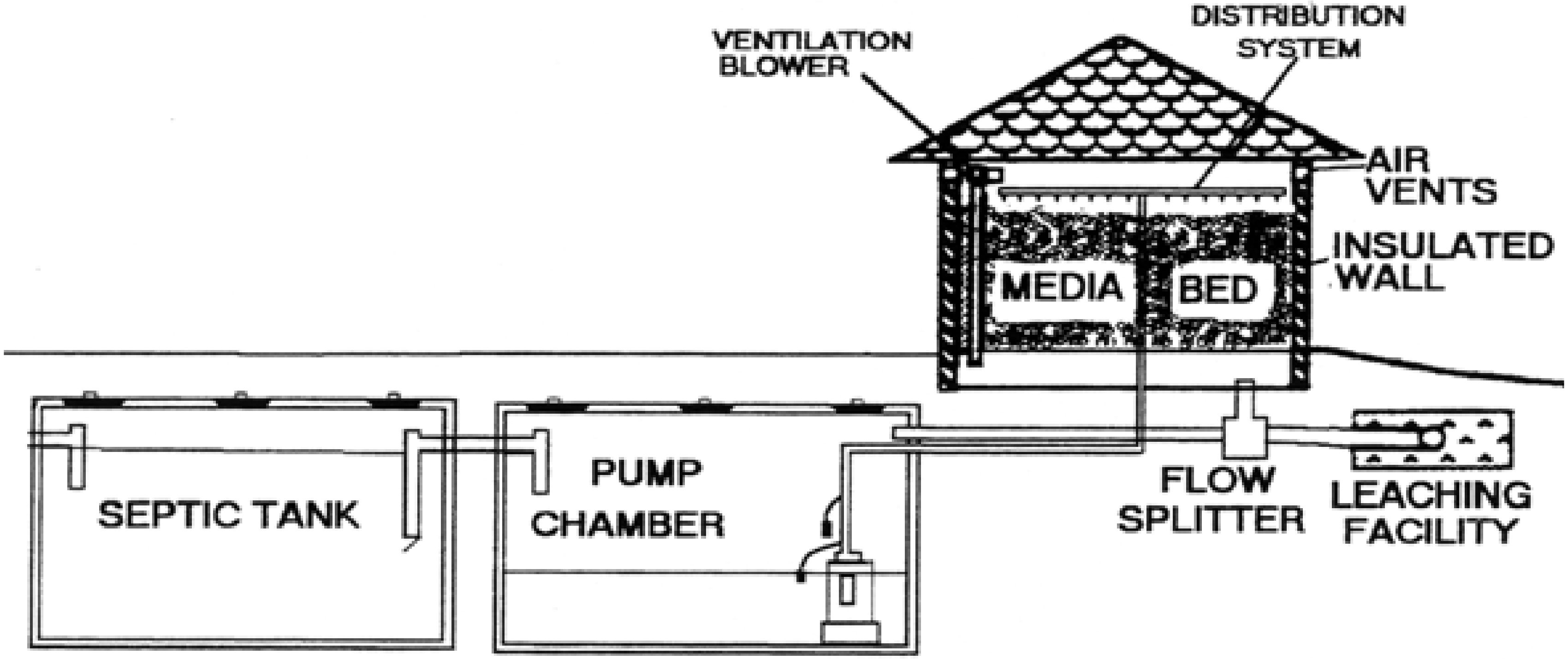
AMPHIDROME SYSTEM

FIGURE 4-15



Source: Buzzards Bay Project, June 2003

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-16 WATERLOO.mxd

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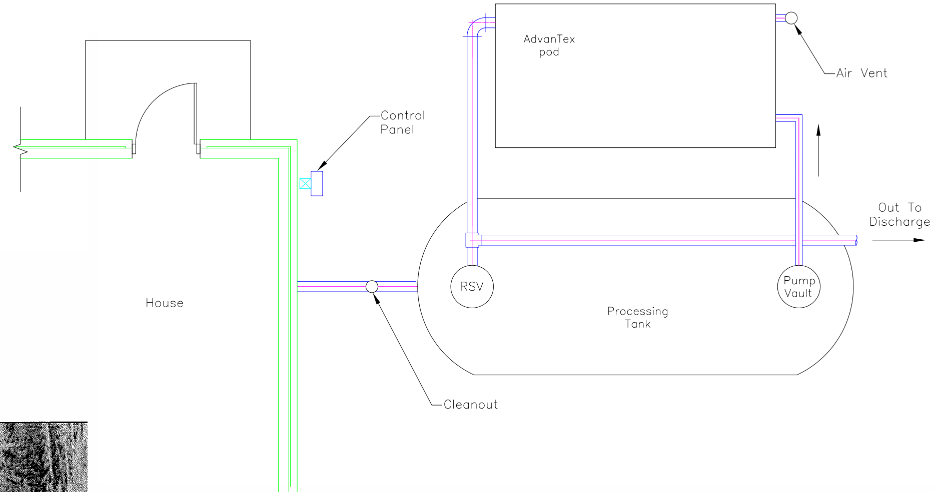
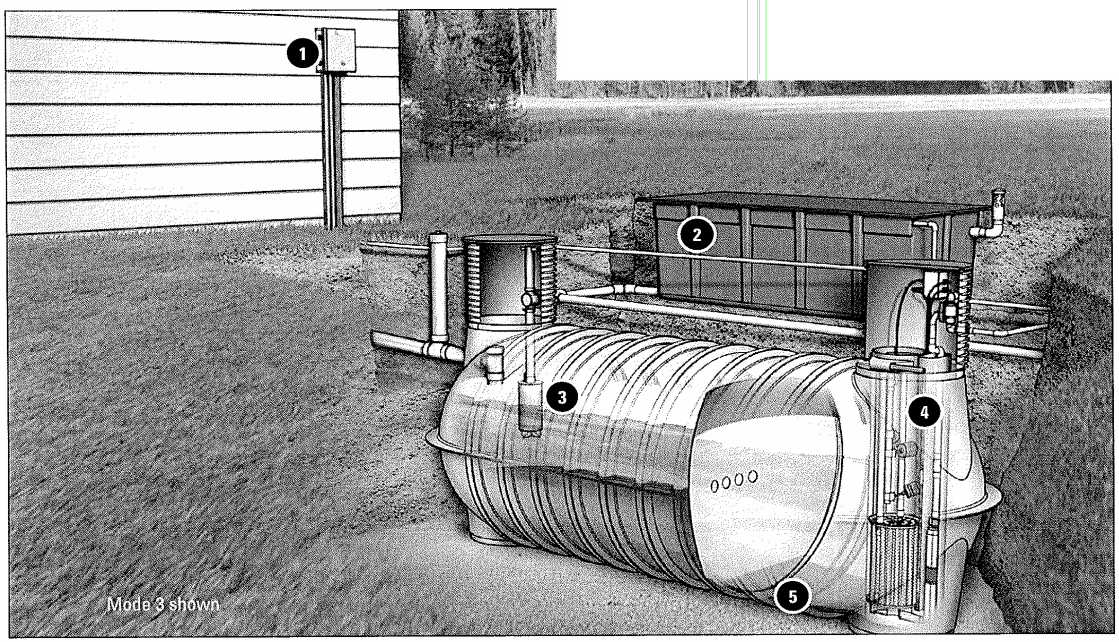
WATERLOO BIOFILTER

FIGURE 4-16



1. Control Panel
2. AdvanTex Filter Pod
3. Recirculating Splitter Valve
4. Biotube® Pumping Package
5. Processing Tank



Source: http://www.orenco.com/pdfs/AXRES_Install_3.31.pdf

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-17 ADVANTEX.mxd

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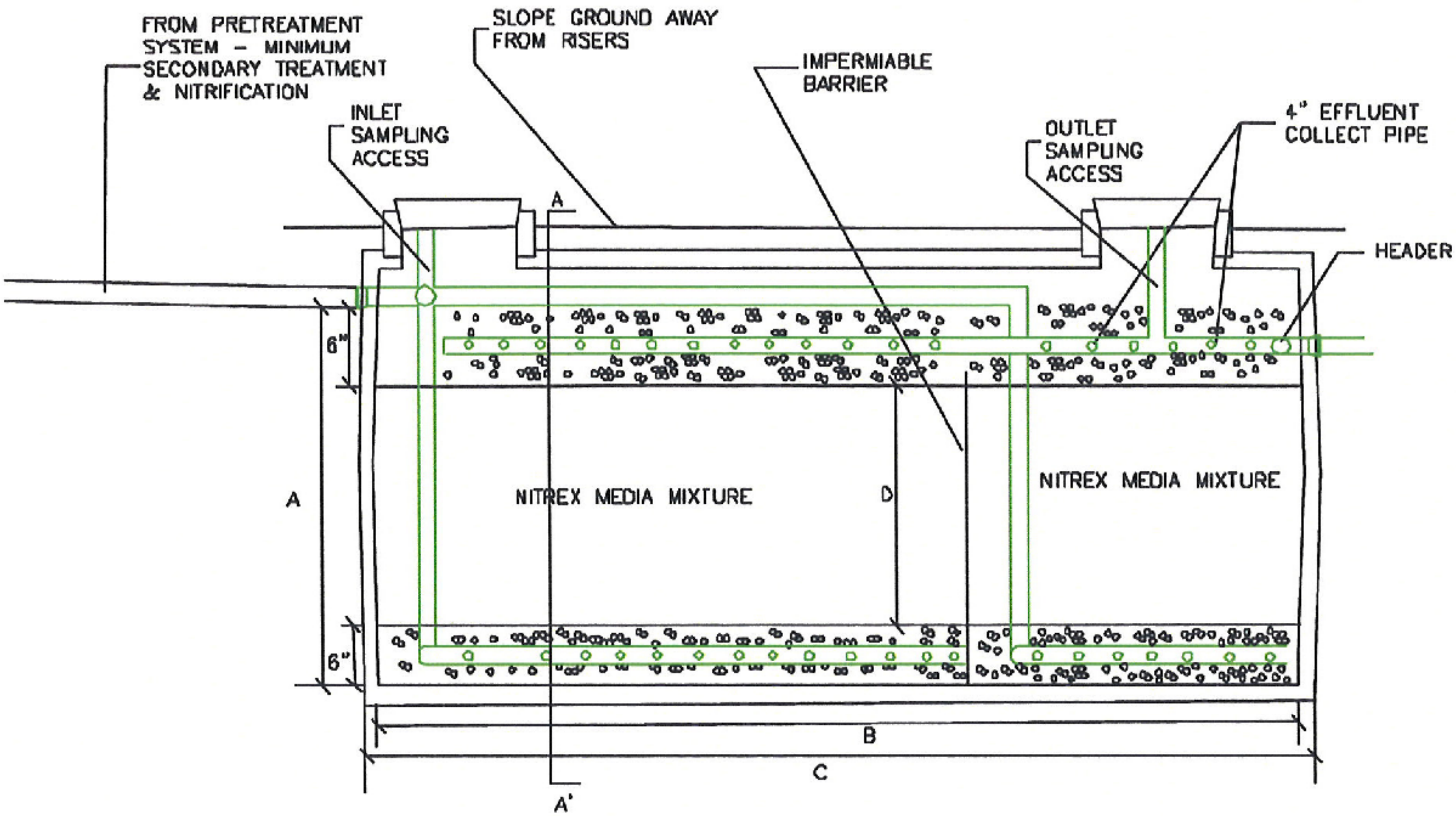
ADVANTEX

FIGURE 4-17



NOT TO SCALE

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-18 NITREX SYSTEM.mxd

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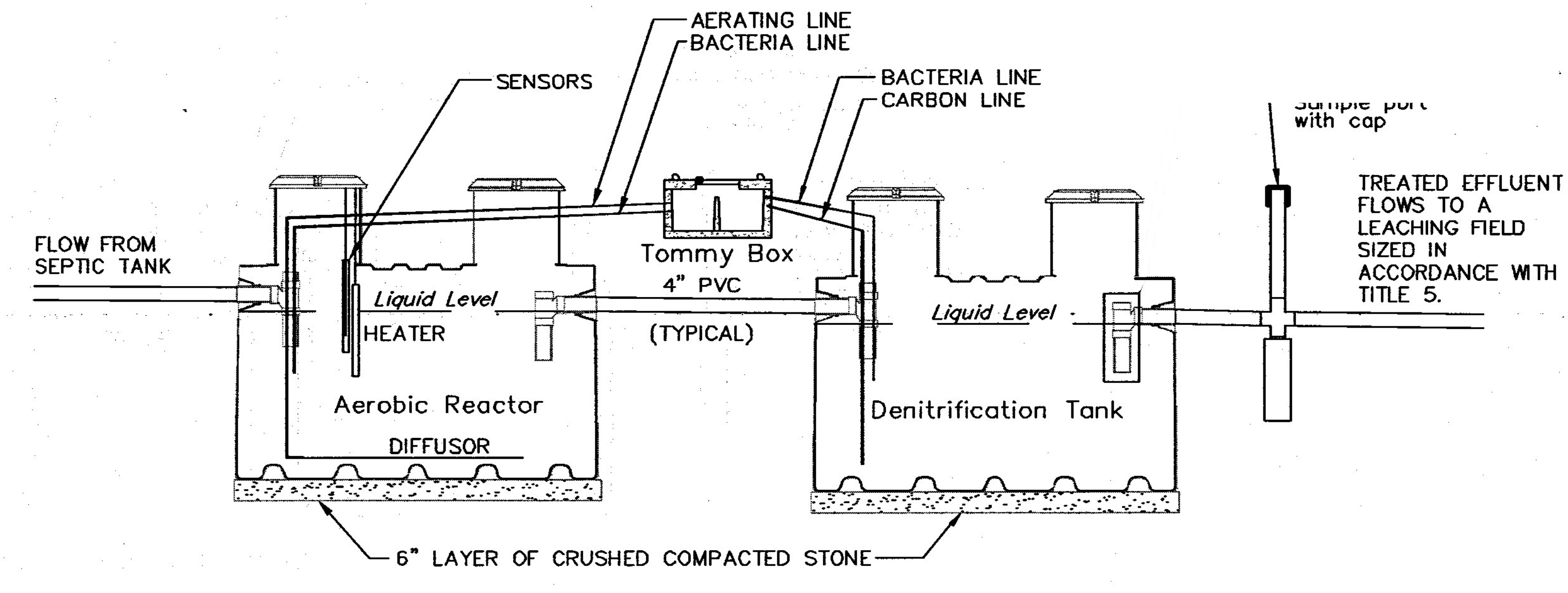
NITREX SYSTEM

FIGURE 4-18



Source: Environmental Operating Solutions, Inc.

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-19_OAR SYSTEM.mxd

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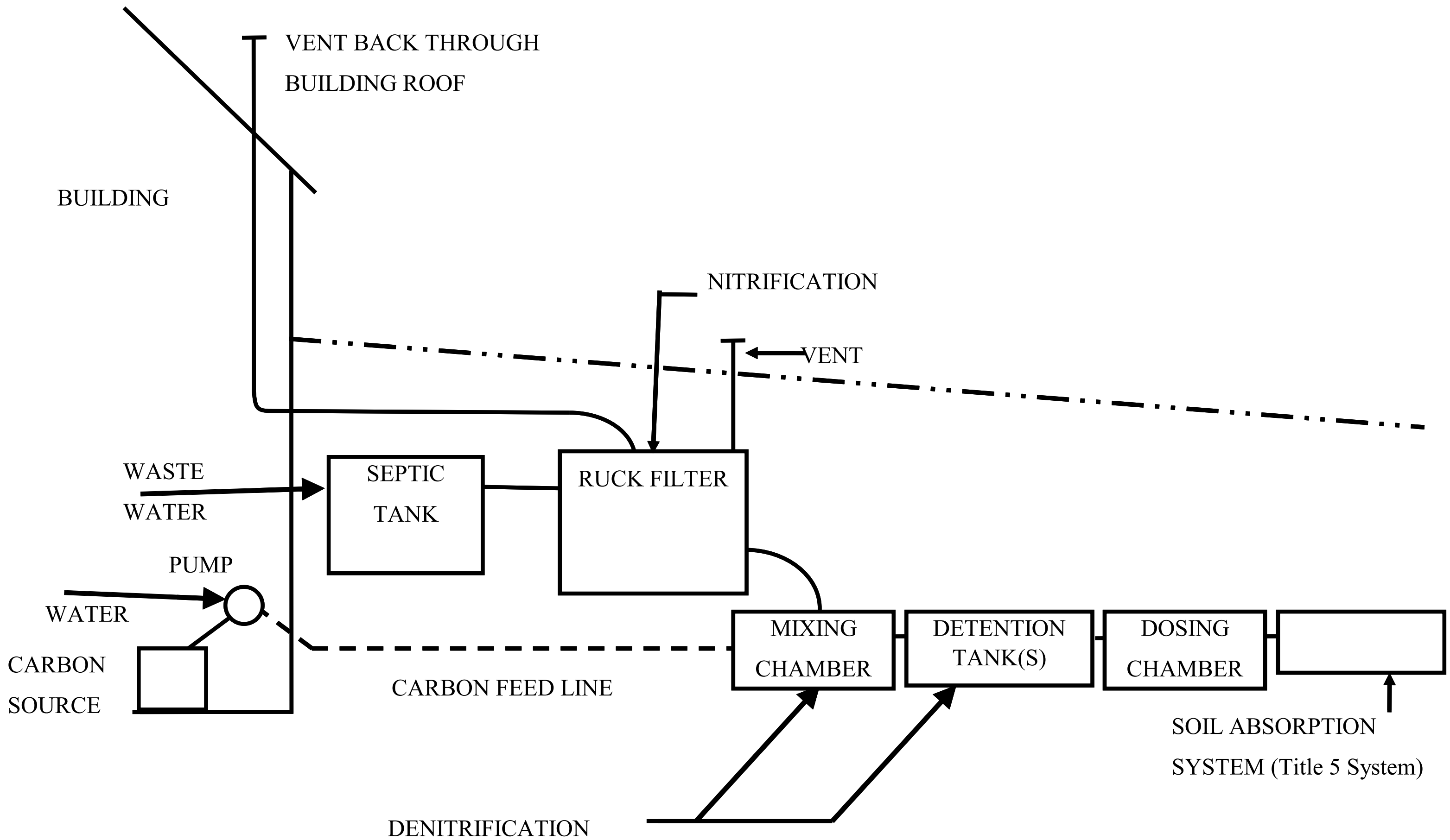
OAR SYSTEM

FIGURE 4-19



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RUCK CFT SYSTEM

FIGURE 4-20

Data Source: Mass GIS
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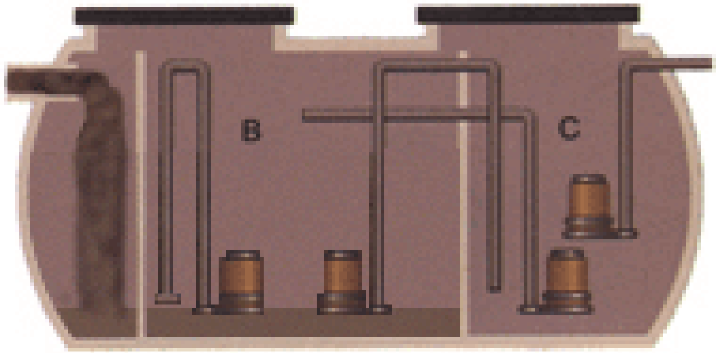

Source: Cromaglass Corp.

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-21_CROMAGLASS SYSTEM.mxd

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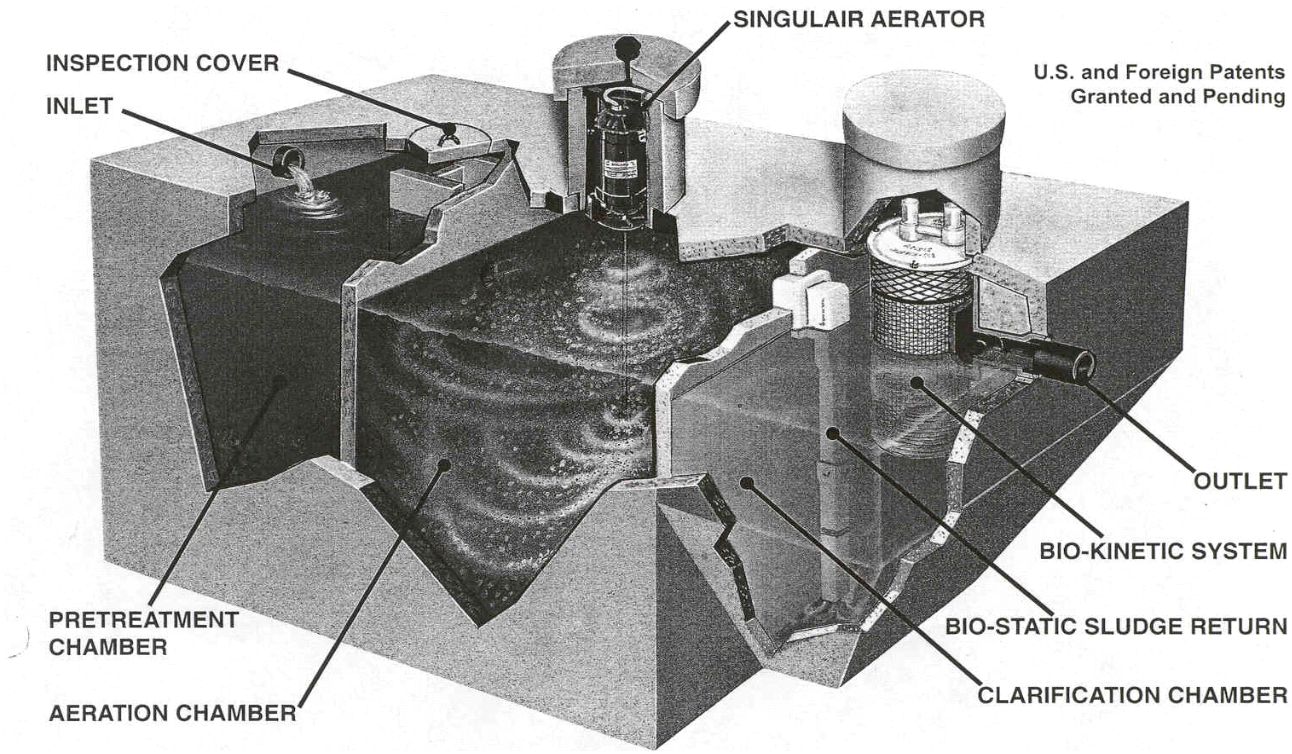
CROMAGLASS SYSTEM

FIGURE 4-21



Source: Norwalk Wastewater Equipment Company, Inc.

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F4-22_NORWECO.mxd

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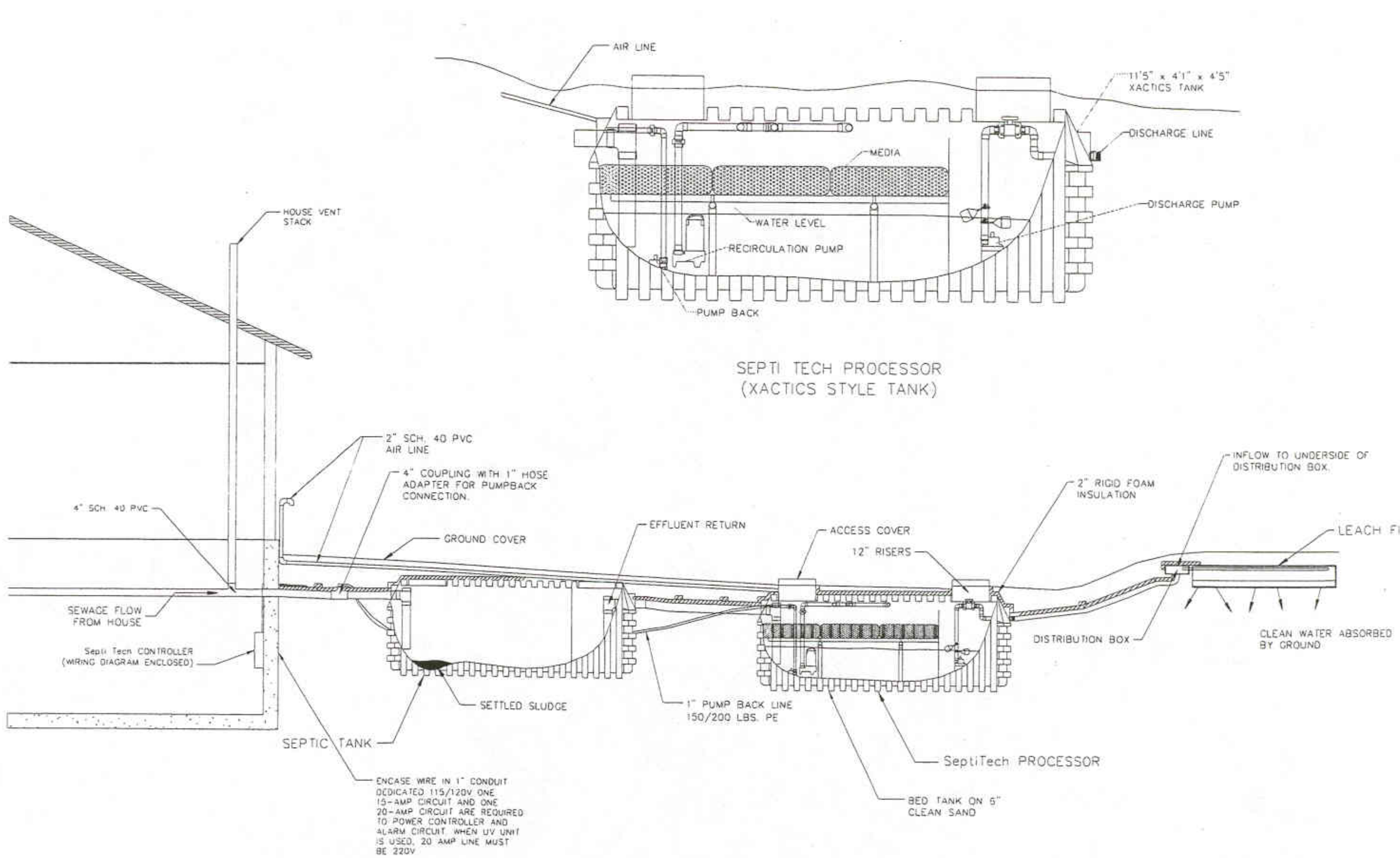
NORWECO SINGULAIR SYSTEM

FIGURE 4-22



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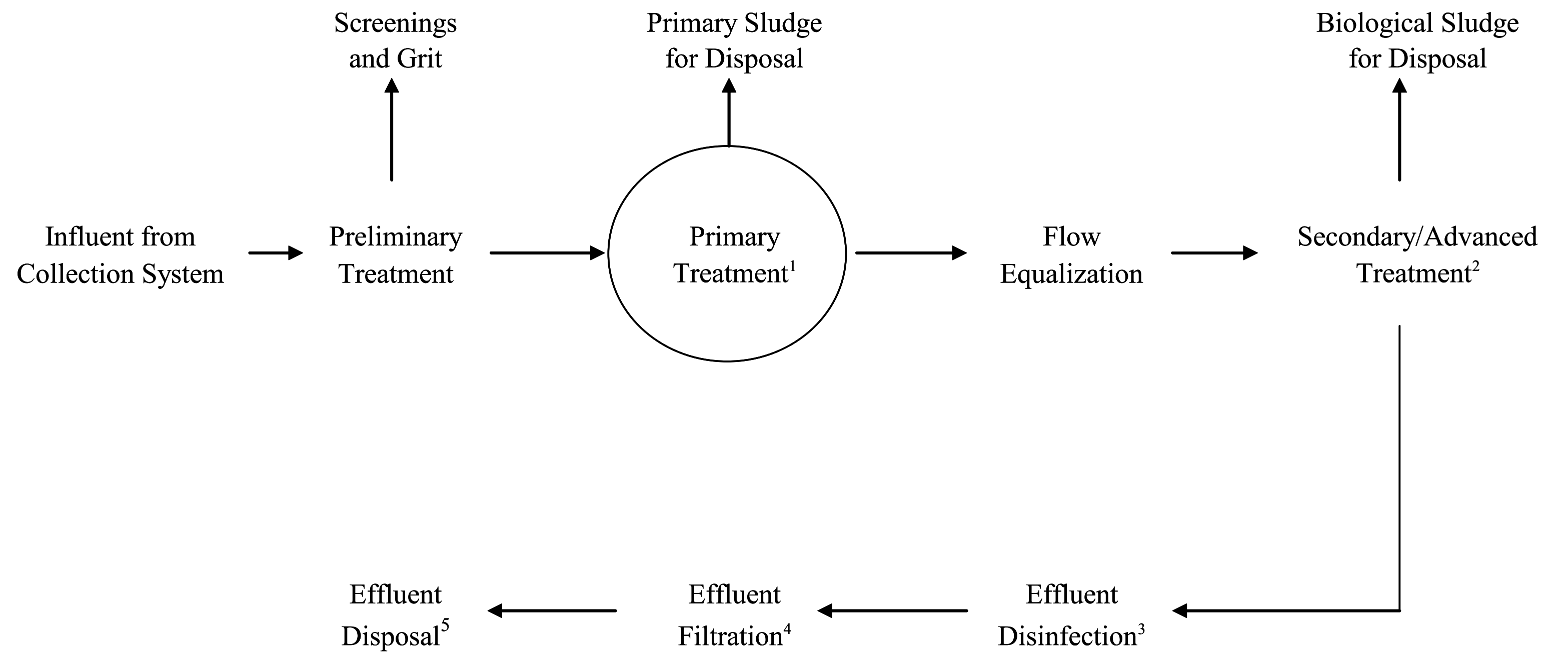
SEPTITECH SYSTEM

FIGURE 4-23



Notes:

1) Primary treatment may not be required for activated sludge or SBR processes.

2) Secondary clarifiers are part of the biological treatment process for the activated sludge and RBC processes.

3) Disinfection is not required if effluent disposal is into sub-surface leaching beds outside of a Zone II.

4) Effluent filtration is already provided in the Amphidrome and Zenon processes, and may not be needed for other processes depending on the effluent discharge method (outside of a Zone II).

5) Facilities with effluent disposal facilities within Zone IIs will have stricter requirements and may require filtration, disinfection, and possibly other treatment processes.

