DRAFT
NASHUA RIVER, MASSACHUSETTS
Total Maximum Daily Load for the Nutrient Phosphorus
MassDEP DWM TMDL
(Report # 81–TMDL-2007-2)

COMMONWEALTH OF MASSACHUSETTS
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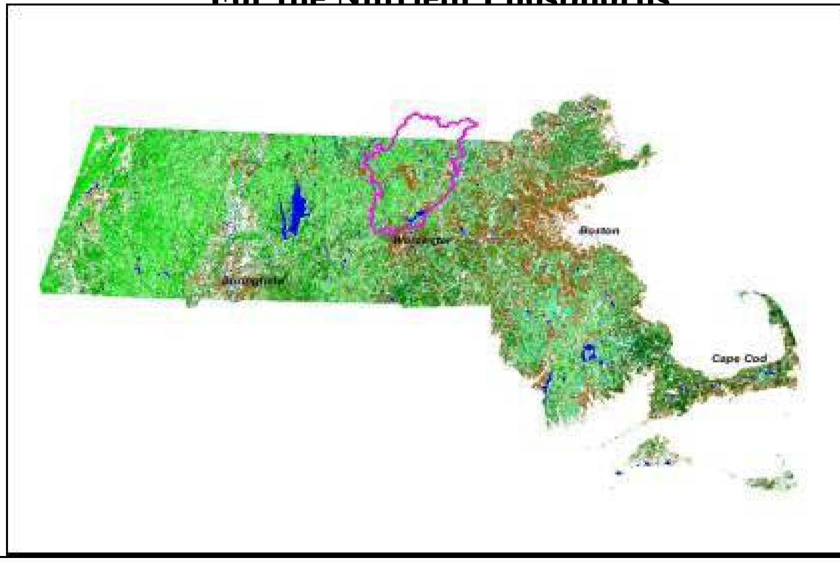
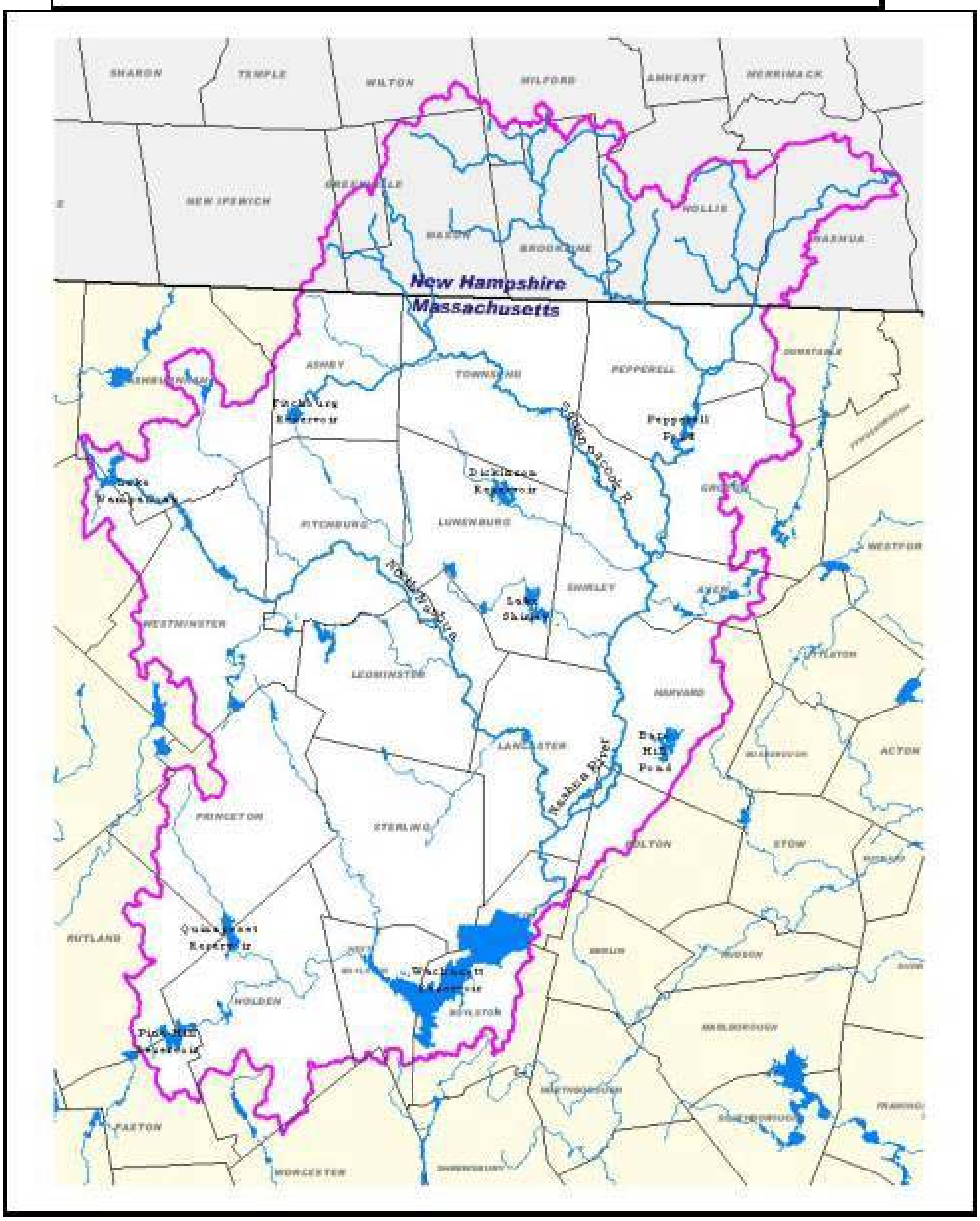
Front Cover
Pepperell Impoundment Showing Surface Coverage
of Floating Algal Mats and Macrophytes

Nashua River, Massachusetts Total Maximum Daily Load For the Nutrient Phosphorus





Project Name: Nashua River Seasonal Total Maximum Daily Load for the Nutrient Phosphorus

Location: EPA Region 1, Massachusetts

The following 3 segments are on the 303(d) list for nutrients.

MA81-05	Confluence with North Nashua River, Lancaster to confluence with Squannacook River, Shirley/Groton/Ayer, **14.2 miles for nutrients**.
MA81-06	Confluence with Squannacook River, Shirley/Groton/Ayer to Pepperell Dam, Pepperell, **9.5 miles for nutrients and organic enrichment/low DO and noxious aquatic plants**.
MA81-07	Pepperell Dam, Pepperell to New Hampshire state line, Pepperell/Dunstable, **3.7 miles for nutrients**.

The following 4 segments are listed on the 303(d) list for other causes but are included here as part of a protective TMDL:

MA81-01	Outlet Snows Millpond, Fitchburg to Fitchburg Paper Company Dam #1, Fitchburg 1.7 miles
MA81-02	Fitchburg Paper Company Dam #1 to Fitchburg East WWTF, Fitchburg, 6.9 miles
MA81-03	Fitchburg East WWTF, Fitchburg to Leominster WWTF, Leominster 1.6 miles
MA81-04	Leominster WWTF, Leominster to confluence with Nashua River, Lancaster 10.4 mi.

Scope/Size: 520 mi^2 watershed; 48 river-mile river length in MA

Land Type: Southern New England Coastal Plains and Hills

Type of Activity: Urban headwaters, residential, forested, and agricultural subwatersheds

Pollutants: Excess nutrients (phosphorus)

Designated Uses: Class B waters

Water Quality Standards: Dissolved oxygen, nutrients, aesthetics

Data Sources: USEPA/MassDEP 1998 and 2000-2004 Nashua River sampling programs
NRWA volunteer monitoring data, NPDES DMR data
Numeric and Tetra Tech Reports on BASINS and HSPF12 Modeling, 2000-2004
MassDEP Nashua River Assessment Report, 2000

Data Mechanisms: HSPF12, GIS, BASINS, QUAL2E

Analytical Approach: Load-response relationship

Monitoring Plan: MassDEP DWM Watershed 5-Year Cycle, MassDEP/CERO Strategic Monitoring Plan; NRWA Monitoring Program

Control Measures: Phosphorus limits implemented via adaptive management and NPDES permits;
WWTP operational improvements;
Watershed BMPs for nonpoint source;
Stormwater Management Phase II Permits, education and grants;
CSO permit reissuance and Long-Term control plans
Development of Lakes' TMDLs for phosphorus.
Macrophyte Management
Designated Use Management in Pepperell Impoundment

Executive Summary

The Massachusetts Department of Environmental Protection (MassDEP) is responsible for monitoring the waters of the Commonwealth and for listing those waters that are impaired. The list of impaired waters historically known as the 303d list, and more recently as Category 5 of the Integrated List, identifies the impaired waters and the reasons for the impairments. MassDEP is required by the Federal Clean Water Act to develop a Total Maximum Daily Load (TMDL) or pollutant budget for all waters listed in Category 5. MassDEP also has outlined a remediation plan to achieve water quality standards. The TMDL identifies the sources of pollutants from point sources or direct discharges, and from non-point sources or indirect discharges, and then determines the maximum amount of the pollutant, with a margin of safety, that can be discharged to the waterbody in order to meet the Massachusetts Surface Water Quality Standards.

This TMDL was developed to address nutrient-related impairments in the Nashua River. Several segments in the Nashua are on the MassDEP Category 5 list of impaired waters for nutrient enrichment, organic enrichment, and low dissolved oxygen. Eutrophic conditions have been observed inducing the formation of excessive algal mats and macrophytic plant growth in Pepperell Pond Impoundment, as illustrated in the following picture (Figure ES-1), with supersaturated dissolved oxygen conditions. Historical water quality surveys have detected low dissolved oxygen 1 mile upstream of the impoundment.

Figure ES-1: Pepperell Pond on the Nashua River

A number of the segments in the upper portion of the watershed, although not identified as being impaired will also be addressed by providing “protective” limits for over 45.5 miles of the mainstem.

This Total Maximum Daily Load (TMDL) focuses on the nutrient phosphorus to address organic enrichment/dissolved oxygen, and noxious aquatic plants in the river system. Effects include supersaturated dissolved oxygen and high chlorophyll_a for 7 segments totaling 50.9 miles on the mainstem of the river. Future TMDLs will be developed for other listed causes of impairment in other river segments and for lakes in the watershed.

The information base for this report and TMDL includes:

- the recent and historical reports ---(over 30 years worth of data and assessments),
- a sampling program undertaken in 1998 by the Massachusetts Department of Environmental Protection, the United States Environmental Protection Agency, the Nashua River Watershed Association, and the WWTFs, to characterize present conditions as compared with 1977 conditions;
- a MassDEP and USEPA sampling program in 2003 and 2004 to update water quality data and provide assessment of tributaries;
- a MassDEP 2000 Water Quality Assessment Report; and
- the development of HSPF12 and QUAL2 models of the river system to assess and predict current and future conditions.

This TMDL project was undertaken by MassDEP and USEPA in cooperation with TetraTech and Numeric Environmental consultants funded through a USEPA grant to the New England Interstate Water Pollution Control Commission (NEIWPCC). Sampling assistance was provided by the Nashua River Watershed Association and the Waste Water Treatment Facilities, (WWTFs). The project included dry-weather water quality sampling and assessment, sediment chemistry and toxicity, biological sampling and assessments, and water-column and effluent toxicity testing, together with nonpoint source modeling utilizing both BASINS and HSPF12, and steady state wasteload allocation modeling utilizing QUAL2E.

The recommended implementation for this TMDL, is primarily changes to WWTF NPDES discharge limits based on model results which indicate the greater importance of point sources compared to non-point sources during summer low-flow conditions (Figure ES-2) through the input of nutrients in the readily available form of dissolved phosphorus. The model also shows the linked nature of all segments of the river. Nutrient point-source effluent discharges to upper reaches where the velocities are higher turn into algal and plant biomass when the river velocity slows in the ponded areas downstream. Pepperell Pond exhibits the main impact from these nutrients as demonstrated by high algal and macrophytic growth, nuisance surface algal and plant mats, as illustrated in Figure ES-1, and conditions of super-saturation in dissolved oxygen. The subwatersheds add non-point source phosphorus during high flow conditions of spring and fall; however, the importance of the non-point sources becomes small in comparison to the point sources during summer low flows. ES-2 also shows as a baseline comparison what the total phosphorus nonpoint source contribution would have been to Pepperell Pond Impoundment if the entire watershed were all forested.

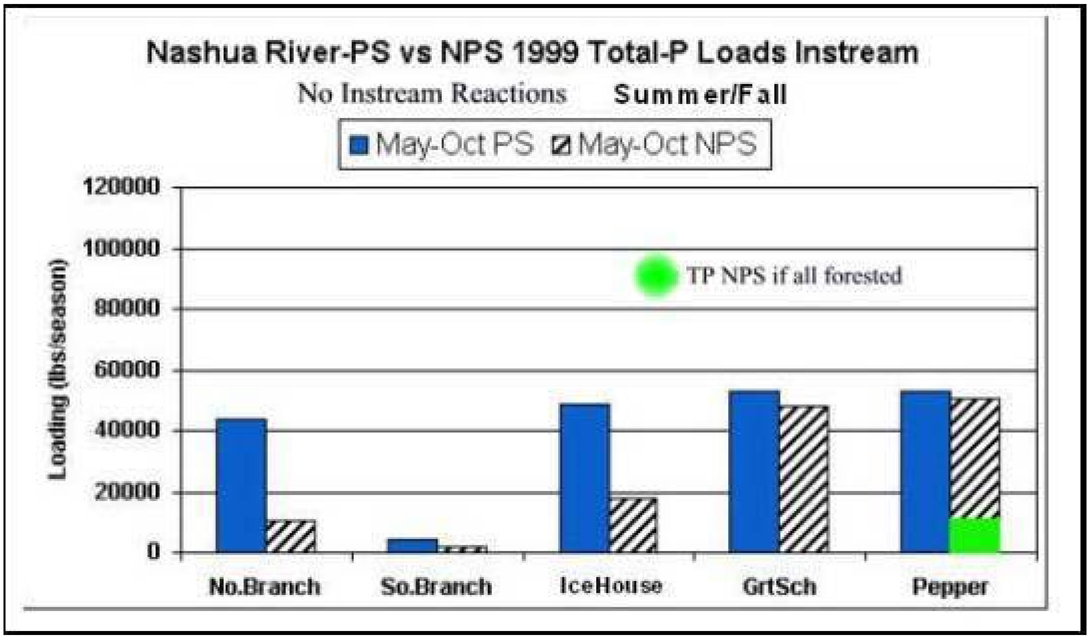


Figure ES-2: Phosphorus Loads from Point and Non-Point Sources

FigureES-2 shows the very large contribution of phosphorus from point sources in the North Branch and the upper part of the mainstem of the Nashua River. This phosphorus from the WWTFs is in the dissolved form and readily useable to produce problem levels of chlorophyll and algae. In these areas the river flow is high and the effects of high dissolved phosphorus are not seen until the river slows in the Groton School and Pepperell Impoundment areas. The large increase in loading between Ice House Impoundment and Groton School is from the introduction of the Squannacook River. It should be remembered that the phosphorus from the Squannacook River is in the much less useable organic phosphorus form, which is difficult to break down and less readily available for uptake by algae than the dissolved phosphorus from the WWTFs. Also, this subwatershed is large and raises the nonpoint source phosphorus load due to watershed size and flow alone rather than increasing the concentration of phosphorus.

To achieve water quality standards a significant reduction in phosphorus discharges is necessary to achieve the removal of surface algal and macrophytic nuisance mats in Pepperell Pond Impoundment, and to eliminate dissolved oxygen impacts in Pepperell Pond and other locations. Model results show phosphorus reductions to 0.2 mg/l for the mainstem above Pepperell Impoundment and 0.5 mg/l for the South Branch and Pepperell WWTF, along with a 20% reduction in non-point source phosphorus, are expected to achieve the needed reductions to eliminate impacts caused by excessive nutrient loads. A corresponding drop in the maximum daily range of dissolved oxygen concentration and percent saturation, as well as lower chlorophyll_a concentrations, is generally seen for each reduction in effluent phosphorus concentration from the WWTFs.

The TMDL also strongly recommends watershed controls be pursued. If these controls are not implemented consistently, the instream changes expected with reductions in WWTF effluent phosphorus will be offset by increased contributions from the watershed as local development continues. A separate management plan for Pepperell Pond is needed to achieve designated uses which would focus on identifying zoned uses of the pond with corresponding structural controls for removal of bottom aquatic vegetation in certain specified recreational use areas.

A margin of Safety (MOS) is provided through several means including the use of conservative assumptions in the model, through the USEPA mandated reductions in combined sewer overflows (CSO) contributions over time, and through implementation of the Phase II Stormwater Regulations. In addition, the on-going development of nutrient watershed TMDLs for phosphorus in lakes in the Nashua River drainage area will assist with reductions in NPS levels. The Phase II stormwater permit program for cities and towns will provide a basis for the NPS level reductions. The discharge permit for CSOs in the City of Fitchburg requires the implementation of CSO separation, which will reduce phosphorus inputs. The TMDL recognizes uncertainty in the modeling approach, and in the prediction of what the final level will be in percentage exceedences of target levels. However, the TMDL supports the conclusions that by utilizing an adaptive implementation approach these point source reductions combined with watershed wide reductions in nonpoint source phosphorus will be enough to achieve standards instream.

Reasonable Assurance exists that this TMDL will be implemented through the state and federal regulatory authority over point sources, and local controls that can address nonpoint sources, and the available federal and state competitive funding to finance improvements.

The monitoring programs incorporated as part of this TMDL monitor the effectiveness of reductions over time. A monitoring program tied to the MassDEP Year 2 watershed sampling portion of the 5-year watershed program cycle is included as part of the implementation efforts to monitor on-going success at meeting water quality standards.

Public involvement will be included as part of the TMDL process. MassDEP and the USEPA met on a regular basis with the former EOEA Nashua River team and other stakeholders to present status reports on the TMDL and model development. Year 1 of the DEP cycle requires public outreach, which will also be used as a method of meeting the TMDL requirements for public involvement during the implementation process. A public meeting will be held to present the results of and receive comments on this TMDL.

