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University of Massachusetts Dartmouth
The School for Marine Science and Technology

DEP #2004-04/604
DEP #2005-05/604
DEP #2006-04/604

Summary of Water Quality Monitoring Program for the Mount Hope Bay Embayment System (2004 – 2006)

(Final August 16, 2007)

Mt. Hope Bay – Estuarine Water Quality Monitoring 604(b) Grant

Submitted to:

MA Department of Environmental Protection

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For:

Southeastern Regional Planning and Economic Development District (SRPEDD)

and the

MA DEP 604(b) Program

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Mt. Hope Bay – Estuarine Water Quality Monitoring
(DEP #2004-04/604, #2005-04/604, #2006-04/604)

Submitted to: MA Department of Environmental Protection

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1.0 BACKGROUND AND OVERVIEW:

The project goal was to collect and analyze water samples and associated field parameters relevant to the nutrient related water quality of the Mount Hope Bay – Taunton River System. This water quality monitoring effort is a collaborative effort between the Coastal Systems Program (CSP) within the University of Massachusetts – Dartmouth, School of Marine Science and Technology and the Southeastern Regional Planning and Economic Development District (SRPEDD) whereby the CSP and SRPEDD assembled a couple water sampling team trained and coordinated by University of Massachusetts – Dartmouth, School of Marine Science and Technology (SMAST), Coastal Systems Laboratory Staff under the direction of Sara Sampieri and Jen Antosca (field oversight) or Dale Goehringer (logistics coordination). Each water sampling team was responsible for collection of water samples at assigned sampling stations with logistical support by SMAST. Personnel from the Coastal Systems Laboratory within SMAST were also involved in the field sampling in order to assist in the collection of samples and insure proper transport and delivery of samples to the Coastal Systems Analytical Facility where chemical assays were performed.

The water quality data collected by the combined efforts of each sampling team is required for application of the Linked Watershed-Embayment Approach of the Massachusetts Estuaries Project (MEP). All embayments undergoing MEP analysis require a minimum of three years of high-quality water chemistry and field data related to nitrogen dynamics. Although there is some existing water quality data that may be incorporated into the Estuaries Project approach, a complete water quality monitoring effort must be implemented in order to satisfy the full water quality monitoring data requirements of the MEP. In order to initiate the needed data collection for the Mt. Hope Bay – Taunton River Estuarine System to support entry into the Estuaries Project and thereby allow full evaluation of protective measures, the SRPEDD received DEP 604(b) funding support for collection, processing and analyses of water samples from the overall embayment system. In total, three grants were obtained allowing water quality data collection at the estuarine stations during the summer of 2004, 2005 and 2006, as well as stream flow and water quality data collection initiated in the spring of 2004 and continuing to present. Stream gaging and water sample collection was begun on the Taunton River and 4 tributary streams discharging into the Taunton River under the first 604(b) grant (2004-04/604). Data collection efforts on those 5 surface water inflows to Mt. Hope Bay were completed under the second 604(b) grant (2005-04/604). Data collection on the three remaining surface water inflows to Mt. Hope Bay were initiated in the spring of 2006 under the third 604(b) grant (2006-04/604) and are on-going for approximately 6 more months into the future. A locus map is provided as Figure 1.

Samples and field data were collected from 22 marine and 5 stream sample stations in the Mt. Hope Bay – Taunton River Estuarine System, during 6 sample rounds from June through mid-September, 2004 (DEP#2004-04/604), 2005 (DEP#2005-04/604) and 2006 (DEP#2006-04/604). Marine stations were sampled at approximately two-week intervals during the falling tide (targeting the 2 hours before and after mid-ebb) during the early morning hours (6-9 A.M.). Streams with tidal influence were sampled at ebb slack tide, independent of time of day. Stream samples were collected on a weekly basis for the entire stream gage deployment period on each surface water system. Sampling was conducted on the marine stations June through mid-

September in order to focus on what is typically the period of poorest nutrient related water quality. Sample stations were located by Global Positioning System (GPS, see detail below) and on-shore landmarks as appropriate during an initial survey with SMAST staff.

At each marine sampling location (MHB 1-21, MHB-DO, water samples were collected for dissolved oxygen by Winkler titration (Hach or YSI 85 meter, see detail below) and temperature. Salinity/specific conductance were measured in the Coastal Systems Laboratory. Sampling teams with SMAST Staff aboard used the YSI for profiling of D.O., temperature and specific conductance, as well as collecting water with a Niskin sampler for D.O. by Winkler Titration and temperature by dial thermometer (Surface and Bottom). A Secchi Disk was used to determine light penetration at each site. Water samples for nutrients and chlorophyll a were collected using a 2.2 liter Niskin Sampler at surface, middle and bottom water depths at most stations due to the large total depths at most stations. At shallower stations, water samples were obtained from either surface and bottom depths or, in the case of very shallow stations, only a middle depth.

At each stream sampling location (MHB-A,B,C,D,E) weekly water quality samples were collected for approximately 16 months. Water samples were collected by SMAST Staff at slack low tide. Whole water samples and filtered samples (0.45 um) were collected at each stream. The stream gauges were downloaded at 1 to 1.5 month intervals.

SMAST received all water samples within 6 hrs of their collection and conducted chemical analyses: nitrate+ nitrite, ammonium, particulate and dissolved organic nitrogen, and ortho-phosphate, chlorophyll *a* and pheophytin, particulate carbon and TSS for all samples and total phosphorus for stream samples. The School for Marine Science & Technology Coastal Systems Analytical Facility (Dr. Brian Howes, Program Manager and Sara Sampieri, Analytical Facility Manager, 508-910-6352) performed all chemical assays under their laboratory SOP and Quality Assurance Plan procedures.

The estuarine watercolumn data for 2004, 2005 and 2006 and stream data for gage locations MHB-A,B,C,D,and E have been incorporated into this report. Results of the stream gaging effort for the gage locations MHB-F,G and H as supported by DEP #2006-04/604 will be submitted to the MassDEP at the end of the grant in the form of a Technical Memorandum. The discussion includes the sampling undertaken, discussion of nutrient related water quality spatial distribution (Section 3.1), as well as flow and nutrient levels in freshwater inputs (Section 3.2). The raw data is presented in electronic format. It is important to note that the major focus of this effort is to support future MEP analysis, which will include a complete water quality and habitat quality assessment. However, based upon the available data it was possible to provide a preliminary assessment of the current status of the Mt. Hope Bay – Taunton River Estuarine System relative to nutrients.

Mt. Hope Bay and Taunton River Estuarine Monitoring
DEP #2004-04/604, #2005-05/604 and #2006-04/604
Coastal Systems Program-SMAST/SRPEDD Collaboration

University of Massachusetts Dartmouth
The School for Marine Science and Technology

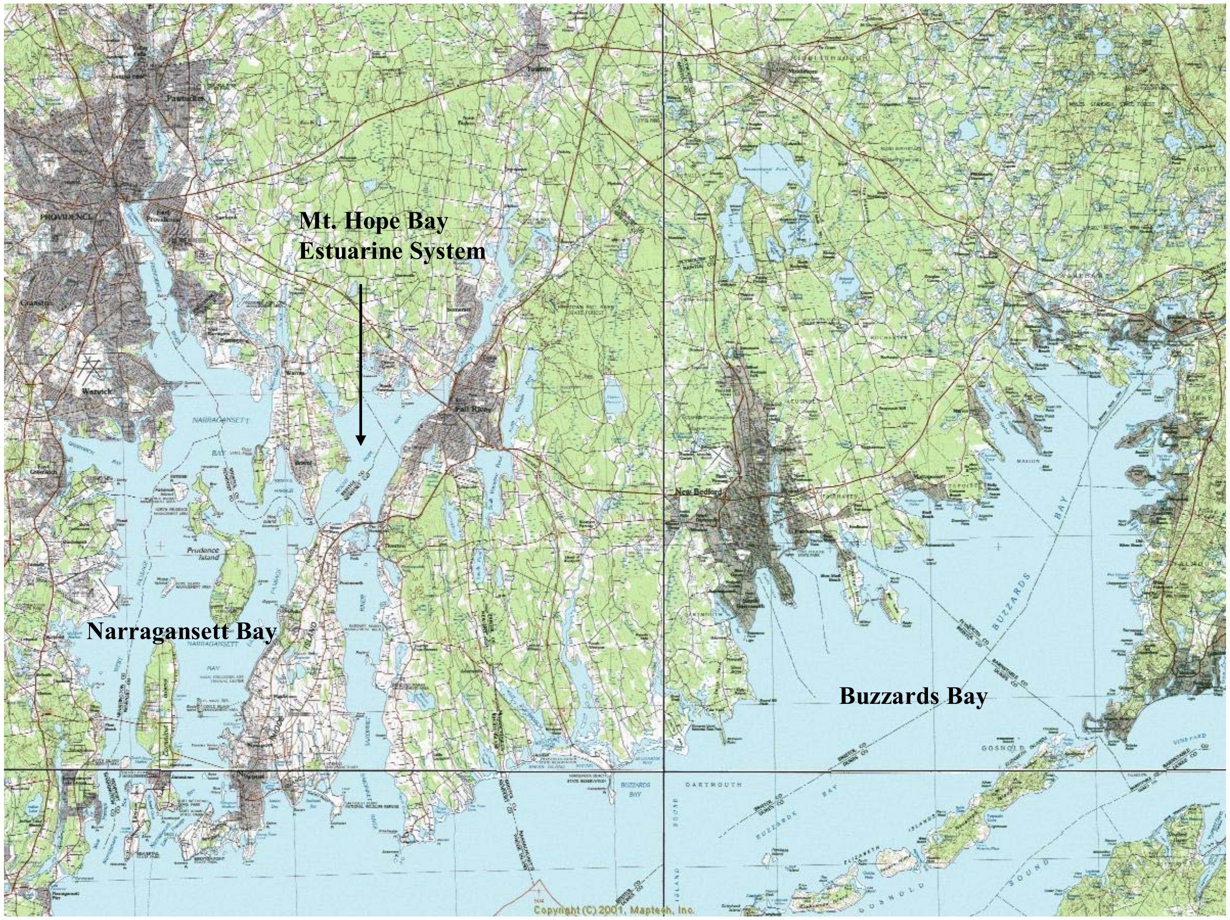

Figure 1 – Locus map depicting Mount Hope Bay and the inflowing Taunton River surface water system

2.0 METHODS:

Sampling and analysis of both estuarine and stream sites followed the Sampling and Analysis Plan (SAP) developed for this project and approved by DEP and EPA.

2.1 Lab analyses:

Marine (M) and stream (S) water samples collected under the 604(b) grant were analyzed at the Coastal Systems Analytical Facility for the following constituents:

- Nitrate + Nitrite (M,S)
- Ammonium (M,S)
- Ortho-phosphate (M,S)
- Total phosphorus (S)
- Particulate Carbon (M,S)
- Particulate Nitrogen (M,S)
- Dissolved Organic Nitrogen (M,S)
- Chlorophyll *a* & pheophytin *a* (M,S)
- Specific Conductance (M,S)
- Total Suspended Solids (M)

Carbon-clean glass fiber filters were used for particulate analysis and nitrocellulose filters for chlorophyll *a* analysis. Dissolved nutrient samples were filtered in the field (0.45um) using cellulose acetate filters. Laboratory analytical standards were met for each batch of samples assayed. Samples were received at the analytical facility within 6 hours of collection and were accompanied by a Chain of Custody Form.

2.2 Field Data Collection:

Dissolved oxygen was assayed in the field by 2 methods: (1) field teams with SMAST Staff used an YSI 85 meter and probes (for temperature also) following the calibration procedures specified by the manufacturer and specified in the SAP and (2) other field teams used the Winkler titration method (Hach, 0.5 mg/L) on samples collected by Niskin sampler, with temperature by dial thermometer. Depending on the total depth at a given station, measurements were collected from surface (0.15 m depth), middle depths generally 2m and bottom waters (0.5 m off bottom). In all cases, water samples were collected for laboratory analysis of salinity. Additionally, sampling teams made measurements of Secchi depth, Wind Speed (Beaufort Scale), tide stage, rainfall.

2.3 Personnel:

The field portion of the estuarine water quality monitoring effort relied upon teams of samplers assembled from a small pool of volunteers identified through a couple of the local NGO's in the region, specifically Save the Bay and Green Futures. In the absence of volunteers on some of the sampling dates, SMAST staff completed the sampling such that 100 percent sample recovery was achieved throughout the duration of the Mt. Hope Bay Sampling Program. The sampling teams were trained and supervised by SMAST personnel under the direction of Sara Sampieri and Jen Antosca (field oversight) or Dale Goehringer (logistics coordination). Each participating group has assigned a point of contact responsible for coordinating a team of samplers tasked to sample designated stations as follows:

- SRPEDD – Bill Napolitano
- Green Futures – Roland Garant (with field assistance from Jen Antosca - SMAST)
- Save the Bay – John Torrgin
- SMAST 1 – Mike Bartlett
- SMAST 2 – Sara Sampieri

Sampling personnel were trained by, SMAST Technical Staff to assure that the sample collection and handling procedures are followed. In addition, SMAST Staff generally partnered with the volunteer teams in the field. All personnel were provided with a copy of the relevant pages of the SAP and field SOP's. Chain of Custody Forms and procedures were followed for all sampling events. This project would not have been possible, but for the efforts of these volunteers, and they deserve credit for the successful completion of the full sampling schedule.

2.4 Materials:

Niskin Samplers for collection of estuarine watercolumn samples and Sampling Kits for each field team (data and COC forms, thermometers, field filters, Hach D.O. Kits, Secchi Disk and misc. supplies) were provided by SMAST. Sampling Teams for each event also received a cooler with the necessary number of high density polyethylene (HDPE) bottles (1 L) for whole water samples for particulate and chlorophyll *a* assays and 60 milliliter polyethylene bottles (HCl leached) for dissolved nutrients. The YSI 85 meters were supplied and maintained by SMAST.

2.5 Estuarine and Stream Sample Locations:

All portions of the overall Mt. Hope Bay – Taunton River estuarine system (MHB 1-21 and MHB-DO) designated as estuarine were tidal. Only the stream gauging/water quality sampling stations (MHB-A,B,C,D,E) were fresh water (<0.2 ppt). All estuarine samples were collected from boats, while stream samples were collected from the center of the channel by wading up gradient of the gage site or by Niskin sampler from a bridge as was the case for the Taunton River gaging station (MHB-A) as the river is too deep to be waded. The marine sample station locations are shown in Figure 2.

The estuarine sampling stations in Mt. Hope Bay are shown in Figure 2 and include:

- The estuarine reach of the Taunton River: MHB-21,19,18,1,2
- The estuarine reach of the Assonet River: MHB-20
- The main basin of Mt. Hope Bay: MHB-3,5,811,12,13,14,15,16, MHB-DO
- The estuarine reach of the Kickamuit River: MHB-9,10
- The estuarine reach of the Cole River: MHB-6,7

- The estuarine reach of the Lee River: MHB-4,17

Each of the major surface fresh water inflows to the Mt. Hope Bay Estuarine System were gauged and sampled just prior to discharge to estuarine waters. The fresh water stream sites shown in Figure 3, 4, 5 as follows:

- Taunton River at Weir Village bridge crossing: MHB-A
- Three Mile River at Route 138: MHB-B
- Segreganset River at Elm Street (up gradient Rt. 138): MHB-C
- Assonet River at the Route 79 bridge crossing: MHB-D
- Quequechan River at rail road bridge (Battleship Cove): MHB-E

All five gaging locations were marginally tidal in that stage records at all sites indicated a high and low tide stage reflective of ebb and flood conditions. Prior to initiating the extended deployments (16-20 months) salinity in the stream flow was checked to confirm that fresh water (salinity < 0.5 ppt) could be measured at low tide. All the gage locations had salinity values at low tide of less than 0.5 ppt and were therefore deemed acceptable locations for conducting stream gaging (e.g. measurement of stage and development of a stage-discharge relation from which to calculate daily flows). In the case of tidal influence on the measured stream stage for each of the five gaging locations, the diurnal low tide stage value was extracted on a day-by-day basis in order to resolve the stage value indicative of strictly freshwater flow. The lowest tidal stage value was selected for a given 24-hour period and that stage value was then entered into the stage – discharge relation in order to compute daily flow.

Table 1. Summary of Sub-Embayments to the Mt. Hope Bay Estuarine System and Parameters to be Analyzed:

Sub-System	**Station I.D.**	**Dissolved Nutrients**	**Particulate Nutrients**	**Chlorophyll /Pheophytin**	**Field Parameters**
Mt. Hope Bay	MHB 3 – 16 & MBH-DO[1]	X	X	X	X
Taunton River Estuary	MHB 1,2,17-21	X	X	X	X

[1] **MBH-DO** is a historic mooring location within the mid-bay.
Dissolved nutrients: nitrate, nitrite, ammonium, dissolved organic nitrogen.
Particulate nutrients: particulate carbon and nitrogen; also specific conductance and TSS
Phytoplankton pigments: chlorophyll *a* and pheophytin *a*
Field parameters: Dissolved oxygen (% sat. & milligrams per liter), temperature, Secchi depth

Table 2. Mt. Hope Bay System estuarine sampling station locations and depth of collection for nutrient (i.e. all chemical analyses) and dissolved oxygen samples. The presented coordinates for these stations were those being used for all years of sampling (summer 2004,05,06) under the multiple 604(b) Grants.

Station	(North) Lat	(West) Lon	Sta Depth (meters)	Nutrient Sampling Depths			D.O. Sampling Depths		
				Surf	2 meter	Btm	Surf	Mid	Btm
MHB-1	41' 43.801	71' 8.902	9.50	X	X	X	X	X	X
MHB-2	41' 42.95	71' 9.731	11.00	X	X	X	X	X	X
MHB-3	41' 41.894	71' 11.413	5.00	X	X	X	X	X	X
MHB-4	41' 42.882	71' 11.872	3.40	X		X	X	X	X
MHB-5	41' 42.24	71' 12.184	5.00	X	X	X	X	X	X
MHB-6	41' 43.714	71' 13.492	4.50	X	X	X	X	X	X
MHB-7	41' 43.064	71' 13.114	4.00	X	X	X	X	X	X
MHB-8	41' 42.233	71' 12.864	4.50	X	X	X	X	X	X
MHB-9	41' 43.456	71' 15.784	1.20		X		X	X	X
MHB-10	41' 42.67	71' 15.027	3.75	X	X	X	X	X	X
MHB-11	41' 41.594	71' 13.867	5.35	X	X	X	X	X	X
MHB-12	41' 41.682	71' 13.129	4.50	X	X	X	X	X	X
MHB-13	41' 40.868	71' 13.303	5.50	X	X	X	X	X	X
MHB-14	41' 40.335	71' 12.489	6.50	X	X	X	X	X	X
MHB-15	41' 39.457	71' 14.097	13.90	X	X	X	X	X	X
MHB-16	41' 39.124	71' 12.827	12.50	X	X	X	X	X	X
MHB-17	41' 43.902	71' 11.506	1.50	X		X	X	X	X
MHB-18	41' 45.443	71' 7.919	7.40	X	X	X	X	X	X
MHB-19	41' 46.599	71' 6.990	5.78	X	X	X	X	X	X
MHB-20	41' 48.136	71' 5.430	1.05		X		X	X	X
MHB-21	41' 48.335	71' 7.110	3.10	X		X	X	X	X
MHB-DO	41' 41.142	71' 12.198	5.75	X	X	X	X	X	X

GPS Datum = WGS84
Water Samples are collected: Mid-water only, if total depth <1.5m; Surface and Bottom, if total depth is 1.5m-3.5m; Surface+2m+Bottom, if total depth >3.5 meters. All estuarine sampling conducted on ebbing tide.

Table 3. Summary of freshwater inflows to the Mt. Hope Bay Estuarine System to be sampled weekly for nutrients, general locations are shown in Figures 3-5. Shaded rivers (MHB F,G,H) are on-going as part of 604(b) grant number DEP#2006-04/604.

Freshwater Inflow	Station I.D.	Particulate Nitrogen & Carbon (PN/PC)	Dissolved Organic Nitrogen (DON)	Nitrate + Nitrite (NOx)	Ammonium (NH^+_4)
Taunton River	MHB-A	X	X	X	X
Three Mile River	MBH-B	X	X	X	X
Segreganset River	MBH-C	X	X	X	X
Assonet River	MBH-D	X	X	X	X
Quequechan River	MBH-E	X	X	X	X
Lewins Brook to Lee River	MBH-F				
Cole Brook to Cole River	MBH-G				
Heath Brook to Kickamuit River	MBH-H				

Table 4. Mt. Hope Bay System stream sampling station locations and depth of collection for nutrient (i.e. all chemical analyses) and dissolved oxygen samples. The presented coordinates for these stations were those being used for the years of stream sampling (2004-2005) under the multiple 604(b) Grants.