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F5-1_CENTRALIZED.mxd

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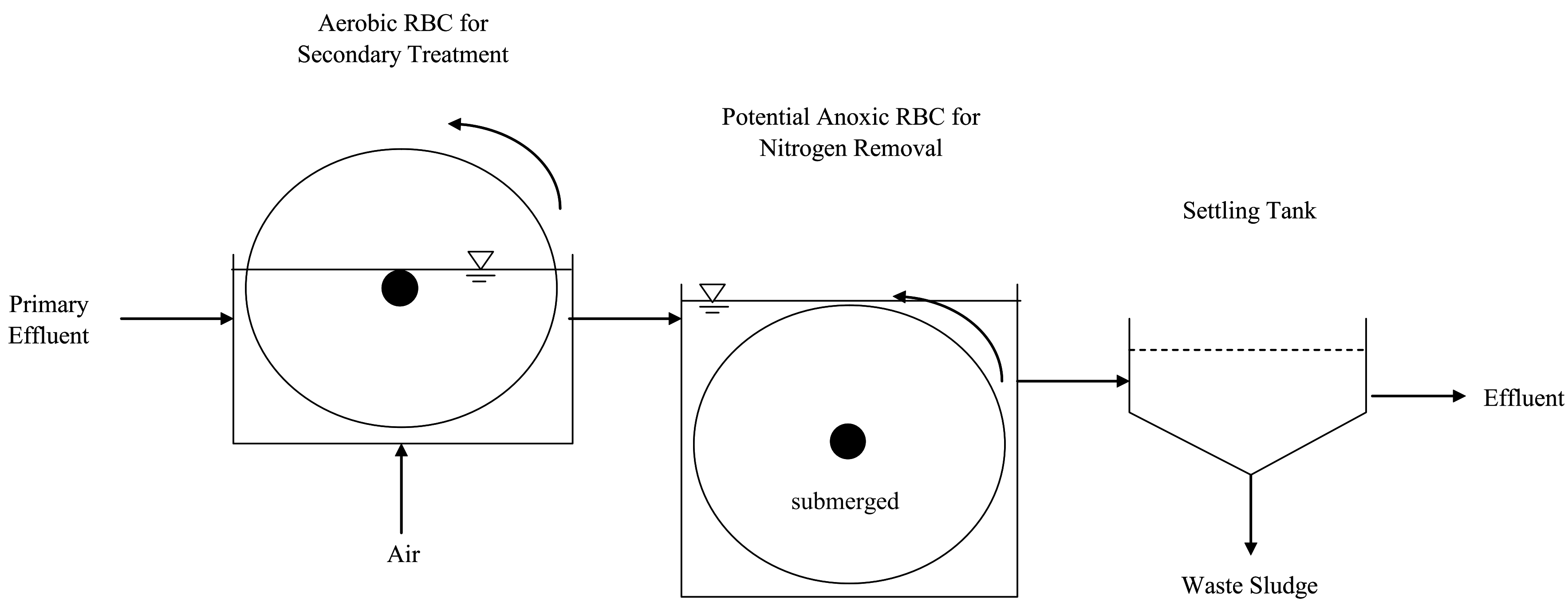
CENTRALIZED TREATMENT SYSTEM COMPONENTS

FIGURE 5-1



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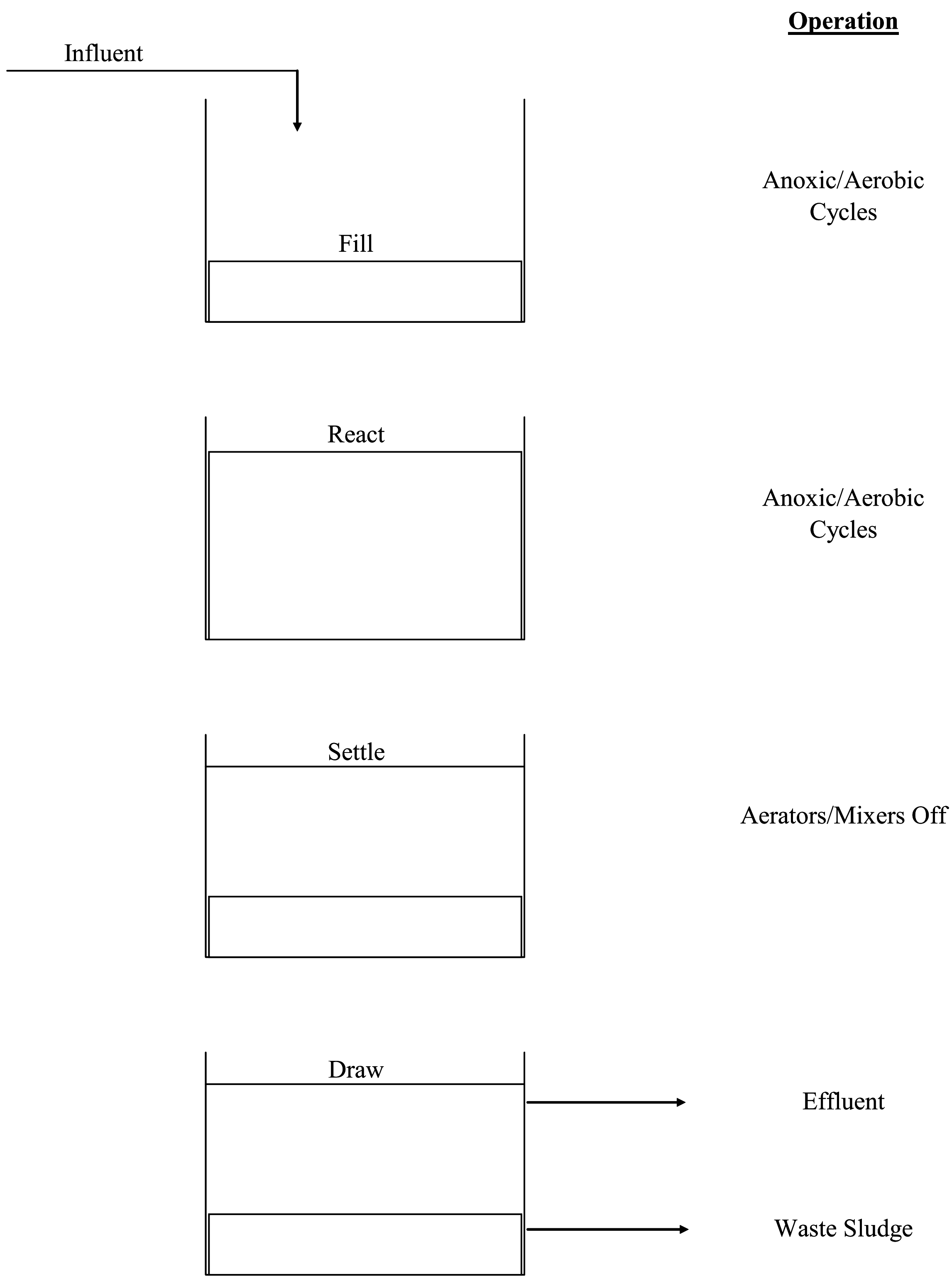
ROTATING BIOLOGICAL CONTACTOR

FIGURE 5-2



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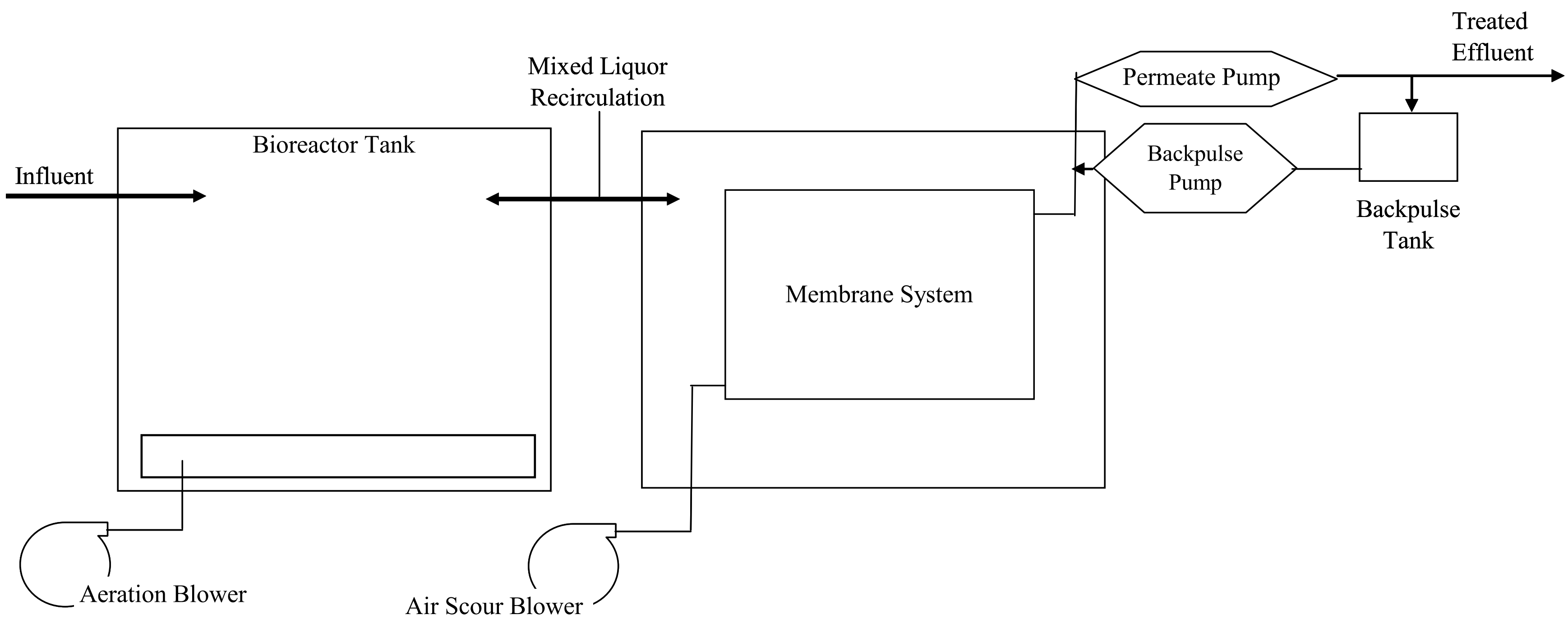
SEQUENCING BATCH REACTOR

FIGURE 5-3



Source: Zenon Environmental, Inc.

Data Source: Mass GIS
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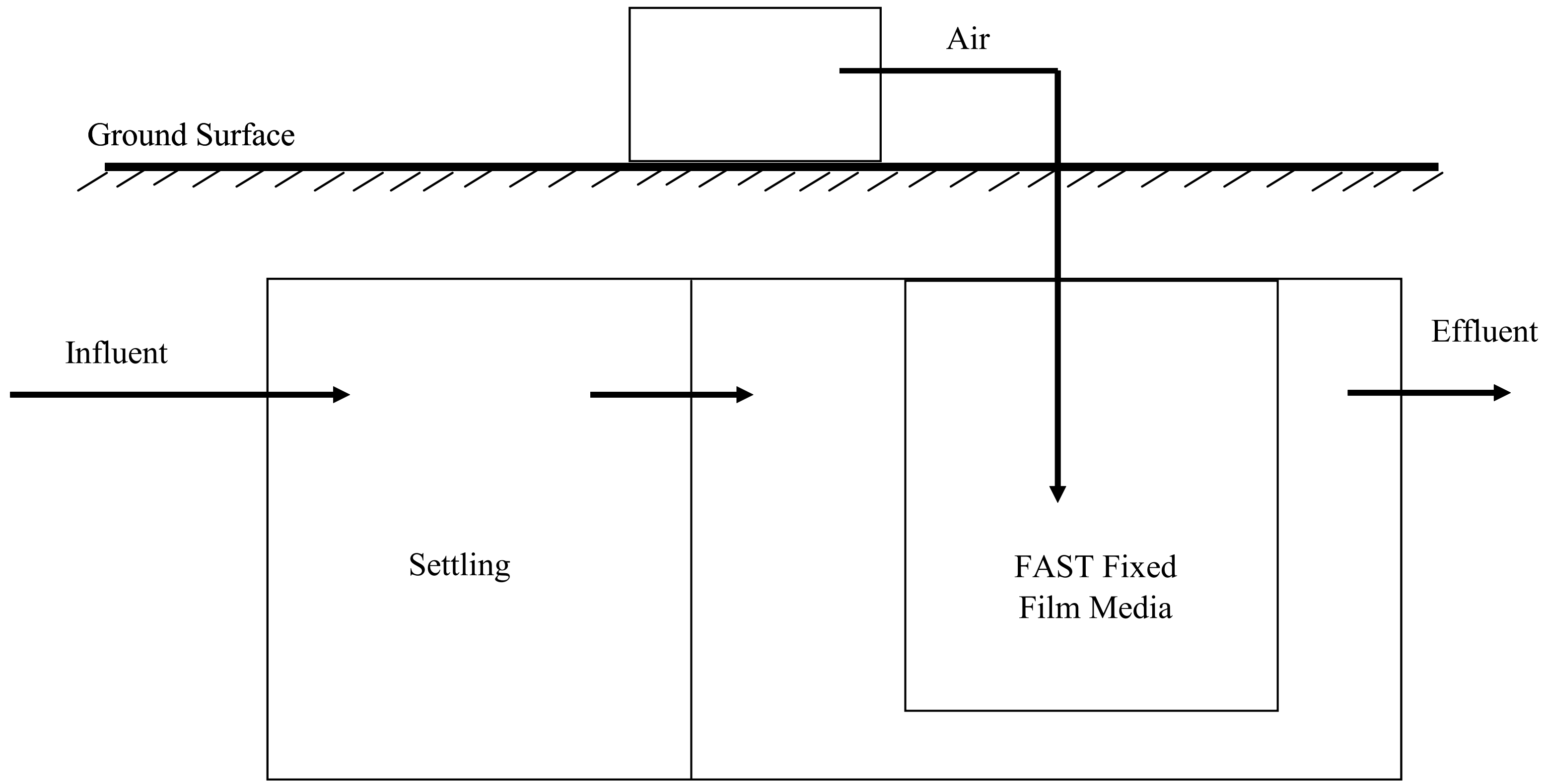
ZENON SYSTEM

FIGURE 5-4



Source: Biomicrobics

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F5-5_MODULAR.mxd

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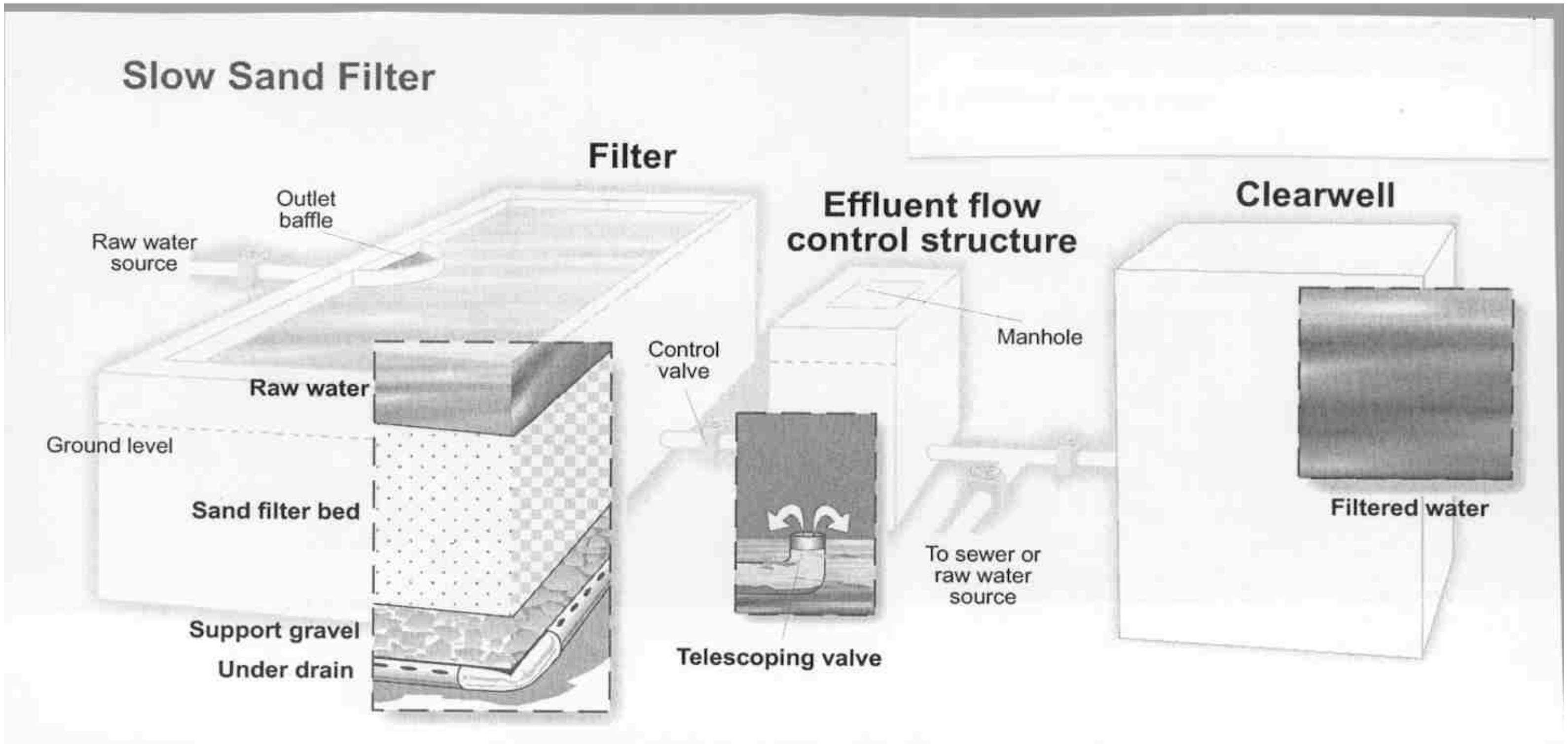
Micro FAST Treatment System

FIGURE 5-5



Source: *Drinking Water News for America's Small Communities*
Summer 1995

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F5-6_SAND.mxd

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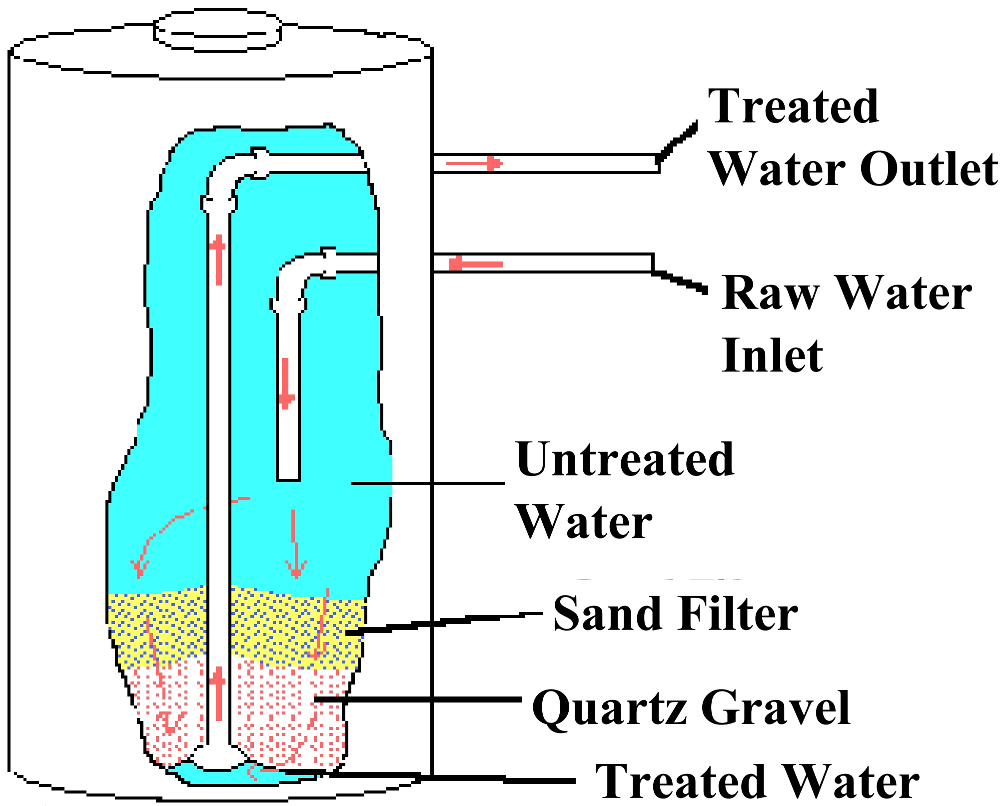
SLOW SAND FILTER

FIGURE 5-6

RAPID SAND FILTER



Source: US EPA

Data Source: Mass GIS
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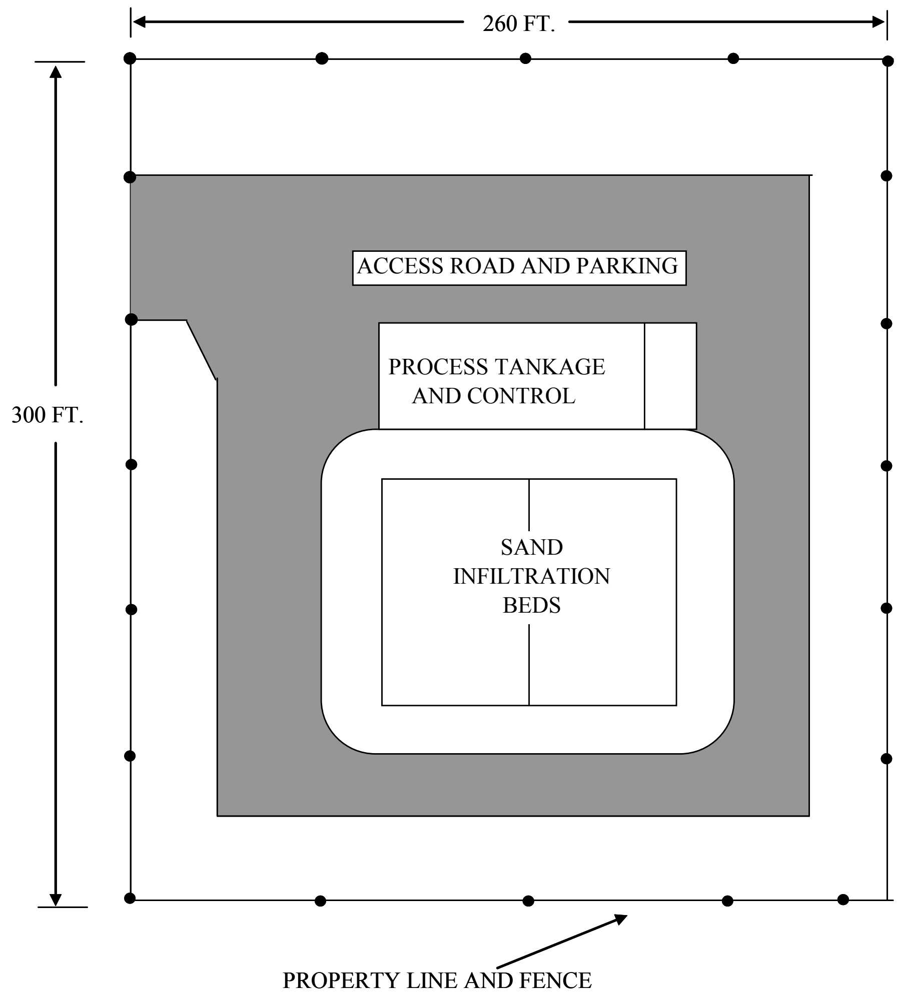
RAPID SAND FILTER

FIGURE 5-7



Note:
1. Total area is approximately 78,000 sq.ft. or 1.8 acres.

Data Source: Mass GIS
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00074F5-8_WWTF.mxd

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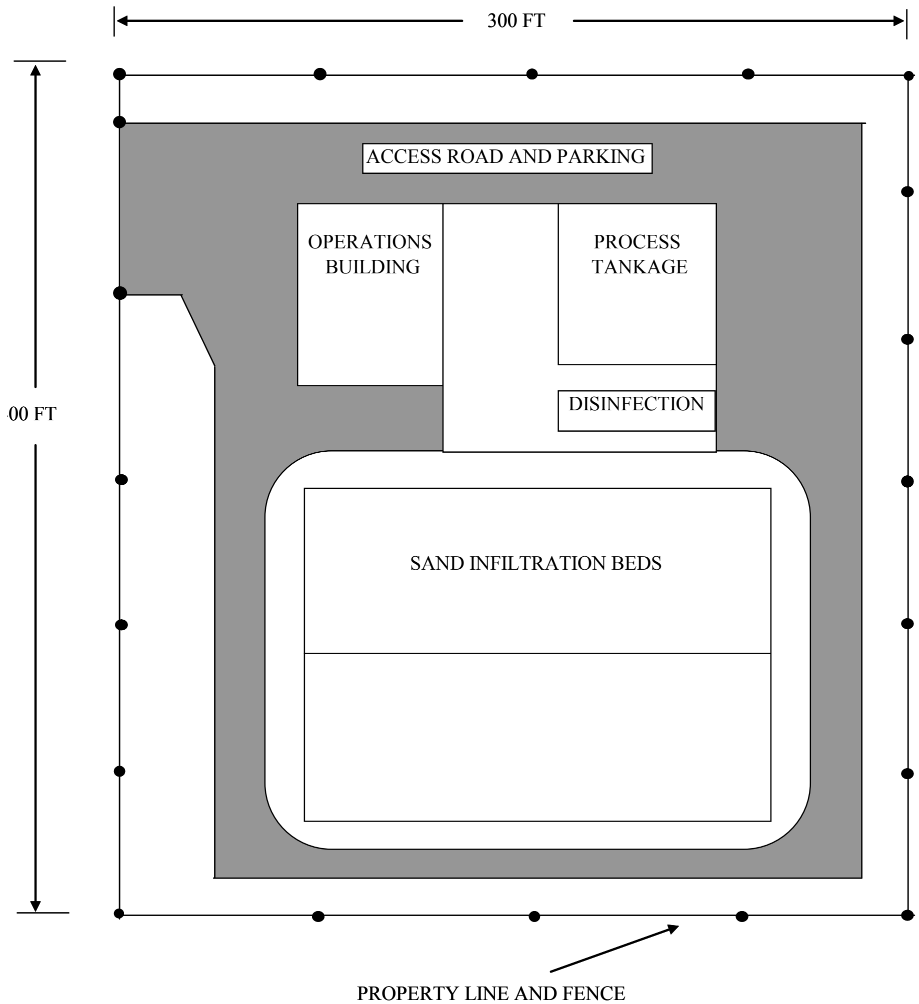
EXAMPLE LAYOUT FOR 10,000 GPD SMALL SEWAGE TREATMENT FACILITY

FIGURE 5-8



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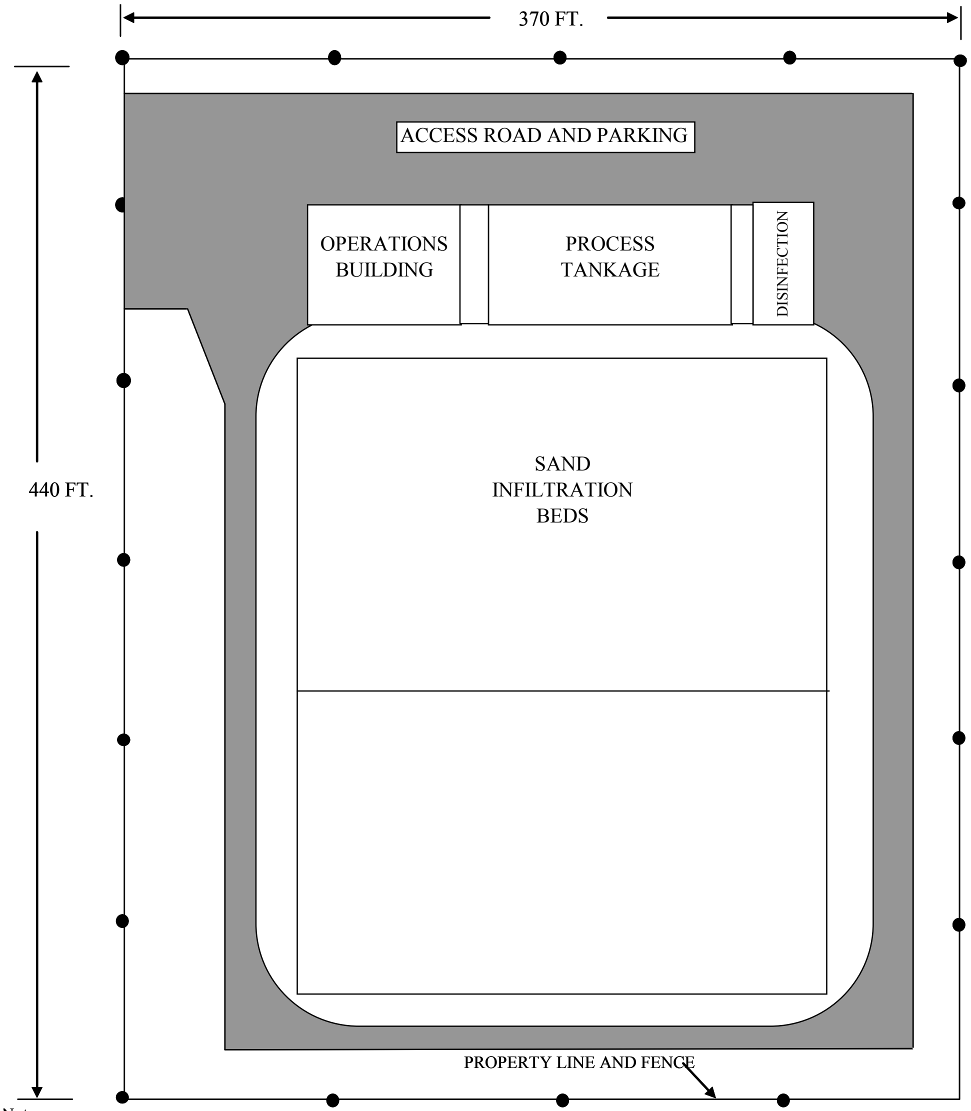
EXAMPLE LAYOUT FOR 35,000 GPD SMALL SEWAGE TREATMENT FACILITY

FIGURE 5-9



Note:

1. Total area is approximately 163,000 sq.ft. or 3.7 acres.

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EXAMPLE LAYOUT FOR 110,000 GPD SMALL SEWAGE TREATMENT FACILITY

FIGURE 5-10

Data Source: Mass GIS
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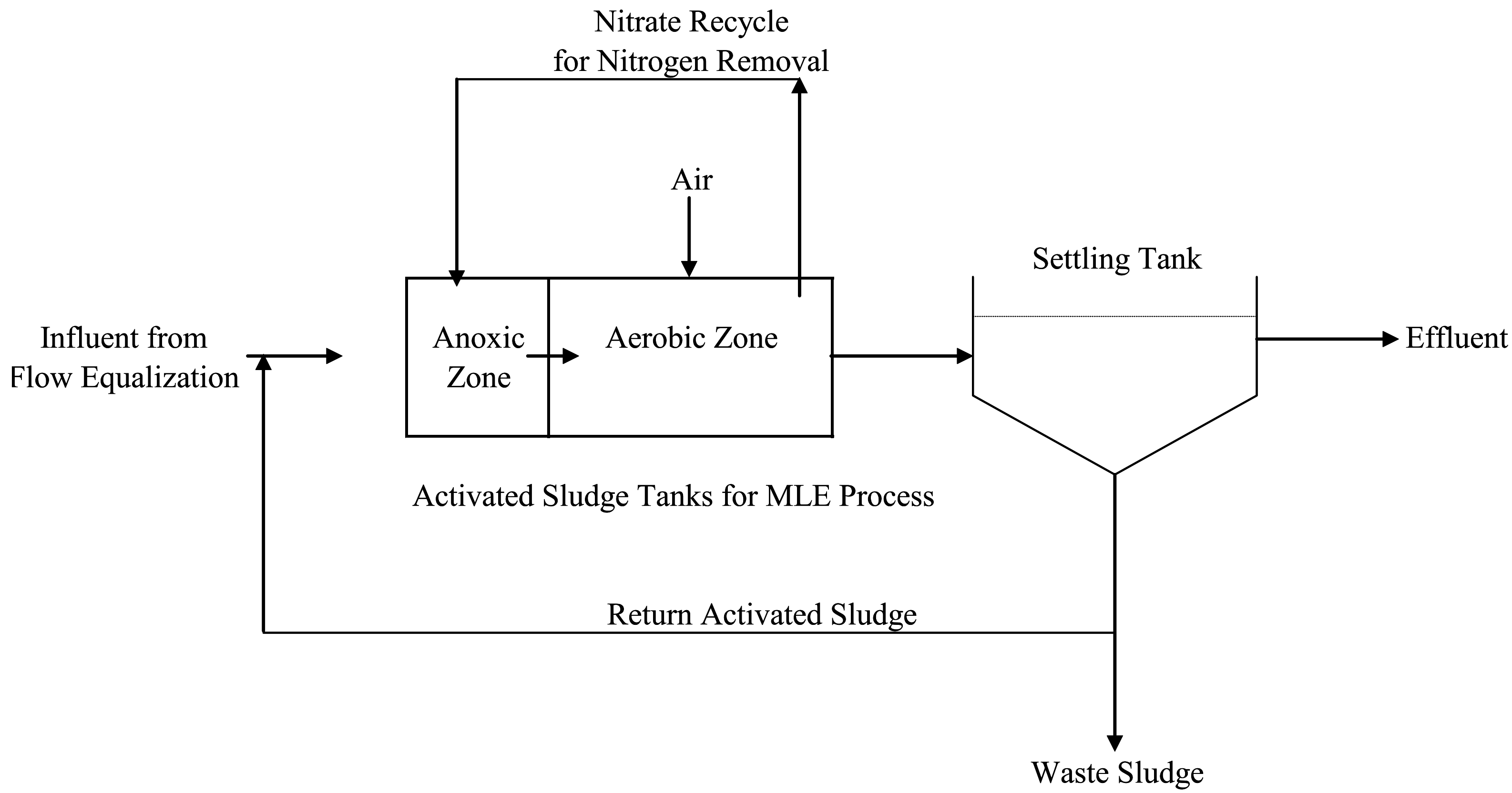

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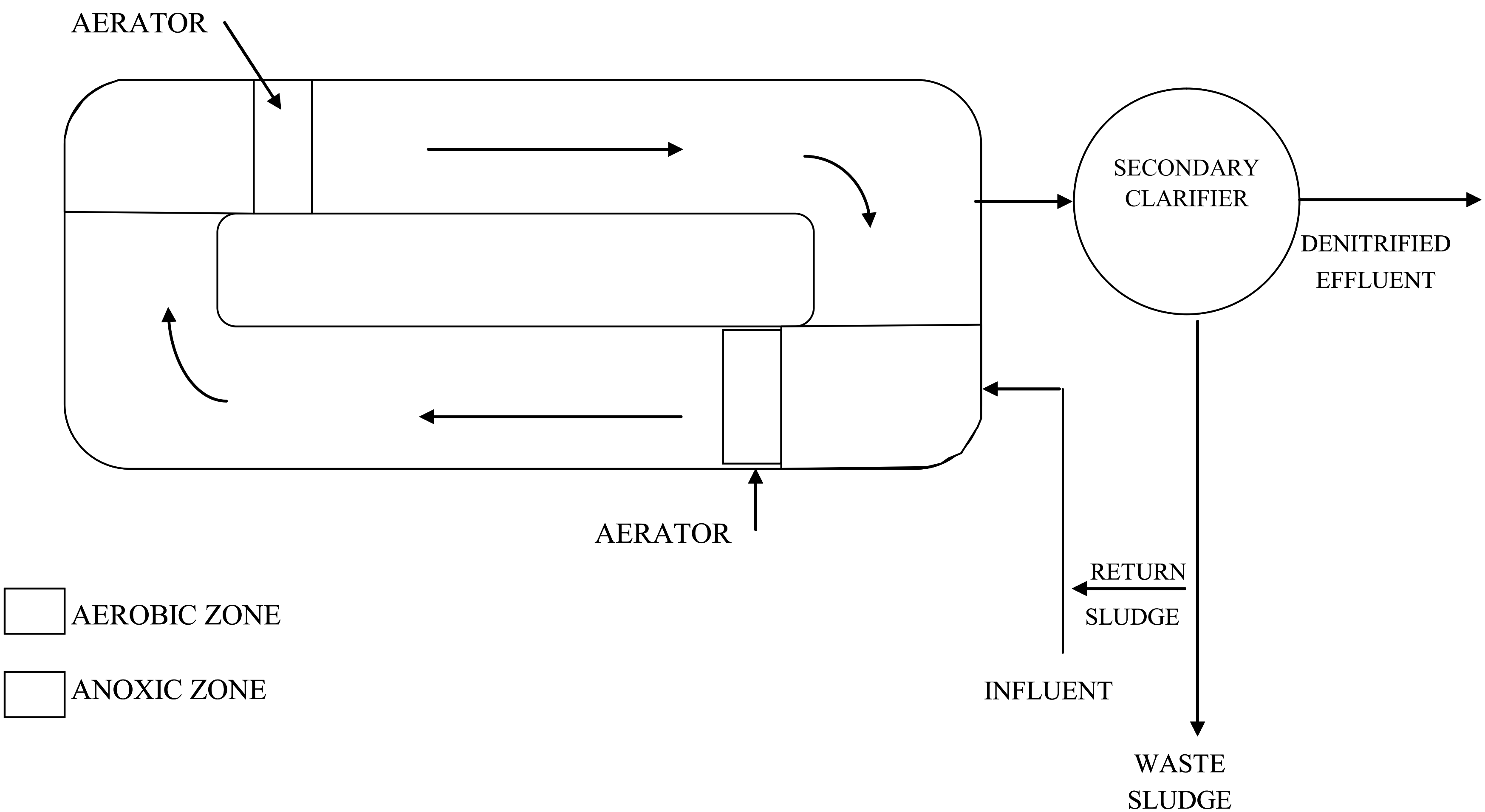
ACTIVATED SLUDGE / MLE PROCESS

FIGURE 5-11



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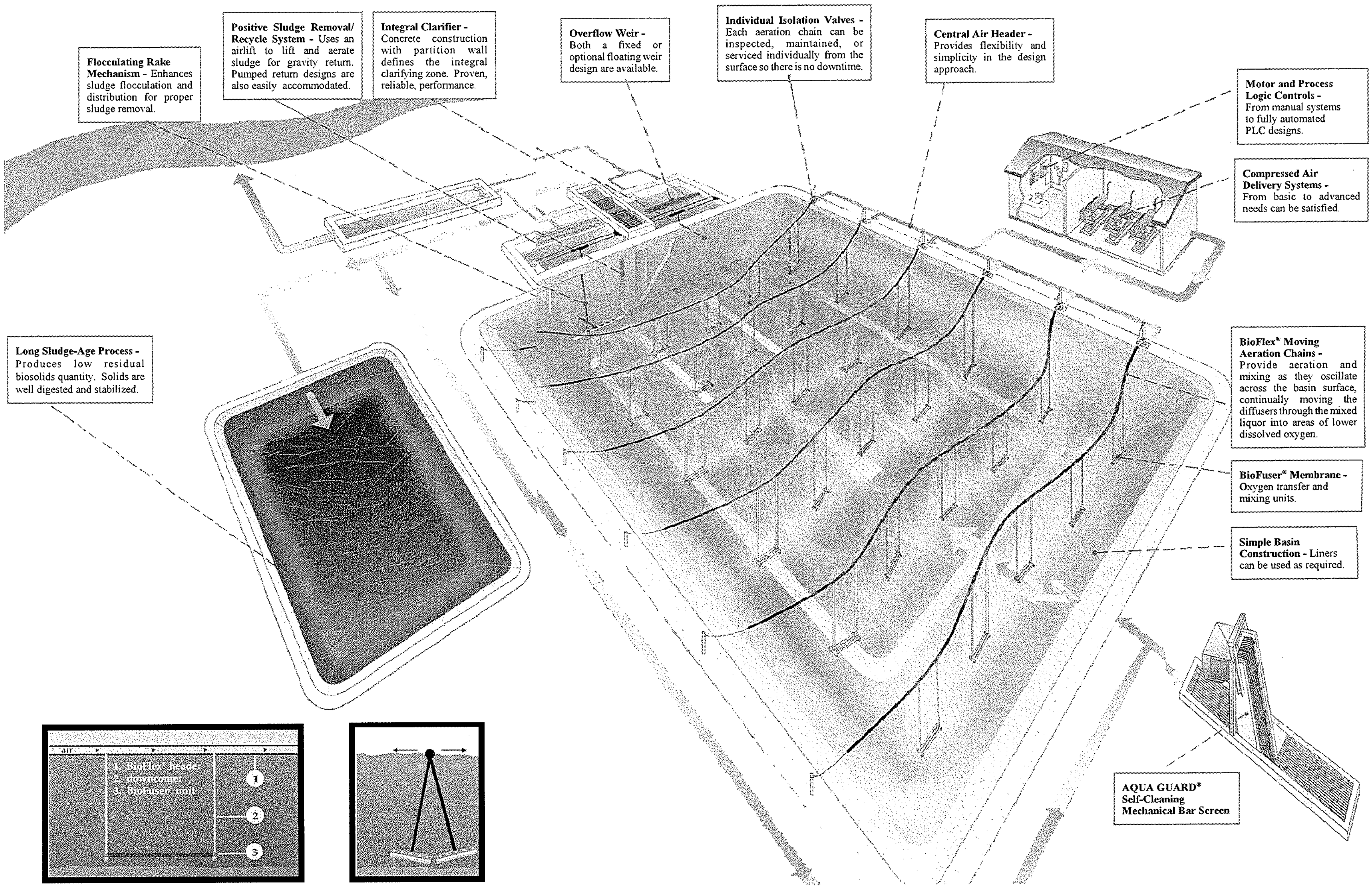
OXIDATION DITCH FOR NITROGEN REMOVAL