TMDL

Based upon the detailed data collection and predictive water quality modeling conducted and in consideration of all of the evidence and analysis previously discussed, MassDEP is establishing in accordance with 314 CMR 4.05(5)(c) an effluent limit of 0.2 mg/l total phosphorus at design flows during the growing season for Fitchburg West, Fitchburg East, Leominster, and Ayer WWTFs discharging to the Nashua River, and 0.5 mg/l total phosphorus limit for the MWRA Clinton WWTF and the Pepperell WWTF, plus a goal of 20% reduction in non-point source phosphorus input. These limits and reductions to nutrient inputs are necessary to control accelerated and cultural eutrophication in the Nashua River so that is can meet its designated uses. In the WLA no room was provided for increases over plant design flow or for other dischargers to be added. Reducing the Clinton WWTF and Pepperell WWTFs to 0.2 mg/l did not show a significant decrease in the mainstem TP, and the results are likely to be within the predictive limits of the current model. Therefore effluent limits less than 0.5 mg/l for these two dischargers are considered not warranted at this time. Also, the Pepperell discharge is downstream of Pepperell Impoundment and therefore does not affect the pond, but does contribute to impairments downstream and in the Merrimack River.

As previously noted, during the non-growing season, effluent limits for phosphorus are not proposed; however, MassDEP and USEPA are concerned that the discharge of particulate phosphorus during the non-growing months may settle in downstream impoundments and slow moving reaches of the river. Therefore, the NPDES permit will require that the WWTFs optimize the removal of particulate phosphorus and monitor both total and dissolved phosphorus to determine if there is a need for non-growing season limits.

The model simulations indicate that a combination of reductions of phosphorus at the WWTFs and from NPS inputs is necessary to meet water quality standards and designated uses. The model predicts that the limits identified above will result in the following:

1. In-stream total phosphorus concentrations are expected to drop from an average concentration projected for 1999 of about 0.36 mg/l to an average concentration of 0.13 mg/l based on the modeling.

This reduction in phosphorus will translate into improvements in the response variables as follows:

2. The minimum dissolved oxygen criterion of 5.0 mg/l will be maintained during low flow conditions in all reaches of the Nashua River below the WWTFs thus meeting the requirements of 314 CMR 4.05(3)(b)1(a).
3. The amount of time in-stream dissolved oxygen levels exceed 125% saturation levels will be reduced by approximately 57% indicating a significant amount of biomass reduction.
4. The peak biomass, as represented by chlorophyll_a concentration, is expected to be reduced by 50% in the system over 1999 projected conditions in order to meet the state criteria for "aesthetics" in 314 CMR 4.05(5)(a) and address most of the public concerns about excessive floating aquatic vegetation.

Table TMDL ES-1

TMDL for Total Phosphorus
NASHUA RIVER

<table>
<tr><th colspan="3"></th><th colspan="2">WWTF Effluent Limits
Total Phosphorus, mg/L
April 1 – October 31[1]</th><th>WWTF Effluent Limits
Total Phosphorus, mg/L
November 1 – March 31</th></tr>
<tr><th>WWTF</th><th>NPDES</th><th>Design Flow, MGD</th><th>mg/L</th><th>lbs/day
@ design flow</th><th>mg/L and lbs/day</th></tr>
<tr><td>Fitchburg West</td><td>MA0101281</td><td>10.5</td><td>0.20</td><td>17.5</td><td rowspan="4">Optimize for particulate phosphorus removal and monitor and report for total and dissolved phosphorus</td></tr>
<tr><td>Fitchburg East</td><td>MA1010986</td><td>12.4</td><td>0.20</td><td>20.7</td></tr>
<tr><td>Leominster</td><td>MA0100617</td><td>9.3</td><td>0.20</td><td>15.5</td></tr>
<tr><td>Clinton</td><td>MA0100404</td><td>3.0</td><td>0.50</td><td>12.5</td></tr>
</table>

Ayer	**MA0100013**	**1.8**	**0.20**	**3.0**	**concentration**
Pepperell	**MA0032034**	**1.1**	**0.50**	**4.6**	
TMDL					
WLA				**73.8**	
LA				**177**	
MOS				**2.0**	**Separation of Fitchburg CSOs**
	Model-conservative assumptions of higher wwtf design loads with lowest river flow; NPS based on avg annual & avg monthly flow during lowest river flows			**IMPLICIT**	
TMDL				**252.8**	

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Introduction

The Federal Clean Water Act requires each state to (1) identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for listed waters for the pollutants of concern. TMDLs may also be applied to waters threatened by excessive pollutant loadings. The TMDL establishes the allowable pollutant loading from all contributing sources at a level necessary to achieve the applicable water quality standards. The TMDLs must account for seasonal variability and include a margin of safety (MOS) to account for uncertainty of how pollutant loadings may impact the receiving water quality. This report and attached documents are required to be submitted to the USEPA as a TMDL under Section 303d of the Federal Clean Water Act, 40 CFR 130.7. After public comment and final approval by the USEPA, the TMDL serves as a guide for future permitting and implementation activities. In this case the TMDL will be used by the MassDEP and USEPA to support and evaluate limits in permits for municipal wastewater and CSO discharges and to review municipal activities and grant funds for Best Management Practice (BMP) implementation to reduce non-point source contributions.

In the Nashua River system, the pollutant of concern for this TMDL (based on observations of eutrophication) is the nutrient, phosphorus. Phosphorus is the limiting nutrient in fresh waters, which means that as the concentration increases, the response variables in the form of increased amounts of plant matter, as algal mats and macrophytes, increases. This creation of nuisance populations of macro-algae and increased density and coverage of macrophytes, impairs water quality and recreation and affects the healthy ecology of the water bodies.

The TMDL for total phosphorus for the Nashua River watershed is based upon the data collected by the MassDEP and USEPA. The data was collected during 1998 and 2000-2004. This TMDL presents the results of water quality studies as utilized to describe the instream conditions and to calibrate and verify two water quality models, HSPF and QUAL2. The models then projected water quality conditions for a five-year period for a series of scenarios, which varied point source effluent discharge concentrations in order to compare effects on the response variables of dissolved oxygen, and biomass as expressed as chlorophyll_a.

The year of comparison for scenarios was selected as 1999, during which instream flows were close to critical 7Q10 conditions. The comparison evaluates changes primarily in total phosphorus from the WWTFs and the corresponding effect on instream water quality concentrations and saturation levels of dissolved oxygen, together with chlorophyll_a levels (as adjusted for algal and macrophytic components).

Results of the HSPF model for the Nashua River watershed showed that point sources were more important than non-point during the low flow dry weather conditions. The results of these scenario runs serve as the basis for generating total phosphorus thresholds for WWTFs and watershed total phosphorus runoff management. This TMDL is based on the site-specific thresholds generated for the river segments and therefore offers a science-based management approach to support the wastewater management planning and decision-making process.

Waterbody Description

The Nashua River watershed, a sub-basin of the Merrimack River, is located in north-central Massachusetts and includes all or part of 31 communities in two states. The watershed has a total drainage area of 520 square miles with a river length of 56 miles. Most of the watershed, 454 square miles or 87%, and 46 miles of the mainstem, is contained within the state of Massachusetts. Major tributaries include the Nissitissit, Stillwater, Quinapoxet, Squannacook, North Nashua and South Nashua. Most of these, in contrast to the mainstem, flow in a southeasterly direction. The river drops 483 feet, predominantly occurring along the North Nashua.

The North Nashua and the South Nashua Rivers join in Lancaster Common, Massachusetts, to form the mainstem Nashua River. The mainstem then flows in a northeasterly direction to the confluence with the Merrimack River in Nashua, New Hampshire. The South Nashua River forms at the confluence of the Stillwater River and the Quinapoxet River in West Boylston in what is now the Wachusett Reservoir, and then flows through Boylston and Clinton to Lancaster. The North Branch forms in the western part of Fitchburg at the confluence of the Whitman River and Flagg Brook, then flows to Leominster and Lancaster. The mainstem of the Nashua River flows through Bolton, Harvard, Ayer, Shirley, Groton, Pepperell and Dunstable, where it crosses the Massachusetts-New Hampshire State Line. Waterbody segments listed as impaired on the 2004 Massachusetts Impaired List are as follows.

Table 1 Nashua River Listing Pollutants of Concern and Waterbody Segments in Category 5 of the Massachusetts 2004 Integrated List[1]

NAME	WATERBODY SEGMENT	DESCRIPTION	SIZE	Pollutant Listed
North Nashua	**MA81-01**	**Outlet Snows Millpond, Fitchburg to Fitchburg Paper Company Dam #1, Fitchburg**	**1.7 miles**	**-Cause Unknown**
North Nashua	**MA81-02**	**Fitchburg Paper Dam #1 to Fitchburg East WWTF, Fitchburg**	**6.9 miles**	**-Cause unknown -- -Taste Odor/Color -Objectionable Deposits**
North Nashua	**MA81-03**	**Fitchburg East WWTF Fitchburg to Leominster WWTF, Leominster**	**1.6 miles**	**-Cause unknown -Taste Odor/Color -Turbidity**
North Nashua	**MA81-04**	**Leominster WWTF to Confluence with North Nashua River, Lancaster**	**10.4 miles**	**-Cause unknown -Taste Odor/Color -Turbidity**
Nashua Mainstem	**MA81-05**	**Confluence with North Nashua River, Lancaster to confluence with Squannacook River, Shirley/Groton/Ayer**	**14.2 miles**	**-Nutrients -Taste Odor/Color -Turbidity**
Nashua Mainstem	**MA81-06**	**Confluence with Squannacook River, Shirley/Groton/Ayer to Pepperell Dam, Pepperell**	**9.5 miles**	**-Nutrients -Organic enrichment /Low DO noxious aquatic plants -Turbidity**
Nashua Mainstem	**MA81-07**	**Pepperell Dam, Pepperell to New Hampshire state line, Pepperell/Dunstable**	**3.7 miles**	**-Nutrients -Turbidity**

The watershed is unique in providing drinking water to two-thirds of the residents of Massachusetts, through the formation in 1905 of the Wachusett Reservoir on the South Nashua (part of the Massachusetts Water Resource Authority water supply system). This reservoir regulates 115 square miles of the watershed as well as storing water transferred from the Quabbin Reservoir to the west. The Nashua watershed exports 98 million gallons per day of water through this system accounting for 20% of the average annual runoff being transported out of the watershed. Combined with the water withdrawal of 10 mgd by the City of Worcester and 19 mgd from 20 other large community water suppliers, these withdrawals affect water quantity for downstream users, biota, and wastewater disposal. The MDC is required by Massachusetts General Law to release at least 12 million gallons per week (or 1.8 mgd) to the South Nashua River. An inflow/outflow study conducted by Camp Dresser and McKee (2002) indicated an overall net outflow from the subwatersheds in the basin.

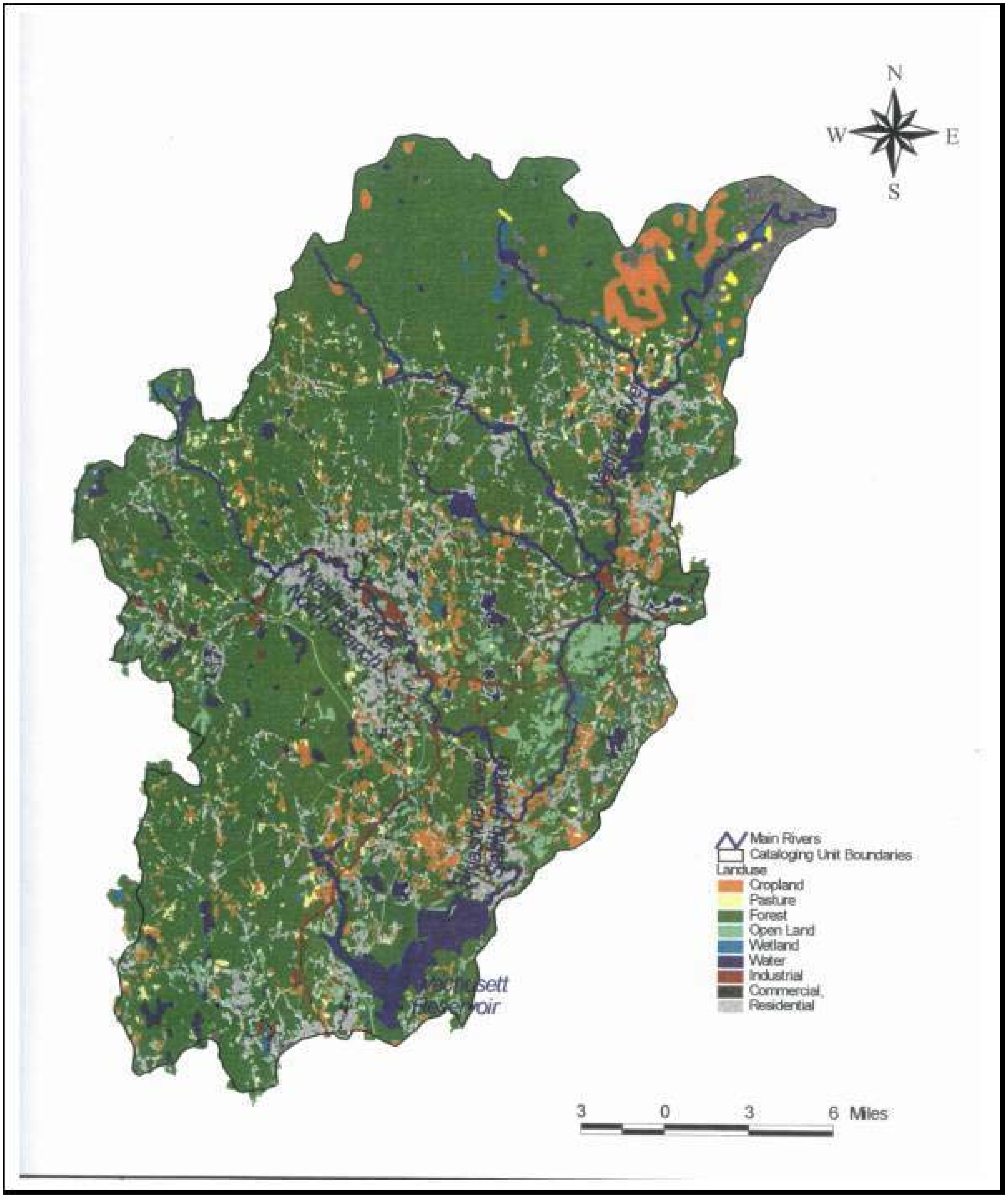
The North Nashua River displays the greatest effect from these river flow reductions and this is especially evident during low flow or 7Q10 periods. A comparison of 7Q10, over the full period of record, with a comparison of 7Q10 over the last 30 years, shows a 10% reduction in flow. The reduction may be due to a combination of increases in water withdrawals together with a reduction in direct flows to the river as the paper mills have closed.

The watershed is also unique as including the former Fort Devens Reservation, a 9,310-acre former military site covering parts of four towns (Ayer, Harvard, Lancaster, Shirley). Although 4,830 acres in the South Post are currently retained by the Army, the remainder of the North and Main Posts are under a ReUse and Development Plan. Paper mills, which began operation in the early part of the nineteenth century, are still a part of the economy in Fitchburg and Leominster together with the newer production activities of plastics, fabricated metal products, machinery, and chemical manufacturing. The schematic of the river in Figure 2 shows the two branches of the river, the mainstem, the relative location of the tributaries, WWTFs, flow gaging stations, and water sampling locations.

The North Nashua River is characterized by a series of high dams with a significant drop in elevation along the length of the river, together with inputs from 3 WWTFs and a large number of Combined Sewer Overflows, CSOs. The South Branch of the Nashua River is characterized by a large water supply reservoir and watershed, which serves as the headwaters, and then flows through a small urban area, after which the MWRA wastewater treatment plant in Clinton discharges downstream of the town area. The Nashua River mainstem is characterized by low relief, significant wetlands, and long stretches through which the river flow is slowed significantly. The final recipient of all watershed inputs is Pepperell Impoundment, a 3-mile river stretch, which is a shallow low flow area with a large number of side embayments, and characterized by extensive coverage of surface algal mats and subsurface macrophytic biomass. Appendix A lists land use and Appendix B discusses the CSOs, important aspects to understand the watershed system.

Land use in the Nashua watershed was characterized by TetraTech as part of the USEPA BASINS (Better Assessment Science Integrating Point and NonPoint Source Pollution) project in 2000 and is displayed in Figure 1. The land use is a mixture of rural development, strip malls, urban areas, with a large portion of undeveloped areas of privately owned open spaces. Distribution is as follows: Forested 65%, Residential 12%, Cropland and Pasture 9%, Industrial and Commercial 3%, and the remaining as 11% Open Water, Wetland and Open Land. The land use analysis developed by the USEPA/TetraTech project, based upon aerial photography from 1990-1992, shows the distribution of land use in Figure 1.

Figure 1: Nashua River Land Use Map Prepared by TetraTech



A schematic showing the relative locations of WWTFs, impoundments, and sampling stations and maps showing major towns, tributaries, and WWTFs are shown on the following pages.