Station	(North) Lat	(West) Lon	Sta Depth (meters)	Nutrient Sampling Depths			D.O. Sampling Depths		
				Surf	2 m	Btm	Surf	Mid	Btm
MHB-A	41° 53’ 09.57	71° 05’ 22.03	grab	X			NA		
MHB-B	41° 51’ 20.94	71° 06’ 59.17	grab	X			NA		
MHB-C	41° 49’ 23.61	71° 07’ 30.33	grab	X			NA		
MHB-D	41° 47’ 37.67	71° 04’ 04.18	grab	X			NA		
MHB-E	41° 42’ 13.15	71° 09’ 38.38	grab	X			NA		

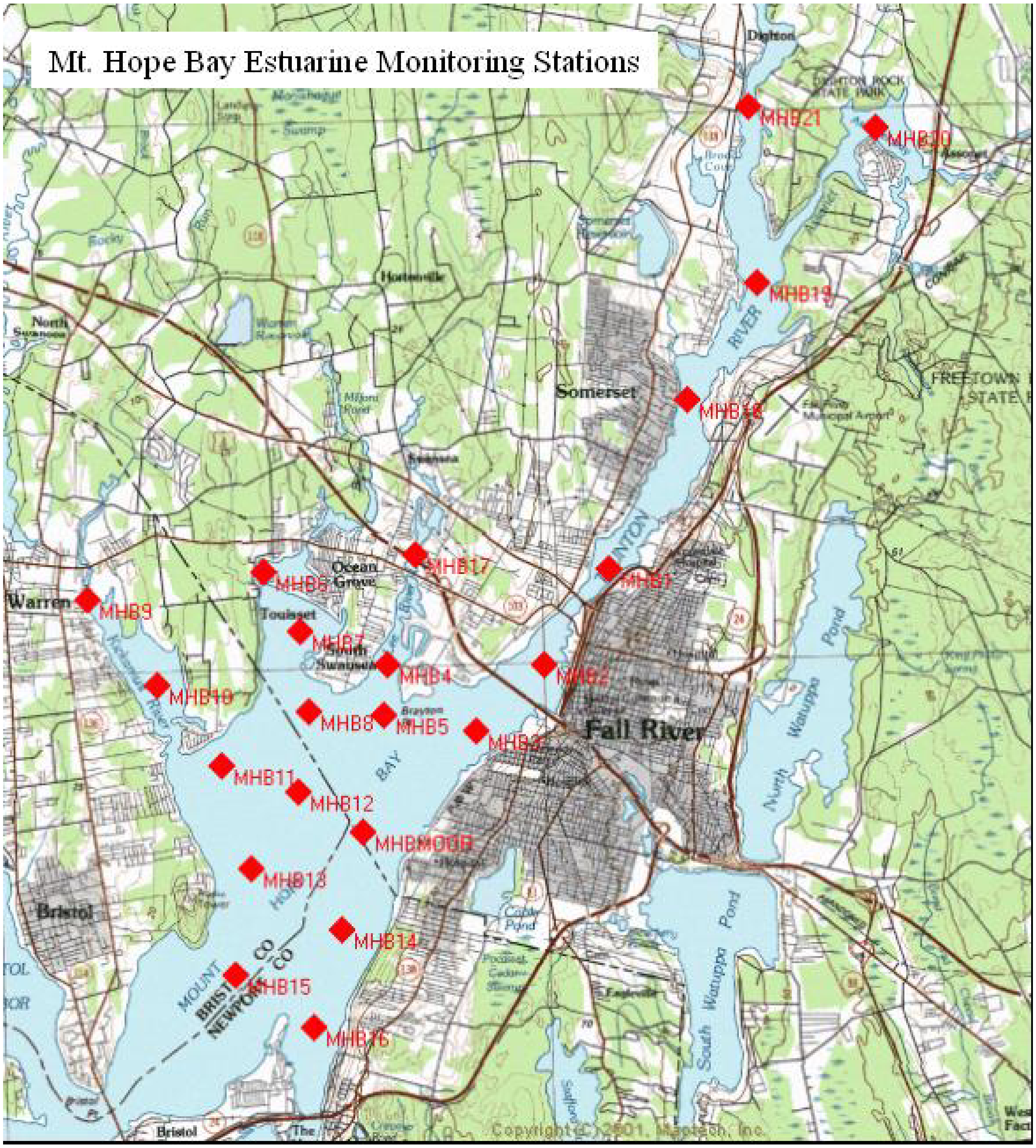

Figure 2. Water quality sampling stations within Mt. Hope Bay and the Taunton River (estuarine region). The stations are positioned to support future application of the MEP Linked Watershed-Embayment Management Model.

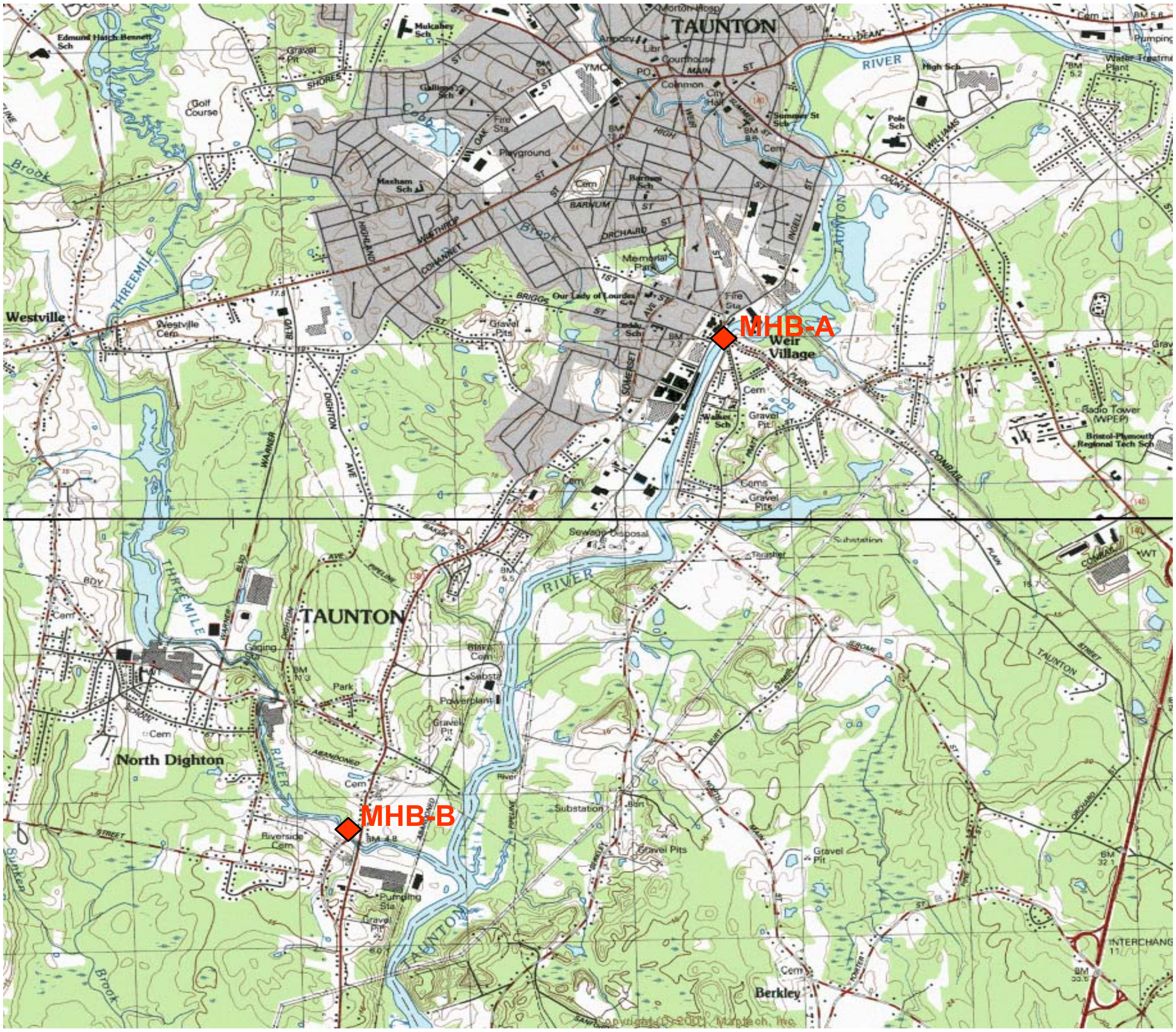

Figure 3. Stream gauging and nitrogen sampling stations on the Taunton River (MBH-A) and Three Mile River (MBH-B). These freshwaters discharge to the headwaters of the Taunton River Estuary

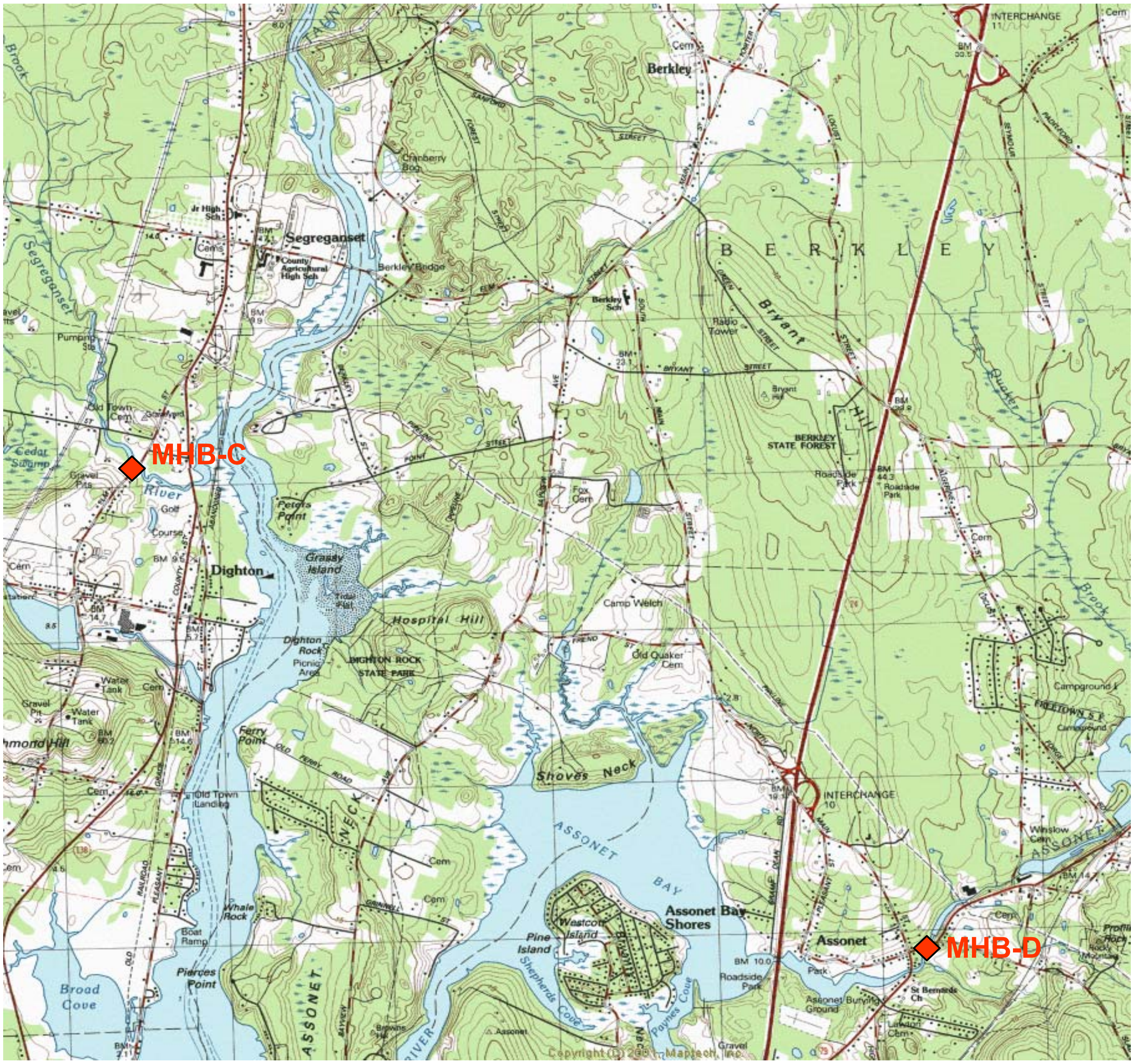

Figure 4. Stream gauging locations on the Segreganset River (MBH-C) and Assonet River (MBH-D). These freshwaters discharge to the headwaters of the Taunton River Estuary

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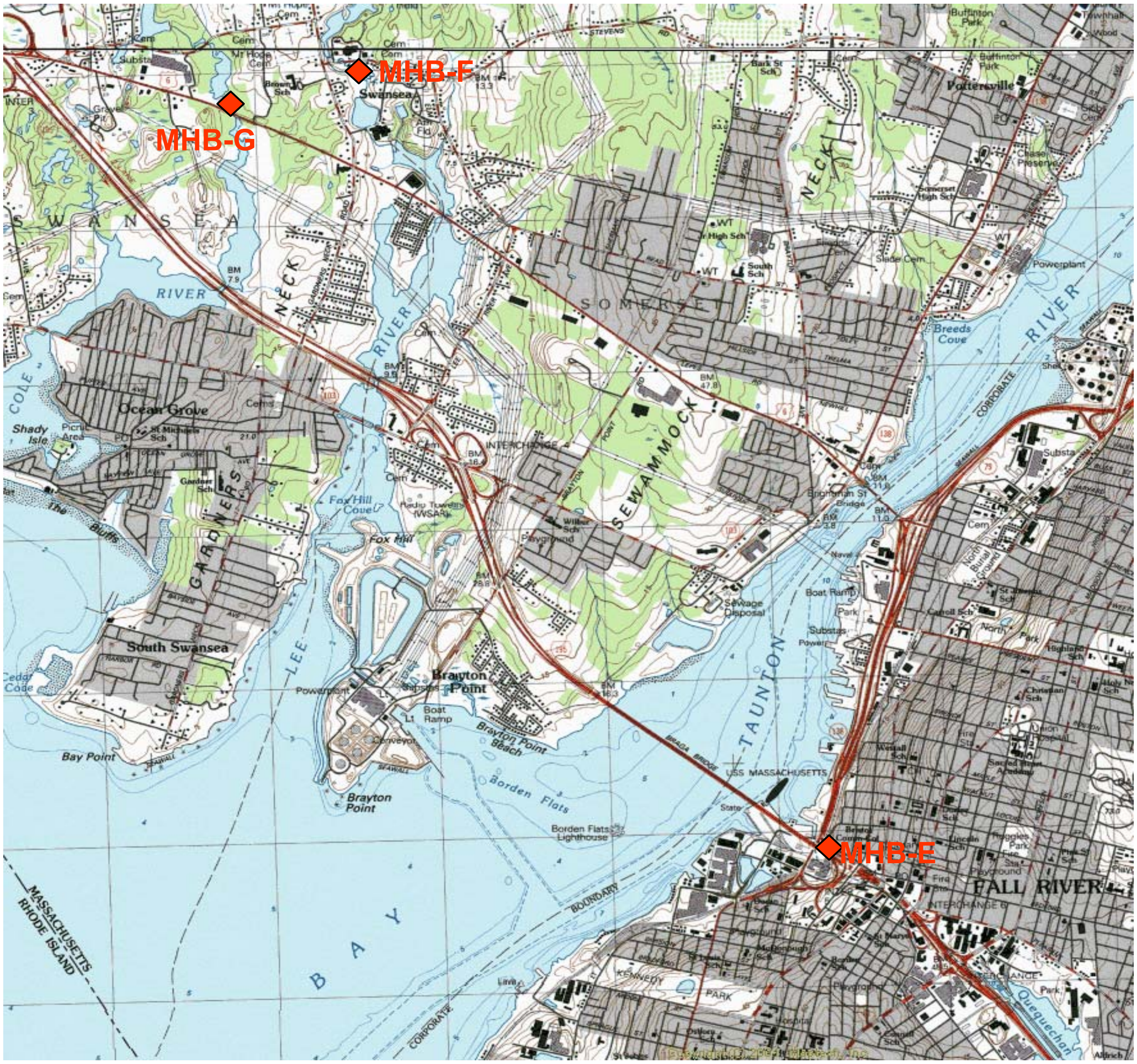

Figure 5. Stream gauging locations on the Quequechan River (MBH-E), Lewins Brook to Lee River (MBH-F, on-going) and Cole Brook to Cole River (MBH-G, on-going). These freshwater inflows transport nutrients to the upper portion of the Mt. Hope Bay basin

3.0 RESULTS AND DISCUSSION

Surface and groundwater flows are pathways for the transfer of land-sourced nutrients to coastal waters. Fluxes of primary ecosystem structuring nutrients, nitrogen and phosphorus, differ significantly as a result of their hydrologic transport pathway (i.e. streams versus groundwater). In glacial outwash aquifers, such as the south coast of Massachusetts, phosphorus is highly retained during groundwater transport as a result of sorption to aquifer mineral. Since throughout southeastern Massachusetts rivers are primarily groundwater fed, watersheds tend to release little phosphorus to coastal waters. In contrast, nitrogen, primarily as plant available nitrate, is readily transported through these oxygenated groundwater systems. The result is that terrestrial inputs to coastal waters tend to be higher in plant available nitrogen than phosphorus (relative to plant growth requirements). However, coastal estuaries and salt ponds tend to have algal growth limited by nitrogen availability, due to their flooding with low nitrogen coastal waters. The Mt. Hope Bay – Taunton River Estuarine System which exchange tidal waters with Narragansett Bay and Rhode Island Sound follow this general pattern, although their upper-most reaches can have excess inorganic nitrogen levels due to localized loading of nitrates at their headwaters (see below). The lower reaches of these estuaries are nitrogen limited based upon their inorganic N to P ratios (<<16) and these regions would be expected to expand inland if nitrogen loading in the upper reaches were to be reduced. However, the primary nutrient of eutrophication in these systems is nitrogen, similar to most other estuaries in Massachusetts.

Nutrient related water quality decline represents one of the most serious threats to the ecological health of the nearshore coastal waters. Coastal salt ponds and embayments, because of their shallow nature and large shoreline area, are generally the first indicators of nutrient pollution from terrestrial sources. By nature, these systems are highly productive environments, but nutrient over-enrichment of these systems world-wide is resulting in the loss of their aesthetic, economic and commercially valuable attributes.

Each embayment system maintains a capacity to assimilate watershed nitrogen inputs without degradation. However, as loading increases a point is reached at which the capacity (termed assimilative capacity) is exceeded and nutrient related water quality degradation occurs. As nearshore coastal salt ponds and embayments are the primary recipients of nutrients carried via surface and groundwater transport from terrestrial sources, it is clear that activities within the watershed, often miles from the water body itself, can have chronic and long lasting impacts on these fragile coastal environments.

Protection and restoration of coastal embayments from nitrogen overloading has resulted in a focus on determining the assimilative capacity of these aquatic systems for nitrogen. This effort is ongoing throughout southeastern Massachusetts (e.g. Massachusetts Estuaries Project). The general approach focuses on changes in nitrogen loading from watershed to embayment, and determination of the changes in habitat health for incremental increases or decreases in nitrogen inputs, hence nitrogen concentrations within the receiving waters. The MEP approach depends upon estimates of nitrogen inputs and embayment recycling of nitrogen, circulation within the embayment; and assessments of habitat quality. The MEP approach requires a sound baseline (not less than 3 years) of nitrogen related water quality monitoring. This latter monitoring is fulfilled for the Mt. Hope Bay – Taunton River Estuarine System by the funded 604(b) grants obtained from the MassDEP over the past 3 years. However, determination of the "allowable N concentration increase" or "threshold nitrogen concentration" will require the MEP assessment, modeling and analysis (i.e. the "MEP approach").

The following assessments are based upon the 3 summers of watercolumn monitoring obtained via 604(b) grant funding and will be refined as additional water quality data is collected up until the MEP is undertaken in this system. Additional levels of analysis of the overall system will be achievable with the "higher level" analysis by the MEP. However, some general conclusions relative to estuarine water quality (Section 3.1) and major stream inputs (Section 3.2) can be made at this time. Note also that the following is meant to be a brief analysis focusing on the nutrient related health of this regions most significant coastal system, Mt. Hope Bay – Taunton River.

3.1 Estuarine Water Quality Monitoring Data

Overall, the Taunton River - Mount Hope Bay estuarine complex appears to be representative of a large nitrogen enriched embayment system that is driven by riverine inputs. The expansive watershed which encompasses large suburban and urban areas carries significant nitrogen loading to the estuary, which coupled with local point and non-point discharges from the lower watershed areas, appears to be above the nitrogen loading threshold of this basin. Nitrogen related habitat impairment is exacerbated by the periodic stratification of Mt. Hope Bay, which results in prolonged oxygen depletion (~4 mg l^{-1}) of bottom waters. As it appears that nitrogen management is the only approach for habitat restoration within this estuary, the elemental ratio method (Redfield molar ratio of N/P <16, indicating N as the management focus) was employed as a check on N vs. P limitation of primary production in this basin. The N/P molar ratios did support the contention that Mt. Hope Bay and the Taunton River estuary are N limited. The average ratio of inorganic nitrogen to inorganic phosphorus (N/P) was quite low, <3, at all stations within the Bay, although the Taunton River estuarine stations showed consistently higher ratios (5-10) as presented in Table 5. While this is only an approximate method, it is consistent with other studies documenting nitrogen limitation in estuaries throughout southeastern Massachusetts. In addition, it is consistent with established theories of nitrogen limitation in temperate estuaries. The conclusion supports the targeting of nitrogen as the key nutrient for management of the habitat quality of these estuarine systems.