FIGURE 5-12



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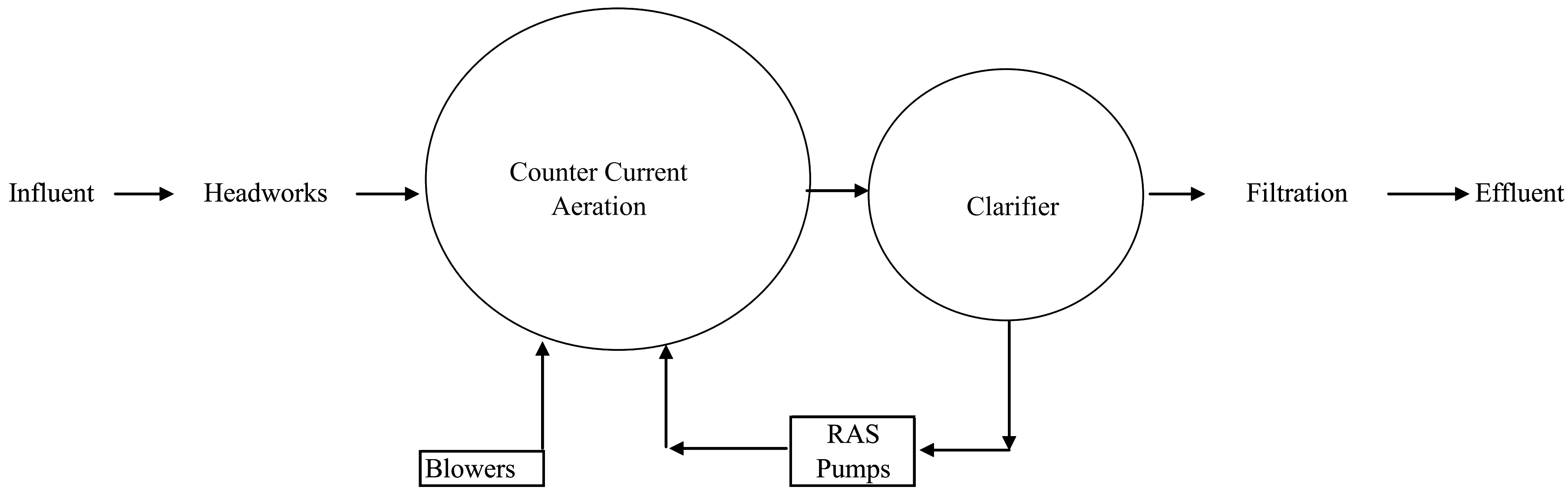
BIOLAC LAGOON

FIGURE 5-13



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SCHREIBER

FIGURE 5-14

Data Source: Mass GIS
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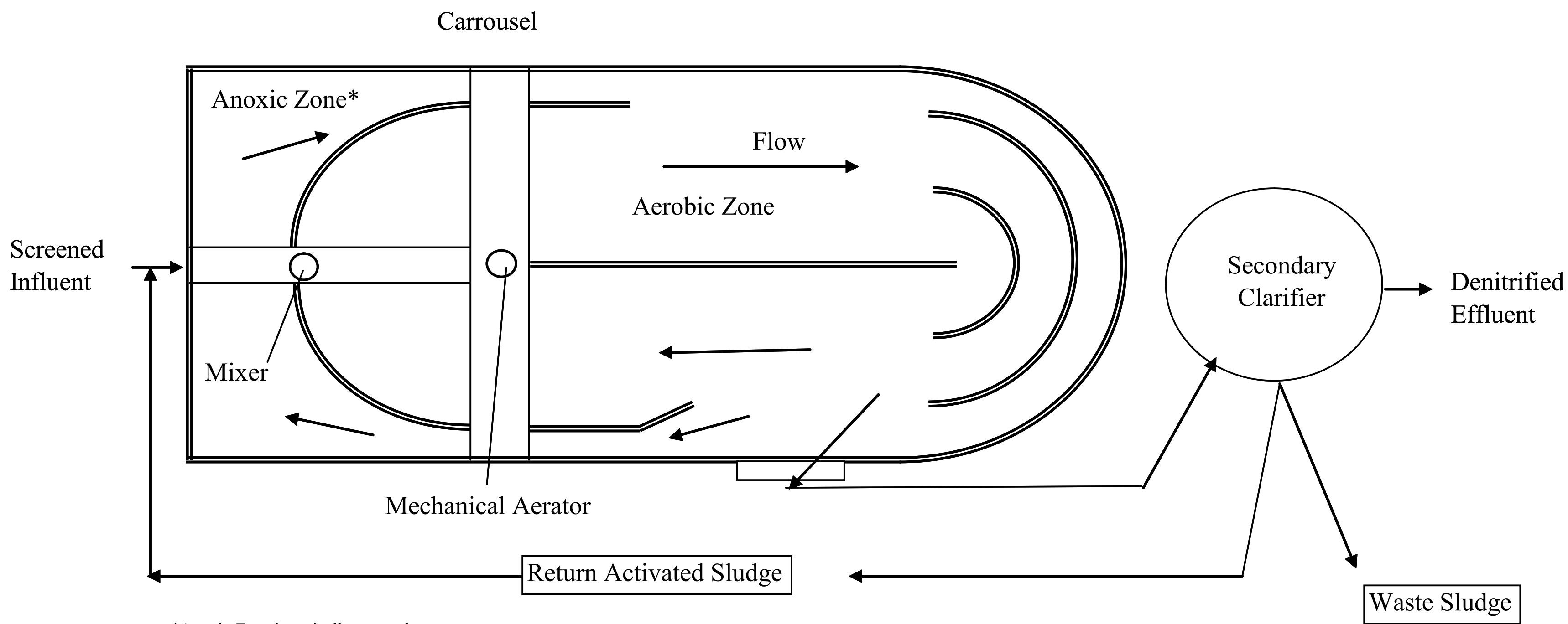

*Anoxic Zone is typically covered

Source: Eimco Water Technologies

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F5-15.mxd

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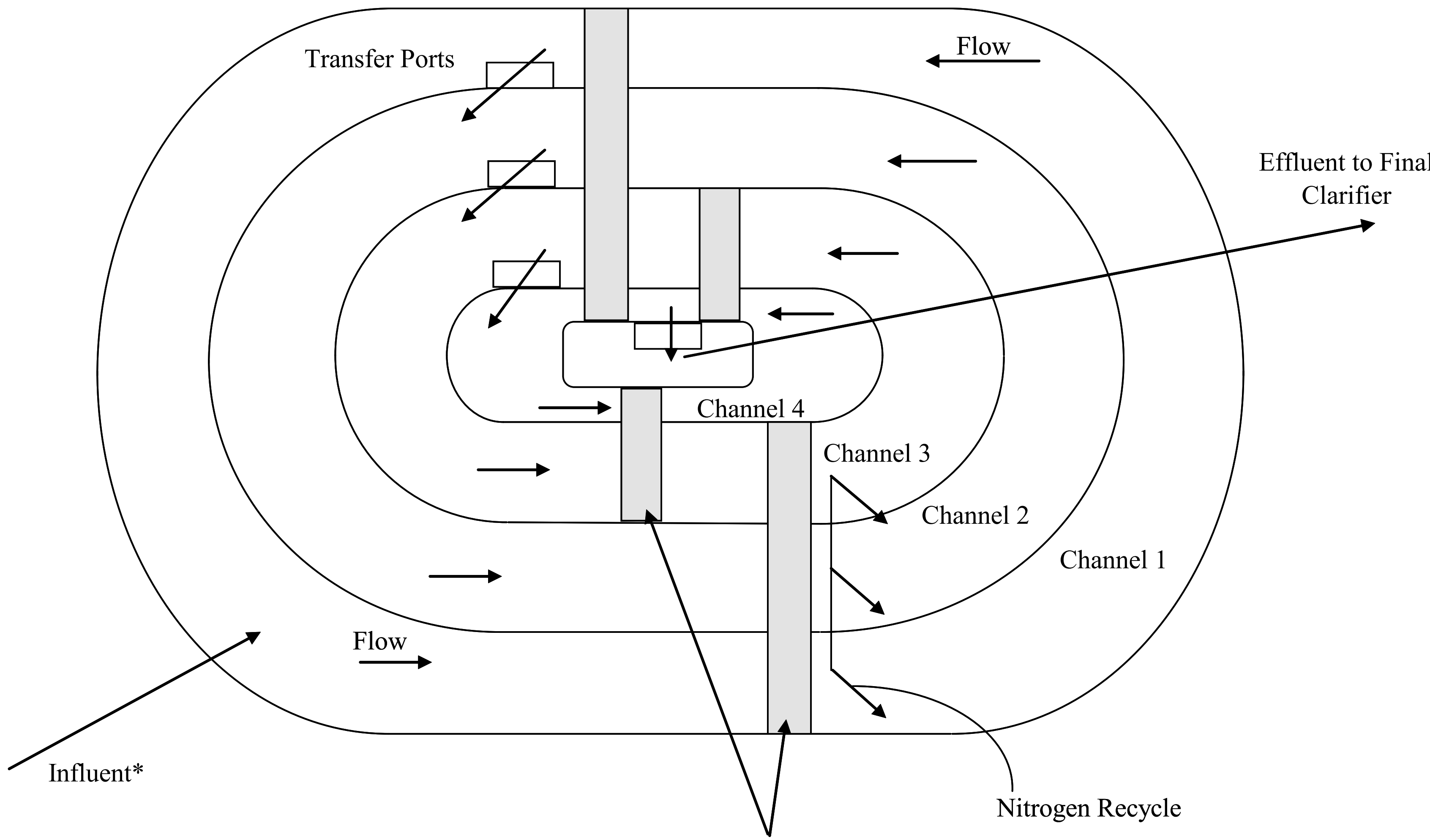
FIGURE 5-15



*Influent can be fed into multiple channels

Source: USFilter

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F5-16_ORBAL.mxd

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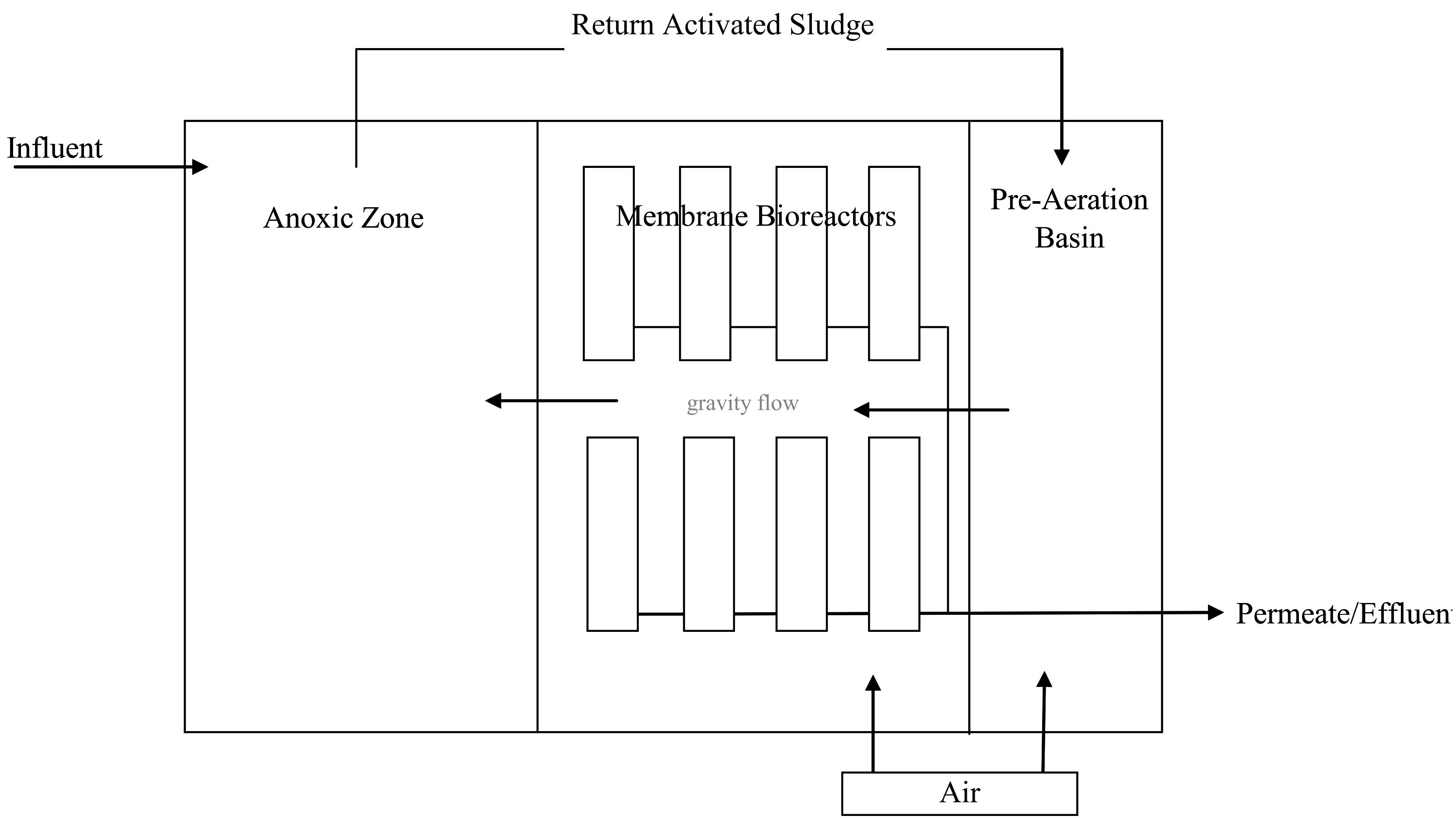
FIGURE 5-16



Source: Enviroquip, Inc.

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F5-17.mxd

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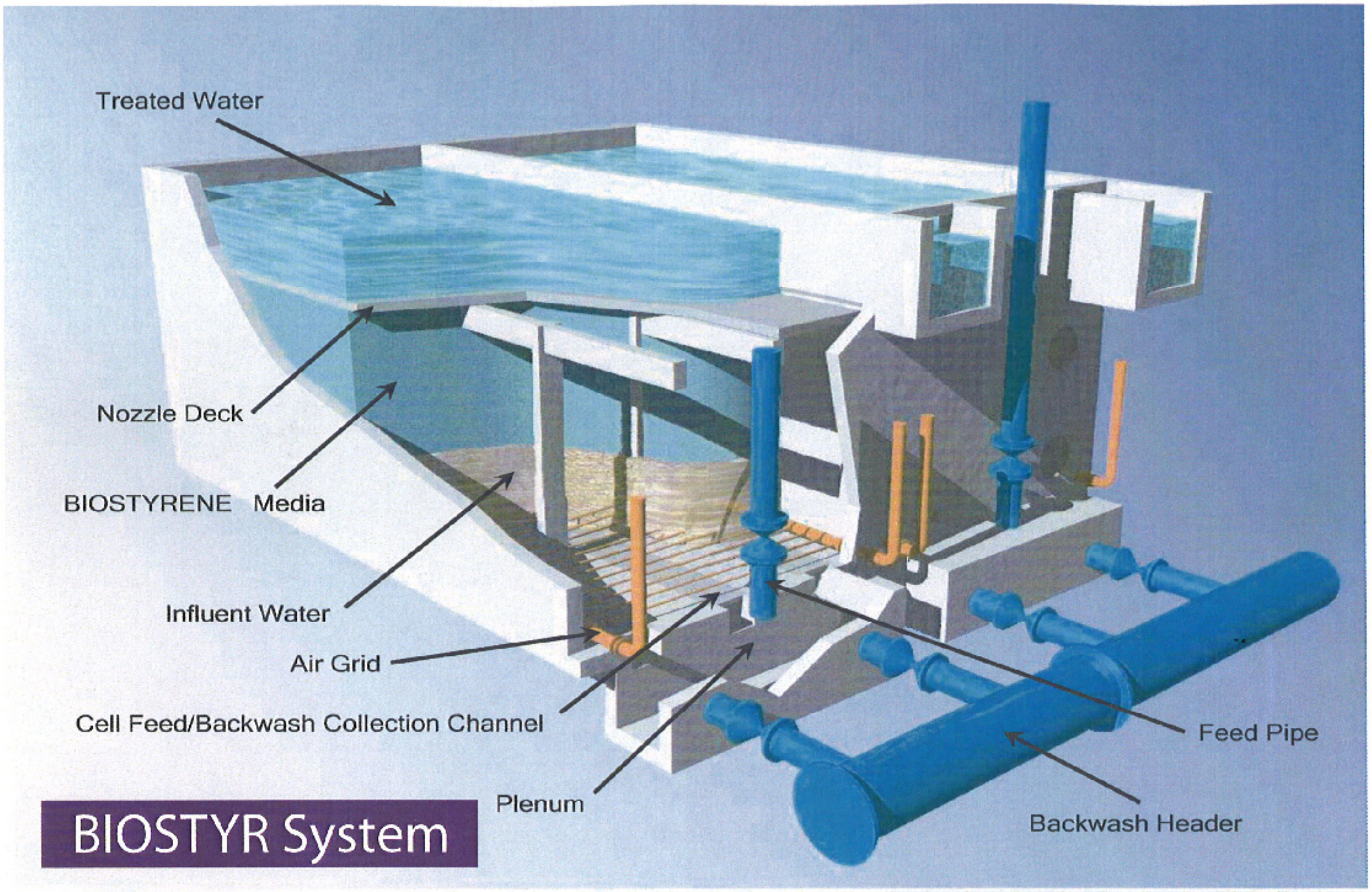
ENVIROQUIP MEMBRANE BIOREACTOR

FIGURE 5-17



FLEXIBLE, COMPACT FOOTPRINT

Source: Kruger, Inc.

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F5-18.mxd

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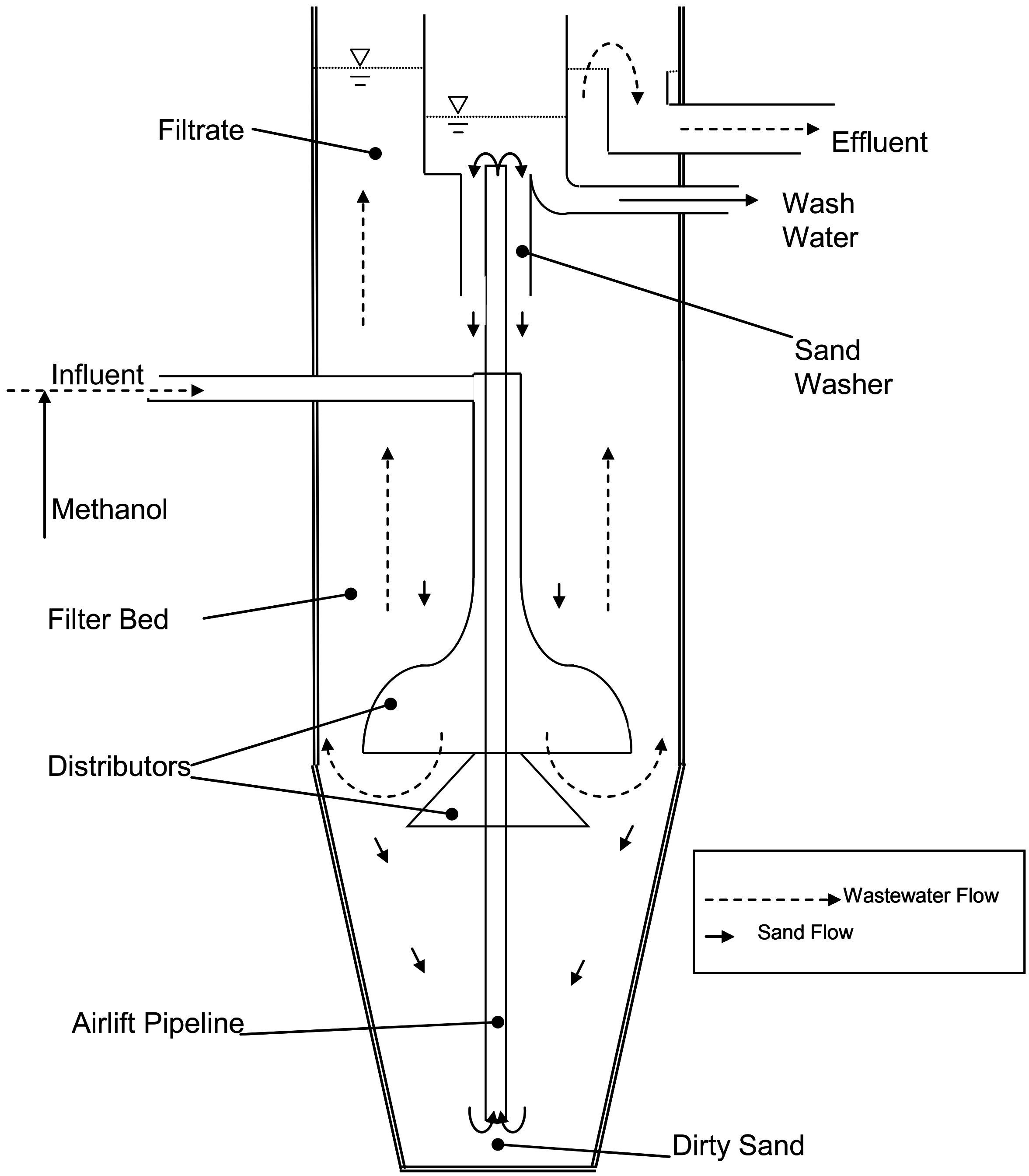
BIOLOGICAL AERATED FILTERS

FIGURE 5-18



Data Source: Mass GIS
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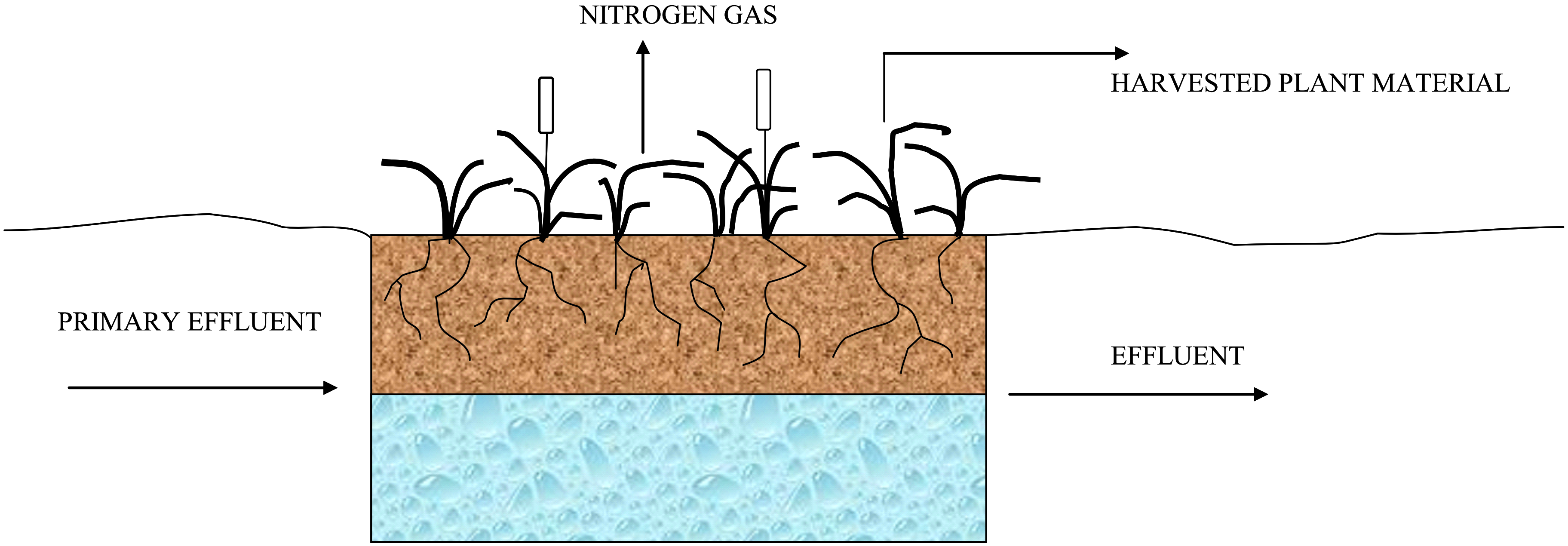
DENITRIFICATION FILTER

FIGURE 5-19



Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F5-20.mxd

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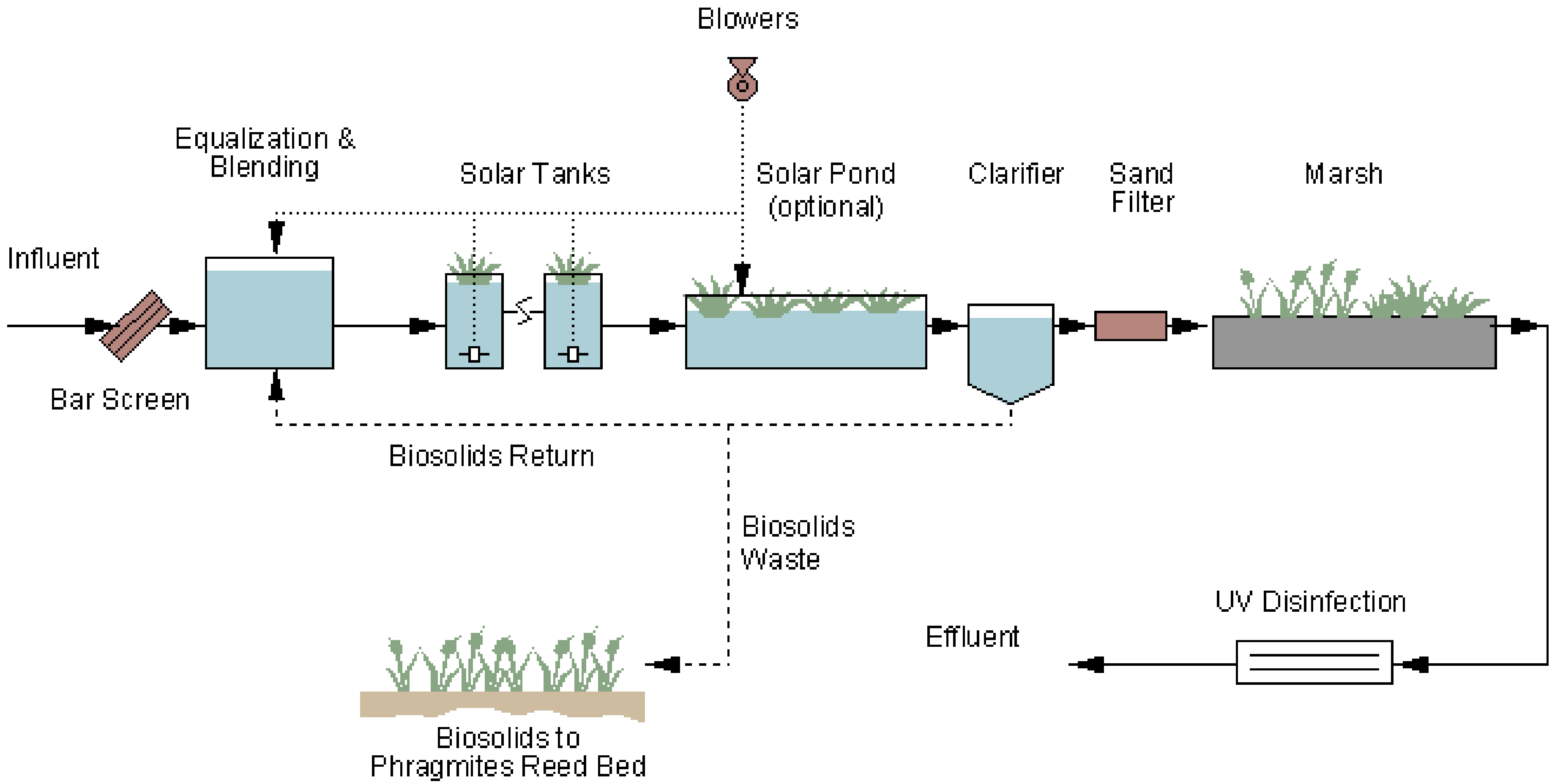
CONSTRUCTED WETLANDS

FIGURE 5-20



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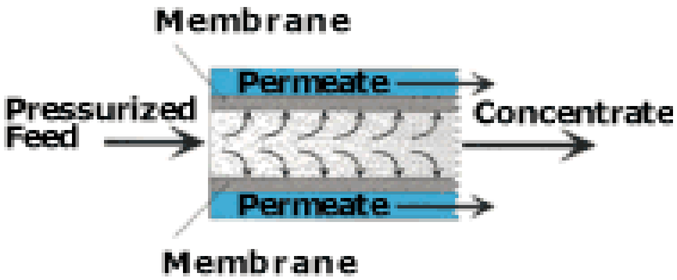
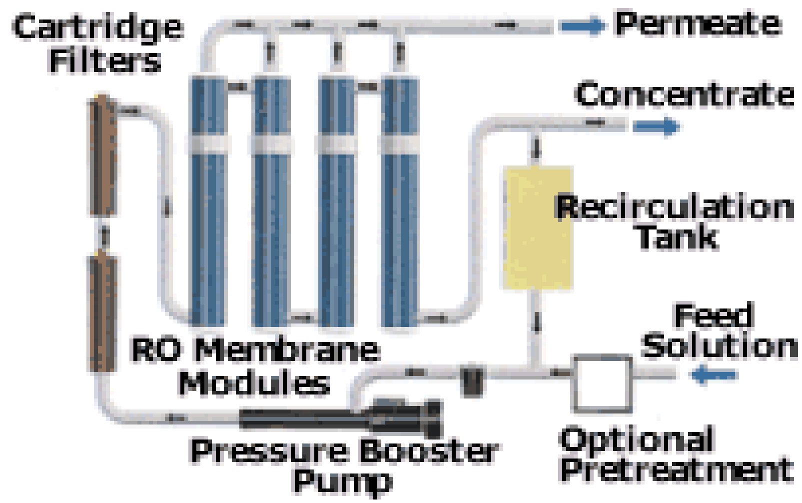
SOLAR AQUATICS SYSTEM

FIGURE 5-21





Source:

http://science.howstuffworks.com/framed.htm?parent=question29.htm

&url=http://www.pfonline.com/articles/089907.html

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F5-22.mxd

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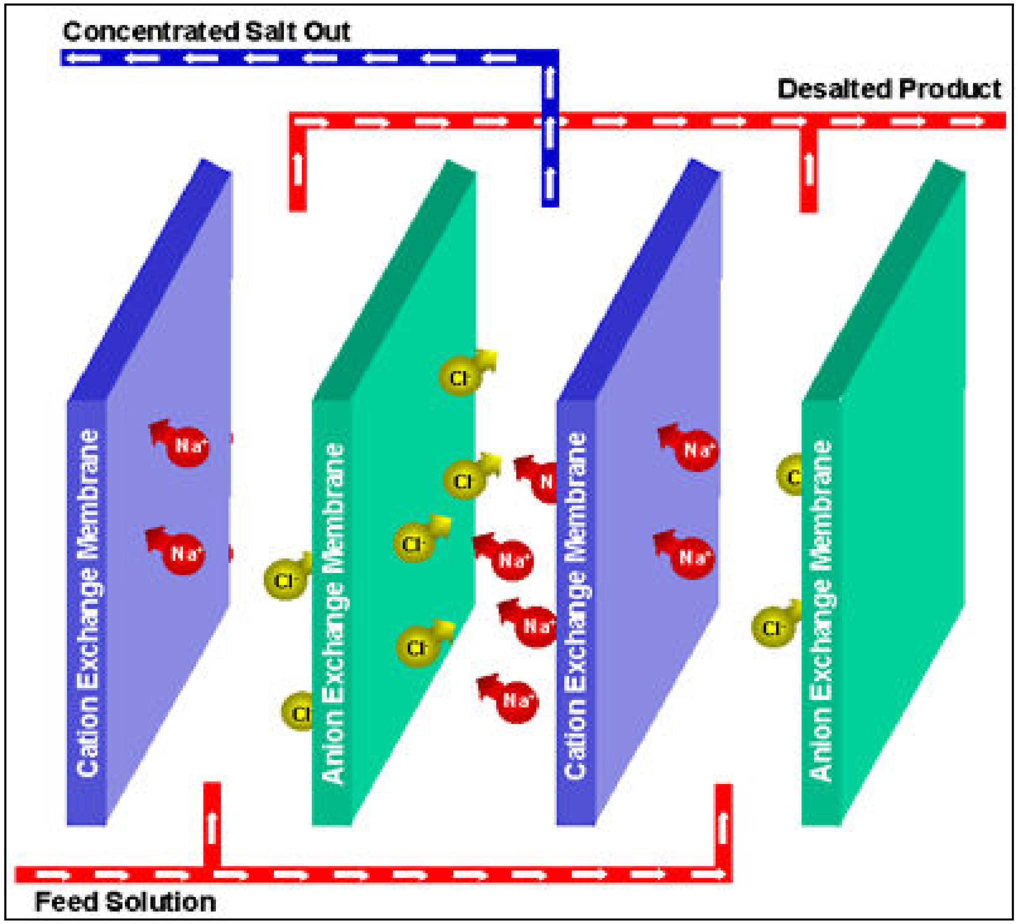
REVERSE OSMOSIS