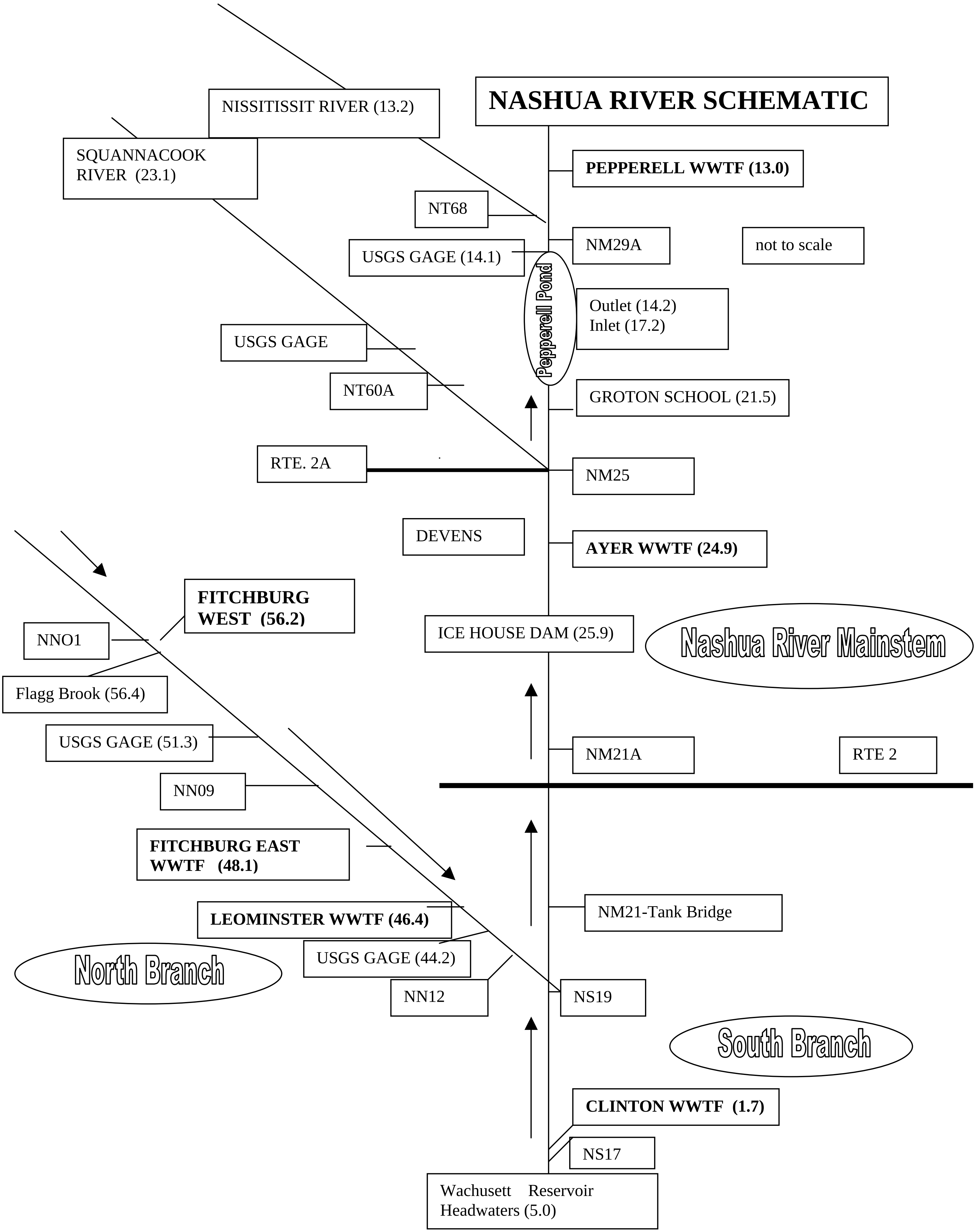
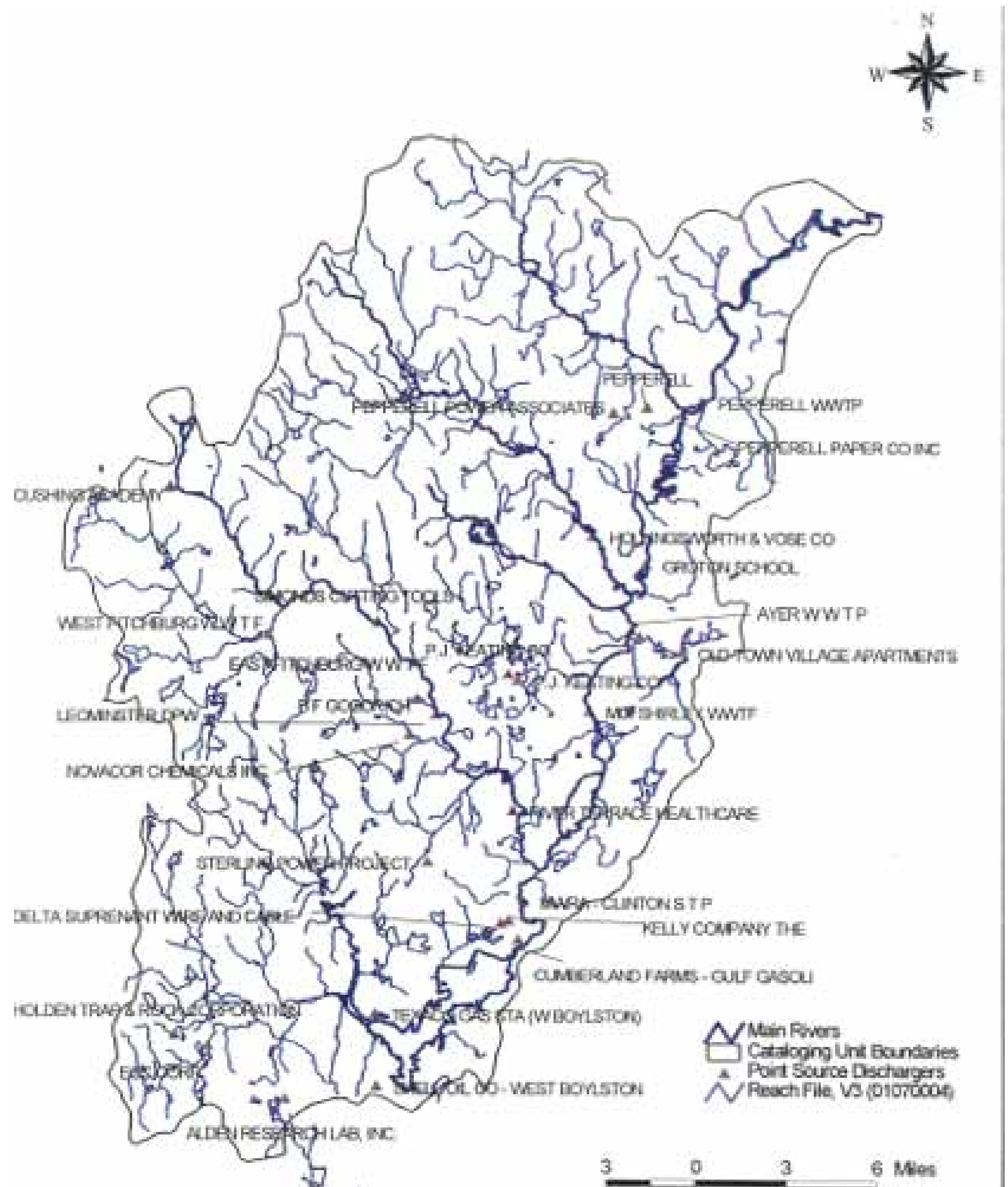


Figure 2: Nashua River Schematic

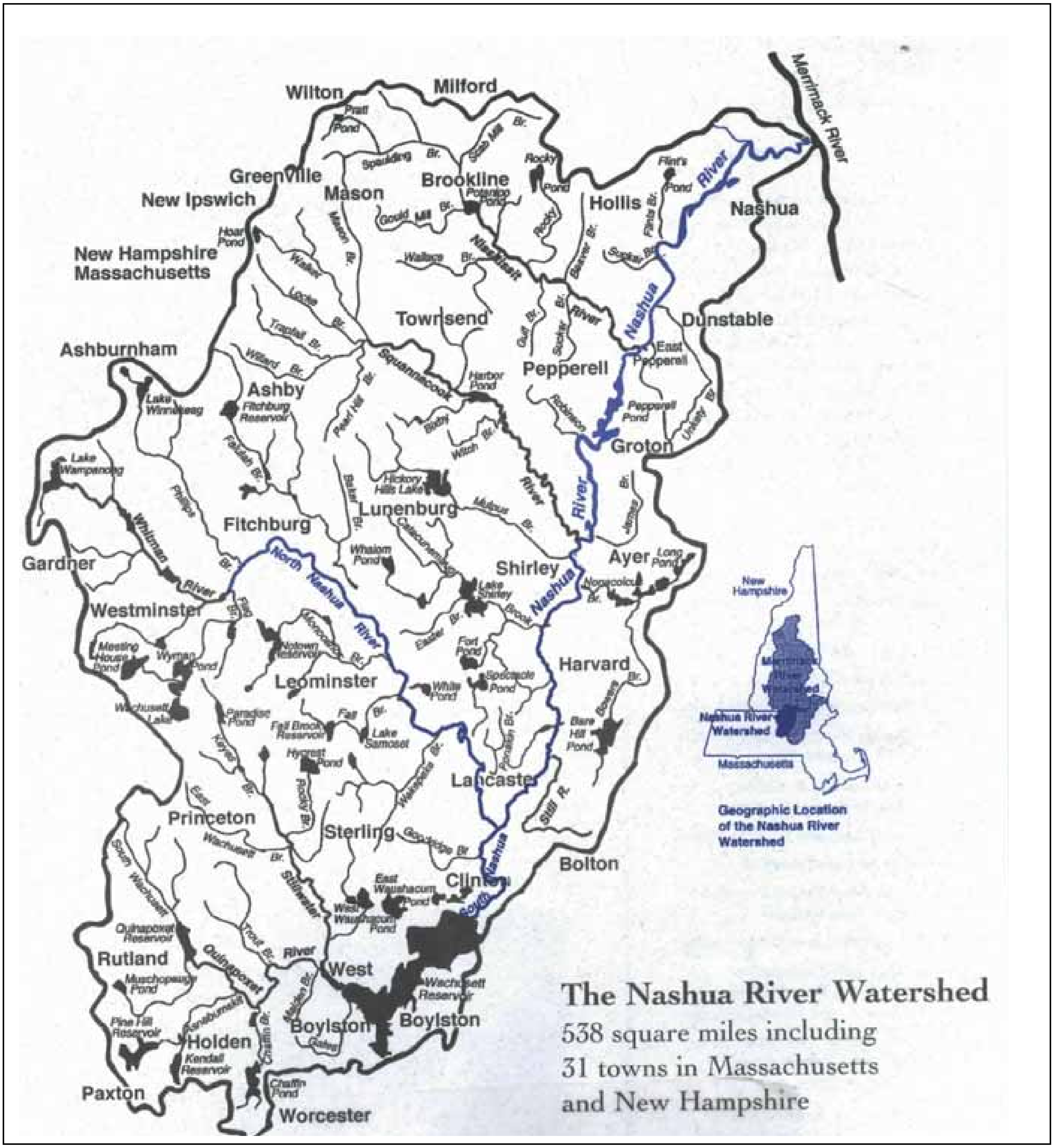
Not to Scale River milepoint listed in parentheses

Figure 3: Nashua River Locus Map for WWTFs and Tributaries



Permit Compliance System Nashua River Watershed	Map Projection State Plan 1983 Massachusetts Data Sources MADEP NPDES Dischargers

Figure 4: Nashua River Watershed Towns and Tributaries
(map prepared by Nashua River Watershed Association)



Priority Ranking

The Nashua River was selected as one of the first rivers on which to develop a complex TMDL as indicated in the State of Massachusetts Total Maximum Daily Loads (TMDL) Strategy, April 1, 1998. The strategy selected one watershed as a pilot project to better define data collection needs and TMDL development procedures for specific pollutants of concern. The strategy created two categories for TMDL development. The categories were based upon availability of technical methods for development of TMDLs for the pollutants of concern. The Nashua River meets Category A: Technical Methods Considered Well Developed for nutrients and organic enrichment, based upon the availability of models such as HSPF or QUAL2 which can be utilized to link the concentrations of specific inputs to water quality instream.

Based on the Integrated List, nutrients and bacteria are by far the single most widespread pollutants responsible for the majority of impairments in the Commonwealth. Thus, MassDEP has given these a high priority for TMDL development.

Monitoring and Data

The MassDEP in conjunction with the USEPA, the Nashua River Watershed Association, and the municipal dischargers, initiated in 1998, a one-year comprehensive study of the water and sediment quality and toxicity, the municipal wastewater effluent quality, and biological assessments, including macroinvertebrate and fish tissue sampling. This sampling and assessment are detailed in Appendix C (Part 1- Sampling Program, and Part 2 - Results) to this report and was structured to provide the information necessary to HSPF model development. The data were used to evaluate changes in the watershed since the 1970s when the first wasteload allocation was completed for the Nashua River. The data were also used to identify problem areas, which needed to be addressed. The comprehensive 1977 MassDEP survey was used as the historical comparison.

The MassDEP has an on-going bimonthly monitoring program in the watershed at 5 selected stations, which were also monitored during the intensive 1998 program. Appendix C Part 2 tabulates the data from these 5 stations for 1999 and 2000 as part of model development and use. Additionally, some mainstem and tributary sampling was conducted in the watershed in 2003 to provide updated information on tributaries and in 2004 to provide additional diurnal measurements. The NRWA volunteer monitoring program also continues with work under an approved Quality Assurance Program Plan. A full description of their program and data is available on their website. (http://www.nashuariverwatershed.org/)

Water Quality Data

Water quality sampling results from 1998 and 2003 indicated no dissolved oxygen levels below minimum water quality criteria, with DO levels above 6.5 mg/l during the morning surveys at all stations. Percent saturation values were all below 100% (between 70-90%), with NS17 on the South Branch and NM21 and NM21A on the mainstem showing the lowest values (between 70-75%) for the 11 water quality stations. (Station locations are displayed on the schematic in Figure 2. However, diurnal dissolved oxygen from the diurnal samplers showed characteristic diurnal cycles with elevated levels during the day, and lower levels at night. No night values were below the 5 mg/l dissolved oxygen criteria. Percent saturation showed a large swing to above 175% in Pepperell Pond. pH values for most of the watershed were all within standards range with the exception of NT60A (Squannacook River) where levels were observed in the low 6 range. The pH values also showed the diurnal fluctuations characteristic of productivity. Conductivity values at some stations showed elevated values on the North Nashua at NN9, NN12, and the Nashua mainstem at NM21, NM29A (above 250 umhos/cm) indicating effects of urbanization.

The volunteer monitoring data for 1998 collected by the Nashua River Watershed Association was comparable with the 1998 MassDEP data. The NRWA data showed only one excursion for dissolved oxygen below the water quality standards on the mainstem. The percent saturation showed fluctuations above 100% indicating effects of eutrophication. In comparison, the NRWA data for 1997 showed a number of samples below the water quality standards, with the lowest values in August close to 7Q10 coinciding with consistently low summer flows all summer. Base flows during 1997 were very low with little rain. Annual QAPP's have been prepared by NRWA (NRWA, 2007).

In general, 1998 flows were higher, about twice 7Q10, and very close to the August 1977 flows. The 1977 flows were used in the calibration of the original 1970s model. The 1996 flow values were also very low. Instream sampling by the Clinton WWTF above the facility showed low concentrations of dissolved oxygen, at 3-4 mg/l.

The 1998 data was used to calibrate and verify the HSPF and QUAL2 models.

The water quality of the South Branch of the Nashua River, downstream of the Clinton treatment plant, showed elevated phosphorus and nitrate levels. The water quality above the treatment plant showed elevated nitrate levels. The effect of the June, 1998 rains were significant on total phosphorus levels in the South Branch of the Nashua River.

The upper reaches of the North Branch of the Nashua River showed good water quality. However, at station NN9 above Fitchburg East on the North Nashua some parameters were elevated. Suspended solids, phosphorus, and nitrate showed some effects from the Fitchburg area, but the water quality would still be considered good. At station NN12 on the North Nashua just above the confluence with the mainstem, the cumulative effects from the Fitchburg and Leominster areas showed instream elevated levels of chlorides to 50-60 umhos/cm, suspended solids of 3-7 mg/l, turbidity values of 1-2 mg/l, ammonia levels of 1-5 mg/l, and nitrate levels of 2-5 mg/l. Total phosphorus levels were high at 0.1-0.2 mg/l, but were much less than those levels measured in the South Branch of the Nashua River below the Clinton WWTF.

Overall, good water quality was measured in the Nissitissit River even after the high rains in June 1998. Phosphorus levels were very low in this tributary, less than 0.01 mg/l at all times. The Squannacook River also displayed good water quality in June, although the nitrate and chloride levels were generally higher than in the Nissitissit River. Phosphorus levels were still very good with most being less than 0.02 mg/l.

Sediment Oxygen Demand Data

Of the five cores taken at each of the 8 stations, SOD ranges were from a low of 0.18 g/m^2/day at Tank Bridge on the mainstem to a high of 3.13 g/m^2/day at the Pepperell Pond impoundment. Average values from the USEPA manual are shown in the following list (Reckhow, 1980). A comparison of the data in this list with the measured data indicate a high level of enrichment in Pepperell Impoundment.

USEPA SOD Values

- WWTF outfall 6 $g/m^2/day$
- WWTF downstream 1.5 $g/m^2/day$
- Sandy soils 0.5 $g/m^2/day$
- Mineral soils 0.07 $g/m^2/day$

Macroinvertebrate and Habitat Data

Sampling indicates moderate improvements in the Nashua River and tributaries since 1985 at most sites. On the South Branch, the health of the aquatic community downstream of the Clinton WWTF has improved. Station NS19, below the Clinton WWTF, improved from the 1977 description of a grayish color, a septic odor, with macroinvertebrates consisting mostly of worms and chironomids, to good water clarity and no odors, no worms, and more diversity, with clean water organisms and chironomids in 1998. The community at NS17, above the Clinton WWTF, has also improved in diversity although still impacted.

Station NN09 on the North Branch showed improvement but still moderate impairment due to the combined effects of effluents and urban runoff. North Branch station NN03, the most upstream station, improved from a slime covered bottom in 1977 with a community of mostly chironomids, to a site with only sparse algal coverage and no obvious sludge deposits, and a community mostly of clean water organisms with more diversity. North Branch, station NN10/10A showed a shift to more diversity although the station still shows some negative affect.

In 1998, stations NM23B and NM29 on the mainstem had sewage odors and extreme turbidity, with moderately impacted communities. Station NM30, also on the mainstem showed some improvement in diversity although also still impacted.

WWTF Sampling

Water quality sampling conducted by the Nashua River Watershed Association in 2000 for instream phosphorus levels, above and below the treatment plants, provides additional data to document relative changes to phosphorus levels in the water column as seen in Figure 5. These data showed the instream levels of phosphorus increased downstream of the Ayer, Clinton and Pepperell WWTFs. These facilities did not have phosphorus removal at the time of the sampling.