Taunton River/Mt. Hope Bay System: The Taunton River/Mt. Hope Bay System is composed of a large riverine estuary discharging to a large open embayment with relatively deep waters (ca. 5-12 m at mid tide) and moderate to high salinity waters throughout (Table 5). The estuary shows a moderate salinity gradient. With the exception of the upper reaches nearest the freshwater entry, almost all of the waters ranged from 19 ppt to 28 ppt nearest the channel at Bristol Point. The salinity gradient results from the high predominantly riverine freshwater inflow and the high tidal flushing of this enclosed basin. Only the stations directly influenced by the Taunton River (MHB19-21) and the Kickamuit River (MHB-9) showed significant dilution of the main Bay. However, freshwater does have a major structuring effect on the habitat quality of the Mt. Hope Bay System. During summer, the Mt. Hope Bay water column frequently has fresher water at the surface than at the bottom. The effect is to reduce vertical mixing of the waters. Since the Bay is nutrient enriched, and therefore supports organic matter production by phytoplankton, there appears to be significant oxygen demand in the water column and sediments. Chlorophyll a levels throughout this system are generally high in the summer, >11 ug L^{-1}, supporting the assessment of a nutrient enriched estuary and indicating that organic matter production is capable of supporting a high level of oxygen demand. As this production settles to the bottom water and sediments and stimulates respiration, the effect of reducing vertical mixing allows oxygen demand below the pycnocline to deplete the bottom water oxygen pool result in periodic hypoxia and stress to benthic animal communities and fish. These low oxygen conditions are primarily found in the upper portion of the main Mt. Hope Bay basin and in the Taunton River estuarine reach (Table 7). Complete data files for dissolved oxygen, salinity as well as nutrients and physical parameters have been sent to MassDEP in digital format under separate cover (as indicated in Appendix D). With regard to the stream gage stations sampling, secchi depth and dissolved oxygen measurements are not taken at the stream stations and as such no data (ND) was presented in the spreadsheet containing the raw water quality data.

Given the high population within the watershed and resultant N loading to this down gradient estuary and the observed high chlorophyll levels and oxygen depletions, it is not surprising that nitrogen levels are moderately to highly enriched over offshore waters. The Taunton River estuarine reach, as the focus of upper watershed N loading, showed very high total nitrogen levels (TN) in its upper reach (1.058 mg N L^{-1}) and maintained high levels throughout most of its reach (>0.6 mg N L^{-1}). The main basin of Mt. Hope Bay supported lower TN levels primarily as a result of mixing with incoming waters (generally 0.5-0.6 mg N L^{-1}). This is consistent with the observed oxygen depletions and infauna animal communities. The highest (Moderate) water quality was found at the stations in the main basin and lower reaches of Mt Hope Bay out to the channels to lower Narragansett Bay and the Sakonet River (Figure 6).

From the water quality data, it appears that the smaller rivers discharging to Mt. Hope Bay had a minor localized effect on water quality in their lower drown river valley basins, due to their relatively small flows (compared to Taunton River) and mixing with waters of the Mt. Hope Bay (Section 3.2). However, it should be noted that although there only appeared to be a localized water quality "effect", the N load from these rivers is proportionately responsible for the impaired nutrient related habitat quality of the Mt. Hope Bay basin.

The water quality data can be used to generate a Bay Health Index as developed and refined by the Buzzards Bay Project, Coalition for Buzzards Bay’s Bay Watcher Program and SMAST. The concept is to integrate the basic water quality monitoring parameters (dissolved inorganic nitrogen, total organic nitrogen, chlorophyll a pigments, Secchi depth and lowest 20% of Dissolved Oxygen measures) into a single index that can be plotted to show the spatial pattern of nitrogen related water quality within an embayment. While the result is general and qualitative, the patterns are useful in gauging overall habitat quality and guiding more detailed quantitative habitat assessments as undertaken by the Massachusetts Estuaries Project Approach. The reference values used in generating the index are shown in Table 6.

Using the Bay Health Index for the Mt. Hope Bay/Taunton River estuarine complex illustrates the overall spatial pattern discussed above (Figure 6). In general, the Taunton River Estuary, with its large watershed N load and high TN levels, is showing poor water quality due to its high chlorophyll and oxygen depletions. The main basin of Mt. Hope Bay, with its greater flushing and access to higher quality waters of the lower Bay, is showing less impairment with moderate water quality. Finally, the lower basin of Mt. Hope Bay, nearest the tidal "inlet", is generally showing moderate water quality. This pattern is consistent with the structure of the watershed and the tidal flushing of estuarine waters resulting, in part, from the moderate tide range. The impaired waters in the regions nearest the river discharges most likely result from their lower flushing rates and from nitrogen loads. In these drowned river valley basins thorough assessments of ecological impairment requires additional habitat parameters before habitat impairments can be firmly documented. However, these data collected via the 604(b) grant program indicate that additional sampling in the basin in the lower region of Mt. Hope Bay, near the tidal inlets, may be warranted. In addition, these data indicate that the MEP analysis of this system should focus on restoration of the main basin of Mt. Hope Bay and the Taunton River estuarine reach, and that it is likely that restoration of the Taunton River Estuary will have a significant positive effect on the habitat quality of the main basin of Mt. Hope Bay.

Overall, it appears that the MEP analysis is warranted for the Mount Hope Bay/Taunton River estuarine complex as assessed by the water quality monitoring data and that the water quality monitoring partnership that has been developed under this 604(b) grant, provides a viable stepping stone for stewardship of this large and complex estuarine system.

Table 5. Summary of average levels of primary nutrient related water quality parameters measured in the summers of 2004, 2005 and 2006 in Mount Hope Bay by SMAST Coastal Systems staff.

Station	Total Depth (m)	20% Low* D.O. (mg/L)	Sal (ppt)	PO4 (mg/L)	NH4 (mg/L)	NOX (mg/L)	DIN (mg/L)	DON (mg/L)	PON (mg/L)	TN (mg/L)	DIN/DIP Molar Ratio	Total Chl a (ug/L)
MHB1	10.0	5.02	23.3	0.054	0.052	0.095	0.147	0.299	0.155	0.601	6	11.75
MHB2	8.9	4.94	26.1	0.052	0.047	0.043	0.090	0.312	0.170	0.572	4	13.50
MHB3	5.2	5.49	26.0	0.051	0.037	0.035	0.072	0.282	0.163	0.517	3	14.32
MHB4	3.5	5.61	25.7	0.052	0.026	0.017	0.043	0.308	0.173	0.525	3	14.71
MHB5	5.6	5.20	26.2	0.050	0.029	0.020	0.050	0.294	0.169	0.512	2	14.53
MHB6	3.9	5.09	24.1	0.061	0.049	0.030	0.079	0.359	0.168	0.606	3	12.87
MHB7	4.5	5.94	25.5	0.049	0.023	0.016	0.039	0.308	0.189	0.536	2	17.46
MHB8	5.1	4.93	25.8	0.046	0.022	0.019	0.041	0.280	0.165	0.486	2	15.84
MHB9	ND	ND	19.7	0.062	0.049	0.040	0.089	0.453	0.263	0.805	3	14.02
MHB10	3.2	5.86	25.7	0.048	0.017	0.012	0.027	0.314	0.167	0.508	1	14.11
MHB11	4.9	5.02	26.2	0.043	0.017	0.012	0.029	0.268	0.175	0.472	1	16.23
MHB12	5.0	5.36	26.4	0.049	0.020	0.021	0.040	0.284	0.168	0.493	2	16.12
MHB13	5.9	6.00	26.8	0.045	0.020	0.013	0.033	0.282	0.158	0.473	2	15.40
MHB14	6.5	5.34	27.0	0.044	0.024	0.009	0.033	0.289	0.197	0.519	2	16.78
MHB15	12.9	6.46	27.9	0.035	0.021	0.009	0.029	0.273	0.143	0.445	2	12.68
MHB16	11.2	6.33	27.7	0.043	0.028	0.012	0.039	0.265	0.157	0.461	2	13.02
MHB17	ND	ND	24.6	0.064	0.057	0.026	0.083	0.404	0.181	0.669	3	11.81
MHB18	6.7	4.96	22.3	0.062	0.061	0.136	0.197	0.300	0.156	0.652	7	11.44
MHB19	4.0	4.93	18.7	0.058	0.074	0.201	0.275	0.342	0.178	0.799	10	12.27
MHB20	1.8	5.09	17.5	0.054	0.063	0.144	0.207	0.372	0.192	0.771	8	13.59
MHB21	2.6	4.60	14.2	0.061	0.066	0.350	0.415	0.420	0.219	1.058	15	13.34
MHBMOOR	6.3	5.85	26.8	0.045	0.025	0.013	0.038	0.284	0.181	0.503	2	15.57

* Average of the lowest 20% of recorded values

Table 6 Reference values used in the Bay Health Index. Scores are generated for each parameter and the mean score computed. In some cases where Secchi data is not available, the mean of the other 4 parameters may be used.

Score	Secchi Depth M	Oxygen Saturation %	Inorganic N mg/L	Total N mg/L	Total Chlorophyll a Pigments ug/L
0%	0.6	0.40	0.140	0.600	10.0
100%	3.0	0.90	0.014	0.280	3.0

The relationship between 0% to 100% for each parameter is logrithmic.

Table 7 Trophic health index scores and status for water quality monitoring stations, Mt. Hope Bay, 2004-2006 (described in Howes et al. 1999 and also at www.savebuzzardsbay.org.)

Station	Secchi SCORE	Low20% Oxsat SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	EUTRO Index	Health Status
MHB1	52.2	57.8	0.0	36.5	0.0	29	Fair/Poor
MHB2	67.7	58.5	19.3	28.7	0.0	35	Mod/Fair
MHB3	62.1	79.4	29.0	39.1	0.0	42	Mod
MHB4	62.0	79.0	51.5	28.7	0.0	44	Mod
MHB5	61.2	71.8	44.9	34.2	0.0	42	Mod
MHB6	65.7	73.5	24.9	17.0	0.0	36	Mod/Fair
MHB7	61.5	87.9	55.4	24.8	0.0	46	Mod
MHB8	61.7	65.3	53.5	39.1	0.0	44	Mod
MHB9	ND	ND	19.6	0.0	0.0	ND	ND
MHB10	60.4	89.4	70.7	29.1	0.0	50	Mod
MHB11	61.6	66.2	68.5	39.8	0.0	47	Mod
MHB12	58.5	78.2	54.1	37.1	0.0	46	Mod
MHB13	57.4	89.9	63.4	40.6	0.0	50	Mod
MHB14	58.8	73.0	63.3	27.5	0.0	45	Mod
MHB15	68.6	92.8	68.3	48.1	0.0	56	Mod
MHB16	65.6	95.5	55.8	45.9	0.0	53	Mod
MHB17	ND	ND	22.5	3.3	0.0	ND	ND
MHB18	47.1	58.0	0.0	36.1	0.0	28	Fair/Poor
MHB19	36.9	54.6	0.0	19.1	0.0	22	Fair/Poor
MHB20	30.5	60.7	0.0	8.1	0.0	20	Fair/Poor
MHB21	24.1	43.5	0.0	0.0	0.0	14	Fair/Poor
MHBMOOR	57.4	84.0	57.1	33.3	0.0	46	Mod

High Quality = >69; High/Moderate = 61-69; Moderate = 39-61; Moderate/Fair = 31-39; Fair/Poor = <31

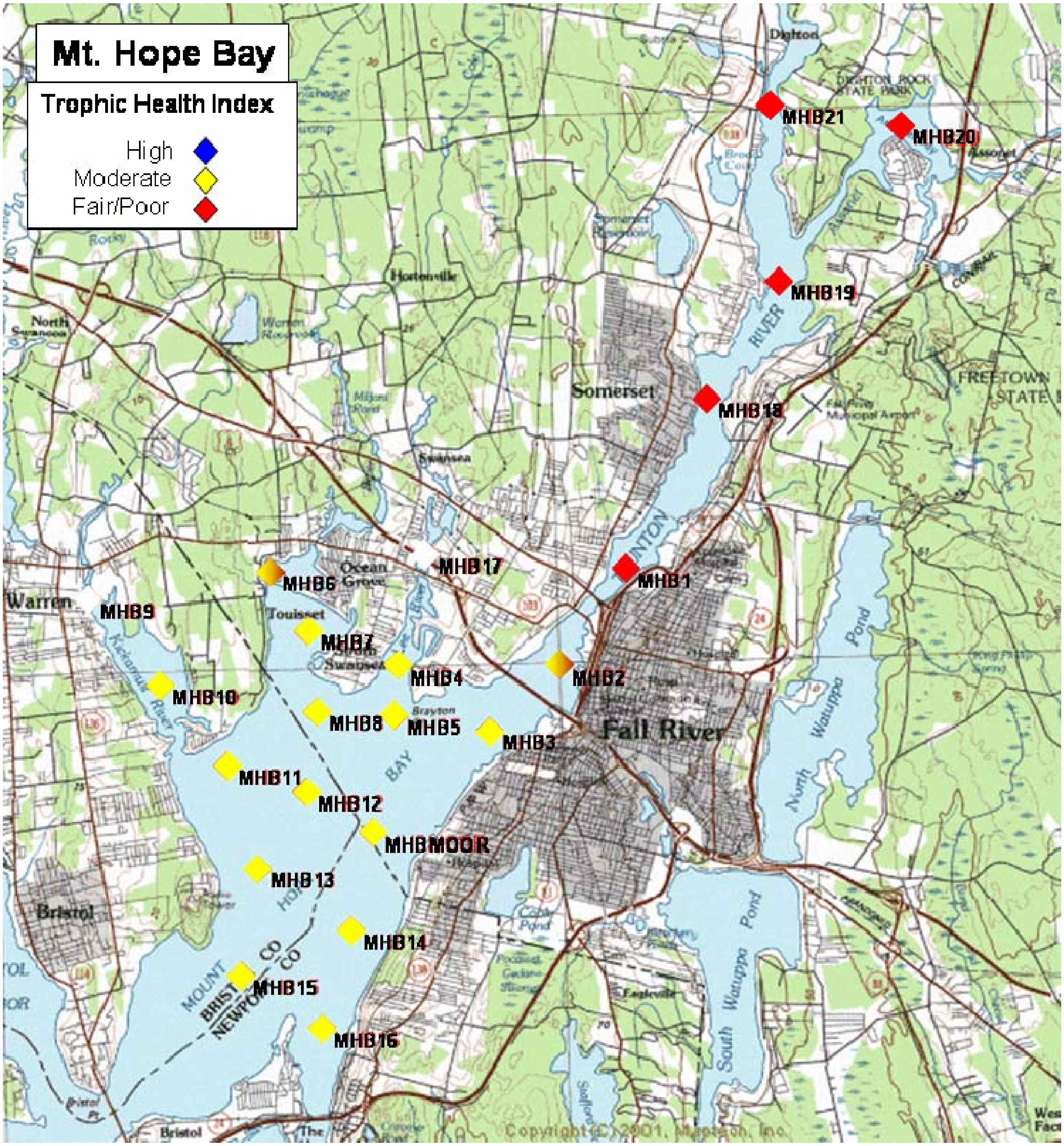

Figure 6 Nutrient Related Water Quality of Mt. Hope Bay – Taunton River Estuary based upon monitoring data from stations in Figure 2. The Health Index was developed for Buzzards Bay

3.2 Stream Discharge and Water Quality Monitoring Data

With regard to the stream gaging and stream water quality monitoring component of the 604(b) grant objectives for the Mt. Hope Bay – Taunton River Estuarine Water Quality Monitoring Project, the stream related tasks where initiated to ultimately generate the data necessary to support critical elements of the Massachusetts Estuaries Project (MEP) Linked Watershed- Embayment Modeling Approach. The MEP is structured to generate site specific embayment nutrient thresholds that serve as targets for watershed wide nutrient load reductions that would be protective or restorative of the habitat quality in any given embayment. As such, MEP modeling and prediction of change in coastal embayment nitrogen related water quality is based, in part, on determination of the inputs of nitrogen from the surrounding contributing land area (watershed). This watershed nitrogen input parameter is the primary term used to relate present and future loads (build-out, sewering analysis, enhanced flushing, pond/wetland restoration for natural attenuation, etc.) to changes in water quality and habitat health of the estuarine receiving water. Therefore, in the context of the MEP nutrient threshold analysis, nitrogen loading is the primary threshold parameter for protection and restoration of estuarine systems. Though the complete nitrogen land use load analysis (watershed-wide) undertaken by the MEP has many more dimensions than those just mentioned, a critical element of the MEP land use load analysis rests on the accurate determination of stream discharges and the associated attenuated nitrogen loads to the embayment being analyzed. The 604(b) grant project for the Mt. Hope Bay – Taunton River embayment system has allowed for the development of daily stream flow values and associated N-loads based on the stream gaging and weekly stream water quality data collection undertaken as part of the 604(b) grant. This effort has yielded a significant data set directly applicable to the objectives to be met by the MEP in the Mt. Hope Bay embayment system.

Surfacewater transport and Nitrogen Load Determination

Measured rates of nitrogen loading from streams discharging to the Mt. Hope Bay embayment system (Taunton River, Three Mile River, Segreganset River, Assonet River, Quequechan River) being investigated under this set 604(b) grants (DEP#2004-04/604, DEP#2005-04/604) were based on long term measurements of stage in each of the mentioned surface waters as well as collection of weekly water quality sampling at each gage location. Ultimately, this data will be merged with the MEP watershed based nutrient loading analysis which is based upon the delineated watersheds to the stream gages in order to determine levels of nitrogen attenuation occurring in the watersheds to each stream. As such, the truest estimate of actual nitrogen loads being discharged from the watershed to Mt. Hope Bay can be determined and utilized in embayment water quality modeling. The complete MEP watershed loading analysis combined with the measured stream loads obtained under the 604(b) grant program will enable the development by the MEP of the embayment specific nitrogen threshold for restoration of Mt. Hope Bay.

If all of the nitrogen applied or discharged within a watershed (based on MEP land use analysis) reaches an embayment the watershed land-use loading rate represents the nitrogen load to the receiving waters. This condition exists in watersheds where nitrogen transport from source to estuarine waters is through groundwater flow in glacial outwash aquifers. The lack of nitrogen attenuation in these aquifer systems results from the lack of biogeochemical conditions needed for supporting nitrogen sorption and denitrification. However, in most watersheds in southeastern Massachusetts, nitrogen passes through a surface water ecosystem (pond, wetland, stream) on its path to the adjacent embayment. Surface water systems, unlike sandy aquifers, do support the needed conditions for nitrogen retention and denitrification. The result is that the mass of nitrogen passing through lakes, ponds, streams and marshes (fresh and salt) is diminished by natural biological processes that represent removal (not just temporary storage). However, this natural attenuation of nitrogen load is not uniformly distributed within the watershed, but is associated with ponds, streams and marshes. In the case of the Mt. Hope Bay – Taunton River embayment system watersheds, most of the freshwater flow and transported nitrogen passes through a surface water system and frequently multiple systems prior to entering the estuaries, producing the opportunity for significant nitrogen attenuation.

Failure to determine the attenuation of watershed derived nitrogen overestimates the nitrogen load to receiving estuarine waters. If nitrogen attenuation is significant in one portion of a watershed and insignificant in another the result is that nitrogen management would likely be more effective in achieving water quality improvements if focused on the watershed region having unattenuated nitrogen transport (other factors being equal). In addition to attenuation by freshwater ponds, attenuation in surface water flows is also important. An example of the significance of surface water nitrogen attenuation relating to embayment nitrogen management was seen in the Agawam River, where >50% of nitrogen originating within the upper watershed was attenuated prior to discharge to the Wareham River Estuary (CDM 2001). Similarly, MEP analysis of the Quashnet River indicates that in the upland watershed, which has natural attenuation predominantly associated with riverine processes, the integrated attenuation was 39% (Howes et al. 2004). In addition, a preliminary study of Great, Green and Bournes Ponds in Falmouth, measurements indicated a 30% attenuation of nitrogen during stream transport (Howes and Ramsey 2001). An example where natural attenuation played a significant role in nitrogen management can be seen relative to West Falmouth Harbor (Falmouth, MA), where ~40% of the nitrogen discharge to the Harbor originating from the groundwater effluent plume emanating from the WWTF was attenuated by a small salt marsh prior to reaching Harbor waters. Similarly, the small tidal basin of Frost Fish Creek in the Town of Chatham showed ~20% nitrogen attenuation of watershed nitrogen load prior to discharge to Ryders Cove. Clearly, proper development and evaluation of nitrogen management options requires determination of the nitrogen loads reaching an embayment, not just those loaded to the watershed. As such, the 604(b) grant program has help to develop the necessary stream flows and nitrogen loads to be able to do the comparison with the MEP developed land use based load values and obtain a percent attenuation for nitrogen flowing to the embayment system.

Given the importance of determining accurate nitrogen loads to embayments for developing effective management alternatives and the potentially large errors associated with ignoring natural attenuation, direct integrated measurements of nitrogen loading and stream flow was undertaken as part of the 604(b) grant objectives. These measurements were conducted in each of the 5 major surface water flow systems discharging to the Mt. Hope Bay embayment system (e.g. Taunton River, Three Mile River, Segreganset River, Assonet River, Quequechan River). The location of the stream gages placed in each of the surface water systems mentioned above are depicted above (Figures 3 – 5).