FIGURE 5-22



Source: Electrosynthesis Company Incorporated

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F5-23.mxd

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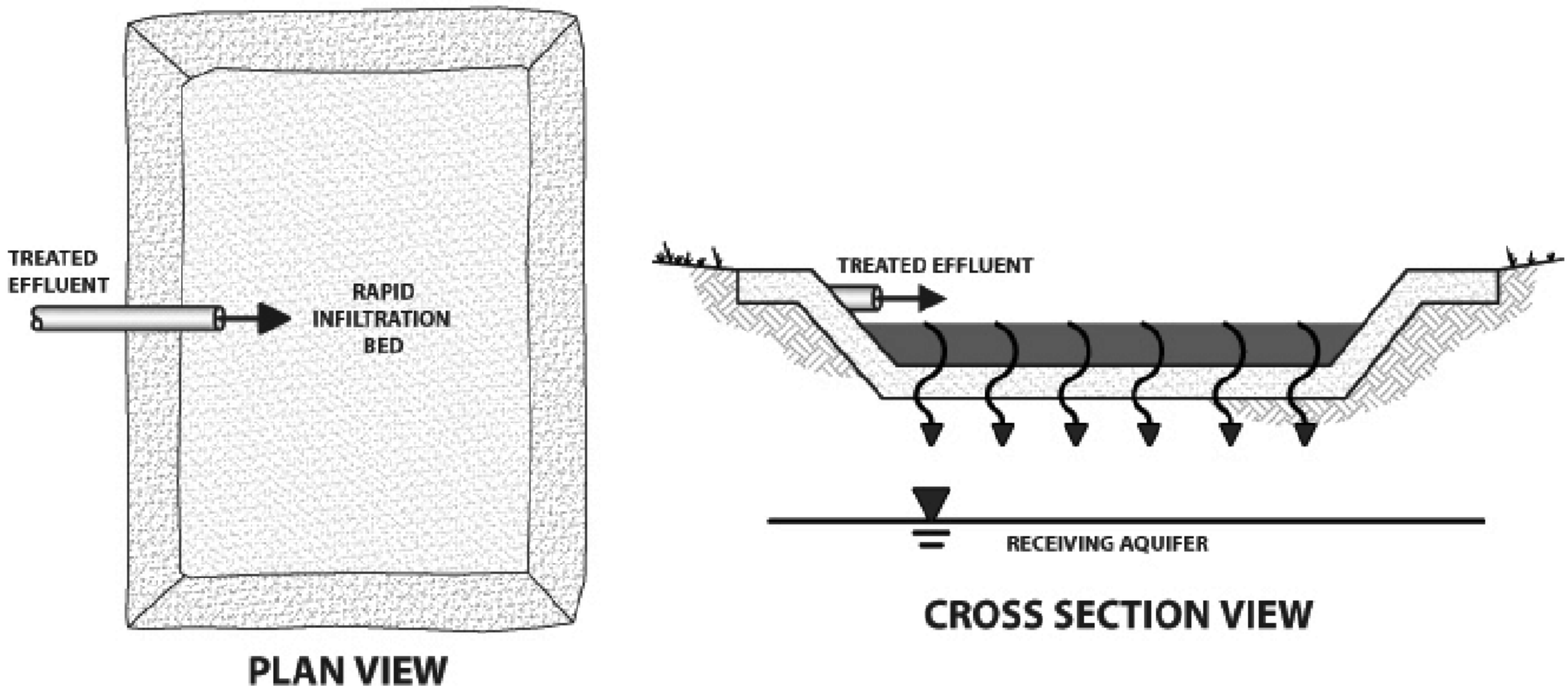
ELECTRODIALYSIS

FIGURE 5-23

RAPID INFILTRATION BED (RIBs)



Data Source: Mass GIS
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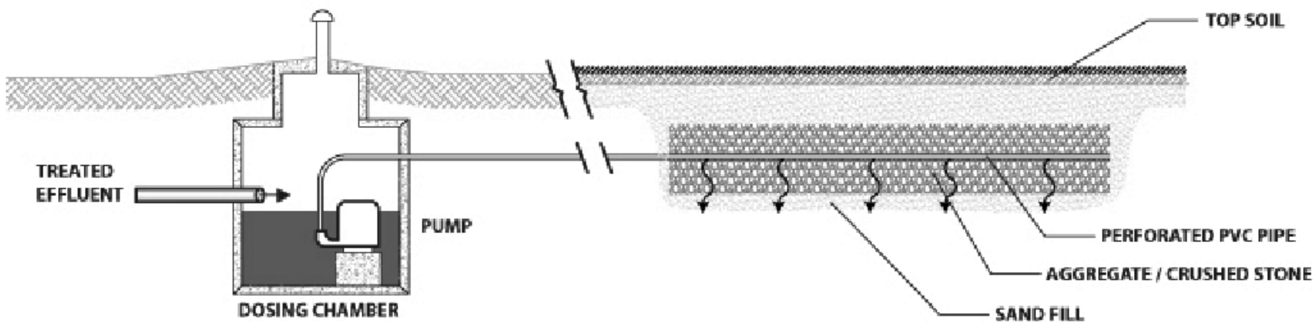
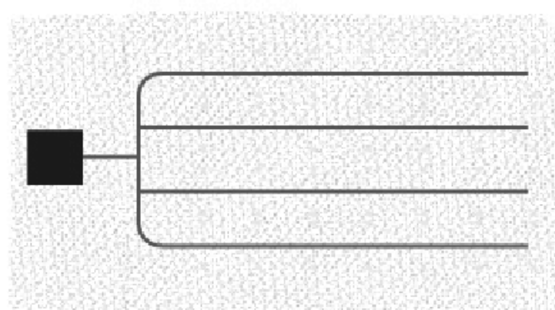
RAPID INFILTRATION BED

FIGURE 6-1

SUBSURFACE INFILTRATION (PRESSURE DOSING)

CROSS SECTION VIEW





PLAN VIEW

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\
00074 Mashpee\2006 WWFP\Report Figures
\Technology Screening Report\
00074F6-2.mxd

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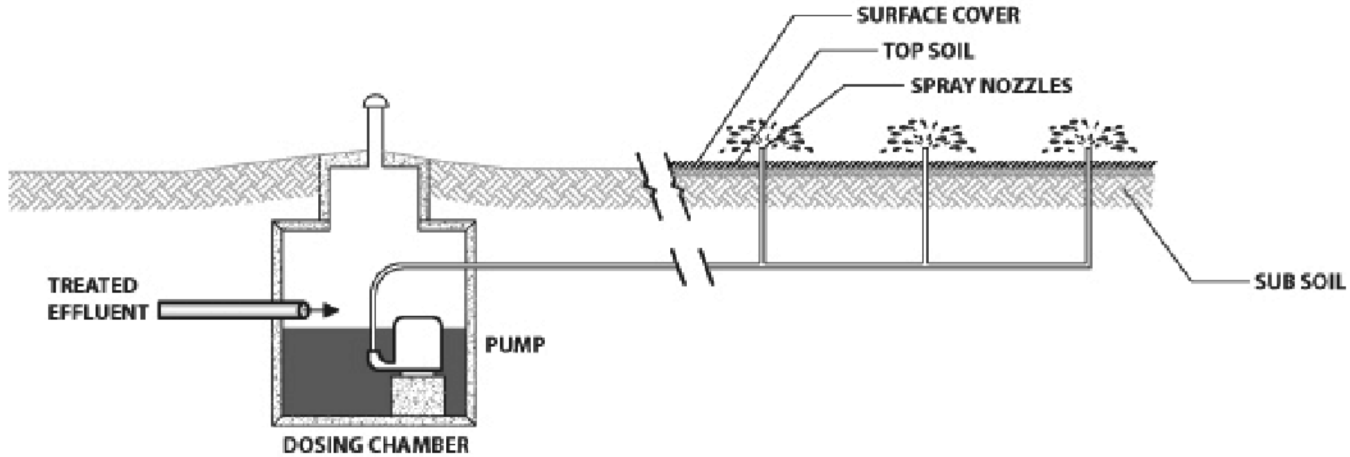
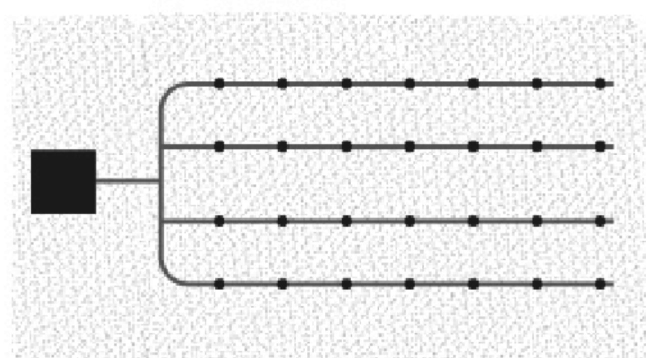
SUBSURFACE INFILTRATION

FIGURE 6-2

SPRAY IRRIGATION

CROSS SECTION VIEW





PLAN VIEW

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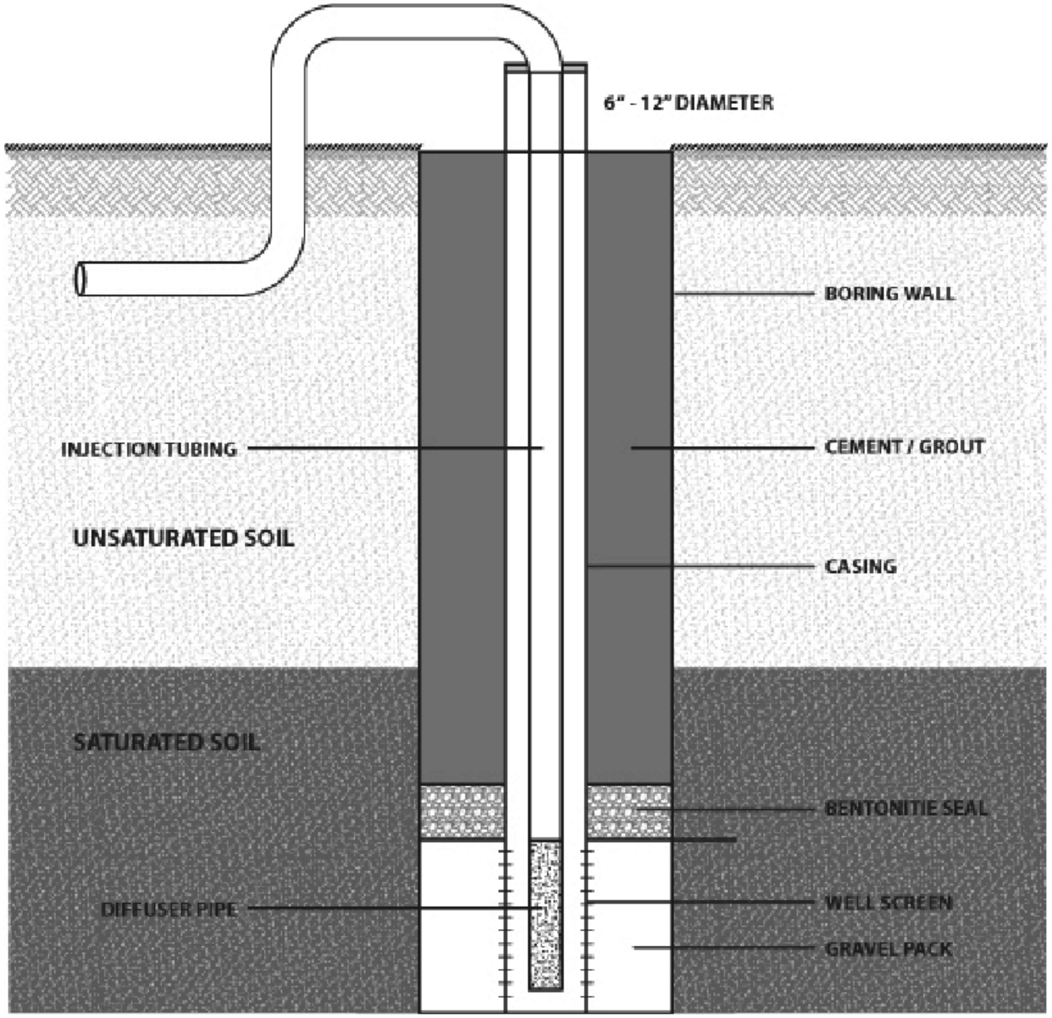
SPRAY IRRIGATION
FIGURE 6-3

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F6-3.mxd

INJECTION WELL



Data Source: Mass GIS
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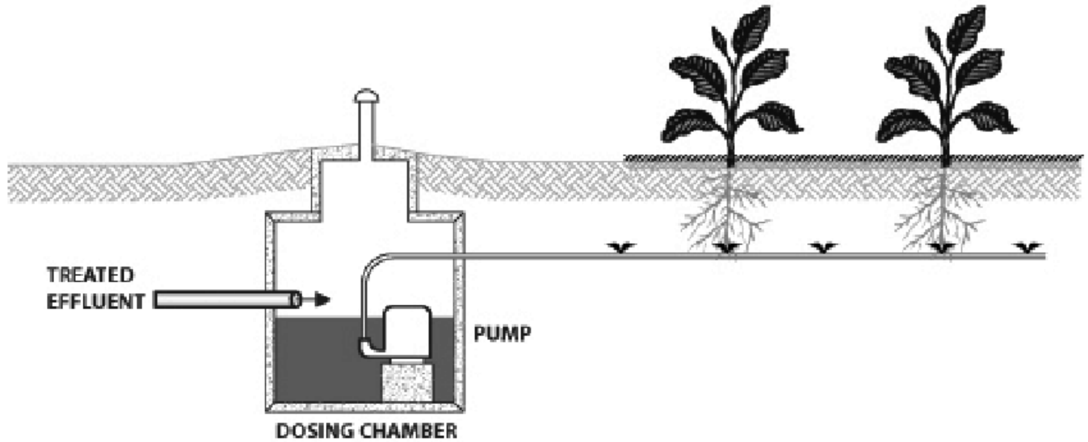
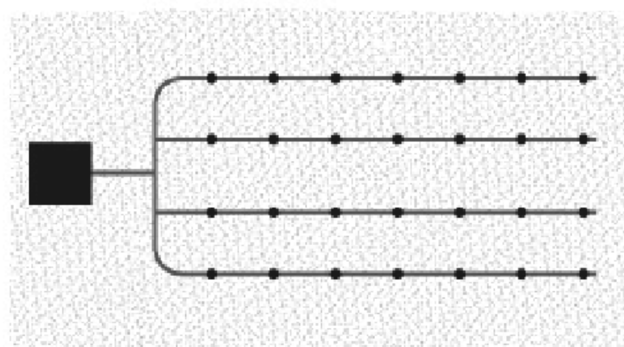
INJECTION WELL

FIGURE 6-4

DRIP SYSTEM

CROSS SECTION VIEW





PLAN VIEW

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F6-5

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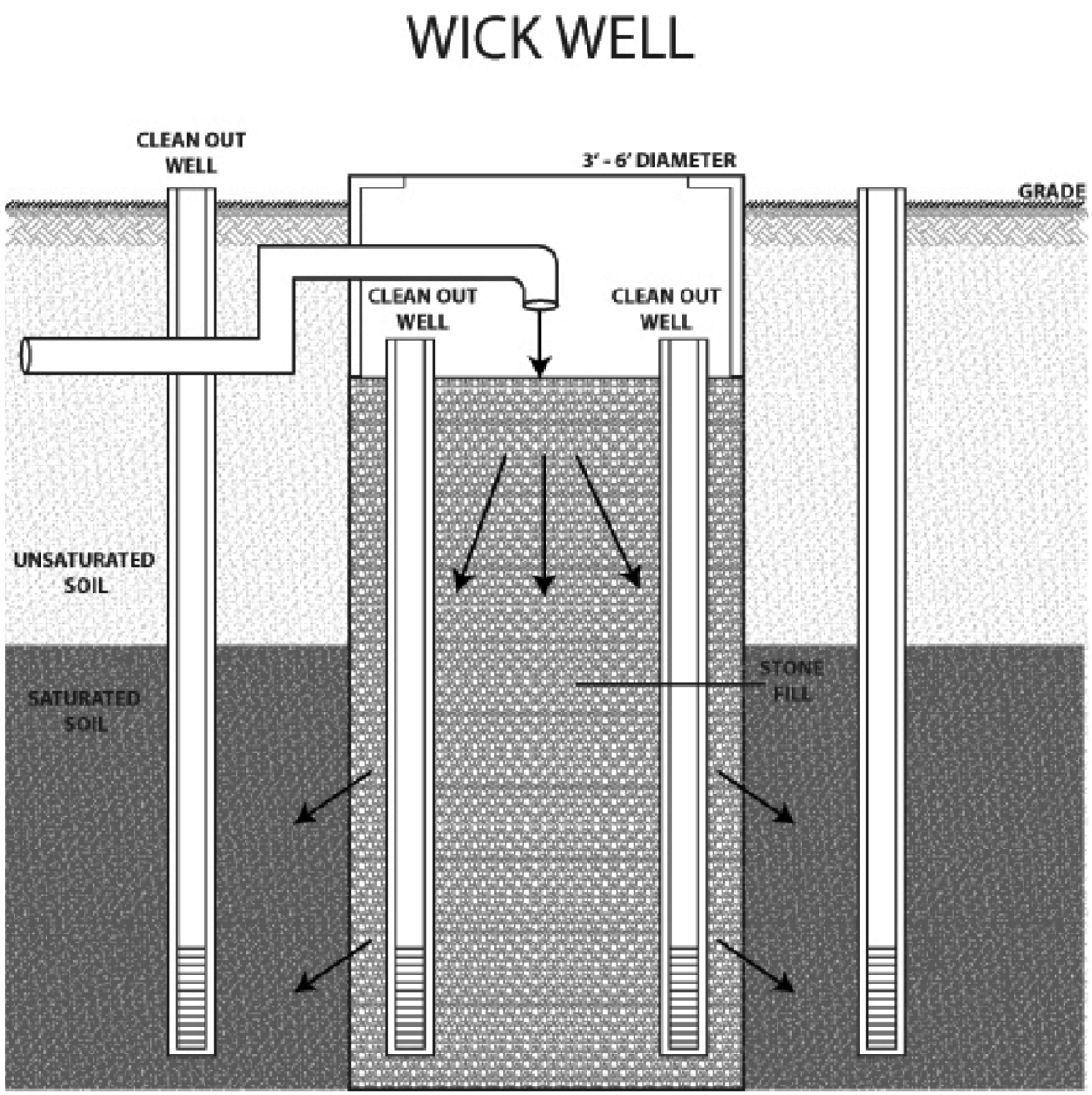
DRIP SYSTEM

FIGURE 6-5



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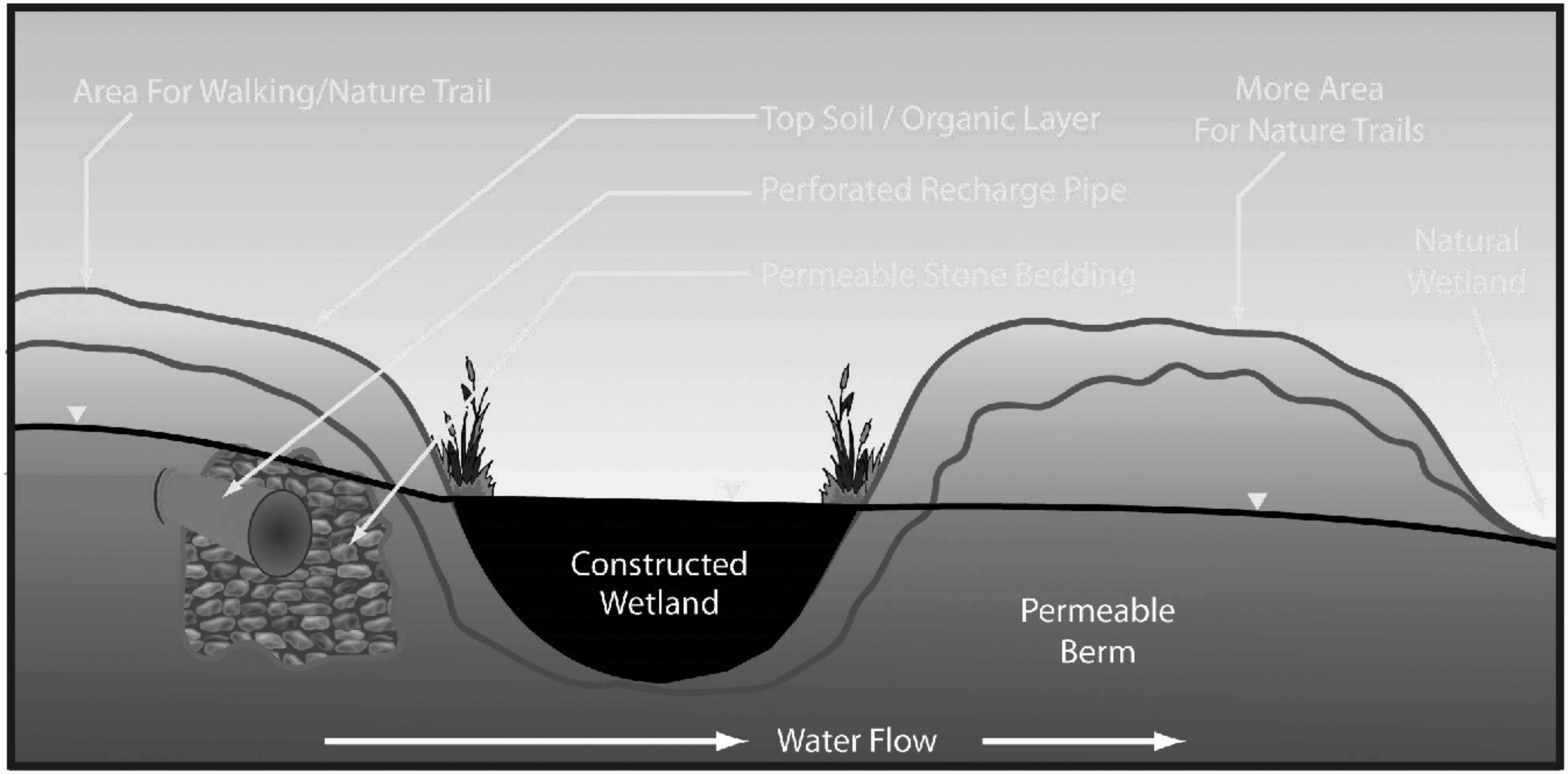
WICK WELL

FIGURE 6-6

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F6-6



Data Source: Mass GIS
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00074F6-7 WETLANDS.mxd

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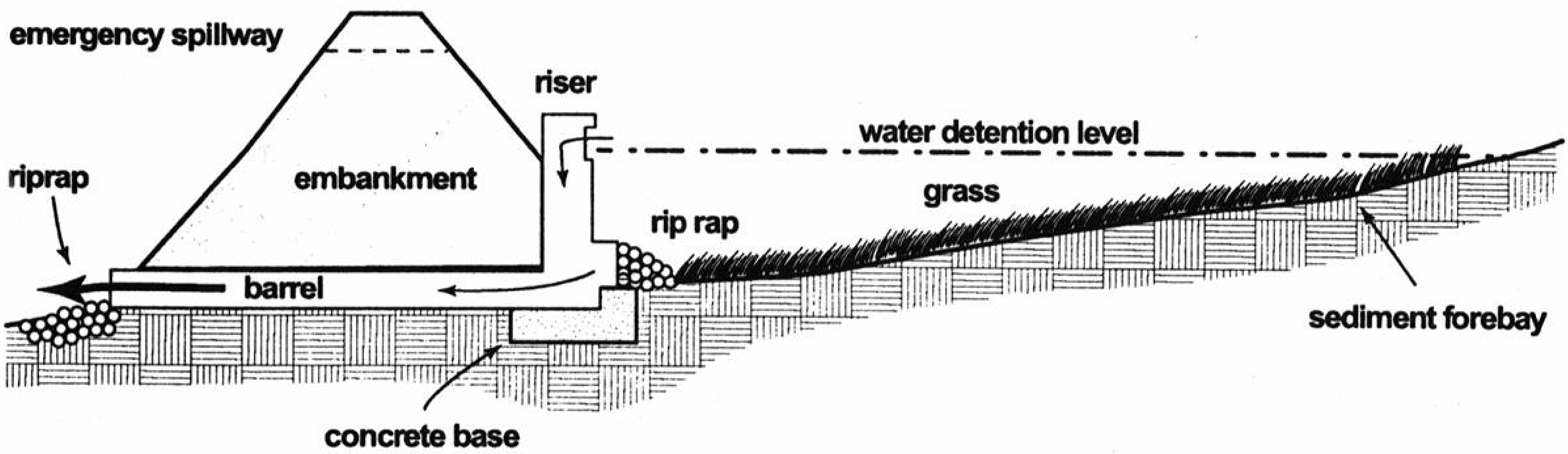
WETLAND RESTORATION

FIGURE 6-7



Source: USEPA NPDES Stormwater
Menu of BMPs

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\
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\Technology Screening Report\
00074F7-1_Detention .mxd

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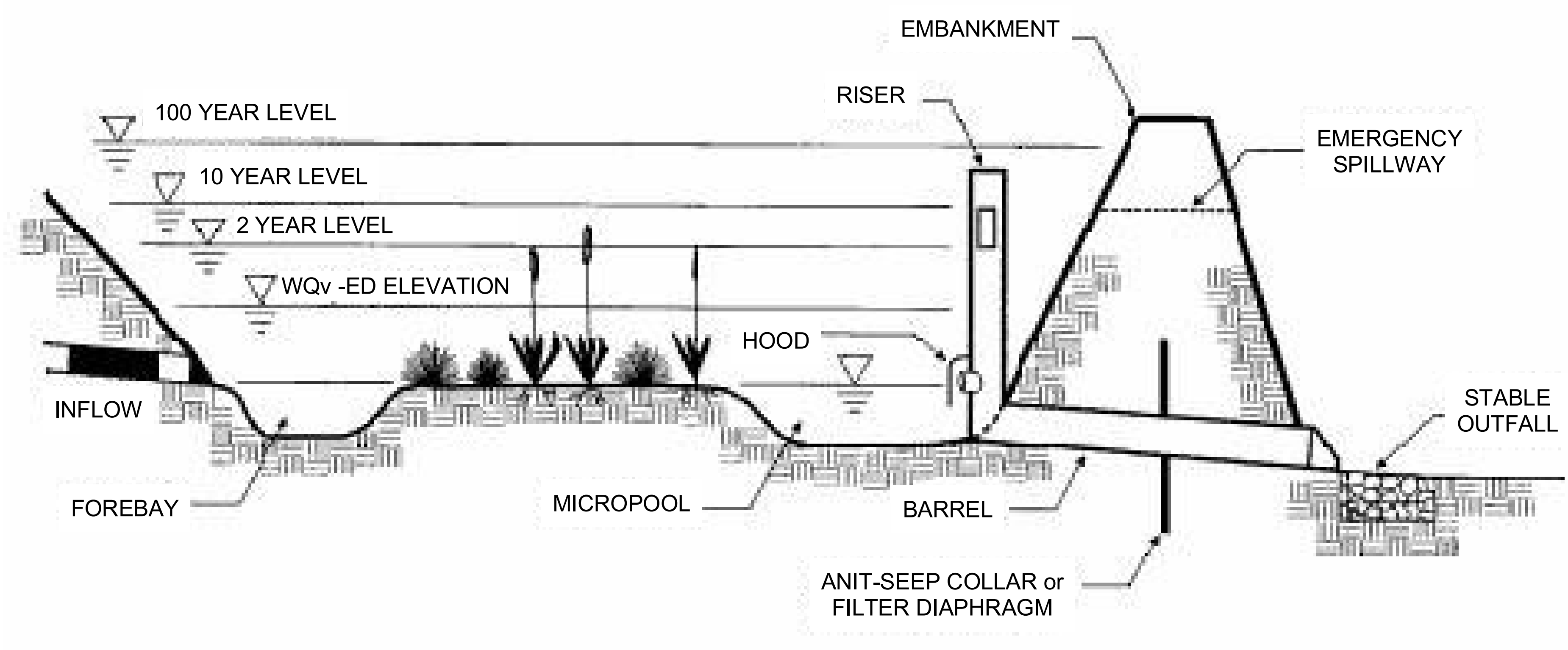
DRY DETENTION POND

FIGURE 7-1



Source: USEPA NPDES Stormwater
Menu of BMPs

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\
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\Technology Screening Report\
00074F7-2_Retention .mxd

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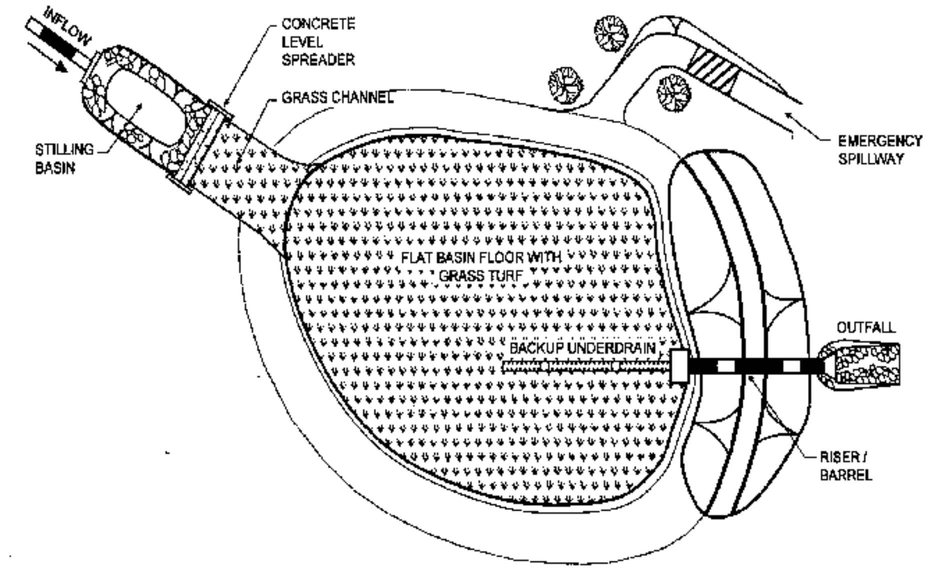
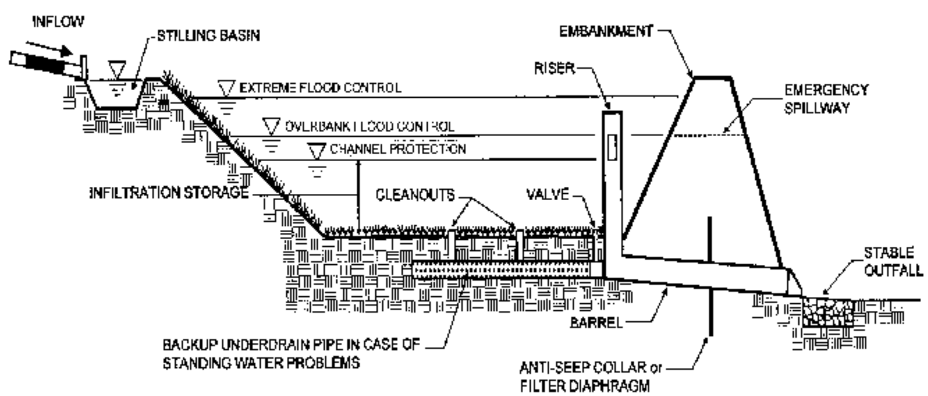
WET RETENTION POND

FIGURE 7-2



PLAN VIEW



PROFILE

Source: Stormwater Manager's Resource Center

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F7-3_Infiltration .mxd

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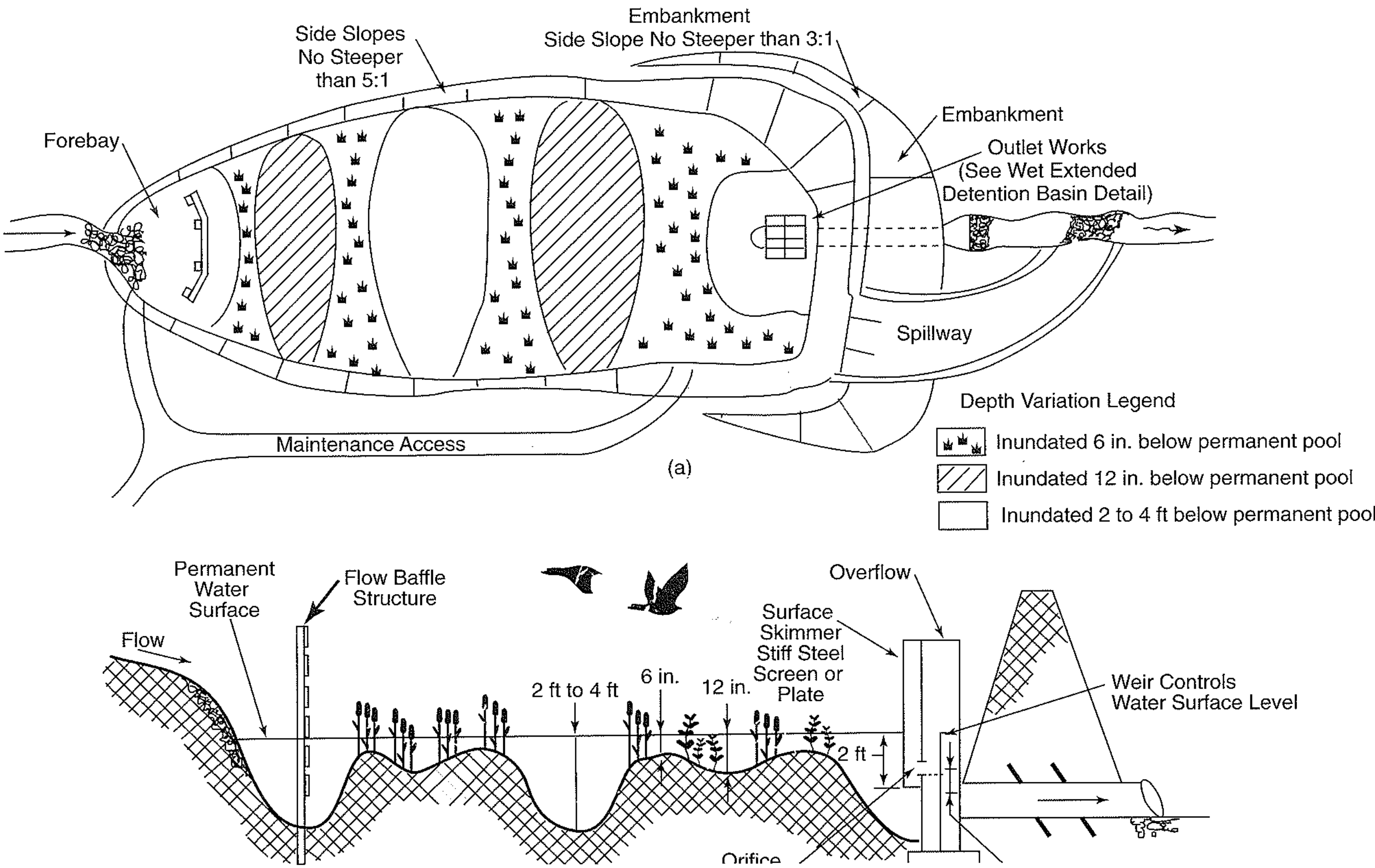
INFILTRATION BASIN

