

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

Nitrex™ Technology Scenario Plan



Submitted to:
Town of Mashpee
Sewer Commission
16 Great Neck Road North
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August 1, 2008

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Table of Contents

Executive Summary	1
1 Objective.....	10
2 Background.....	10
2.1 Wastewater Flows	11
2.2 Hydrogeology	13
3 Needs Definition	20
3.1 Data Management - Methodology	20
3.2 Planning Area Parcel Summary.....	31
3.3 Nitrogen Loading and TMDLs.....	33
3.3.1 Data Overview	34
3.3.2 Popponesset Bay Nitrogen Removal Requirements	38
3.3.3 East Waquoit Bay Nitrogen Removal Requirements	41
3.3.4 Existing PPA Wastewater Treatment Facilities.....	44
3.3.5 Mashpee Nantucket Sound Discharge	45
4 Wastewater Treatment Options & Cost Estimates.....	46
4.1 Nitrex™ Technology Scenario 1: Cluster Systems.....	46
4.2 Nitrex™ Technology Scenario 2: On-Site Systems Only	55
4.3 Nitrex™ Technology Scenario 3: Groundwater Treatment, Pump & Treat	56
4.4 Nitrex™ Technology Scenario 4: Nitrex™ PRB	60
4.5 Nitrex™ Technology Scenario 5: Hybrid of Scenarios 1-4.....	63
4.6 Scenario 6: Sewering	64
5 Nitrogen Removal Conclusions.....	65
6 Santuit Pond Phosphorous Removal	65
7 Management Issues	69
7.1 Nitrex™ Cluster Scenario	69
7.2 Nitrex™ On-Site Scenario	69
7.3 Groundwater Treatment.....	69
8 Regulatory Issues	70
8.1 Cluster Scenario	70
8.2 On-Site Systems.....	70
8.3 Groundwater Treatment.....	70
APPENDIX A – Database Metafile.....	71
APPENDIX B – Examples of Nitrex™ Technology Projects.....	72

List of Tables

Table 1. Nitrex™ Scenario Costs Compared to Complete WW System.....	1
Table 1b. Nitrex™ Scenario O&M Costs Per EDU.....	2
Table 1c. Other Nitrex™ Technology Options for Specific Areas of PPA.....	2
Table 2. Costs for Cluster Systems in PPA.....	5

Table 3. Nitrex™ Scenarios Cost Estimates by Watershed	5
Table 2.1.1. Existing and Future Average Annual Wastewater Flows for Entire PPA ...	11
Table 2.2.1. East Waquoit Bay Groundwater Discharge	13
Table 2.2.2. Popponeset Bay Groundwater Discharge	14
Table 3.2.1. Wastewater Flow & Nitrogen Loading Information by Town.....	31
Table 3.2.2. Waquoit Parcel Information by Subwatershed (No Soil or Watershed Attenuation)	32
Table 3.2.3. Popponeset Bay Parcel Information by Subwatershed (No Soil or Watershed Attenuation)	33
Table 3.3.1. Non-Wastewater Nitrogen Sources.....	33
Table 3.3.2A. Comparison of Existing Nitrogen Loading Data for Popponeset Bay	35
Table 3.3.2B. Comparison of Future Nitrogen Loading Data for Popponeset Bay	36
Table 3.3.3A. Comparison of Existing Nitrogen Loading Data for East Waquoit Bay ...	37
Table 3.3.3B. Comparison of Future Nitrogen Loading Data for East Waquoit Bay	38
Table 3.3.4. TMDL Components for Popponeset Bay	39
Table 3.3.5. Nitrogen Removal Requirements – Popponeset Bay	40
Table 3.3.6. TMDL Components for East Waquoit Bay	41
Table 3.3.7. Nitrogen Removal Requirements – East Waquoit Bay	43
Table 3.3.4.1. WWTF Total Nitrogen Concentrations	44
Table 3.3.4.2. WWTF TN Concentration & Removal to TN = 4 mg/l.....	45
Table 3.3.5.1. Mashpee Nantucket Sound Discharge Nitrogen Loads.....	45
Table 4.1.2. Nitrogen Loads Treated with Cluster Scenario (Includes the Return Loads)	48
Table 4.1.3. Nitrex™ Technology Cluster Systems Scenario Cost Estimate	49
Table 4.1.4. Capital Cost Breakdown – Cluster Systems.....	50
Table 4.1.5. O&M Cost Breakdown – Cluster Systems.....	51
Table 4.2.1 Town of Mashpee Year Built Data	55
Table 4.2.2. On-Site Systems Only Cost Estimate.....	56
Table 4.2.3. Nitrex™ Technology Scenarios O&M Costs.....	56
Table 4.3.1. Pump & Treat Cost Estimate Summary	59
Table 4.3.3. Pump & Treat O&M Summary	60
Table 4.3.4. Pump & Treat Compared to Cluster System Scenario Costs.....	60
Table 4.4.1. Preliminary Cost Estimates for Nitrex™ Technology PRB Scenario	63
Table 4.6.1. Stearns & Wheler Sewer Cost Estimates for the Town of Mashpee	64
Table 5.1. Nitrex™ Alternatives Cost Comparisons	65
Table 5.2. Other Nitrex™ Technology Options for Specific Areas of PPA	65
Table 6.1. Santuit Pond Phosphorus Calculation.....	67
Table 6.2. Rough Estimated Phosphorus Removal Costs	68

List of Figures

Figure 1. Popponeset Bay – Existing Attenuated Watershed Behavior and Total Wastewater Nitrogen Contribution as % of N Removal Required	7
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Figure 2. East Waquoit Bay – Existing Attenuated Watershed Behavior and Total Wastewater Nitrogen Contribution as % of N Removal Required	8
Figure 3. PPA Treated Areas	9
Figure 2.1.1. Mashpee Existing Flows and Treatment Plants	12
Figure 2.2.1. Mashpee Groundwater Discharge Model Runs 1, 2, 9 & 10	15
Figure 2.2.2. Mashpee Groundwater Discharge Model Runs 3, 4, 5 & 6	16
Figure 2.2.3. Mashpee Groundwater Discharge Model Runs 7 & 8	17
Figure 2.2.4. USGS Groundwater Recharge Areas	18
Figure 2.2.5. USGS Groundwater Recharge Areas for Waquoit Bay and Popponesset Bay.....	19
Figure 3.1. Methodology Process Flow Diagram	22
Figure 3.2. Subwatersheds in Major Watersheds	24
Figure 3.3. Topographic Relief.....	25
Figure 3.4. Topographic Relief with Groundwater Contour Lines	26
Figure 3.5. USGS Topography Quads	27
Figure 3.6. Title V Setbacks	28
Figure 3.7. Waquoit Bay Surface and Groundwater Flow Diagram	29
Figure 3.8. Popponesset Bay Surface and Groundwater Flow Diagram.....	30
Figure 4.1.1. LAI Cluster Locations.....	52
Figure 4.1.2. LAI Cluster Locations on Aerial Photograph	53
Figure 4.1.5 Cluster 15 Layout.....	54
Figure 4.3.1. Pump and Treat Scenario 1	58
Figure 4.4.1. EPA Schematic of Groundwater Barrier.....	61
Figure 4.4.2. Groundwater Nitrogen Removal Performance of Nitrex™ PRBs in Waquoit Bay.....	62

Town of Mashpee
Sewer Commission
August 1, 2008

Executive Summary

Lombardo Associates, Inc. (LAI) was retained by the Mashpee Sewer Commission to prepare a Nitrex™ Technology based wastewater management plan for the Town of Mashpee for the Project Planning Area (PPA) of the East Waquoit and Popponeset Watersheds. The Nitrex™ Technology based plan was to achieve the TMDL requirements as specified by the Massachusetts Department of Environmental Protection, and thereby can be compared on an equal basis with the conventional sewerage option for nitrogen management.

The Nitrex™ Technology Scenario Plan includes the options of:

1. Cluster Systems
2. Individual Onsite Nitrex™ Treatment Systems for application as:
 - a. Retrofit to properties
 - b. New systems
3. Nitrex™ Groundwater Treatment System
 - a. Pump and Treat
 - b. Permeable Reactive Barrier (PRB)

Per the request of the Mashpee Sewer Commission, LAI also examined Santuit Pond Phosphorus Treatment.

A summary of the costs of the Nitrex™ Technology based Scenarios are presented below.

Table 1. Nitrex™ Scenario Costs Compared to Complete WW System

Nitrex™ Technology Scenarios	Capital Cost	Capital Cost / EDU	Capital Cost / (lb/year) N Removed	Capital Cost / (kg/day) N Removed	Capital Cost / (kg/year) N Removed	Nitrex™ Technology Capital Cost as % of Complete WW System w/ Sewers	Nitrex™ Technology Capital Cost as % of Sewers Connected to Existing WWTP & Expansion
1. Cluster Systems	\$272,810,000	\$37,779	\$21,220	\$3,520,563	\$9,645	59%	51%
2. Individual Systems	\$237,510,000	\$32,891	\$18,474	\$3,065,023	\$8,397	52%	44%
3. Stearns & Wheler Scenario 4 Proposed Estimates - low end ^(2,3)	\$460,000,000+	\$66,000	\$22,329	\$3,704,618	\$10,150		
4. Stearns & Wheler Scenario 1 Proposed Cost Estimates - high end ^(2,3)	\$540,000,000+	\$66,000	\$19,021	\$3,155,786	\$8,646		

⁽¹⁾ MA State Tax Credit of \$6,000 may be available to property owners with septic system repair.

⁽²⁾ The Stearns & Wheler proposed cost estimates in the March 2008 Draft Alternative Scenarios Analysis Report do not include allowances for land acquisition, acquisition of needed WWTPs, and treatment costs at the Falmouth and Barnstable WWTPs.

⁽³⁾ Ratio of Capital Cost are higher than the per EDU ratio due to the fact that the Stearns & Wheler proposal is to sewer more properties than proposed by LAI.

Table 1b. Nitrex™ Scenario O&M Costs Per EDU

Nitrex™ Technology Scenarios	Annual O&M Costs / EDU
1. Cluster Systems	\$389
2. Individual Systems	\$703
3. Groundwater Treatment - Pump & Treat	\$135
4. Groundwater Treatment - PRB	\$144
5. Conventional Sewerage System	\$700 - \$1,000 ¹

¹Based on Stearns & Wheeler Presentation.

Table 1c. Other Nitrex™ Technology Options for Specific Areas of PPA

Nitrex™ Technology Scenarios	Capital Cost / (lb/year) N Removed
1. Groundwater Treatment - Pump & Treat	\$9,397
2. Groundwater Treatment - PRB	\$11,172

It is noted that the TMDLs developed for the PPA require approximately 75-85+/-% of wastewater nitrogen to be removed. The Town may deem it equitable that a portion of the costs be apportioned to those properties whose wastewater is not being treated as they also will be the beneficiaries of the improved water quality.

Speed of Implementation & Water Quality Improvement.

The Nitrex™ Technology options can achieve the desired water quality improvements more quickly than treating wastewater because:

1. The Nitrex™ PRB and pump and treat systems can address groundwater just prior to its reaching surface water bodies. Treating wastewater will require the groundwater to cleanse itself after excess nitrogen loadings are reduced.

According to the USGS, this will take 10-20 years **after** the treatment systems are functioning. Conventional sewerage may take 10 – 20 years to complete.

In addition to the speed of implementation, these two options have the benefit of treating land use nitrogen loads as well as nitrogen loads from upstream sources. The Nitrex™ on-site and cluster approaches can be implemented quicker and achieve nitrogen loadings faster than conventional sewerage.

Nitrogen Load Removal-Based Solutions

Due to data availability, the Nitrex™ Scenario that was most thoroughly developed was the Cluster System Scenario. This scenario delineates the parcels that need to be treated to achieve the water quality goals for the project planning area. The Onsite Scenario is similar to the Cluster System Scenario, in that the same basic parcels are treated, with minimal adjustments made to account for watersheds that require 100% removal of wastewater nitrogen. The pump and treat and PRB scenarios are presented as alternatives that offer benefits such as significant capital and operational cost savings as well as the speed of implementation and water quality improvement. However, their detailed evaluation requires additional groundwater quality information. The common factor for all scenarios is the required nitrogen removal. The groundwater pump and treat and PRB options require more groundwater flow and quality data than is currently available, as well as specific solute transport data, to accurately locate the systems. Therefore these scenarios are strictly conceptual and for comparison purposes only.

The following are the Watersheds in Popponesset Bay and the Sub-Watersheds to target, taking into consideration the attenuation of each, and the Clusters that will remove the necessary nitrogen loads:

- Mashpee River Watershed
 - Main Subwatersheds to treat: Upper Mashpee River and Lower Mashpee River
 - Clusters 1, 2, 3, 6, 10, 11, 13 and 16
- Shoestring Bay
 - Subwatersheds to treat: Santuit River and Shoestring Bay
 - Clusters 1, 5, 11-14 and 16
- Ockway Bay
 - Treat all
 - Cluster 3
- Pinquisset Cove
 - No treatment needed

- Cluster 14 does pick up some parcels in Pinguickset Cove
- Popponeset Bay
 - Subwatersheds to treat: Popponeset Creek and Popponeset Bay
 - Clusters 3 and 14

The following are the Watersheds in East Waquoit Bay and the Sub-Watersheds to target, taking into consideration the attenuation of each, and the Clusters that will remove the necessary nitrogen loads:

- Quashnet River
 - Subwatersheds to treat: Upper Quashnet River and Johns Pond
 - Clusters 2, 4, 8, 10, and 15
- Hamblin Pond / Red Brook
 - Subwatersheds to treat: Hamblin Pond and Red Brook
 - Clusters 3, 6, and 9
- Jehu Pond / Great River
 - Subwatersheds to treat: Lower Great River and Jehu Pond
 - Clusters 3, 7, and 9
- Sage Lot / Flat Pond
 - No TMDL – No Treatment required
 - Cluster #7 does pick up some parcels in Sage Lot / Flat Pond

Table 2 presents the costs for the cluster systems for the entire PPA. As some of the Clusters do overlap into neighboring watersheds, treating one watershed may achieve some treatment in another.

Table 2. Costs for Cluster Systems in PPA

Planning Area	# of Subwatersheds in Cluster	Existing Wastewater Flow (gpd)	Total EDUs	Total Capital Cost	Total Capital Cost with 20% Contingency	Total Capital Cost per EDU	Total O&M	Total O&M per EDU	Total Present Worth	Total Present Worth per EDU*
Cluster #1	2	37,680	245	\$11,959,000	\$14,350,800	\$48,877	\$159,067	\$650	\$10,931,328	\$44,677
Cluster #2	6	40,711	264	\$9,598,000	\$11,517,600	\$36,307	\$157,108	\$594	\$9,135,919	\$34,559
Cluster #3	5	69,365	450	\$19,760,000	\$23,712,000	\$43,870	\$178,693	\$397	\$17,016,913	\$37,780
Cluster #4	7	86,129	559	\$22,412,000	\$26,894,400	\$40,073	\$187,276	\$335	\$19,105,871	\$34,162
Cluster #5	1	80,714	524	\$18,729,000	\$22,474,800	\$35,734	\$181,028	\$345	\$16,275,008	\$31,052
Cluster #6	2	67,247	437	\$13,886,000	\$16,663,200	\$31,800	\$170,800	\$391	\$12,524,544	\$28,682
Cluster #7	4	59,123	384	\$15,212,000	\$18,254,400	\$39,623	\$169,867	\$442	\$13,498,919	\$35,161
Cluster #8	2	47,011	305	\$14,031,000	\$16,837,200	\$45,964	\$164,565	\$539	\$12,551,845	\$41,118
Cluster #9	6	48,044	312	\$14,380,000	\$17,256,000	\$46,093	\$165,307	\$530	\$12,820,094	\$41,093
Cluster #10	4	103,480	672	\$21,426,000	\$25,711,200	\$31,886	\$191,572	\$285	\$18,423,406	\$27,418
Cluster #11	5	70,710	459	\$15,097,000	\$18,116,400	\$32,880	\$173,394	\$378	\$13,457,866	\$29,310
Cluster #12	3	42,508	276	\$7,592,000	\$9,110,400	\$27,505	\$155,210	\$562	\$7,606,262	\$27,556
Cluster #13	6	80,025	520	\$21,257,000	\$25,508,400	\$40,907	\$183,917	\$354	\$18,199,011	\$35,022
Cluster #14	3	35,974	234	\$8,554,000	\$10,264,800	\$36,619	\$154,333	\$661	\$8,317,332	\$35,606
Cluster #15	3	65,012	422	\$16,202,000	\$19,442,400	\$38,379	\$172,941	\$410	\$14,277,227	\$33,820
Cluster #16	6	178,324	1,158	\$42,715,000	\$51,258,000	\$36,889	\$241,481	\$209	\$34,984,390	\$30,212
Totals	-	1,112,056	7,221	\$272,810,000	\$327,372,000	\$37,779	\$2,806,559	\$389	\$239,125,934	\$33,115

Table 3 disaggregates the costs by watershed.

Table 3. Nitrex™ Scenarios Cost Estimates by Watershed

Planning Area	Existing Wastewater Flow in Cluster Section in Sub-Watershed (gpd)	Total EDUs in Cluster Section in Sub-Watershed	Nitrex™ Solution Range of Total Capital Costs					
			Total Cost		\$/EDU			
POPPONESSET BAY WATERSHED								
Mashpee River	394,398	2,561	\$39,475,300	-	\$89,472,500	\$15,500	-	\$35,000
Shoestring Bay	274,763	1,784	\$37,200	-	\$66,194,200	\$100	-	\$37,200
Ockway Bay	25,766	167	\$2,915,200	-	\$7,339,900	\$17,500	-	\$43,900
Pinquisset Cove	5,584	36	\$673,400	-	\$1,327,700	\$18,600	-	\$36,700
Popponneset Bay	38,885	253	\$43,800	-	\$11,048,600	\$200	-	\$43,800
POP TOTAL	739,395	4,801	\$75,998,900	-	\$175,382,700	\$15,900	-	\$36,600
EAST WAQUOIT BAY WATERSHED								
Quashnet River	202,140	1,313	\$39,900	-	\$52,300,600	\$100	-	\$39,900
Hamblin Pond / Red Brook	100,630	653	\$40,900	-	\$28,048,400	\$100	-	\$43,000
Jehu Pond / Great River	63,126	410	\$40,700	-	\$16,671,400	\$100	-	\$40,700
Sage Lot / Flat Pond	6,625	43	\$635,400	-	\$1,704,700	\$14,800	-	\$39,700
WAQ TOTAL	372,521	2,419	\$1,412,100	-	\$97,393,900	\$600	-	\$40,300
PPA Total	1,111,916	7,220	\$84,430,700	-	\$272,776,500	\$11,700	-	\$37,800

Figures 1 and 2 illustrate the existing attenuated watershed behavior (ATT) and the total wastewater nitrogen contribution as a percentage of the total nitrogen removal required for each of the MEP sub-watersheds (ET). Figure 3 illustrates the treated cluster areas

to achieve the nitrogen removal requirements. The Nitrex™ Cluster Scenario database has been submitted to UMass – Dartmouth for determination if the Nitrex™ Scenario achieves the required nitrogen removal for compliance with TMDL requirements.

Figure 1. Popponeset Bay – Existing Attenuated Watershed Behavior and Total Wastewater Nitrogen Contribution as % of N Removal Required

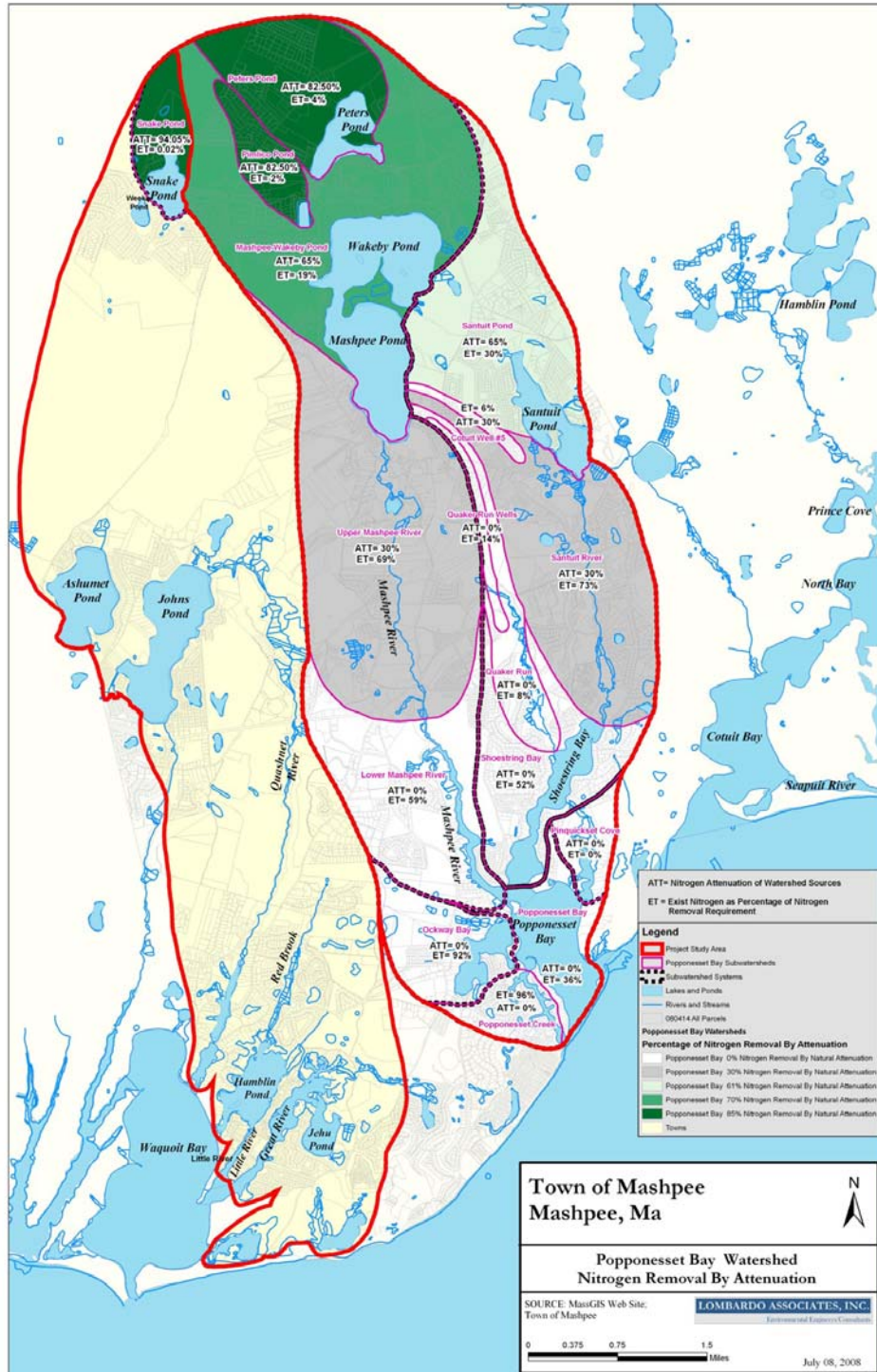
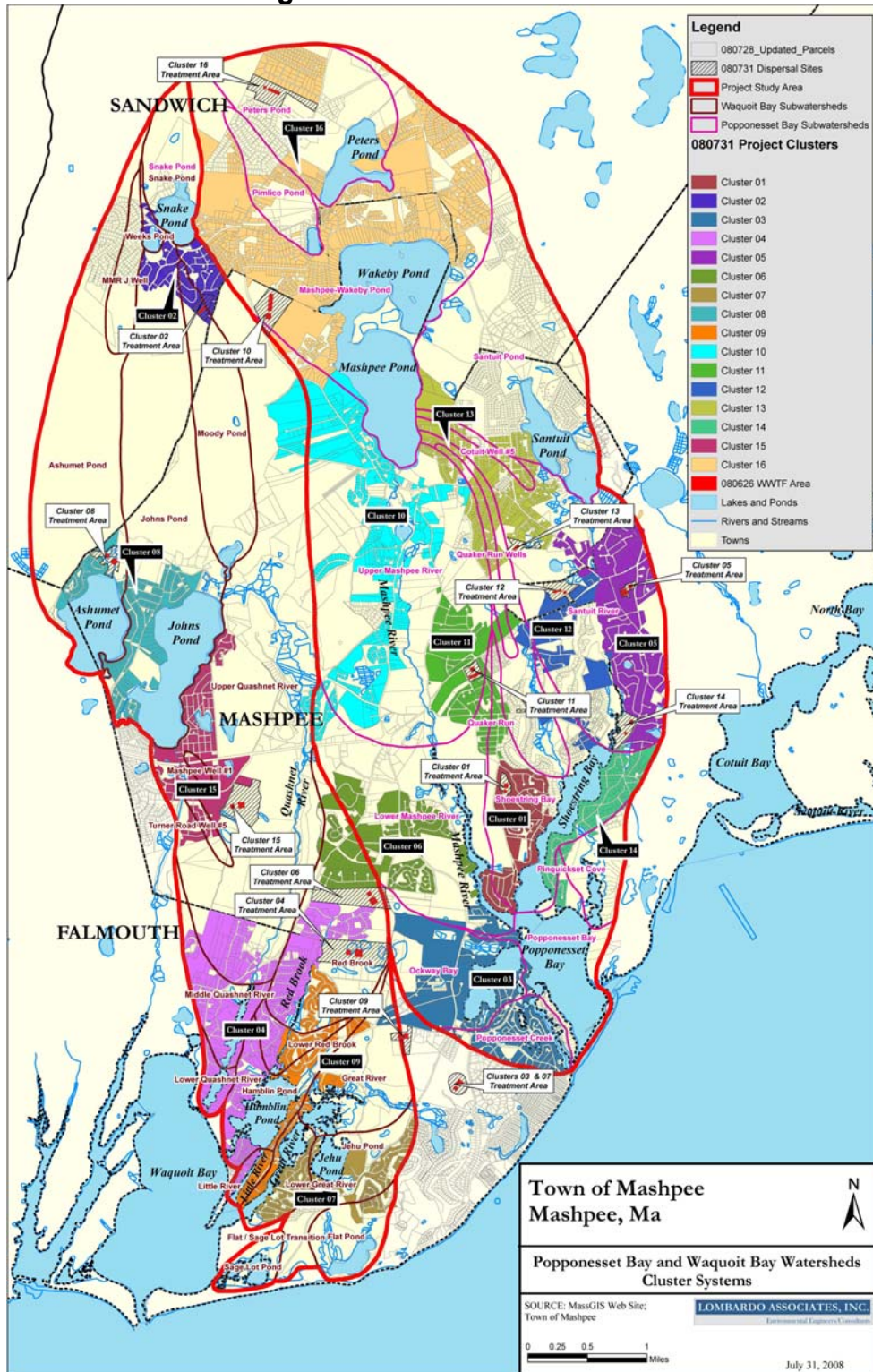


Figure 3. PPA Treated Areas



1 Objective

In accordance with the June 19, 2007 Agreement between the Town of Mashpee Sewer Commission and Lombardo Associates, Inc., Lombardo Associates, Inc. (LAI) has developed a conceptual Nitrex™ Technology Scenario Plan to achieve compliance with the TMDL reports' nitrogen loading requirements, as well as to address concerns regarding phosphorus overloading in Santuit Pond.