Quantification of watershed based nitrogen attenuation is contingent upon being able to compare nitrogen load to the embayment system directly measured in freshwater stream flow (or in tidal marshes, net tidal outflow) to nitrogen load as derived from the detailed land use analysis (MEP analysis). Measurement of the flow and nutrient load associated with the Taunton River (at Weir Village bridge crossing), Three Mile River (immediately up gradient of Route 139 bridge), Segreganset River (at Elm Street immediately up gradient of the Route 139), Assonet River (at the Route 79 bridge crossing) and the Quequechan River (at the rail road bridge up gradient of Battleship Cove) provide a direct integrated measure of all of the processes presently attenuating nitrogen in the sub-watersheds up gradient from the gauging sites. Flow and nitrogen concentration were measured at the gages on the Taunton River, Three Mile River, Segreganset River, the Assonet River and the Quequechan River for a total 20 to 22 months of record depending on the gage location.

During the study period, velocity profiles were completed on each river every month to two months in order to ultimately develop a rating curve (stage – discharge relation) that could be utilized to convert measured stream stages into daily flows. The summation of the products of stream subsection areas of the stream cross-section and the respective measured velocities represent the computation of instantaneous stream flow (Q).

Determination of stream flow was calculated and based on the measured values obtained for stream cross sectional area and velocity. Stream discharge was represented by the summation of individual discharge calculations for each stream subsection for which a cross sectional area and velocity measurement were obtained. Velocity measurements made across the entire stream cross section were not averaged and then applied to the total stream cross sectional area.

The formula that was used for calculation of stream flow (discharge) is as follows:

$$Q = \Sigma(A * V)$$

where by:

Q = Stream discharge (m^3/s)
A = Stream subsection cross sectional area (m^2)
V = Stream subsection velocity (m/s)

Thus, each stream subsection will have a calculated stream discharge value and the summation of all the sub-sectional stream discharge values will be the total calculated discharge for the stream.

Periodic measurement of flows over the entire stream gauge deployment period allowed for the development of a stage-discharge relationship (rating curve) that could be used to obtain flow volumes from the detailed record of stage measured by the continuously recording stream gauges. Water level data obtained every 10-minutes was averaged to obtain hourly stages for a given river. These hourly stages values where then entered into the stage-discharge relation to compute hourly flow. Hourly flows were summed over a period of 24 hours to obtain daily flow and further, daily flows summed to obtain annual flow.

In the case of tidal influence on stream stage, the diurnal low tide stage value was extracted on a day by day basis in order to resolve the stage value indicative of strictly freshwater flow. The lowest low tide stage values for any given day were entered into the stage – discharge relation in order to compute daily flow. A complete annual record of stream flow (365 days) was generated for each of the surface water discharges flowing into the Mt. Hope Bay – Taunton River embayment system.

The annual flow record for each surface water flow was merged with the nutrient data sets generated through the weekly water quality sampling to determine nitrogen loading rates to the tidally influenced portion of the Taunton River and Mt. Hope Bay. Nitrogen discharge from a given stream was calculated using the paired daily discharge and daily nitrogen concentration data to determine the mass flux of nitrogen through the gaging sites.

For a given gaging location, weekly water samples were collected (at low tide for a tidally influenced stage) in order to determine nutrient concentrations from which nutrient load was calculated. In order to pair daily flows with daily nutrient concentrations, interpolation between weekly nutrient data points was necessary. These data are expressed as nitrogen mass per unit time (kg/d) and can be summed in order to obtain weekly, monthly, or annual nutrient load to the embayment system as appropriate. Ultimately, by comparing these measured nitrogen loads based on stream flow and water quality sampling to predicted loads based on the land use analysis to be performed by the MEP, the degree to which natural biological processes within the watershed to each embayment reduces (percent attenuation) nitrogen loading will be determined.

Surface water Discharge and Watershed Nitrogen Load: Taunton River to Mt. Hope Bay

Stream gaging on the Taunton River provides for a direct measurement of the nitrogen loading to the Mt. Hope Bay embayment system. The combined rate of nitrogen attenuation by watershed-wide biological processes will be determined in the future by comparing the present predicted nitrogen loading (to be determined by the MEP) to the sub-watershed region contributing to the Taunton River above the gauge site and the measured annual discharge of nitrogen to the tidal portion of the Taunton River as determined under the 604(b) grant.

At the Taunton River gauge site, a continuously recording vented calibrated water level gauge was installed to yield the level of water in the freshwater portion of the Taunton River that carries the flows and associated nitrogen load to Mt. Hope Bay. As the Taunton River is tidally influenced up gradient of the Weir Village bridge, the gage was located such that it be above the influence of saltwater at low tide. In this manner, flow measurements conducted at low tide would be a measure of freshwater being discharged from the Taunton River at the gage. To confirm that freshwater was being measured at low tide, salinity measurements were conducted on the weekly water quality samples collected from the gauge site. Average low tide salinity was determined to be 0.2 ppt therefore, the gauge location was deemed acceptable for making freshwater flow measurements. Additionally, prior to deployment of the gage a detailed salinity profile was conducted across the stream section where flow measurements would be undertaken for development of the rating curve for the site. This was to check that there was no stratification of the water column at the site and that freshwater would be measured exclusively under both neap and spring tide conditions. The salinity profiling confirmed the lack of water column stratification at the site thus eliminating the concern over measuring a combination of fresh and brackish water which would result in an over estimate of flow. Calibration of the gauge was checked monthly. The gauge on the Taunton River was installed on May 19, 2004 and operated continuously for 20 months such that one summer season would be captured in the flow record. The gage was retrieved from the field in December 2005. During the period of deployment there was one period of instrument failure (approximately 3 weeks October 2004-November 2004) during which time invalid stage data was generated by the instrument. Since no stage data was generated during that period it was not possible to calculate daily flows for that period using the rating curve discussed above. For the period of instrument failure, an assumed stage that split the difference between the last record stage and the stage at the time of the new instrument deployment as used in order to fill the gap in the daily flow record develop under the 604(b) grant project. The 12-month uninterrupted record used in this analysis encompasses the summer 2004 field season and extends from September of 2004 to the end of August 2005 (one complete hydrologic year).

River flow (volumetric discharge) was measured at low tide every 4 to 6 weeks using a Marsh-McBirney electromagnetic flow meter. A rating curve was developed for the Taunton River gage based upon these flow measurements and measured water levels at the gage site. The rating curve was then used for conversion of the continuously measured stage data to obtain daily freshwater flow volume. Before using the continuously measured stage data to determine volumetric flow, tidal influence on stage was filtered out of the record by examining stage at ebb slack tide. Based on the daily flows obtained from the Taunton River stage record, measured flows, and the rating curve, the annual freshwater flux was determined to be 1,172,417,821 m^3/yr with an average daily discharge of 3,212,104 m^3/d to the embayment system (Figure 7). Water samples were collected weekly for nitrogen analysis. Integrating the flow and nitrogen concentration datasets will allow for the future determination of nitrogen mass discharge to the estuarine portion of Mt. Hope Bay.

Total nitrogen concentrations within the Taunton River outflow were relatively high, average of 1.39 mg N L^{-1}, where as Nitrate + Nitrite (NOx) was on average 0.748 mg N L^{-1}. In the Taunton River, nitrate was the predominant form of nitrogen (54 %), indicating that groundwater nitrogen (typically dominated by nitrate) discharging to the freshwater ponds and to the river was not completely taken up by plants within the pond or stream ecosystems. Dissolved inorganic nitrogen (DIN) which includes NOx was the next most abundant nitrogen specie with an average of 0.792 mg N L^{-1} (57 % of the Total Nitrogen pool) followed by dissolved organic nitrogen (DON) with an average concentration of 0.488 mg N L^{-1} (35 % of the Total Nitrogen pool). Particulate organic nitrogen (PON) represented a small fraction of the TN pool with an average concentration of 0.111 mg N L^{-1} (8 % of the Total Nitrogen pool). Figures 8 and 9 depicts the daily freshwater flow in the Taunton River relative to the concentrations of Total Nitrogen (TN) and Nitrate + Nitrite (NOx) as determined from the weekly water quality sampling at the gage as supported by the 604(b) grant.

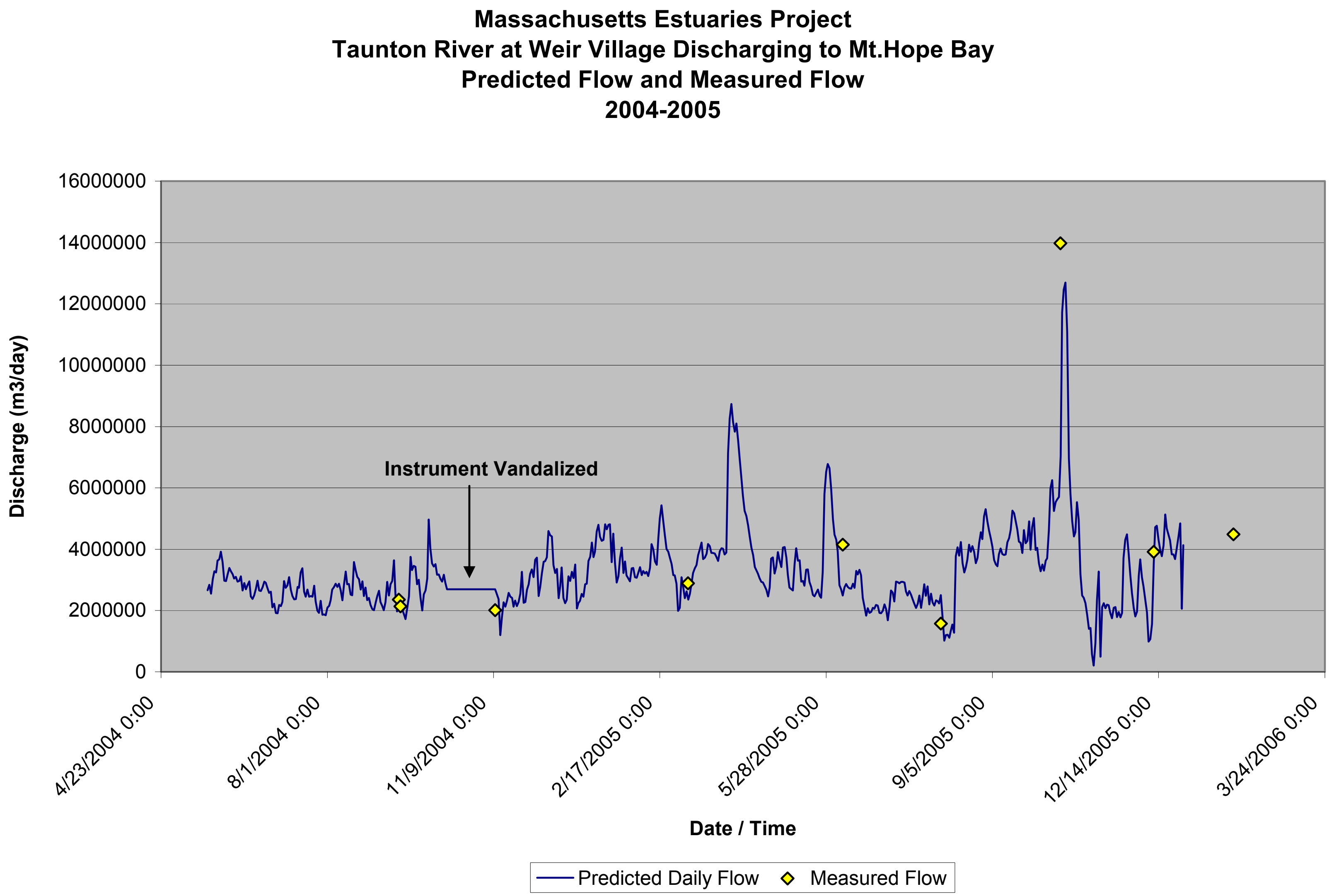

Figure 7 – Predicted daily discharge for the Taunton River discharging to Mt. Hope Bay.

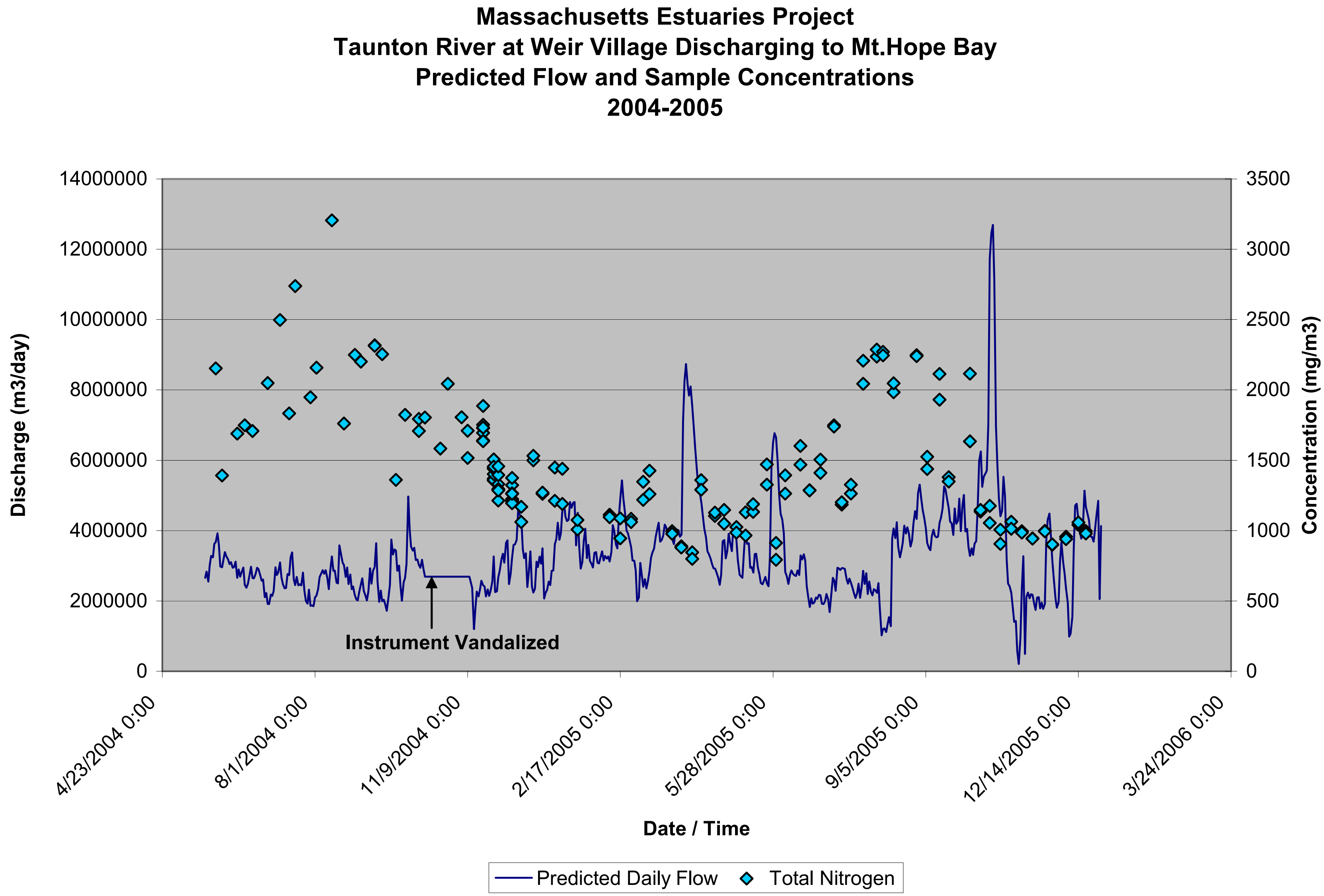

Figure 8 - Predicted daily discharge and Total Nitrogen (TN) concentrations for the Taunton River discharging to Mt. Hope Bay

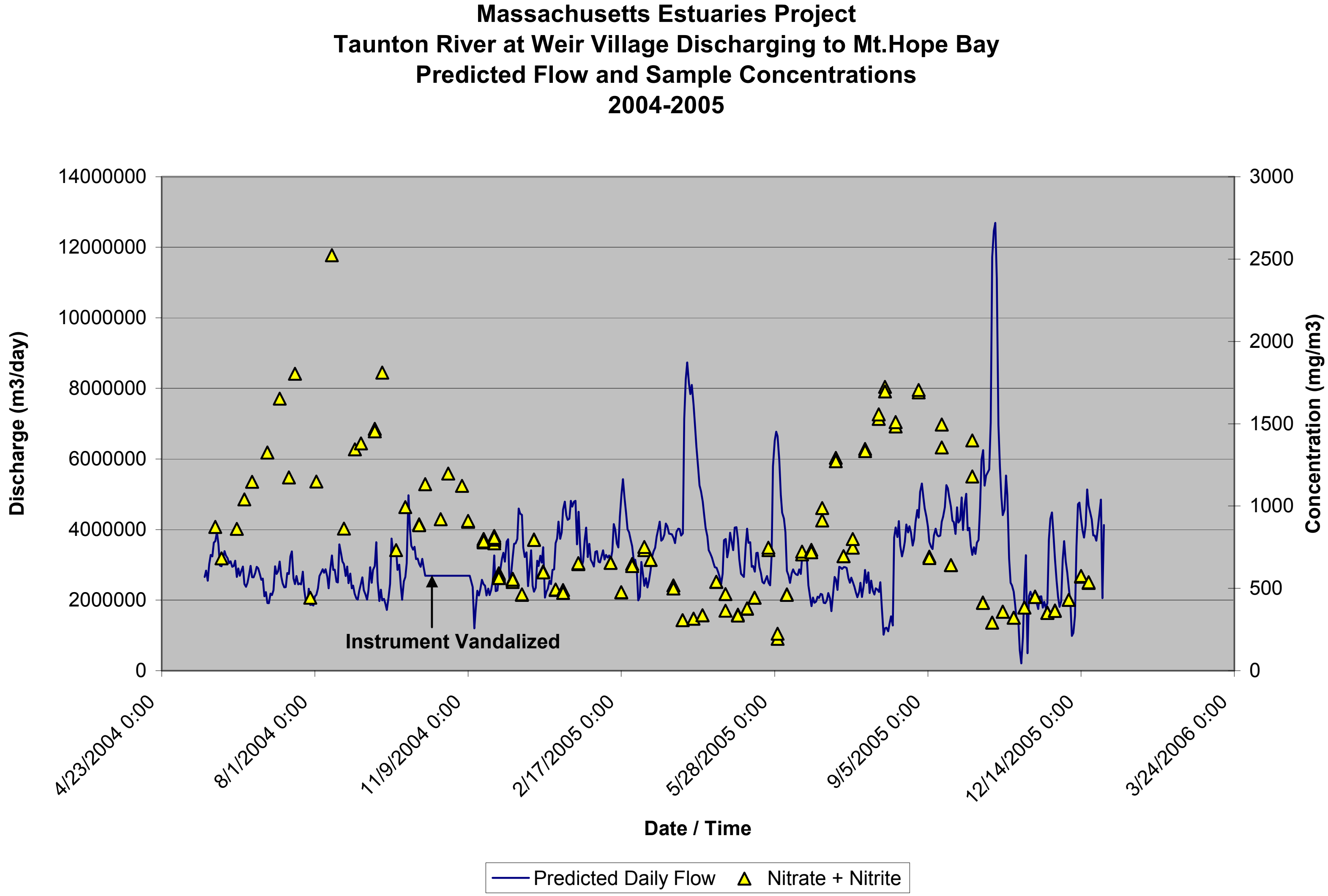

Figure 9 – Predicted daily discharge and Nitrate + Nitrite (NOx) concentrations for the Taunton River discharging to Mt. Hope Bay.

Surface water Discharge and Watershed Nitrogen Load: Three Mile River to Taunton River Estuarine Reach

Stream gaging on the Three Mile River provides for a direct measurement of the nitrogen loading to the estuarine reach of the Taunton River and ultimately, the Mt. Hope Bay embayment system. The combined rate of nitrogen attenuation by watershed-wide biological processes will be determined in the future by comparing the present predicted nitrogen loading (to be determined by the MEP) to the sub-watershed region contributing to the Three Mile River above the gauge site and the measured annual discharge of nitrogen from the Three Mile River as determined under the 604(b) grant.

At the Town Brook gauge site, a continuously recording vented calibrated water level gauge was installed to yield the level of water in the freshwater portion of the Three Mile River that carries the flows and associated nitrogen load to the estuarine reach of the Taunton River enroute to Mt. Hope Bay. To confirm that freshwater was being measured at low tide, salinity measurements were conducted on the weekly water quality samples collected from the gauge site. Average low tide salinity was determined to be 0.2 ppt therefore, the gauge location was deemed acceptable for making freshwater flow measurements.

Based on flow measurements taken throughout the gage deployment period and the detailed stage record, a rating curve relating stage to flow was developed in order to determine predicted daily flows in the Three Mile River. Predicted daily flows agree favorably with measured flows used in the development of the rating curve. Calibration of the gauge was checked monthly. The gauge on the Three Mile River was installed on May 19, 2004 and operated continuously for 19 months such that one summer season would be captured in the flow record. The gage was retrieved from the field in November 2005 due to vandalism. The 12-month uninterrupted record used in this analysis encompasses the summer 2004 field season and extends from September of 2003 to the end of August 2004 (one complete hydrologic year).