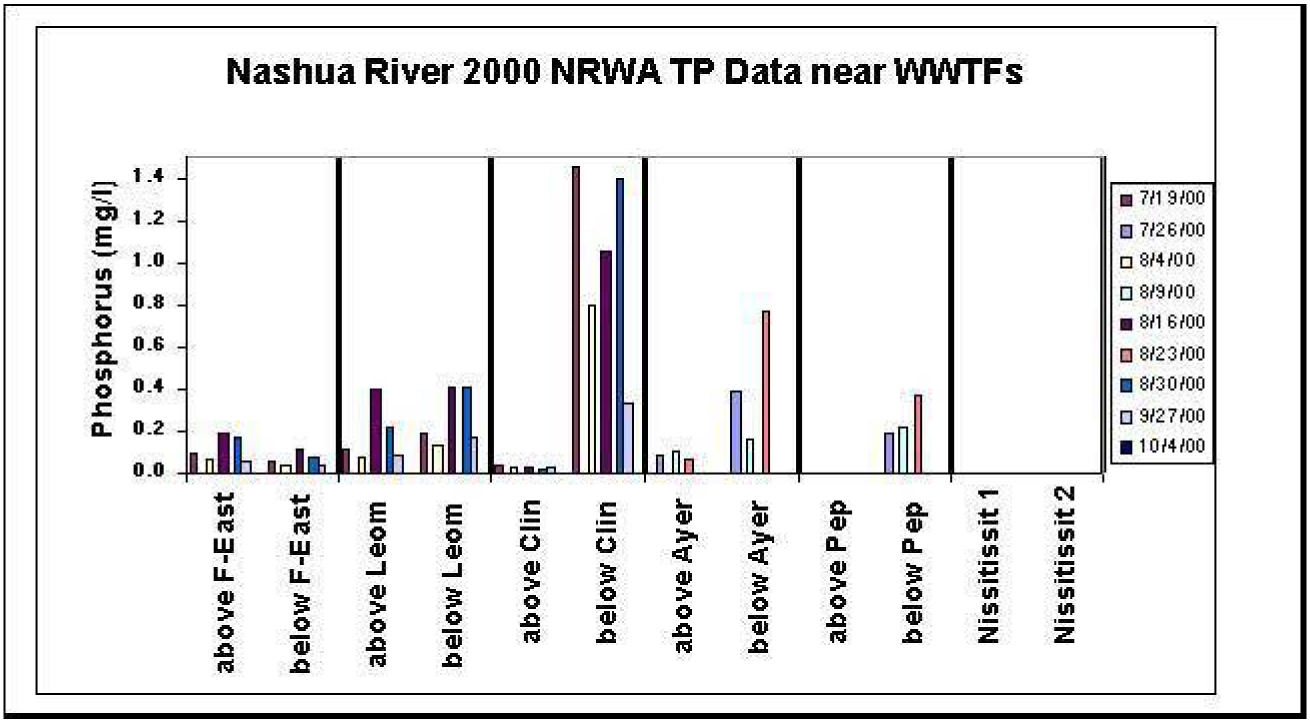
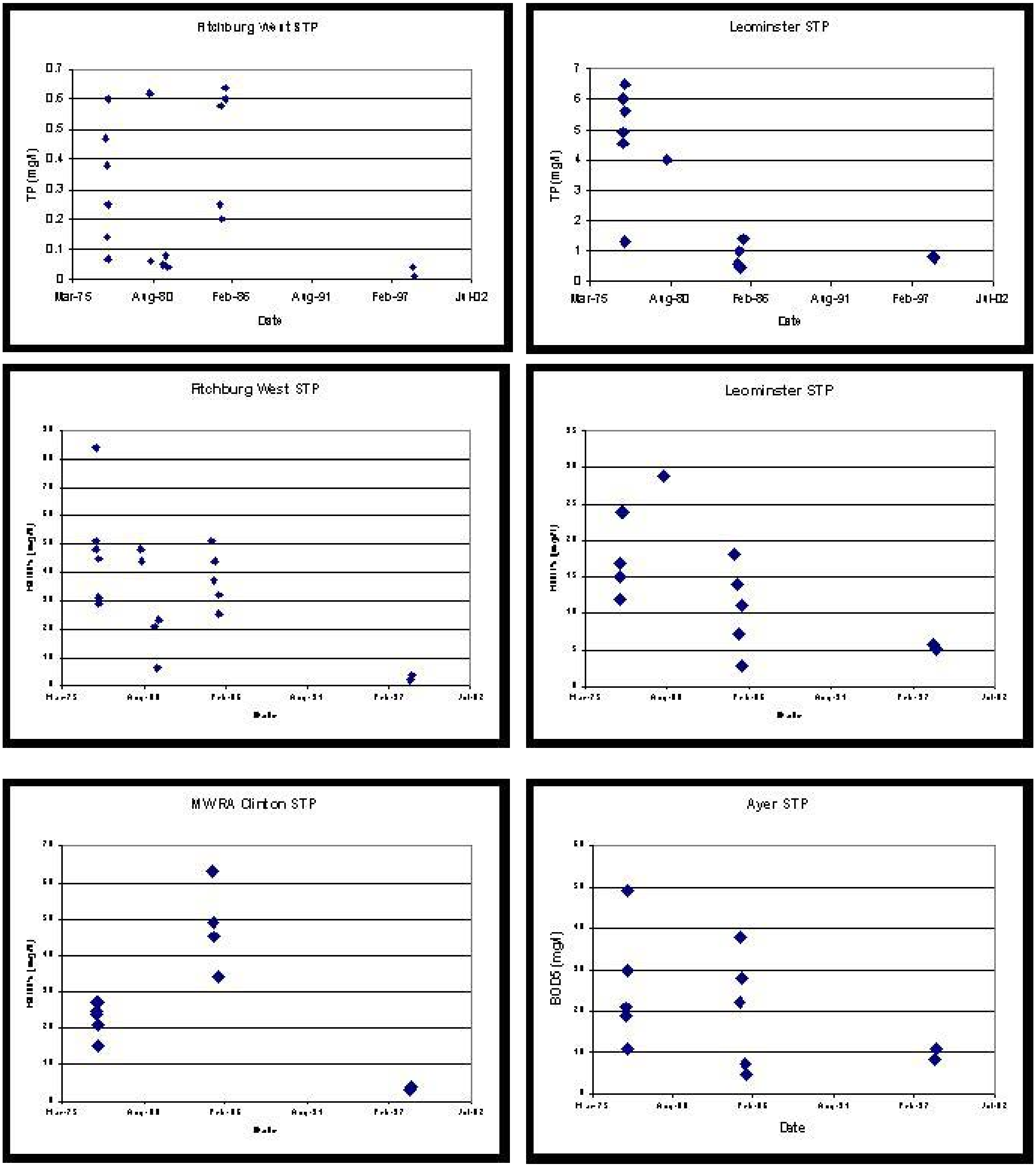


Figure 5: Nashua River 2000 NRWA TP Data near WWTFs

The USEPA also conducted direct effluent testing of the WWTFs during 1998-1999. Effluent data showed phosphorus levels from the Clinton WWTF between 1-4 mg/l, and Ayer WWTF levels around 2-3 mg/l. The Fitchburg East, and Leominster WWTFs had phosphorus levels below 1 mg/l during the summer, with the levels discharged from the Fitchburg West WWTF (not shown) being below 0.1 mg/l. The Clinton WWTF and the Ayer WWTF did not have phosphorus limits in their NPDES permits prior to 2000 and therefore the levels of phosphorus in the effluent were much higher than the other facilities during the 1998 surveys. Levels of ammonia from the Fitchburg West WWTF ranged between 0.8 mg/l to 3.9 mg/l. The Fitchburg East ammonia levels were 0.5-2.0 mg/l. This is important in the effect on the oxygen levels downstream, as instream nitrification will lower the DO as the ammonia is oxidized to nitrate.

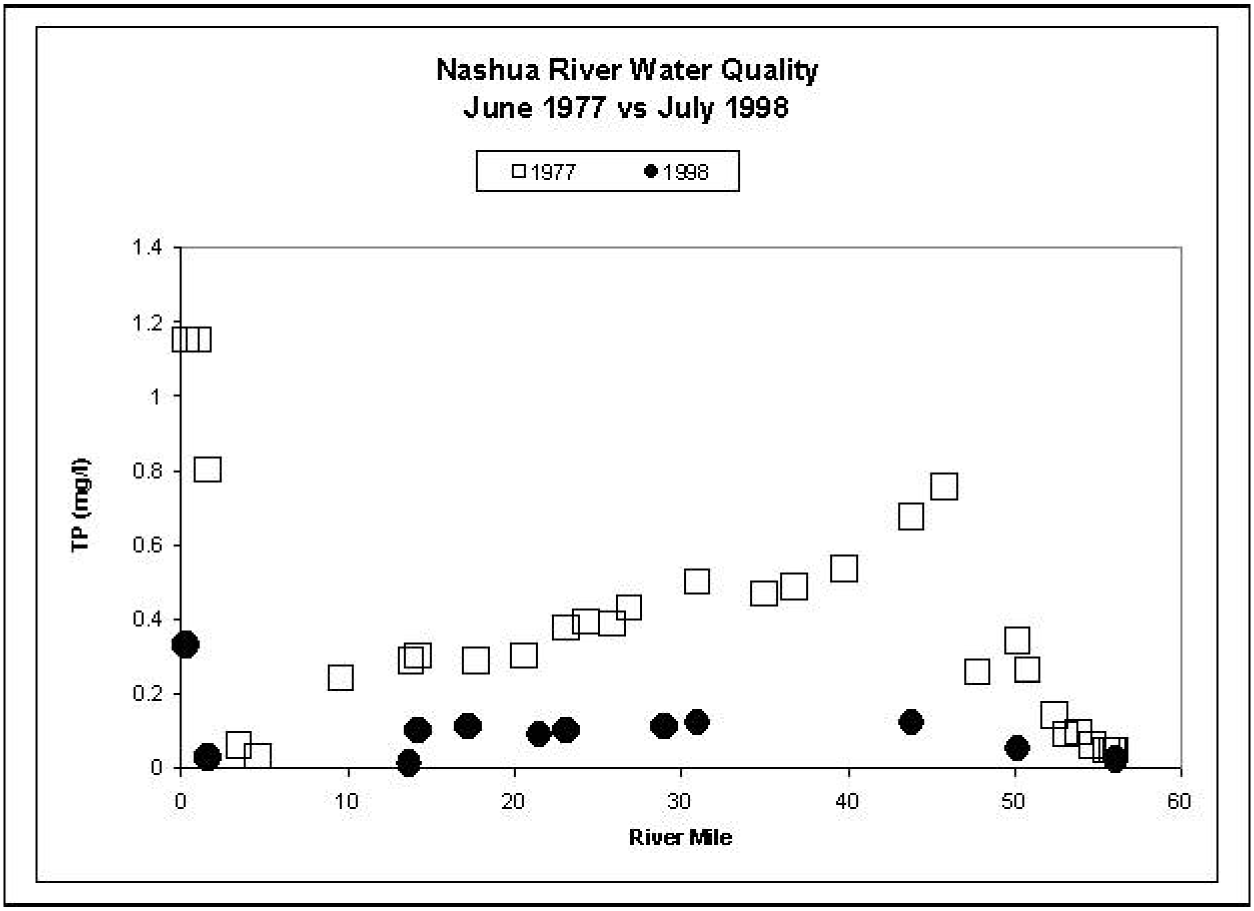
A comparison was made between the 1977 and the 1998 effluent and instream water quality. These years were used in the building and calibrating of the models as they were the most extensive data sets and provided a wide variability in loads. The data showed that changes in the NPDES permit effluent discharges during that time period, have produced significant reductions in the discharge of solids, nutrients, and BOD at all 5 wastewater treatment facilities, including reductions in total phosphorus from the Fitchburg East and Leominster WWTFs. Figure 6 shows examples of the decrease in effluent concentrations between 1977 and 1998 for four of the facilities, the Fitchburg West WWTF, Leominster WWTF, Ayer WWTF and the MWRA Clinton facility.

Figure 6: Comparison of historical with 1998 WWTF Effluent Data



These reductions in effluent loads have translated into measurable reductions in instream water constituent concentrations for the entire river. Figure 7 shows the reductions in instream total phosphorus over the last 30 years.

Figure 7: Nashua River Water Quality June 1977 versus July 1998



Problem Assessment

The Nashua River is identified in the 303(d) listing and the Massachusetts Year 2004 Integrated List of Waters as consisting of 3 mainstem segments, plus 4 segments which comprise the North Branch and 1 segment which comprises the South Branch of the Nashua River. (See Table 1 for the current impairment listing). This TMDL is focused on the 7 segments comprising the North Branch and the mainstem Nashua River. On the mainstem this includes the 3 segments for nutrients, 1 of these mainstem segments also for organic enrichment and dissolved oxygen, and 1 of these mainstem segments for noxious aquatic plants. TMDLs for the 4 segments of the North Nashua were included and are considered a protective TMDL for nutrients. This TMDL addresses a total of 5 impairments all in the 3 mainstem segments.

The river has had a long history of pollution problems associated with both industrial and municipal discharges. Water quality has improved significantly over the last 30 years due to reductions in effluent flows and concentrations from these facilities based upon an early wasteload allocation performed by the MassDEP (Johnson, 1980). During the last couple of decades, the river has been transformed from being one of the worst rivers in Massachusetts, due to excessive suspended solids, organic matter, and pigments and dyes from the paper industries, and inadequate sewage treatment, which raised bacterial levels, solids, and nutrients instream, to one which supports a variety of aquatic life. However, water quality issues and eutrophication due to excessive concentrations of phosphorus are still present in these segments. Additionally, combined sewer overflows (CSOs) in Fitchburg and Leominster, and high bacteria concentrations in the North Nashua, along with metal and toxicity issues are also still prevalent.

As discussed earlier, field investigations of the Nashua River system were conducted by the MassDEP with assistance from the USEPA and the Nashua River Watershed Association during 1998, 2003, and 2004. The field investigations collected data on the hydrology and water quality of the Nashua River with the goal to document current water quality conditions as compared with historical water quality conditions and associated factors in the Nashua River in order to provide the data necessary to model the river using HSPF12. Nutrient loadings and dynamics in the Nashua River were a primary focus of the investigation.

Results of the field investigations confirmed that the Nashua River receives an excess of the nutrients, in the form of available phosphorus, resulting in nutrient saturation and excessive growth of algal mats and other aquatic vegetation. The river system currently displays impacts of increased eutrophication as the mainstem of the river slows in the Ice House Impoundment and Groton School areas and substantially slows as it travels through the most downstream impoundment in Massachusetts, Pepperell Impoundment (Figure 8). Historically, a dissolved oxygen sag has been observed in the slow moving and impounded areas of the mainstem.

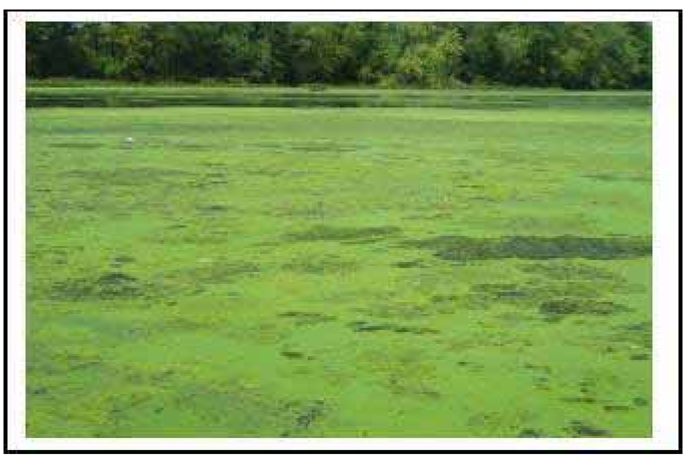


Figure 8: Pepperell Pond Surface Mats

Pepperell Impoundment is the final area of accumulation of all of the inputs from the full watershed. Impacts are displayed in increased levels of algal mats and macrophytic biomass creating issues for aquatic life, swimming, boating, and safety in the impoundment. Impacts are also shown in super-saturation of dissolved oxygen, increased diurnal dissolved oxygen swings, and in chlorophyll biomass as evidenced in the photos of the impoundment. The modeled chlorophyll_a level, rather than the field measured water column levels, more accurately reflect the presence of algal mats and macrophytes through predicted summer chlorophyll_a values. The field measured values are from water samples taken below the surface algal mats and therefore do not include those blooms. The field measured values do not include samples from the macrophytes. Through the model, attempts were made to accurately model dissolved oxygen by reflecting the effects of chlorophyll generated in the water column, the surface algal mats and the macrophytes.

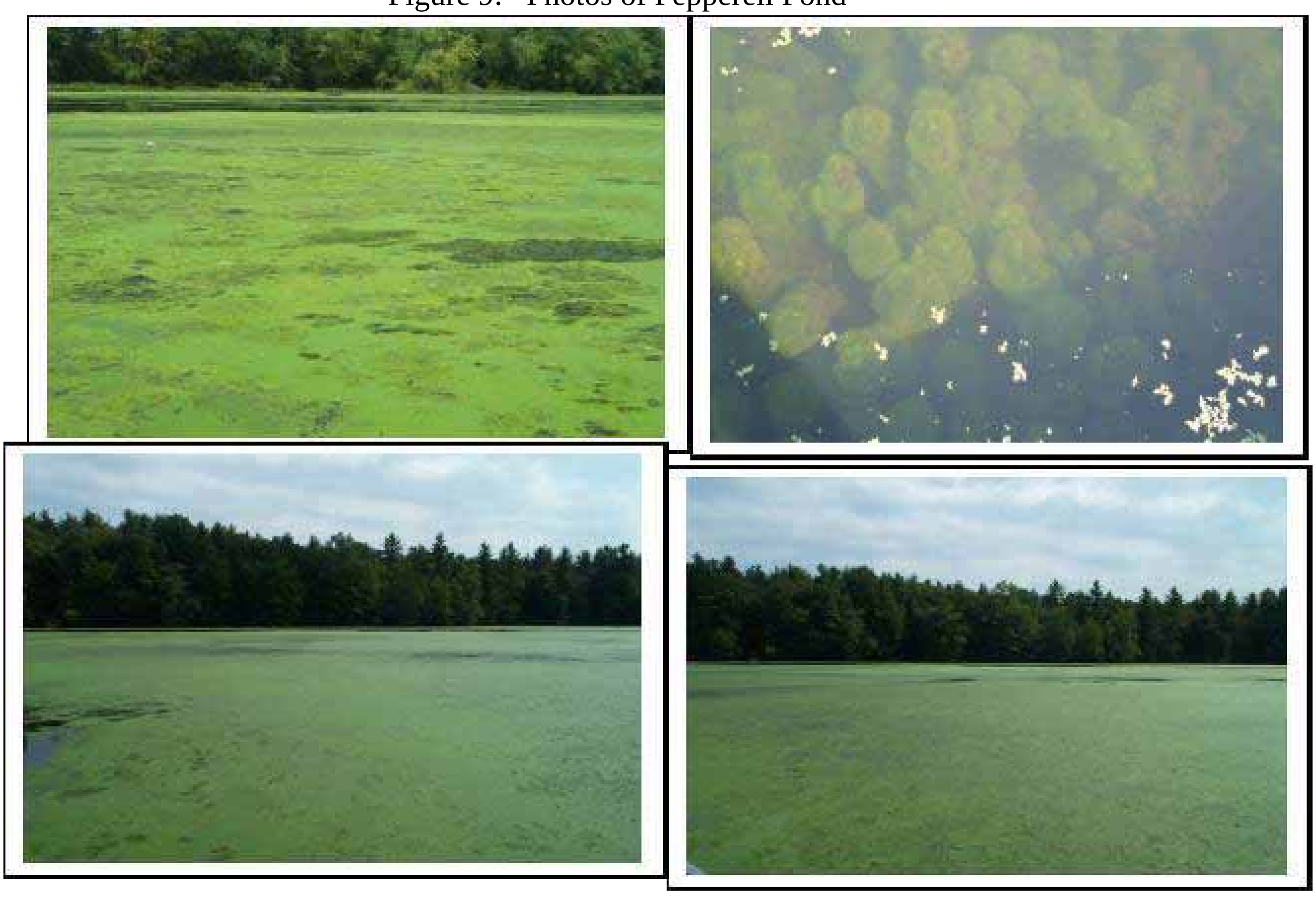
During the surveys the upper areas of the river did not display high levels of aquatic biomass, due to the faster velocities. These higher velocities in the upper reaches do not allow algae to accumulate. However, once the velocity slows and the river deepens near Ice House Impoundment, Groton School, and Pepperell Impoundment these segments then serve as a catch basin for all the nutrients discharged above.