FIGURE 7-3



Source: Urban Runoff Quality Management (ASCE 1998)

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F7-4_Wetlands .mxd

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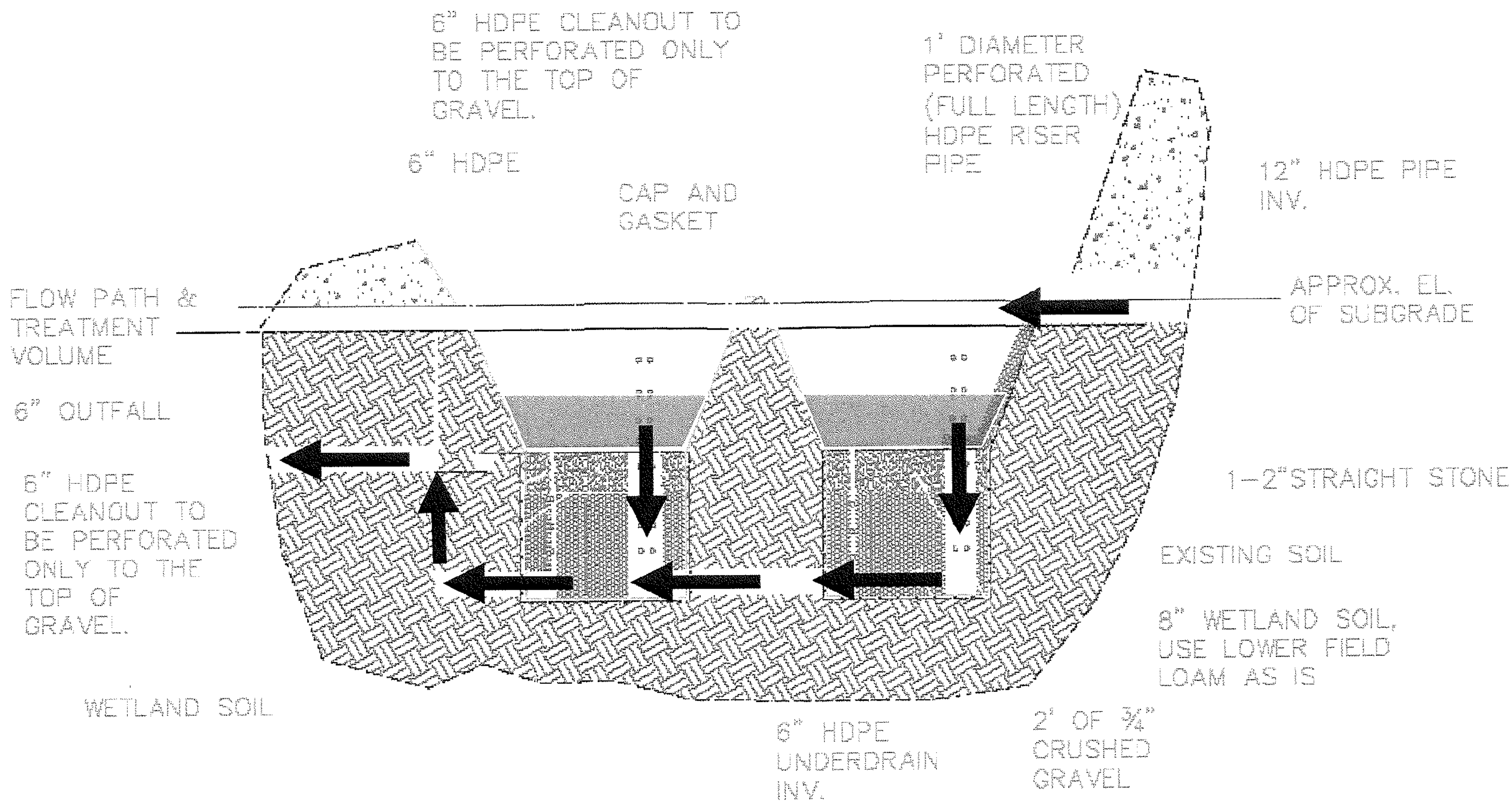
STORMWATER WETLANDS

FIGURE 7-4



Source: UNH Stormwater Center

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F7-5_Gravel .mxd

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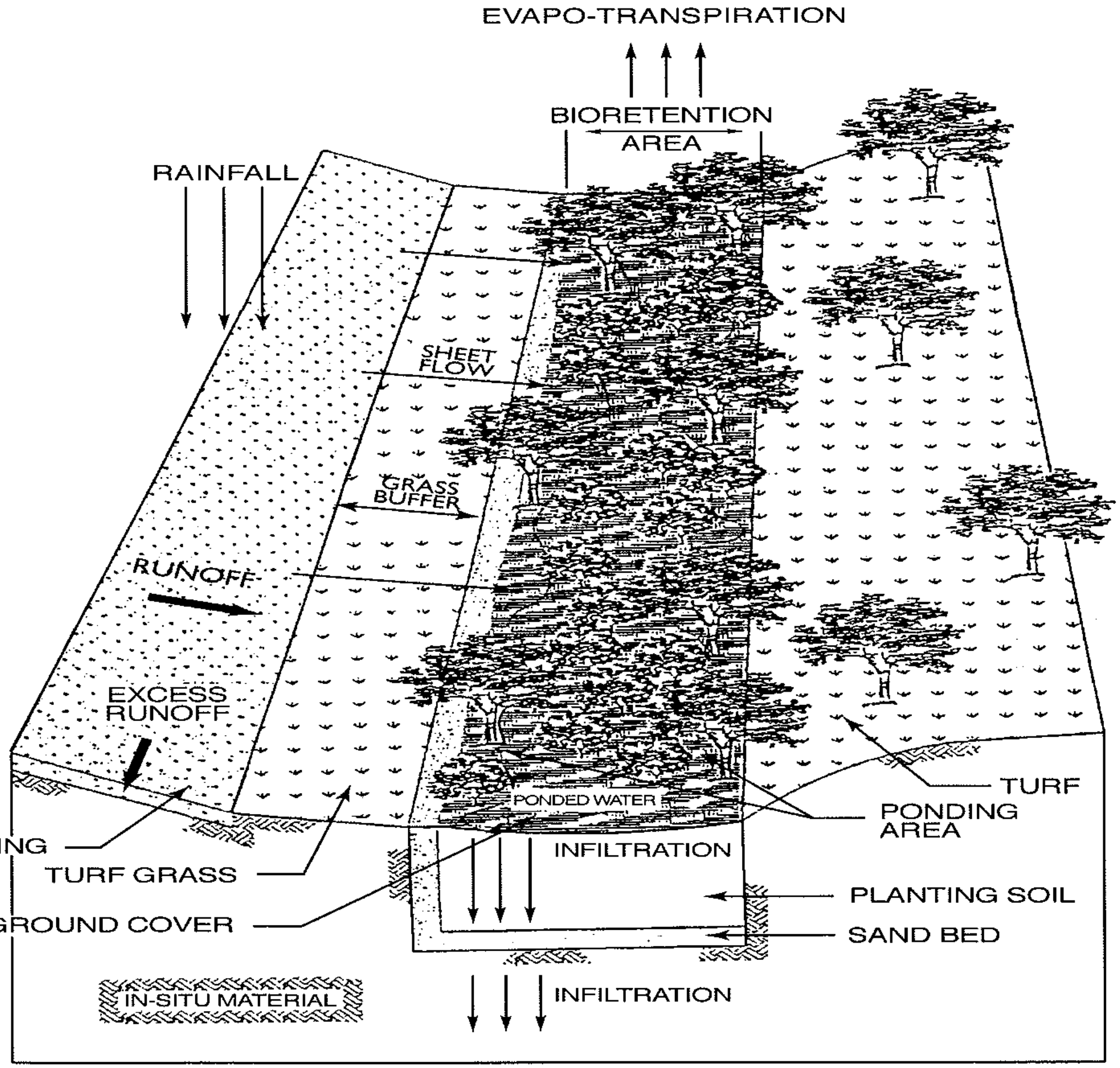
GRAVEL WETLANDS

FIGURE 7-5



Source: Stormwater Technology Fact Sheet – USEPA

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F7-6_Bioretention .mxd

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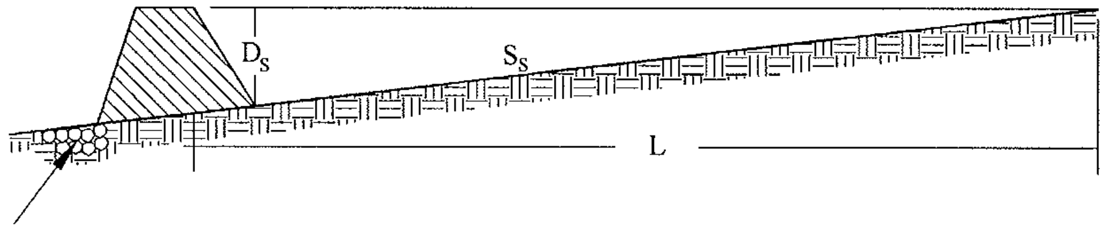
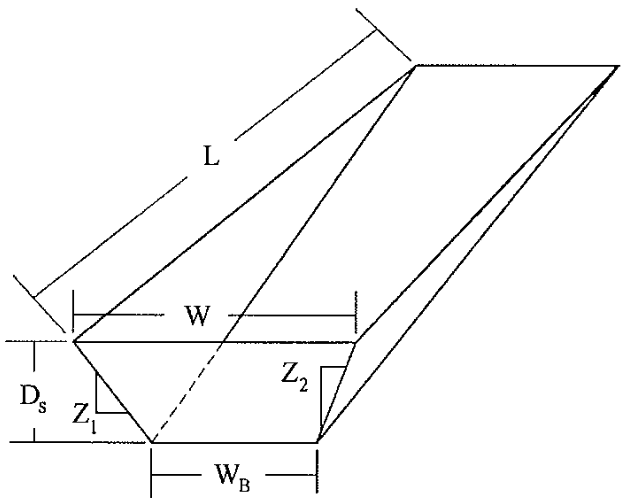
BIORETENTION (RAIN GARDEN)

FIGURE 7-6



Provide for scour protection.

(a) Cross section of swale with check dam.



(b) Dimensional view of swale impoundment area.

Notation:

L = Length of swale impoundment area per check dam (ft)
D_S = Depth of check dam (ft)
S_S = Bottom slpe of swale (ft/ft)
W = Top width of check dam (ft)
W_B = Bottom width of check dam (ft)
$Z_{1\&2}$ = Ratio of horizontal to vertical change in swale side slope (ft/ft)

Source: Stormwater Technology Fact Sheet – USEPA

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F7-7_VegSwale .mxd

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web. www.stearnswheler.com

Date: 11/2007 Project No. 00074

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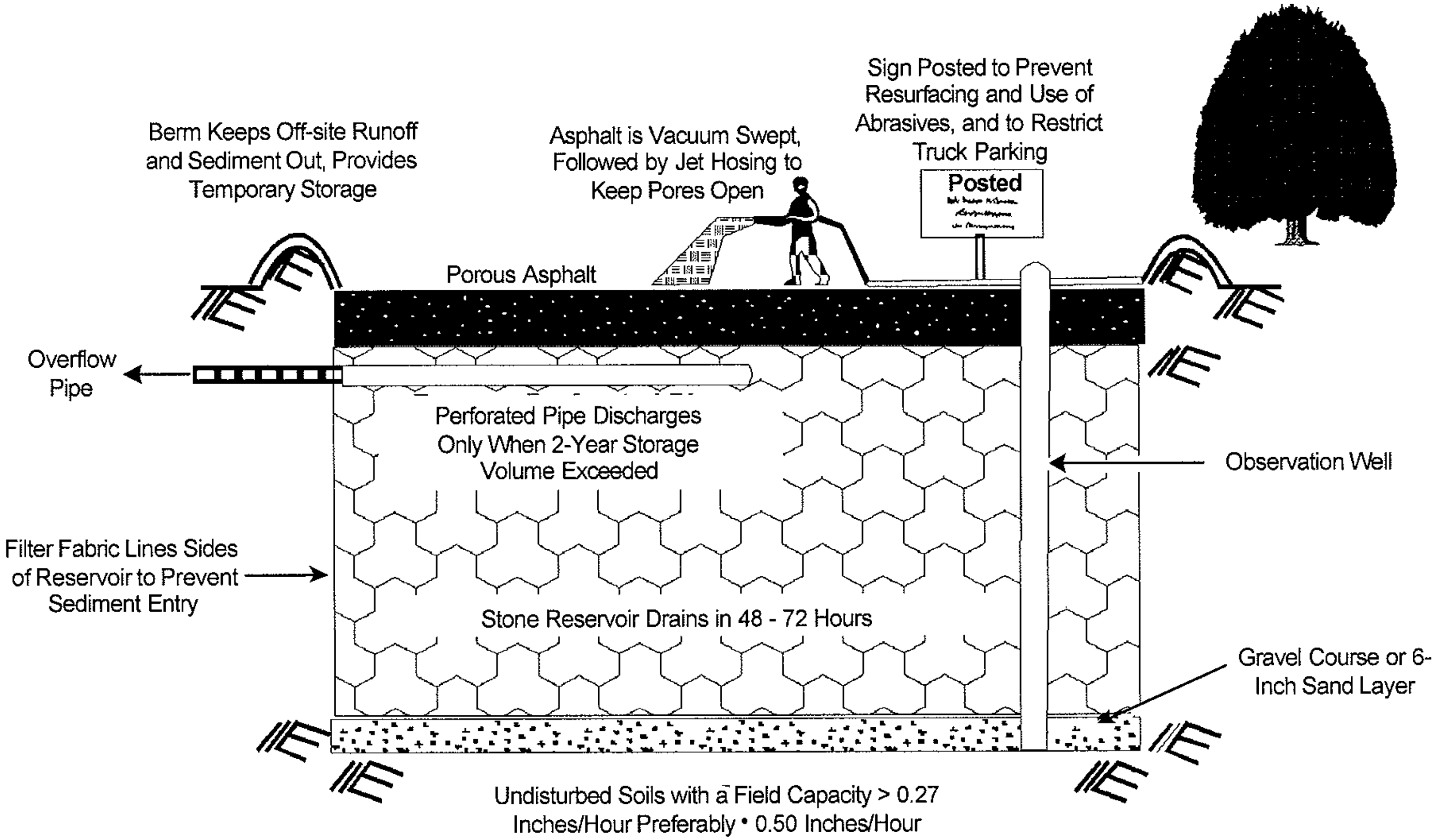
VEGETATED SWALE

FIGURE 7-7



Source: Stormwater Technology Fact Sheet – USEPA

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\00074 Mashpee\2006 WWFP\Report Figures\Technology Screening Report\00074F7-8_Porous .mxd

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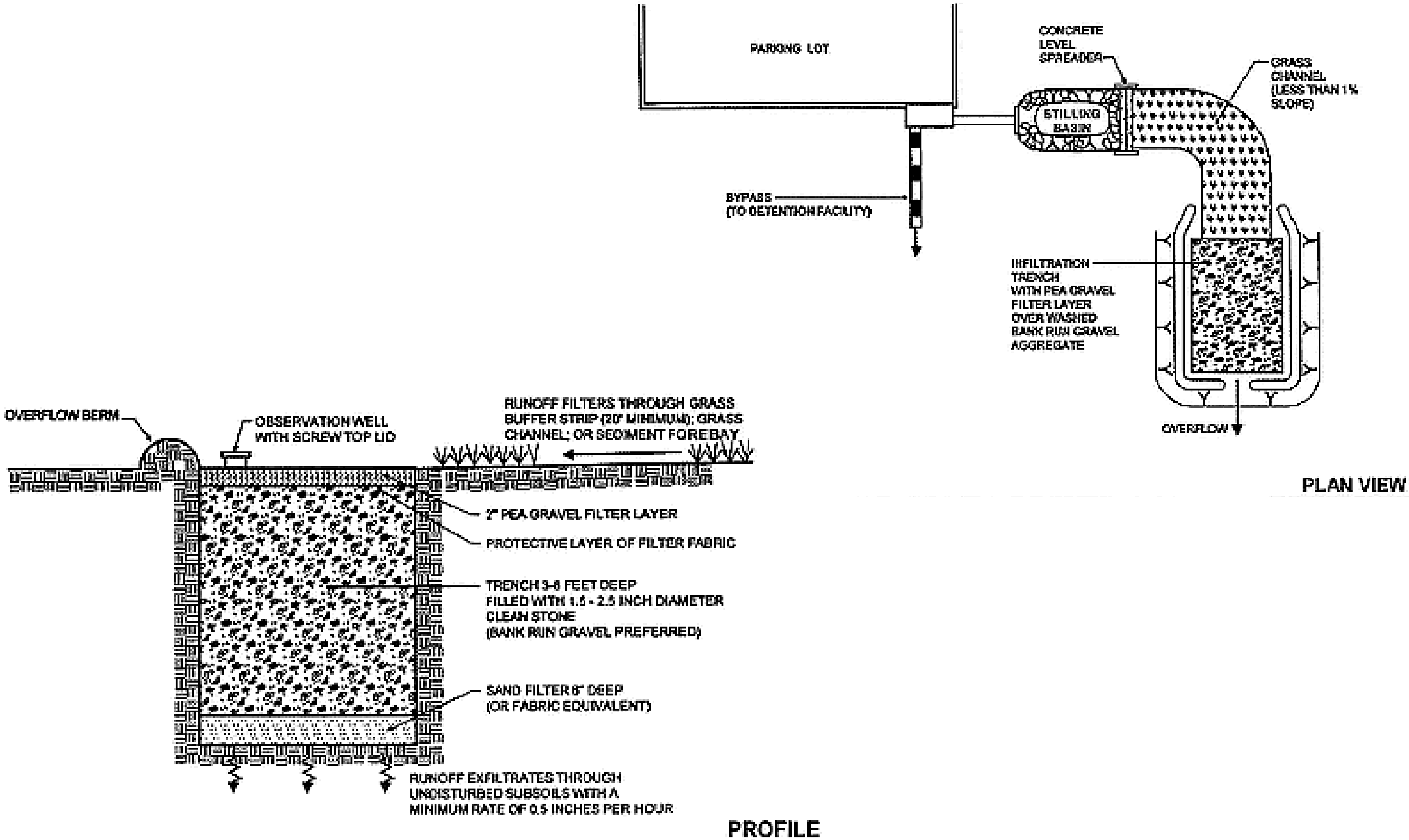
POROUS PAVEMENT

FIGURE 7-8



Source: USEPA NPDES Stormwater
Menu of BMPs

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\
00074 Mashpee\2006 WWFP\Report Figures
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00074F7-9_Trench .mxd

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INFILTRATION TRENCH

FIGURE 7-9

Source: Clean Air Gardening

Data Source: Mass GIS
File Location: J:\GIS\GIS Project Folder\Job#\
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\Technology Screening Report\
00074F7-10_Barrels .mxd

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TYPICAL RAIN BARRELS

FIGURE 7-10

Appendix A

Certificate of the Secretary of Environmental Affairs

Copies to: - file 00074.5
- file 00074.0
Original to NAW.

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
251 Causeway Street, Suite 900
Boston, MA 02114-2119

REC'D NOV 18 2001

JANE SWIFT
GOVERNOR

BOB DURAND
SECRETARY

Tel. (617) 626-1000
Fax (617) 626-1181
http://www.magnet.state.ma.us/envir

November 9, 2001

CERTIFICATE OF THE SECRETARY OF ENVIRONMENTAL AFFAIRS
ON THE
ENVIRONMENTAL NOTIFICATION FORM

PROJECT NAME	: Comprehensive Nitrogen and Wastewater Management Plan
PROJECT MUNICIPALITY	: Mashpee
PROJECT WATERSHED	: Cape Cod
EOEA NUMBER	: 12615
PROJECT PROPONENT	: Town of Mashpee
DATE NOTICED IN MONITOR	: October 10, 2001

Pursuant to the Massachusetts Environmental Policy Act (G. L. c. 30, ss. 61-62H) and Section 11.03 of the MEPA regulations (301 CMR 11.00), I hereby determine that this project **requires** the preparation of an Environmental Impact Report.

This project involves the development of a comprehensive nitrogen and wastewater management plan for the Town of Mashpee. The project is expected to proceed in phases with the submission of reports dealing with four major work elements: (1)a Needs Assessment Report, defining those areas that need nitrogen and wastewater management and establishing project flows from those areas; (2) an Alternatives Screening Analysis Report, evaluating the various means of meeting the wastewater requirements of the needs areas; (3) the Nitrogen and Wastewater Management Plan and Draft EIR, which will identify a proposed management plan and assess the potential environmental impacts of that plan; and (4) the Nitrogen and Wastewater Management Plan and Final EIR, which will provide what additional environmental analysis might be required and will address the comments received on the Draft EIR.

The first two reports will be prepared and reviewed prior to submission of the Draft EIR, and their analyses and recommendations will be reflected in that document.

The project is subject to MEPA review and to the Mandatory EIR provisions of the MEPA Regulations (301 CMR 11.03(5)(a)3) since it is presumed that the project will ultimately result in the construction of more than 10 miles of new sewers. The Town is also seeking financial assistance from the Commonwealth under the State Revolving Fund.

The Town has requested that the project be reviewed under the Joint Environmental Review Process established between the Executive Office of Environmental Affairs (EOEA) and the Cape Cod Commission (CCC). Each of the documents filed under this Certificate should be prepared to satisfy both the EIR requirements of MEPA and the Development of Regional Impact (DRI) requirement of the CCC.

The Draft and Final EIR should follow the outline contained at Section 11.07 for form and content. The ENF filed for the project contains a proposed scope for each of the filings anticipated by the process. I find that the scope has provided detailed direction for each and that, with the addition of the several issues that follow, it should ensure that the necessary issues are addressed in appropriate detail. Consequently, I adopt that scope as my own, modified by the scoping items that follow.

RESOURCE DELINEATION

The Town should create a clear delineation of coastal and other resources that might be directly or indirectly affected by the proposed project. This information is necessary to allow designers to avoid or minimize impacts to such resources. The comments of the Office of Coastal Zone Management (CZM) and the CCC provide detailed guidance on what resources need to be identified.

EXECUTIVE ORDER #149; FEMA AND FLOODPLAIN USE

EO#149 directs agencies with permitting responsibilities over project involving construction of infrastructure to evaluate the flood damage potential to these facilities and to consider flood hazards when evaluating infrastructure proposals. The EIR should provide an analysis of the flood damage potential of any facilities that would be located within flood hazard zones and should otherwise show compliance with the intent of EO#149.

EXECUTIVE ORDER #181; BARRIER BEACHES

EO#181 directs agencies that would issue funding for projects to avoid using public monies to encourage growth and development on barrier beaches. The EIR should provide assurances that the project will be consistent with EO#181.

EXECUTIVE ORDER #385; PLANNING FOR GROWTH

Executive Order #385 requires that state and local agencies engage in proactive and coordinated planning oriented towards both resource protection and sustainable development. For reasons both of environmental protection and fiscal prudence, investments in public infrastructure should be carefully targeted toward those areas for which clear existing need has been established and for areas where denser development is appropriate, thereby relieving pressures on open space, agricultural lands, and other valuable natural resources.

Consequently, the EIR should provide a clear delineation of sensitive resources in the project area and should describe the ways in which the project will consider local and regional land use and growth management plans, and ensure consistency with those plans.

COMMENTS

The EIR should contain detailed responses to the issues raised in the public and agency comments received on the ENF, which are listed below.

November 9, 2001
Date

Jay Wickersham for
Bob Durand

Comments received :

Department of Environmental Protection
Coastal Zone Management
Massachusetts Historical Commission
Cape Cod Commission
Edward Baker

BD/rf

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
20 RIVERSIDE DRIVE, LAKEVILLE, MA 02347 508-946-2700

DF

JANE SWIFT
Governor

BOB DURAND
Secretary

LAUREN A. LISS
Commissioner

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November 1, 2001

Secretary Bob Durand
Executive Office of
Environmental Affairs
251 Causeway Street, 9th Floor
Boston, Massachusetts 02202

RE: MASHPEE – ENF Review
EOEA # 12615 – Watershed
Nitrogen Management Planning
Study
Mashpee, MA

Dear Secretary Durand,

"For Use in Intra-Agency Policy Deliberations"

The Southeast Regional Office and the Boston Office of the Department of Environmental Protection have reviewed the Environmental Notification Form (ENF) for the proposed project for a Watershed Nitrogen Management Planning Study to be located in Mashpee, Massachusetts (EOEA #12615). The project proponent provides the following information for the project:

"The Watershed Nitrogen Management Planning Study (Project) is a comprehensive nitrogen and wastewater management planning project for the Town of Mashpee, the Popponessett Bay Watershed, and Mashpee's portions of the Waquoit Bay Watersheds. The Project Area is illustrated in Figure 1; and Figure 2 illustrates the location of the Project Area on Cape Cod. The Project will result in a comprehensive Nitrogen and Wastewater Management Plan and Environmental Impact Report for the Town.

Because the Project is a study, there is no facility or construction project at this time. Therefore, this document is submitted for the planning process that is proposed to perform the study and the project. The planning process is detailed in the attached Proposed project Scope."

The DEP Cape Cod Watershed Team indicates that the ENF prepared for the nitrogen management planning study presents an acceptable scope of work for the project. The Town of Mashpee and its consultant have worked in close cooperation with DEP and the Cape Cod Commission in developing the proposed plan and is using an appropriate nitrogen-loading model on which to base management options. The Town is proposing a comprehensive review of wastewater management alternatives. The Department is happy to note that Mashpee is actively pursuing the formation of a Citizens Advisory Committee that is representative of the community.

DEP had previously approved a Scope of Work (SOW). The following items are absent from the SOW presented in the ENF and should be addressed. They are:

1. Pg.19: Phase VII. A. The consultant was supposed to have developed a screening process with criteria for rating potential disposal sites.

2. Pg. 19 VII.B. The approved SOW referenced alternatives (as opposed to a single disposal site) for infiltration and was supposed to account for the evaluation of multiple disposal sites.

3. Pg. 21 VII.1. The approved SOW referenced evaluation of more than one discharge site to account for the potential for multiple disposal sites.

The project is a Planning Study and does not propose any construction. To assist the Town of Mashpee during this planning process, disposal sites identified by the Bureau of Waste Site Cleanup(BWSC) in Mashpee are available online at the Department's website at http://www.state.ma.us/dep/bwsc/sites/report.htm

The Department appreciates the opportunity to comment on this proposed project. If you have any questions regarding these comments, please contact Sharon Stone at (508) 946-2846.

Very truly yours,

Robert P. Fagan,
Regional Engineer,
Bureau of Resource Protection

RPF/SS/LM

cc: DEP/SERO
ATTN: David DeLorenzo,
Deputy Regional Director

David Johnston,
Deputy Regional Director

John Viola,
Deputy Regional Director

Paul L. Grady Jr.
Service Center Director

Elizabeth Kouloheras
Chief, Wetlands

Jeffrey Gould
Chief, Water Pollution Control

Brian Dudley
SERO Watershed Team Leader

Ronald Lyberger
Project Manager, BMF/Boston

cc: EOEA/SERO
ATTN: Patti Kellogg
EOEA Basin Team Leader
Cape and Islands Watershed

THE COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
OFFICE OF COASTAL ZONE MANAGEMENT
251 CAUSEWAY STREET, SUITE 900, BOSTON, MA 02114-2136
(617) 626-1200 FAX: (617) 626-1240

DF

MEMORANDUM

TO: Bob Durand, Secretary, EOEA
ATTN: Dick Foster, MEPA Unit
FROM: Tom Skinner, Director, CZM
DATE: October 29, 2001
RE: EOEA #12615 – Mashpee Watershed Nitrogen Management; Mashpee

The Massachusetts Office of Coastal Zone Management (CZM) has completed its review of the above-referenced Environmental Notification Form (ENF), noticed in the Environmental Monitor dated October 10, 2001. CZM recommends that the following matters be addressed in the Draft Environmental Impact Report (DEIR)

The Town of Mashpee is undertaking a study to develop a comprehensive nitrogen management plan for the entire town, including Popponesset Bay and the Mashpee watershed to Waquoit Bay, in order to determine the most appropriate means to address its nitrogen overload problem to these estuaries.

Nitrogen Load and Management Plans

CZM commends the Town of Mashpee for including the Towns of Barnstable, Falmouth and Sandwich as members of the Community Advisory Committee set up to oversee the project and to assist in its implementation. Multi-town cooperation will be critical to ensuring that the nitrogen loading limits established through this study will be addressed effectively and fairly across all municipalities impacting the watersheds.

CZM recommends that the methodology for determining critical nitrogen loading values be clearly defined in the Phase VIII reports and that the University of Massachusetts School for Marine Science and Technology (SMAST) allow the state agencies and the Town to participate in the critical loading value determination process, where appropriate.

CZM suggests that, in addition to recommending wastewater management plans, the proponent provide recommendations to achieve target levels of nitrogen by reducing the load from non-wastewater sources (e.g., fertilizers, impervious surface runoff, pet waste, etc.).

Resource Delineation

The initial planning effort includes a limited amount of resource delineation. CZM believes that the information requested below is necessary to facilitate the analysis of potential nitrogen and wastewater management alternatives and will assist the Town and permitting agencies in their assessment of future project proposals resulting from this planning study.

- Delineation of coastal resources including coastal dune, coastal beach, barrier beach, land subject to coastal storm flowage, salt marsh, coastal bank, and endangered species habitat overlaid onto proposed project plans;

- A description of alternatives considered to avoid potential adverse impacts to resource areas. If impacts are unavoidable, a description of measures that will be taken to minimize short-term and long-term impacts as well as any mitigation plan to address those impacts;

- If there are no alternatives to siting any infrastructure within flood zones, documentation that any proposed infrastructure is protected from flood and erosion-related damage and that any utility connections will be capable of withstanding storm forces without damage or contamination of natural resource areas;

- Preliminary construction plans and cross-sections, with elevations and relevant resource delineations of any proposed infrastructure;

- Construction sequencing and methodology, including appropriate erosion and sedimentation controls.

As the project progresses and alternatives are considered, CZM recommends that the proponent address the applicability of Executive Orders 149, 181, and 385 to any proposed activities.

Executive Order 149: FEMA and Floodplain Use, directs state agencies responsible for the administration of grant or loan programs involving the construction of infrastructure to evaluate potential flood hazards to such facilities and the need for future state expenditures for flood protection and disaster relief. The Order also directs state agencies reviewing such proposals to take flood hazards into account when evaluating plans.

Executive Order 181: Barrier Beaches, states that state funds and federal grants for construction projects shall not be used to encourage growth and development in hazard prone barrier beach areas. CZM notes that there are six mapped barrier beach units within Mashpee.

Executive Order 385: Planning For Growth, emphasizes the importance of balancing economic development and resource protection. It also states that infrastructure should not result in or contribute to avoidable loss of environmental quality and resources.

- In light of Executive Orders 149, 385, and 181, as outlined above, CZM recommends that the proponent explore mechanisms to address growth and development that may be able to occur based upon the implementation of a selected nitrogen management alternative. Depending on the selected alternative and based on the wording in Massachusetts General Law Chapter 83, special legislation may be necessary for the implementation of growth controls.

CZM is available to provide technical assistance to the Town and other permitting agencies to assist in the planning process and address the issues raised in this memorandum.

The proposed project may be subject to CZM federal consistency review, in which case the project must be found to be consistent with CZM's enforceable program policies. For further information on this process, please contact Jane W. Mead, Senior Project Review Coordinator, at 617-626-1219 or visit the CZM web site at www.state.ma.us/czm/fcr.htm.

TWS/tpc/wq

cc: Nathan Weeks, Senior Project Manager
Stearns and Wheeler, LLC, 255 Stevens St., PO Box 975, Hyannis, MA 02601
Mashpee Sewer Commission
Mashpee Conservation Commission
Truman Henson
CZM Cape and Islands Regional Coordinator
Elizabeth Kouloheras, Section Chief
DEP Southeast Regional Office
Patti Kellogg, Team Leader
Cape and Islands Watershed
Sharon Pelosi, Section Chief
Waterways Program, MA DEP
Karen Kirk Adams, Chief
Regulatory Branch, US Army Corps of Engineers

DF

CAPE COD COMMISSION

3225 MAIN STREET
P.O. BOX 226
BARNSTABLE, MA 02630
(508) 362-3828
FAX (508) 362-3136
E-mail: frontdesk@capecodcommission.org

October 25, 2001

Mr. Bob Durand, Secretary
Executive Office of Environmental Affairs
Attn: MEPA Office,
Richard Foster, EOEA No:12615
251 Causeway Street, Suite 900,
Boston, MA 02114

Attention:

RE: Mashpee Watershed Nitrogen Management Plan
EOEA #: 12615
CCC: JR#20076

Dear Secretary Durand:

The proposed Mashpee Watershed Nitrogen Management Plan is being reviewed jointly by the Executive Office of Environmental Affairs (EOEA) – MEPA Unit, and by the Cape Cod Commission as a Development of Regional Impact (DRI) in accordance with the Memorandum of Understanding (MOU) between the Commission and EOEA. The Commission received an Environmental Notification Form on September 26, 2001. A joint public hearing/scoping session for the Commission and EOEA was held on October 16, 2001 in Mashpee, MA.

The proposed project is intended to develop a comprehensive nitrogen and wastewater management plan for the Town of Mashpee. The purpose of the study is to ascertain the most feasible options for addressing the nitrogen overload problems that have been identified in the Popponesset Bay Watershed and Mashpee's portion of the Waquoit Bay Watershed. These estuarine systems have shown significant signs of degradation attributable to excessive inputs of nitrogen from a variety of sources.

The ENF included a comprehensive draft scope of services for the planning process. The plan will identify the existing and projected nitrogen inputs to the watersheds from wastewater and other sources, identify alternative solutions to address any needs with a detailed evaluation of the feasible alternatives, followed by a recommended plan to address the Town's needs. No facilities or construction are proposed at this time.

The Commonwealth of Massachusetts
William Francis Galvin, Secretary of the Commonwealth
Massachusetts Historical Commission

RECEIVED
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MEPA

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October 30, 2001

Secretary Bob Durand
Attn.: MEPA Office
Executive Office of Environmental Affairs
251 Causeway Street, 9th Floor
Boston, MA 02114-2150

ATTN: Richard Foster

RE: Watershed Nitrogen Management Planning Study, Mashpee, MA. MHC #RC.29581. **EOEA #12615.**

Dear Secretary Durand:

Staff of the Massachusetts Historical Commission have reviewed the Environmental Notification Form (ENF) for the proposed project referenced above and have the following comments.

The Watershed Nitrogen Planning Study (WNPS) is now in the preliminary planning stage, and specific project alternatives that may affect specific geographical areas have yet to be identified. Once specific project alternatives have been determined, project information should be submitted to the MHC. Typically, the information submitted should consist of completed Project Notification Form (available online at http://www.state.ma.us/sec/mhc/), a photocopy of the appropriate section of the US Geological Survey quadrangle map with the boundaries of the project area(s) clearly indicated, and scaled project plans showing existing and proposed conditions within the project area(s). Current, representative photos of the project area(s) and any buildings or objects that may be located there are also helpful for MHC review of the project(s).