River flow (volumetric discharge) was measured at low tide every 4 to 6 weeks using a Marsh-McBirney electromagnetic flow meter. A rating curve was developed for the Three Mile River gage was based upon these flow measurements and measured water levels at the gage site. The rating curve was then used for conversion of the continuously measured stage data to obtain daily freshwater flow volume. Based on the daily flows obtained from the Three Mile River stage record, measured flows, and the rating curve, the annual freshwater flux was determined to be 233,887,161 m^3/yr with an average daily discharge of 640,787 m^3/day to the estuarine reach of the Taunton River and Mt. Hope Bay (Figure 10). Integrating the flow and nitrogen concentration datasets discussed below will allow for the future determination of nitrogen mass discharge to the estuarine portion of Mt. Hope Bay.

Water samples were collected weekly for nitrogen analysis. Total nitrogen concentrations within the Three Mile River outflow were relatively high, 1.096 mg N L^{-1}, where as Nitrate + Nitrite (NOx) and dissolved inorganic (DIN) was 0.648 mg N L^{-1} and 0.671 mg N L^{-1} respectively. In the Three Mile River, nitrate + nitrite was the predominant forms of nitrogen (59 %), indicating that groundwater nitrogen (typically dominated by nitrate) discharging to the freshwater ponds and to the river was not completely taken up by plants within the pond or stream ecosystems. Dissolved organic nitrogen (DON) was clearly a less abundant nitrogen specie with an average of 0.357 mg N L^{-1} (33 % of the Total Nitrogen pool) followed by particulate organic nitrogen (PON) with an average concentration of 0.068 mg N L^{-1} (6 % of the Total Nitrogen pool). Figures 11 and 12 depict the daily freshwater flow in the Three Mile River relative to the concentrations of Total Nitrogen (TN) and Nitrate + Nitrite (NOx) as determined from the weekly water quality sampling at the gage as supported by the 604(b) grant.

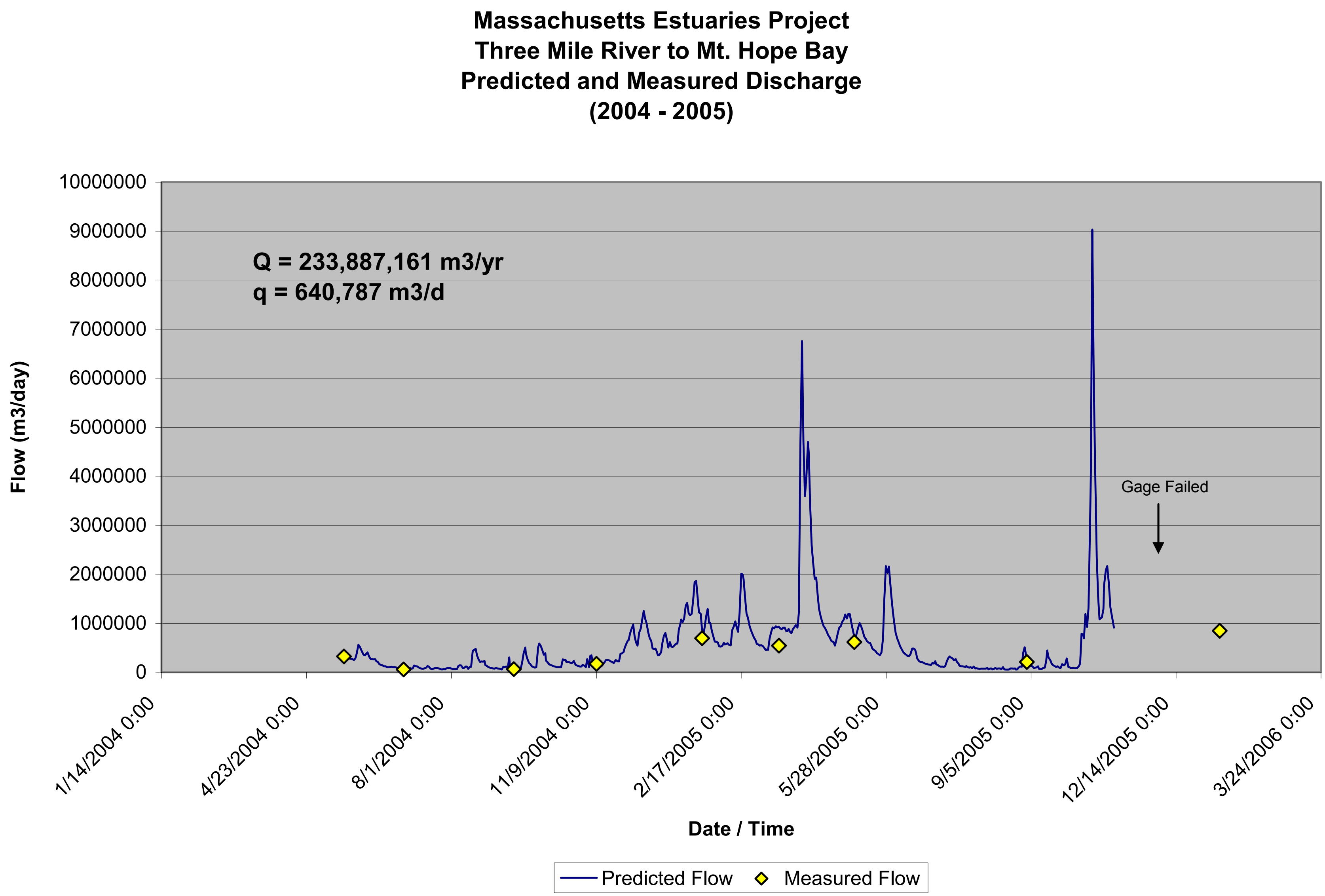

Figure 10 - Predicted daily discharge for the Three Mile River discharging to the estuarine reach of the Taunton River.

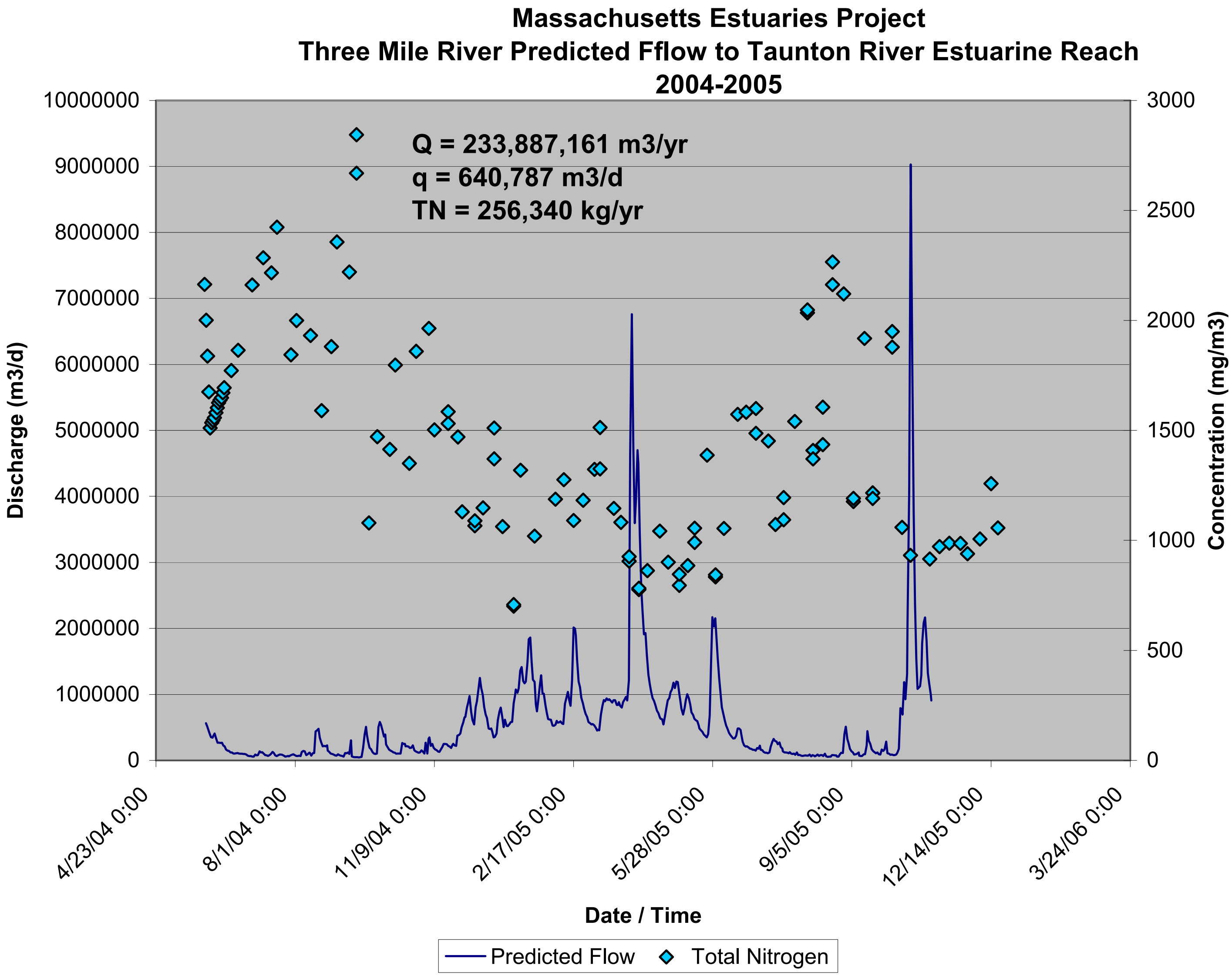

Figure 11 - Predicted daily discharge for Three Mile River relative to Total Nitrogen (TN) concentrations.

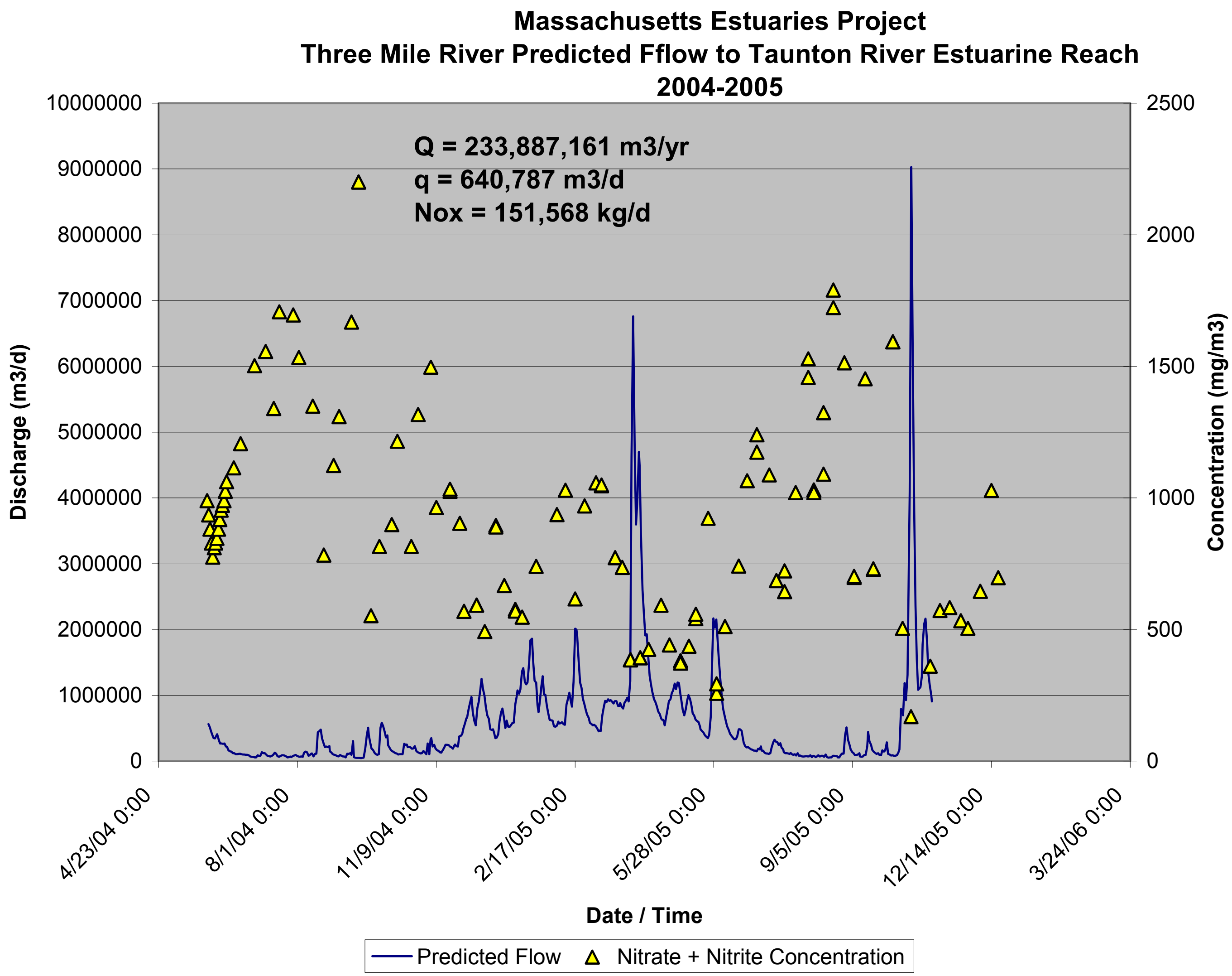

Figure 12 - Predicted daily discharge for Three Mile River relative to Nitrate + Nitrite (NOx) concentrations.

Surface water Discharge and Watershed Nitrogen Load: Segreganset River to Taunton River Estuarine Reach

Stream gaging on the Segreganset River provides for a direct measurement of the nitrogen loading to the estuarine reach of the Taunton River discharging to the Mt. Hope Bay embayment system. The combined rate of nitrogen attenuation by watershed-wide biological processes will be determined in the future by comparing the present predicted nitrogen loading (to be determined by the MEP) to the sub-watershed region contributing to the Segreganset River above the gauge site and the measured annual discharge of nitrogen to the tidal portion of the Segreganset River as determined under the 604(b) grant.

At the Segreganset River gauge site, a continuously recording vented calibrated water level gauge was installed to yield the level of water in the freshwater portion of the Segreganset River that carries the flows and associated nitrogen load to the estuarine reach of the Taunton River. As the Segreganset River is tidally influenced down gradient of the Elm Street bridge, the gage was located such that it be above the influence of saltwater at low tide. In this manner, flow measurements conducted at low tide would be a measure of freshwater being discharged from the Segreganset River at the gage. To confirm that freshwater was being measured at low tide, salinity measurements were conducted on the weekly water quality samples collected from the gauge site. Average low tide salinity was determined to be 0.5 ppt therefore, the gauge location was deemed acceptable for making freshwater flow measurements. Additionally, daily flows calculated using the rating curve developed under the 604(b) grant were confirmed relative to measured flows at the stream gage. Predicted daily flows agree favorably with measured flows used in the development of the rating curve. Calibration of the gauge was checked monthly.

The gauge on the Segreganset River was installed on May 19, 2004 and operated continuously for 21 months such that one summer seasons would be captured in the flow record. The gage was retrieved from the field in March 2006. The 12-month uninterrupted record used in this analysis encompasses the summer 2004 field season and extends from September of 2004 to the end of August 2005 (one complete hydrologic year).

River flow (volumetric discharge) was measured at low tide every 4 to 6 weeks using a Marsh-McBirney electromagnetic flow meter. A rating curve was developed for the Segreganset River gage based upon these flow measurements and measured water levels at the gage site. The rating curve was then used for conversion of the continuously measured stage data to obtain daily freshwater flow volume. Before using the continuously measured stage data to determine volumetric flow, tidal influence on stage was filtered out of the record by examining stage at ebb slack tide. Based on the daily flows obtained from the Segreganset River stage record, measured flows, and the rating curve, the annual freshwater flux was determined to be 41,288,006 m^3/yr yielding a daily discharge of 113,118 m^3/day (Figure 13). Water samples were collected weekly for nitrogen analysis. Integrating the flow and nitrogen concentration datasets will allow for the future determination of nitrogen mass discharge to the estuarine portion of the Taunton River and Mt. Hope Bay.

Total nitrogen concentrations within the Segreganset River outflow were moderate, on average 0.751 mg N L^{-1}, where as average Nitrate + Nitrite (NOx) concentration was 0.249 mg N L^{-1} (33 % of the Total Nitrogen pool). Additionally, particulate organic nitrogen (PON) with an average concentration of 0.061 mg N L^{-1} represented 8 % of the total nitrogen pool. In the Segreganset River, dissolved organic nitrogen (DON) with an average concentration of 0.264 mg N L^{-1} was as prevalent a form of nitrogen (35% of the Total Nitrogen pool) as NOx, indicating that groundwater nitrogen (typically dominated by nitrate) discharging to the freshwater ponds and to the river was significantly taken up by plants within the pond or stream ecosystems prior to discharging to the Lower Taunton River system. Figures 14 and 15 depict the daily freshwater flow in the Segreganset River relative to the concentrations of Nitrate + Nitrite (NOx) and Total Nitrogen (TN) as determined from the weekly water quality sampling at the gage as supported by the 604(b) grant.

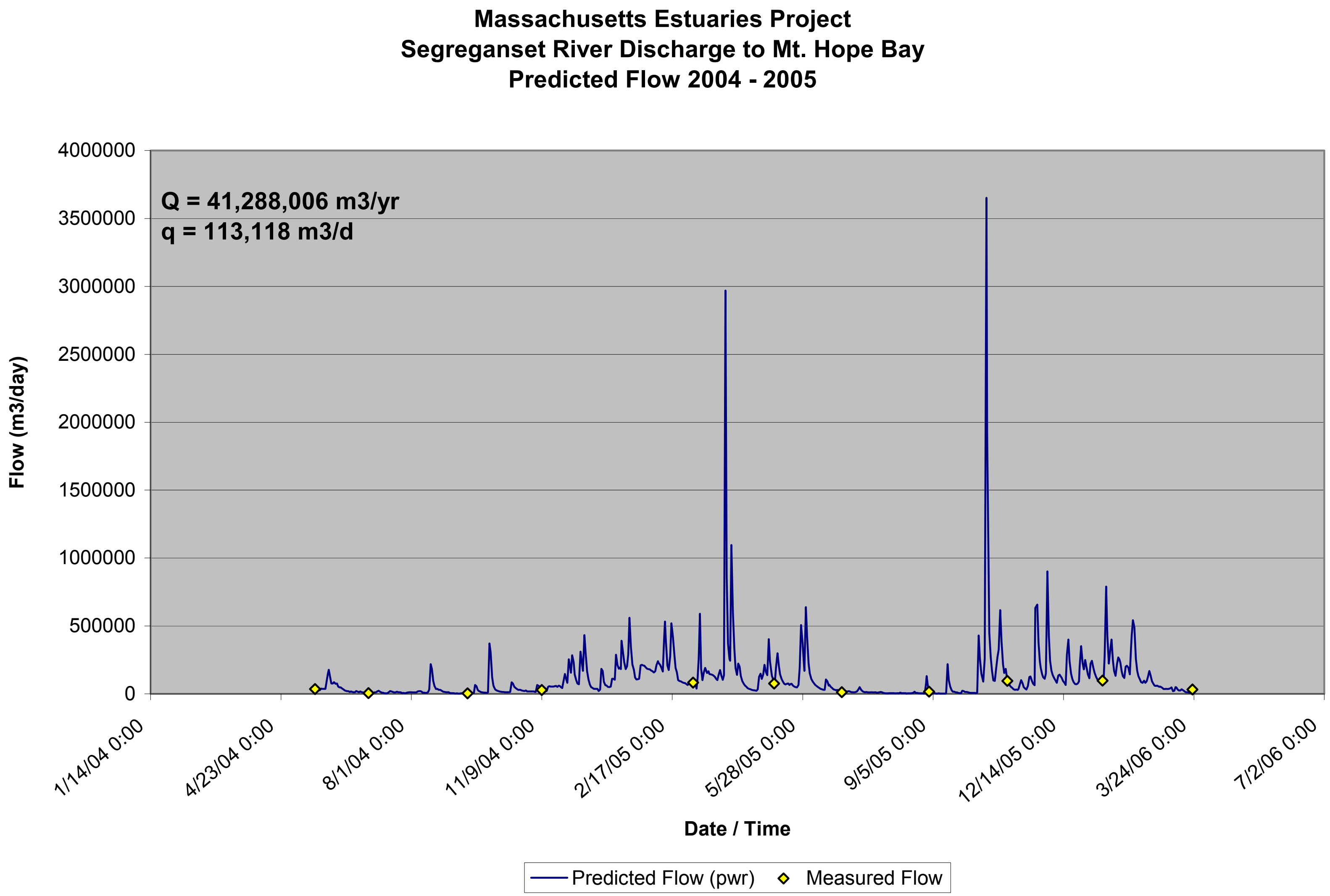

Figure 13 – Predicted daily discharge in the Segreganset River discharging to estuarine reach of the Taunton River.