The river shows effects of nutrient enrichment through a number of response variables including chlorophyll_a and biological productivity as evidenced in the photos of the impoundment, through super-saturation of dissolved oxygen measured in the impoundments as shown in the graphs, and through large swings in diurnal dissolved oxygen also graphically presented. These response variables will be used in a weight-of-evidence management approach tied to the phosphorus levels.

Chlorophyll_a and Biological Productivity

Due to the high phosphorus loading and the effects of the slower moving water in the river impoundments, the river is experiencing excessive accumulations of Lemna species and dense algal mats which often cover the river's surface, as seen in the photos of Pepperell Pond. Also evident are the abundant rooted macrophytic growth, which may be more a result of the pond being a shallow flooded meadow susceptible to high plant growth. Excessive growths of macrophytes are detrimental to primary and secondary contact recreation. During the summer season, these excessive plant and algal populations lead to large swings in DO resulting in supersaturation.

Figure 9: Photos of Pepperell Pond



Pepperell Impoundment is a large shallow flooded meadow in which river velocity decreases and the time of travel through the pond is relatively slow compared with the time of travel in the river stretches of the mainstem. Pepperell Impoundment is the final location to which all of the inputs from all the upstream reaches of the watershed ultimately flow. As seen in the photos, the impacts include surface coverage with algal/macrophyte mats and bottom coverage by macrophytes, all creating impairment for aquatic life, swimming, boating, and safety in the impoundment. These factors allow the full extent of nutrient loads, which enter the river system from the point sources and the watershed, to have the opportunity to be expressed as plant mass.

Water column cholorphyll_a sampling was conducted along with algal community analyses at selected sites during the summers of 1998 and 2003. The data show a dominance of the green algae in the outlet to Pepperell Pond, which, with the elevated chlorophyll values, indicate that this portion of the river is eutrophic. The upstream Groton School area and Ice House Impoundment, are also large stretches of slowing moving reaches just upstream of Pepperell Impoundment. These two areas had more diatoms and flagellated genera, with a dominance of sewage fungus colonization the Groton School site. Sewage fungus are indicative of areas with organic enrichment and appear as slimy growths of microcorganisms which may include filamentous bacteria, fungi, and protozoa such as *Sphaerotilus natans, Leptomitus lacteus,* and *Carchesium polypinuym*, respectively.

The excessive level of eutrophication is further documented by the super-saturation of dissolved oxygen measured in the impoundments, through large swings in diurnal dissolved oxygen, and through the chlorophyll biomass as evidenced in the photos of the impoundment.

These response variables are being used in the weight-of-evidence approach for this TMDL.

Chlorophyll_a data collected during the summer of 1998 (the year selected for calibration of the model) indicated low water column levels in the Ice House Impoundment and Groton School area, with a sharp increase in Pepperell Impoundment. This was replicated in the 2003 data. However, the instream chlorophyll_a levels were measurements of water column algae and did not include algal and macrophytic masses floating on the surface of the pond or plant masses rooted in the sediments. Therefore, although these water column numbers are not high, the visual inspection of the Pepperell Impoundment area readily shows heavy nutrient enrichment as documented in the photos. These summertime vegetation densities were observed to be at levels associated with impairment of water quality and designated uses such as secondary recreation and aesthetics. Large surface algal and macrophytic plant masses made boat passage difficult and swimming unsafe.

A method was needed which could provide relative levels of all of the chlorophyll_a that exists in the surface mats, in the water column chlorophyll, and in the bottom macrophytes in order to compare each of the wastewater treatment plant effluent scenarios. The HSPF model was the method selected. The model provides a sum of the water column chlorophyll, the surface algal mats, and the macrophytic chlorophyll. The field measured water column chlorophyll_a values are from water samples taken below the surface algal mats and therefore do not include those blooms. Neither do the field measured water column values include the chlorophyll from the macrophytes. Therefore it is important to utilize a tool such as HSPF, which predicts relative levels of chlorophyll_a from all sources, including surface mats, water column, and macrophytes in order to compare the scenarios. The modeled chlorophyll_a level, rather than the field measured water column levels, more accurately reflect the presence of these algal mats and macrophytes through predicted summed chlorophyll_a values.

In order to understand this situation Table 2 compares the July and August 1998 chlorophyll levels. Ice House Impoundment, the Groton School area, and the inlet to Pepperell Pond all had lower measured levels of water column chlorophyll_a that did not include the algal mats and macrophytes. The sampling location near the outlet of Pepperell Pond had levels indicating increased eutrophication but none of these values reflected all the biomass composed of the surface algal blooms and duckweed, and the dense macrophyte community on the bottom. The HSPF model was the method utilized to integrate these three sources of chlorophyll, and this integration is reflected in the model's output. (The HSPF model was calibrated to reflect dissolved oxygen values including diurnal DO, which was driven by the biomass and chlorophyll levels.) Future mapping and tracking of surface algal mats, macrophytes and duckweed would be more representative of actual conditions and should be conducted as part of the monitoring program to track changes.

Table 2 1998 Nashua River Chlorophyll_a Levels (ug/l)

	July	August
Ice House Impoundment	**5.8**	**3.4**
Groton School	**1.3**	**2.4**
Inlet Pepperell Pond	**3.1**	**3.2**
Outlet Pepperell Pond	**10.1**	**19.6**

Diurnal Dissolved Oxygen and Percent Saturation

The effects of the excess level of nutrients on dissolved oxygen cycles and supersaturation levels is shown in the following graphs for the Groton School area and for the inlet and outlet of Pepperell Impoundment. The graphs show diurnal percent saturation values within range for the Groton School area and for the inlet to Pepperell Impoundment. However, as the water traveled through Pepperell Impoundment, greater ranges of saturation values were seen, with values exceeding 175% indicating the presence of very high levels of chlorophyll generating excessive levels of oxygen.

A closer look at the dissolved oxygen diurnal patterns for the outlet area of Pepperell Impoundment exhibited the expected day to night ranges, these ranges were as high as 6.5 mg/l with maximum DO values close to 16 mg/l and corresponding cycling of pH. These diurnal swings are the result of increased biological activity in the impoundment. The graph for Groton School is shown for comparative purposes and displays expected values in a relatively non-impacted river system. Diurnal measurements in 1998 showed no concentrations below the water quality standard of 5 mg/l in 1998. The daytime super-saturation prevented levels from falling below standards.

In follow-up efforts to assess diurnal variation in dissolved oxygen concentrations, the USEPA again deployed recording monitors in two locations during August 2-6, 2004. Both stations in the mainstem of the Nashua River (Groton School dock and Pepperell Pond) met the Massachusetts water quality standards for minimum dissolved oxygen, pH and temperature (Figures 10-13). However, large diurnal swings of dissolved oxygen were again seen in Pepperell Impoundment indicating excessive levels of nutrient induced eutrophication, with percent saturation values reaching to 138%.

Figure 10: Nashua River 1998 Percent Saturation (based upon data collected by USEPA)

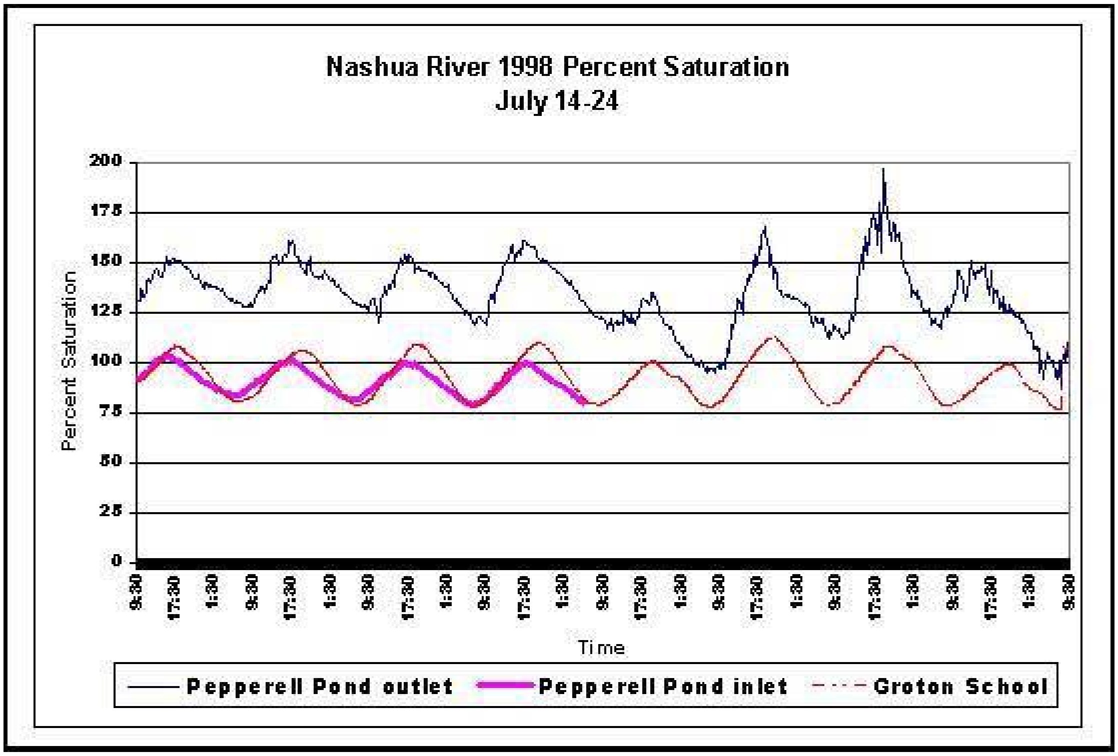


Figure 11: Nashua River 1998 Pepperell Pond Outlet DO, pH, Temperature
(based upon data collected by USEPA)

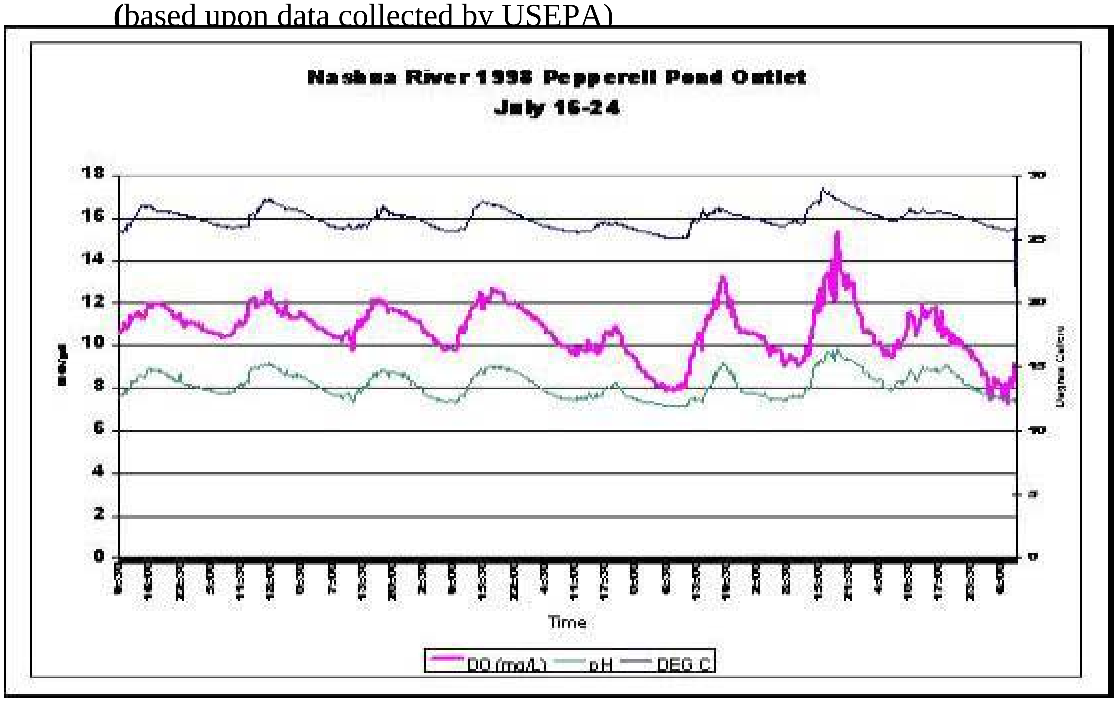


Figure 11: Nashua River 1998 Groton School DO, pH, Temperature
(based upon data collected by USEPA)

Figure 12: Nashua River 1998 Groton School DO, pH, Temperature
(based upon data collected by USEPA)

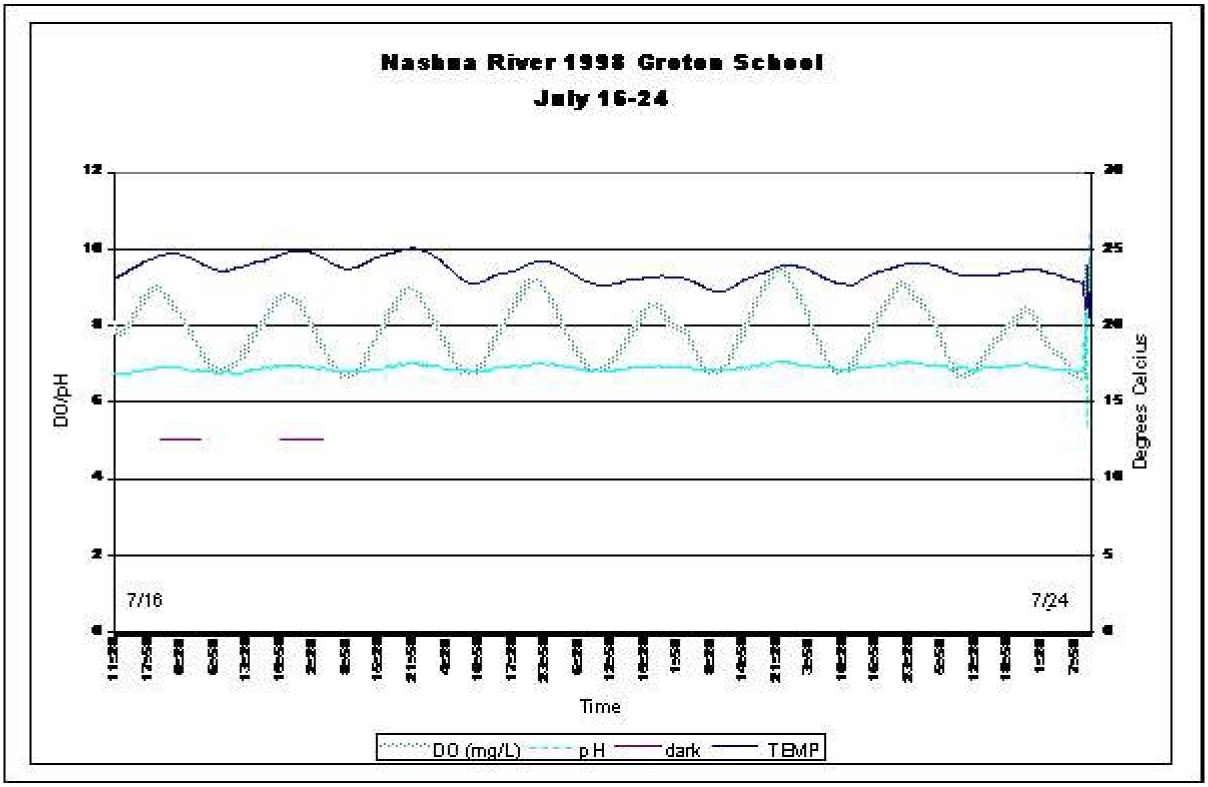
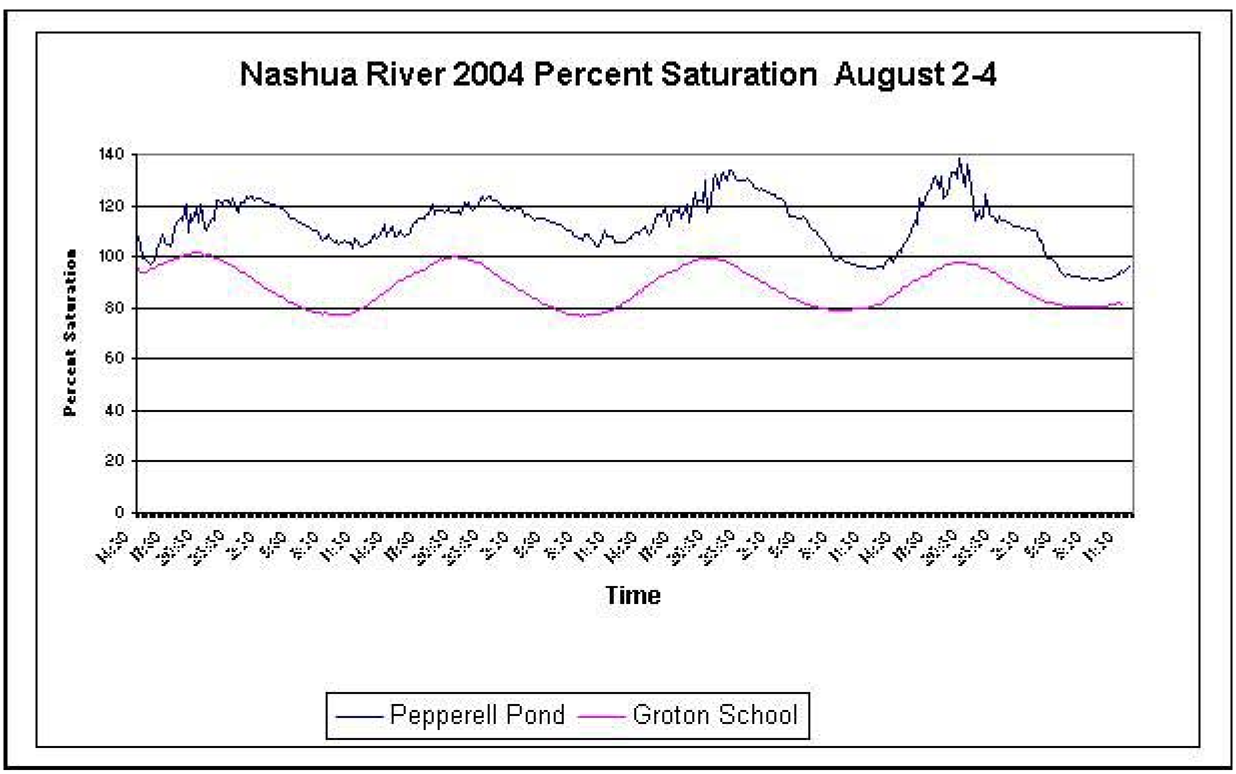


Figure 13: Nashua River 2004 Percent Saturation
(based upon data collected by USEPA)



Pollutants of Concern, Pollutant Sources and Controllability

Phosphorus is the pollutant of concern tied to the weight-of-evidence approach for the response variables of diurnal DO, super-saturation of DO, chlorophyll_a and biological productivity. Water quality surveys by the Division of Watershed Management of the Massachusetts DEP, the USPEA, and the Nashua River Watershed Association document in-stream total phosphorus concentrations that greatly exceed minimum growth guidance requirements for aquatic plants.