The following Nitrex™ Technology Scenario Plan includes:

1. Cluster Systems
2. Individual Nitrex™ Treatment Systems for application as:
 - a. Retrofit to properties
 - b. New systems
3. Nitrex™ Groundwater Treatment - PRB
4. Nitrex™ Groundwater Treatment System – Pump and Treat

LAI is also examining Santuit Pond Phosphorus Treatment.

The purpose of this Report is to provide an environmentally compatible and economically feasible plan for nitrogen reduction, wastewater treatment, and effluent recharge in the Project Planning Area (PPA), utilizing the Nitrex™ Nitrogen Removal Technology, as well as addressing phosphorous issues in Santuit Pond. This report is based on the MEP Water Quality Assessment findings and the MADEP TMDL Reports for the watersheds and the Stearns and Wheler, LLC's *Final Town of Mashpee, Popponesset Bay, & Waquoit Bay East Watersheds Needs Assessment Report* (Assessment Report), dated April 2007 and March 2008 Report.

2 Background

Located on Cape Cod, the Town of Mashpee is the fastest growing municipality in the Commonwealth, and felt by its new and old residents to be one of the most gifted with natural beauty. The total area of the Town is 23.48 square miles, with an annual population of 12,946, according to the 2000 census, and a summer population approaching 30,000.

Mashpee is located almost entirely within the watersheds of two shallow, nitrogen-sensitive embayments – Popponesset Bay and Waquoit Bay East. Excessive inputs of nitrogen has been identified as the cause of the degradation of both watersheds.

As stated in the Needs Assessment Report, "The Town of Mashpee's (Town) Watershed Nitrogen Management Plan (WNMP) project was initiated in 1999 to address

the Town's need for reducing nitrogen impacts to its coastal embayments and to evaluate all options for restoring those embayments." The Popponeset Bay and the Waquoit Bay East watershed systems, as described in the Massachusetts Estuaries Project (MEP) Reports have been added to the Project Planning Area (PPA).

The PPA includes the following areas:

- The entire town of Mashpee
- The Popponeset Bay watershed that extends into the towns of Barnstable and Sandwich, as defined by MEP
- The Waquoit Bay East watershed that extends into the towns of Falmouth and Sandwich, as defined by MEP

2.1 Wastewater Flows

The existing and future average annual wastewater flows given in the Stearns & Wheler Needs Assessment Report for the entire PPA are presented in Table 2.1.1.

Table 2.1.1. Existing and Future Average Annual Wastewater Flows for Entire PPA

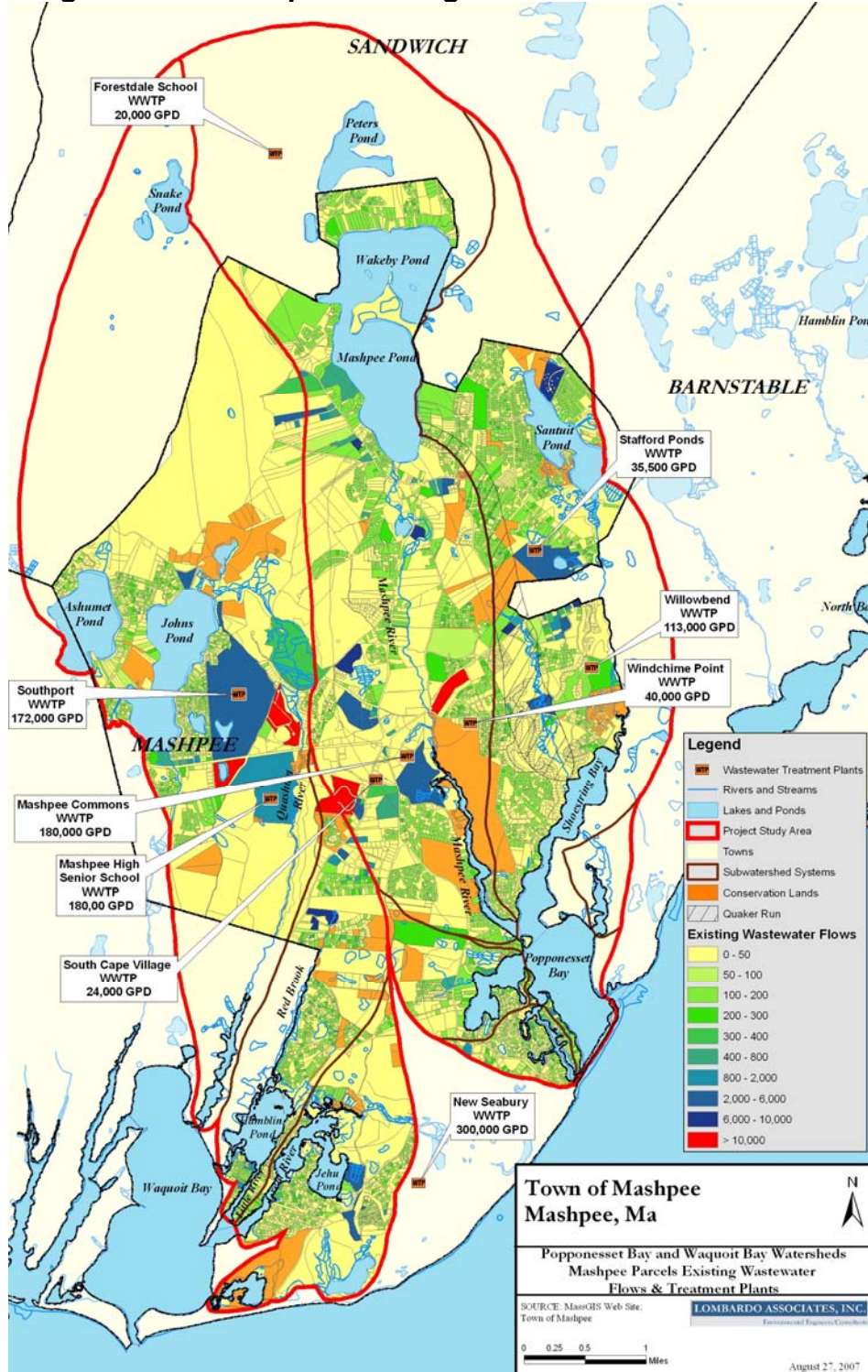
Land Use	Existing Flow (gpd)	Future Flow (gpd)
Multiuse	2,900	4,100
Residential	1,400,000	2,400,000
Commercial	93,000	200,000
Industrial	14,000	72,000
Institutional	15,000	67,000
Total	1,500,000	2,700,000

Source: Table 7-3 on page 7-5 of the Stearns & Wheler *Needs Assessment Report*, April 2007.

It is noted that the Town's database state existing wastewater flows are 1,383,780 gpd and future flow 2,353,009 gpd – see Table 3.1.1.

Figure 2.1.1 illustrates the locations of the existing WWTPs in the PPA.

Figure 2.1.1. Mashpee Existing Flows and Treatment Plants



2.2 Hydrogeology

The daily groundwater discharge to each of the sub-embayments in the East Waquoit Bay system and the Popponeset Bay system, as determined from the USGS groundwater model, is presented below in Tables 2.2.1 and 2.2.2, respectively.

The Town of Mashpee had groundwater flow modeling performed in existing and potential effluent discharge locations. These ten (10) modeling results, which show subsurface flow direction and time of travel, are presented on Figures 2.2.1 through 2.2.3.

Table 2.2.1. East Waquoit Bay Groundwater Discharge

Watershed	Discharge		
	ft ³ /day	gpd	m ³ /day
Great River/Jehu Pond			
Lower Great River	39,070	292,244	1,106
Jehu Pond	65,473	489,738	1,853
Great River	110,631	827,520	3,131
Sage Lot/Flat Pond	92,654	693,052	2,622
SUBTOTAL	307,828	2,302,553	8,712
Little River/Hamblin Pond			
Red Brook	215,913	1,615,029	6,110
Lower Red Brook	31,425	235,059	889
Hamblin Pond	66,615	498,280	1,885
Little River	13,082	97,853	370
SUBTOTAL	327,035	2,446,222	9,255
Quashnet River			
Upper Quashnet River	1,649,859	12,340,945	46,691
Middle Quashnet River	65,937	493,209	1,866
Lower Quashnet River	14,910	111,527	422
SUBTOTAL	1,730,706	12,945,681	48,979
East Waquoit Watershed Total	2,365,569	17,694,456	66,946

Source: MADEP Massachusetts Estuaries Project *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for The Quashnet River, Hamblin Pond, and Jehu Pond, in the Waquoit Bay System of the Towns of Mashpee and Falmouth, Massachusetts*. September 2004.

Table 2.2.2. Popponeset Bay Groundwater Discharge

Watershed	Discharge		
	ft ³ /day	gpd	m ³ /day
Popponeset Bay			
Popponeset Bay	41,496	310,390	1,174
Popponeset Creek	60,596	453,258	1,715
SUBTOTAL	102,092	763,648	2,889
Ockway Bay			
Ockway Bay	75,887	567,635	2,148
SUBTOTAL	75,887	567,635	2,148
Shoestring Bay			
Shoestring Bay	146,455	1,095,483	4,145
Santuit River	709,625	5,307,995	20,082
Quaker Run	131,724	985,296	3,728
SUBTOTAL	987,804	7,388,774	27,955
Mashpee River			
Upper Mashpee River	1,597,053	11,945,956	45,197
Lower Mashpee River	204,105	1,526,705	5,776
SUBTOTAL	1,801,158	13,472,662	50,973
Pinquisset Cove			
Pinquisset Cove	54,914	410,757	1,554
SUBTOTAL	54,914	410,757	1,554
Popponeset Watershed Total	3,021,855	22,603,475	85,518

Source: MADEP Massachusetts Estuaries Project *Linked Watershed- Embayment Model to Determine Critical Nitrogen Loading Thresholds for Popponeset Bay, Mashpee and Barnstable, Massachusetts*. September 2004.

Figure 2.2.1. Mashpee Groundwater Discharge Model Runs 1, 2, 9 & 10

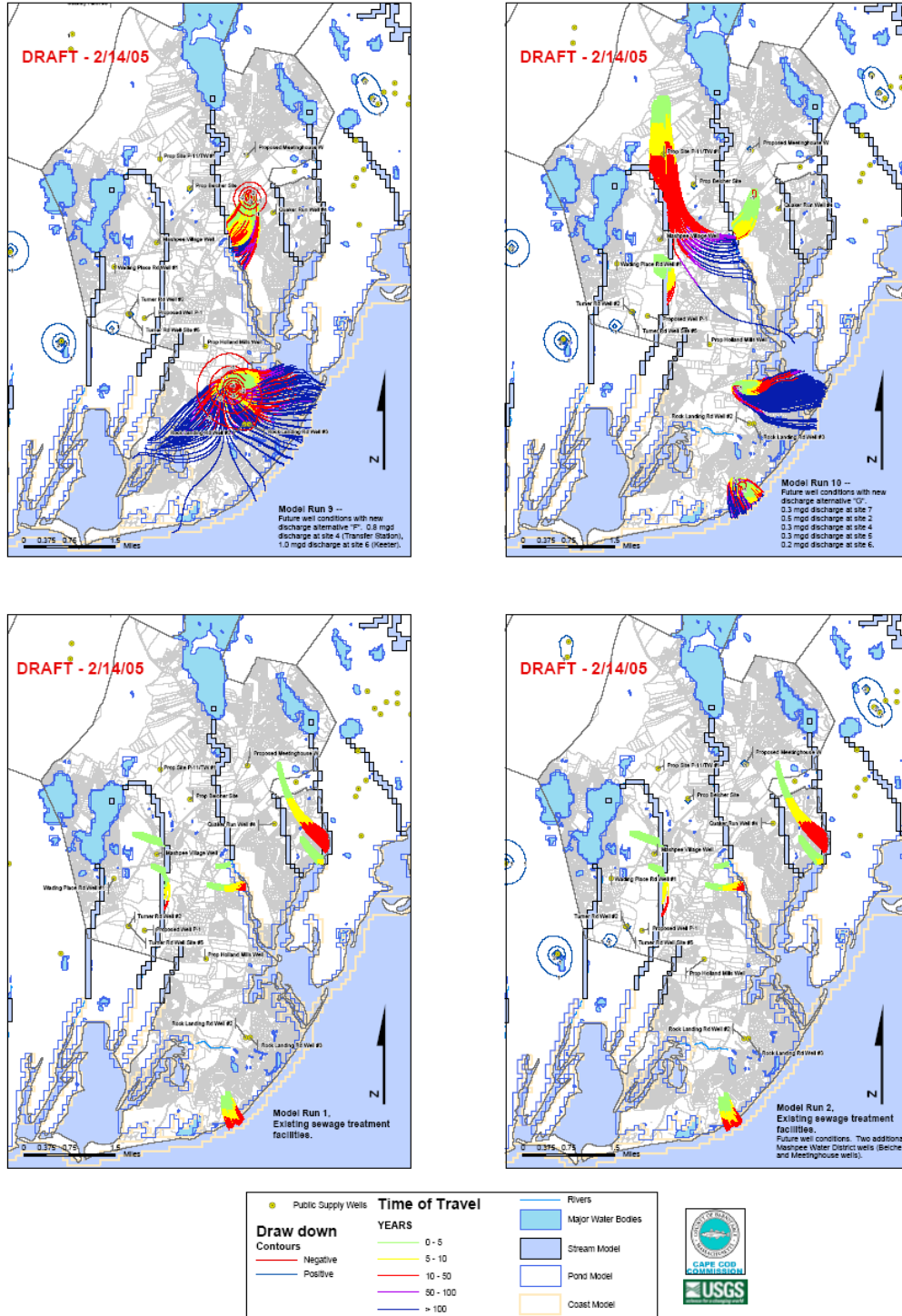


Figure 2.2.2. Mashpee Groundwater Discharge Model Runs 3, 4, 5 & 6

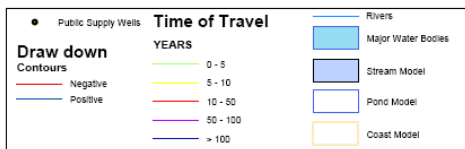
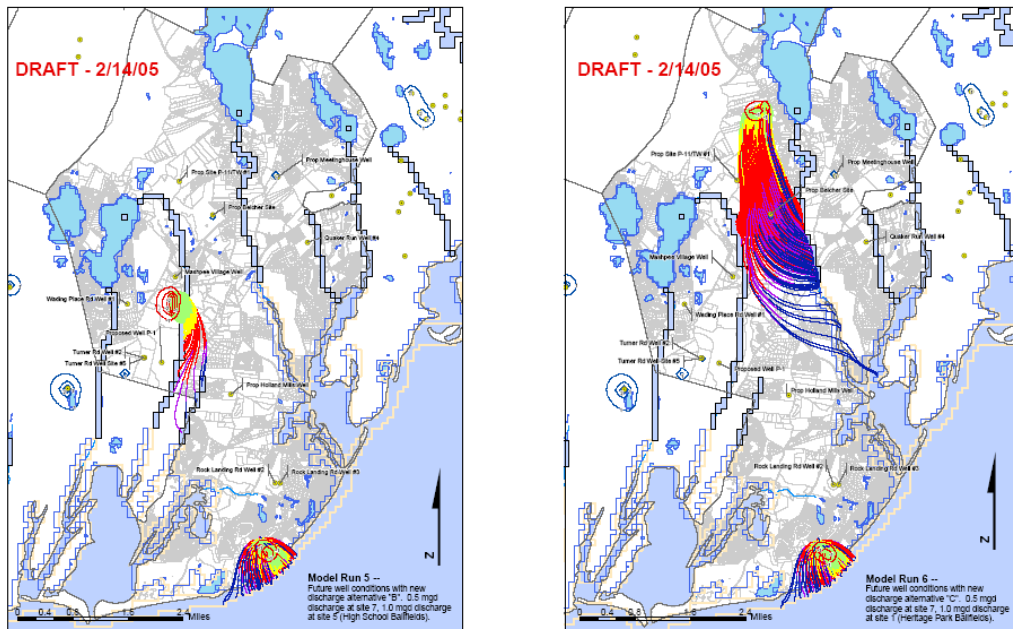
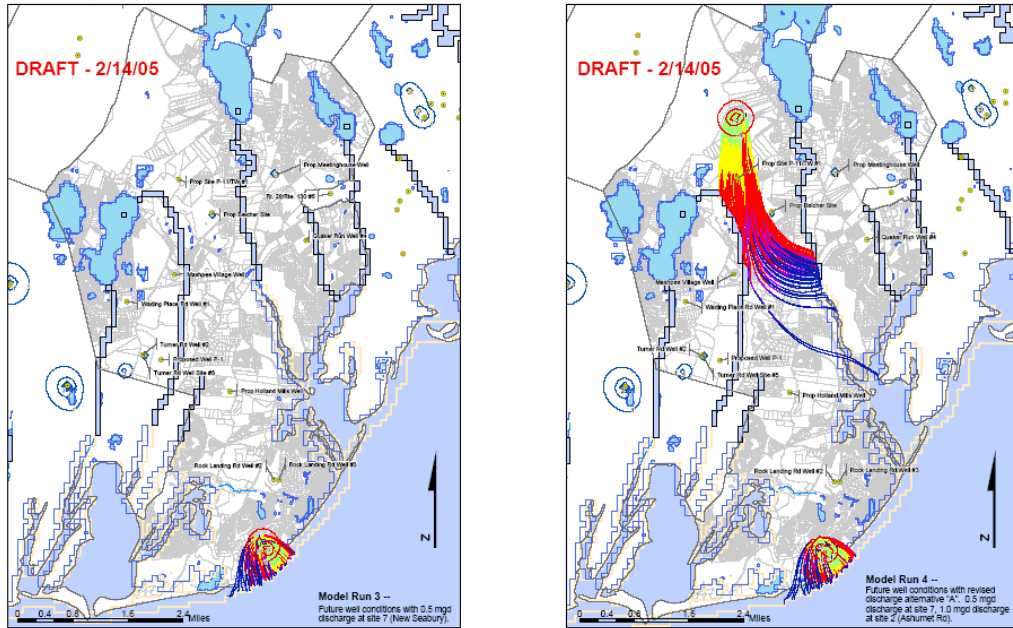


Figure 2.2.3. Mashpee Groundwater Discharge Model Runs 7 & 8

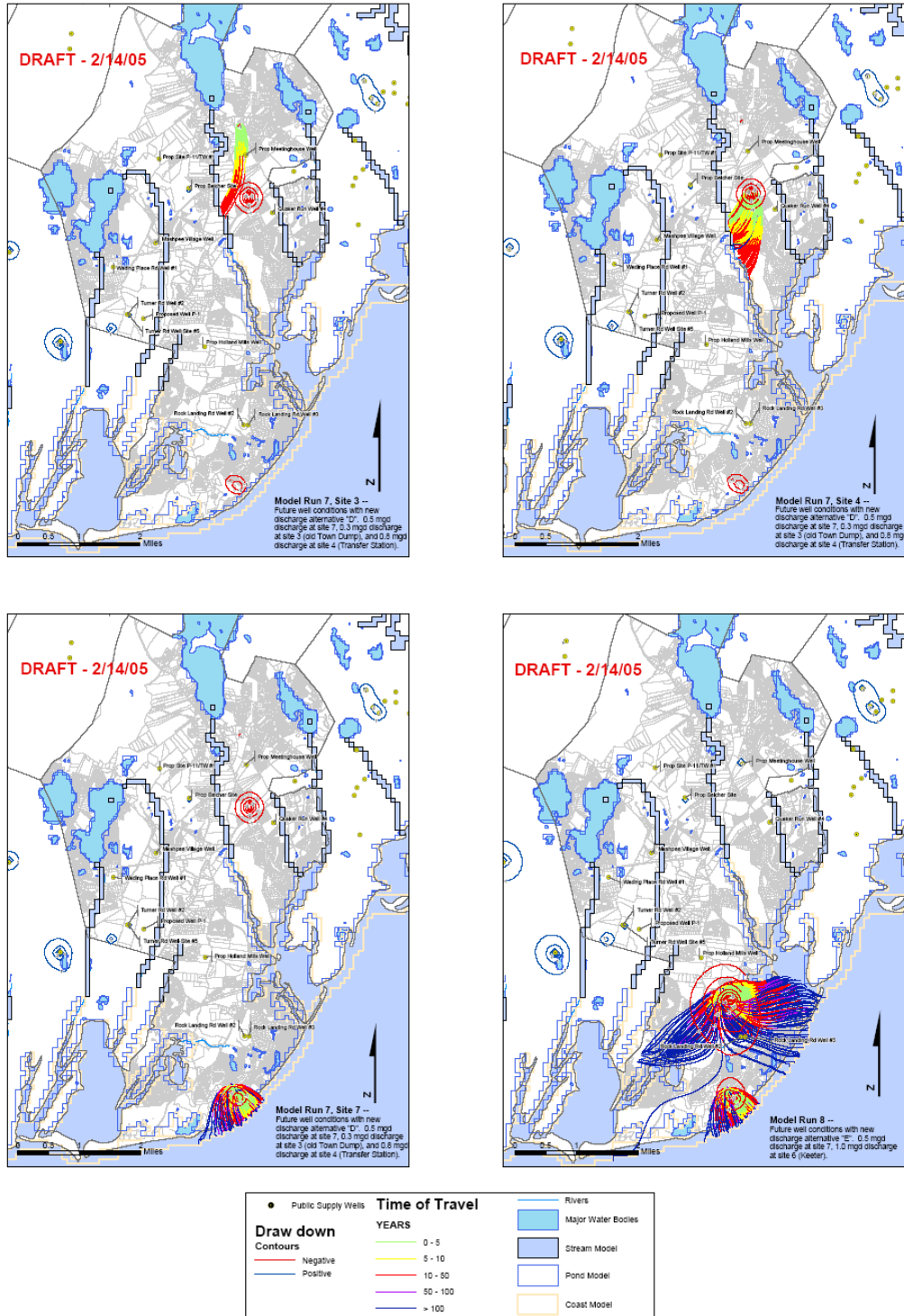


Figure 2.2.4 shows the USGS Groundwater Recharge Areas and Figure 2.2.5 shows the Recharge areas extrapolated to the PPA.