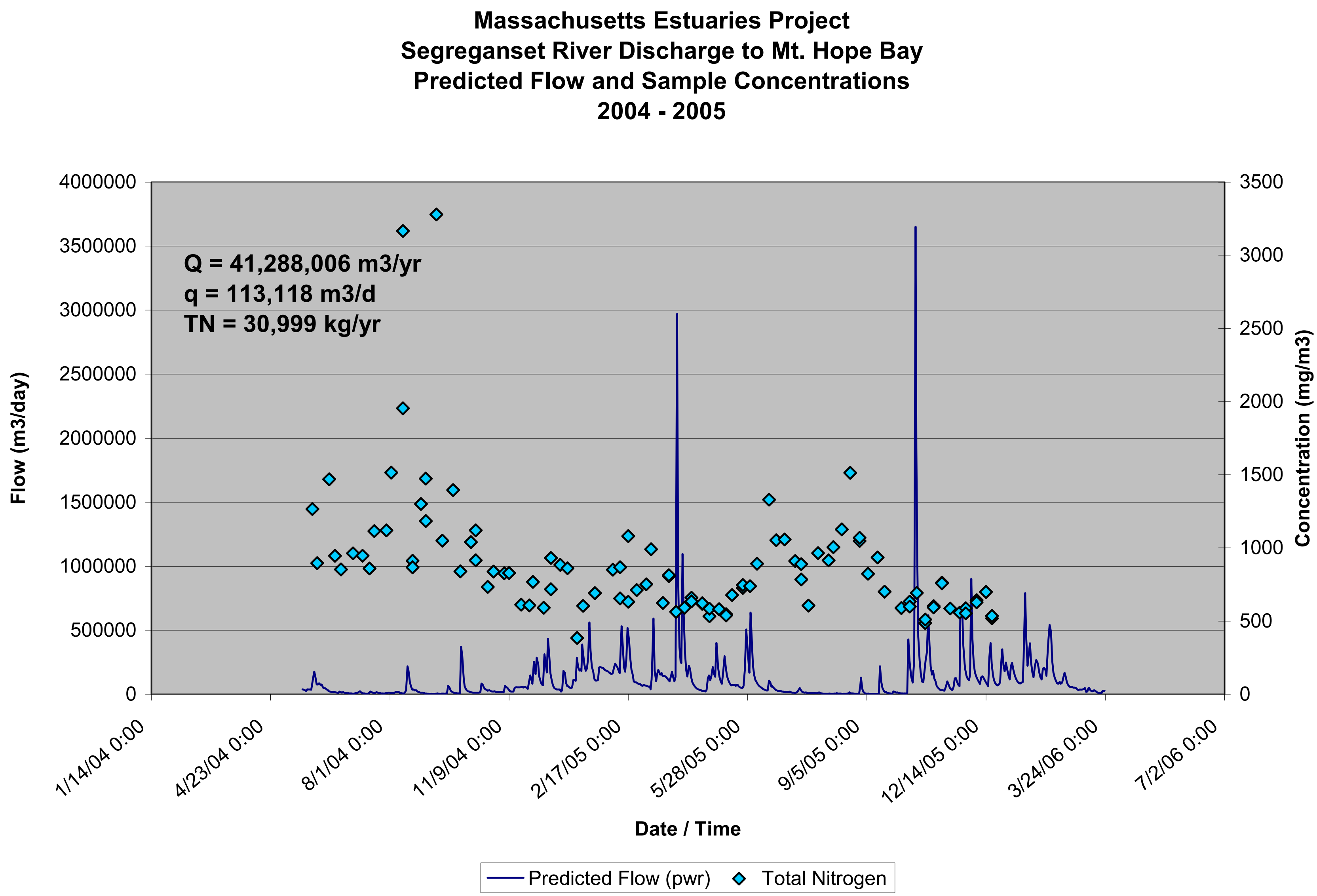

Figure 14 - Predicted daily discharge for the Segreganset River relative to Total Nitrogen (TN) concentrations

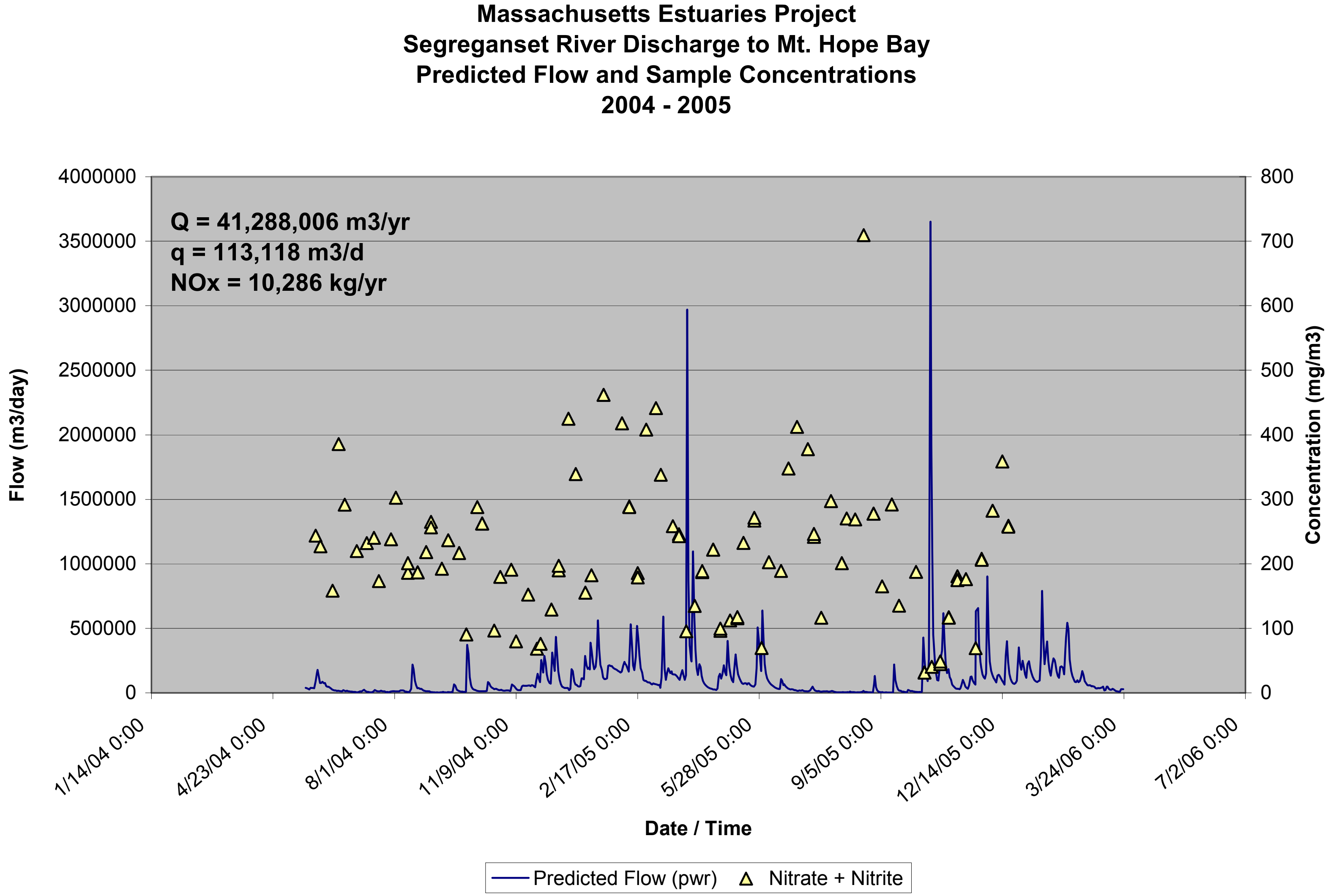

Figure 15 - Predicted daily discharge for the Segreganset River relative to Nitrate + Nitrite (NOx) concentrations.

Surface water Discharge and Watershed Nitrogen Load: Assonet River discharge to Mt. Hope Bay

Stream gaging on the Assonet River to the estuarine reach of the Taunton River provides for a direct measurement of the nitrogen loading to the Mt. Hope Bay embayment system. The combined rate of nitrogen attenuation by watershed-wide biological processes will be determined in the future by comparing the present predicted nitrogen loading (to be determined by the MEP) to the sub-watershed region contributing to the Assonet River above the gauge site and the measured annual discharge of nitrogen to the tidal portion of the Assonet River system as determined under the 604(b) grant.

At the Assonet River gage site, a continuously recording vented calibrated water level gage was installed to yield the level of water in the freshwater portion of the Assonet River that carries the flows and associated nitrogen load to the estuaine reach of the Taunton River and ultimately, Mt. Hope Bay. As the Assonet River is tidally influenced down gradient of the Route 79 bridge crossing, the gage was located such that it be above the influence of saltwater at low tide. In this manner, flow measurements conducted at low tide would be a measure of freshwater being discharged from the Assonet River at the gage. To confirm that there was not tidal influence at the gage, salinities where measured for indication of freshwater flow at the gage. Salinity measurements were conducted on the weekly water quality samples collected from the gauge site. Average salinity was determined to be 0.3 ppt therefore, the gage location was deemed acceptable for making freshwater flow measurements. Additionally, daily flows calculated using the rating curve developed under the 604(b) grant were confirmed relative to measured flows used in the development of the rating curve. As depicted in Figure 16, predicted flows agree well with measured flows obtained during the deployment period. Calibration of the gauge was checked monthly. The gage on the Assonet River was installed on May 20, 2004 and operated continuously for 21 months such that one summer seasons would be captured in the flow record. The gage was retrieved from the field in March 2006. The 12-month uninterrupted record used in this analysis encompasses the summer 2004 field season and extends from mid September of 2004 to mid September of 2005 (one complete hydrologic year).

River flow (volumetric discharge) was measured at low tide every 4 to 6 weeks using a Marsh-McBirney electromagnetic flow meter. A rating curve was developed for the Assonet River gage based upon these flow measurements and measured water levels at the gage site. The rating curve was then used for conversion of the continuously measured stage data to obtain daily freshwater flow volume. Before using the continuously measured stage data to determine volumetric flow, tidal influence on stage was filtered out of the record by examining stage at ebb slack tide. Based on the daily flows obtained from the Assonet River stage record, measured flows, and the rating curve, the annual freshwater flux was determined to be 106,115,523 m^3/yr yielding a daily discharge of 290,727 m^3/day (Figure 20). Water samples were collected weekly for nitrogen analysis. Integrating the flow and nitrogen concentration datasets will allow for the future determination of nitrogen mass discharge to the estuarine portion of Mt. Hope Bay.

Total nitrogen concentrations within the Assonet River outflow were moderate, on average 0.717 mg N L^{-1}, where as Nitrate + Nitrite (NOx) was on average 0.083 mg N L^{-1} (12% of the Total

Nitrogen pool). In the Assonet River, dissolved organic nitrogen (DON) was by far the predominant form of nitrogen relative to the Total Nitrogen pool (76%), indicating that groundwater nitrogen (typically dominated by nitrate) discharging to the freshwater ponds and to the river was significantly taken up by plants within the pond or stream ecosystems prior to discharging to the estuarine reach of the Taunton River. Figures 17 and 18 depict the daily freshwater flow in the Assonet River relative to the concentrations of Total Nitrogen (TN) and Nitrate + Nitrite (NOx) as determined from the weekly water quality sampling at the gage as supported by the 604(b) grant.

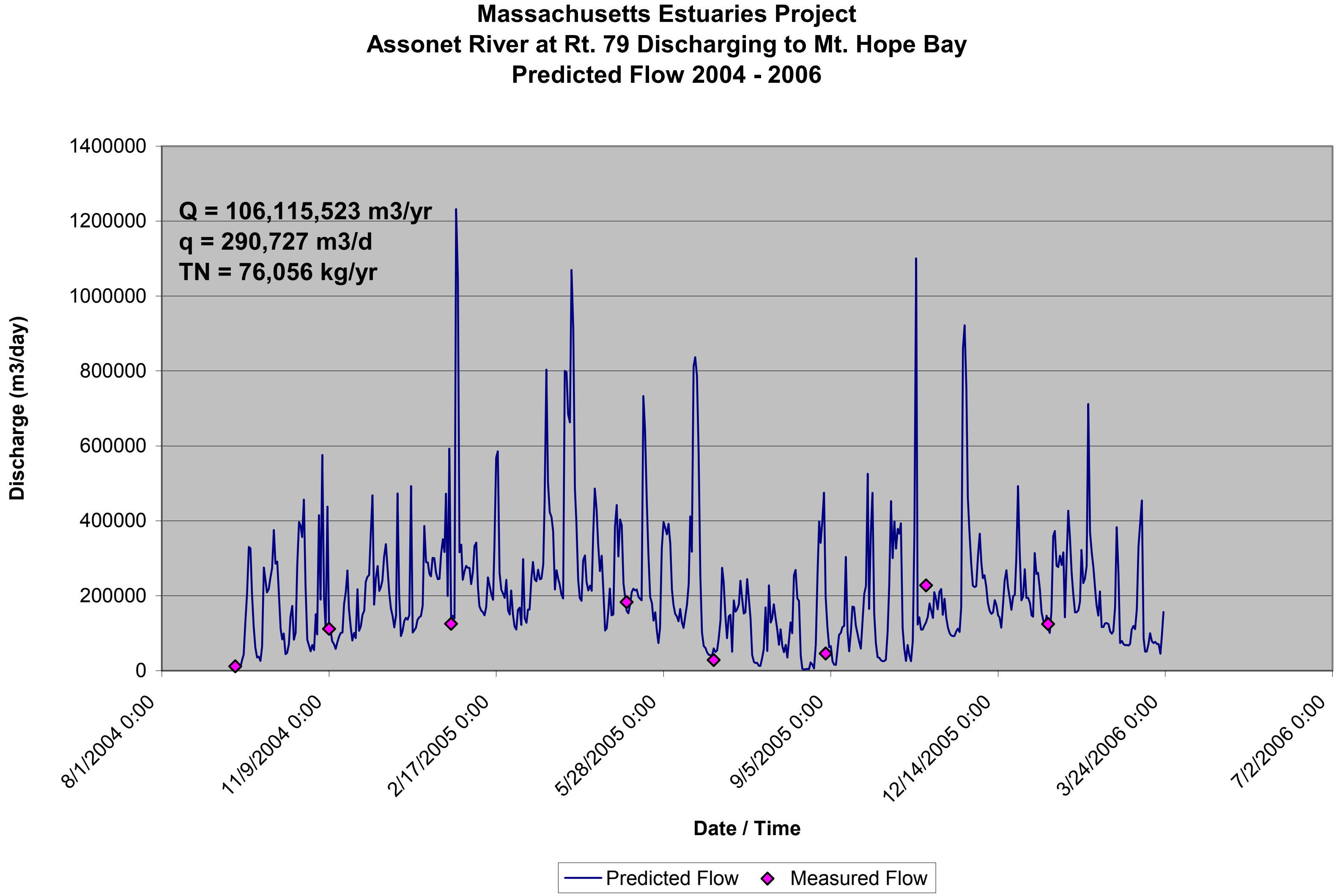

Figure 16 – Predicted daily discharge for the Assonet River discharging into the estuarine reach of the Taunton River.

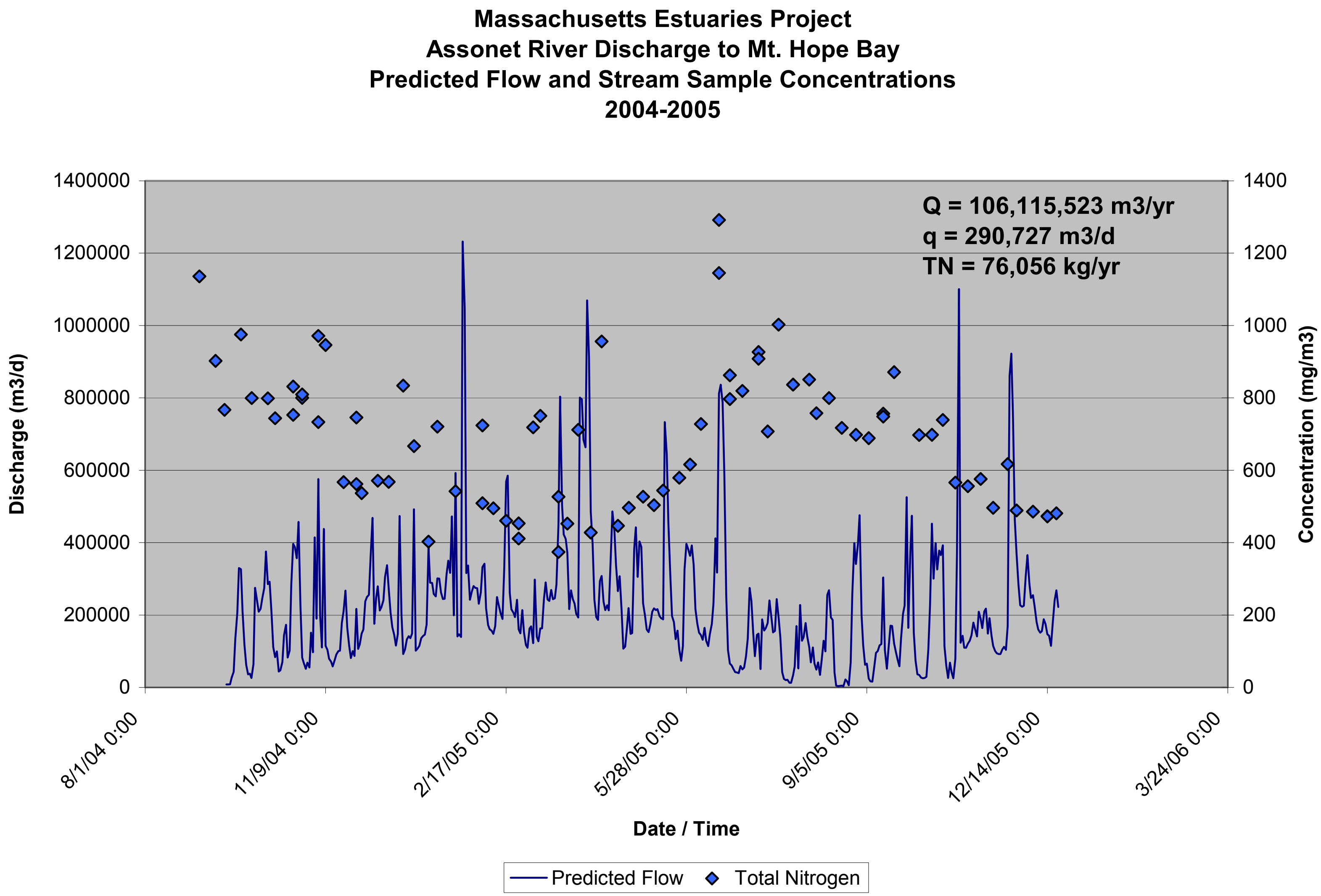

Figure 17 – Predicted daily discharge relative to Total Nitrogen (TN) concentrations for the Assonet River discharging to the estuarine reach of the Taunton River.

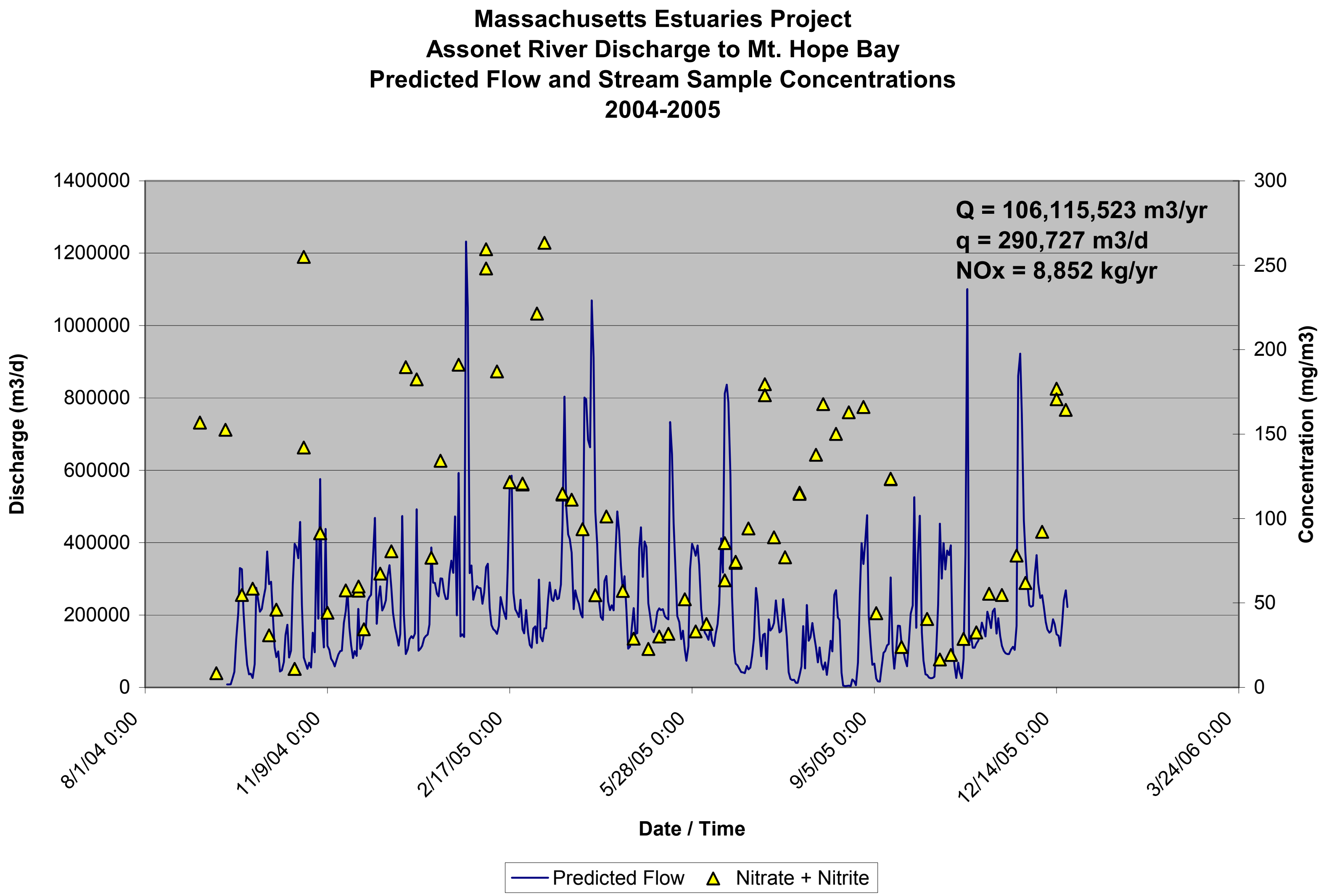

Figure 18 – Predicted daily discharge relative to Nitrate + Nitrite (NOx) concentrations for the Assonet River discharging to the estuarine reach of the Taunton River.