The sources of this phosphorus could be overland runoff from land use, point sources e.g. WWTFs and CSOs, and sediments. An HSPF model was developed and used to compare the response variables as affected by different levels of the pollutant of concern and the sources of the pollutant of concern.

The HSPF model indicated that phosphorus concentrations have led to excessive growth of floating and rooted macrophytes in the river. The HPSF model documents that point source effluents are the major source of total phosphorus during the low flow summer growth period. As part of the analysis, forested load was compared to total load including point and nonpoint sources in order to determine the relative importance of sources to evaluate controllability of these sources, both for remediation and for the protective aspect of the TMDL. Information from the HSPF model was also used for Margin of Safety (MOS) aspects.

In the determination of controllability, while both phosphorus and nitrogen are nutrients, phosphorus generally is the one judged to be limiting or more easily made so in freshwater. Controlling phosphorus rather than nitrogen also makes sense since phosphorus is easier to remove and some organisms can convert atmospheric nitrogen into a useable form thereby creating a nearly limitless supply (Allan, 1995; NAP, 2000). In the case of the Nashua, not only is the habitat for nitrogen fixation available, but also it is likely enhanced by the presence of duckweed (Lemna) as a host for nitrogen-fixing bacteria and the abundance of available nitrogen discharged from the WWTFs. Therefore it would be nearly impossible to control nitrogen levels and therefore control eutrophication with this nutrient.

Total phosphorus concentrations beyond those expected naturally contribute to undesirable conditions, including the growth of excessive plants and algae, and nuisance vegetation. Potential sources include nonpoint overland runoff, effluent discharges of the wastewater treatment facilities, CSOs and sediments. Appendix A lists by subwatershed, the land area, including the Massachusetts protected land and the total priority habitat, as well as the effluent discharges under the MassDEP NPDES permits program (all sources of phosphorus). Appendix B describes the CSOs in the watershed (another potentially major contributor of phosphorus).

The impoundments themselves also can be a source through contributing nutrients from flooded fertile soils that enable both floating and rooted macrophytes to reach nuisance proportions on they become established. In the Nashua impoundments, the river slows, warms and allows the full use of available nutrients to create conditions suited for algal and plant growth.

Additionally, the importance of overland runoff was considered as potentially important as a phosphorus source. However, the form of phosphorus delivered from overland runoff is not in the more useable and readily available form that can be taken up by plants and algae. The dissolved phosphorus form that comes from the WWTFs is much more readily used. The phosphorus from overland runoff is primarily in the form of phosphorus that needs to be broken down and transformed before it can be used. However, in a system such as the Nashua, it is important to maintain control of this phosphorus and to reduce it as much as possible, in order that any improvements effected through WWTF controls are not lost through uncontrolled development which would result in increased total phosphorus from overland runoff.

Since the potential importance of overland runoff as a source is dependent upon the types of land use in the watershed and the expected levels of runoff from those land uses, the Nashua River watershed land use was evaluated. Land use in the Nashua watershed is a mixture of rural development, strip malls, urban areas, with a large portion of undeveloped areas of privately owned open spaces. A land use analysis developed by the USEPA/TetraTech project based upon previously completed aerial photography from 1990-1992 showed the following distribution of land use (for the Massachusetts portion only). This land use as seen earlier in the map in Figure 1 was then used in the HSPF modeling effort.

Table 3: Nashua River Basin Land Use Distribution

Nashua River Basin Land use Distribution (%)		
Land Use	**Area (Acres)**	**Percent**
Forest	185,165	65
Residential	35,071	12
Cropland	19,014	7
Open Land	14,556	5
Water	11,284	4
Pasture	6,446	2
Industrial	6,332	2
Wetland	4,440	2
Commercial	2,936	1

Source: USEPA & TetraTech (1999)

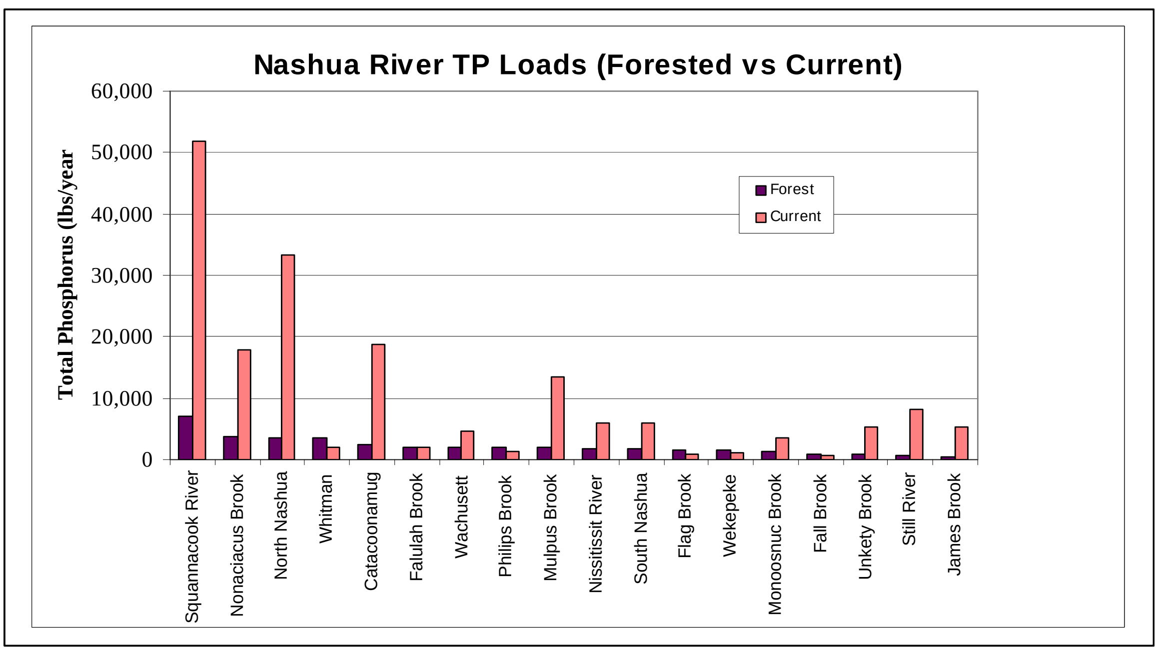
Although the modeling conducted for this TDML used the best available land use at the time of development, concern had arisen that substantial land use changes may have occurred since that analysis and these changes would affect the results of the model. MassDEP GIS evaluated the land use changes from 1985 to 1999 and the changes were found to be minimal as shown in Table 4.

Table 4: Nashua Land Use Changes from 1985 to 1999

Nashua Land Use Changes from 1985 to 1999			
Landuse (%)	**1985**	**1999**	**Difference**
Cropland	5.5	4.9	-0.6
Pasture	2.2	1.8	-0.4
Forest	65.0	62.7	-2.3
Open Land	5.0	5.6	0.6
Residential	12.0	15.3	3.3
Commercial/Industrial	3.3	3.4	0.1
Wetland	1.7	1.9	0.2
Water	4.0	4.0	0.0

As a baseline for determination of land uses as a potential source, a loading analysis was used to calculate total phosphorus loading per subwatershed assuming all the land use were at historical forested levels, prior to any development. A comparison was made of the baseline phosphorus load for an all forested condition with the current phosphorus load. Total load was compared to point and nonpoint source phosphorus loads to provide comparative information for future watershed reduction and protection. Figure 14 shows the increase by subwatershed.

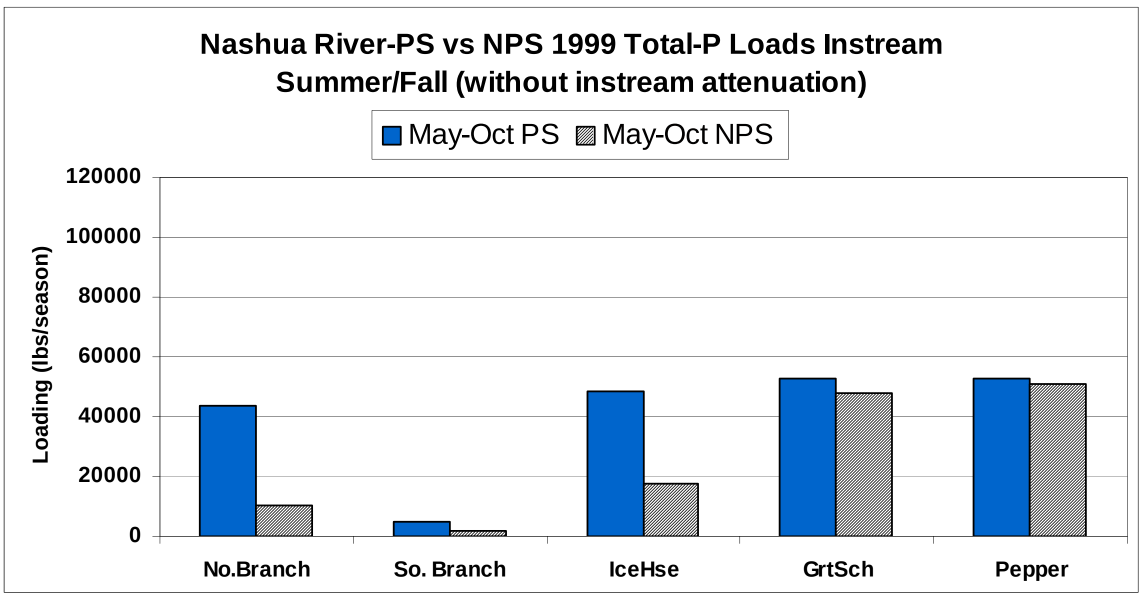
Figure 14: Nashua River TP Loads (Forested versus Current)



Additional analysis of the watershed conducted for this TMDL through GIS and through the HSPF model under present land use conditions showed that the total phosphorus loading was significantly larger in some watersheds, for example Squannacook, Nona, North Nashua, South Nashua, Catacoonamug, Mulpus Brook, Still River, and James Brooks, than under natural conditions.

The HSPF modeling also showed that the most important source of phosphorus loading was primarily from the point sources, i.e.WWTFs, during the summer.   Summer is the critical time for aquatic communities due to instream low flows and higher temperatures. The modeling showed that the higher loads seen in the lower reaches are from the upstream point sources. An additional source is the large watershed of the Squannacook River, however this is a source of phosphorus in a less useable organic form and needs to be broken down prior to uptake by algae and plant. Also, this subwatershed is large and raises the nonpoint source phosphorus load due to watershed size and flow alone rather than increasing the concentration of phosphorus.

Figure 15:   Nashua River Point Source versus NonPoint Source Total Phosphorus Loads



The HSPF modeling showed point sources to be the more significant source of summer phosphorus.   Table 5 summarizes each municipal point source, their permitted flow, typical summer flow, 7Q10 river flow at the point of discharge, dilution factor for the permit, receiving water segments to which those WWTFs discharge, and the downstream segments affected by the discharge, all factors which affect their importance as a source of phosphorus.   Even though a treatment plant does not discharge directly into an impaired river segment, the wasteload allocation modeling has shown that the nutrient and organic enrichment factors from these upstream WWTFs are transported downstream and therefore affect that downstream segment.

Table 5: Municipal WWTFs which discharge above or to the impaired segments

Facility*	**FITCHBURG WEST**	**FITCHBURG EAST (9/2002)**	**LEOMINSTER (9/2006**	**CLINTON (9/2000)**	**AYER (2/2006)**	**Pepperell (2/2005)**
Permit Flow	**10.5 MGD 16.2 CFS**	**12.4 MGD 19.2 CFS**	**9.3 MGD 14.4 CFS**	**3.01 MGD 4.7 CFS**	**1.79 MGD 2.8 CFS**	**1.1 MGD 1.7 CFS**
Typical Summer Discharge	**5.3 MGD**	**5.5 MGD**	**4.7 MGD**	**2.0 MGD**	**1.6 MGD**	**0.46 MGD**
7Q10 River Flow	**2.02 MGD 3.1 CFS**	**17.3 MGD 26.7 CFS**	**22.5 MGD 34.9 CFS**	**1.8 MGD 2.8 CFS**	**30.8 MGD 47.6 CFS**	**29.1 MGD 45 CFS**
Dilution Factor	**1.2**	**2.4**	**3.4**	**1.6**	**18**	**27**
Downstream Segment	**MA81-02&03 MA81-05, MA81-06 & MA81-07**	**MA81-04 MA81-05, MA81-06 & MA81-07**	**MA81-05, MA81-06 & MA81-07**	**MA81-05, MA81-06 & MA81-07**	**MA81-06 & MA81-07**	**NH river segments**
Receiving Water	**NORTH NASHUA Segment 81-01**	**NORTH NASHUA Segment 81-03**	**NORTH NASHUA Segment 81-04**	**SOUTH NASHUA Segment 81-09**	**MAINSTEM NASHUA Segment 81-05**	**MAINSTEM NASHUA Segment 81-07**

*Devens is presently permitted for 3 MGD to groundwater

An important factor to consider in determining the relative importance of the WWTF as a potential source is the percent of effluent flow as compared to allowable permit flow from the WWTFs during the summer. For example, during the summer survey of 1998, the two Fitchburg plants were close to 50% of permitted flow, Clinton was at 66% of permitted flow and Ayer had the highest percentage at close to 90% of permitted flows as seen in Table 6. During the summer, the flows and loads from the WWTFs are significantly reduced from what is allowed under the full permit. Additionally, the instream flows are at their lowest during this time of year and can provide less dilution. During the summer surveyed, only 71% of the allowable load was being discharged and impacts were seen. If the full permitted load were discharged the load would be even greater as seen in Table 6. There would be a significant increase at design conditions of both flow and load as compared to 7Q10. The HSPF model was able to compare effects instream on the response variables from the current source loads with the higher permitted source loads in order to compare present sources to future potential sources. These are discussed later in the TMDL report.