Figure 2.2.4. USGS Groundwater Recharge Areas

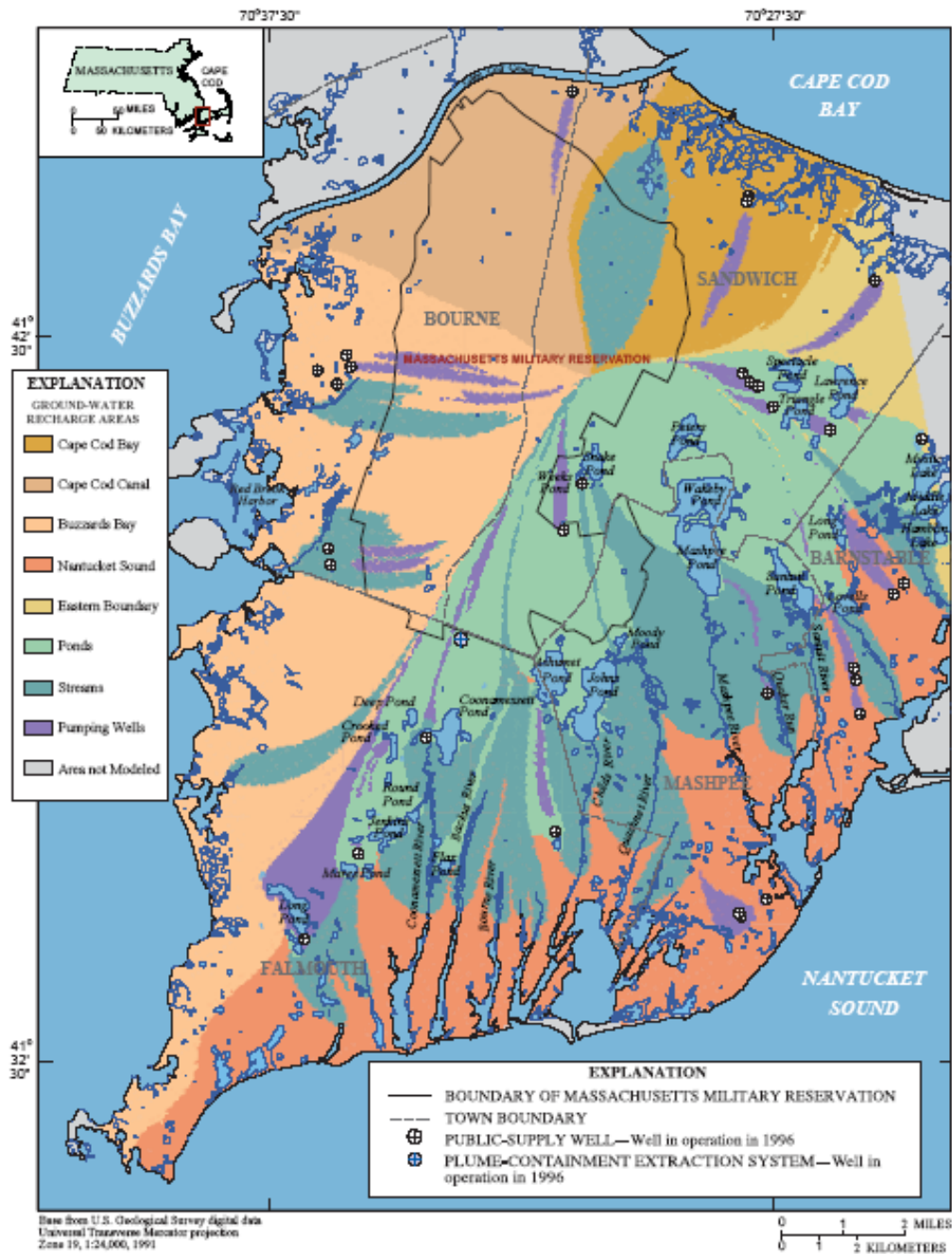
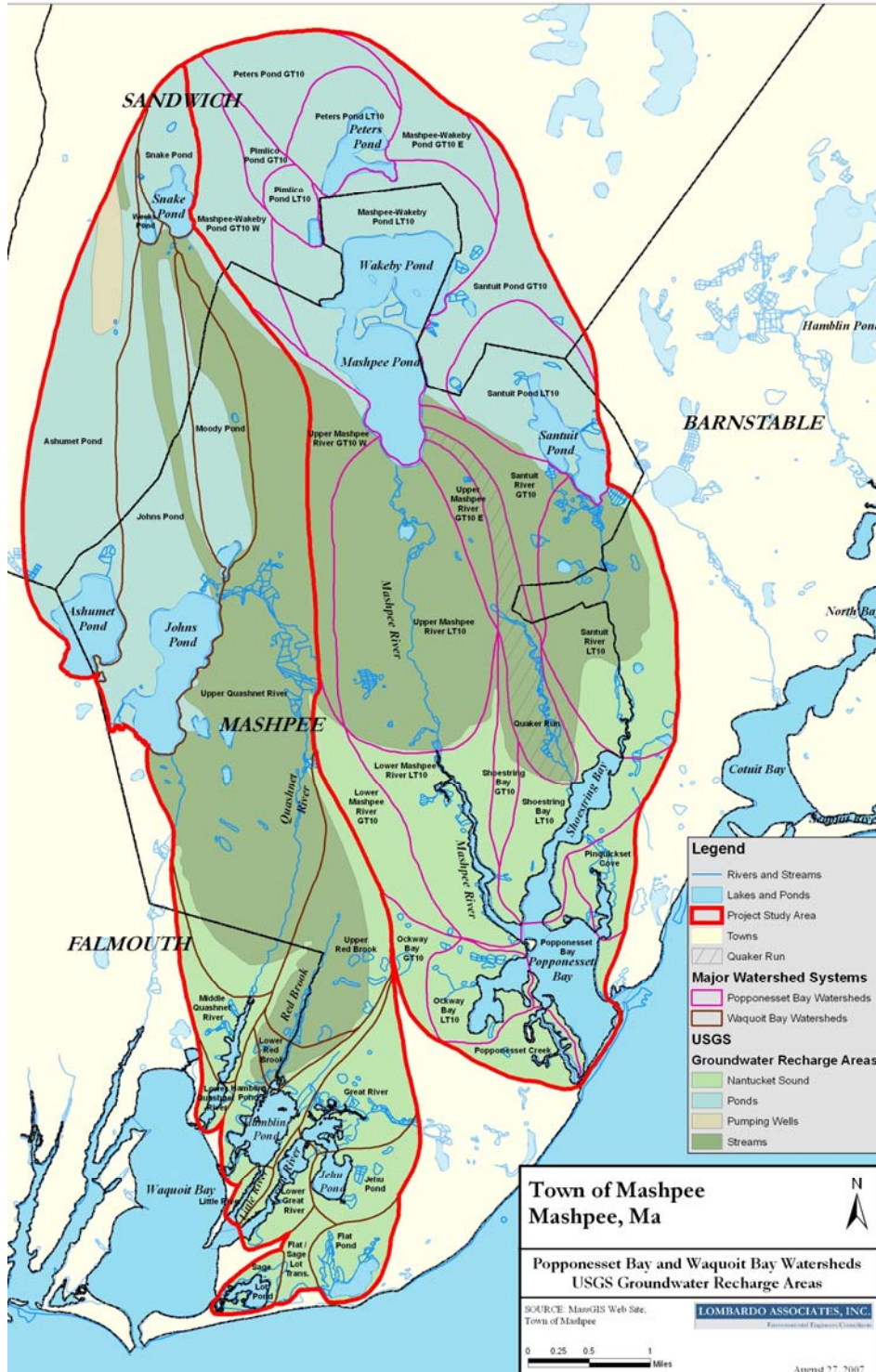


Figure 2.2.5. USGS Groundwater Recharge Areas for Waquoit Bay and Popponesset Bay



3 Needs Definition

3.1 Data Management - Methodology

LAI used the following Methodology to accomplish the Project objectives:

1. Create Master Database with furnished and calculated parcel data for the PPA
 - a. LAI received shapefiles from S&W on May 21, 2008 for the following Towns:
 - i. Barnstable
 - ii. Falmouth
 - iii. Mashpee
 - iv. Sandwich – Popponesset
 - v. Sandwich – Waquoit

Each parcel has a Unique S&W ID within the Town, but the ID is not unique when the Towns are combined into one database file.

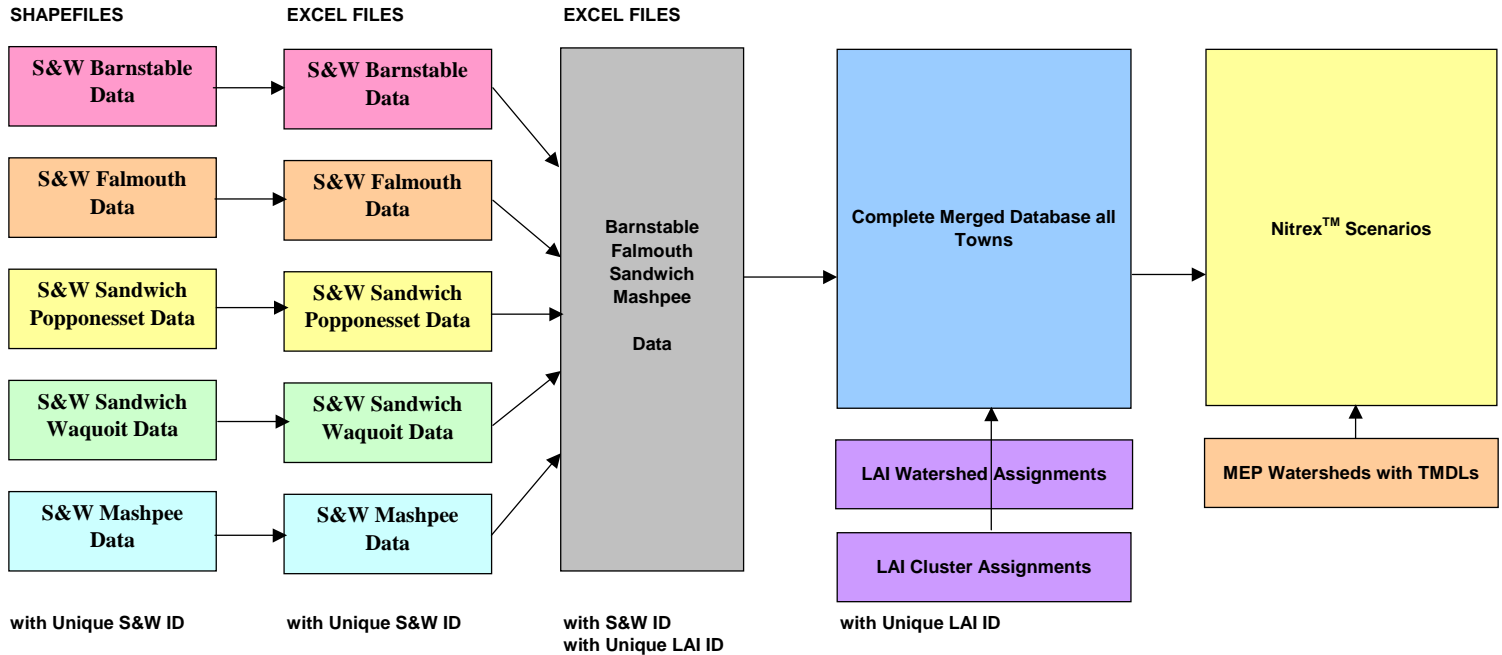
- b. LAI exported the shapefiles into Excel files and combined the five Towns into one master sheet
- c. LAI created a unique ID for each parcel in the Master Database
- d. LAI assigned each parcel to each of the following headings
 - i. Major Watershed: Popponesset or Waquoit (provided by S&W)
 - ii. Town: Barnstable, Falmouth, Mashpee, or Sandwich (provided by S&W)
 - iii. MEP SubWatershed within the Major Watershed (S&W Assigned for Mashpee and LAI assigned for other Towns)
 - iv. TMDL Subwatershed within Major Watershed (provided by MEP and assigned by LAI)
- e. Raw nitrogen loads were calculated and adjusted so each parcel had loads with consistent units across the database
 - i. S&W provided loads for Town of Mashpee converted from kg/year to kg/day
 - ii. S&W provided flows for Barnstable, Sandwich and Falmouth used to calculate N Loads in kg/day

Note: Future Seasonal Loads were used for the Town of Mashpee.
- f. Total N Loadings by subwatershed were compared to MADEP reported loadings to verify consistency of Parcel N Loading Data
- g. LAI adjusted the Town Database Nitrogen Loadings to take into account attenuation.
 - i. LAI assumed 25% soil attenuation
 - ii. LAI then applied the additive waterbody attenuation values given by MEP to determine the N loadings after attenuation.

2. Determine Nitrogen Removal Needed to Meet TMDLs
 - a. The attenuated loads from Step 1 were then added to the Land Use N Loadings given in the MEP reports, to give us a controllable N load.
 - b. LAI used the published target N Load from the MEP reports.
 - c. The N removal requirement was calculated by subtracting the target load from the loads determined in Step 1.
 - d. LAI assumed 90% removal from each treated parcel
 - e. All future systems are assumed to be connected to an existing system or have their own onsite systems.
 - f. N Removal from future systems is assumed to be 90%
 - g. LAI determined the amount of nitrogen that must be removed from existing septic loads to create capacity for future build out development.
 - h. No credit was taken for public water supply well withdrawals.
 - i. LAI calculated the return loads from each cluster's dispersal site and added that into the existing load for each subwatershed.
3. NitrexTM Alternatives Layout
 - a. The Scenarios LAI developed to achieve the nitrogen removal requirements determined in Step 2 in the PPA are:
 - i. Cluster Systems
 - ii. All Individual On-Site Systems
 - iii. Pump and Treat
 - iv. Permeable Reactive Barrier (PRB)
 - v. Hybrid of the above options
4. Cost Estimates – LAI determined cost estimates for each of the above scenarios and compared them to the sewerage costs typical of Cape Cod.

Figure 3-1 is a Process flow diagram that illustrates the LAI Methodology for the Project:

Figure 3.1. Methodology Process Flow Diagram



The Waquoit Bay Watershed and Popponeset Bay watershed have been broken down into the following TMDL Subwatersheds, in order to correspond with MEP and TMDL Reports.

Popponeset Bay:

- Popponeset Bay (includes Popponeset Creek)
- Ockway Bay
- Pinkquickset Cove
- Shoestring Bay, with Quaker Run Subwatershed
- Mashpee River

Waquoit Bay:

- Great River / Jehu Pond
- Little River / Hamblin Pond
- Quashnet River

The boundaries of these subwatersheds are presented in Figure 3.2 below. Figures 3.3, 3.4, and 3.5 present the Topographic Relief, the Topographic Relief with Contour Lines, and the USGS Topography Quads respectively.

Figure 3.6 below shows the Title V Setbacks within the PPA, which illustrate the locations of environmentally sensitive areas and setbacks.

The Waquoit Bay and Popponesset Bay subwatersheds are interconnected as illustrated in Figures 3.7 and 3.8, respectively.