Surface water Discharge and Watershed Nitrogen Load: Quequechan River discharge to Mt. Hope Bay

Stream gaging on the Quequechan River to lower estuarine reach of the Taunton River (Battleship Cove) provides for a direct measurement of the nitrogen loading to the Mt. Hope Bay embayment system. The combined rate of nitrogen attenuation by watershed-wide biological processes will be determined in the future by comparing the present predicted nitrogen loading (to be determined by the MEP) to the sub-watershed region contributing to the Quequechan River above the gauge site and the measured annual discharge of nitrogen to the tidal portion of the lower Taunton River system as determined under the 604(b) grant.

At the Quequechan River gage site, a continuously recording vented calibrated water level gage was installed to yield the level of water in the freshwater portion of the Quequechan River that carries the flows and associated nitrogen load to the lower Taunton River. As the Quequechan River is tidally influenced down gradient of the rail road bridge crossing, the gage was located such that it be above the influence of saltwater at low tide. In this manner, flow measurements conducted at low tide would be a measure of freshwater being discharged from the Quequechan River at the gage. To confirm that there was not tidal influence at the gage, salinities where measured for indication of freshwater flow at the gage. Salinity measurements were conducted on the weekly water quality samples collected from the gauge site. Average salinity was determined to be 0.5 ppt therefore, the gage location was deemed acceptable for making freshwater flow measurements. Additionally, daily flows calculated using the rating curve developed under the 604(b) grant were confirmed relative to measured flows used in the development of the rating curve. As depicted in Figure 19, predicted flows agree well with measured flows obtained during the deployment period. Calibration of the gauge was checked monthly. The gage on the Quequechan River was installed on May 21, 2004 and operated continuously for 21 months such that one summer season would be captured in the flow record. The gage was retrieved from the field in March 2006. The 12-month uninterrupted record used in this analysis encompasses the summer 2004 field season and extends from September of 2004 to the end of August 2005 (one complete hydrologic year).

River flow (volumetric discharge) was measured at low tide every 4 to 6 weeks using a Marsh-McBirney electromagnetic flow meter. A rating curve was developed for the Quequechan River gage based upon these flow measurements and measured water levels at the gage site. The rating curve was then used for conversion of the continuously measured stage data to obtain daily freshwater flow volume. Before using the continuously measured stage data to determine volumetric flow, tidal influence on stage was filtered out of the record by examining stage at ebb slack tide. Based on the daily flows obtained from the Quequechan River stage record, measured flows, and the rating curve, the annual freshwater flux was determined to be 45,351,644 m^3/yr yielding a daily discharge of 124,251 m^3/day (Figure 20). Water samples were collected weekly for nitrogen analysis. Integrating the flow and nitrogen concentration datasets will allow for the future determination of nitrogen mass discharge to the estuarine portion of Ellisville Harbor.

Total nitrogen concentrations within the Quequechan River outflow were moderately high, on average 0.805 mg N L^{-1}, where as Nitrate + Nitrite (NOx) was on average 0.143 mg N L^{-1} (18% of the Total Nitrogen pool) In the Quequechan River, dissolved organic nitrogen (DON) was a prevalent fraction of the total nitrogen pool (52%) indicating that groundwater nitrogen (typically dominated by nitrate) discharging to the freshwater ponds and to the river was significantly taken up by plants within the pond or stream ecosystems prior to discharging to the lower Taunton River and the Mt. Hope Bay system. Figures 20 and 21 depict the daily freshwater flow in the Quequechan River relative to the concentrations of Total Nitrogen (TN) and Nitrate + Nitrite (NOx) as determined from the weekly water quality sampling at the gage as supported by the 604(b) grant.

EXHIBIT J
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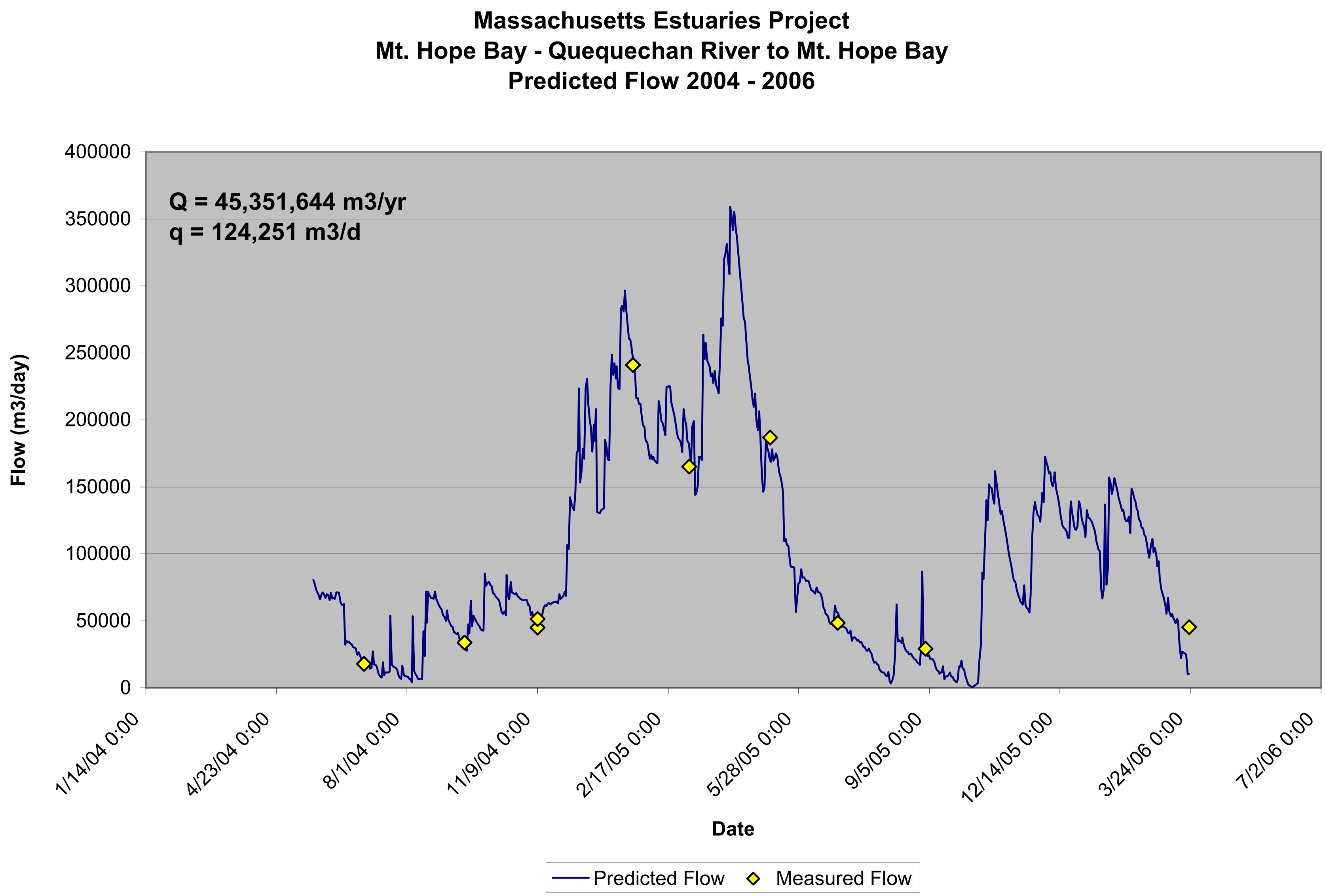

Figure 19 – Predicted daily discharge for the Quequechan River discharging into the estuarine reach of the Taunton River.

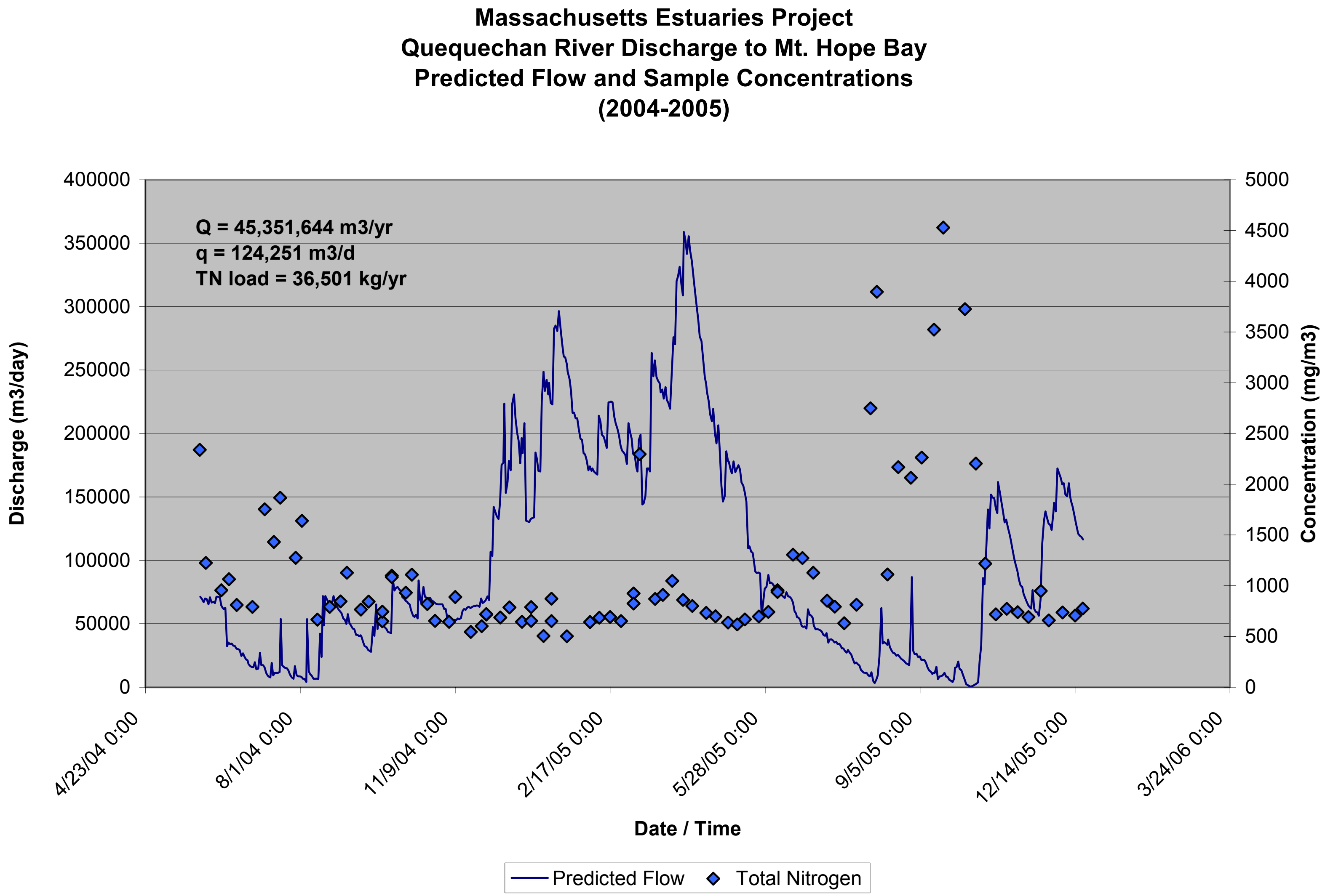

Figure 20 – Predicted daily discharge relative to Total Nitrogen (TN) concentrations for the Quequechan River discharging to the estuarine reach of the Taunton River.

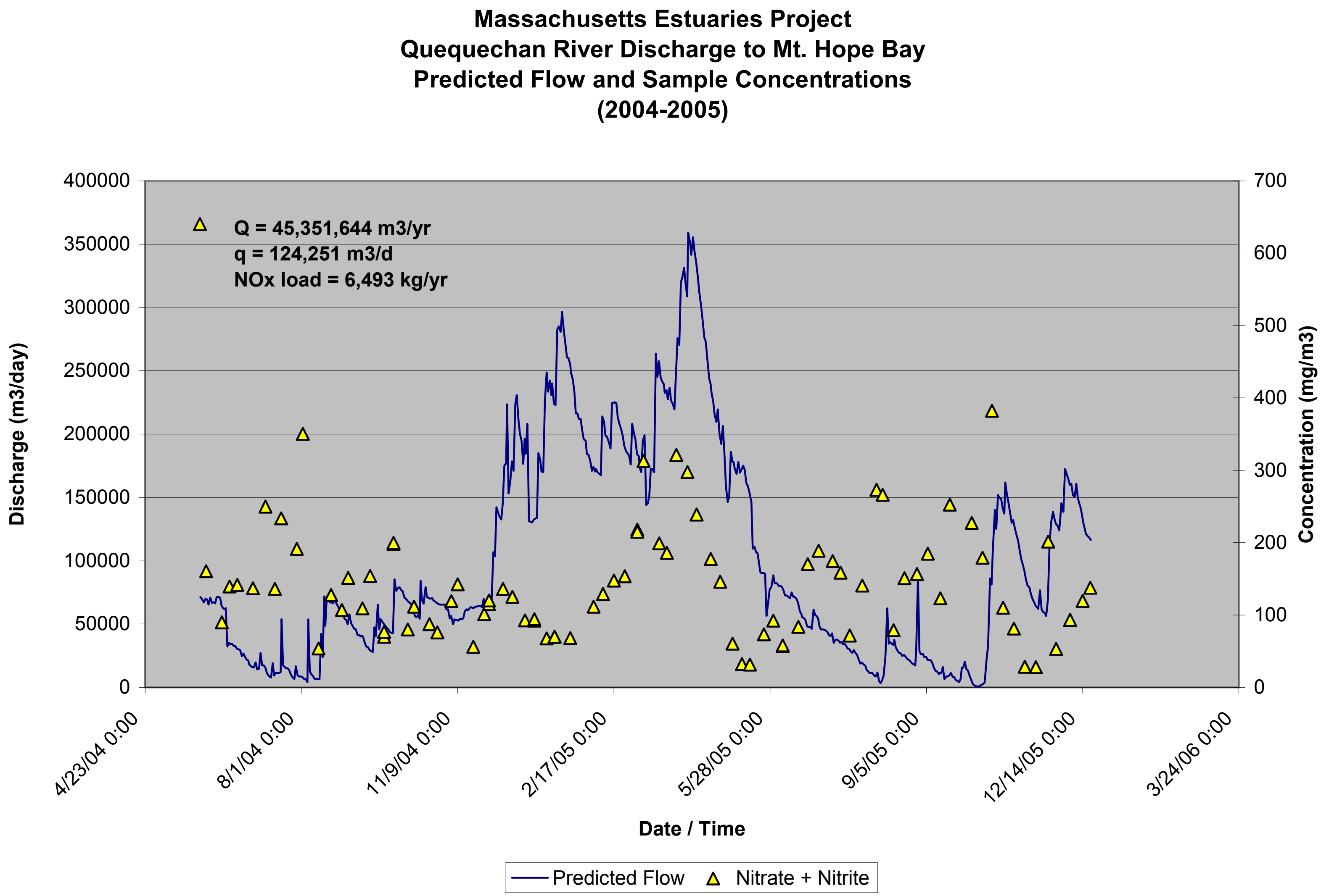

Figure 21 – Predicted daily discharge relative to Nitrate + Nitrite (NOx) concentrations for the Quequechan River discharging to the estuarine reach of the Taunton River.

EMBAYMENT SYSTEM	PERIOD OF RECORD	DISCHARGE (m3/year)	ATTENUATED LOAD (Kg/yr)	
			Nox	TN
Taunton River at Weir Village Bridge	**September 1, 2004 to August 31, 2005**	**1172417821**	**876951**	**1629974**
Three Mile River at Route 139	**September 1, 2004 to August 31, 2005**	**233887161**	**151568**	**256340**
Segreganset River at Elm Street	**September 1, 2004 to August 31, 2005**	**41288006**	**10286**	**30999**
Assonet River at Route 79 Bridge	**September 15, 2004 to September 14, 2005**	**106115523**	**8852**	**76056**
Quequechan River at Rail Road Bridge (Battleship Cove)	**September 1, 2004 to August 31, 2005**	**45351644**	**6493**	**36501**

Table 8 – Summary of stream flows and nutrient loads to the estuarine reach of the Taunton River discharging to Mt. Hope Bay.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Overall, it appears that the Massachusetts Estuaries Project (MEP) analysis is warranted for both estuarine systems (Taunton River estuarine system and Mt. Hope Bay embayment system) monitored under these 604(b) projects and that water quality monitoring needs to continue in order to develop the best baseline possible to invoke the MEP nutrient threshold analysis.

With regards to the specifics of each embayment monitored under the 604(b) grant program, certain water quality characteristics have become apparent as follows:

- The N/P molar ratios did support the contention that Mt. Hope Bay and the Taunton River estuary are N limited. The average ratio of inorganic nitrogen to inorganic phosphorus (N/P) was quite low, <3, at all stations within the Bay, although the Taunton River estuarine stations showed consistently higher ratios (5-10).

- The estuary shows a moderate salinity gradient. With the exception of the upper reaches nearest the freshwater entry, almost all of the waters ranged from 19 ppt to 28 ppt nearest the channel at Bristol Point. The salinity gradient results from the high predominantly riverine freshwater inflow and the high tidal flushing of this enclosed basin. Only the stations directly influenced by the Taunton River (MHB19-21) and the Kickamuit River (MHB-9) showed significant dilution of the main Bay.

- Chlorophyll a levels throughout this system are generally high in the summer, >11 ug L^{-1}, supporting the assessment of a nutrient enriched estuary and indicating that organic matter production is capable of supporting a high level of oxygen demand.

- The Taunton River estuarine reach, as the focus of upper watershed N loading, showed very high total nitrogen levels (TN) in its upper reach (1.058 mg N L^{-1}) and maintained high levels throughout most of its reach (>0.6 mg N L^{-1}).

- The main basin of Mt. Hope Bay supported lower TN levels primarily as a result of mixing with incoming waters (generally 0.5-0.6 mg N L^{-1}). This is consistent with the observed oxygen depletions and infauna animal communities.

- The highest water quality was found at the stations nearest the channels to lower Narragansett Bay and the Sakonet River (MHB-15, 16).

- The Taunton River Estuary, with its large watershed N load and high TN levels, is showing poor water quality due to its high chlorophyll and oxygen depletions.

- The main basin of Mt. Hope Bay, with its greater flushing and access to higher quality waters of the lower Bay, is showing less impairment.

- The lower basin of Mt. Hope Bay, nearest the tidal "inlet", is generally showing moderate to high water quality. The impaired waters in the regions nearest the river discharges most likely result from their lower flushing rates and from nitrogen loads.

- The data collected via the 604(b) grant program indicate that additional sampling in the basin in the lower region of Mt. Hope Bay, near the tidal inlets, may be warranted. In addition, these data indicate that the MEP analysis of this system should focus on restoration of the main basin of Mt. Hope Bay and the Taunton River estuarine reach. It is likely that restoration of the Taunton River Estuary will have a significant positive effect on the habitat quality of the main basin of Mt. Hope Bay

- Overall, it appears that the MEP analysis is warranted for the Mount Hope Bay/Taunton River estuarine complex as assessed by the water quality monitoring data

5.0 DATA QUALITY ASSURANCE AND CONTROL

The lab data will be reviewed by Dr. Brian Howes to assure that the data meets SMAST Quality Assurance requirements. At this stage, the source identity of blind duplicate samples will reside solely with Dr. David White, Project QA Officer. The resulting data will then be evaluated by Dr.s White and Howes to compare blind duplicate results with their source samples to assess the accuracy of the lab analyses. The level of repeatability of the data collected by the monitoring program and the chemical assays conducted by the SMAST Coastal Systems Analytical Facility are presented in Table B.1-4 of the approved over-arching Massachusetts Estuaries Project QAPP (June 13, 2003). As stated in the MEP QAPP, in some cases these data acceptance criteria are more rigorous than minimum requirements put forth in Tables B.1-1 and B.1-2. If acceptance criteria are not met, a detailed field study will have to be undertaken to determine if the cause of the difference between replicate samples is due to the hydrodynamics of the system or sampling and analysis procedures. Since duplicates are collected on consecutive casts, there is a possibility that patchiness in the water column is being seen in the data. Significant difference in a single duplicate sample is not sufficient to trigger action. The acceptability of the data is assessed based upon the overall pattern of agreement between blind duplicates.