If they have not already done so, the project proponents should also contact the Mashpee Historical Commission, the Wampanoag Tribe of Gay Head (Aquinnah), and the Mashpee Wampanoag Tribal Council Inc. These groups may wish to participate in the project planning activities and may wish to have representatives on the Community Advisory Committee now in formation.

These comments are offered to assist in compliance with Section 106 of the National Historic Preservation Act of 1966 as amended (36 CFR 800), Massachusetts General Laws, Chapter 9, Sections 26-27C as amended by Chapter 254 of the Acts of 1988 (950 CMR 71), and MEPA (301 CMR 11). If you have any questions, please feel free to contact Margo Muhl Davis at this office.

Sincerely,

Brona Simon

Brona Simon
State Archaeologist
Deputy State Historic Preservation Officer
Massachusetts Historical Commission

xc: Ron Lyberger, DEP/BRP
Steve Hallem, DEP/BRP
Cape Cod Commission
Mashpee Historical Commission
Mashpee Wampanoag Tribal Council Inc.
Mark Harding, Deputy THPO, WTGHA

220 Morrissey Boulevard, Boston, Massachusetts 02125
(617) 727-8470 • Fax: (617) 727-5128
www.state.ma.us/sec/mhc

A Commission subcommittee has reviewed the proposed scope and offers the following comments:

General

1. As the project is currently only a planning study, with no construction or locations specified, specific comments regarding issue areas are limited. However, as specific sites and facilities are considered as potential alternatives, the impacts on resources protected under the Regional Policy Plan will need to be more closely and comprehensively studied and addressed. For instance, impacts on land use, economic development, community character, historic preservation and transportation may vary depending on the final plan recommendations.

2. The subcommittee would like to ensure that project reviewers are aware that the Commission is in the process of completing some of the activities indicated in the scope. Using a portion of a state Department of Environmental Protection grant and in coordination with the School for Marine Science and Technology (SMAST), Sterns &Wheler, and the Mashpee Town Planner, the Commission has gathered together the parcel and water use information that will be used to assess the nutrient management needs within the town. Staff previously consulted with the USGS under the state grant to provide a revised watershed for Popponesset Bay, including groundwater time of travel bands and pond recharge area delineations. These delineations, and revised delineations developed by Commission staff in the project's portion of the Waquoit Bay watershed, are being combined through the use of the Commission's Geographic Information System (GIS) with parcel, assessors, and wateruse information from Mashpee, Falmouth, Barnstable, and Sandwich. This information will be used to calibrate the SMAST water quality models of Waquoit and Popponesset Bays. Buildout information developed by the Town Planner will also be incorporated into the GIS in order to assess potential future conditions. Most of these activities are described under Phase I of the scope of services attached to the ENF.

3. The scope of services indicates that the Mashpee Sewer Commission will provide direction for preparation of the plan, and that the town is also forming a Community Advisory Committee (CAC) to oversee the details of the project and to assist in the implementation. The subcommittee recommends that the town clarify the role of each of these committees in the planning process.

Natural Resources

4. The nitrogen management strategy developed in Mashpee will likely result in the development of infrastructure that may pose impacts to sensitive resources, including wetlands, rare species habitat and other wildlife and plant habitats. The EIR should address both how the nitrogen management strategy may have beneficial impacts on these sensitive resources (i.e. reductions in nitrogen that may improve water quality in degraded areas), and how the installation of infrastructure may negatively impact sensitive habitats. Where infrastructure development may pose adverse impacts the

project should be designed to minimize those impacts, and where impacts to sensitive resources are unavoidable, appropriate mitigation should be proposed.

5. The subcommittee supports the proposal in the scope to consider growth management strategies to address future nitrogen loading potential. This may include changes in local zoning and regulations and a focus on open space acquisition.

Marine Resources

6. The scope proposes investigating the feasibility of dredging as a means for increasing flushing within nitrogen sensitive embayments. Although new dredging is typically prohibited in the Regional Policy Plan (RPP), new dredging to improve water quality may be permitted in certain instances. However, dredging of this kind may only alleviate the short-term effects unless appropriate nitrogen reduction and wastewater treatment strategies are in place. Therefore, the plan should only recommend dredging as part of a comprehensive overall strategy.

Thank you for the opportunity to comment,

Sincerely,

Jay Schlaikjer

Jay Schlaikjer
Subcommittee Chair

cc: Subcommittee Members
Tom Fudala, Mashpee Town Planner
Nate Weeks, Stearns and Wheler
Ed Baker, 197 Captains Row, Mashpee, MA 02640

Edward A. Baker
197 Captains Row
Mashpee, MA 02649

October 16, 2001

Bob Durand, Secretary
Executive Office of Environmental Affairs
Attn: MEPA Office
Mr. Richard Foster, EOEA No. 12615
251 Causeway Street, Suite 900
Boston, MA 02114

Re: Watershed Nitrogen Management Planning Study, Environmental Notification Form (ENF)

Dear Secretary Durand,

I am concerned that the proposed study will not yield the information needed to develop an adequate road map to the solution of Mashpee's Nutrient overload problem.

Although it is obvious that major gains may be accomplished via reductions in wastewater nutrient concentrations and movement of infiltration sites to less sensitive areas, that is only a partial solution. Reduction of existing levels and nutrient growth controls for Mashpee's already impaired waters will require actions for all nutrient sources

If, in fact, there are only minor activities for items such as flushing improvements, estuarine regeneration reductions, stormwater and fertilizers as the ENF seems to suggest; it may be appropriate for the Town to undertake additional activities in areas not currently covered in an adequate manner for the development of a realistic plan.

1. A minor correction to the ENF to include the Town of Mashpee, Conservation Commission representative as a committee member is needed.
2. The review of existing data should include, Rapid Formation And Degradation Of Barrier Spits In Areas With Low Rates Of Littoral Drift, Aubrey, D.G. and Gaines Jr., A.G., 1982, Marine Geology 49 (1982): 257-278 and Coastal Sediment Transport Popponesset Beach, MA, Aubrey, D.G. and Goud, M.R., 1983, Woods Hole Oceanographic Institution, WHOI-83-26.
3. The review of existing data should also include Cape Cod Commission Non-wastewater nitrogen-loading data prepared for the various Developments of Regional Impact (DRI's) located within the study area.
4. I am concerned regarding the use of CCC TB91-001 if occupancy rates, critical load formula or volumetric estimating portions are utilized.
5. I would suggest that the location of nitrogen inputs from non-wastewater sources be identified at least down to the Planning Zone level. Areas of greatest stormwater or fertilizer nitrogen inputs may become important. If a target Nitrogen load for some watersheds cannot be met at a zero wastewater level, these other sources rise in importance.
6. Critical loading values for subembayments are to be based in part on "desired water Quality". The target for "desired water quality" should be in the ENF. I hope it is at least swimable and open to shell fishing (SA?).

7. Phase IV scenarios should include acquisition and enlargement of the MMR STP facility using the max capacity of the existing piping to the infiltration filters as a guide. A scenario that moves treated wastewater from the Stratford Ponds-Willowbend-Pheasant Run area to the Phase VII disposal site and transfers any rotary local excess to MMR disposal seems logical to me.
8. Phase IV scenarios should include volume impact identifications to help in the determination of phase VII requirements.
9. Vacuum sewer technology should be included in phase III. It might be useful in places like the islands where a low-lying area could be connected to a community system. Remember Seconsett is surrounded by water and Falmouth on the land side.
10. A lot of these sewage treatment systems produce sludge. Sludge disposal technologies and preparation of sludge volume estimates should be addressed in the ENF. You need to get rid of it somehow, somewhere.
11. The Buzzards Bay Project appears to have established that flushing times are important. Partial implementation of Poppy Bay channel ideas in line with WHOI-83-26, Aubrey & Goud should be evaluated. Mashpee River residents have long discussed and complained about the negative flow impacts of other Bay internal dredging. Implementing these changes could have other positive results, i.e. spit protection. Meadow Point protection and shellfish bed restoration.
12. I would suggest public awareness start now. The ENF could have the Town supporting distribution and cable TV exposure of the new CCC video that discusses nutrient impacts. The Town can certainly afford to make copies for distribution to local groups that could in turn utilize them for public education.
13. Although, a plea for charitable donations sent out with tax bills was unpopular, the potential for a "stuffer" with the 4/year mailing has been established. Shouldn't the plan include evaluation of this public information potential?
14. As the difficulty in minimizing nutrient impacts increases with treated wastewater disposal volumes, both in terms of increased infiltration requirements and the difficulty in reducing further already reduced concentrations. It seems appropriate to include a review of potential methods for minimizing total volumes.

Sincerely,

Ed Baker

Edward A. Baker

Cc: Town of Mashpee Sewer Commission, attn: F. T. Fudala
Stearns & Wheler, attn: N.C. Weeks
Cape Cod Commission, attn: Phil Dascombe (JR#20076)

Appendix B

Clean-Green Lawn Program Educational Flyer

TOWN OF DENNIS
&
DENNIS WATER DISTRICT

Published by the Comprehensive Wastewater Mangemetn Task Force - Public Outreach Subcommittee

CLEAN-GREEN LAWN PROGRAM

The primary nutrients in lawn fertilizers are Nitrogen, Phosphorus, and Potassium. While Phosphorus and Potassium are important to promote growth and fight disease, Nitrogen has the greatest impact on lawn quality and is the principle ingredient in fertilizers. Over application can damage the lawn and result in run off into our estuaries and groundwater. Excessive nitrogen in our estuaries causes rapid algae growth. These algae mats block out sunlight and deprive the underwater environment of its ability to maintain aquatic life.

Simple Steps You Can Take to Improve the Health of Your Lawn, Save Money and Help Reduce the Amount of Nitrogen in Our Estuaries and Groundwater

SOIL PREPARATION

1. Test the pH (acidity), nutrient availability and mineral content of your soil. The pH should be between 6.5-7.0. For soil test information call the Cape Cod Extension Service 508-375-6690.

2. Determine if you have at least 6" of topsoil. Lawns grow best, require less water and care if there is *at least* 6" of good topsoil. If yours is not that deep, add ¼ to ½ inch of loam or compost each fall after the annual weeds have died out and rake it in, until you reach a minimum of 6". If you are installing a new lawn, insist on at least 6" of topsoil.

3. Apply seed to the new top dressing using a mixture of fescues and perennial ryegrass. These grasses require less nitrogen and are drought and shade tolerant.

APPLICATION OF FERTILIZER

1. Determine the square footage of your lawn. Do not apply more than 1 lb. of Nitrogen per 1,000 square feet of lawn. Fertilizer manufacturers provide the proper formulation and label their packages accordingly. They provide instructions for setting your spreader so that it will apply no more than 1 lb.s of Nitrogen per 1,000 sq. ft. If you have fertilizer left over when you have finished, do not put it on your lawn. **In this case more is not better.** The excess Nitrogen can become a pollutant.

2. You can maintain a beautiful lawn and minimize nitrogen-runoff by either: using light rates of *rapid release* materials such as *water soluble nitrogen* (WSN)* or using heavier rates of *slow release* materials such as *water insoluble nitrogen* (WIN)*. Fertilizer manufacturers use a combination of these types of nitrogen to meet the needs during various times of the year.

3. It is best to apply fertilizer when the grass is actually growing, late April through October when the ground is warmer and the plants can easily absorb the nitrates. The number of applications depends on the type of grass. Kentucky Blue grass requires four applications: **first in late April, second in late May or June, third in early September and fourth in late October**. Fescues may need only two applications.

4. Under no circumstances should fertilizer be applied to areas having exposed bedrock or gravel. Always sweep up any fertilizer spilled on sidewalks, driveways, streets or graveled areas to prevent runoff and leaching.

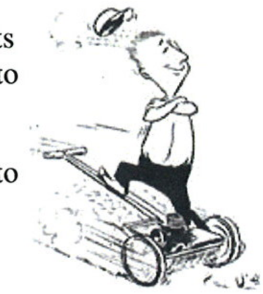
5. Fertilizer should not be applied when the soil is saturated or when heavy rainfall is expected.

6. Fertilizers containing higher amounts of water-soluble nitrogen should be avoided during the cooler portions of the year when plant growth and uptake are minimal.

7. In environmentally sensitive areas (near wetlands, salt or fresh water) slow release fertilizers with a higher percentage of water insoluble nitrogen (50% or more) are recommended to reduce the potential for nitrogen runoff to these areas.

8. Whenever possible, landscape with low maintenance shrubs and plants to reduce lawn area and maintenance thereby minimizing fertilizer applications. For information regarding low maintenance shrubs call the Cape Cod Cooperative Extension 508-375-6690 or ask your garden center for suggestions.

MAINTENANCE



1. Set the height of your lawnmower blade at 3" or at its highest cutting height. Grass roots will be about as deep as the cutting height. The deeper the root the better the resistance to drought and disease. Prevent damage to the grass by keeping the blades sharp.

2. Don't pick up your grass clippings. Mulch them to return nutrients, particularly nitrogen, to your lawn. Recycling the nitrogen-enriched clippings throughout the season provides the equivalent of one regular fertilizer application.

WATERING

Do not over water. Lawns need only about 1" of water per week to encourage deep roots. This amount is a weekly cumulative of natural rainfall and irrigation. Use a rain gauge to measure how much water you put on the lawn. If needed, it is best to water your lawn early in the morning. Watering mid-day or early afternoon should be avoided because it is not only wasting a natural resource and your money, it can damage the lawn.

WEEDING

The best weed control is a thick lawn. Weeds typically grow in the voids created by conditions not favorable to good growth (i.e. soil compaction, shade, insect damage, improper pH, infertility). All of these conditions can be controlled by good turf management.

****FORMS OF NITROGEN***

Water Soluble Nitrogen (WSN): **Urea, Ammoniacal**
Quick release, readily absorbed by the plants

Water Insoluble Nitrogen (WIN):	**Natural**	**(Miloganite)***
Slow release	**S.C.U.**	**(Sulfur Coated Urea)**
	U.F.	**(Urea formaldehyde)**
	I.B.D.U.	**(Isobutylidene diurea)**

WIN products, with the exception of natural fertilizers including Miloganite, encapsulate the nitrogen using substances such as sulfur, formaldehyde or similar products. The particle sizes are varied to alter the release rate or solubility. The nitrogen in U.F. is released through microbial degradation while S.C.U. and I.B.D.C. are slowly soluble products. *Miloganite should not be used on edible plants.

Appendix C

2006 Greenscapes Reference Guide

Saving water and money doesn't mean your landscape has to suffer.

See inside for tips and special offers to keep your landscape and wallet green!

The Greenscapes Reference Guide is published once a year by the North and South Rivers Watershed Association on behalf of the Greenscapes Program partners and sponsors.

NSRWA
NSRWA
P.O. Box 43
Norwell, MA 02061

Non-Profit Org.
U.S. Postage
PAID
Brockton, MA
Permit No. 1000

Save over $200 on Greenscapes goods and services!

greenscapes

2006 Greenscapes Reference Guide

April 22, 2006 **Volume 2, Issue 1**

Learn how to have a beautiful landscape that protects our water.

See inside for:

www.Greenscapes.org

What are Greenscapes?

Beautiful landscapes that protect our water.

Greenscapes are full of color and interest, and require very little water and chemicals to maintain. Greenscaping is a compilation of landscape practices that drastically reduce water usage, encourage groundwater recharge, protect our water supply and reduce stormwater pollution.

The goal of Greenscapes is to let nature provide the landscapes' water and nutrient needs. In southeastern Massachusetts our soils, climate and water supply make it unrealistic to have lawns that resemble golf greens, even if we had all the time and money in the world. Established Greenscapes have plants and turf with deep roots, which are naturally resistant to drought, weeds and disease.

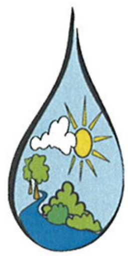
Greenscapes are good for you, your wallet and your environment in many ways. By following the recommendations in this Guidebook, you will:

- Increase your property values;
- Save money on your water bills;
- Nuture a safe environment for your family;
- Create more habitat for wildlife;
- Enjoy more free time by doing less landscape maintenance;
- Reduce stormwater pollution; and
- Protect your community's water resources.

A beautiful and functional Greenscape with plenty of lawn for recreation. The low-maintenance plants provide interest and color to frame the backyard, including Black-eyed Susan, Butterfly Bush, Autumn Joy Sedum, and ornamental grasses.

Why should I Greenscape?

We need to make sure there is enough clean water for people and the environment.



There are two major threats facing the water resources of southeastern Massachusetts. First, like many urbanized areas in the U.S., we are running out of drinkable water sources and there is less and less water available to sustain our rivers, streams and wetlands. Second, water quality of our ponds, rivers and bays is impaired, and improvements are difficult and expensive. These two inter-related problems are partially due to maintainance of our landscapes.

Consider the amount of drinkable water that is being used to irrigate our landscapes. During the summer season, many communities are faced with water demands that are 2-3 times more than the winter season. Not only does this place a stress on the environment, but our water supply systems cannot keep up with demand. This can result in a loss of pressure and potentially cause safety concerns for fire fighting. In addition, the more water we use, the more sources of water we will have to find and develop. The cost of developing new sources of water is large and those costs are transferred to consumers and citizens.

Now consider the fertilizers, herbicides, insecticides and fungicides being used on our landscapes. Chemicals that are not immediately absorbed by plants in our landscapes can end up polluting our water through stormwater runoff. Excess nutrients either leach through the soil to the groundwater, or they are washed by rain into stormdrains that lead to the nearest waterbody, contaminating our drinking water and causing rapid alga growth in ponds and bays.

Keep reading to learn how you can have a beautiful landscape that is good for your family, your wallet and your environment too. For additional information about the Greenscapes program, be sure to visit out website **www.Greenscapes.org**.

Greenscapes Reference Guide • April 22, 2006 • Volume 2, Issue 1
The Greenscapes Reference Guide is published once a year by the North and South Rivers Watershed Association
P.O. Box 43, Norwell, MA 02061 • greenscapes@nsrwa.org • 781.659.8168

The 2006 Greenscapes program is a multi-partner outreach effort sponsored by the North and South Rivers Watershed Association, the Massachusetts Bays Program, Aquarion Water Co. (Hingham, Hull), Pinehills Water Company, and the Towns of Cohasset, Duxbury, Hanover, Kingston, Marshfield, Norwell, Pembroke, Plymouth, Scituate and Weymouth.

The 2006 Greenscapes program is also financed in part by grants from the MA Department of Environmental Protection, Massachusetts Environmental Trust, and the U.S. Environmental Protection Agency. Views expressed do not necessarily reflect those of the Greenscapes partners or sponsors, nor does the mention of any trade names or commercial products constitute endorsement or recommendation for use.

EPA United States Environmental Protection Agency New England

Massachusetts Department of Environmental Protection

MASSACHUSETTS ENVIRONMENTAL TRUST

We greatly appreciate the assistance and support of these and other people who have led the Greenscapes program in their communities:

Aquarion Water Company
Larry Bingaman and Ann Hiltz

Cohasset Water Department
Eileen Commane, John McNabb and Jim Kinch

Duxbury Water Department
Paul Anderson, Tom Daley and Louise Hatfield

Hanover Dept. Public Works
Victor Diniak and Doug Billings

Kingston Water Department
Matthew Darsch and Pine DuBois, JRWA

Marshfield Dept. Public Works
Jeb DeLoach, John Patch and Donna Beals

Norwell Water Department
John McInnis and Nancy Dooley

Pembroke Dept. Public Works
Mike Valenti and Donna Kawa

Pinehills Water Company
John Judge and Deborah Sedares

Plymouth Dept. Public Works
George Crombie, David Gould and Paul Wohler

Scituate Conservation Commission
Mike Clark, Vinny Kalishes & Anthony Antoniello

Weymouth Water Department
David Madden, Robert O'Connor and David Tower

How Do I Greenscape?

Follow the suggestions in this Guidebook.

This Guidebook will tell you everything you need to know to get started. Keep reading to learn how you can immediately and easily implement some Greenscapes principles, such as modifying how you mow and water your lawn. Other Greenscapes recomendations will require a bit more effort, such as amending your soil and overseeding your lawn with drought-tolerant grasses. Over time, consider replacing problem or low-priority areas of your lawn with beautiful planting beds.

Attend free workshops this May.

Learn about different aspects of Greenscaping from highly-qualified landscaping professionals at our free workshop series, Thursday evenings in May. The back cover of this Guide has the complete schedule and details. You must register either online at **www.greenscapes.org** or by sending us the registration form on page 20.

Sign-up for our free email newsletter.

We will send you six monthly issues with timely landscaping tips and information about the weather, watering restrictions, and upcoming Greenscapes opportunities. To subscribe, send a blank email to **greenscapes-subscribe@lists.nsrwa.org.** We will not use your email for any other purpose nor share it with others.

Take advantage of our special offers.

This Reference Guide is full of special offers to keep your landscape and your wallet green! Keep reading to find out how you can save money on Greenscapes goods and services such as rainbarrels, sprinkler timers, irrigation system checks, compost bins, private consultations and more.

Participate in the Greenscapes Contest and Tour.

Show the South Shore your fabulous Greenscape — you could win fame and fortune! Winning entries will receive gift certificates and may be showcased on the NSRWA 2006 House Tour on September 10, 2006. See page 18 for rules.

Display a Greenscapes lawn sign.

Are you already a Greenscaper or are you willing to try at least five Greenscapes tips? Let your community know you are doing your part to help protect our water with a small, attractive Greenscapes sign in your yard. Your neighbors will be green with envy as they admire your beautiful landscape and coveted sign. To get your free sign, send us the registration form on page 20.

Hire professionals who Greenscape.

When hiring a landscaping contractor to help with your landscape, provide them with a copy of this Guide and ask them to follow the recommendations. Consider choosing a contractor who is a Massachusetts Certified Horticulturist (certified by the Massachusetts Nursery and Landscaping Association: **www.mnla.com**), an Accredited Organic Landcare Professional (**www.organiclandcare.net**), and/or a certified specialist from the Irrigation Association (**www.irrigation.org**).

Encourage your landscaper to attend one of our co-sponsored training workshops for landscaping professionals, such as the NOFA Organic Lawn & Turf course in August (see page 4). Our website **www.greenscapes.org** has additional information on choosing a qualified landscape professional, as well as a list of local contractors who have attended our past training workshops.

Greenscapes is an "ally" of the U.S. EPA's GreenScapes Program. **www.epa.gov/greenscapes.** GreenScapes Environmentally Beneficial Landscaping

Have a technical question?

There are lots of places to look for more information about environmentally-responsible landscaping! Consider scheduling a Greenscapes Consultation (see below) if you would like some individualized advice for your landscape. You can also call the Massachusetts Horticultural Society's free "Hort Line" at 617-933-4929 (Mondays, Wednesdays and Fridays from 10 am to 2 pm) and speak directly with a volunteer certified Master Gardener. A great source of information is the University of Massachusetts Cooperative Extension. Their website (**www.umassgreeninfo.org**) is full of fact sheets, publications, training opportunities, and other resources. Another option is to consult your local garden center with a trained horticulturist on staff.

Help sustain the Greenscapes program.

This free program is provided to citizens because of contributions from regional environmental organizations, South Shore communities, state and federal grant programs, and private donations. Please contact your community representative (see page 2) and let them know you appreciate their support of the Greenscapes program!

SPECIAL OFFER!

GREENSCAPES CONSULTATIONS

Register now for a 90-minute private consultation at your home or business to learn how you can save time, money and water by implementing Greenscapes practices. A Greenscapes Advisor will conduct a site inspection, soil analysis, and review of your existing maintenance practices. You will receive customized recommendations for improving your soil, strengthening your lawn, and beautifying your landscape. Initial 90-minute consultations are $75; optional follow-up 60-minute consultations are $50. Call Barbara Anglin at 508-732-9962 (extension 2) to schedule.

Mowing...

Mow correctly for a healthy, attractive lawn.

Proper mowing techniques help create a lush, dense lawn that is naturally resistant to drought, weeds and disease. This dramatically reduces the need for adding water and chemicals – saving you time and money while protecting the environment.

Mowing with a dull blade causes serious harm to your lawn, making it weak and susceptible to drought, weeds and disease. Many of us try to repair the damage by adding water, fertilizer, chemicals and pesticides. It's much easier on you, your wallet and the environment if you mow correctly and don't cause damage in the first place.

Mow with a sharp mower blade.

Dull blades rip and tear your lawn instead of cutting it, causing disease, serious stress and damage. Look closely at a blade of your grass – if the top edge is frayed and shows split ends, your blade is dull and causing damage to the grass. Learn the Thumb Test (see below) and whenever your blade is dull, switch to a spare sharpened blade. Be prepared to change your mower blade frequently by keeping the necessary wrench handy as well as a spare blade that is already sharpened. Most places that repair lawn mowers also sharpen blades and sell spares.

The Thumb Test.

Use this simple test every time you take out your mower to check your blade for sharpness. Before you start the mower, reach your hand under the deck and press your thumb on the cutting edge of the blade. The blade should be sharp enough to crease your skin; if it doesn't, switch the dull blade with a sharp one.

Mow frequently and not more than 1/3 of the height at once.

Frequent mowing results in an attractive lawn and causes the least stress to the grass. Mow often enough that you never remove more than an inch, otherwise you will shock your lawn and weaken its resistance to drought, weeds and disease. If the height of your lawn gets very long, cut it down to the proper height in stages, no more than 1/3 of the total height at a time.

Keep your grass 3 inches tall.

Taller grass has deeper, healthier roots. It is also denser and naturally crowds out weeds (especially crabgrass) and shades the soil so it retains moisture. When your grass is 3 1/2" (just taller than a credit card), mow it down to 3". The necessary mowing frequency will vary greatly through the season; it can even be different between your frontyard and backyard.

Use a mulching mower and leave grass clippings on the lawn.

Mulching mowers create fine grass clippings that break down and add nitrogen and organic matter to the soil. Grass clippings are approximately 85% water, so they decompose quickly and will not smother your lawn. Grass clippings are a free and easy way to provide the equivalent of one regular fertilizer application each year, and will not cause thatch (thatch is an indicator of too much fertilizer).

Mow when the lawn is dry.

If the lawn is wet, the mower blades can't cut the grass cleanly and you'll create an opportunity for disease to spread. Mowing a wet lawn also causes grass clippings to clump and decompose slower. It can also compact the soil and create ruts.

Better Grasses...

Fescue lawns are easier to care for.

Like a well-diversified stock portfolio, healthy lawns are comprised of a mixture of grass types. The predominant grass species in the lawn will determine the maintenance requirements that are necessary to keep the lawn healthy.

Not all lawns are created equal. The majority of lawns in southeastern Massachusetts are primarily comprised of bluegrass (90% of commercial "sod" is comprised of this species). Bluegrass requires lots of water to stay healthy. Bluegrass naturally turns brown and goes dormant when it doesn't get lots of water, which is typically every summer. When this happens, weeds and crabgrass take over — and many property owners spend countless hours and dollars hopelessly trying to fix the problem with water and chemicals.

In southeastern Massachusetts, lawns comprised of mostly "fescue" grasses (chewings, hard, creeping red, and sheep) are a better choice than bluegrass lawns. Fescue lawns are drought tolerant and insect-resistant, and will survive in sunny or shady areas. They are easier to maintain than other grass types because they require less water and fertilizer. An added benefit is that fescues are slow growing grasses, so they require less frequent mowing. They can also tolerate the slightly acidic soils that are common in this area.

Upgrade your lawn so it's greener and more drought-tolerant.

You will save time, money and the environment by upgrading your lawn to a mix of fescue grasses, and you will have a more beautiful lawn all year long. Make the switch by either overseeding or reseeding. Overseeding is very easy to do – in the fall (best time) or spring simply use a mechanical spreader to evenly scatter seeds over your existing lawn. Do this annually for best results.

If you have more weeds than grass, it may be better to clear everything out and re-seed in the early fall (fescue grasses are currently not available as sod). Reseeding will also give you the opportunity to add nutrient-rich topsoil to a depth of at least six inches, so your new lawn can have deep, strong roots.

Several manufacturers now carry fescue grass mixes – compare labels and buy the blend with the highest percentage purity and germination ratings. A good choice is "Cape Cod Mix" manufactured by the Massachusetts Nursery and Landscape Association, available at many local retailers. Also look for seed mixes that include beneficial fungi known as endophytes, which naturally help control leaf-feeding insects such as grubs.

Pesticide Alternatives...

Prevent your lawn from becoming a "drug addict."

It is a myth that pesticides (chemicals including insecticides, herbicides, and fungicides) are a mandatory part of landscape care. Pesticides are toxic substances that may pose a health risk to your family, pets and wildlife that ventures into your yard if they are overused or carelessly applied.

Recently, nearly 70 cities and towns in Canada have imposed restrictions and bans on the use of lawn and garden pesticides. This was due to mounting evidence that such chemicals may pose an unacceptable and unnecessary risk to humans and the environment. *(American Water Works Assoc. Journal, Feb. 2006)*

There is no such thing as a weed-free or insect-free lawn.

If you look closely at even the healthiest landscapes, you will see a complex blend of plants and insects. Finding a few weeds or insects in your lawn is not a cause for alarm.

Eliminating weeds and insects altogether is not realistic nor necessary for a beautiful lawn. Pesticides can disrupt the ecological balance of your landscape by killing the microbial life, earthworms, beneficial insects and birds that keep "bad" insects in check.

Don't be tempted to rely on pesticides as a quick-fix solution to landscape problems — most insect and weed problems are signs that your landscape is not getting what it needs.

The good news is pesticides are not necessary for a beautiful, low maintenance landscape. So why take the chance if you don't have to? By following the Greenscapes recommendations on this page and elsewhere in this Guide, you will be able to naturally control most insect and weed problems.

Reconsider your definition of "weed".

Although advertisements will try to convince you they are "weeds", plants such as clover and dandelion can be attractive and useful additions to a lawn. They add color and texture, feel great to walk on barefoot, and even provide your lawn with nutrients. Regular mowing will keep these plants from taking over your lawn and make them less attractive to bees.

Remember that a "weed" is defined as any plant that exists where you don't want it – consider accepting a variety of plants in your lawn, and you automatically won't have "weeds" at all!

Routine chemicals aren't necessary.

If you have been using a chemical program in the past (either do-it-yourself or lawn treatment service), you can stop and still have a beautiful lawn. You may initially experience an increase in weeds; however, this will change as the healthy grass crowds them out. Once restored, it is still important to replenish the soil nutrients. A lawn in transition may need more fertilizer (test your soil to find out for sure), but as your soil gets healthier, the fertilizer requirement will decrease.

Your best defense is your mower.

Taller grass (mowed to approximately 3") will help prevent weeds by shading out the competition. Be sure your mower blade is sharp or you will rip and tear the grass blades, which invites disease. See page 4 for more information.

If you have a few weeds, eliminate them before they spread.

Use the "ounce of prevention" approach to weeds – if you stop ten from developing, you won't have a million to deal with. Look for weed seedlings every time you mow and persistently eliminate them before they get a foothold and spread. Pull them out by hand using a weed fork, making sure to remove the whole plant and the long taproot. To treat recurring weeds, use a vinegar-based herbicide.

Prevent weed germination organically.

Corn gluten meal can help prevent weed seeds from germinating, particularly crabgrass. Corn gluten is a natural by-product of the wet milling process of corn. Follow the directions on the bag and apply to trouble areas in the early spring before the forsythia blooms (do not apply at the same time as grass seed). Corn gluten contains 10% nitrogen, so be careful to avoid over-fertilization (see page 6 for more information). Corn gluten may require up to three years of application to achieve maximium effectiveness.

Encourage natural predators.

Put up bird feeders and bat houses to attract natural predators of insects. Birds and bats in your yard will consume insects by the thousands and provide you with entertainment too. Attracting birds and bats will not increase the likelihood of them moving into your attic or wall spaces.

If insect problems persist, seek professional help.

Before spending money on insecticides, first improve your maintenance techniques by following the recommendations in this Guide. If you still suspect an insect problem, don't self-medicate! Instead, seek advice from a respected garden center or trusted landscape specialist and follow their instructions for selecting insecticides for a specific pest (*not* a broadcast control that could kill beneficial insects). Follow their recommendations for using organic controls such as insecticidal soaps, beneficial nematodes, and/or milky spore powder.

Dispose of unused pesticides wisely.

Pesticides (insecticides, herbicides, and fungicides) are considered "household hazardous waste". Due to their toxicity and potential to pollute water resources, **it is illegal to dispose of unwanted pesticides with the trash** and you must take them to a Household Hazardous Waste collection event. Residents may attend their own town's event at no charge (see schedule below), or you may attend another town's event with permission from your town's Recycling Coordinator. For more information, contact your Town Hall or the South Shore Recycling Cooperative at 508-785-8318 or **www.ssrc.info.**

HOUSEHOLD HAZARDOUS WASTE COLLECTION

Free disposal of unwanted pesticides, herbicides, fungicides and insecticides

4/8/06	Weymouth DPW, 120 Winter St.
4/22/06	Hanover Transfer Station, Rt. 139 (Hanover residents only)
4/29/06	Duxbury Middle School, St. George St. (with Kingston)
5/6/06	Plymouth DPW, 159 Camelot Dr.
5/20/06	Hingham — Plymouth River School
6/10/06	Cohasset / Hull — DCR lot, Rockland House Rd. @ G.W. Blvd., Hull

Fertilizing Alternatives...

Let nature provide the nutrients.

Fertilizers contain nitrogen, phosphorous, potassium, and other elements that help build strong roots and plants. But as the saying goes, too much of a good thing can be bad.

Many of us unknowingly waste time and money by putting too much of the wrong kind of fertilizer on our landscapes, often at the wrong times. This is partially because our soil is not properly balanced (that is, it's too acidic or alkaline) to allow plants to absorb the nutrients they need in the first place. Not only does your lawn and bank account suffer, but so does the environment.

Generally speaking, lawns need much less fertilizer than is advertised. Fertilizers that are not immediately absorbed by plants in our landscapes end up polluting our water through stormwater runoff. These excess nutrients either leach through the soil to the groundwater or they are washed by rain into stormdrains that lead to the nearest waterbody. These nutrients can contaminate our drinking water and cause rapid alga growth in ponds and bays. Alga blooms not only make swimming and boating unpleasant, but also block sunlight and deplete oxygen, killing fish and other animals.

Save time and money by following these helpful guidelines to provide your lawn with all the nutrients it needs to be healthy, beautiful, and easy to maintain.

Have your soil professionally tested.

The foundation of a Greenscapes lawn is balanced soil that is nutrient-rich. If your soil isn't healthy, your lawn and other plants aren't healthy. Find out your soil's pH and other characteristics by sending a sample to the soil lab at the University of Massachusetts (call 413-545-2311 or visit **www.umass.edu/plsoils/soiltest** for instructions). For a small fee, you will receive an analysis and recommendations for improving your soil. Some local nurseries also provide soil sample analyses.

Add lime if your soil is acidic.

Your soil's pH should be between 6.0 and 7.0 for a healthy lawn. Most landowners in southeastern Massachusetts will find that their soil's pH is below 7, which means it is acidic. Acidic soil is more hospitable to weeds than grass because it prevents nutrient absorption. Adding lime will remedy this problem. To raise your soil's pH one point, use a mechanical spreader to evenly broadcast 40 pounds

The NSRWA is a member of the *Think Blue Coalition*. See the *Think Blue* website for a calendar of free events.

of pelletized lime per 1000 square feet of grass (that's approximately 400 pounds for a quarter-acre lawn). Be sure to determine lime quantity by the lawn surface area, *not* the total acreage of your lot.