Figure 3.2. Subwatersheds in Major Watersheds

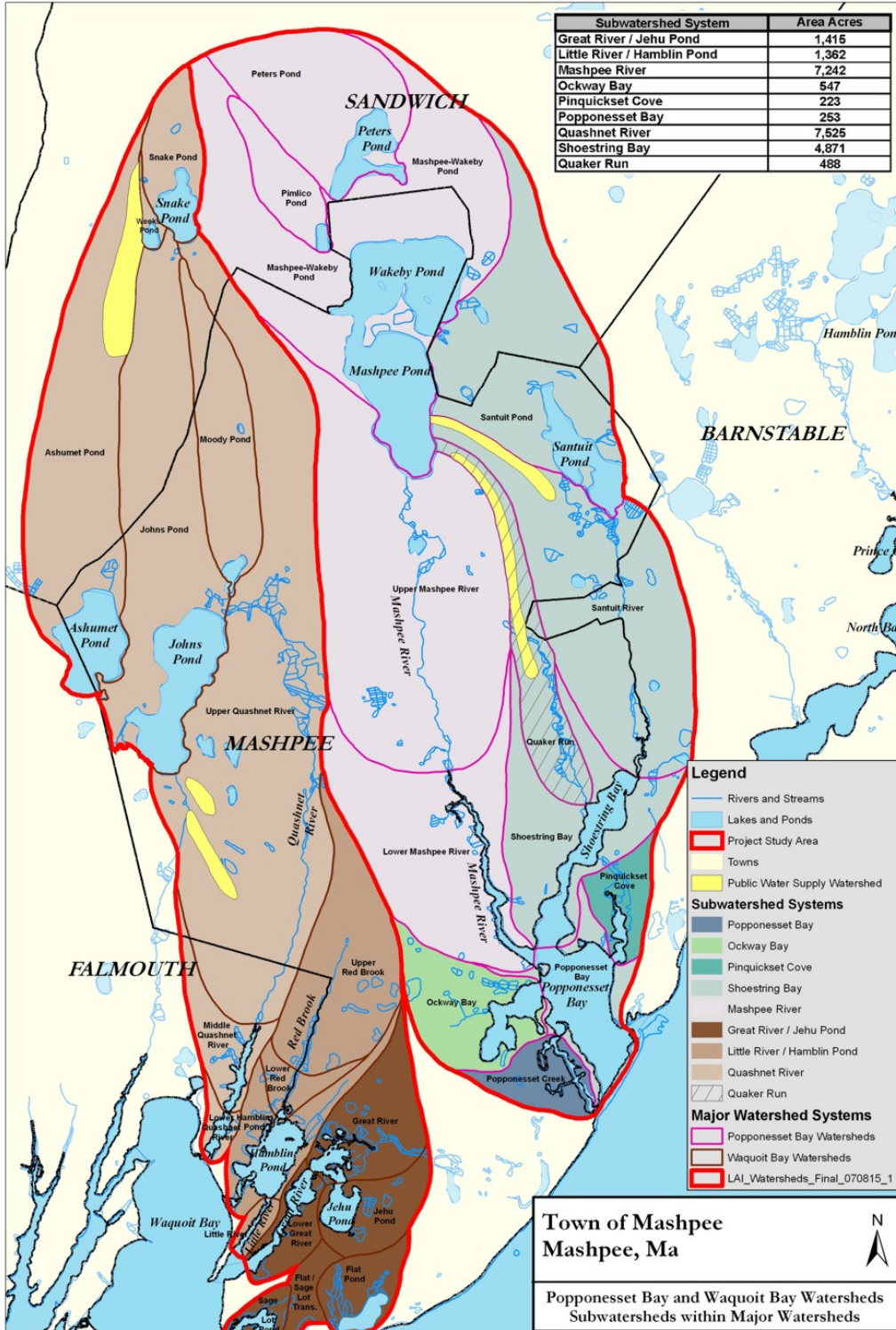


Figure 3.3. Topographic Relief

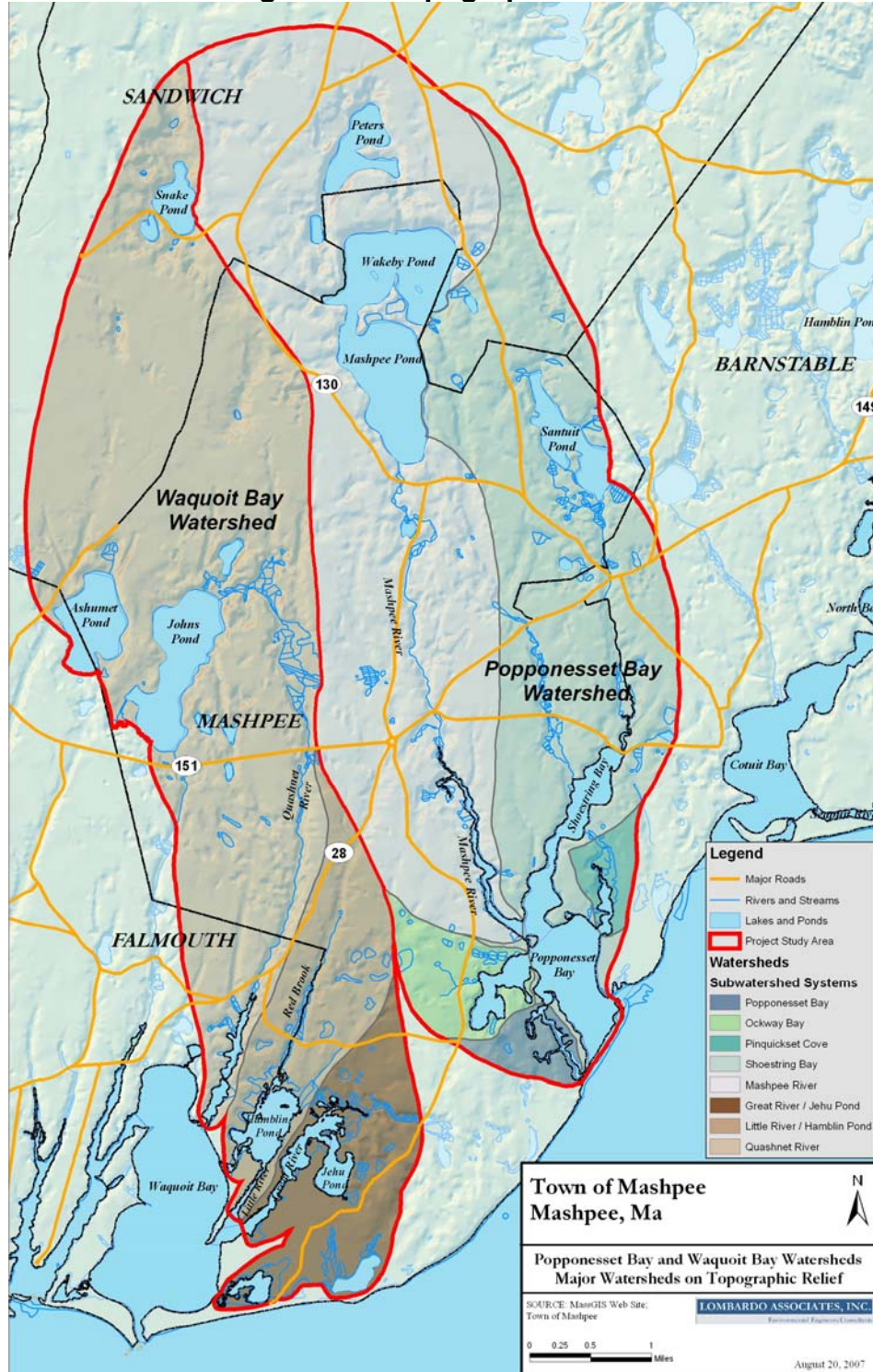


Figure 3.4. Topographic Relief with Groundwater Contour Lines

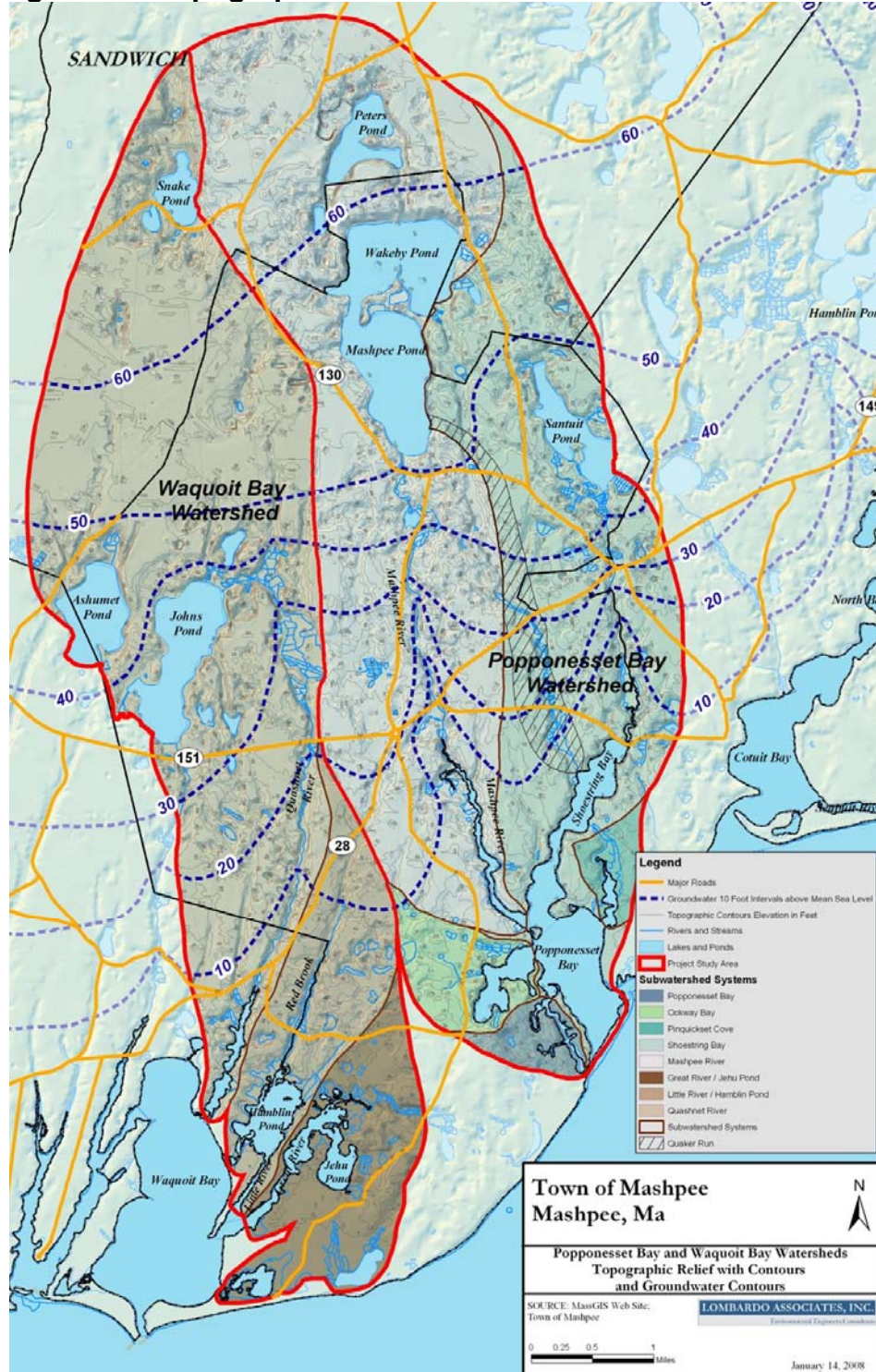


Figure 3.5. USGS Topography Quads

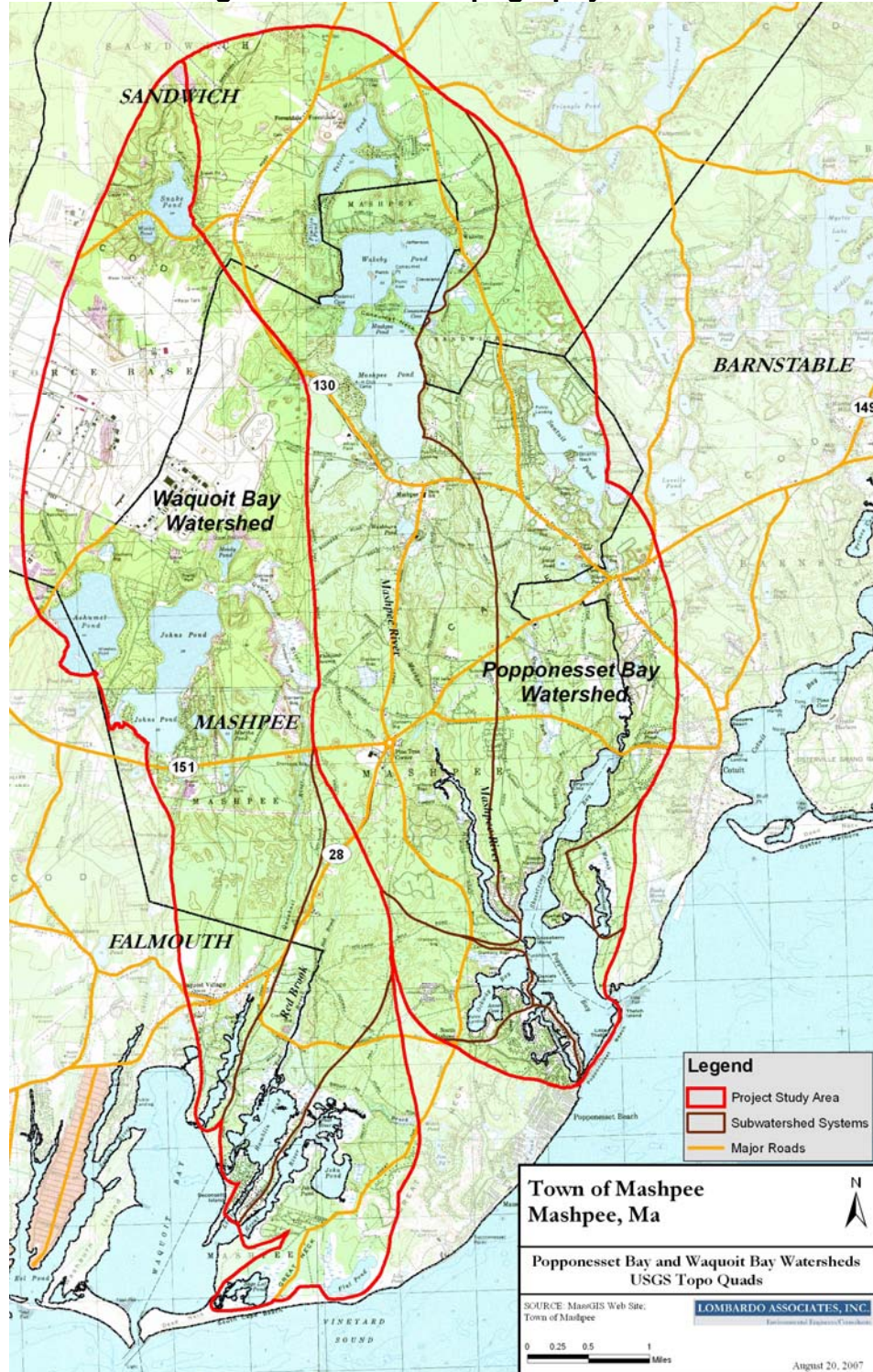


Figure 3.6. Title V Setbacks

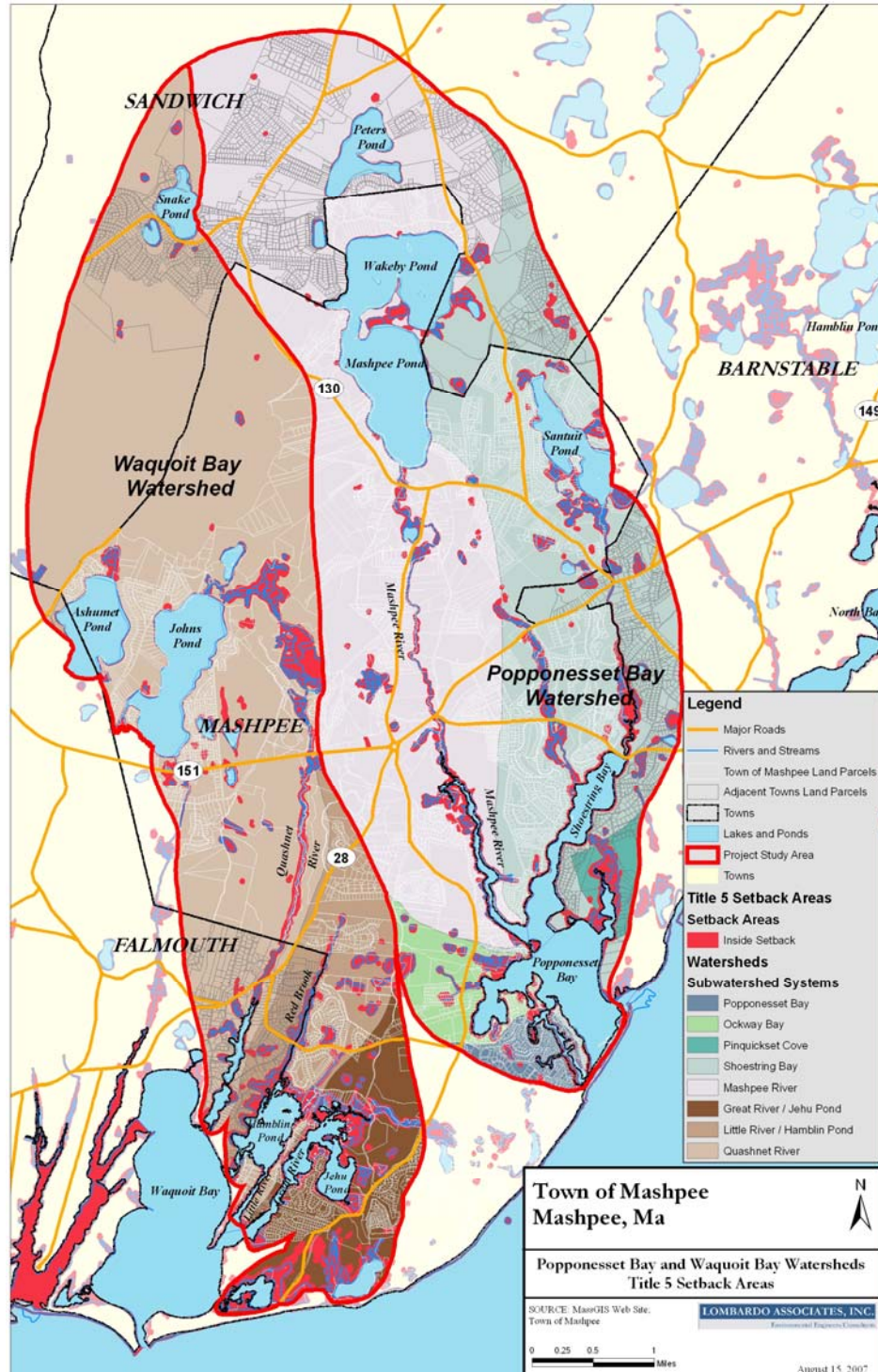


Figure 3.7. Waquoit Bay Surface and Groundwater Flow Diagram

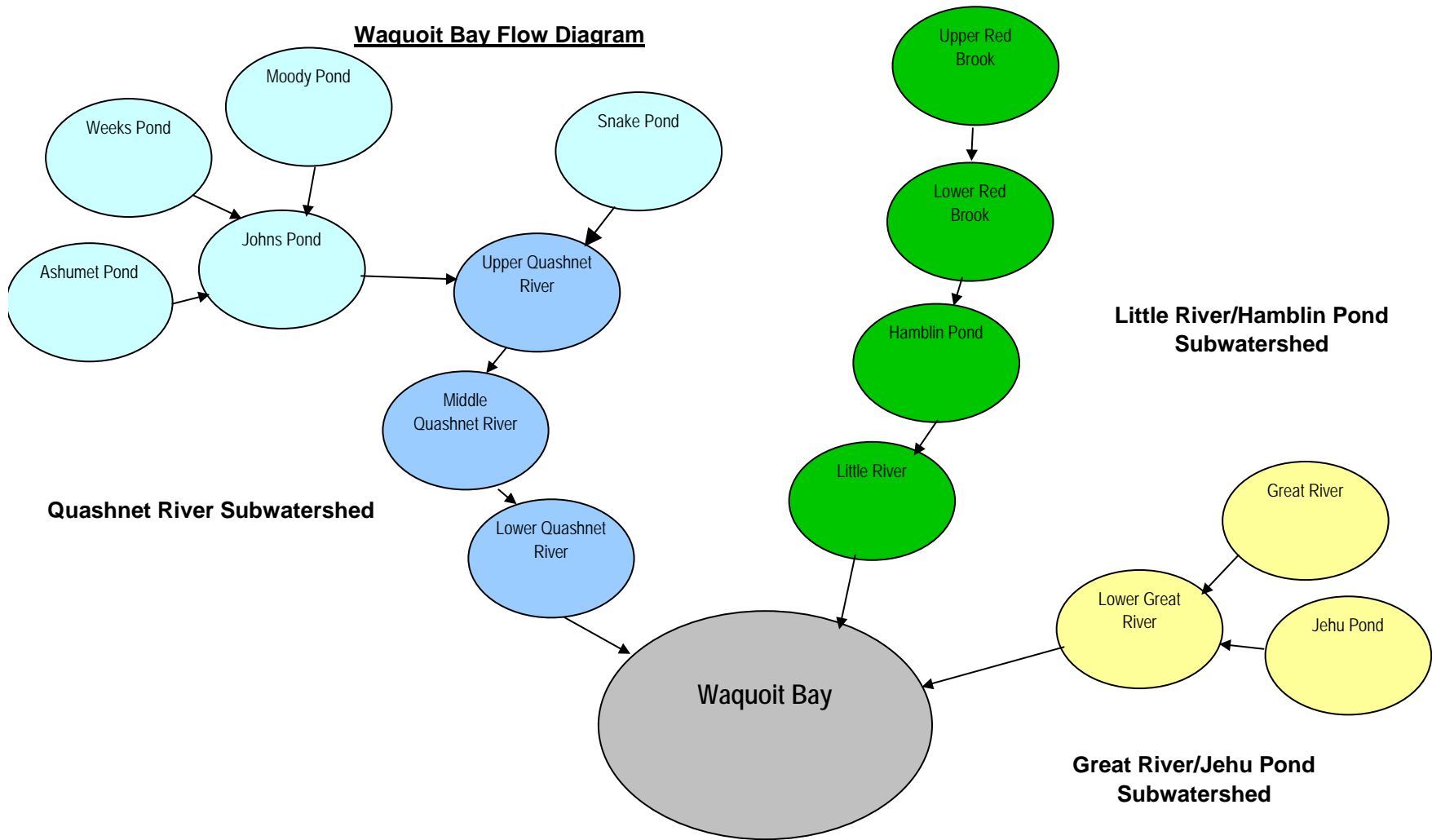
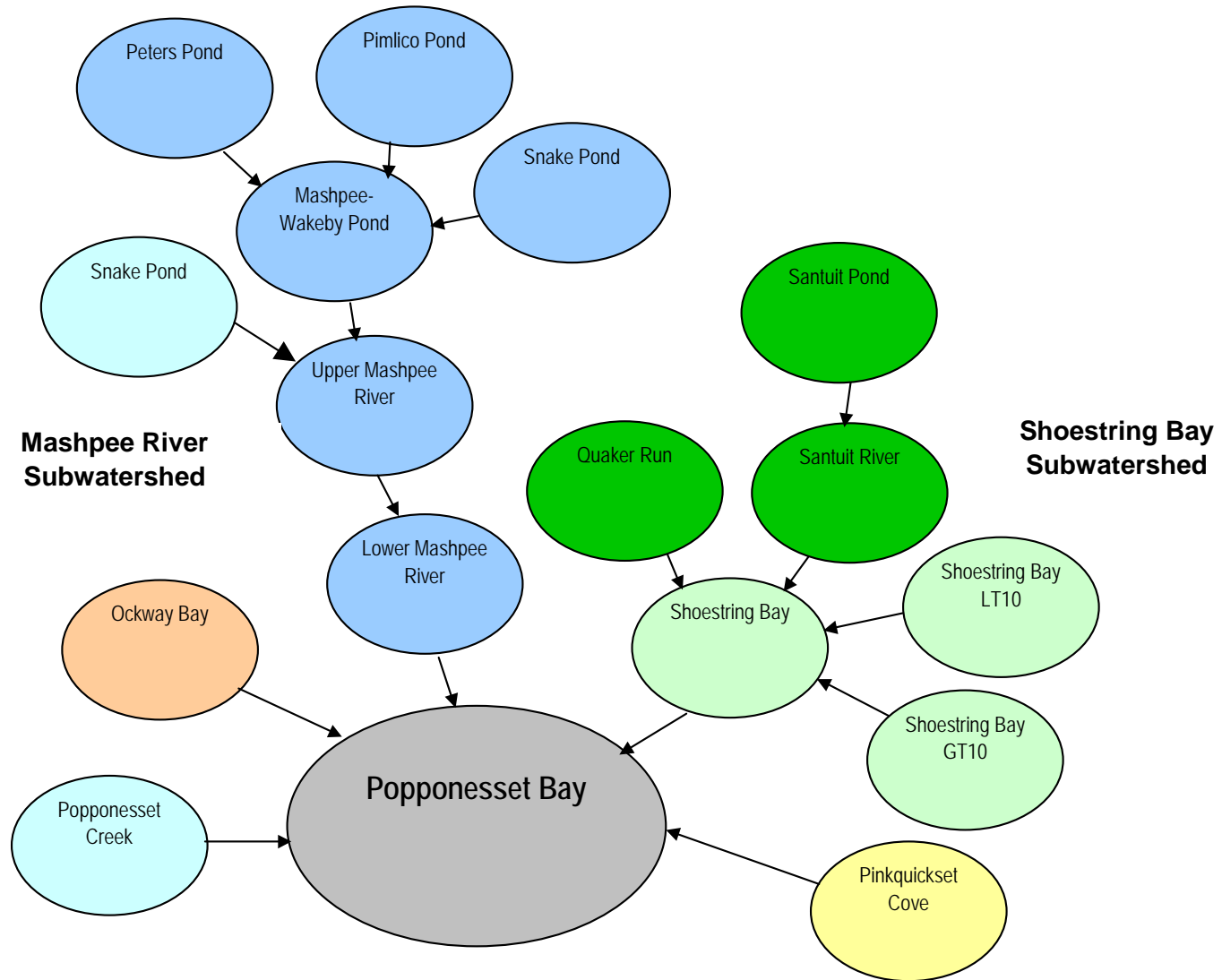


Figure 3.8. Popponeset Bay Surface and Groundwater Flow Diagram



3.2 Planning Area Parcel Summary

The S&W Database total raw Nitrogen Loads and wastewater flow for the Planning area, by town, is presented in Table 3.2.1.

Table 3.2.1. Wastewater Flow & Nitrogen Loading Information by Town

	Existing WW Flow (gpd)	Future WW Flow (gpd)	Existing N Load (kg/day)	Future N Load (kg/day)
Sandwich	328,772	394,677.37	43.66	52.42
Falmouth	62,157	116,450.28	8.25	15.47
Barnstable	118,569	175,958.30	15.74	23.37
Mashpee	1,150,537	2,022,918.46	140.60	225.91
Total	1,660,035	2,710,004	208.26	317.16

Tables 3.2.2 and 3.2.3 show the Waquoit Bay and Popponesset Bay Parcel and Nitrogen Loading Information by Subwatershed, respectively.

Table 3.2.2. Waquoit Parcel Information by Subwatershed (No Soil or Watershed Attenuation)

MAP ID	MEP Watersheds	Existing WW Flows (gpd)	Future Seasonal WW Flows (gpd)	Existing WW N Load (kg/day)	Future Seasonal WW N Load (kg/day)
Quashnet River					
1	Snake Pond	280	280	0.04	0.04
2	Weeks Pond	2,703	3,347	0.36	0.44
3	Ashumet Pond	39,182	48,224	5.20	6.40
4	Johns Pond	52,069	77,517	6.91	10.29
5	Moody Pond	4,802	8,859	0.64	1.18
6	Upper Quashnet River	119,684	391,897	15.73	39.84
7	Middle Quashnet River	20,773	29,007	2.76	3.85
8	Lower Quashnet River	8,456	11,941	1.12	1.59
19	Turner Road Well #5 ³	2,660	3,780	0.35	0.50
20	Mashpee Well #1 ³	2,376	2,707	0.26	0.34
21	MMR J Well ^{3,4}	18,984	22,390	2.52	2.97
Subtotal Quashnet River		271,968	599,948	35.89	67.44
Hamblin Pond / Red Brook					
9	Red Brook	52,654	117,904	6.78	11.65
10	Lower Red Brook	8,238	17,451	1.09	2.32
11	Hamblin Pond	31,769	45,211	4.22	6.00
12	Little River	7,968	10,068	1.06	1.34
SubTotal Hamblin/Red		100,630	190,634	13.15	21.30
Jehu Pond / Great River					
13	Great River	4,652	5,912	0.62	0.78
14	Jehu Pond	34,046	48,531	4.52	5.99
15	Lower Great River	24,599	28,221	3.26	3.74
SubTotal Jehu / Great		63,296	82,664	8.40	10.52
Sage Lot / Flat Pond					
16	Flat Pond	6,013	18,067	0.80	2.40
17	Flat / Sage Lot Transition	4,489	5,749	0.60	0.76
18	Sage Lot Pond	0	0	0.00	0.00
SubTotal Sage Lot / Flat Pond		10,503	23,816	1.39	3.16
East Waquoit Bay Totals		446,396	897,063	58.82	102.42

Table 3.2.3. Popponesset Bay Parcel Information by Subwatershed (No Soil or Watershed Attenuation)

MEP ID	MEP Watersheds	Existing WW Flows (gpd)	Future Seasonal WW Flows (gpd)	Existing WW N Load (kg/day)	Future Seasonal WW N Load
	Mashpee River				
1	Snake Pond	0	0	0.00	0.00
2	Pimlico Pond	32,147	42,029	4.27	5.58
3	Peters Pond	57,767	64,436	7.67	8.56
4	Mashpee-Wakeby Pond	128,955	192,896	17.12	25.61
6	Upper Mashpee River	177,602	259,560	19.67	34.72
7	Lower Mashpee River	104,688	226,882	10.47	17.78
	Mashpee River SubTotal	501,158	785,802	59.20	92.25
	Shoestring Bay				
5	Santuit Pond	124,072	141,638	16.47	18.80
8	Quaker Run	28,402	52,550	1.59	4.19
9	Santuit River	160,170	252,873	20.82	29.61
10	Shoestring Bay	92,074	117,866	10.53	13.42
15	Quaker Run Well ³	20,431	21,837	2.71	2.90
16	Cotuit Well #5 ³	9,706	10,966	1.29	1.45
	Shoestring Bay SubTotal	434,854	597,730	53.41	70.36
12	Ockway Bay	25,766	41,306	3.42	5.48
11	Pinquickset Cove	8,276	13,329	1.10	1.77
	Popponesset Bay				
13	Popponesset Creek	40,886	45,926	5.42	5.97
14	Popponesset Bay	12,321	14,141	1.63	1.88
	Popponesset Bay SubTotal	53,207	60,067	7.06	7.84
	Popponesset Bay Totals	1,023,262	1,498,235	124.18	177.71

3.3 Nitrogen Loading and TMDLs

Table 3.3.1 presents the non-wastewater nitrogen sources design criteria from the MEP technical reports, referenced in the Stearns & Wheler Needs Assessment Report.

Table 3.3.1. Non-Wastewater Nitrogen Sources

Nitrogen Source	Nitrogen Concentration or Load	Recharge Rate
Pavement Runoff	1.5 mg/l	40 in/year
Roof Runoff	0.75 mg/l	40 in/year
Precipitation to Natural Areas	0.072 mg/l	27.25 in/year
Lawn Fertilizer	0.49 kg/lawn ²	NA

1. MEP used 1.08 lb/lawn. The Nitrogen Load is shown as kg/lawn to correlate with the concentrations in mg/l

2. Source: Stearns & Wheler *Needs Assessment Report*, April 2007.

Nitrogen limits for the Popponeset Bay estuary were determined by MEP in September 2004 and for Waquoit Bay East in January 2005. These nitrogen limits led to the development of TMDLs for these embayments. The TMDLs were issued in April 2006 (Final) and October 2005 (Final Draft), respectively.

3.3.1 Data Overview

There are fundamental differences in how the nitrogen loading data is presented in the TMDL and MEP reports. The first step toward defining the nitrogen removal requirements is to establish the existing and future nitrogen loads and the TMDL in similar units. The following three sources of data were used:

1. Stearns and Wheler provided parcel databases for each Town
2. MEP watershed loadings and delineations
3. TMDL Threshold Watershed Nitrogen Loadings

3.3.1.1 Stearns & Wheler provided Databases

The parcel data contained wastewater flow data for each parcel within the watershed. The Town of Mashpee parcels contained nitrogen loading per parcel, and in the case of parcels that have WWTFs on them, the nitrogen loading reflected the treatment removals. The nitrogen loadings from the database represent raw loads, prior to septic system removal or water body attenuation. The nitrogen concentration for these flows is 35 mg/L.

3.3.1.2 MEP Data

The data presented in the “rainbow” spreadsheets of the MEP reports represent the loadings that the groundwater sees from the septic systems. These numbers reflect the expected removal by the septic systems, assumed to be 25%. The nitrogen concentration for these flows is 26.5 mg/L. Additionally, the following data was furnished by MEP and used in the detailed analysis of the fate of nitrogen following introduction to groundwater in different subwatersheds:

- % of pond outflow to other subwatersheds and outside the PPA
- Existing and buildout land use nitrogen loads
- Buildout septic loads
- Natural attenuation within individual water bodies

The MEP data was used to establish the total existing and future controllable nitrogen load and to determine the cumulative natural nitrogen attenuation for all subwatersheds.

3.3.1.3 TMDL Data

The TMDL data for wastewater loading represents attenuated loads. The attenuation depends on the subwatershed where the nitrogen is introduced. In some cases, where it is introduced prior to a pond that drains to another pond that drains to a river, the natural attenuation can be greater than 75%. For areas that drain directly to the embayment or into a river close to the embayment, there is little to no attenuation beyond the septic system.

3.3.1.4 Data Comparison

The basis of the Nitrex™ scenario is nitrogen removal from the parcels that are treated. The only source that can be used on a parcel by parcel basis is the database. It is therefore important to verify that the initial nitrogen loads in the database are comparable to the MEP reported values. Table 3.3.2A presents the database totals for existing raw and septic nitrogen loads in the Popponesset Bay watershed. The septic system effluent values are compared to the MEP reported loadings to establish initial conditions. The results show some discrepancies between the data sources.