Table 6: WWTF Permit Flows, Average Summer Flows as mgd and percent of permit flows

WWTF Permit Flows, Average 1998 Summer Flows as mgd and percent of total permit flows

	permit	1999 summer	percent
Fitchburg West	10.5	5.3	50
Fitchburg East	12.4	5.5	44
Leominster	9.3	4.7	51
Ayer	1.79	1.6	89
Clinton	3.01	2.0	66
Pepperell	1.1	0.4	36

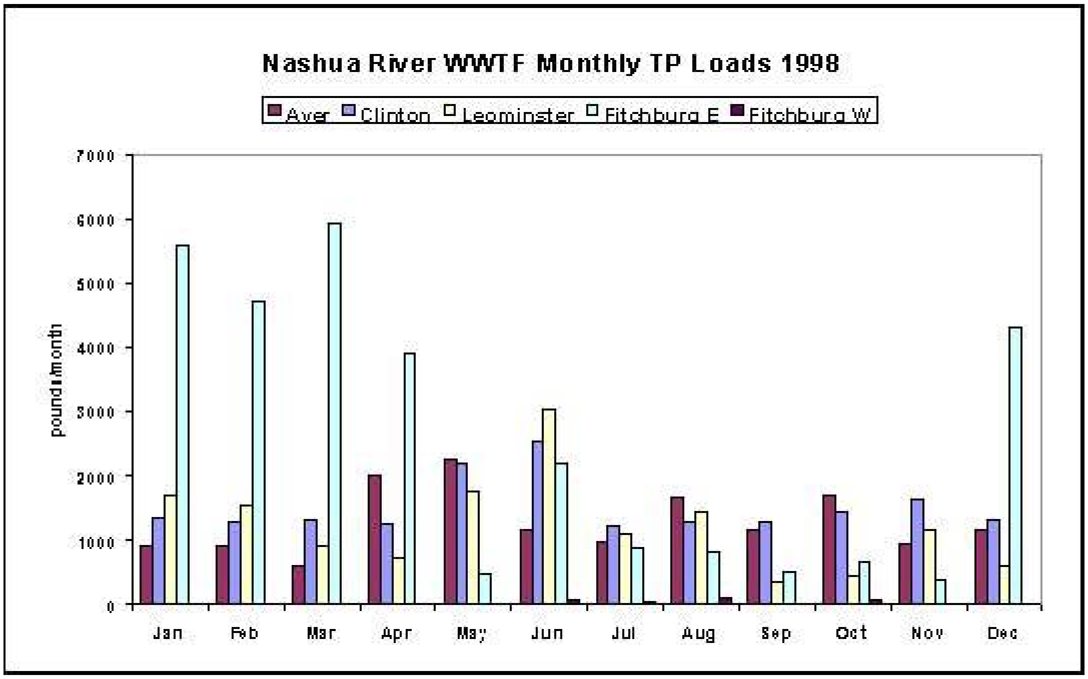
*Devens is presently permitted for 3 MGD to groundwater

WWTF 2000 Permited Flow & Loads			
1999 summer flows	mgd	lbs/day	lbs
with 1 mg/l TP limit	flow	daily P	May-Oct P
Fitchburg West	10.5	87.57	15,982
Fitchburg East	12.4	103.42	18,873
Leominster	9.3	77.56	14,155
Ayer	1.79	14.93	2,724
Clinton	3.01	25.10	4,581
Total			56,316

WWTF 1998 Average Summer Flow & Loads			
1999 summer flows	mgd	lbs/day	lbs
and summer loads	flow	daily P	May-Oct P
Fitchburg West	5.3	8.84	1,613
Fitchburg East	5.5	45.87	8,371
Leominster	4.7	39.20	7,154
Ayer	1.6	26.69	4,871
Clinton	2	50.04	18,265
Total			40,273

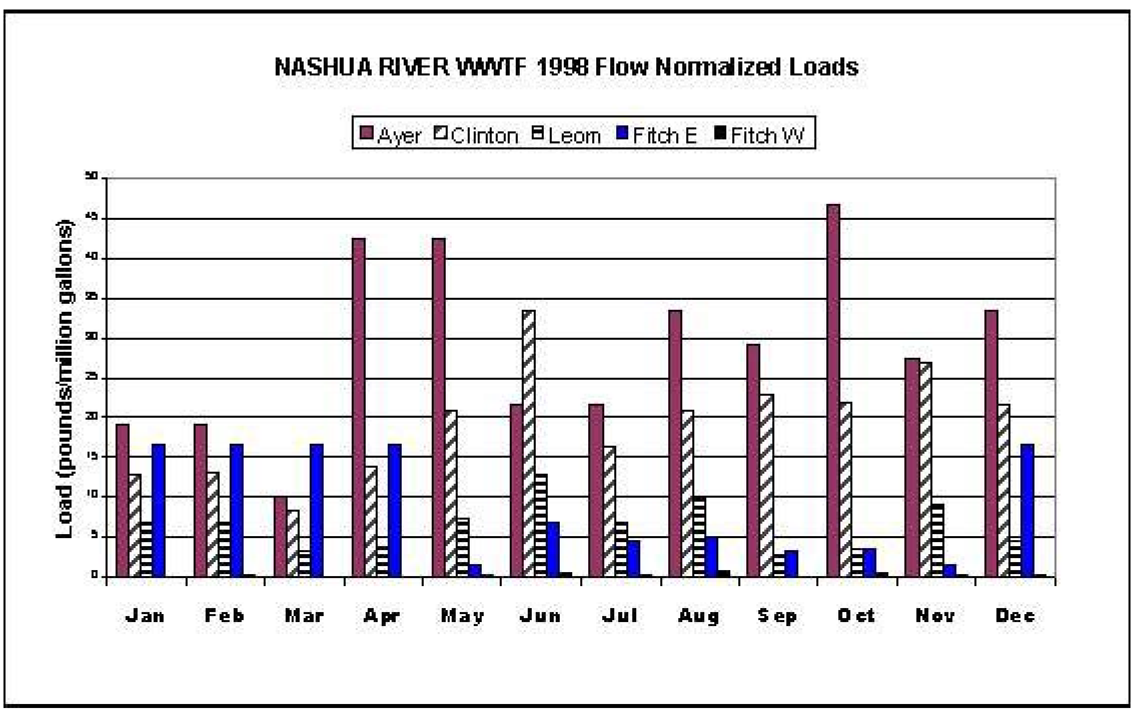
Monthly total phosphorus loads from the treatment plants were calculated and compared to provide a comparison of which treatment facilities were sources of the highest overall loading of phosphorus during the 1998 survey (Figure 16). Fitchburg West had the smallest overall annual and monthly loading. Fitchburg East had the largest with higher levels in the spring months and months during which rainfall was higher. These levels may reflect infiltration/inflow and CSO contributions. Ayer and Clinton WWTF loads were higher in the summer months in 1998 than presently as this was prior to the 1mg/l phosphorus NPDES permit limit.

Figure 16: Nashua River WWTF Monthly TP Loads 1998



A comparison was also made of the monthly loading of phosphorus from each of the treatment plants calculated on a per million gallon basis (Figure 17). This identifies which effluents had higher concentrations of phosphorus in the effluent on an average monthly basis. Concentration is important as a determination of which sources are more important as affecting response variables. For 1998, Ayer and Clinton WWTFs had the highest effluent concentrations of phosphorus. Fitchburg West had the lowest overall phosphorus concentrations.

Figure 17: Nashua River WWTF 1998 Flow Normalized Loads



The North Nashua River is also the recipient of CSO discharges from the cities of Fitchburg and Leominster. CSOs can be a significant source of phosphorus and can deliver large amounts of material in a short time frame. Appendix B describes the results of the study of the Fitchburg CSOs. The USEPA and the MassDEP review of these CSO studies has led to an Administrative Order for complete separation in the City of Fitchburg. The report proposes modifications to 24 of the 58 CSO regulators, which discharge via 38 outfalls. Other regulators, which do not activate for the 3-month storm, have no modifications proposed. This proposal will reduce CSO discharges to no more than 4 times per year at 11 of the outfalls at a projected cost of $3 million. In order to support the CSO efforts by reducing the effects on the East Fitchburg WWTF, an additional $5.5 million proposal for constructed facilities to equalize wet weather flows is proposed. The East Fitchburg WWTF will receive an additional 4.8 million gallons of wet weather flows for the 2-month storm. During the 3-month storm, 3.8 million gallons will be discharged as CSO from 17 regulators, and convey 5 million gallons for treatment. (Dufresne-Henry, Inc, 1998-2004)

A report by Numeric discussed the annual phosphorus loading from the Fitchburg CSOs based on event mean concentrations measured in the field at the CSOs during 1996. Total annual CSO loads were estimated to be 33,421 pounds of $CBOD_5$, 2, 492 pounds of ammonia-N and 796 pounds of total phosphorus. The Numeric report states that these annual loads account for approximately 1% of the total non-point source annual pollutant loadings for pollutants, but that the use of EMCs for typical urban stormwater and CSOs from the literature suggests that the total annual CSO loads due to the Fitchburg CSO may be higher than those measured in Fitchburg during 1996 by up to a factor of 3.

Applicable Water Quality Standards

Category 5 of the 2004 Integrated List (Table 1), formerly referred to as the 303(d) list, identifies causes of impairment in different segments of the Nashua River. The primary causes, nutrients and organic enrichment as affecting dissolved oxygen, can be addressed through the control of the nutrient phosphorus. The waters of the Nashua are Class B and a warmwater fishery.

The Massachusetts Water Quality Standards 314 CMR 4.0 contain numeric criteria for dissolved oxygen but do not contain numeric criteria for phosphorus or biomass. The Standards do contain narrative criteria to address nutrients and organic enrichment, which are significant problems in a number of the waters in the state. This narrative states nutrient levels should not exceed the site-specific limits necessary to control accelerated or cultural eutrophication. Since nutrients and organic enrichment lead to eutrophication and are present, as evidenced by the dissolved oxygen (DO) swings and chlorophyll levels, the DO standard and chlorophyll guidelines will be utilized as the target reference.

Water Quality Standards Violations: Three segments are listed for nutrients and one of these segments is also listed for organic enrichment/low dissolved oxygen, and noxious aquatic plants. Four segments are listed for taste, odor and color. In consideration that the waters listed are a designated Class B water under the Massachusetts Surface Water Quality Standards, the data placed these segments on the Massachusetts Integrated List 2004 (DEP, 2005) with organic enrichment (phosphorus) and low dissolved oxygen listed as the causes for violation of the Water Quality Standards related to impairment of primary and secondary contact recreation and aesthetics. These Water Quality Standards are described in the Code of Massachusetts Regulations as follows:

- 314 CMR 4.05 (3)(b): "these waters are designated as a habitat for aquatic life, and wildlife, and for primary and secondary contact recreation…these waters shall have consistently good aesthetic value."
- 314 CMR 4.05(5)(a) states "Aesthetics – All surface waters shall be free from pollutants in concentrations that settle to form objectionable deposits; float as debris, scum, or other matter to form nuisances, produce objectionable odor, color, taste, or turbidity, or produce undesirable or nuisance species of aquatic life."
- 314 CMR 4.05(5)(c) states, "Nutrients – Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication".
- 314 CMR 4.05 (3)(b): "Dissolved Oxygen a. Shall not be less than…5.0 mg/l in warm water fisheries unless background conditions are lower.".

In the absence of numeric criteria in the State Water Quality Standards, the Department uses best professional judgment (BPJ) and a "weight-of-evidence" approach that considers all available information to set site-specific permit limits, pursuant to 314 CMR 4.05(5)(c). The weight of evidence approach also considers available guidance that may have been developed related to the issue. Although little guidance is available related to specific response variables such as biomass and aesthetics, USEPA has published some additional national and regional guidance for phosphorus that is outlined below.

Thus, the assessment of eutrophication is based on site-specific information within a general framework that emphasizes impairment of uses and preservation of a balanced indigenous flora and fauna. This approach is recommended by the USEPA in their draft Nutrient Criteria Technical Guidance Manual. The Guidance Manual notes that lakes, reservoirs, streams, and, rivers may be subdivided by classes, allowing reference conditions for each class and facilitating cost-effective criteria development for nutrient management.

Summary of Available Guidance

In July 2000 the U.S. Environmental Protection Agency issued a technical guidance manual for nutrient criteria in Rivers and Streams (USEPA, 2000a). The purpose of this document was to provide scientifically defensible guidance to assist States and Tribes in developing regionally based numeric nutrient and algal criteria for river and stream systems. The document also describes candidate response variables that can be used to evaluate or predict the condition or degree of eutrophication in a water body. Those variables include direct measurement of nutrient concentrations as well as observable response variables such as biomass and turbidity. Among other indicators, USEPA focuses on periphyton in the chlorophyll pool as a measure for assessing nutrient enrichment. In the Nashua River however, floating biomass, particularly duckweed and algal mats, are a better metric and of critical concern to local environmentalists and the general public because these mats impede recreational uses and create objectionable odors in late summer and early fall when they die and degrade.

The USEPA guidance also notes the need in some cases for an adaptive management approach where uncertainty exists. Specifically, the guidance notes the need to "(m)monitor effectiveness of nutrient control strategies and reassess the validity of nutrient criteria" as part of the criteria development process. The USEPA expands this point to say:

"Nutrient criteria can be applied to evaluate the relative success of management activities. Measurements of nutrient enrichment variables in the receiving waters preceding, during and following specific management activities, when compared to criteria, provide an objective and direct assessment of the success of the management project."

USEPA also published two additional guidance documents relative to this issue. The first is a document produced in 2000 titled "Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion XIV (USEPA, 2000b) and the second was an earlier document developed by USEPA in 1986 titled "Quality Criteria for Water", commonly referred to as the "Gold Book" (USEPA, 1986).

The former document was intended to provide additional technical guidance and recommendations to States to develop water quality criteria and standards. The document notes that the recommendations are not a substitute for the Clean Water Act (CWA) or USEPA regulations; nor is it a regulation itself. The document also notes that State authorities retain the discretion to adopt approaches on a case-by-case basis that differ from the guidance when appropriate and scientifically defensible. The guidance goes on to recommend, based upon a statistical analysis, in-stream phosphorus criteria for all of Ecoregion XIV (encompasses most of the eastern coast of the United States) of 31.25 µg/l and for sub-Ecoregion 59 (where the Nashua is located) 23.75 µg/l. These criteria represent the 25th percentile of available data collected within the ecoregion and sub-ecoregion, respectfully (from both impaired and unimpaired waters). The major downside to the guidance, which is of concern to MassDEP, is that the criteria were not based upon in-stream response variables or site-specific conditions. MassDEP believes an objective based on instream response is critical to the success of any nutrient management strategy.

USEPA also developed statistically based guidance values for different seasons. Given that the Nashua River is an effluent dominated stream and that approximately 90% of the phosphorus discharged from the WWTFs is in dissolved form and does not settle, the primary need for phosphorus removal occurs during the summer months when river flows are low and the phosphorus is taken up by the biomass for growth. When viewed as a summer time issue the USEPA guidance criteria change slightly to the following: Ecoregion XIV – 40.0 µg/l and sub-Ecoregion 59 – 25.0 µg/l. The standard errors of the data as referenced in the document for summer time conditions are 12.0 µg/l and 26.8 µg/l respectively.

The 1986 "Gold Book" criteria also provide guidance on this issue. The guidance states for phosphate phosphorus "To prevent the development of biological nuisances and to control accelerated or cultural eutrophication, total phosphates as phosphorus (P) should not exceed 50 µg/l in any stream at the point where it enters any lake or reservoir, nor 25 µg/l within the lake or reservoir. A desired goal for the prevention of plant nuisances in streams or other flowing waters not discharging directly to lakes or impoundments is 100 µg/l total P". Thus, this guidance provides a range of acceptable criteria for phosphorus based upon specified conditions. It is with the spirit of this guidance that the TMDL for total phosphorus in the Nashua River has been developed.

USEPA, in summarizing their available guidance, clearly acknowledges the lack of definitive numerical criteria and the need for criteria that vary not only by ecoregion but also by site-specific conditions. As a result, a major effort involving detailed water quality sampling, model development and the use of the model in a predictive mode was undertaken to assess the site-specific impacts and multiple response variables to phosphorus loading in the Nashua River.

Water Quality Targets

Nutrients – Total Phosphorus

TMDLs for nutrients, specifically total phosphorus for the Nashua River, present several challenges. Among them is the fact that straightforward relationships between nutrient concentrations and environmental responses are complex and variable. In the case of rivers, this is compounded by the fact that no generally agreed framework for evaluating nutrient impacts exists. As previously noted, in the absence of numeric criteria in the Massachusetts Water Quality Standards, MassDEP uses best professional judgment (BPJ) and a "weight-of-evidence" approach that considers all available information to set site-specific permit limits, pursuant to 314 CMR 4.05(5)(c). The weight-of-evidence approach also considers available guidance that may have been developed related to the issue. Limited guidance is available from USEPA relating specific response variables, such as biomass and aesthetics, to nutrient concentrations.

Massachusetts has narrative criteria for nutrients as described in the section above on Applicable Water Quality Standards. The goal of this TMDL is to determine site-specific daily loads for nutrients, specifically total phosphorus, to control eutrophication. The symptoms of eutrophication include undesirable or nuisance concentrations of aquatic macrophytes, and, in particular for the Nashua River, excessive growths of floating algal mats and macrophytes. In addition, the water quality goal is to ensure dissolved oxygen is above the minimum criterion and to maintain protective and reasonable daily variations of dissolved oxygen concentrations so that existing uses are maintained and designated uses are achieved.

No specific in-stream target concentration for total phosphorus will be established. Under the weight-of-evidence approach all available information will be used to set site-specific permit limits. The overall goal is to significantly reduce the amount of biomass in the system fully recognizing that not all the biomass can be removed (attached macrophytes) and that some level of biomass is necessary to provide habitat to fish and other aquatic organisms. Additional goals are to ensure the dissolved oxygen criterion is met and to reduce the degree of dissolved oxygen supersaturation. A comparison of instream total phosphorus concentrations, although not a target, to USEPA guidance was used to further validate the model and weight-of-evidence approach.

Biomass

Excessive biomass is considered a major impairment of designated uses in the Nashua River. Decay of dying duckweed causes odors and violations of dissolved oxygen standards. Excessive growths of both floating and rooted macrophytes are detrimental to primary and secondary contact recreation. The biomass also causes extreme variations in dissolved oxygen leading to both supersaturation and to possible violations of the minimum criterion of dissolved oxygen.

The primary locations where biomass accumulates are the impoundments where conditions most suitable for excessive macrophyte growth exist: low velocity, shallow depths, large surface area open to sunlight, and nutrient enrichment. The major impoundments and wide slow reaches on the Nashua River (Ice House Impoundment, Groton School area, and Pepperell Impoundment) provide the physical setting, while the major WWTFs provide the nutrients that result in the observed excessive algal mats in Pepperell Impoundment and macrophyte growth in all three impoundments, although most evident in Pepperell Impoundment.

Elsewhere on the Nashua, in the free flowing reaches (and especially in the shaded free flowing reaches), excessive floating macrophytes (especially duckweed) growth is not observed. While macrophytes do exist in the sunlit free flowing reaches, they are generally rooted species adapted to the higher velocities and do not appear to be excessive or a nuisance. It can be assumed that the point source controls implemented towards controlling floating macrophyte growth in the impoundments will have the beneficial effect of reducing rooted macrophytes, to the extent they can utilize dissolved phosphorus from the water column, in the free flowing reaches.

For the purpose of this TMDL, a substantial reduction in total biomass of at least 50% from summer values is considered a minimum target for achieving designated uses. The expectation is that 90% of any reduction would be from floating biomass. Chlorophyll_a concentration is being used as the surrogate for biomass. Although it is difficult to quantify without mapping, it appears that 50% of the biomass is as surface coverage and the rest as bottom macrophytes. If 90% of this surface coverage could be reduced a significant change in use could be achieved in the river.

Dissolved Oxygen

The water quality standards require that dissolved oxygen concentration not be lower than 5.0 mg/l for all flows at or greater than 7Q10. Dissolved oxygen is relatively easy to monitor and concentrations in the Nashua River are documented in this report and, historically, in data reports by the Massachusetts DEP. Dissolved oxygen is also a primary component of most models including the HSPF model for the Nashua River developed by TetraTech and Numeric. Model output for dissolved oxygen is easily compared to the 5.0 mg/l minimum dissolved oxygen criterion to determine if this water quality target would be met under the conditions of the various modeled scenarios.