Leave grass clippings on the lawn.

Mulching mowers create fine grass clippings that will break down and add nitrogen and organic matter to the soil. Leaving grass clippings on the lawn over the season provides the equivalent of one regular fertilizer application, and will not cause thatch. Take advantage of this free natural fertilizer and let nature do the work!

Top dress with compost.

If your soil analysis shows that your lawn needs nutrients, a thin layer of compost (1/4" or less) will provide most of what your soil needs. Compost also adds organic materials that help the soil retain moisture. High-quality compost is available in nurseries by the bag or in bulk, or you can make your own. The best time to treat your lawn with compost is in the spring, by using a wheelbarrow, shovel and lawn rake. You will need about one cubic yard of compost per 1,500 to 2,000 square feet of lawn area. For more about composting, see page 7.

Aerate compacted turf.

If water puddles on high-use areas of your lawn, the soil may be compacted and need to be aerated. Aerating the lawn punches holes in the soil to allow air, water, and nutrients to reach the roots. You can rent a powered aerator from rental yards or large garden centers. Leave the small plugs of thatch and soil on your lawn and they will quickly decompose. The best time to aerate is in the early fall.

Clover is a free source of nutrients.

Dutch white clover is a beautiful low-growing, broadleaf species that used to be a welcome addition to many lawns. However, society's recent quest for the "perfect" lawn has changed this perception. White clover is a great addition to any Greenscape lawn because this hardy perennial smothers weeds, prevents erosion, retains moisture and builds fertility as it naturally "fixes" nitrogen in your soil. Clover is tough enough to withstand foot traffic and offers beautiful dark green foliage and small white flowers. If bees are a concern to your family, control the blooms with frequent mowing.

If necessary, use organic fertilizers.

If you follow the guidelines on this page, chances are your lawn already gets enough nutrients. However, if your soil test shows that you still need to add additional nutrients, choose an organic fertilizer as this will supplement your soil as well as "feed" your plants. Be sure to: (1) use an organic, slow-release, water-insoluble fertilizer at the recommended dose; (2) don't spread the fertilizer if heavy rain is predicted; (3) evenly distribute the fertilizer using a mechanical spreader at the lowest setting, going over the area two or three times; and (4) sweep up fertilizer that accidentally lands on paved surfaces.

Organic fertilizers and synthetic fertilizers are not the same.

Organic fertilizers are less concentrated, but have longer lasting benefits because they gradually release nutrients. Synthetic fertilizers are more concentrated which makes it is easier to overfertilize, burning the plant, and potentially harming soil organisms. Synthetic fertilizers also tend to be more water-soluble, leaching out of the soil faster and potentially polluting our water resources. Organic fertilizers offer an additional benefit of recycling waste that would otherwise contribute to pollution.

Composting...

Keep your landscape healthy by using compost.

The best way to raise healthy plants is to have healthy soil, and the best way to have healthy soil is to enrich it with high-quality compost. Using compost adds essential minerals and nutrients, improves soil structure, allows better root growth, and increases moisture and nutrient retention in the soil.

Composting is a controlled process of decomposition of organic material. Naturally occurring soil organisms (bacteria, fungi, molds, worm, insects) recycle nitrogen, potassium, phosphorus, and other plant nutrients as they convert the material into humus. The process of composting is simply a matter of providing the soil organisms with food, water, and oxygen – and letting them do the work.

Composting is easy!

Making your own compost has the additional benefits of reducing the volume of garbage to be landfilled, and saves you money on disposal costs and fertilizer purchases. As much as 50% of our household waste and nearly all of our landscape "waste" can be composted. Start by getting a bin from your garden center or town hall, or make your own using wire mesh or a trash can with holes drilled into the bottom.

The table below shows South Shore communities that offer compost bins at a reduced price for residents (around $20), subsidized by the MA Department of Environmental Protection. Please call the number listed to determine availability and sales information.

Once you have a bin, follow these four easy steps. Within a few months you'll have your own supply of what seasoned landscapers call "black gold". For more details about making compost, visit **www.mass.gov/dep/recycle.**

South Shore Towns that Sell Discounted Compost Bins	
Cohasset	781-383-0273
Hull	781-925-1207
Marshfield	781-834-5575
Norwell	781-659-2015
Plymouth	508-830-4166
Weymouth	781-337-5100

Step One: Add three parts "browns".

These are materials high in carbon, and include dried leaves, straw, salt marsh hay, shredded paper (cardboard, newspaper, paper towels, paper plates, paper bags), chipped brush, sawdust, used potting soil and pine needles (pine needles should not make up more than 10% of total material in the pile).

Step Two: Add one-part "greens".

These are materials high in nitrogen, and include grass clippings, green leaves, vegetable and fruit scraps, seaweed, eggshells, coffee grounds and filters, tea bags, and animal manure (NOT dog or cat). You can add weeds from your landscape, but do not add those that are invasive or have already gone to seed.

Step Three: Keep the pile aerated.

Compost critters need oxygen to do their work. Every time you add material to your pile, fluff and turnover the pile with a hoe or pitchfork. More aeration makes faster compost.

Step Four: Keep the pile damp.

If you hear dry material rustling when you aerate your pile, you need to add water. Only damp compost piles will decompose.

Liquid compost is another alternative.

High-quality, organic compost is also now available in liquid form, sometimes known as "compost tea". This easy-to-use brew of worm castings, oxygen, and other nutrients contains millions of critters and bacteria that enrich your soil.

Consider these other ways to recycle while you Greenscape.

Each year Americans send 24 million tons of lawn clippings, leaves and tree and shrub cuttings to landfills, taking up about 20% of our landfill space. Making your own compost out of recycled garden waste and kitchen scraps is a great way to enhance your Greenscape as well as protect the environment by keeping these materials out of our landfills.

When designing and maintaining your Greenscape, consider these other opportunities for helping to reduce, reuse and recycle:

- Chip woody waste and tree clippings into mulch.
- Use rubberized asphalt (made from recycled tires) for driveways, sidewalks, or walking paths.
- Select plastic lumber made from recycled bottles and bags for benches and other outdoor structures.
- Purchase patio blocks and lawn edging containing recovered plastic or postconsumer rubber.
- Use high-efficiency lighting for roadways, parking lots, security, and landscaping.
- Use solar powered lighting and signage.
- Buy hoses, tubing, trickle irrigation systems made from recovered plastic and old tires.
- Rent or borrow equipment instead of buying it.
- Use biobased cleaners and solvents to maintain equipment and recycle used oil and tires.
- Donate healthy plants to local non-profit organizations when redoing your landscape.

For more information about these and other recycling opportunities, visit the EPA GreenScapes website at **www.epa.gov/greenscapes.**

GreenScapes
Environmentally Beneficial Landscaping

Watering...

Water your lawn only when it's thirsty, but not if there is a watering ban.

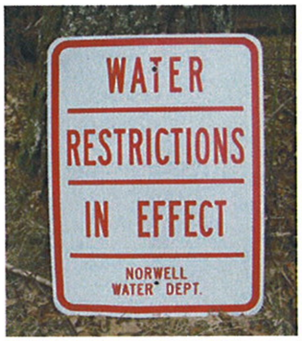
It is a mistake to believe that you can't over-water your lawn. Lawns that get too much water are weaker, and more susceptible to disease and "shallow root syndrome" (see below). Once the lawn suffers damage, many of us try to repair the problem by adding even more water and chemicals. This is harmful to you, your lawn and the environment.

Lawn irrigation can use a huge amount of water. Did you know that the typical garden hose at normal household pressure carries about 1900 gallons per hour? During the summer, some households in southeastern Massachusetts use nearly seven times more water for their lawns than they use inside their homes for consumption, flushing, bathing and all other indoor uses combined.

Timing is everything when it comes to watering your lawn efficiently with an automatic or manual sprinkler system. Proper timing is essential for a beautiful and healthy lawn, for saving you time and frustration, and for protecting our water.

Prevent your lawn from becoming a waterholic! Save yourself time, effort, and expense by watering correctly and training your lawn to be more drought-tolerant in the first place. Follow these guidelines to provide your lawn with the water it needs, without threatening the environment, public health or safety.

These tips are applicable to both traditional sprinkler users and those who have automatic irrigation systems. If you have an automatic system, there are additional guidelines on page 10 just for you!



Abide by local watering restrictions, even if you have a private well.

Water is our most precious natural resource. Towns spend large sums of our tax dollars finding sources of water and treating it to drinking quality standards. Our communities require adequate supplies at all times for human consumption and fire protection. In the summer months, this supply can be severely threatened because too much water is being used to irrigate lawns. This is why towns implement "watering bans" to restrict outdoor water use.

Private wells and municipal wells often draw from the same underground aquifers. Do your part to protect your community's water supply so there is enough for drinking and fire protection. People are more important than lawns – if your town has implemented a watering ban, be sure to comply with all regulations.

Don't know if there's a watering restriction in effect?

Call your Town Hall and find out. If you sign up for our free email newsletter, we'll let you know each month which communities have implemented watering bans. To sign up, send a blank email to: **greescapes-subscribe@lists.nsrwa.org.**

Water only between Memorial Day and Labor Day.

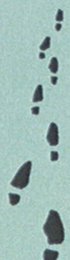
In southeastern Massachusetts during normal rainfall years, the only time that established lawns usually need to be watered is during the months of June, July, and August. Your lawn doesn't want extra water in a typical spring or fall because of the cooler weather, shorter days and increased rainfall. If you water when your lawn doesn't need it, you will cause it to be weaker and susceptible to disease.

Let your lawn tell you when it's thirsty.

Watering needs can't be determined by a clock or calendar, but rather by a combination of factors including grass type, soil type, drainage, and exposure to sun or shade. It's much better for your lawn and the environment if you learn to recognize its need for water by conducting the "Walk Test".

The Walk Test

Your lawn is thirsty if it can't stand up straight after being walked on. Test your lawn's posture by taking a walk across your lawn, then turning around to look for your footprints. If you can clearly see your footprints in the lawn, the grass is thirsty. If the grass pops up after you walk on it, it doesn't need water.



Different areas of lawn have different watering needs.

Various zones of your lawn have different drainage, soil types, and exposure to sun and wind, and therefore have different watering needs. Conduct the Walk Test in each area of your yard to determine if they are thirsty, and water accordingly.

The Shovel Test

Conduct this simple experiment to determine how long to run your sprinklers to saturate six inches of soil. Run your sprinklers for 20 minutes. Then use a shovel like a lever to open a gap in the soil. You will see that the wet soil is darker than dry soil. If the soil is not damp six inches down, replace the turf and keep watering. Repeat this process every 20 minutes. Record how long it takes for the water to reach six inches, so you will know how long you need to run the sprinklers in this area of your lawn. Different zones will have different watering needs at different times of year, so repeat this test around your yard as the seasons change (ideally around Memorial Day, July 4th and mid-August).

Water Facility Tours

Ever wonder how fresh, clean water gets to your tap? Join us for an Open House tour of Aquarion's water treatment facility and find out! Free tours will take place on August 5, 2006 and run approximately every half hour from 9 am to 3 pm. Kids can meet Thirsty the Penguin and enjoy free refreshments. The facility is located at 900 Main Street (Route 228) in Hingham, behind the House of Prayer Lutheran Church (same driveway). Reservations are not required but space is limited. For more information, visit:

www.aquarion.com/massachusetts.html

Water deeply to prevent "shallow root syndrome."

Deep watering will encourage grass to have strong, deep roots, whereas brief watering will promote shallow roots that are vulnerable to drought, disease, and traffic damage. Train your lawn to be stronger by soaking the soil to a depth of six inches every time you water (if you have that much soil). Use the Shovel Test or a soil moisture probe to find out how long it takes.

Water your lawn at dawn.

Once you know your lawn is thirsty and you know how much water to use, run your sprinklers at dawn. Watering at daybreak is about 10 times more effective and conserves water. If you are not an early riser or do not have a programmable automatic irrigation system, you can buy a simple affordable timer to attach to your faucet (see offer at right).

Don't water if it's going to rain.

If rain is predicted, don't waste time and money on irrigation. Too much water is harmful to your lawn and it wastes our water resources. Let Mother Nature do her thing and then wait until your lawn "tells" you it is thirsty when you do the Walk Test.

Water plants, not pavement.

Nothing is more wasteful than a sprinkler that waters the street or sidewalk. For manual systems, adjust the water pressure so the spray doesn't overshoot the lawn. In difficult-to-reach areas, use a sprinkler head with adjustable nozzles. For automatic systems, make sure sprinkler heads are at least 8 inches from paved areas. Avoid sprinklers that produce a fine mist that easily evaporates and blows off target.

Harvest rainwater with rainbarrels or cisterns.

The average roof will shed over 5,000 gallons of water during the summer months! Rainbarrels and cisterns collect clean rainwater from your roof so you can stockpile it when it's plentiful and use it later during a drought. Rainbarrels are great for watering small areas by hand (see offer at right) and cisterns can even be connected to an automatic irrigation system. For more about cisterns, see page 15.

Use in-line drip tubing for beds.

These tube systems can be easily installed in the spring and be hidden with a layer of mulch (the mulch also helps retain the moisture). These systems water the roots rather than the foliage, which is healthier for the plants.

SPECIAL OFFER!

RAINBARRELS SAVE $16!

Pre-order for just $69 (regular retail $85) by calling New England Rainbarrel at 978-977-3135. Pick up your rainbarrel on Saturday June 3rd at the NSRWA office (214 South St., Norwell).

SPECIAL OFFER!

SPRINKLER TIMERS SAVE $22!

Watering your lawn at dawn is the best time for the health of your landscape and to conserve water. A programmable sprinkler timer makes it simple. Get an Orbit™ digital timer for just $20 (model 62001, retail $42), thanks to a generous donation by Orbit Inc. Send NSRWA a check for $20 with the form on page 20.

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Automatic Irrigation Systems . . .

They don't have brains, only clocks.

When left on "automatic," irrigation systems can waste large quantities of water. A clock can't conduct the Walk Test, and has no way of knowing when your lawn is thirsty. Only YOU can determine when your lawn should be watered, not a clock.

Protect your lawn and your community's water by following the tips below for using your irrigation system responsibly. For more information, consult a certified irrigation specialist (find one near you by contacting the Irrigation Association at **www.irrigation.org** or 703-536-7080).

Come to a free workshop.

Want to learn more about controlling your automatic irrigation system from a certified specialist? Come to our free Greenscapes Workshop just for automatic irrigation system users on May 25 at the South Shore Voc. Tech. School in Hanover from 7-9 pm (see page 20 for more details).

Start with the right design.

Designing an irrigation system that is water-efficient is a specialized field that requires training and certification. If you care about conserving water, don't trust just anybody to do the job! A professional irrigation designer will evaluate your site conditions and prepare professional plans to meet the needs of your landscape, using the most efficient irrigation equipment available. If you plan to install a new automatic irrigation system, use a designer certified by the Irrigation Association.

Keep your system maintained.

Unbalanced sprinkler systems can waste water and harm your lawn. Repair leaks and broken heads immediately — they can waste more than 12 gallons a minute! Ensure the sprinkler heads are operating at the proper pressure by using heads with built-in pressure regulators. Proper maintenance will also increase the life of many irrigation components. The Irrigation Association has additional guidelines for irrigation system maintenance.

Have your system checked every 2-3 years.

A certified irrigation auditor will perform a series of tests and analyses, and then offer suggestions for changes in the irrigation design, installation or operation. Implementing these changes will save you money and headaches as well as resolve problems with turf hot spots, drooping shrubbery, swamping, and erosion. See special offer below.

The best setting for automatic irrigation systems is "off."

Don't trust the automatic timer. Program the system to run every morning at dawn, but keep it turned off until you need it. This will allow you to monitor your lawn and weather; and then make an active decision to irrigate. This is the easiest way to use your system responsibly and is how professional turf managers use irrigation systems. When you decide your lawn needs water, turn the system on before you go to bed. Be sure to turn it off the next morning so it won't automatically run again the next day. Remind yourself to turn your system off by putting a note next to your toothbrush or coffee mug until you have the habit.

Move your system controller to a place that is convenient for you.

If your controller is hidden in the back of the basement, it will be hard to remember to use it responsibly. Have it moved (this is not expensive to do) to a prominent place so it will be easier for you.

Install a "rain sensor" to prevent watering during rainfall.

You definitely need one of these because your watering cycle will take place at dawn, when you may be asleep. Make sure the sensors are not sheltered by a roof overhang or other obstruction. Soil moisture sensors are also available, but they must be installed in every irrigation zone and carefully calibrated – ask an irrigation specialist for more information.

Consider upgrading to underground drip irrigation.

Drip irrigation gets water directly to the roots (causing less disease and fewer weeds and insects) and uses about 25-30% less water than above-ground sprinklers. Converting to this new type of system is affordable and can be done without damaging the lawn. Routine audits and maintenance of these systems by a professional are particularly important since they are underground and cannot be seen. Ask an irrigation specialist if your lawn is a good candidate for this system.

Reuse rainwater for irrigation.

The average roof sheds more than 5000 gallons of water a year – you can capture that free water to irrigate your landscape by using a large cistern such as SmartStorm™ Rainwater Recovery System. This underground storage tank holds up to 2400 gallons and can be connected to your automatic irrigation system. Call the Charles River Watershed Association at 781-788-0007 (x 302) or visit crwa.org for more information.

For more information about maintaining your automatic irrigation system or finding a certified irrigation contractor, see **www.irrigation.org**

Planting Beds...

Want to eliminate lawn problems altogether?

Plant something instead of grass!

Beautiful landscapes don't have to have expansive lawns covering the entire property, or for that matter include any lawn at all. Replacing part of your lawn with low maintenance ground covers, planting beds, gardens, patios or walkways will add color and dimension to your landscape, while increasing your property value at the same time.

Chances are there are parts of your lawn that are giving you headaches, or perhaps parts that you really don't see or want in the first place. Sections of your lawn that might be better as something other than grass include areas where:

- weeds are taking over;
- the grass just won't survive, such as on a hill or shady spots;
- you can't see, such as behind the garage;
- it's really tough to take care of, such as on a slope, against the house or at the base of trees;
- you need privacy, such as the sides of the back yard; and/or
- you want more color and interest; such as opposite your favorite window.

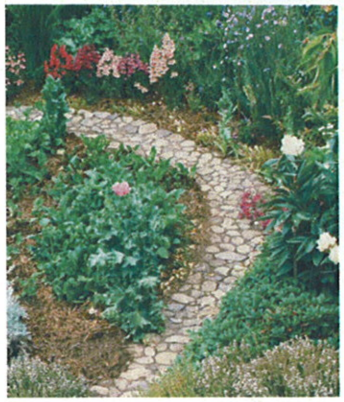
Almost any plant is easier to maintain than grass — especially shrubs, trees and some types of perennial flowers. By minimizing your lawn and maximizing your planting beds, you'll save time, money and the environment.

Create a design plan.

You can do this yourself or with help from software, garden centers, the Internet or a designer. A good design will save you time, energy and money in the long run. Your design should take into account the conditions of the site, existing vegetation, topography and intended uses of the property. Plan your work in phases to suit your resources.

Choose the best locations for beds.

Your first beds should be along the borders or in the center of the property to provide lawn areas with visual contrast. Concentrate beds on the focal points of the yard, which are usually towards the entrance of the house and opposite the most-used windows. When choosing plants for the beds, consider the plants' light and water requirements and preferred soil conditions, and group the plants together according to these needs.



Choose the right plants.

Select low-maintenance, drought-tolerant shrubs, trees, perennials, and groundcovers (see page 12-14). When selecting plants, be aware of prevailing conditions in various areas of your yard (hot/sunny, cool/shady, moist/dry). Avoid invasive species or high-maintenance plants that need lots of chemicals and water to survive. See **www.mnla.com** for more information about invasive species in Massachusetts or visit the New England Wildflower Society at **www.newfs.org**.

Lay out, dig and plant the new beds.

Creating planting beds isn't back-breaking work. Just follow these simple steps:

1. Lay out the bed's shape with a garden hose. Curves look great and are easy to mow around.
2. Paint along the line with "athletic field" paint and remove the hose.
3. Cut and dig a new edge 4" deep and 6" wide along the painted line.
4. Remove the grass inside the edge with a shallow spade (put the unwanted turf in your compost bin) or you can slowly kill it by covering with a sheet of plastic for several weeks.
5. Plant as directed, mixing compost with the soil.
6. Add mulch to help retain moisture.
7. Water the new plants as instructed, until they are well established.

Plant in "masses" and "layers" for impact and easy care.

Plant only special or "specimen" plants by themselves. All the rest should be in groups of at least three. Arrange plants in layers of differing heights, with short ones in the foreground and higher in the rear. Plant closely enough to squeeze out the weeds without maintenance. Clustering plants with similar care requirements will save you time and limit watering needs.

Use mulch and ground covers.

Mulches and ground covers can be a Greenscaper's best friend, particularly in the areas under trees and bushes where grass won't grow but weeds will. Mulch is very beneficial to plants and soil because it helps retain water, minimize evaporation, inhibit weed growth, moderate soil temperature and prevent erosion. Organic mulches also improve the condition of your soil as they decompose. You can use wood bark chips, pine straw, nut shells, shredded leaves or composted grass clippings.

Low Maintenance Plants...

All plants listed below are drought-tolerant and require little maintenance once established. Plants marked with an asterisk * are native to New England. Please note that all plants require supplemental watering during the establishment period. This is just a sampling of beautiful, low-maintenance plants — ask a trusted landscape professional for more recommendations or visit our website (**www.Greenscapes.org**) for additional information.

Perennials

Sedum Autumn Joy (*Sedum x* 'Autumn Joy') A well-known favorite that attracts butterflies. Flower heads form in mid-summer and look like broccoli until they turning pink as the summer progresses. Flowers are a deeper rusty-red in the fall.

Sedum Autumn Joy

Moonbeam Coreopsis (*Coreopsis verticillata*)* Clusters of light yellow, daisy-like blooms with green airy fern-like foliage. Blooms from June through October and is mildew resistant. Stands 24" tall and spreads 18-24" wide. Perennial of the Year in 1992.

Moonbeam Coreopsis

Liatris

Black-eyed Susan (*Rudbeckia fulgida* 'Goldsturm') 2-3' tall gold-petaled, black-centered, daisy-type flowers bloom continuously from August to October. Seed heads are attractive to birds. Named Perennial Plant of the Year in 1999.

Black-eyed Susan

Stella D'oro Daylilly (*Hemerocallis*) One of the finest dwarf daylilies available. Outstanding masses of bright, golden-yellow flowers appear all summer. First flowers appear in May and repeat every few weeks into fall.

Stella D'oro Daylily

Liatris (*Liatris species*)* A robust and striking perennial also known as Blazing Star and Gayfeather. This attractive plant has an interesting vertical spike of purplish-pink or white flowers. Excellent flower for cutting and drying. Attracts butterflies and hummingbirds.

Purple Dome New England Aster (*Aster novae-angliae* 'Purple Dome')* Compact aster with dark green foliage and profuse bloom of dark purple flowers (up to 1.5" across) which can entirely cover the plant from mid-August until early October. Attractive to butterflies.

Purple Dome New England Aster

Purple Coneflower (*Echincea purpurea*)* 2-3' tall, stunning purple-pink flowers (also available in white) with orange centers that resemble large daisies, and are great for cutting. Attracts butterflies; seed heads are good food source for birds. Named Perennial Plant of the Year in 1998.

Purple Coneflower

Ornamental Grasses

Tall Switchgrass *(Panicum virgatum)** This prairie native stands 4-8' tall and has sturdy erect stems that flower in airy panicles to create a cloud-like effect. Many good cultivars available, including 'Heavy Metal', 'North Wind', and 'Shenandoah'.

Tall Switchgrass

Little Bluestem *(Schizachyrium scoparium)** Clump forming grass growing from 2-4' tall. Summer color is green to blue green, with pinkish-tan fall color. Best in full sun and poor soils for massing or as a groundcover.

Little Bluestem

Feather Reed Grass *(Calamagrostis x acutiflora 'Karl Foerster')* A medium sized grass with upright foliage, very carefree and versatile. Buff-colored plumes bloom early (June-July), has sterile seeds. Tolerates clay soils. Perennial Plant of 2001.

Feather Reed Grass

Shrubs

American Cranberry Viburnum *(Viburnum trilobum)** Tall (8'-10') deciduous shrub with maple shaped leaves and red berries. Sun or medium shade. Good red fall color.

American Cranberry Viburnum

Fothergilla

Virginia Sweetspire *(Itea virginica)** Deciduous 3-5' shrub with white flowers in June-July and purplish red fall foliage. Grows in sun or shade. Itea 'Henry's Garnet' is also an excellent selection.

Virginia Sweetspire

Fothergilla *(Fothergilla species)** Spectacular interest throughout the seasons. Small, white, honey-scented flowers on upright spikes in the spring. Summer foliage varies from dark green to blue green; fall leaf color ranges from yellow to orange to red.

Winterberry *(Ilex verticillata)** Small rounded shrub with 3-4 inch light green leaves turning yellowish-red in autumn. Striking pinkish fruit opening to uncover the vivid orange seeds that are food for wildlife. Tolerant of drought and a wide range of soil types.

Butterfly Bush *(Buddleia davidii)* Large, fast-growing shrub with arching branches and long panicles of showy summer flowers in pink, purple, white, or orange. Especially attractive to butterflies.

Butterfly Bush

Winterberry

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Groundcovers

Creeping Mazus (*Mazus repens*) Great alternative to grass, however, not suitable for heavy foot-traffic. Low-growing plant has creeping and spreading habit. Semi-evergreen, oval shaped leaves. Attractive, small purple blooms in the late spring.


Creeping Mazus

Bearberry (*Arctostaphyllis uva ursi*)* Creeping native groundcover that grows 6-12" tall, with glossy evergreen foliage that forms broad mats up to 15' wide. Red berries in July and August. This slow growing shrub provides food for wildlife.


Bearberry

Barren Strawberry (*Waldsteinia fragarioides*)* An ornamental, strawberry-like plant that may be used in a variety of landscape situations, including slopes. Drought tolerant. Foliage is evergreen, but will turn brown-bronze in cold winters.


Barren Strawberry

Allegheny Spurge Pachysandra (*Pachysandra procumbens*)* An attractive native pachysandra that does well in shade to partial shade. Most winters it is deciduous.


Allegheny Spurge Pachysandra

Deciduous Trees

Kousa Dogwood (*Cornus kousa*) Beautiful white flowers in June; large raspberry-like fruit in late summer. Interesting, exfoliating bark. Resistant to dogwood anthracnose and dogwood borer. Cultivar 'Rosabella' has deep rose-pink flowers.


Kousa Dogwood

Gingko tree (*Gingko biloba*)* Large shade tree, 50-80' at maturity, tolerant of dry conditions and pollution. Spectacular yellow fall foliage. One of oldest trees, growing on earth for 150 million years.


Gingko tree

Eastern Red Cedar (*Juniperus virgininiana*)* Handsome native evergreen with light blue berries that attract wildlife. Excellent as a specimen and useful in masses for windbreaks and screening. Also salt tolerant.


Eastern Red Cedar

Donald Wyman Crabapple (*Malus* 'Donald Wyman') A disease-resistant crabapple that grows 20-25' tall. Small red fruit attractive to birds. Interesting bark as it matures.


Donald Wyman Crabapple

Managing Stormwater...

Make rain an asset, not a problem.

Reduce and reuse stormwater runoff.

We all need clean water to drink. We also want to have plentiful, clean water in our ponds, rivers, and bays so we can enjoy activities such as swimming, boating, fishing, and nature watching. But what does that have to do with how we design and maintain our landscapes? In many ways, our landscapes are connected to our aquifers, ponds, rivers, and bays by water.

In an unaltered forested landscape, 99% of rainfall seeps (recharges) into the ground, gets absorbed by plants, or evaporates as nature intends. As we build communities to support our growing population, the natural hydrologic cycle is altered as forestland is replaced with hard (impervious) surfaces such as roads, roofs, driveways, and lawns that prevent rainfall from seeping into the soil below. Instead, most stormwater runs off these impervious surfaces and into stormdrains that discharge into the nearest body of water. Runoff from developed areas is dirtier and in much greater volume than runoff from natural areas, and can cause serious environmental problems such as flooding, erosion, water pollution, and loss of groundwater recharge and habitat.

Typical suburban lawns are a contributor to these problems because the compacted soils underneath prevent significant rainwater from recharging our ponds, rivers, and aquifers. When storms or hyperactive sprinklers give the landscape more water than it can absorb, it runs off our lawns and carries pollutants and high water volumes into our local bodies of water, causing damage.

This section of the Guide provides suggestions for reducing and reusing stormwater, so it becomes an asset to your property instead of a problem to the environment.

Maximize natural areas.

The easiest way to protect water quality and reduce the quantity of runoff is to keep part of your landscape in its natural condition. If you have a large lot, consider letting part of it revert to woodland. If you are planning new construction, set aside a portion of the lot for a natural area. This has the added benefit of preserving habitat for wildlife.

Limit paved surfaces.

Paved surfaces keep rain from seeping into the ground. Consider using porous materials instead, such as permeable pavers, mulch, stone, or shell. There are even porous versions of asphalt and concrete that perform great and look much like the regular material. For more information about these and other innovative technologies, visit the Massachusetts Low Impact Development website: **www.mass.gov/envir/lid**.

Redirect runoff from your roof and driveway.

Most driveways and sidewalks are designed to whisk water away from your property, usually onto the street where it gets channeled down stormdrains that lead to the nearest body of water. You can redirect this water to let it recharge into the ground instead. Extend or move your downspouts so they drain into French drains (holes filled with gravel), or vegetated areas such as a grassy swale (depression) or rain garden (see page 16). If redesigning or constructing a new driveway, slope it to drain onto a vegetated area rather than the street.

Create vegetated buffers along bodies of water.

Buffers of shrubs and trees along rivers, streams and ponds will protect water quality, recreational resources, wildlife habitat and property values. These plants will intercept and filter excess chemicals and eroded soil before they pollute the water resource. An ideal vegetated buffer is at least 100 feet wide, and includes bushes such as winterberry, elder berry, high bush blueberry, and trees such as cottonwood, black willow, and red maple. For more information about vegetated buffers, see **www.crjc.org/riparianbuffers.htm**. Landscaping projects within 200 feet of a river or 100 feet of a wetland may be subject to regulation by your local Conservation Commission. Contact your town's Conservation Department for more information.

Consider green roofs.

Vegetated green roofs consist of a layer of lightweight soil and low-growing, drought-tolerant plants on top of traditional roofing materials. Green roofs are used extensively in Europe to save energy and reduce stormwater runoff. Locally, they can be seen in Massachusetts at Boston City Hall, the World Trade Center in South Boston, and the new Ikea in Stoughton. The fourth annual Greening Rooftops for Sustainable Communities Conference is in Boston this year, on May 10-12. For more information, visit **www.greenroofs.org**.

Install rainbarrels or cisterns.

The average roof will shed over 5,000 gallons of water during the summer months! Rainbarrels allow you to collect rainwater from your roof and reuse it to water your landscape. Save more than pennies on a rainy day – get your own rainbarrel at a significant cost savings and help support the Greenscapes program too (see page 9). For more information, call New England Rainbarrel at 978-977-3135.

Another alternative is SmartStorm™, an underground cistern that captures up to 2400 gallons of clean rooftop runoff and stores it for irrigation. As an added benefit, excess water is sent to a drywell and recharged into groundwater supplies.

Photo: Charles River Watershed Association

For more information about these and other innovative technologies for managing stormwater, visit the MA Low Impact Development website: www.mass/gov/envir/lid.

Rain Gardens...

A beautiful way to clean and recycle stormwater.

A rain garden is a bowl-shaped garden designed to collect and absorb runoff from a roof or parking lot. Rain gardens are constructed by filling a basin in a low-lying area with a special soil blend, hearty plants, mulch and sometimes a layer of gravel.

Why should I make a rain garden?

By capturing runoff, raingardens prevent polluted stormwater from going down the storm drain and out to our rivers, ponds and bays. Rain gardens also help replenish our aquifers and groundwater-fed rivers and ponds by recharging rainwater into the ground rather than down the stormdrains. In fact, rain gardens absorb 30% more water than the same size area of lawn!

Create your own rain garden.

Follow these seven easy steps to make your very own rain garden. More detailed instructions and plans can be found at **www.raingardens.org** or **www.raingardennetwork.com.**

1) Choose a location. Pick a site for your garden that tends to collect water or where runoff from your driveway or downspout can be diverted into it. Your raingarden should be at least 10 feet away from building foundations, underground utilities, and septic system drainfields. Keep a 1-2 foot grass buffer between any downspouts and your garden to prevent washout.

2) Measure your garden. Your rain garden should be 20-30% of the drainage area it is treating. So, if you are treating runoff from your 1000 ft^2 driveway, you want a 200-300 ft^2 garden. Rain gardens are versatile – they can be any shape you want, from a regular rectangle to an amorphous blob. It should be graded slightly so water flows towards the center, about six inches lower in the center than the edges.

3) Check the drainage. It is important that your rain garden drains quickly. Determine if water can infiltrate fast enough by digging a hole approximately 8 inches deep and pouring in a few inches of water. If the water drains slower than an inch an hour, you will need to add a layer of gravel to the bottom of your raingarden (at least 6 inches).

4) Prepare your soil. Soils on the South Shore tend to be sandy, which is good because most can simply be improved by loosening them and mixing them with some compost. The ideal soil is a mix of two parts sand, one part topsoil (no clay), and one part compost. Loosen the soil to a depth of 2 feet.

5) Choose your plants. Select a variety of native, low-maintenance flowers and grasses that will provide color and interest throughout the seasons and can tolerate both wet and dry conditions (remember the rain garden will fill with rainwater periodically). Consider light and water preferences of the plants – some will thrive in sun, others shade; some prefer the drier edges of the garden, others may thrive in the soggy center. Group the plants together for the most impact, and estimate one small plant per square foot. Use our suggested raingarden plan or see **www.raingardens.org** for more designs.

6) Plant your garden. This is the fun part. You may want to create a grid of string if you are following a gridded plan. Remove each plant from its pot, break up the root ball slightly, and gently press it into its designated location. Be careful not to walk on the prepared soil or you will compact it. Once all your plants are in their new home, give your garden a good drink of water.

7) Add mulch. A 2-3 inch layer of shredded hardwood mulch is necessary to keep the soil moist and ready to soak up rain, and it helps reduce weeds. Chipped bark mulch tends to float when flooded.

Caring for your garden.

For the first two or three weeks, water plants about every other day until they show they are growing and doing well. After they are well-established with deep roots, they won't need additional watering. Keep the garden free of debris that might affect drainage and weeds that could overtake it. If there are parts of the garden that seem to be eroding from too much flow, use stones to divert and spread out the water entering the garden.

What about mosquitoes?

Mosquitoes won't find rain gardens to be good breeding areas because if a rain garden is properly constructed the water will drain within 24 hours (but usually within an hour or two). The Culex mosquito, the primary variety that transmits West Nile virus to humans, prefers to breed in small containers of water that remain stagnant for at least 10 days at a time.