Table 3.3.2A. Comparison of Existing Nitrogen Loading Data for Popponesset Bay

Row #	Source of Nitrogen Loading Data	Mashpee River (kg/day)	Shoestring Bay (kg/day)	Ockway Bay ¹ (kg/day)	Pinquickset Cove ¹ (kg/day)	Popp. Creek / Cove ¹ (kg/day)	Total (kg/day)	
1	S&W March 2008 Report Nitrogen Loads	Raw	59.00	53.6	3.4	0.73	7.40	124.13
2		Septic	44.25	40.2	2.55	0.55	5.55	93.10
3	Stearns and Wheler Database Provided to LAI on May 21, 2008, using Provided Existing Nitrogen Load for Mashpee	Raw	59.20	53.41	3.42	1.10	7.06	124.18
4		Septic	44.40	40.05	2.56	0.82	5.29	93.14
5	MEP Existing N Loads Summary (septic + WWTF)	Septic	44.56	39.12	2.39	0.58	5.56	92.21
6	Variance - MEP less S&W Report	= 5 - 2	0.31	-1.08	-0.16	0.03	0.01	-0.88
7	Ratio - MEP/S&W Report	= 5 / 2	101%	97%	94%	105%	100%	99%
8	Variance - MEP less S&W Database Provided to LAI	= 5 - 4	0.15	-0.93	-0.17	-0.25	0.27	-0.92
9		Ratio - MEP/S&W Database Provided to LAI	= 5 / 4	100%	98%	93%	70%	105%
10	Variance - S&W Database less S&W Report	= 4 - 2	0.15	-0.15	0.01	0.28	-0.26	0.04
11	Ratio - S&W Database/S&W Report	= 4 / 2	100%	100%	101%	151%	95%	100%

¹No fresh water attenuation in these subwatersheds

²Cape Cod Commission database using 35 mg/L and parcel wastewater generation data

³Values calculated by applying a 25% attenuation factor to account for septic system N removal.

⁴Rainbow spreadsheet is Table IV-5 from the September 2004 *MEP Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Popponesset Bay, Mashpee and Barnstable, Massachusetts*

⁵Values calculated for smaller subwatersheds within these subwatersheds using attenuation factors from Table IV-5

⁷Data from Stearns & Wheler April 2007 Watershed Nitrogen Management Plan

⁶Values calculated from Table 4 in December 2006 MAPEP *Final Popponesset Bay Total Maximum Daily Loads for Total Nitrogen Report*

Table 3.3.2B presents the comparison of Future Nitrogen Loading data for Popponesset Bay.

Table 3.3.2B. Comparison of Future Nitrogen Loading Data for Popponeset Bay

Row #	Source of Nitrogen Loading Data		Mashpee River (kg/day)	Shoestring Bay (kg/day)	Ockway Bay (kg/day)	Pinquickset Cove (kg/day)	Popp. Creek / Cove (kg/day)	Total (kg/day)
1	S&W March 2008 Report Future Nitrogen Loads	Raw	95.10	74.00	6.60	1.10	10.70	187.50
2	S&W March 2008 Report Future Nitrogen Loads Septic System Effluent N Load	Septic	71.33	55.50	4.95	0.83	8.03	140.63
3	Stearns & Wheeler Database Provided to LAI on May 21, 2008, Future Nitrogen Load (with Mashpee seasonal adjustments)	Raw Seasonal	92.25	70.36	5.48	1.77	7.84	177.71
4	Stearns & Wheeler Database Provided to LAI on May 21, 2008, Septic Sys. Eff N Load (with Mashpee seasonal adjustments)	Septic Seasonal	69.19	52.77	4.11	1.33	5.88	133.28
5	MEP Total Buildout Nitrogen Loads - Wastewater Only	Septic	59.64	44.22	3.40	0.78	6.08	114.11
6	Variance - MEP - S&W Report	= 5 - 2	-11.69	-11.28	-1.55	-0.05	-1.95	-26.51
7	Ratio - MEP/S&W Report	= 5 / 2	84%	80%	69%	94%	76%	81%
8	Variance - MEP - S&W Database provided to LAI on May 21, 2008 (with seasonal adjustments)	= 5 - 4	-9.55	-8.55	-0.71	-0.55	0.19	-19.17
9	Ratio - MEP/S&W Database provided to LAI on May 21, 2008 (with seasonal adjustments)	= 5 / 4	86%	84%	83%	59%	103%	86%
10	Variance - S&W Database less S&W Report	= 4 - 2	-2.14	-2.73	-0.84	0.50	-2.14	-7.34
11	Ratio - S&W Database/S&W Report	= 4 / 2	97%	95%	83%	161%	73%	95%

Table 3.3.3A presents the database totals for raw, septic system effluent and water body attenuated nitrogen loads in the East Waquoit Bay. The septic system effluent values are compared to the MEP reported loadings to establish initial conditions. The results show some discrepancies between the data sources. This comparison shows that the database provided to LAI appears to have low values for existing nitrogen loads.

Table 3.3.3A. Comparison of Existing Nitrogen Loading Data for East Waquoit Bay

Row #	Source of Nitrogen Loading Data		Little River / Hamblin Pond (kg/day)	Great River / Jehu Pond (kg/day)	Quashnet River (kg/day)	Total (kg/day)
1	S&W March 2008 Report Existing Nitrogen Loads	Raw	13.80	8.42	30.73	52.95
2	S&W March 2008 Report Existing Nitrogen Loads, Septic System Effluent N Load	Septic	10.35	6.32	23.05	39.71
3	Stearns and Wheeler Database Provided to LAI on May 21, 2008, using Provided Existing Nitrogen Load for Mashpee	Raw	13.15	1.88	35.89	50.91
4	Stearns and Wheeler Database Provided to LAI on May 21, 2008, Septic System Effluent Nitrogen Load	Septic	9.86	1.41	26.92	38.18
5	MEP Existing N Loads Summary (septic + WWTF)	Septic	12.02	5.36	24.68	42.06
6	Variance - MEP less S&W Report	= 5 - 2	1.67	-0.96	1.64	2.35
7	Ratio - MEP/S&W Report	= 5 / 2	116%	85%	107%	106%
8	Variance - MEP less S&W Database Provided to LAI	= 5 - 4	2.16	3.95	-2.23	3.87
9	Ratio - MEP/S&W Database Provided to LAI	= 5 / 4	122%	380%	92%	110%
10	Variance - S&W Database less S&W Report	= 4 - 2	-0.49	-4.91	3.87	-1.53
11	Ratio - S&W Database/S&W Report	= 4 / 2	95%	22%	117%	96%

¹No fresh water attenuation in these subwatersheds

²Cape Cod Commission database using 35 mg/L and parcel wastewater generation data

³Values calculated by applying a 25% attenuation factor to account for septic system N removal.

⁴Rainbow spreadsheet is Table IV-5 from the September 2004 *MEP Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Popponesset Bay, Mashpee and Barnstable, Massachusetts*

Table 3.3.3B presents the comparison of Future Nitrogen Loading data for East Waquoit Bay.

Table 3.3.3B. Comparison of Future Nitrogen Loading Data for East Waquoit Bay

Row #	Source of Nitrogen Loading Data		Little River / Hamblin Pond (kg/day)	Great River / Jehu Pond (kg/day)	Quashnet River (kg/day)	Total (kg/day)
1	S&W March 2008 Report Future Nitrogen Loads	Raw	24.50	13.47	61.04	99.01
2	S&W March 2008 Report Future Nitrogen Loads Septic System Effluent N Load	Septic	18.38	10.10	45.78	74.26
3	Stearns & Wheler Database Provided to LAI on May 21, 2008, Future Nitrogen Load	Raw Seasonal	21.30	10.52	67.44	99.26
4	Stearns & Wheler Database Provided to LAI on May 21, 2008, Septic Sys. Eff N Load (with Mashpee seasonal adjustments)	Septic Seasonal	15.98	7.89	50.58	74.44
5	MEP Total Buildout Nitrogen Loads - Wastewater Only	Septic	17.95	6.94	47.85	72.74
6	Variance - MEP - S&W Report	= 5 - 2	-0.43	-3.17	2.07	-1.52
7	Ratio - MEP/S&W Report	= 5 / 2	98%	69%	105%	98%
8	Variance - MEP - S&W Database provided to LAI on May 21, 2008 (with seasonal adjustments)	= 5 - 4	1.97	-0.95	-2.72	-1.70
9	Ratio - MEP/S&W Database provided to LAI on May 21, 2008 (with seasonal adjustments)	= 5 / 4	112%	88%	95%	98%
10	Variance - S&W Database less S&W Report	= 4 - 2	-2.40	-2.22	4.80	0.18
11	Ratio - S&W Database/S&W Report	= 4 / 2	87%	78%	110%	100%

3.3.2 Popponeset Bay Nitrogen Removal Requirements

The TMDL report presents a nitrogen loading scenario by subwatershed that will result in meeting the target nitrogen concentration at the sentinel station in Popponeset Bay. The TMDL was developed by separating the controllable loads from the non-controllable loads. A target threshold watershed nitrogen load was developed for the controllable load. When this concentration is added to the non-controllable load, the result is the TMDL. Table 3.3.4 shows the TMDL components for Popponeset Bay. As discussed previously, the TMDL loads are attenuated loads, representing the loads seen in the receiving water body as a result of loadings throughout the watershed.

Table 3.3.4. TMDL Components for Popponesset Bay

Subwatershed Group	Target Threshold Watershed Load - Controllable (kg/day)	Non-Controllable		TMDL (kg/day)
		Atmospheric Deposition (kg/day)	Benthic Flux ¹ (kg/day)	
Mashpee River	16.2	0.7	9.4	16
Shoestring Bay	19.7	2.2	-8.7	13
Ockway Bay	0.8	1.1	1.1	3
Pinquisset Cove	0.8	0.3	-0.3	1
Popponesset Bay	2.8	4	-5.5	1
Total Popponesset Bay	40.3	8.3	-4	34

Source: MADEP December 5, 2006 Report, Final Popponesset Bay Total Maximum Daily Loads for Total Nitrogen

¹Projected sediment N loadings obtained by reducing the present loading rates proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON.

In order to meet the target threshold watershed load, enough nitrogen must be removed from the existing controllable load to achieve the target. The difference between the current controllable load and the target represents the nitrogen removal requirement. The Nitrex™ scenarios assume that this load must be removed from the wastewater load only, as measures to reduce land use and runoff contributions were not considered, as specified by the Mashpee Sewer Commission. In addition, enough nitrogen must be removed from existing loads to provide capacity for future loads. The controllable load was calculated by adding the land use and runoff contributions, as reported by MEP, to the wastewater loads.

Attenuation varies greatly between subwatersheds, as mentioned previously. For this reason, nitrogen loads from both wastewater and land use / runoff were converted to attenuated loads to illustrate each subwatershed's nitrogen loading contribution to Popponesset Bay. This also helps to identify areas where nitrogen removal will likely be more cost effective. Areas with high levels of natural attenuation are the least cost effective areas for nitrogen removal, and should be included last and only if necessary to meet the target. Table 3.3.5 details the conversion of existing loads to attenuated loads and the subsequent calculation of the nitrogen removal requirement within each of the subwatershed groups listed in Table 3.3.4.

The mass and percent removal calculated in Table 3.3.5 for the subwatershed groups is the basis for selecting parcels to be treated in the Nitrex™ scenarios for Popponesset Bay.

Table 3.3.5. Nitrogen Removal Requirements – Popponeset Bay

MEP ID	MEP Watersheds	Number of Parcels			Existing WW Flows (gpd)	Future Seasonal WW Flows (gpd)	% of Watershed Total Flow	Existing WW N Load (kg/day)	Future Seasonal WW N Load	Existing WW N Load Septic Effluent (25% Attm.)	Treatment Plant N Load (kg/day)	Exist. Land Use + Runoff (kg/day) ^{5, 6}	Total Existing Cont. N Load (kg/day)	Total Buildout Addn'l N Load (kg/day)	Buildout N Load from Septic (kg/day)	Buildout N Load from Septic w/Trt. (kg/day) ¹	Other Buildout N Load (kg/day) ⁷	Total Buildout Addn'l N Load (kg/day)	Total Buildout Cont. N Load No Trt. (kg/day)	Total Buildout Cont. N Load (kg/day)	TMDL (kg/day)	Existing N Removal to Reach TMDL (kg/day)	Total Atten. %	Existing Septic N Load with Atten. (kg/day)	Existing Cont. N Load with Atten. (kg/day)	Buildout Cont. N Load with Atten. (kg/day)	Buildout Cont. N Load with Atten. No Trt. (kg/day)	Target N Load (kg/day)	N Removal Required (kg/day)	Req'd % Removal from Existing Cont.	Req'd % Removal from Existing Septic		
		Total	Exist. Dev.	Total Future Dev.																													
Mashpee River																																	
1	Snake Pond	0	0	0	0	0.00%	0.00	0.00	0.00		0.17	0.17	0.08	0.07	0.01	0.01	0.01	0.01	0.25	0.18	27	32		94%	0.00	0.01	0.01	0.01	16.17	19.22	61%	79%	
2	Pimlico Pond	225	184	215	32,147	42,029	6.41%	4.27	5.58	3.20	0.53	3.74	1.54	1.41	0.14	0.13	0.27	5.28	4.01				83%	0.56	0.65	0.70	0.92						
3	Peters Pond	319	273	292	57,767	64,436	11.53%	7.67	8.56	5.75	0.15	1.17	7.07	0.22	0.20	0.02	0.02	0.04	7.29	7.11				83%	1.01	1.24	1.24	1.28					
4	Mashpee-Wakeby Pond	1,086	830	978	128,955	192,896	25.73%	17.12	25.61	12.84	0.22	2.87	15.94	0.32	0.29	0.03	0.03	0.06	16.26	15.99				65%	4.49	5.58	5.60	5.69					
6	Upper Mashpee River	1,084	665	807	177,602	259,560	35.44%	19.67	34.72	14.76	0.92	4.03	19.71	10.40	9.85	0.98	0.55	1.54	30.11	21.25				30%	10.33	13.79	14.87	21.07					
7	Lower Mashpee River	609	423	518	104,688	226,882	20.89%	10.47	17.78	7.85		2.35	10.20	5.69	3.26	0.33	2.43	2.76	15.89	12.96				0%	7.85	10.20	12.96	15.89					
Mashpee River SubTotal		3,323	2,375	2,810	501,158	785,802	100%	59.20	92.25	44.40	1.29	11.13	56.82	18.25	15.08	1.51	3.17	4.68	75.08	61.51													
Shoestring Bay																																	
5	Santuit Pond	1,062	880	965	124,072	141,638	28.53%	16.47	18.80	12.35		2.66	15.01	3.05	2.79	0.28	0.26	0.54	18.06	15.55				65%	4.32	5.25	5.44	6.32					
8	Quaker Run	254	180	191	28,402	52,550	6.53%	1.59	4.19	1.19		1.39	2.59	0.50	0.34	0.03	0.15	0.19	3.08	2.77				0%	1.19	2.59	2.77	3.08					
9	Santuit River	1,192	814	961	160,170	252,873	36.83%	20.82	29.61	15.61	2.59	3.86	22.06	2.00	1.27	0.13	0.73	0.85	24.06	22.92				30%	10.93	15.45	16.04	16.84					
10	Shoestring Bay	836	598	734	92,074	117,866	21.17%	10.53	13.42	7.90	0.50	2.26	10.66	0.55	0.40	0.04	0.15	0.19	11.22	10.85				0%	7.90	10.66	10.85	11.22					
15	Quaker Run Well ³	86	73	83	20,431	21,837	4.70%	2.71	2.90	2.03		0.21	2.24	0.14	0.13	0.01	0.01	0.02	2.38	2.27				0%	2.03	2.24	2.27	2.38					
16	Cotuit Well #5 ³	85	69	78	9,706	10,966	2.23%	1.29	1.45	0.97		0.16	1.13	0.18	0.16	0.02	0.02	0.03	1.31	1.16				30%	0.68	0.79	0.81	0.92					
Shoestring Bay SubTotal		3,515	2,614	3,012	434,854	597,730	100%	53.41	70.36	40.05	3.09	10.54	53.69	6.42	5.10	0.51	1.32	1.83	60.11	55.52													
Ockway Bay																																	
12	Ockway Bay	303	215	249	25,766	41,306	100%	3.42	5.48	2.56		0.76	3.32	1.10	1.01	0.10	0.09	0.20	4.42	3.51	25	-24		2.56	3.32	3.51	4.42	0.76	2.75	83%	107%		
11	Pinquisset Cove	72	51	68	8,276	13,329	100%	1.10	1.77	0.82		0.19	1.01	0.22	0.20	0.02	0.02	0.04	1.23	1.05				0.82	1.01	1.05	1.23	0.76	0.29	29%	35%		
Popponeset Bay																																	
13	Popponeset Creek	423	350	375	40,886	45,926	76.84%	5.42	5.97	4.07		0.95	5.02	0.41	0.37	0.04	0.05	0.08	5.44	5.11				4.07	5.02	5.11	5.44						
14	Popponeset Bay	58	48	52	12,321	14,141	23.16%	1.63	1.88	1.23		0.24	1.47	0.16	0.15	0.01	0.01	0.03	1.63	1.50				1.23	1.47	1.50	1.63						
Popponeset Bay SubTotal		481	398	427	53,207	60,067	100%	7.06	7.84	5.29	0.00	1.19	6.49	0.58	0.51	0.05	0.06	0.11	7.06	6.60													
Popponeset Bay Totals		7,694	5,653	6,566	1,023,262	1,498,235		124.18	177.71	93.14	4.39	23.81	121.34	26.57	21.90	2.19	4.67	6.86	147.91	128.20	54				59.97	79.28	84.75	98.35	40.18	44.57	56%	74%	

¹All future systems, including commercial and industrial, that are not connecting to an existing WWTF will be required to connect to one of the proposed cluster systems or have their own onsite systems. Nit assumed

²Amount of nitrogen that must be removed from existing septic loads to create capacity for Buildout additional N load.

³No credit taken for public water supply well withdrawals

⁵Existing Land Use + Runoff N Loading is the sum of the total Fertilizer, Impervious and Natural Surfaces values taken from Table IV-5 of the January 2005 MEP Report

⁶% of Buildout load from wastewater taken from Figure IV-4 of the January 2005 MEP Report. Future % assumed to be the same as existing.

⁷Other N loading are the total buildout N load minus the septic component. This includes runoff, fertilizer, and all increased loads to existing WWTFs.

3.3.3 East Waquoit Bay Nitrogen Removal Requirements

The TMDL report presents a nitrogen loading scenario by subwatershed that will result in meeting the target nitrogen concentration at the sentinel station in East Waquoit Bay. The TMDL was developed by separating the controllable loads from the non-controllable loads. A target threshold watershed nitrogen load was developed for the controllable load. When this concentration is added to the non-controllable load, the result is the TMDL. Table 3.3.6 shows the TMDL components for East Waquoit Bay. As discussed previously, the TMDL loads are attenuated loads, representing the loads seen in the receiving water body as a result of loadings throughout the watershed.

Table 3.3.6. TMDL Components for East Waquoit Bay

Subwatershed Group	Target Threshold Watershed Load - Controllable (kg/day)	Non-Controllable		TMDL (kg/day)
		Atmospheric Deposition (kg/day)	Benthic Flux ¹ (kg/day)	
Great River / Jehu Pond	1.88	1.97	21.51	25
Little River / Hamblin Pond	3.83	1.75	-3.44	2
Quashnet River	15.92	0.58	10.62	27
Total East Waquoit Bay	21.63	4.3	28.69	54

Source: MADEP October 14, 2005 Report, *Final Draft Quashnet River, Hamblin Pond, Little River, Jehu Pone, and Great River in the Waquoit Bay System Total Maximum Daily Loads for Total Nitrogen*

¹Projected sediment N loadings obtained by reducing the present loading rates proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON.

In order to meet the target threshold watershed load, enough nitrogen must be removed from the existing controllable load to achieve the target. The difference between the current controllable load and the target represents the nitrogen removal requirement. The Nitrex™ scenarios assume that this load must be removed from the wastewater load only, as measures to reduce land use and runoff contributions were not considered, as specified by the Mashpee Sewer Commission. In addition, enough nitrogen must be removed from existing loads to provide capacity for future loads. The controllable load was calculated by adding the land use and runoff contributions, as reported by MEP, to the wastewater loads.

Attenuation varies greatly between subwatersheds, as mentioned previously. For this reason, nitrogen loads from both wastewater and land use / runoff were converted to attenuated loads to illustrate each subwatershed's nitrogen loading contribution to East Waquoit Bay. This also helps to identify areas where nitrogen removal will likely be more cost effective. Areas with high levels of natural attenuation are the least cost

effective areas for nitrogen removal, and should be included last and only if necessary to meet the target. Table 3.3.7 details the conversion of existing loads to attenuated loads and the subsequent calculation of the nitrogen removal requirement within each of the subwatershed groups listed in Table 3.3.6.

The mass and percent removal calculated in Table 3.3.7 for the subwatershed groups is the basis for selecting parcels to be treated in the Nitrex™ scenarios for East Waquoit Bay.

Table 3.3.7. Nitrogen Removal Requirements – East Waquoit Bay

MAP ID	MEP Watersheds	Number of Parcels			Existing WW Flows (gpd)	Future Seasonal WW Flows (gpd)	% of Watershed Total Flow	Existing WW N Load (kg/day)	Future Seasonal WW N Load (kg/day)	Existing WW N Load Septic Effluent (25% Attn.)	Treatment Plant N Load (kg/day)	Exist. Land Use + Runoff (kg/day) ^{4,5}	Total Existing Cont. N Load (kg/day)	Total Buildout Addn'l N Load (kg/day)	Buildout N Load from Septic (kg/day)	Buildout N Load from Septic w/Trt. (kg/day) ¹	Other Buildout N Load (kg/day) ⁷	Total Buildout Addn'l N Load (kg/day)	Total Buildout Cont. N Load (kg/day)	TMDL (kg/day)	Existing N Removal to Reach TMDL (kg/day)	Total Atten. %	Existing Septic N Load with Atten.	Existing Cont. N Load with Atten.	Buildout Cont. N Load with Atten.	Target N Load (kg/day)	N Removal Required (kg/day)	Req'd % Removal from Existing Cont.	Req'd % Removal from Existing Septic
		Total	Existing Developed	Future Developed																									
Quashnet River																													
1	Snake Pond	30	1	1	280	280	0.10%	0.04	0.04	0.03		0.17	0.20	0.080	0.073	0.007	0.007	0.014	0.212	27	9	78%	0.006	0.043	0.046	15.92	8.38	42%	64%
2	Weeks Pond	23	13	16	2,703	3,347	0.99%	0.36	0.44	0.27		0.06	0.33	0.060	0.055	0.005	0.005	0.011	0.336			87%	0.035	0.042	0.043				
3	Ashumet Pond	306	225	267	39,182	48,224	14.41%	5.20	6.40	3.90	0.07	2.66	6.64	2.144	1.961	0.196	0.183	0.380	7.018			91%	0.364	0.619	0.655				
4	Johns Pond	515	392	457	52,069	77,517	19.15%	6.91	10.29	5.18		4.95	10.13	1.363	1.246	0.125	0.117	0.241	10.375			71%	1.487	2.908	2.978				
5	Moody Pond	66	23	47	4,802	8,859	1.77%	0.64	1.18	0.48	0.15	1.45	2.07	0.621	0.568	0.057	0.053	0.110	2.183			70%	0.144	0.623	0.656				
6	Upper Quashnet River	855	572	727	119,684	391,897	44.01%	15.73	39.84	11.80	0.33	5.80	17.93	21.777	18.020	1.802	3.756	5.558	23.488			30%	8.260	12.551	16.442				
7	Middle Quashnet River	159	94	132	20,773	29,007	7.64%	2.76	3.85	2.07		0.36	2.43	0.862	0.788	0.079	0.074	0.153	2.581			30%	1.448	1.700	1.807				
8	Lower Quashnet River	44	31	41	8,456	11,941	3.11%	1.12	1.59	0.84		0.22	1.06	0.100	0.092	0.009	0.009	0.018	1.079			0%	0.842	1.061	1.079				
19	Turner Road Well #5 ³	29	19	26	2,660	3,780	0.98%	0.35	0.50	0.26		0.03	0.30	0.140	0.128	0.013	0.012	0.025	0.324			0%	0.265	0.299	0.324				
20	Mashpee Well #1 ³	8	6	6	2,376	2,707	0.87%	0.26	0.34	0.19		0.07	0.26	0.074	0.073	0.007	0.001	0.009	0.268			0%	0.192	0.260	0.268				
21	MMR J Well ^{3,4}	110	95	106	18,984	22,390	6.98%	2.52	2.97	1.89		0.34	2.23	0.180	0.165	0.016	0.016	0.032	2.266			100%	0.000	0.000	0.000				
Subtotal Quashnet River		2,145	1,471	1,826	271,968	599,948	100%	35.89	67.44	26.92	0.56	16.11	43.58	27.40	23.17	2.32	4.23	6.55	50.13				13.04	20.11	24.30				
Hamblin Pond / Red Brook																													
9	Red Brook	520	256	465	52,654	117,904	52%	6.78	11.65	5.09	1.00	1.28	7.36	4.66	4.36	0.436	0.304	0.740	8.101	2	11	50%	2.543	3.680	4.050	3.83	6.25	66%	85%
10	Lower Red Brook	128	57	116	8,238	17,451	8%	1.09	2.32	0.82		0.28	1.10	0.56	0.51	0.051	0.048	0.099	1.199			0%	0.820	1.100	1.199				
11	Hamblin Pond	304	149	222	31,769	45,211	32%	4.22	6.00	3.16		0.48	3.64	1.00	0.92	0.092	0.086	0.178	3.820			0%	3.162	3.642	3.820				
12	Little River	90	71	79	7,968	10,068	8%	1.06	1.34	0.79		0.19	0.98	0.16	0.15	0.015	0.014	0.028	1.011			0%	0.793	0.983	1.011				
SubTotal Hamblin/Red		1,042	533	882	100,630	190,634	100%	13.15	21.30	9.86		2.23	13.09	6.38	5.93	0.59	0.45	1.04	14.13				7.32	9.40	10.08				
Jehu Pond / Great River																													
13	Great River	75	33	42	4,652	5,912	7%	0.62	0.78	0.46		0.32	0.78	0.90	0.82	0.082	0.077	0.160	0.943	25	-17	0%	0.463	0.783	0.943	1.88	6.60	81%	105%
14	Jehu Pond	239	186	209	34,046	48,531	54%	4.52	5.99	3.39		0.96	4.35	0.40	0.37	0.037	0.034	0.071	4.418			0%	3.387	4.347	4.418				
15	Lower Great River	282	229	250	24,599	28,221	39%	3.26	3.74	2.45		0.60	3.05	0.42	0.38	0.038	0.036	0.075	3.122			0%	2.447	3.047	3.122				
SubTotal Jehu / Great		596	448	501	63,296	82,664	100%	8.40	10.52	6.30		1.88	8.18	1.72	1.58	0.16	0.15	0.31	8.48				6.30	8.18	8.48				
Sage Lot / Flat Pond																													
16	Flat Pond	68	55	57	6,013	18,067	57%	0.80	2.40	0.60		0.90	1.50	0.00	0.00	0.000	0.000	1.498	NA	NA		0.598	1.498	1.498	NA	NA	NA	NA	
17	Flat / Sage Lot Transition	57	45	54	4,489	5,749	43%	0.60	0.76	0.45		0.14	0.59	0.14	0.13	0.013	0.012	0.025	0.611			0.447	0.587	0.611					
18	Sage Lot Pond	3	0	0	0	0	0%	0.00	0.00	0.00		0.04	0.04	0.00	0.00	0.000	0.000	0.040				0.000	0.040	0.040					
SubTotal Sage Lot / Flat Pond		128	100	111	10,503	23,816	100%	1.39	3.16	1.04		1.08	2.12	0.14	0.13	0.01	0.01	0.02	2.15				1.04	2.12	2.15				
East Waquoit Bay Totals		3,911	2,552	3,320	446,396	897,063		58.82	102.42	44.12		21.30	66.97	35.65	30.81	3.08	4.84	7.92	74.89	54			27.70	39.81	45.01	21.63	21.23	53%	77%

¹All future systems, including commercial and industrial, that are not connecting to an existing WWTF will be required to connect to one of the proposed cluster systems or have their own onsite systems. systems is assumed t

²Amount of nitrogen that must be removed from existing septic loads to create capacity for Buildout additional N load.