Lab results will be scrutinized both for each station over the course of the sampling program and for all stations within the embayment system during each sampling round. The data will be compared to identify suspicious outliers that will be assessed first by examining the lab accuracy for that date and then by considering the setting at the sample site to determine any unique conditions that might cause the observed results. Possible causative factors for data outliers are anticipated to include: proximity to a fresh water discharge; location within a poorly circulated recess of the estuary; recent rainfall (collected from National Weather Service station at the New Bedford Municipal Airport); handling or collection errors; and lab error as indicated by blind duplicate results for that date.

Record keeping of Quality Assured (QAed) data will follow the Coastal Systems Program Analytical Facility Laboratory Quality Assurance Plan which has been submitted and accepted by the MA DEP and is available for DEP internal use only. Hard copy data such as raw data books, field data sheets, and chain of custody forms are all held by the Laboratory Manager in data notebooks. Analytical data sheets, field data sheets, COC's, electronic spreadsheets, calculation sheets are annotated with personnel's name and date when they were created and modified (when and by whom). Electronic databases are held both on the access protected hard drives of the Laboratory Manager and/or the QA Manager. In addition, immediate backup is held on the SMAST central computer which is maintained by professional full-time CIT staff. CD copies are also generally created for larger projects. Synthesized data will be reported to the Southeast Regional Planning and Economic Development District (SRPEDD) in a technical report developed by Dr.s White and Howes discussing the details of the sampling program, water quality data presented in tabular format, discussion of water quality trends, flow and nutrient loads from freshwater inputs, and a discussion of seasonal differences. A summary will be provided describing the general state of the embayment systems relative to the water quality data collected under this monitoring program. Data submittals will include field data, laboratory analyses and duplicates.

APPENDIX – A

FIELD SAMPLING PROTOCOL (NUTRIENTS)

MEP FIELD SAMPLING PROTOCOLS: NUTRIENTS

5.1 Nutrient Sample Collection Overview (MEP QAPP Appendix B-1, H)

The goal of the Water Quality Monitoring Program is to provide needed data with which to evaluate overall water quality conditions in nearshore waters and harbors. These waters are most likely to be impacted by excessive nutrient loading originating from local land use. Because of the value of this data, it is very important that measurements are made using the protocol provided and that collections occur during the last three hours of an outgoing tide. Through training sessions, hands-on instruction and sampling tips, we will provide sampling teams with the information necessary to ensure efficiency and accuracy in the measurements. Please call (Sara Sampieri) 508-910-6352) if you have any questions and note any problems on the data sheet.

In addition to nutrient sample collection and filtering, the following measurements need to be taken at each station: dissolved oxygen (milligrams per liter), water temperature, specific conductance, water clarity (Secchi disk) and total depth. Samples collected for nutrients will be analyzed at the SMAST laboratory for:

Ammonium	Nitrate+Nitrite	Particulate Organic Nitrogen
Ortho-Phosphate	Chlorophyll a & pheophytin a	Particulate Organic Carbon
Dissolved Organic N	Total Phosphorus (streams only)	Specific Conductance/Salinity
Total Suspended Solids		

5.2 Arriving On Station

The on-shore landmarks will be used to approximate sample station location, with final sample station determined by GPS. However, it is anticipated that, for the stream stations and nearshore marine stations, that landmarks or navigational bouys will provide sufficient location information once sampling is underway. All stations will be located by GPS so that future sampling programs can easily return to them. The boat will be anchored so that it remains in a fixed position while samples are collected and profile readings taken. The boat should approach the sample location moving into the current to minimize sediment disturbance for all sample stations but particularly for shallow stations (anticipated water depth less than 1 meter).

5.3 Order of Data Collection on Station

In order to avoid bottom disturbance, the following data collection order will be followed:

- Use Secchi disk to determine light penetration and to determine exact depth from stern of boat and wait until after touching bottom (5 minutes) before proceeding
- Collect meter data in vertical profile using depth information to collect data to within 0.5 meters of the bottom (from side or bow of boat)
- Collect water samples (from the side or bow of boat)

5.4 General Information and Weather (Appendix A also MEP QAPP Append B-1 H)

The following parameters will be recorded on the data sheet:
*Time of nearest low tide from tide table and whether the tide is ebbing (approaching low) or flooding (approaching high).
*Wave conditions - see Beaufort scale
*Wind direction - the direction the wind is coming from
*Weather conditions
*Rainfall in last 24 hours (collected by SMAST from NOAA weather station located at New Bedford Regional Airport, Lat. 41 40 31N Lon. 070 57 25W, in New Bedford, MA.).
* Any unusual natural or man-made conditions.
*Fill out each field data sheet with the pond, station number, time, cloud cover and wind direction and speed and wave height if it has changed from the previous station.

5.5 Dissolved Oxygen, Field Data Collection with YSI-55 Meter and Probe

The meter is calibrated each day on shore before starting the sampling. Calibration is described in Appendix B. Once calibrated, the meter should be left on throughout the course of the sampling day. If turned off, it must be re-calibrated for Dissolved Oxygen prior to proceeding with data collection. The meter provides readings of: dissolved oxygen milligrams per liter and temperature (percent saturation can be calculated combining these data with the laboratory assays of specific conductance). When arriving on station, once the boat is secured with the anchor, remove the probe from its protective housing and place it into the surface water to allow it to equilibrate with the surface water temperature.

The meter data should be collected in the same order as listed above (Section 5.3). At each depth interval, record the data on the field data sheets. The meter cable is marked in 10 cm intervals. At each depth, the probe should be moved in an up and down manner over a distance of several inches to circulate water over the probe. Wait to record data until the reading for each parameter has stabilized. If the water depth is <1.5 meter, samples should be collected at mid water, if 1.5-3.5 meter, then samples should be collected at surface (15 cm) and bottom (0.30-0.5 meter above sediment) and if >3.5 meter at surface, 2 meters and bottom. If the D.O. reading from the YSI 55 is less than 5 mg/L, collect a water sample for dissolved oxygen by Winkler analysis.

5.6 Nutrient & Chlorophyll Sample Collection Protocol (MEP QAPP Appendix B-1, H)

Sample collection should proceed in the up-current or up-wind direction from the meter readings and only after any suspended bottom sediments have settled. Each task described herein will be performed at each station in the embayment beginning in the inner portion and moving outward (toward the inlet). Samples are collected by Niskin Bottle. If the water depth is <1.5 meter, samples should be collected at mid water, if 1.5-3.5 meter, then samples should be collected at surface (15 cm) and bottom (0.30-0.5 meter above sediment) and if >3.5 meter at surface, 2 meters and bottom.

5.7 Water Quality Sampling Protocol: Nutrients, Oxygen, Physical Parameters:

1. The day before

(a) Review Checklist for all equipment – Call for replacements.
(b) Label all bottles with Station ID, Date and Depth (Top, Middle or Bottom).
(c) Mount filters in filter holders.
(d) Put ice packs in freezer.
(e) Add capped waste bottle, paper towels & wash bottle w/distilled water to kit.

MAKE SURE ICE IS IN COOLER

2. Anchor at Sampling Station & Record Station Observation Data including:
Sampler Names, Station Number, Date & Time, Wind Info, Weather Conditions.

3. Collect Depth & Secchi Disk Information

(a) Lower Secchi disk until it just disappears from view. Read & record depth at waterline.
(b) Lower Secchi disk further then raise until just visible. Read & record depth at waterline.
(c) Average 2 Secchi disk readings & record.
(d) Lower Secchi disk to bottom & record total depth.

4. Collect Nutrient and Chlorophyll a Samples.

(a) Label one 1 liter nutrient (white) bottle and one 1 liter chlorophyll (brown) bottle with station I.D., date, depth, and time of collection).
(b) Lower Niskin Bottle to 15 cm below the surface and pull stopper, bring to surface, shake and dump to rinse bottle; reset and repeat at appropriate depths. If a sample is collected for dissolved oxygen Winkler analysis, the sample will be collected first and processed as in Section 7.5, below.
(c) Add about 50 mL to 1L nutrient (white) bottle, cap, shake and dump out, repeat. Then fill bottle to shoulder then put in cooler, and shut cooler lid.
(d) Repeat rinse and filling procedure with 1 liter brown Chlorophyll bottle, cap and put in cooler.

PUT NUTRIENT AND CHLOROPHYLL SAMPLES IN COOLER IMMEDIATELY

(e) A filtered sample needs to be processed as indicated in the next section (Section 6).

Note: Surface samples can be taken by hand if desired. If taking samples by hand you must hold the open bottle in an inverted vertical position while submerging to the desired depth and then tip upright to fill.

6.0 FIELD SAMPLE PROCESSING (on station filtering)

Samples will be prepared for dissolved nutrient analyses by filtration. Samples for dissolved nutrient analyses will be filtered through a 0.45-micron cellulose acetate filter 47 millimeters in diameter into a 60 cc acid-leached plastic bottle.

- **TO BE DONE AS SOON AS POSSIBLE AFTER COLLECTION (<1 hr)**
- Filtered samples are to be shipped in the small white 60 cc plastic bottle (these bottles are acid leached and provided by SMAST)

Filtering for Dissolved Nutrients Procedure (MEP QAPP Appendix B-1, H):

1. Remove white 1 liter sample bottle from cooler, one station bottle at a time.
2. Label a 60cc bottle with identical station information:
   a. Embayment abbreviation name
   b. Station ID
   c. Sample Depth (in meters)
   d. Date (mo/dy/yr)

3. Place filter (using provided forceps) in clear plastic filter holder. (white filter, not the blue paper).
4. Vigorously Shake 1-liter nutrient (white) sample bottle (in case of particulate settling) and fill 60cc syringe with water from bottle by removing plunger and pouring in, replace plunger.
5. Attach filter (cup side up) to syringe (most filter holders have an arrow drawn on side indicating the direction of flow) and push through and discard the first approx. 30 cc of water through the filter.
6. Push next 20 cc – 30 cc of water through the filter into the small 60 cc sample bottle, replace cap, shake and discard water.
7. Now refill syringe, **attach to filter** (cup side up) and collect all water through the filter into the now rinsed bottle until bottle is full to shoulder, **taking care that no unfiltered water drips into sample**, Fill bottle to top leaving only a small (2-3 ml) bubble, cap and put on ice.
8. Cap 1-liter nutrient (white) sample bottle with the remaining water, check label and put on ice. The bottle must be at least ¾ full to be used for analysis.
9. Remove used white filter paper and discard.
10. Repeat steps a) through h) for each 1 liter nutrient (white) sample bottle.

Place samples in cooler with 1 Liter bottles for transport.

7.0 SAMPLING USING DISSOLVED OXYGEN (D.O.) METER – YSI 55

7.1 Instrument Warmup

Turn on D.O. meter and allow 10 minutes for meter to stabilize. Ensure that the sponge in calibration/storage chamber is moist and the probe is inserted in the calibration chamber.

7.2 Calibration

(a) If reading is in mg/l, **Hit Mode key to put in % saturation mode** before entering calibration mode.
(b) **Press UP ARROW & DOWN ARROW** at same time to enter calibration menu.
(c) Now in Altitude menu. **Put at 0** using up or down arrows and hit enter key (left arrow).
(d) Now in % saturation menu. Make sure the D.O. reading in large display is **stable** and **Hit Enter** key.
(e) Now in salinity menu. **Enter 0** salinity (salinity will be corrected for during data processing).
(f) **Hit Enter** key.
(g) Meter now ready to take readings but need to return to mg/l mode, so **Hit Mode** key.

If temperature units need to be changed (F to C), press Down Arrow & Mode key at same time.

CALIBRATION IS NOW COMPLETE.

7.3 Initial Reading

At each station, record dissolved oxygen (mg/l) and temperature while the probe is still in the calibration chamber. This is called Initial Reading on Data Sheet.

7.4 Data Reading and Recording

Remove the probe and take Dissolved Oxygen and Temperature readings at depths required for your station, i.e. surface, mid-depth and bottom. Readings will vary slightly because the probe consumes oxygen so **jiggle the probe** while reading the instrument to expose the probe to new water. Read to nearest tenth of mg/l.

After each station, rinse probe and return it to the calibration chamber. The probe does not stay in the storage/calibration chamber very well because of the weight of the cable so be careful that the probe doesn't fall out on deck when moving the meter about the boat.

If dissolved oxygen readings are less than 5 mg/L, you must take a 300 mL BOD Bottle for Winkler DO Assay. Please collect QA sample by Modified Winkler Method, below.

DO NOT RECALIBRATE. **LEAVE D.O. METER ON until the day's sampling is completed.

7.5 Dissolved Oxygen (D.O.) Sample Collection/Analysis Modified Winkler Method

Note to YSI meter Teams: If the D.O. reading from the YSI 55 is less than 5 mg/L, collect a water sample for dissolved oxygen by Winkler analysis, that sample will be collected first. All other Teams collect Winkler D.O. samples at each location.

D.O. Sample by Winker Analysis Procedure

(a). Label one 300 mL glass Winkler bottle with station I.D., date, and depth.

(b). Using Niskin Bottle collect sample from depth and bring to surface.

(c). Remove glass stopper from 300 mL Winkler bottle
(d). Lower rubber tube from Niskin Bottle to the bottom of the glass reagent bottle from the blue oxygen kit.
(e). Drain ¾ of the Niskin Bottle through the glass Winkler bottle, overflowing the glass bottle.
(f). Gently tap glass bottle to insure that no bubbles stick to sides.
(g). As volume reaches ¾ of the Niskin, slowly remove the rubber tube from the glass bottle and then carefully insert glass stopper so as not to trap any bubbles. Dropping glass stopper in from above works best.

Now: Fix the sample for transport to the lab, as follows:

(h). Open Reagent packet #1 (use the scissors in your kit);
(i). Open Reagent packet #2
(j). Remove glass stopper from glass oxygen reagent bottle;
(k). Pour Reagent #1 into bottle and then add reagent packet #2 to bottle.
(l). Replace glass stopper, careful not to trap bubbles.
(m). Mix bottle for 45 seconds by turning bottle upside down & rightside up. A little left over reagent on the bottom is OK.
(m). Let bottle sit for 2 minutes then mix again for 45 seconds. Put water into bottle lip.
(n). Allow floc to settle until below half way in the glass 300 mL BOD bottle, usually takes ~5 min
(o). Add reagent 3 to the 300 mL glass BOD bottle & replace stopper with no bubbles. Mix until ALL reagent dissolved. Water will now be yellow/amber.
(p). Put some water in bottle lip and put on snap cap. Place in cooler with the other sample bottles to be sent back to SMAST for titration.

8.0 EQUIPMENT CLEANUP FOR STORAGE

(a) Rinse sampling pole and Secchi disk with fresh water.
(b) Rinse D.O. glassware and filter holders with distilled water & dry before returning to sampling kit.
(c) Rinse D.O. probe with distilled water and return to storage/calibration chamber.

SHIPPING AND HANDLING

All samples will be transported to the Coastal Systems Analytical Facility by SMAST technical personnel involved in the field program. The SMAST person transporting the samples will check the Chain of Custody and verify that the samples are as stated before accepting them for transport. After collection, samples will be kept continuously on ice or in refrigeration. Samples will be shipped in heavy-duty styrofoam coolers with ice or cold packs adequate to maintain cold internal temperatures. All shipments will be accompanied by a Chain of Custody (sample in Appendix B).

APPENDIX – B

CHAIN OF CUSTODY AND FIELD DATA SHEETS

SRPEDD-SMAST

Mt. Hope Bay Estuarine Monitoring Program – Water Sampling Data Sheet 2004,05,06

General Conditions

MBH- ____ Station ID. Embayment ________________________

__________ Sample Date Volunteers Names ____________________

__________ Beaufort Scale (Force# 0 - 12)

__________ E / F Ebb (outgoing) or Flood (incoming) tide

Time of nearest LOW tide ________am / pm (refer to your tide table)

#_________ Weather Conditions: (choose one) 1. Cloudless 2. Pt. Cloudy 3 Overcast 4. Rain 5. Fog/Haze 6. Drizzle 7. Intermit. Rain

#_________ 24 hour Precipitation (choose one) 1 None 2 Light 3 Heavy

__________ Wind direction (ie. SE, NW)

Secchi Depth __________(m)Disappearance/descending
__________(m)Reappearance/ascending
__________(m) Average

__________(meter) Total water depth at station

Observations: Birds ______ # , _________type; Moorings _________ #
Swimming ________yes/ no ; Shellfishing ________ yes / no

Please continue comments on back

Oxygen Meter Initial Reading		**D.O. (mg/L)**		**Temp (°C)**		

Depth Specific Parameters

	SURFACE **15 cm below**		MID see protocol		BOTTOM **40 cm from bottom**	
Collection Time						
Collection Depth		**Meters**		**Meters**		**Meters**
Oxygen Reading		**mg/L**		**mg/L**		**mg/L**
Temperature Reading		°C		°C		°C
Oxygen - Winkler Bottle if Meter < 5 mg/L						check if bottle is filled

Did you collect a 1 L Brown, 1 L Clear and 60cc bottle at each nutrient depth?
Return data sheet with samples to Coastal Systems Program, SMAST c/o Dr. Brian Howes, 706 S. Rodney French Blvd., New Bedford, MA 02744.

COASTAL SYSTEMS GROUP
Chain of Custody Record

Personnel Contacts

RECEIVED		RECEIVED	
name		name	
date	time	date	time
COLLECTED		**CONTACT**	
name		name	
date	local	phone/address	

Sample Notes

Special notes/ Sample Handling	Total number of samples

Sample Status

Sample ID	NH4	PO4	NO3/NO2	TDN	POC/N	TSS	CHLA	TP	Salinity	pH	Alkalinity				

This form is to be completed and signed at sample transfer to the Coastal Systems Analytical Facility at SMAST.
706 Rodney French Blvd., New Bedford, MA 02649; 508-910-6352

EXHIBIT J
AR J7

APPENDIX – C

EQUIPMENT TO BE USED AND CALIBRATION

GPS Station Location:

Garmin Global Positioning Units will be used to locate all sample stations by each team. Location measurements will proceed only with at least 5 satellites available to assure accuracy. The goal will be a minimum of six satellites using the High Precision setting. Station locations will be corrected with the download data available at the National Geodetic Survey CORS site (continuously operating reference system). Corrected station locations are expected to be accurate within 3 meters and probably within 1 meter.

YSI 55 Field Meter:

The YSI-55 model field monitoring equipment will be maintained and checked as per manufacturers' instruction. The probe is a non-detachable, combination sensor that reads dissolved oxygen and temperature. As suggested, the probe and its storage cell will be rinsed with clean tap water after each use and stored in the cell as per manufacturers specification.

It will be the responsibility of SMAST Laboratory Manager to check the calibration status of any meter prior to using the instrument and to check its calibration periodically during use. A log documenting problems experienced with the instruments nd corrective measures taken will be maintained by the Sampling Coordinator for each instrument (identified by serial number).

All equipment to be utilized during the field analysis and laboratory analysis will be checked, prior to its use, to see that it is in operating condition. This includes checking the manufacturer's operating manuals and the instructions with each instrument to ensure that all maintenance items are being observed.

The YSI 55 Meter and Probe will be calibrated for dissolved oxygen before each sampling event following manufacturers recommended procedures. The accuracy of dissolved oxygen readings will be checked by collection of samples for Winkler method DO determination at two-week intervals. Additional QA data is provided from Winkler assays conducted when a meter reading is <5 mg L^{-1}.

Any issues relating to calibration will be documented in the field logbooks and the monitoring of the work plan. Instruments will be left on for the duration of the sampling round, at station and en route. At the beginning and end of each field season a two-point calibration will be performed for each dissolved oxygen probe. Temperature will be calibrated quarterly, by validating the temperature in a known temperature water bath.

CALIBRATION OF DISSOLVED OXYGEN PROBE

The probe is equipped with a polargraphic Clark-type sensor. A new dissolved oxygen membrane will be installed at the beginning of the field season and at 8-week intervals as per the manufacturer's recommendations outlined below:

1. Before departing from the shore, turn the meter on by pressing the ON/OFF button, and then

press MODE button until dissolved oxygen is displayed in mg/l or %. Allow the readings of dissolved oxygen and temperature to stabilize for 15 minutes.

2. The meter has two buttons with arrows; one pointing up and the other pointing down. Push both buttons simultaneously. The screen will read "0", press "enter" if at sea level to set altitude. If above sea level, use the arrow keys to set the altitude in units of 100 feet (i.e. 12 is 1200 feet). For work on all coastal ponds the altitude will be set at zero. When correct altitude is shown, press ENTER.

3. The YSI 55 will now display CAL in the lower left of the display screen. The calibration value should be displayed in the lower right of the screen and the current % reading shows in the main display of the screen. This reading should be within the range of 99 to 101 percent. When the current reading display is stable, press ENTER button. The display will then read SAVE and return automatically to the Normal Operation Mode.

DISSOLVED OXYGEN MEMBRANE CAP REPLACEMENT

The membrane cap will be replaced annually at the beginning of field season and again at 8-week intervals or as needed based on inspection of the membrane for defects.

1. Unscrew and remove the probe sensor guard.
2. Unscrew and remove the old membrane cap.
3. Thoroughly rinse the sensor tip with distilled water.
4. Prepare the KCl electrolyte according to the directions provided by the manufacturer with the solution .
5. Hold the membrane cap and fill at least ½ full with electrolyte solution.
6. Screw the membrane cap onto the probe moderately tight. A small amount of electrolyte should overflow.
7. Screw the probe sensor guard on moderately tight.

EXHIBIT J
AR J7

APPENDIX – D

NUTRIENT WATER QUALITY DATA

(Data Transmitted Electronically as Excel Files)