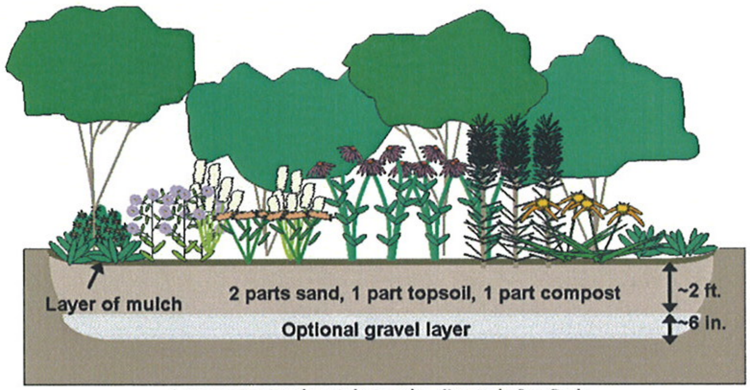
Demonstration rain garden at Lily Pond Water Treatment Plant, 339 King Street in Cohasset. Project designed by Mike Clark, Norfolk Ram Group.

Visit a rain garden.

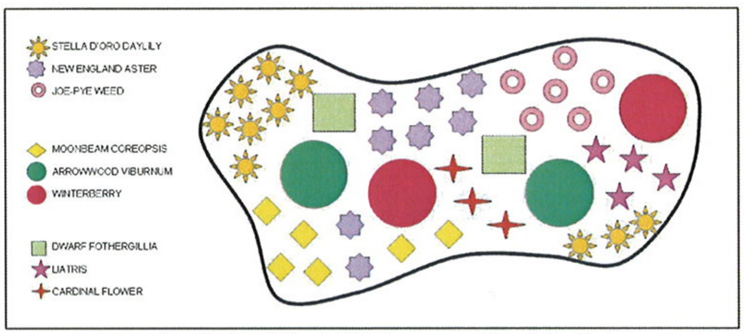
There are lots of public places on the South Shore where you see rain gardens in action! In Cohasset, visit the Water Treatment Plant at 339 King Street or one of many small rain gardens along Pond Street, Arrowwood Street, Evergreen Lane and King Street. There is another at the Marshfield Town Hall parking lot (870 Moraine Street), built by local high school students. In front of Plymouth Town Hall (11 Lincoln Street) there are two "container" rain gardens and another at Stephen's Field just around the corner. In Scituate, there is one at the High School (by the playground) and another just before the end of Hughey Rd.

Adopt a rain garden.

Looking for a great community-service project? The NSRWA was recently awarded a grant from the Environmental Protection Agency to construct rain garden demonstration sites in South Shore communities and we need your help! We need suggestions for places to build these rain gardens so that they are highly visible and publicly accessible, as well as volunteers to help plan, construct and maintain the rain gardens. We are also seeking donations of materials such as gravel, soil and plants. If you would like to be a part of this two-year project, please contact NSRWA's Watershed Ecologist, Sara Grady at sara@nsrwa.org or 781-659-8168.



A cross-section view of a typical rain garden. Drawing by Sara Grady.



A sample rain garden layout suitable for sunny areas. Design by Sara Grady.

Suggested Rain Garden Plants for the South Shore

COMMON NAME	SPECIES NAME	LIGHT NEEDS	OTHER BENEFITS
Blazing star	*Liatris spicata*	Sun	Attracts butterflies
Purple coneflower	*Echinacea purpurea*	Sun	Seed heads provides food for wildlife
Moonbeam coreopsis	*Coreopsis verticillata*	Sun	Attracts butterflies
Sedums	*Sedum spp.*	Sun	Good ground cover
Winterberry holly	*Ilex verticillata*	Sun/partial shade	Food, shelter for wildlife
Dwarf fothergilla	*Fothergilla gardenii*	Sun/partial shade	Spectacular fall color
Lowbush blueberry	*Vaccinium angustifolium*	Sun/partial shade	Food for wildlife
New England aster	*Aster novaeangliae*	Sun/partial shade	Attracts butterflies
Daylilies	*Hemerocallis spp.*	Sun/shade	Good ground cover
Joe-pye weed	*Eupatorium maculatum*	Sun/shade	Attracts butterflies
Arrowwood viburnum	*Viburnum dentatum*	Sun/shade	Shelter for wildlife, attracts butterflies

Greenscapes Lawn Care Calendar

Early Spring (March-April)

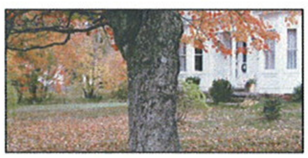
- ❑ Test soil
- ❑ Add compost, lime and other soil amendments if test indicates
- ❑ Start new compost bin/pile
- ❑ Remove leaves and add to compost bin
- ❑ Rake to remove thatch buildup
- ❑ Apply corn gluten for crabgrass control (do not apply same time as seeding)
- ❑ Re-seed bare patches and top dress with compost
- ❑ Conduct Thumb Test; sharpen mower blade and reset height to 3 inches
- ❑ Leave clippings on the lawn
- ❑ No need to water in average years

Late Spring (May-June)

- ❑ Attend FREE Greenscapes Workshops Thursday evenings in May (see pg. 20)
- ❑ Continue to conduct Thumb Test; sharpen mower blade and reset height to 3 inches
- ❑ Pull weeds by hand or treat with vinegar
- ❑ Re-seed bare spots, top dress with 1/4 inch compost
- ❑ Leave clippings behind
- ❑ Before Memorial Day, no need to water in average years
- ❑ Around Memorial Day, conduct Shovel Test to determine watering times
- ❑ After Memorial Day, conduct Walk Test and water if thirsty (but only if no drought)
- ❑ Aerate and water compost pile

Summer (July-August)

- ❑ Redo Shovel Test around July 4th & mid-August
- ❑ Enter Greenscapes contest by August 1st
- ❑ Continue to conduct Thumb Test; sharpen mower blade and reset height to 3 inches
- ❑ Leave clippings behind
- ❑ If grubs, treat with milky spore or beneficial nematodes
- ❑ Routinely conduct Walk Test and water if thirsty (but only if no drought)
- ❑ Continue to pull weeds or treat with vinegar herbicide
- ❑ Allow grass to go dormant during drought
- ❑ Aerate and water compost pile



Fall (September-October)

- ❑ Best time to start or renovate lawn
- ❑ Continue to conduct Thumb Test; sharpen mower blade and reset height to 3 inches
- ❑ Leave clippings behind
- ❑ Until Labor Day, conduct Walk Test and water if thirsty (but only if no drought)
- ❑ After Labor Day, no need to water in average years
- ❑ Apply corn gluten to control next year's crabgrass (do not apply same time as seeding)
- ❑ Overseed with drought-tolerant grass seed
- ❑ Top-dress lawn with 1/4 inch of compost
- ❑ Aerate compacted areas
- ❑ Rake leaves; use as mulch and/or add to compost pile
- ❑ Call Town Hall to thank them for supporting the Greenscapes program!

2006 Greenscapes Contest and Tour

Show the South Shore your fabulous Greenscape – you could win fame and fortune!

Winning Greenscapes will:

- help protect our water
- look great and enhance the surrounding area
- show creativity
- be easy to maintain
- be awarded with recognition and prizes!

To qualify, your Greenscape must:

- be in a community participating* in the 2006 Greenscapes program
- be at least partially visible from a public street
- implement at least five Greenscapes principles
- display a free Greenscapes lawn sign (see page 3)

How To Enter

Please submit the following by August 1, 2006:
1. Three color photographs of your landscape (at least one showing your free Greenscapes lawn sign).
2. A short narrative (up to 150 words) describing how your Greenscape helps protect our water.
3. A list of five Greenscapes principles that your landscape demonstrates. If you practice more than five principles, please only list the top five.

Entries may be submitted electronically or by mail (must be postmarked by August 1, 2006). Include your name, mailing address, the physical address of your Greenscape, telephone and email address. Send your entry to either **greenscapes@nsrwa.org** or to NSRWA, P.O. Box 43, Norwell MA 02360. Entries will be reviewed by a panel of landscape experts and Greenscapes program partners. Winners will be announced by August 15, 2006. Submitted photos and essays become property of the NSRWA and may be used for promotional purposes.

Prizes

The top three entries will receive gift certificates worth $200, $100 and $50 and may be showcased on the NSRWA 2006 House Tour on September 10, 2006. At the discretion of the winners, NSRWA House Tour participants may view the winning landscapes either from the street or by walking the property.

* 2006 Greenscapes communities include: Cohasset, Duxbury, Hanover, Hingham, Hull, Kingston, Marshfield, Norwell, Pembroke, Plymouth, Scituate, The Pinehills and Weymouth.

Help protect our water.

Southeastern Massachusetts is one of the most beautiful places in the country and is rich in biological diversity. However, it is also one of the fastest growing regions in the state and faces tremendous development pressures. The best way to protect our region's vital natural resources is to understand and manage them on a watershed basis. Watershed management is an effective and efficient way to sustain the local economy, public health, and environmental health too.

What is a watershed?

A watershed is a geographical area of land that drains into a variety of water bodies (rivers, streams, springs, lakes, ponds, swamps, wetlands, estuaries, coastal bays, underlying aquifers and oceans). Rainwater, melting snow and landscape irrigation runs downhill towards these water bodies and carry along a variety of pollutants, such as sediments, nutrients, minerals and dissolved materials.

Why are watersheds important?

Watersheds are the places we call home, where we work, and where we play. Everyone lives in a watershed and is part of a watershed community, including animals, birds and fish. Each of us influences the quality of life in your watershed by how you treat the natural resources – soil, water, air, plants and animals. What happens in a small watershed also affects the larger watershed downstream.

Healthy watersheds are vital for a healthy environment and economy. Our watersheds provide water for drinking, irrigation and industry. Many people also enjoy lakes and streams for their beauty and for boating, fishing and swimming. Wildlife also need healthy watersheds for food and shelter.

What else can I do?

Greenscaping is just one way to help protect your watershed. There are many other things that individuals can do, many of which require very little effort. Believe it or not, little things such as keeping your vehicle maintained, picking up after your dog, and pumping out your septic system on a regular basis will all help keep our water resources clean. Becoming a member of your local watershed association is a great way to learn more about these issues, get involved, and help these non-profit organizations achieve their mission. For more information, contact the watershed association nearest you.

NSRWA

The North and South Rivers Watershed Association, Inc. is a nonprofit grassroots environmental organization on the South Shore of Massachusetts. The mission of the NSRWA is to preserve, restore, maintain and conserve in their natural state, the waters and related natural resources within the watershed. The NSRWA was founded in 1970 and has grown to over 1,500 members today. Please visit **www.nsrwa.org** for information about our programs, events and membership. The NSRWA is the South Shore regional partner of the Massachusetts Bays National Estuary Program (**www.massbays.org**).

Other South Shore Watershed Associations:

Billington Sea Watershed Association
196 Black Cat Road, Plymouth, MA 02360
JSimpson@cssi-tlo.com

Eel River Watershed Association
52 Clifford Road, Plymouth, MA 02360
www.eelriverwatershed.org

First Herring Brook Watershed Initiative
150 Old Oaken Bucket Road, Scituate, MA 02066
www.fhbwi.org

Gulf Association
P.O. Box 140, North Scituate, MA 02066

Jones River Watershed Association
P.O. Box 73, Kingston, MA 02364
www.JonesRiver.org

Massachusetts Bays Estuary Association
99 Derby Street Suite 200, Hingham, MA 02043
www.massachusettsbays.org

Pembroke Watershed Association
P.O. Box 368, Pembroke, MA 02359
www.pembrokeponds.org

Six Ponds Improvement Association
725 Long Pond Road, Plymouth, MA 02360
www.sixponds.org

Watershed Action Alliance
P.O. Box 75, Kingston, MA 02364
www.watershedaction.org

Weir River Watershed Association
P.O. Box 1112, Hull, MA 02045
www.weirriver.org

View of the North River from Blueberry Island in Marshfield. Photo by Brian Sugarman.

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Free Greenscapes Workshops

May 4, 2006
Recycling Rainwater and Creating Raingardens
Mike Clark (Norfolk Ram Group) and Sally Coyle (Coyle & Caron)

Impervious surfaces such as rooftops and driveways shed rainwater often containing sediments and chemicals that eventually pollute our streams, ponds, and bays. Learn about creative landscaping methods that will help filter pollutants as well as recharge rainwater into the ground. Learn step-by-step how to create your own backyard raingarden. Other topics include porous pavers, rainbarrels, cisterns and vegetated roofs.

May 11, 2006
Easy Composting for Healthy Landscapes
Ann McGovern, MA Dept. of Environmental Protection

Would you like to enrich your soil while getting rid of nearly half of your household garbage at the same time? Using high quality compost eliminates the need for synthetic fertilizers and pesticides in our lawns, gardens and landscapes. Learn the basics of composting with different types of bins and how compost can eliminate the need for chemical fertilizers and pesticides in your yard and garden. Ann will also present other ways to reduce, reuse and recycle in your landscape.

May 18, 2006
Sustainable Plants for Sustainable Landscapes
Deborah Swanson, Plymouth County Extension

Learn how to choose sustainable plants that will provide beauty, reduce pesticide usage, conserve water, enhance wildlife habitat and tolerate environmental stresses. Topics include native plants, low maintenance ground covers, herbaceous perennials, ornamental grasses and trees and shrubs. This is an encore presentation from last year's series with some new information.

May 25, 2006
Take Control of Your Irrigation System
Ted Moriarty, Smart Watering Company

Irrigation systems abound on the South Shore, but many of us do not know how to use or maintain them properly. This can lead to water overuse which can hurt your landscape and our environment. Irrigation systems can help conserve water when designed, maintained and used properly. Learn maintenance and troubleshooting techniques, and water conservation strategies.

All workshops will be held at the South Shore Vocational Technical High School in Hanover. From Route 3, take Exit 13 and head north on Route 53. At the first traffic light, turn left on Route 123 West. The school is approximately one mile on your left. The Lecture Hall is in the right wing of the building.

Registration is required as space is limited. Register online at **www.greenscapes.org** or mail us the registration form.

Please note: You will not receive tickets nor confirmation for the workshops, however we will contact you if space is not available. Your name will be on a list at the door. You must arrive 15 minutes early to claim your seat.

Greenscapes Registration Form

Mail to NSRWA, P.O. Box 43, Norwell MA 02061 or register online at **www.Greenscapes.org**

Name: ______

Street: ______

City/Zip: ______

Phone: ______

☐ **FREE EMAIL NEWSLETTER** (see pg. 3)
Please sign me up. My email address is: ______

☐ **FREE LAWN SIGN** (see pg. 3)
Please send me a free Greenscapes Lawn Sign. I pledge to practice at least five Greenscapes principles.

☐ **FREE WORKSHOP SERIES** (see pg. 20)
I will be attending the following workshops:

# in your party	Date	Topic
______	May 4	Raingardens
______	May 11	Composting
______	May 18	Plants
______	May 25	Irrigation

☐ **SPRINKLER TIMER** (see pg. 9)
Please send me a programmable sprinkler timer. Enclosed is my check to "NSRWA" for $20.

☐ **GREENSCAPES CONSULT** (see pg. 3)
Please contact me to schedule a private Greenscapes consultation on my property. I understand there will be a $75 fee for this service.

☐ **IRRIGATION SYSTEM CHECK** (see pg. 10)
Please contact me to schedule a consultation. I understand there will be a fee for this service.

☐ **2005 WORKSHOPS ON DVD** (see pg. 20)
Please send me the 4-volume set. Enclosed is my check to "NSRWA" for $20.

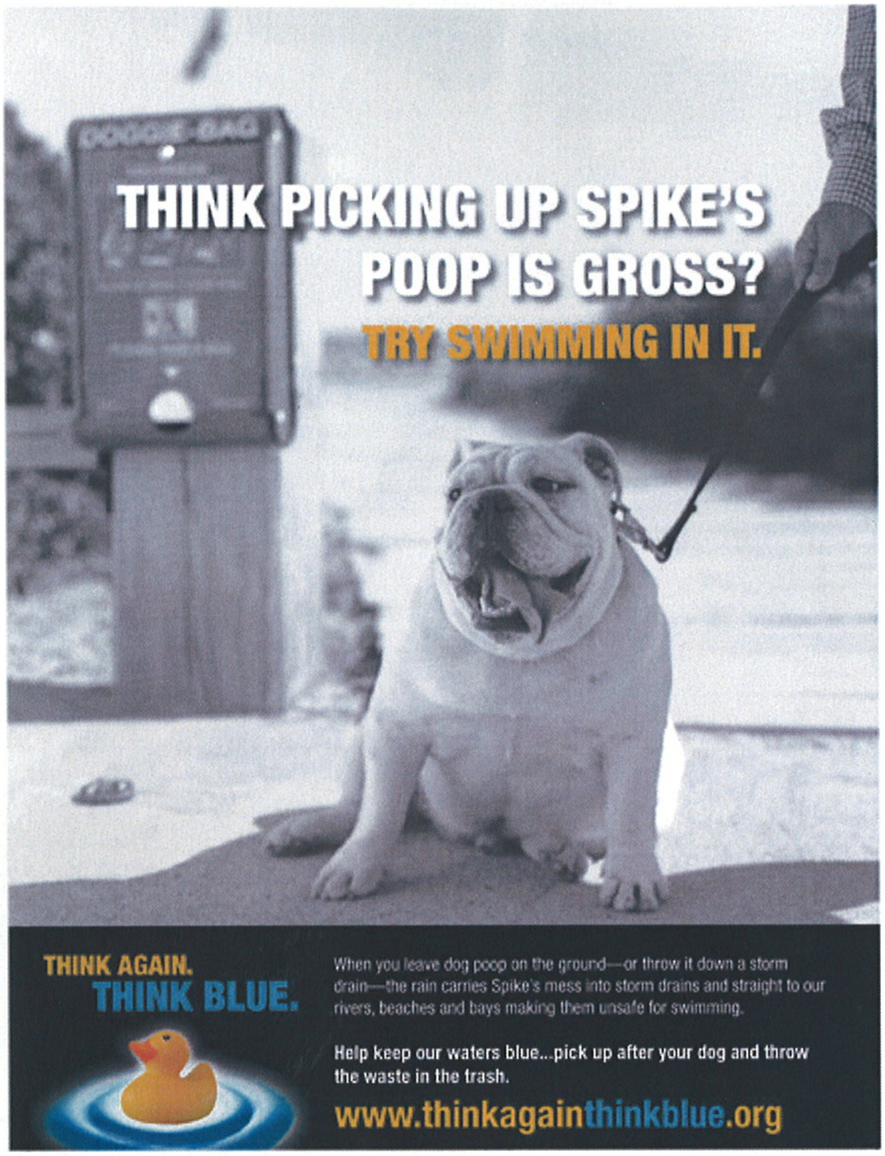
2005 Workshop Series on DVD

Watch your local cable access TV station this spring and summer for showings of last year's Greenscapes Workshop Series. The four DVD set is available at your public library or get your own for just $20 (see form on this page). Enjoy eight hours of footage from these informative presentations:

- **Soils: Building Blocks of Sustainable Landscapes**
- **Protecting Watersheds from Landscaping Chemicals**
- **Landscape and Turfgrass Irrigation**
- **Stormwater Management Through Creative Landscaping**

Appendix D

Think Again. Think Blue. Educational Posters


DOGGIE BAG
THINK PICKING UP SPIKE'S POOP IS GROSS?
TRY SWIMMING IN IT.
THINK AGAIN.
THINK BLUE.
When you leave dog poop on the ground—or throw it down a storm drain—the rain carries Spike's mess into storm drains and straight to our rivers, beaches and bays making them unsafe for swimming.
Help keep our waters blue...pick up after your dog and throw the waste in the trash.
www.thinkagainthinkblue.org


THINK MORE IS BETTER?
TELL THAT TO THE FISH.
THINK AGAIN.
THINK BLUE.
When you fertilize too much, right before heavy rains, or onto pavement, it can flow into rivers, beaches and bays, harming plants and animals.
Help keep our waters blue...use less fertilizer, use it at the right time, and keep it on your lawn.
www.thinkagainthinkblue.org

Appendix E

Cape Keepers Educational Information

What you can do:

Learn

- Visit the Cape Keeper website at **www.CapeKeepers.org** for more information and links to other relevant organizations
- Get information about wastewater planning efforts in your community – be part of the solution

Act

- Become a Cape Keeper (call **1-888-33CAPECOD** or order a free kit from the website)
- Talk to your children and neighbors about these issues
- Maintain your current system well while long-term solutions are being explored

Keep

- Get involved in your community's wastewater planning efforts
- Offer to be a community coordinator for Cape Keepers
- Arrange for a Cape Keeper speaker to attend one of your organization's events

Cape Keepers
We are all responsible.

1-888-33CAPECOD
www.CapeKeepers.org

Cape Keepers
We are all responsible.

P.O. Box 226
Barnstable, MA 02632
www.CapeKeepers.org

What does your septic system do?

What doesn't it do and why does it matter?

Cape Keepers
We are all responsible.

1-888-33CAPECOD
www.CapeKeepers.org

Septic systems are the most common form of wastewater treatment on Cape Cod. More than 85% of Cape residents depend on them. Over the last decade, Cape residents and businesses have learned that nitrogen discharged from septic systems affects the water quality of Cape saltwater ponds, bays and estuaries. Nitrogen is a nutrient that leaches into these bodies of water, causing blooms of algae or weeds, consuming oxygen and reducing water quality. Poor water quality can kill or impact fish and shellfish populations and it kills eelgrass that protects local marine life. Nitrogen can also affect drinking water and the natural beauty of the Cape's waters. Tourism, property values and employment in the fishing and shellfishing industries could be affected over the long term.

In most communities on Cape Cod, individual septic systems are the primary source of nitrogen.

How does your septic system work?

Septic systems use the soil to provide basic treatment of sanitary sewage generated by your household. Household sewage includes wastewater from toilets, sinks, showers, washing machines, garbage disposals and dishwashers. This sewage flows into your septic tank, which separates the wastewater from the solids (sludge and scum). The liquid waste then flows into the ground through the leaching facility or field – where it is discharged into the soil. While some contaminants are removed in this process, a typical septic system removes only limited amounts of nitrogen. The remaining nitrogen mixes easily with groundwater and eventually discharges into saltwater bays and estuaries.

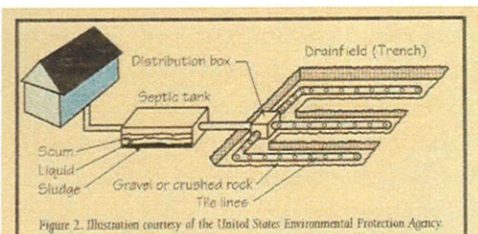
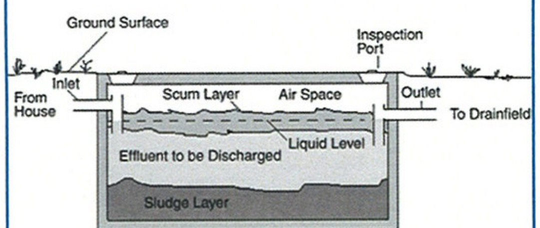


Figure 2. Illustration courtesy of the United States Environmental Protection Agency.

Schematic of a Drainfield



The nitrogen problem

Many Cape Cod estuaries are suffering from an over-abundance of nitrogen, called "nitrogen-loading," which causes algae to grow in saltwater bays, ponds and estuaries. This is called eutrophication. Excessive algae growth decreases the amount of light reaching the bottom, causing eelgrass to die from lack of sufficient sunlight. Algae can also contribute to low oxygen levels in the water. Muck builds up in the water, creates offensive odors and reduces depths. Oxygen depletion also places fish and shellfish at risk.

On-site septic systems are the main source of nitrogen entering most of Cape Cod's estuaries. Too much nitrogen in drinking water can cause a human health problem. Too much nitrogen in an estuary causes health problems for the entire ecosystem.

Title 5 regulations do not solve the nitrogen problem

In 1978, Massachusetts implemented Title 5 of the State Environmental Code (Minimum Requirements for the Subsurface Disposal of Sanitary Sewage). It included basic rules for regulating on-site wastewater disposal. Since Title 5 was enacted, understanding of the way contaminants act within the subsurface has grown significantly. Title 5 regulations were designed principally for the control of human pathogens such as bacteria. The regulations did not, however, foresee the need to control nitrogen from septic systems at the level needed on Cape Cod. Title 5 systems remove some of the nitrogen from the wastewater flow, but not enough to protect our coastal resources.

Do enhanced septic systems remove enough nitrogen?

Testing is underway on Cape Cod on the effectiveness of enhanced septic system configurations that can remove more nitrogen from the wastewater before it enters the ground. These systems provide some hope of reducing nitrogen loads to estuaries and bays, but cannot solve the problem alone. Smart growth planning, individual homeowner actions and community plans to evaluate wastewater collection and treatment alternatives will also be required.

It's up to us to keep Cape Cod waters beautiful. We are all responsible.

What is Your Wastewater IQ?

QUIZ

Do you help pollute Cape Cod bays and inlets?

Which applies to you:

- ☐ I flush a toilet.
- ☐ I own a septic system or cesspool.
- ☐ I own a Title 5 septic system.

If you checked any of the boxes above, *you* are part of the solution. Take the time to learn more about wastewater and septic systems. *We are all responsible.*

Call 1-888-33CAPECOD or visit www.CapeKeepers.org

Cape Keepers

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We are all responsible.

Sponsored by Barnstable County in part through grants from the Cape & Islands Regional Competitiveness Council, the Association to Preserve Cape Cod and the Cape Cod Chamber of Commerce.

What is Your Wastewater IQ?

QUIZ

What do you know about your septic system & Cape Cod?

Check the boxes that are TRUE:

- ☐ Over 85% of Cape homeowners use septic systems.
- ☐ Septic systems contribute 70% of the nitrogen that damages our bays and estuaries.
- ☐ Even new Title 5 systems don't remove much nitrogen.

All of these statements are true. If you own a septic system, please learn about what it does to our beautiful coastal waters. Be part of the solution. Learn more about wastewater and your septic system. *We are all responsible.*

Call 1-888-33CAPECOD or visit www.CapeKeepers.org

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What is Your Wastewater IQ?

What do you know about nitrogen?

QUIZ

Check the boxes that are TRUE:

- [ ] Your septic system is a main source of nitrogen on Cape Cod.
- [ ] Nitrogen causes algae to grow in coastal waters.
- [ ] Algae harms fish and shellfish, damaging their habitats.
- [ ] Nitrogen in drinking water can cause human health problems.

All of these statements are true. Learn more about the effects of nitrogen from your septic system on Cape Cod groundwater and coastal waters. *We are all responsible.*

Call 1-888-33CAPECOD or visit www.CapeKeepers.org

Cape Keepers

CK

We are all responsible.

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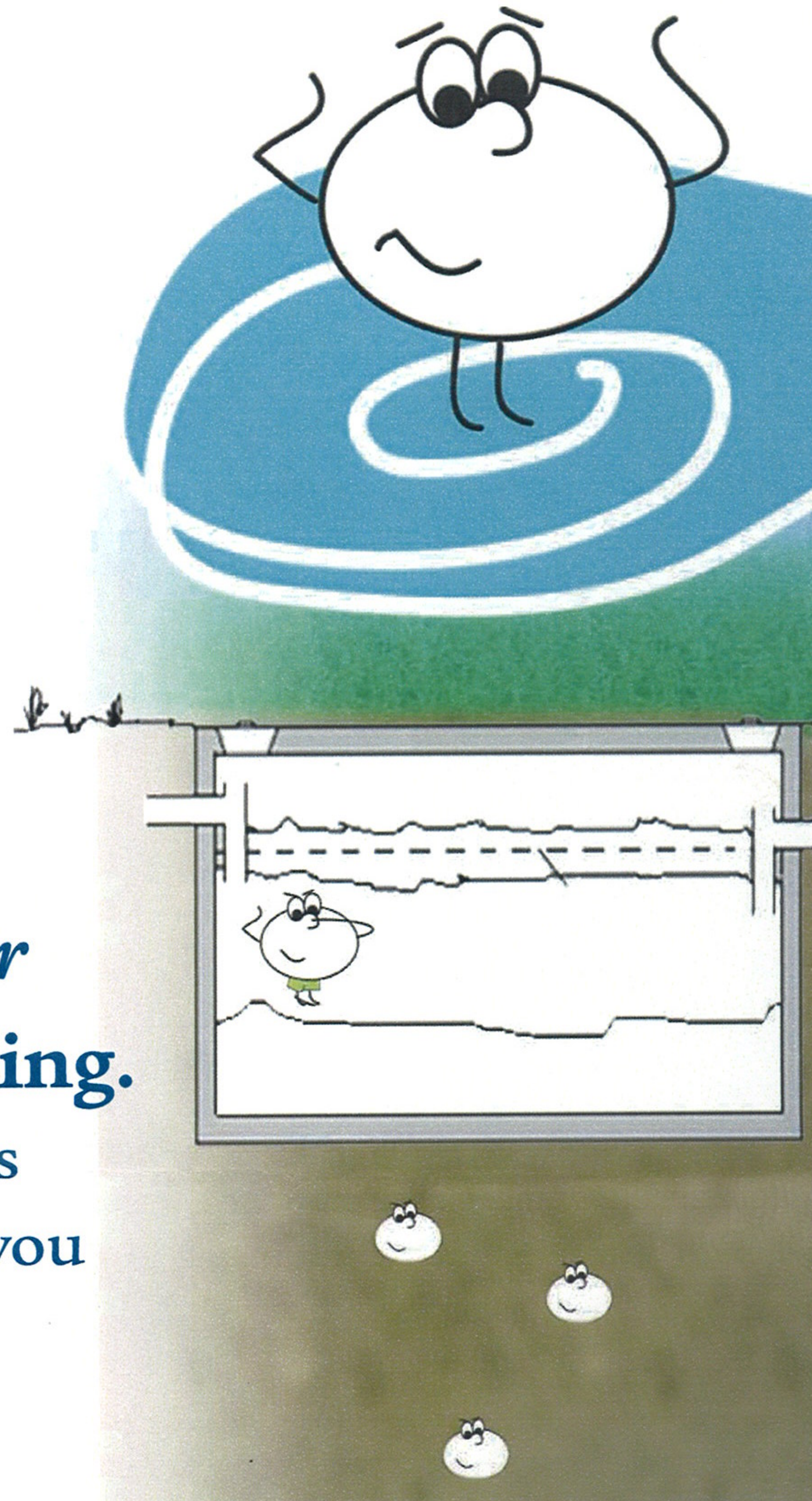
Meet NiTro & Bloomer

NiTro, short for nitrogen, enters your septic system, and hitches a ride to the coast through the groundwater.

Too much nitrogen in our harbors, bays and estuaries means trouble for water quality – it turns into algae blooms, cloudy water and too much plant growth. An army of Bloomers is the result.



Got a septic system in *your* life? Find out what it's doing.

Get the facts about septic systems and nitrogen and find out what you can do to make a difference.

We are all responsible.

Cape Keepers

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We are all responsible.

1-888-33CAPECOD

www.CapeKeepers.org

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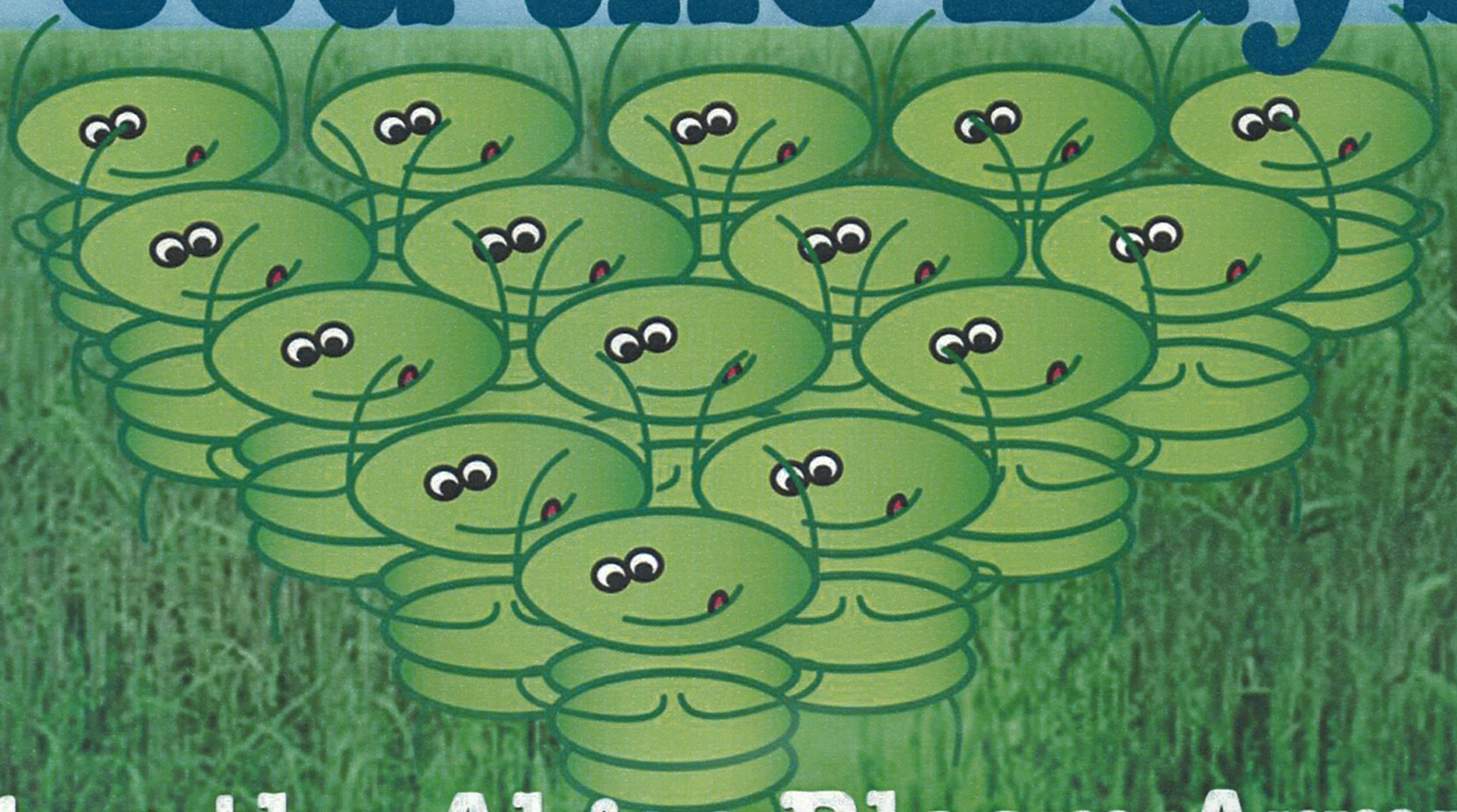
Please Don't Feed the Bays



Stop the Algae Bloom Army

If you own a septic system, you are sending lots of nitrogen toward Cape Cod's bays and estuaries. The result of too much nitrogen? Algae blooms, too much plant growth (eutrophication), and not enough oxygen for fish and shellfish – resulting in a body of water no one wants to claim. Don't feed the bays with nitrogen. You'll wind up with an army of algae Bloomers.

Got nitrogen in your life?

Find out what it's doing.

Cape Keepers
We are all responsible.

1-888-33CAPECOD

www.CapeKeepers.org

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