³No credit taken for public water supply well withdrawals, except for MMR Well

⁴MMR J Well withdrawals discharge outside the watershed. Outflow set to 100% to account for this.

⁵Existing Land Use + Runoff N Loading is the sum of the total Fertilizer, Impervious and Natural Surfaces values taken from Table IV-5 of the January 2005 MEP Report

⁶% of Buildout load from wastewater taken from Figure IV-4 of the January 2005 MEP Report. Future % assumed to be the same as existing.

⁷Other N loading are the total buildout N load minus the septic component. This includes runoff, fertilizer, and all increased loads to existing WWTFs.

3.3.4 Existing PPA Wastewater Treatment Facilities

It is understood that the main source of nitrogen is the sub-surface disposal of domestic wastewater through septic systems or cesspool systems and the migration of the nitrogen in the wastewater to the estuary via groundwater. The other source of wastewater nitrogen loading is the eight (8) small wastewater treatment facilities (WWTFs) in Mashpee and one WWTF in Sandwich.

The following table presents the Nitrogen loads for the Wastewater Treatment Facilities.

Table 3.3.4.1. WWTF Total Nitrogen Concentrations

WWTF	Watershed	Sub-Watershed	TN (mg/l) ¹	Design Flow (gpd)	Average Annual Existing Flow (gal/day)	Average Annual Future Flow (gal/day)	TN at Existing Flow	TN at Future Flow
							(kg/day)	(kg/day)
Willowbend	Popponesset	Santuit River	7.7	113,000	24,860	59,890	0.724	1.745
Southcape	Popponesset	Mashpee River	9.5	24,000	8,400	15,840	0.302	2.152
Stratford Ponds	Popponesset	Santuit River	11.2	35,500	12,070	21,300	0.511	2.537
Mashpee Commons	Popponesset	Mashpee River	6.3	180,000	19,800	106,200	0.472	1.427
Windchime Point	Popponesset	Mashpee River	6.0	40,000	10,000	22,000	0.227	1.359
Forestdale School - Sandwich	Popponesset	Sandwich	NA	20,000	1,200	NA	NA	NA
Popponesset Subtotal				412,500	76,330	225,230	2.236	9.221
Southport	Waquoit	Upper Quashnet River	8.4	172,000	29,240	104,920	0.929	1.903
Mashpee Senior High School	Waquoit	Upper Quashnet River	43.5	18,000	2,700	3,600	0.444	9.855
Waquoit Subtotal				190,000	31,940	108,520	1.373	11.759
New Seabury	Ocean Discharge		2.5	300,000	9,000	69,000	0.085	0.566
Total				902,500	117,270	402,750	3.695	21.546

1. Source: Table 7-4 on page 7-7 of the Stearns & Wheler Needs Assessment Report, April 2007.

The total nitrogen loading from the treatment plants is 3.67 kg/day, from Table 3.3.4.1. The database values for nitrogen loading from the eight (8) treatment plant in Mashpee is 3.54. This confirms that the database loadings associated with the WWTFs is representative of the treated effluent from these facilities.

Table 3.3.4.2. presents the nitrogen loading reductions associated with adding nitrogen removal facilities to each of the WWTFs. This is presented for discussion purposes only, as no load reduction was assumed from the existing WWTFs.

Table 3.3.4.2. WWTF TN Concentration & Removal to TN = 4 mg/l

WWTF	Watershed	Sub-Watershed	Average Annual Existing Flow (gal/day)	Average Annual Future Flow (gal/day)	TN at Existing Flow	TN at Future Flow	TN at 4 mg/l & Existing Flows	TN at 4 mg/l & Future Flows	Nitrogen Removed from Existing	Nitrogen Removed from Future
					(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)
Willowbend	Popponeset	Santuit River	24,860	59,890	0.724	1.745	0.376	0.906	0.348	0.838
Southcape	Popponeset	Mashpee River	8,400	15,840	0.302	2.152	0.127	0.240	0.175	1.913
Stratford Ponds	Popponeset	Santuit River	12,070	21,300	0.511	2.537	0.183	0.322	0.329	2.215
Mashpee Commons	Popponeset	Mashpee River	19,800	106,200	0.472	1.427	0.300	1.607	0.172	0.000
Windchime Point	Popponeset	Mashpee River	10,000	22,000	0.227	1.359	0.151	0.333	0.076	1.026
Forestdale School - Sandwich	Popponeset	Sandwich	1,200	NA	NA	NA	NA	NA	NA	NA
Popponeset Subtotal			76,330	225,230	2.236	9.221	1.137	3.408	1.099	5.993
Southport	Waquoit	Upper Quashnet River	29,240	104,920	0.929	1.903	0.442	1.588	0.487	0.315
Mashpee Senior High School	Waquoit	Upper Quashnet River	2,700	3,600	0.444	9.855	0.041	0.054	0.403	9.801
Waquoit Subtotal			31,940	108,520	1.373	11.759	0.483	1.642	0.890	10.116
New Seabury	Ocean Discharge		9,000	69,000	0.085	0.566	0.136	1.044	-	-
Total			117,270	402,750	3.695	21.546	1.756	6.094	1.990	16.109

1. Source: Table 7-4 on page 7-7 of the Stearns & Wheler Needs Assessment Report, April

3.3.5 Mashpee Nantucket Sound Discharge

There are Mashpee parcels that fall outside the boundaries of both Waquoit Bay and Popponeset Bay. These parcels discharge to Nantucket Sound, and consequently do not impact either the Popponeset Bay or Waquoit Bay Watersheds.

The Nitrogen Loads for these parcels are summarized in Table 3.3.5.1.

Table 3.3.5.1. Mashpee Nantucket Sound Discharge Nitrogen Loads

	Parcel Information								
	Nitrogen Loads			Parcels				Wastewater Flows	
	Present Nitrogen Load (kg/day)	Additional Future Nitrogen Load (kg/day)	Total Future Nitrogen Loads (kg/day)	Total No. of Parcels	Existing Developed	Future Developed	Undeveloped	Present Flow (gpd)	Future Flow (gpd)
Mashpee Parcels Ocean Discharge	66	50	116	1,587	1,253	149	185	176,287	308,635
Totals	229	169	399	9,685	6,568	1,133	1,985	1,061,511	2,011,006

WWTF	TN (mg/l) ¹	Design Flow (gpd)	Average Annual Existing	Average Annual Future	TN at Existing Flow		TN at Future Flow	
					(kg/yr)	(kg/day)	(kg/yr)	(kg/day)
New Seabury	2.5	300,000	9,000	69,000	0.085	0.00023	0.653	0.00179

1. Source: Table 7-4 on page 7-7 of the Stearns & Wheler Needs Assessment Report, April 2007.

4 Wastewater Treatment Options & Cost Estimates

The Wastewater Treatment Options for the Town of Mashpee are:

Nitrex™ Technology:

- Cluster Systems
- On-Site Only
- PRB
- Groundwater Treatment via Pump & Treat
- Hybrid of the above

Conventional Sewering Technology

- Sewers with varying service areas and locations

These scenarios and their cost estimates are discussed below. Examples of installations using these Scenarios are presented in Appendix B.

All options are to achieve the MADEP TMDL requirements and to provide capacity for buildout assuming buildout occurs with future wastewater systems removing 90% of its wastewater nitrogen. In other words, 10% of future loadings are removed from existing wastewater sources to create capacity for future buildout.

4.1 Nitrex™ Technology Scenario 1: Cluster Systems

The Cluster Systems Scenario most resembles conventional sewerage and is the highest cost option of all of the Nitrex™ Technology Scenarios. The Cluster Scenario consists of:

1. Septic Tanks on individual properties either salvaging the existing septic tank or replacing it with a new septic tank.
2. Septic tank effluent collection system from the served properties to a cluster treatment plant.
3. Drainfield Discharge with new facilities – although existing drainfields may be used.

The following assumptions were made for treatment by a Nitrex™ cluster system:

1. Influent Nitrogen Concentration – 35 mg/L
2. Effluent Nitrogen Concentration – 5 mg/L – Nitrex™ System
3. Drainfield Discharge Nitrogen Concentration – 3.75 mg/L – after septic system attenuation

This scenario consists of multiple cluster systems located throughout the PPA, treating areas where the density of developed parcels is relatively high and natural attenuation is low. One scenario, using 16 cluster systems has been developed by LAI. This number and their location has been prepared for Nitrex™ Technology cluster systems approach feasibility and budgeting purposes only. Figures 4.1.1 and 4.1.2 illustrate the locations of the fifteen clusters. For this planning level study, the delineation of the cluster systems is not as important as the number, type and location of the parcels that they include. Of importance also are the subwatersheds to which the cluster systems discharge treated effluent. Figures 4.1.3 and 4.1.3 illustrate the Nitrex™ Scenario Plan by Parcel and Development Status. Figure 4.1.5 illustrates one representative layout for a cluster system. Table 4.1.2 details the nitrogen loads removed by the cluster scenario and how this will meet the MADEP TMDL Report Target Threshold Nitrogen Levels. If the target was not met in one subwatershed, additional nitrogen loads were removed from others so that enough nitrogen will be removed from the receiving watershed to ensure that the water quality goal at the sentinel station will be met. The TMDL reports emphasize the fact that those targets are *one* possible combination that will achieve the water quality goals and that there may be others.

Tables 4.1.3 and 4.1.4 present the final nitrogen loadings to the subwatersheds after Nitrex™ treatment for the cluster systems. These tables are the basis for input into the MEP model. The nitrogen loadings reported in these tables are septic system effluent values, which do not account for natural attenuation. It is understood that the MEP model uses septic system effluent nitrogen loading as the input values for analysis.

Table 4.1.2. Nitrogen Loads Treated with Cluster Scenario (Includes the Return Loads)

	Popponneset Bay Watershed						East Waquoit Bay Watershed		
	Popponneset Bay	Shoestring Bay	Ockway Bay	Pinquickset Cove	Mashpee River	Sub-Totals	Little River / Hamblin Pond	Great River / Jehu Pond	Quashnet River
Total Existing Cont. N Load (kg/day)	6.49	53.69	3.32	1.01	56.82	121.34	13.09	8.18	43.58
Target Loads	2.77	19.72	0.76	0.76	16.17	40.18	3.83	1.88	15.92
Total Buildout Cont. N Load (kg/day)	6.60	55.52	3.51	1.05	61.51	128.20	14.13	8.48	50.13
N Removal Required w/ Database Loads (kg/day)	3.83	18.47	2.75	0.29	19.22	44.57	6.25	6.60	8.38
Cluster Number	LAI Removal Loads w/ Atten Consideration					Sub-Totals	LAI Removal Loads w/ Atten Consideration		
1		2.69			0.56	3.25			
2						0.00			2.16
3	3.81		2.56		0.41	6.78		0.12	
4						0.00	3.06		3.20
5		4.83				4.83			
6					4.88	4.88	0.29		
7						0.00		5.22	
8						0.00			1.12
9						0.00	2.97	0.94	
10					6.33	6.33			0.52
11		2.28			2.68	4.96			
12		2.54				2.54			
13		4.37			0.96	5.33			
14	0.06	2.22		0.56		2.84			
15						0.00			4.30
16		0.02			5.22	5.24		0.01	
N Loads Removed	3.87	18.95	2.56	0.56	21.04	46.98	6.32	6.28	11.30
Actual - Required Removal w/ Database Loads	0.04	0.47	-0.19	0.27	1.82	2.41	0.07	-0.32	2.92
N Loads from Non-Treated Parcels	1.39	5.14	0.00	0.22	1.17	7.91	0.00	0.00	1.17
TOTAL Existing N Controllable Loads for PPA									

A summary of the capital, O&M costs and present worth for the Cluster System Scenario are presented in Table 4.1.3.

Table 4.1.3. Nitrex™ Technology Cluster Systems Scenario Cost Estimate

Planning Area	# of Subwatersheds in Cluster	Existing Wastewater Flow (gpd)	Total EDUs	Total Capital Cost	Total Capital Cost with 20% Contingency	Total Capital Cost per EDU	Total O&M	Total O&M per EDU	Total Present Worth	Total Present Worth per EDU*
Cluster #1	2	37,680	245	\$11,959,000	\$14,350,800	\$48,877	\$159,067	\$650	\$10,931,328	\$44,677
Cluster #2	6	40,711	264	\$9,598,000	\$11,517,600	\$36,307	\$157,108	\$594	\$9,135,919	\$34,559
Cluster #3	5	69,365	450	\$19,760,000	\$23,712,000	\$43,870	\$178,693	\$397	\$17,016,913	\$37,780
Cluster #4	7	86,129	559	\$22,412,000	\$26,894,400	\$40,073	\$187,276	\$335	\$19,105,871	\$34,162
Cluster #5	1	80,714	524	\$18,729,000	\$22,474,800	\$35,734	\$181,028	\$345	\$16,275,008	\$31,052
Cluster #6	2	67,247	437	\$13,886,000	\$16,663,200	\$31,800	\$170,800	\$391	\$12,524,544	\$28,682
Cluster #7	4	59,123	384	\$15,212,000	\$18,254,400	\$39,623	\$169,867	\$442	\$13,498,919	\$35,161
Cluster #8	2	47,011	305	\$14,031,000	\$16,837,200	\$45,964	\$164,565	\$539	\$12,551,845	\$41,118
Cluster #9	6	48,044	312	\$14,380,000	\$17,256,000	\$46,093	\$165,307	\$530	\$12,820,094	\$41,093
Cluster #10	4	103,480	672	\$21,426,000	\$25,711,200	\$31,886	\$191,572	\$285	\$18,423,406	\$27,418
Cluster #11	5	70,710	459	\$15,097,000	\$18,116,400	\$32,880	\$173,394	\$378	\$13,457,866	\$29,310
Cluster #12	3	42,508	276	\$7,592,000	\$9,110,400	\$27,505	\$155,210	\$562	\$7,606,262	\$27,556
Cluster #13	6	80,025	520	\$21,257,000	\$25,508,400	\$40,907	\$183,917	\$354	\$18,199,011	\$35,022
Cluster #14	3	35,974	234	\$8,554,000	\$10,264,800	\$36,619	\$154,333	\$661	\$8,317,332	\$35,606
Cluster #15	3	65,012	422	\$16,202,000	\$19,442,400	\$38,379	\$172,941	\$410	\$14,277,227	\$33,820
Cluster #16	6	178,324	1,158	\$42,715,000	\$51,258,000	\$36,889	\$241,481	\$209	\$34,984,390	\$30,212
Totals	-	1,112,056	7,221	\$272,810,000	\$327,372,000	\$37,779	\$2,806,559	\$389	\$239,125,934	\$33,115

*Using 20 year planning period and interest rate of 5%

	Cost / EDU	Cost / Parcel
Capital	\$37,779	\$34,459
Annual O&M	\$389	\$354
Present Worth	\$33,115	\$33,115

Table 4.1.4 is the backup for the components that make up the total capital costs. The land acquisition budget is presented for a reasonableness check.

Table 4.1.5 presents a detailed O&M cost breakdown for each cluster system. The Nitrex™ system does not require full time operator attention and the energy costs are associated mostly with pumping requirements.

Table 4.1.4. Capital Cost Breakdown – Cluster Systems

Cluster Number	Parcel Information	WW Flow (gpd)			WW Flow / Parcel		Nitrogen Load Removed (kg/day)	Septic Tank Effluent Pipe Length (ft)	Septic Tank Effluent Collection Costs	WW Treatment Total Cost using Existing Parcels	Total Construction Costs	Total Development Costs	Total Capital Cost	Land Acquisition		Total Capital Cost per Existing Parcel	Total Capital Cost per EDU		
	Total Parcels	Existing	Additional Future	Total Future	Existing	Total Future	Existing			\$60				per gpd	Land Required (ft ²)			Allocated Budget for Land Acquisition (\$/acre)	
																			2.3
																			154
Cluster #1	399	37,680	8,970	46,650	94	117	3.75	39,900	\$5,097,225	\$2,261,000	\$7,359,000	\$4,600,000	\$11,959,000	107,294	\$224,074	\$29,972	\$49,000		
Cluster #2	271	40,711	12,007	52,718	150	195	2.31	27,100	\$3,462,025	\$2,443,000	\$5,906,000	\$3,692,000	\$9,598,000	121,250	\$159,133	\$35,417	\$37,000		
Cluster #3	626	69,365	-16,648	52,718	111	84	6.90	62,600	\$7,997,150	\$4,162,000	\$12,160,000	\$7,600,000	\$19,760,000	121,250	\$327,642	\$31,565	\$44,000		
Cluster #4	675	86,129	2,556	88,685	128	131	6.72	67,500	\$8,623,125	\$5,168,000	\$13,792,000	\$8,620,000	\$22,412,000	203,976	\$220,901	\$33,203	\$41,000		
Cluster #5	523	80,714	22,577	103,291	154	197	5.63	52,300	\$6,681,325	\$4,843,000	\$11,525,000	\$7,204,000	\$18,729,000	237,570	\$158,489	\$35,811	\$36,000		
Cluster #6	353	67,247	55,779	123,026	191	349	5.71	35,300	\$4,509,575	\$4,035,000	\$8,545,000	\$5,341,000	\$13,886,000	282,959	\$98,659	\$39,337	\$32,000		
Cluster #7	455	59,123	28,779	87,902	130	193	5.88	45,500	\$5,812,625	\$3,548,000	\$9,361,000	\$5,851,000	\$15,212,000	202,174	\$151,268	\$33,433	\$40,000		
Cluster #8	455	47,011	25,034	72,044	103	158	1.20	45,500	\$5,812,625	\$2,821,000	\$8,634,000	\$5,397,000	\$14,031,000	165,702	\$170,229	\$30,837	\$46,000		
Cluster #9	467	48,044	13,255	61,300	103	131	3.91	46,700	\$5,965,925	\$2,883,000	\$8,849,000	\$5,531,000	\$14,380,000	140,989	\$205,049	\$30,792	\$47,000		
Cluster #10	546	103,480	100,264	203,744	190	373	7.07	54,600	\$6,975,150	\$6,209,000	\$13,185,000	\$8,241,000	\$21,426,000	468,612	\$91,921	\$39,242	\$32,000		
Cluster #11	395	70,710	36,012	106,721	179	270	5.88	39,500	\$5,046,125	\$4,243,000	\$9,290,000	\$5,807,000	\$15,097,000	245,459	\$123,648	\$38,220	\$33,000		
Cluster #12	166	42,508	16,630	59,138	256	356	3.20	16,600	\$2,120,650	\$2,551,000	\$4,672,000	\$2,920,000	\$7,592,000	136,017	\$112,217	\$45,735	\$28,000		
Cluster #13	648	80,025	11,152	91,176	123	141	5.72	64,800	\$8,278,200	\$4,802,000	\$13,081,000	\$8,176,000	\$21,257,000	209,706	\$203,789	\$32,804	\$41,000		
Cluster #14	243	35,974	10,507	46,481	148	191	3.58	24,300	\$3,104,325	\$2,159,000	\$5,264,000	\$3,290,000	\$8,554,000	106,907	\$160,864	\$35,202	\$37,000		
Cluster #15	475	65,012	22,626	87,638	137	185	4.63	47,500	\$6,068,125	\$3,901,000	\$9,970,000	\$6,232,000	\$16,202,000	201,568	\$161,593	\$34,109	\$39,000		
Cluster #16	1,220	178,324	68,453	246,777	146	202	5.41	122,000	\$15,585,500	\$10,700,000	\$26,286,000	\$16,429,000	\$42,715,000	567,588	\$151,301	\$35,012	\$37,000		
Totals	7,917	1,112,056	417,953	1,530,009	2,343	3,274	77	\$791,700	\$101,139,675	\$66,729,000	\$167,879,000	\$104,931,000	\$272,810,000	\$3,519,021	\$2,720,776	\$34,459	\$38,000		
Total N in PPA (kg/day)																			
Total % Removal from Clusters																			
												Total Capital Cost	Total Capital Cost per EDU	Total Capital Cost per Parcel					
												\$272,810,000	\$38,000	\$34,459					

Nitrogen Removed (kg/day)	\$ / (kg/day) N Removed	\$ / (kg/year) N Removed	\$ / (lb/year) N Removed	\$ / gpd Flow WW Treated
77	\$3,520,563	\$9,645	\$21,220	\$245.32

Table 4.1.5. O&M Cost Breakdown – Cluster Systems

Cluster #	Existing Flow (gpd)	# of Parcels	Contract Operations	Annual Sludge Generation	Septic Sludge Disposal	Electricity	Equipment Maintenance	Collection System Maintenance	Sampling - Lab Costs	Administration & Oversight	Groundwater Discharge Permit Compliance Fee	Annual Misc. O&M Costs	Total O&M Costs	O&M / Parcel
Cluster #1	37,680	399	\$80,000	13,753	\$1,520	\$4,654	\$11,304	\$10,194	\$11,395	\$15,000	\$15,000	\$10,000	\$159,067	\$399
Cluster #2	40,711	271	\$80,000	14,859	\$1,640	\$4,936	\$12,213	\$6,924	\$11,395	\$15,000	\$15,000	\$10,000	\$157,108	\$580
Cluster #3	69,365	626	\$80,000	25,318	\$2,790	\$7,704	\$20,810	\$15,994	\$11,395	\$15,000	\$15,000	\$10,000	\$178,693	\$285
Cluster #4	86,129	675	\$80,000	31,437	\$3,460	\$9,336	\$25,839	\$17,246	\$11,395	\$15,000	\$15,000	\$10,000	\$187,276	\$277
Cluster #5	80,714	523	\$80,000	29,461	\$3,250	\$8,806	\$24,214	\$13,363	\$11,395	\$15,000	\$15,000	\$10,000	\$181,028	\$346
Cluster #6	67,247	353	\$80,000	24,545	\$2,700	\$7,512	\$20,174	\$9,019	\$11,395	\$15,000	\$15,000	\$10,000	\$170,800	\$484
Cluster #7	59,123	455	\$80,000	21,580	\$2,380	\$6,730	\$17,737	\$11,625	\$11,395	\$15,000	\$15,000	\$10,000	\$169,867	\$373
Cluster #8	47,011	455	\$80,000	17,159	\$1,890	\$5,552	\$14,103	\$11,625	\$11,395	\$15,000	\$15,000	\$10,000	\$164,565	\$362
Cluster #9	48,044	467	\$80,000	17,536	\$1,930	\$5,637	\$14,413	\$11,932	\$11,395	\$15,000	\$15,000	\$10,000	\$165,307	\$354
Cluster #10	103,480	546	\$80,000	37,770	\$4,160	\$11,022	\$31,044	\$13,950	\$11,395	\$15,000	\$15,000	\$10,000	\$191,572	\$351
Cluster #11	70,710	395	\$80,000	25,809	\$2,840	\$7,853	\$21,213	\$10,092	\$11,395	\$15,000	\$15,000	\$10,000	\$173,394	\$439
Cluster #12	42,508	166	\$80,000	15,515	\$1,710	\$5,111	\$12,752	\$4,241	\$11,395	\$15,000	\$15,000	\$10,000	\$155,210	\$935
Cluster #13	80,025	648	\$80,000	29,209	\$3,220	\$8,738	\$24,007	\$16,556	\$11,395	\$15,000	\$15,000	\$10,000	\$183,917	\$284
Cluster #14	35,974	243	\$80,000	13,130	\$1,450	\$4,487	\$10,792	\$6,209	\$11,395	\$15,000	\$15,000	\$10,000	\$154,333	\$635
Cluster #15	65,012	475	\$80,000	23,729	\$2,620	\$7,286	\$19,504	\$12,136	\$11,395	\$15,000	\$15,000	\$10,000	\$172,941	\$364
Cluster #16	178,324	1,220	\$80,000	65,088	\$7,160	\$18,258	\$53,497	\$31,171	\$11,395	\$15,000	\$15,000	\$10,000	\$241,481	\$198
Totals	1,112,056	7,917	\$1,280,000	\$405,900	\$44,720	\$123,623	\$333,617	\$202,279	\$182,320	\$240,000	\$240,000	\$160,000	\$2,806,559	
Average	69,503	495	\$80,000		\$2,795	\$7,726	\$20,851	\$12,642	\$11,395	\$15,000	\$15,000	\$10,000	\$175,410	\$354

Figure 4.1.1. LAI Cluster Locations

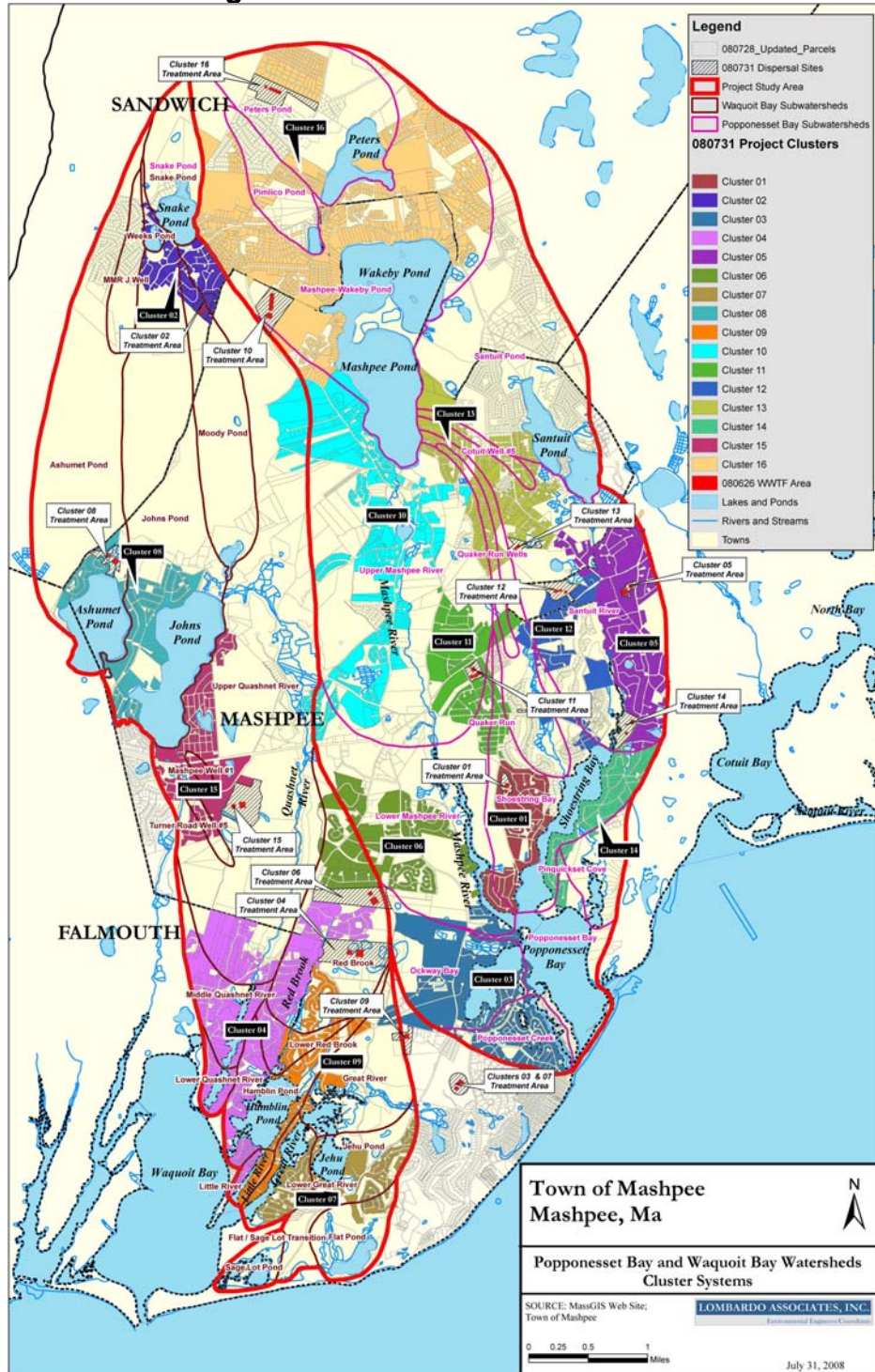


Figure 4.1.2. LAI Cluster Locations on Aerial Photograph

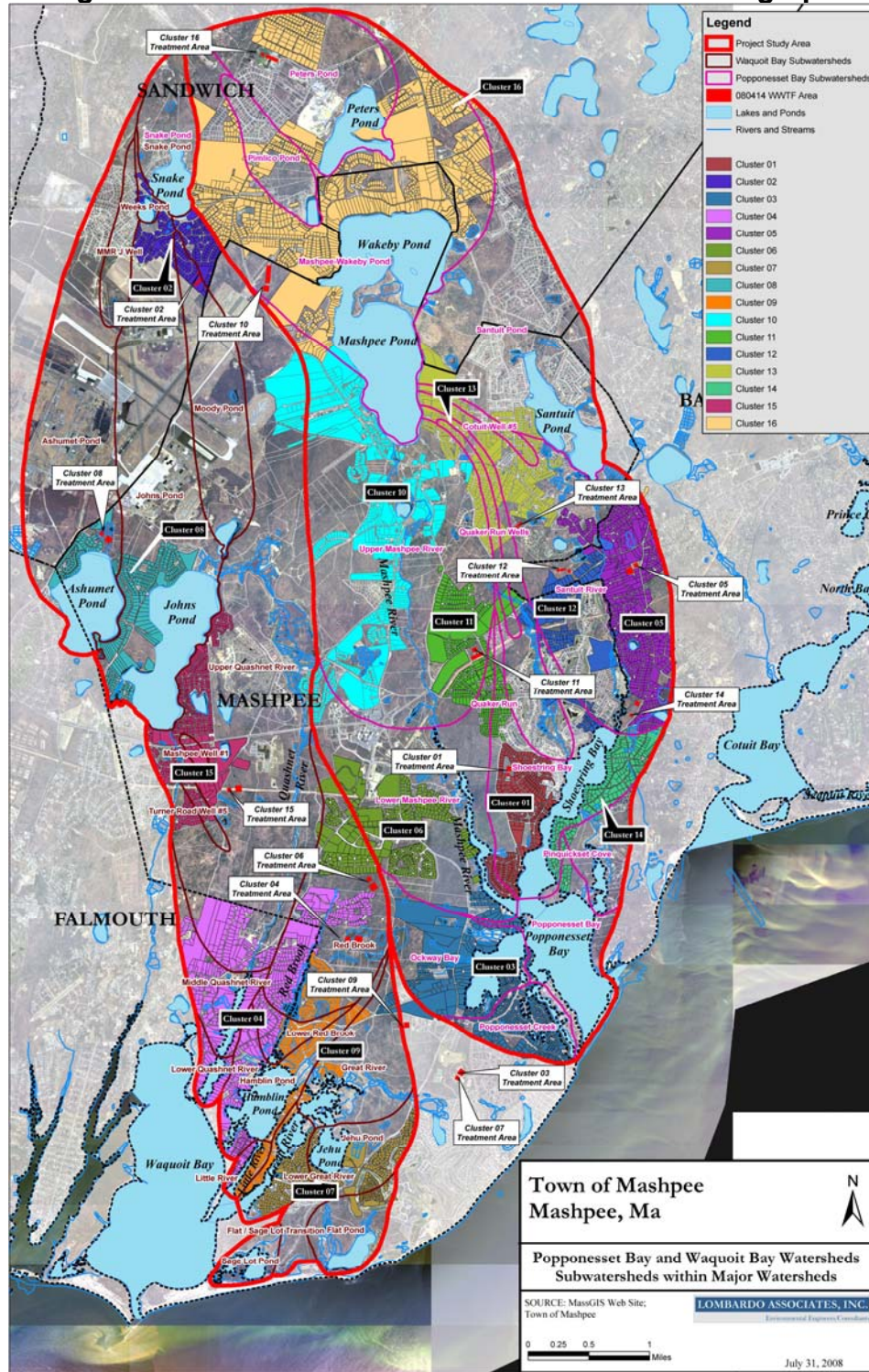
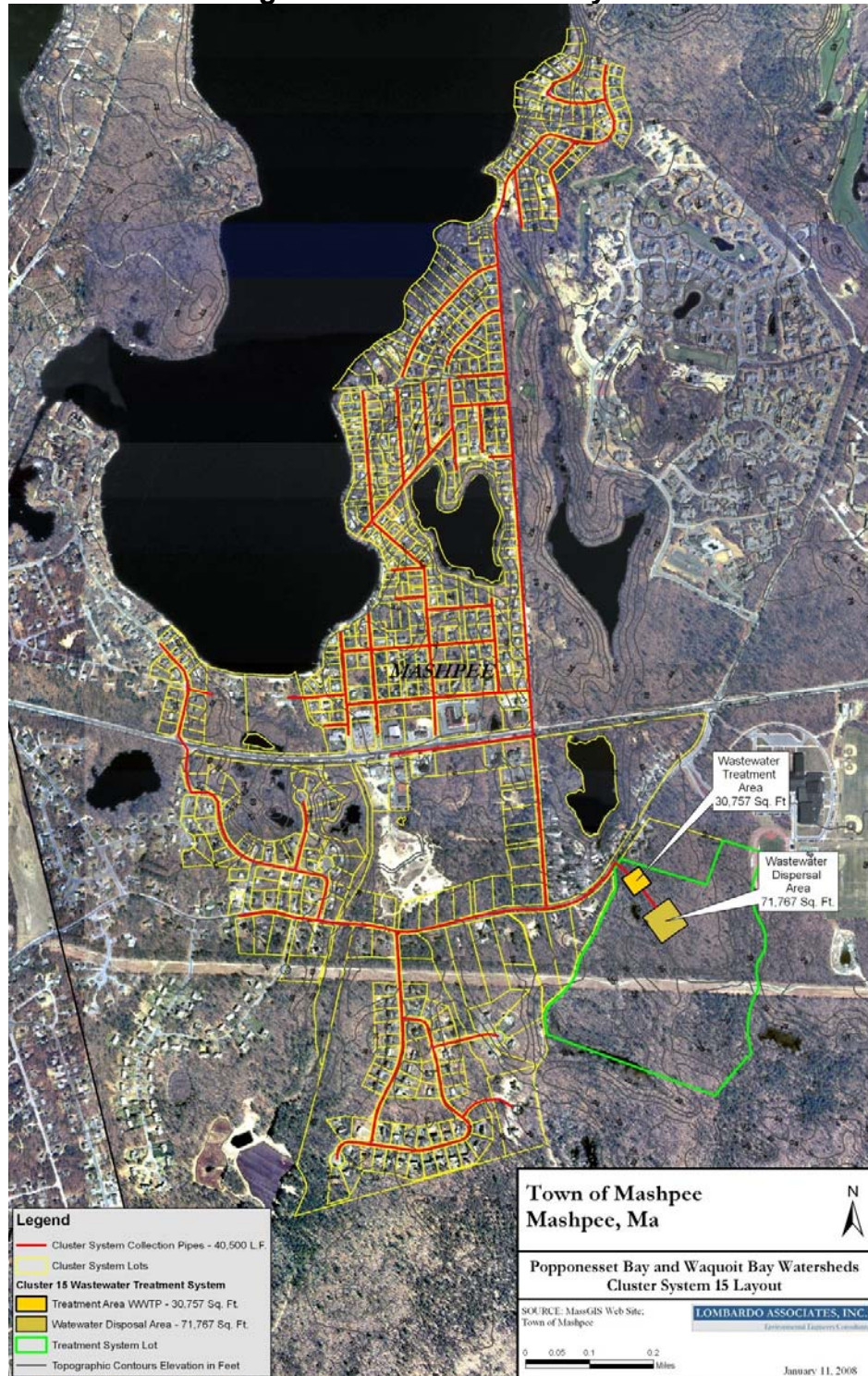


Figure 4.1.5 Cluster 15 Layout



4.2 Nitrex™ Technology Scenario 2: On-Site Systems Only

Table 4.2.1 summarizes the year built data for the parcels within the Town of Mashpee according to the Mashpee Database provided to LAI on 9/27/07. Half of the existing homes in Mashpee were built after 1985 and 25% after 1995 (the adoption of the current Title V rules), so we have assumed 50% of the septic tanks and drainfields are salvageable.

Table 4.2.1 Town of Mashpee Year Built Data

Year	Cumulative Existing	Developed within Time Period	Developed		Developed as % of Buildout	
			% of Current Total	Cumulative %	% of Total	Cumulative %
before 1990	12	12	0.15%	0.15%	0.12%	0.12%
1900-1910	28	16	0.20%	0.36%	0.17%	0.29%
1910-1920	32	4	0.05%	0.41%	0.04%	0.33%
1920-1930	73	41	0.52%	0.93%	0.43%	0.76%
1930-1940	135	62	0.79%	1.72%	0.64%	1.40%
1940-1950	285	150	1.91%	3.63%	1.56%	2.96%
1950-1960	747	462	5.88%	10%	4.80%	7.76%
1960-1970	1,476	729	9.28%	19%	7.57%	15%
1970-1980	2,604	1,128	14.36%	33%	12%	27%
1980-1985	3,383	779	9.92%	43%	8%	35%
1985-1990	4,991	1,608	20.48%	64%	17%	52%
1990-1995	5,634	643	8.19%	72%	7%	59%
1995-2000	6,455	821	10.45%	82%	9%	67%
2000	6,753	298	3.79%	86%	3%	70%
2001	7,048	295	3.76%	90%	3%	73%
2002	7,236	188	2.39%	92%	2%	75%
2003	7,384	148	1.88%	94%	2%	77%
2004	7,548	164	2.09%	96%	2%	78%
2005	7,741	193	2.46%	99%	2%	80%
2006	7,853	112	1.43%	100%	1%	82%
Buildable	1,772				18%	100%
Total	9,625					

Assuming that each parcel treated will achieve 90% nitrogen removal and 50% of the parcels will require new systems (new septic tanks & drainfields in addition to N removal unit), while the other 50% will use retrofit systems, the following tables present the costs for the On-Site Systems only Scenario.

Table 4.2.2. On-Site Systems Only Cost Estimate

Watershed	Cost	Parcels Treated	Total Capital Cost	Wastewater Flow Treated (gpd) ¹	Total N Removed (kg/day) ²
Total Planning Area	\$30,000	7,917	\$237,510,000	1,112,056	77

1. Assume 154 gpd wastewater flow per parcel
2. Assume each on-site system will remove 0.018 kg/day Nitrogen
3. In Sub-Watersheds where more than 100% of the parcels need to be treated, the difference in the Parcels Treated and

	Cost / EDU
Capital	\$30,000
Annual O&M	\$138
Present Worth	\$15,387

Table 4.2.3 presents the O&M Breakdown for each of the four Nitrex™ Scenarios.

Table 4.2.3. Nitrex™ Technology Scenarios O&M Costs

Nitrex™ Technology Scenarios	Annual O&M Costs / EDU
1. Cluster Systems	\$389
2. Individual Systems	\$703
3. Groundwater Treatment - Pump & Treat	\$135
4. Groundwater Treatment - PRB	\$144
5. Conventional Sewerage System	\$700 - \$1,000 ¹

¹Based on Stearns & Wheler Presentation.

4.3 Nitrex™ Technology Scenario 3: Groundwater Treatment, Pump & Treat

The Nitrex™ Technology Groundwater Treatment by pump and treat consists of installing groundwater extraction wells in locations down gradient of drainfields to remove the groundwater where the drainfield plumes are expected to be located at or near surface water discharge locations – based upon LAI’s experiences in similar situations. Detailed data collection will be needed for further planning and detailed design purposes. Conservative planning assumptions have been made for this

analysis. The extracted groundwater would be treated by a strategically located Nitrex™ unit and treated effluent dispersed back into the groundwater.

A detailed layout was developed for a pump and treat system that would capture Cluster 15 nitrogen contributions. For this example, the entire length of the downgradient side of the cluster was lined with extraction wells. A treatment and dispersal site was selected in a location downgradient of the extraction sites.

Figure 4.3.1 illustrates the layout for this representative Pump and Treat Scenario Application. Table 4.3.1 shows a summary of the costs for all the clusters, if a similar system were installed. Table 4.3.2 presents a comparison of the total costs of the Pump and Treat and the Cluster scenarios. In comparing the two approaches, it is important to note that the Pump and Treat system will not only treat the septic system nitrogen loads, it will treat the land use and runoff nitrogen in the groundwater as well. In addition, the attenuated nitrogen loads of all upgradient subwatersheds that flow through the extraction point will also be treated. A thorough examination of the hydrogeology and nitrogen concentration profile would be required to accurately assess both location and size of extraction wells and the associated nitrogen load treated.

The flow rate required for the Pump and Treat system is not a critical design criteria, as the Nitrex™ system is sized for mass removal. If there is more dilution water than anticipated, then the treatment plant flow will be higher and the nitrogen concentration will be lower. In this case, although the flow rate will increase for the treatment system, the associated size of the Nitrex™ treatment system is not likely to change significantly. For preliminary sizing, the treatment system is assumed to be treating the groundwater equivalent of twice the wastewater flow associated with the parcels in each cluster.

As can be seen in Table 4.3.2, there is significant potential savings using the Pump and Treat option. It is also noted that some areas are much more cost effective than others, and that Pump and Treat may not be applicable in all areas. However, in areas where conditions appear to be favorable, significant saving and additional nitrogen removal can be achieved with the Pump and Treat option.

Figure 4.3.1. Pump and Treat Scenario 1



Table 4.3.1. Pump & Treat Cost Estimate Summary

Planning Area	Existing Wastewater Flow Treated (gpd)	Total EDUs	Existing Nitrogen Load Removed (kg/day)	Total Capital Cost	Total Capital Cost per EDU	Total Annual O&M	Annual O&M per EDU	Annual O&M Per Parcel	Present Worth	Present Worth per EDU	Present Worth Per Parcel
P&T #1	37,680	245	3.75	\$4,248,000	\$18,000	\$56,180	\$230	\$141	\$3,868,127	\$15,809	\$9,695
P&T #2	40,711	264	2.31	\$4,212,000	\$16,000	\$56,608	\$214	\$209	\$3,857,459	\$14,592	\$14,234
P&T #3	69,365	450	6.90	\$7,848,000	\$18,000	\$60,735	\$135	\$97	\$6,624,890	\$14,708	\$10,583
P&T #4	86,129	559	6.72	\$10,872,000	\$20,000	\$63,167	\$113	\$94	\$8,919,197	\$15,948	\$13,214
P&T #5	80,714	524	5.63	\$7,740,000	\$15,000	\$62,376	\$119	\$119	\$6,567,337	\$12,530	\$12,557
P&T #6	67,247	437	5.71	\$6,894,000	\$16,000	\$60,444	\$138	\$171	\$5,907,267	\$13,528	\$16,734
P&T #7	59,123	384	5.88	\$6,120,000	\$16,000	\$59,270	\$154	\$130	\$5,318,640	\$13,854	\$11,689
P&T #8	47,011	305	1.20	\$5,760,000	\$19,000	\$57,520	\$188	\$126	\$5,026,831	\$16,467	\$11,048
P&T #9	48,044	312	3.91	\$8,226,000	\$27,000	\$57,657	\$185	\$123	\$6,874,529	\$22,035	\$14,721
P&T #10	103,480	672	7.07	\$10,233,000	\$16,000	\$65,677	\$98	\$120	\$8,471,482	\$12,607	\$15,516
P&T #11	70,710	459	5.88	\$7,074,000	\$16,000	\$60,948	\$133	\$154	\$6,053,548	\$13,184	\$15,325
P&T #12	42,508	276	3.20	\$4,698,000	\$18,000	\$56,866	\$206	\$343	\$4,216,682	\$15,276	\$25,402
P&T #13	80,025	520	5.72	\$7,902,000	\$16,000	\$62,274	\$120	\$96	\$6,688,069	\$12,871	\$10,321
P&T #14	35,974	234	3.58	\$4,338,000	\$19,000	\$55,931	\$239	\$230	\$3,935,018	\$16,845	\$16,193
P&T #15	65,012	422	4.63	\$6,912,000	\$17,000	\$60,109	\$142	\$127	\$5,921,090	\$14,026	\$12,465
P&T #16	178,324	1,158	5.41	\$17,739,000	\$16,000	\$76,473	\$66	\$63	\$14,232,020	\$12,291	\$11,666
P&T Totals	1,112,056	7,221	77.49	\$120,816,000	\$12,067	\$972,234	\$135	\$123	\$102,482,184	\$14,192	\$12,945

	Cost / EDU	Cost / Parcel
Capital	\$12,067	\$15,260
Annual O&M	\$135	\$123
Present Worth	\$14,192	\$12,945

Table 4.3.3. Pump & Treat O&M Summary

PT #	Existing Flow (gpd)	# of Parcels	Contract Operations	Electricity	Equipment Maintenance	Sampling - Lab Costs	Administration & Oversight	Groundwater Discharge Permit Compliance Fee	Annual Misc. O&M Costs	Total O&M Costs	O&M / Parcel
PT #1	37,680	399	\$19,500	\$2,017	\$3,768	\$11,395	\$5,000	\$7,500	\$7,000	\$56,180	\$141
PT #2	40,711	271	\$19,500	\$2,142	\$4,071	\$11,395	\$5,000	\$7,500	\$7,000	\$56,608	\$209
PT #3	69,365	626	\$19,500	\$3,403	\$6,937	\$11,395	\$5,000	\$7,500	\$7,000	\$60,735	\$97
PT #4	86,129	675	\$19,500	\$4,159	\$8,613	\$11,395	\$5,000	\$7,500	\$7,000	\$63,167	\$94
PT #5	80,714	523	\$19,500	\$3,909	\$8,071	\$11,395	\$5,000	\$7,500	\$7,000	\$62,376	\$119
PT #6	67,247	353	\$19,500	\$3,324	\$6,725	\$11,395	\$5,000	\$7,500	\$7,000	\$60,444	\$171
PT #7	59,123	455	\$19,500	\$2,963	\$5,912	\$11,395	\$5,000	\$7,500	\$7,000	\$59,270	\$130
PT #8	47,011	455	\$19,500	\$2,424	\$4,701	\$11,395	\$5,000	\$7,500	\$7,000	\$57,520	\$126
PT #9	48,044	467	\$19,500	\$2,457	\$4,804	\$11,395	\$5,000	\$7,500	\$7,000	\$57,657	\$123
PT #10	103,480	546	\$19,500	\$4,934	\$10,348	\$11,395	\$5,000	\$7,500	\$7,000	\$65,677	\$120
PT #11	70,710	395	\$19,500	\$3,482	\$7,071	\$11,395	\$5,000	\$7,500	\$7,000	\$60,948	\$154
PT #12	42,508	166	\$19,500	\$2,221	\$4,251	\$11,395	\$5,000	\$7,500	\$7,000	\$56,866	\$343
PT #13	80,025	648	\$19,500	\$3,876	\$8,002	\$11,395	\$5,000	\$7,500	\$7,000	\$62,274	\$96
PT #14	35,974	243	\$19,500	\$1,938	\$3,597	\$11,395	\$5,000	\$7,500	\$7,000	\$55,931	\$230
PT #15	65,012	475	\$19,500	\$3,213	\$6,501	\$11,395	\$5,000	\$7,500	\$7,000	\$60,109	\$127
PT #16	178,324	1,220	\$19,500	\$8,245	\$17,832	\$11,395	\$5,000	\$7,500	\$7,000	\$76,473	\$63
Totals	1,112,056	7,917	\$312,000	\$54,708	\$111,206	\$182,320	\$80,000	\$120,000	\$112,000	\$972,234	
Average	69,503	495	\$19,500	\$3,419	\$6,950	\$11,395	\$5,000	\$7,500	\$7,000	\$60,765	\$123

Table 4.3.4. Pump & Treat Compared to Cluster System Scenario Costs

Planning Area	Existing Wastewater Flow Treated (gpd)	Existing Nitrogen Load	Total Capital Cost	Total Capital Cost per EDU	Total Annual O&M	Annual O&M per EDU	Annual O&M Per Parcel	Present Worth	Present Worth per EDU	Present Worth Per Parcel
P&T Total	1,112,056	77	120,816,000	12,067	972,234	135	123	102,482,184	14,192	12,945
Cluster Total	1,112,056	77	272,810,000	37,779	2,806,559	389	354	239,125,934	33,115	33,115
% Savings with P&T		-	56%	68%	65%	65%	65%	57%	57%	61%

4.4 Nitrex™ Technology Scenario 4: Nitrex™ PRB

The Nitrex™ Permeable Reactive Barrier (PRB) Scenario consists of installing the Nitrex™ treatment system in groundwater in strategic locations to remove nitrate from groundwater prior to the groundwater entering surface water bodies. Figure 4.4.1 presents schematic drawings of PRBs. Based upon our analysis, determining the feasibility and costs of the Nitrex™ PRB is challenged by the uncertainty on groundwater flow patterns and nitrogen concentrations. Very importantly, the Nitrex™ PRB Scenario development requires information on groundwater flow paths and expected nitrogen concentrations aerially and with depth. This information is not known to exist to the needed level of detail for a PPA wide analysis. The best available information to our knowledge is the generalized USGS groundwater flow directions as illustrated on Figure 3.4.4. Also, the groundwater flow analysis for dispersal sites on Figures 3.4.3 – 3.4.5 suggest that there are areas where groundwater discharge to surface water is more concentrated. No information has been identified that would describe the vertical extent of nitrogen contamination. Consequently, we are unable to accurately determine the appropriate lengths and locations of Nitrex™ PRBs, their associated costs and expected effectiveness.

Using the watershed boundaries and groundwater contours to assume flow directions, the total barrier length necessary to capture all nitrogen containing flow from each cluster area

was generated. These barrier lengths were used to generate representative costs for using the PRB approach to treat the nitrogen from each cluster area. Table 4.4.1 summarizes these results. The costs presented in Table 4.4.1 use worst-case assumptions for PRB depth and a heavy contingency was applied to account for the uncertainty at this level of planning.

The PRB approach offers the lowest lifecycle costs. While there is a great deal of uncertainty as to the exact locations and size of the barriers, given the overwhelming cost savings associated with the PRB approach and the potential for immediate results, this option merits further development. LAI has identified areas conducive to the use of the Nitrex™ PRB.

Figure 4.4.2 illustrates the groundwater nitrogen removal performance of two Nitrex™ PRBs designed and installed by Lombardo Associates, Inc. in Waquoit Bay in 2005 and independently tested by the Woods Hole MBL.

Figure 4.4.1. EPA Schematic of Groundwater Barrier

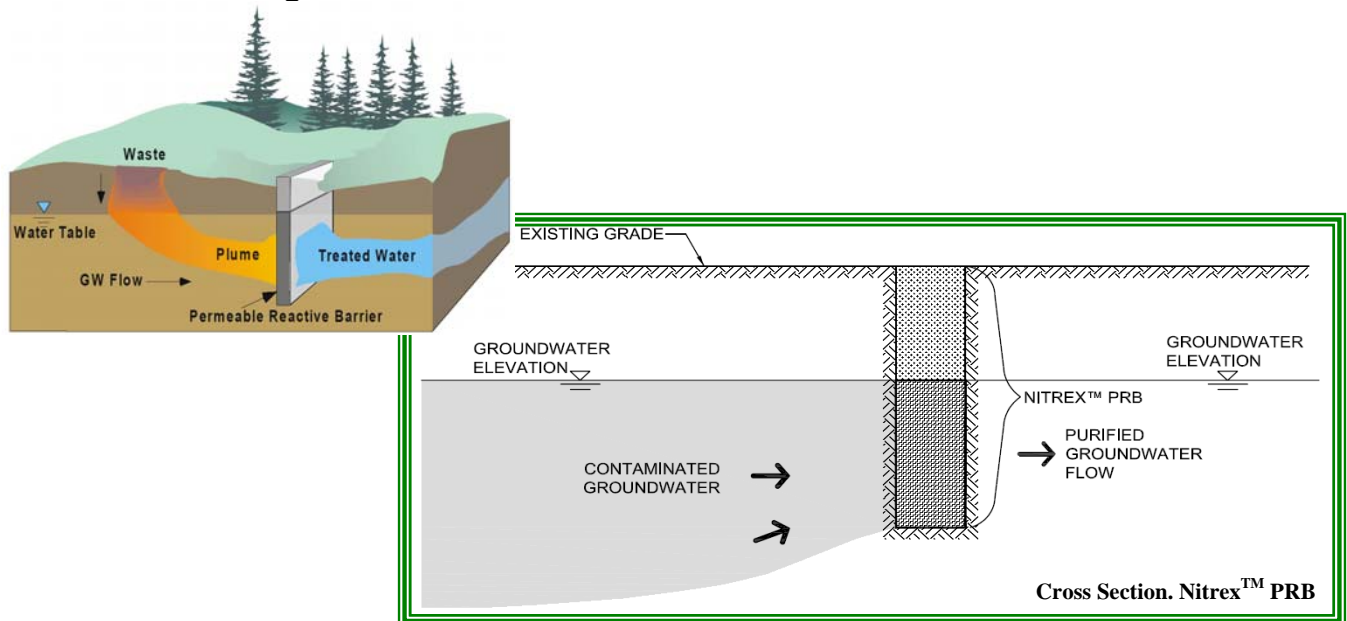


Figure 4.4.2. Groundwater Nitrogen Removal Performance of Nitrex™ PRBs in Waquoit Bay

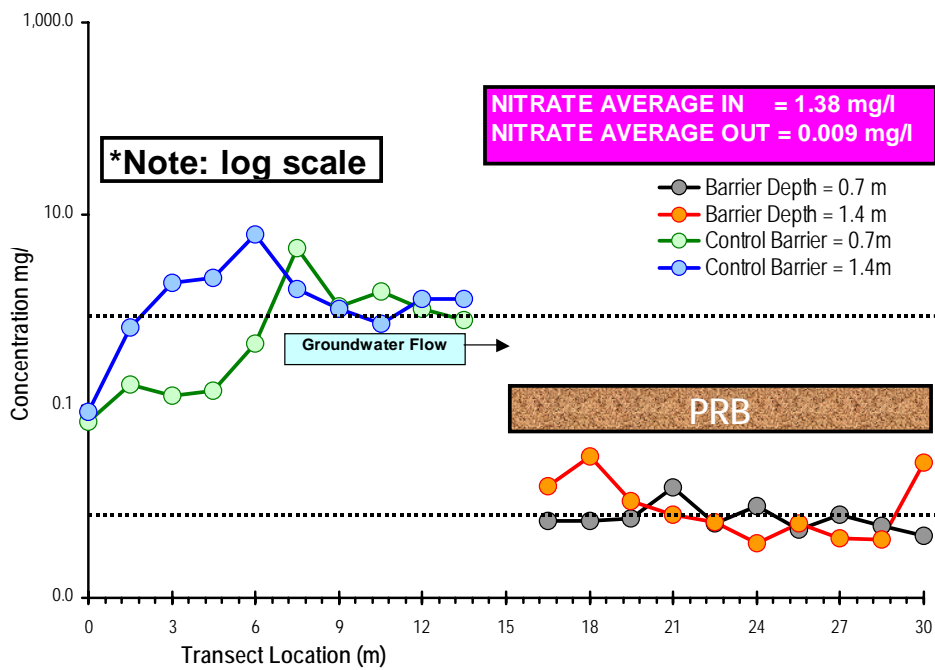
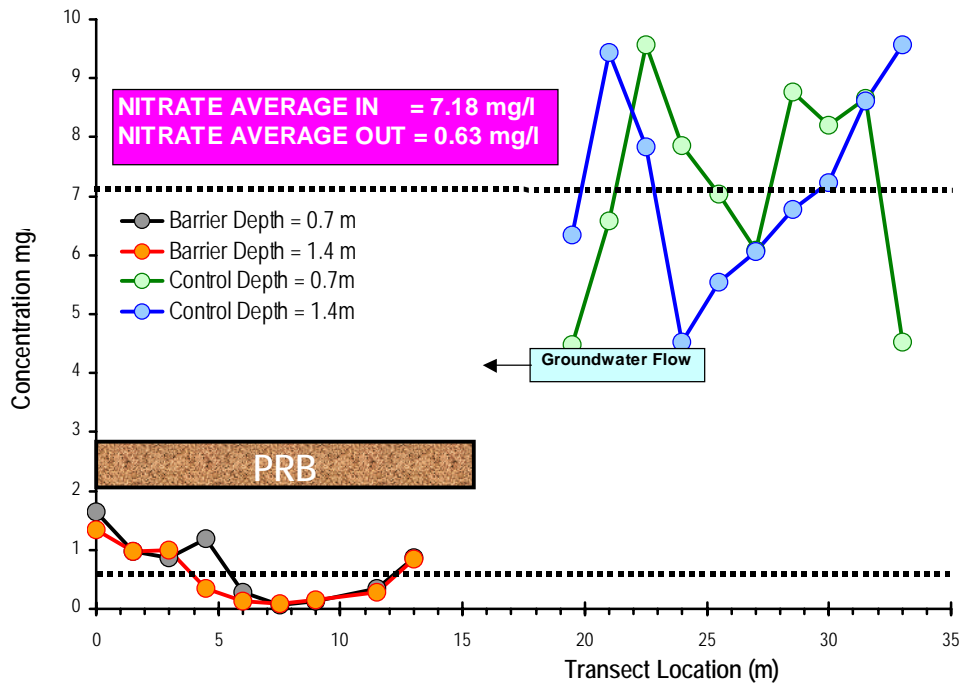


Table 4.4.1. Preliminary Cost Estimates for Nitrex™ Technology PRB Scenario

Planning Area	Total Parcels	WW Flow (gpd)			Nitrogen Load Removed (kg/day)	PRB		Total Capital Cost	Total Capital Cost / EDU
		Existing	Add'l Future	Total Buildout	Existing	PRB Length	PRB Cost		
Cluster #1	399	37,680	8,970	46,650	3.75	10,200	\$ 3,060,000	\$4,590,000	\$18,760
Cluster #2	271	40,711	12,007	52,718	2.31	7,200	\$ 2,160,000	\$3,240,000	\$12,256
Cluster #3	626	69,365	-16,648	52,718	6.90	24,600	\$ 7,380,000	\$11,070,000	\$24,577
Cluster #4	675	86,129	2,556	88,685	6.72	44,400	\$ 13,320,000	\$19,980,000	\$35,725
Cluster #5	523	80,714	22,577	103,291	5.63	13,800	\$ 4,140,000	\$6,210,000	\$11,848
Cluster #6	353	67,247	55,779	123,026	5.71	15,000	\$ 4,500,000	\$6,750,000	\$15,458
Cluster #7	455	59,123	28,779	87,902	5.88	12,600	\$ 3,780,000	\$5,670,000	\$14,769
Cluster #8	455	47,011	25,034	72,044	1.20	18,000	\$ 5,400,000	\$8,100,000	\$26,534
Cluster #9	467	48,044	13,255	61,300	3.91	44,400	\$ 13,320,000	\$19,980,000	\$64,043
Cluster #10	546	103,480	100,264	203,744	7.07	22,500	\$ 6,750,000	\$10,125,000	\$15,068
Cluster #11	395	70,710	36,012	106,721	5.88	13,200	\$ 3,960,000	\$5,940,000	\$12,937
Cluster #12	166	42,508	16,630	59,138	3.20	9,000	\$ 2,700,000	\$4,050,000	\$14,673
Cluster #13	648	80,025	11,152	91,176	5.72	14,400	\$ 4,320,000	\$6,480,000	\$12,470
Cluster #14	243	35,974	10,507	46,481	3.58	10,200	\$ 3,060,000	\$4,590,000	\$19,649
Cluster #15	475	65,012	22,626	87,638	4.63	15,000	\$ 4,500,000	\$6,750,000	\$15,989
Cluster #16	1,220	178,324	68,453	246,777	5.41	44,693	\$ 13,407,802	\$20,111,703	\$17,368
Totals	7,917	1,112,056	417,953	1,530,009	77	319,193	95,757,802	143,636,703	\$19,891

	Cost / EDU	Cost / Parcel
Capital	\$19,891	\$19,891
Annual O&M	\$144	\$138
Present Worth	\$16,671	\$15,387

4.5 Nitrex™ Technology Scenario 5: Hybrid of Scenarios 1-4

A hybrid scenario would consist of a mix of the Nitrex™ Technology approaches of:

- Cluster
- On-Site
- Groundwater Pump & Treat
- PRB

in an economically optimized manner. The development of optimized hybrid solutions would be the focus of follow – up studies once the technical feasibility and cost – competitiveness of the Nitrex™ approach presented in this report is accepted.

4.6 Scenario 6: Sewering

Stearns & Wheler developed the Sewering Option for the Town of Mashpee. Table 4.6.1 presents their numbers.

Table 4.6.1. Stearns & Wheler Sewer Cost Estimates for the Town of Mashpee

Nitrex™ Technology Scenarios	Annual O&M Costs / EDU	Capital Cost / EDU (house)
1. Groundwater Treatment - PRB	\$460,000,000	\$66,000
2. Conventional Sewerage System	\$540,000,000	\$66,000

⁽²⁾ The Stearns & Wheler proposed cost estimates in the March 2008 Draft Alternative Scenarios Analysis Report do not include allowances for land acquisition, acquisition of needed WWTPs, and treatment costs at the Falmouth and Barnstable WWTPs.

⁽³⁾ Ratio of Capital Cost are higher than the per EDU ratio due to the fact that the Stearns & Wheler proposal is to sewer more properties than proposed by LAI.

5 Nitrogen Removal Conclusions

Table 5.1. Nitrex™ Alternatives Cost Comparisons

Nitrex™ Technology Scenarios	Capital Cost	Capital Cost / EDU	Capital Cost / (lb/year) N Removed	Capital Cost / (kg/day) N Removed	Capital Cost / (kg/year) N Removed	Nitrex™ Technology Capital Cost as % of Complete WW System w/ Sewers	Nitrex™ Technology Capital Cost as % of Sewers Connected to Existing WWTP & Expansion
1. Groundwater Treatment - Pump & Treat	\$120,816,000	\$16,731	\$9,397	\$1,559,108	\$4,272	26%	22%
2. Groundwater Treatment - PRB	\$143,636,703	\$19,891	\$11,172	\$1,853,605	\$5,078	31%	27%
3. Stearns & Wheeler Scenario 4 Proposed Estimates - low end ^(2,3)	\$460,000,000+	\$66,000	\$22,329	\$3,704,618	\$10,150		
4. Stearns & Wheeler Scenario 1 Proposed Cost Estimates - high end ^(2,3)	\$540,000,000+	\$66,000	\$19,021	\$3,155,786	\$8,646		
6. Santuit Pond Phosphorus Treatment ⁽²⁾	\$7,544,000	\$10,000	N/A				

⁽¹⁾ MA State Tax Credit of \$6,000 may be available to property owners with septic system repair.

⁽²⁾ The Stearns & Wheeler proposed cost estimates in the March 2008 Draft Alternative Scenarios Analysis Report do not include allowances for land acquisition, acquisition of needed WWTPs, and treatment costs at the Falmouth and Barnstable WWTPs.

⁽³⁾ Ratio of Capital Cost are higher than the per EDU ratio due to the fact that the Stearns & Wheeler proposal is to sewer more properties than proposed by LAI.

Table 5.2. Other Nitrex™ Technology Options for Specific Areas of PPA

Nitrex™ Technology Scenarios	Capital Cost / (lb/year) N Removed
1. Groundwater Treatment - Pump & Treat	\$9,397
2. Groundwater Treatment - PRB	\$11,172

6 Santuit Pond Phosphorous Removal

Achieving phosphorus removal for Santuit Pond can be accomplished by:

1. Cluster Wastewater Systems with active chemical feed systems, which will require phosphorus sludge removal.
2. Cluster Wastewater Systems with passive phosphorus mineralization systems, such as the MADEP approved PhosRID™ Technology.
3. Individual On-Site Systems using the PhosRID™ Technology.
4. Groundwater pump and treat using:

- a. Active chemical feed and sludge management.
 - b. Passive phosphorus mineralization
5. Groundwater treatment via a permeable reactive barrier.

As LAI is not aware of Pond water quality studies to specify the amount of phosphorus that needs to be removed, along with the sources and mass of phosphorus contributions, it is not possible to develop an explicit phosphorus removal budgets. However, phosphorus removal could be integrated with a nitrogen removal system that would serve wastewater discharges that enter Santuit Pond. A TMDL study of Santuit Pond should be performed so that the optimal phosphorus remediation strategy can be developed.

However, in an attempt to understand the potential magnitude of the situation, Table 6.1 presents the estimated phosphorus loadings to Santuit Pond based upon the Town's database and USGS delineated contributing watershed areas. The significant unknown variable is phosphorus removal by the soils and attenuation prior to reaching Santuit Pond. Assuming the conservative (however, observed on Cape Cod) assumption that phosphorus removal by soils is insignificant, then it is estimated that 90+% removal of wastewater phosphorus is necessary in the watershed to achieve in Pond steady state levels of < 0.03 mg/l, the generally accepted maximum Pond phosphorus concentration to avoid excessive algae growth.

Table 6.2 presents a range of phosphorus removal costs based upon a variety of assumptions in an attempt to bracket this issue. LAI has received MADEP approval for its PhosRID™ phosphorus removal technology, which has been achieving 90+/-% phosphorus removal. A PhosRID™ unit added to a Nitrex™ system would add approximately \$5,000 - \$10,000 / EDU.

Table 6.1. Santuit Pond Phosphorus Calculation

Santuit Pond Watershed		
Contributing Watershed Area		3,145 acres
Pond Area	<u>697</u>	acres
Total Watershed		3,842 acres
Rainfall Recharge		
Land Contributing Watershed (in/yr)		18 in/yr
Pond (in/yr)		40 in/yr
Rainfall Recharge		
Land Contributing Watershed (gpd)		4,211,226 gpd
Pond (gpd)	<u>2,074,800</u>	gpd
Total recharge		6,286,026 gpd

Parcels	Existing		Add'l Buildout	
Barnstable	0	0%	4	4%
Mashpee	552	61%	56	62%
Sandwich	<u>350</u>	<u>39%</u>	<u>31</u>	<u>34%</u>
Total	902	100%	91	100%

WW Flow	Existing		Add'l Buildout	
Barnstable	-	0%	560	2%
Mashpee	77,905	61%	22736	81%
Sandwich	<u>49,219</u>	<u>39%</u>	<u>4851</u>	<u>17%</u>
Total	127,124	100%	28147	100%

Nitrogen		
Existing Wastewater Flow (gpd)		127,124 gpd
Future WW Flow (gpd)	<u>28,147</u>	gpd
Buildout WW Flow (gpd)		155,271 gpd
Existing N Load		
		15.21 kg/day
Future N Load	<u>3.42</u>	kg/day
Buildout N Load		18.63 kg/day
Existing N Load		
		31.56 mg/l
Future N Load	<u>32.05</u>	mg/l
Buildout N Load		31.65 mg/l
Calculated Steady State Pond N Conc. Exist Development		0.64 mg/l

Phosphorus	6 mg/l	Wastewater Phosphorus Conc
Existing P Load		2.9 kg/day
Future P Load	<u>0.64</u>	kg/day
Buildout P Load		3.5 kg/day
Calculated Steady State Pond P Conc. Exist Development		0.12 mg/l
Target P Lake Concentration		0.03 mg/l
Percent P Required to be Removed by Treatment		75%
90% P Removal Assumed		84%

Table 6.2. Rough Estimated Phosphorus Removal Costs

Potential Santuit Pond Phosphorus Removal Costs				
Percent P removed by Soils - Attenuation	0%	60%	70%	75%
No Parcels requiring Tr't	754	383	176	11
% of Total Parcels	84%	42%	20%	1%
\$/Parcel Tr't	\$ 10,000	\$ 10,000	\$ 10,000	\$ 10,000
\$/ all Existing Parcels	\$ 8,364	\$ 4,246	\$ 1,951	\$ 122
Capital Cost	\$ 7,544,000	\$ 3,830,000	\$ 1,760,000	\$ 110,000

	Cost / EDU
Capital	\$8,364
Annual O&M	\$574
Present Worth	\$13,420

7 Management Issues

The Town of Mashpee could establish its own “Wastewater Management Department” to manage the systems or outsource the work. The components of a Management System are:

- Ownership Management
- Program Management for Capital Improvements
- Use Regulation
- Regulatory Compliance Reporting
- Customer Service, Billing, and Collections
- User-Charge System
- Financial Management
- Operations & Maintenance

7.1 Nitrex™ Cluster Scenario

The management issues with the Nitrex™ Cluster Scenario are similar to those of any wastewater system with the refinement that the wastewater system begins with the septic tank in each property. Blanket easements are commonly used for access / maintenance of the septic tank and effluent line on each parcel.

7.2 Nitrex™ On-Site Scenario

The Town’s On-Site Scenario management requirements are dictated primarily by ownership – whether the on-site systems stay in private ownership or have public ownership. The benefits of private ownership are:

- Maintenance of current practice
- Potential MA Tax Credit
- Barnstable County System currently supports this approach

The key monitoring issue will be the necessary monitoring frequency to validate nitrogen removal requirements.

7.3 Groundwater Treatment

Due to the reduced required treatment facilities, the major management issue will be performance monitoring.

8 Regulatory Issues

8.1 Cluster Scenario

Regulatory requirements will be dictated in large part by MADEP groundwater discharge requirements. Sewer lines and any other construction in jurisdictional areas will require permitting from appropriate agencies, i.e. Conservation Commission, as with any sewer system.

8.2 On-Site Systems

On-Site systems under 10,000 gpd are regulated by Title 5, generally administered by local Board of Health. The NitrexTM on-site system will need General Use permit, which requires additional performance data for its General Use designation.

8.3 Groundwater Treatment

Groundwater withdrawal and discharge permits will be needed for a pump and treat option.

Due to its uniqueness, a NitrexTM permeable reactive barrier option will need to be reviewed with MADEP regarding permitting issues in non-jurisdictional (i.e. outside wetland buffer areas) areas.

APPENDIX A – Database Metafile

Field	Description			
LAI_ID_57	Unique IDs linked to shapefiles	LAI ID	LAI Link to Shapefiles for All Towns	
KEY		SW ID	Mashpee only	
TOWN	Location	Town	from shapefiles received 5/9/08	
SubWatersh		Subwatershed	Assigned by SW for Mashpee and by LAI for	
Watershed		Major Watershed	Assigned by SW for Mashpee and by LAI for	
TMDL_Shed		TMDL Watershed	Defined by MEP, assigned by LAI	
SW_Water		SW Watershed	provided by SW for Mashpee only; keep for	
NAME1	Assessor's Information	Owner Last Name		
NAME2		Owner First Name		
NUMBER		Address Number		
LOCATION		Street Name		
L_Ex	Loading Information	Existing Load	Provided by SW for Mashpee only	kg/yr
L_Fut_Sea		Future Seasonal Load	Provided by SW for Mashpee only	kg/yr
L_Raw_EX		Existing Load	Calculated by LAI from SW provided information	kg/day
L_Raw_Fu		Future Seasonal Load	Calculated by LAI from SW provided information	kg/day
L_Sep_EX		Existing Septic Load	75% of Raw Loads	kg/day
L_Sep_Fu		Future Seasonal Septic Load	75% of Raw Loads	kg/day
ATTEN		% Atten.	Provided by MEP	
L_Att_EX		Existing Attn. Load		kg/day
L_Att_Fu		Future Attn. Load		kg/day
F_Ex		Flow	Existing Flow	Provided by SW
F_Fut_Sea	Future Flow		Provided by SW	gpd
Cluster_Re	Nitrex™ Scenario	Cluster Assignments	16 Clusters	
RET_NLOAD		Return Loads	10% of the Treated Loads in each cluster	
DISPER_SIT		Dispersal Sites	15 Sites (3 and 7 are combined)	
FU_RET_NL		Future Return Load	Calculated by LAI	
FU_NL_NTRX	Future Load with Nitrex Scenario	Calculated by LAI		
SW_Comment	Misc.	SW Comments		
EX_Dev		Existing Developed	1 = Yes; 0 = No	
FU_Dev		Future Developed	1 = Yes; 0 = No	

APPENDIX B – Examples of Nitrex™ Technology Projects

Attached are the Performance Summaries for the following Nitrex™ Technology Projects:

- Mashpee, MA
- Eastham, MA
- Malibu, CA
- Otis Test Center, MA
- Groundwater Treatment
- Phosphorus Removal