Also of concern are large daily fluctuations of dissolved oxygen and the extremely high concentrations (supersaturation) that occur during the diurnal cycle. This condition is directly related to eutrophication and the cause of the impairment because of the amount of both floating and fixed biomass in the system. Large fluctuations and the amount of time saturated conditions are exceeded are indicators of biomass production and dissolved oxygen swings caused by plant and algae photosynthesis and respiration.

No specific targets were set for either super saturated conditions or in-stream phosphorus concentrations since these metrics were used as a surrogate to estimate the biomass response to various control measures.

Linking Water Quality and Pollutant Sources

Modeling Assumptions, Key Input, Calibration, and Validation

A number of surveys were conducted on the Nashua River in 1998 and 2003-4 and a predictive model was developed and used to assess the effects of various control strategies. If one were interested solely in phosphorus concentrations, then a relatively simple water quality model might suffice. Because there is no specific quantitative link between phosphorus concentrations and impacts on water quality, MassDEP believes phosphorus concentrations are of secondary importance as an indicator of achieving designated uses. Thus, MassDEP chose to develop a model that related water quality variables and their response to different phosphorus concentrations and loads` being discharged from the WWTFs as the metric by which reaching water quality goals would be measured. The system response variables modeled were selected jointly by MassDEP and USEPA. These variables include dissolved oxygen, total phosphorus concentration, and chlorophyll_a (both directly and as a surrogate for biomass).

The application used, HSPF v 12, is a complex, time variable (dynamic) one that simulates hydrology generated from precipitation and specified land uses in the watershed. It predicts in-stream water quality for several variables. HSPF was used to develop, calibrate, and verify a model for the Nashua River based on conditions monitored in 1998. During the lowest flow week of July 1999, river flow was near 7Q10. Therefore, that week in 1999 was selected for model output comparison.

Once the model was calibrated and verified, various runs were made to evaluate improvements from reduced phosphorus loads on several response variables including chlorophyll_a, minimum and maximum dissolved oxygen, percent dissolved oxygen saturation (indicator of biomass), and in-stream phosphorus concentrations. The output from the calibrated model for the low flow week of July 1999 was used as the baseline. Output from each scenario was compared to the baseline. While it should be recognized that predicting biomass response is on the edge of the state of the art to model, MassDEP believes large predicted differences are qualitatively correct. Therefore these differences are important and significant in assessing whether overall water quality goals are predicted to be met and designated uses achieved.

Many model runs were made looking at the system response variables using different assumptions. WWTF effluent concentrations for total phosphorus were varied from those observed in 1999. Nonpoint source phosphorus was varied from those that existed in the model during calibration (100%) to an assumption that a 20% reduction in total phosphorus from the watershed could be reasonably achieved. WWTF flows and effluent phosphorus concentrations were compared using permit flows and phosphorus loads. Conditions and results from all scenarios are presented in Table 13.

Two models (HSPF v.12 and QUAL2) were utilized to provide the load response relationship between the target pollutant and the dissolved oxygen and chlorophyll levels. Model development, assumptions used in the model, model calibration, and validation are detailed in Appendices D and G, as development of the models was complex. A number of reports were produced by the consultants, Numeric and TetraTech, who worked on various phases of the model (USEPA, 2000 and Baker (2001, 2002).

The intensive data collection in 1998, as described in the appendices, included physical, chemical and biological data collection and evaluation. Those data were then used to develop, calibrate and validate the HSPF dynamic point source/nonpoint source model. The primary objective of the project was to evaluate instream levels as related to inputs, to prevent algal blooms and maintain dissolved oxygen concentration and saturation levels consistent with Massachusetts Water Quality Standards and the designated uses they are intended to protect.

The core of the analytical method of this TMDL is the HSPF model (partly based upon the QUAL2 model see Attachment E) that links the watershed inputs with instream phosphorus concentrations in all stretches of the river and is characterized as follows:

- describes the watershed and subwatersheds, the river structure and flow dynamics;
- requires site specific measurements for the watershed and subwatersheds; and
- utilizes these measurements to calibrate and verify the model for hydrology and water quality prior to development of various scenario runs.

The HSPF and QUAL2 models have been utilized for other watersheds in Massachusetts. Once the models were calibrated and verified management tools exist for the evaluation of point source/versus nonpoint source importance, and for the evaluation of various effluent point source loads to the corresponding instream effect. Additionally, up-dates were made to reflect changes, which may happen in the watershed in the future. The Nashua HSPF model encompasses the entire watershed and provides a complete picture of the effects in different river segments as well as those segments to which the WWTFs discharge directly.

The QUAL2 model was developed and run first, to provide initial information and predictions that could then be translated with additional measurements and information into the HSPF12 model. QUAL2 is a steady state model used primarily for predicting impacts from point source loading during summer low flows or 7Q10 conditions. HSPF12 was then utilized to provide information on both point source and non-point source loading, for more predictions over more years, and to be able to evaluate conditions seasonally as well as for low flow.

The Nashua River watershed HSPF model was initially developed by TetraTech within the USEPA BASINS framework (a GIS based tool for developing models) and extensively calibrated for flows. The model was expanded and improved by Numeric, who developed the REACHES portion (the actual riverine part) based upon QUAL2 to model individual nutrient components and the DO/BOD cycle, which were not available through the original BASINS version. Numeric also incorporated the field sediment oxygen demand data (SOD), developed more extensive time-series WWTF input files, an expanded meteorological data set, stage-discharge relationships based upon the FEMA HECII data, and a better representation of the Wachusett Reservoir/South Branch.

Numeric developed and initially calibrated the model based upon the 1977 field data and then re-calibrated and verified the data using the 1998 data, where flows were about twice 7Q10. Numeric developed a series of executables to allow MassDEP to run a variety of scenarios. Scenarios were run for 1999, which was close to 7Q10.

An important feature to remember is that the model was calibrated for dissolved oxygen not chlorphyll, and recalibrated to reflect diurnal DO fluctuations. DO was selected as it could be more easily measured and quantified. The instream DO is a response variable to the chlorophyll_a. Since the HSPF model placed all chlorophyll in the algal compartment without specifying which portion of the chlorophyll is attributable to the macrophytes or surface algal mats a translator was needed to separate the biomass into components.

The HSPF model (and most other models) is not designed to partition the biomass. Surface algal mats are an important segment of the biota in Pepperell Impoundment. This is very important in understanding and modeling the dynamics of Pepperell Impoundment. The field measured chlorophyll values represent only algae suspended in the water column and do not represent the overall growth. Most of the growth in Pepperell Impoundment is attached growth (macrophytes) and surface coverage from algal blooms, duckweed and other non-rooted aquatic plants. Chlorophyll values in the model were a surrogate to represent plant biomass in the river including both fixed and floating vegetation. The following table shows the chlorophyll values from the field sampling program and the chlorophyll values estimated from the model. A translator was calculated for the 4 sampling locations to determine the amount of the HSPF calculated chlorophyll levels that should be attributed to the algal component. These translators were then applied to the riverine portions of the model in order to develop a second set of chlorophyll graphs which show only water column levels.

Chlorophyll Partitioning

	July 98 Chlorophyll_a (ug/l)	Sampling 1998	Model 1998	Water Column Algal % 1998
Mile		July	July	
25.9	Ice House Dam	5.8	9.95	58.3
21.5	Groton School	1.3	9.78	13.3
17.2	Inlet Pepperell Pond	3.1	21.09	14.7
14.2	Outlet Pepperell Pond	10.1	45.54	22.2

	August 98 Chlorophyll_a (ug/l)	Sampling 1998	Model 1998	Water Column Algal % 1998
Mile		August	August	
25.9	Ice House Dam	3.4	30.00	11.3
21.5	Groton School	2.4	30.68	7.8
17.2	Inlet Pepperell Pond	3.2	60.08	5.3
14.2	Outlet Pepperell Pond	19.6	51.17	38.3

Table 7: Chlorophyll Partitioning Sampled versus Modeled

Total Maximum Daily Load Analysis

Identification of Target

Since there is no standard for phosphorus at this time a weigh-of-evidence approach was used which evaluates the response variables to different levels of phosphorus. These response variables include large diurnal fluctuations in DO, super-saturated DO, and chlorophyll_a levels expressed as biological productivity. Field evaluations confirmed the excessive production of floating biomass in Pepperell Pond with the productivity being driven by the nutrient phosphorus. Point source discharges of phosphorus, in this case in the most readily useable dissolved form, are causing large fluctuations in diurnal dissolved oxygen and higher water column chlorophyll levels. Graphs of model output were developed to show the concentration response results of decreasing levels of effluent phosphorus from the WWTFs and the respective changes to instream phosphorus, chlorophyll, and dissolved oxygen (for the weight-of-evidence approach). Additionally, a summary table was prepared of scenarios, which lists phosphorus, and the response variables, including DO and chlorophyll parameters for comparison.

This TMDL addresses the eutrophication expressed as surface algal mats. Although one segment containing Pepperell Pond exhibits both large algal mats and nearly 80% bottom coverage by macrophytes, the history of the pond is one of a flooded meadow ideal for the growth of aquatic macrophytes. Since the pond cannot be restored to a situation that did not exist previously, i.e. oligotrophic state, this TMDL proposes the following.

Since Pepperell Impoundment is a shallow water habitat ideal for the growth of aquatic macrophytes, and the primary source of nutrients to these plants originates from the flooded soils, this TMDL is designed to primarily control floating biomass which is directly related to the water column levels of phosphorus input upstream from the WWTFs and non-point sources. Therefore, a zoned use management plan is proposed for Pepperell Pond. The management plan would go beyond just a loading capacity for phosphorus. The management plan would target the algal mats and dissolved oxygen super-saturation, and target areas of the pond for removal of macrophytes through harvesting /hydroraking areas for swimming and boating, while maintaining other areas for fish and wildlife habitat thereby providing a balance between recreational use and habitat for wildlife. The Nashua River Watershed Association, in combination with the towns, would develop a 319 Implementation Grant to hire a consultant to write the plan and work with the towns and watershed association on implementation of the recommendations.

Current versus Modeled Predicted Permitted Conditions

The field results were for current operating loads and conditions at the municipal treatment facilities. The modeling effort was required to predict the instream conditions at full permitted loads. Scenarios were run to compare projections. Some scenarios combined lowering nonpoint source inputs from urban and rural runoff for comparative purposes together with the lowering of effluent discharges from WWTFs.

Numerous scenarios were run for comparative purposes for this TMDL to compare current versus permitted conditions versus projected permitted conditions. The results from eight of those scenarios are presented in this TMDL. All scenario predictions were compared for the low flow week in July 1999. These scenarios are:

1. Baseline using Current Load as measured during 1998 Surveys
2. Baseline using Permit Loads TP = 1mg/l & 20% reduction in nonpoint source loads
3. Permit Loads with the following changes TP = 0.5 mg/l & 20% reduction in NPS loads
4. Permit Loads with the following changes TP = 0.2 mg/l 20% reduction in NPS loads
5. Permit Loads with the following changes TP = 0.2 mg/l & 20% reduction in NPS loads & 5 BOD
6. Permit Loads with the following changes TP = 0.024 mg/l & 20% reduction in NPS loads
7. Permit Loads with the following changes TP = 0.2 mg/l & 20% reduction in NPS loads with Clinton WWTF and Ayer WWTF = 0.5 mg/l TP
8. Permit Loads with the following changes TP = 0.2 mg/l & 20% reduction in NPS loads & Clinton WWTF = 0.5 mg/l TP

The HSPF12 model, developed and calibrated by NUMERIC, was run by MassDEP utilizing WWTF flow and concentration limits from the year 2000 permits. Development of the model is discussed in Appendices D and G. MassDEP developed the WWTF data input files based upon levels stated in the permits, together with a combination of DMR data, field data, and additional data collected by the WWTFs. Best professional judgement was used, if no actual data were available. Output from the model was compared for 1999, the year with flows closest to lowest flows (7Q10) as shown in the table below. The table below provides a comparison of flows at the USGS Leominster gage.

Table 8: Leominster Flows Daily Means (cfs) 70 years of record

1998 July	1999 July	Long-term July	7Q10
124 cfs	**40 cfs**	**90 cfs**	
			32.8 cfs
1998 August	1999 August	Long-term August	
55cfs	**34cfs**	**81 cfs**	

An evaluation was also made of whether or not the phosphorus was retained within Pepperell Impoundment from month to month or from the winter/spring time to the summer/fall time. Although this cannot be estimated with certainty, the output from the HSPF model was evaluated to predict the amount retained or moved through the impoundment as a guideline on a month-by-month basis for 1998 and 1999.

Table 9: Total Phosphorus HSPF Input /Output to Pepperell Pond 1998-99

TP LOADS INLET-OUTLET PP

	1998	1999
JAN	15.80	-2.02
FEB	3.41	29.31
MAR	63.02	12.35
APR	-7.37	7.65
MAY	25.98	-36.20
JUN	-157.30	-16.90
JUL	-214.10	418.95
AUG	-7.97	-2.90
SEP	13.13	-28.03
OCT	-5.18	23.79
NOV	50.48	58.96
DEC	-32.03	-32.67

Positive indicates accumulation.
Negative indicates outflow.

As indicated by a previous loading graph, HSPF results indicate that point sources currently dominate during the growing season. Additionally, the phosphorus from point sources is phosphorus which is readily available to the algal and plant community, versus the nonpoint source phosphorus, which tends to be organic phosphorus and is not readily available for algal and plant growth until it is broken down through decomposition. Figures 18-26 show the HSPF instream concentration projected for various scenarios of WWTF effluent concentrations. Table 12, which appears prior to the graphs, shows river miles and associated descriptions for reference purposes.

For most scenarios, the HSPF model indicated that a 20% reduction in nonpoint source watershed inputs was necessary for total phosphorus load reduction in order to meet water quality conditions. A reduction of this magnitude is substantiated by a separate study (Waterhsed Based Plan for the Nashua River, Draft 2006) conducted by the BETA Group of Lincoln Rhode Island, which showed the following for initial estimates of recommended nonpoint source load percent reductions based on their simulation results.

Table 10: Initial Estimates of Nashua Nonpoint Source Load Percent Reductions based on WMM Simulation Results (from draft report by BETA Group)

USGS HUC ID	Subwatershed Name	Subwatershed Area (acres)	NPS % Load Reduction Estimates (from WMM)			
			TSS	TP	TN	F-Coli
010700040101	Whitman River	27,328	---	---	---	---
010700040102	North NR - Phillips to Monoosnoc	28,289	---	19.0%	---	32.4%
010700040103	North NR - Monoosnoc to mouth	29,597	---	21.1%	---	45.5%
010700040201	Quinapoxet River	36,701	---	---	---	---
010700040202	Stillwater River	25,215	---	---	---	1.0%
010700040203	Nashua - HW to North NR	22,162	---	17.4%	---	25.5%
010700040204	Nashua - North NR to Cat. Brook	11,641	---	35.6%	---	28.7%
010700040205	Nashua - Cat. Brook to Squannacook River	38,712	---	38.0%	---	9.3%
010700040301	Willard Brook MA	18,136	---	---	---	---
010700040302	Squannacook River MA	18,487	---	---	---	---
010700040401	Nissitissit River MA	9,419	---	---	---	---
010700040402	Nashua - Squanacook to mouth MA	21,478	---	---	---	---

The BETA Group study also provides the following for removal efficiencies attributable to land use best management practices. For total phosphorus, estimates of average removal efficiencies were from 30-47%.

Table 11: Average Pollutant Removal Efficiencies for Land Use-Based Best Management Practices

BMP Land Use Category	Average Removal Efficiency (%)			
	TSS	TN	TP	F-Coli
Urban	72	30	34	71
Forestry	85	40	40	43
Agriculture	70	52	47	43
Mining	77	25	30	82

*figures averaged from multiple sources, including:
USEPA 840-B-92-002 (January 1993)
National Academies Press (2000)
http://www.epa.gov/owow/nps/Section319III/SC.htm (as of 2006)
Coyne, et. Al (2005), Washington State University

The results of the model runs are displayed graphically by showing a comparison of selected instream parameter levels at each river mile for a 7-day time period, Figures 18-26. Table 12 lists important milepoint and descriptive locations for reference with the graphs. Table 13 lists for scenario comparison, each of the scenarios and the corresponding values for instream DO, chlorophyll, phosphorus, and percent saturation projected. This time period selected was to reflect instream levels at a critical low flow week, July 13-20, 1999. The values are output from the HSPF watershed model. The graphs show the baseline loading with current WWTF flows and concentrations, potential baseline loading at full WWTF permitted loads (1 mg/l TP), and then instream levels at various WWTF phosphorus loadings including, 0.5 mg/l TP, 0.2 mg/l TP and a potential reduction in BOD levels, and nonpoint source loadings.

The comparison of the instream concentration resulting from varying the WWTF effluent concentrations for total phosphorus, BOD, and flow was made to the baseline riverine conditions to evaluate different combinations of WWTF effluent concentrations for selecting permit levels. Figures 18-26 are presented for instream levels at each river mile for total phosphorus, ortho-P, adjusted instream chlorophyll_a, number of hours DO is greater than the 125% saturation level, and diurnal DO differences.

Figures 18-26 indicate that nutrient related impacts are not observed in the free flowing mainstem. The phosphorus related impacts are primarily in the impoundments, especially Pepperell Pond. The main response variable is productivity as reflected in the chlorophyll_a levels.

A comparison of scenarios shows that if the effluent WWTF total phosphorus were reduced from 1 mg/l to 0.5 mg/l, an approximately 40% reduction would be seen instream for the mean TP. If the effluent WWTF TP were reduced from 1 mg/l to 0.2 mg/l an approximately 67% reduction would occur for mean TP levels.

For instream chlorophyll_a, the maximum projected levels occur between Ice House Impoundment and Pepperell Dam with levels at the full effluent WWTF permit loads. If the WWTF effluent TP were reduced from 1 mg/l to 0.5 mg/l, approximately a 30% reduction of peak chlorophyll_a would be seen instream. If the WWTF effluent TP were reduced from 1 mg/l to 0.2 mg/l, approximately a 50% reduction of peak chlorophyll_a would be seen instream.

Table 12: River Miles and Descriptive Locations

NASHUA RIVER

56.4	Flagg Brook
56.3	Whitman River
56.2	**Fitchburg West WWTF**
55.3	Phillips Brook
55.1	Fitchburg Paper
51.3	USGS Fitchburg Gage
49.8	Fallulah (Baker) Brook
48.1	**Fitchburg East WWTF**
46.6	Monoosnoc Brook
46.4	**Leominster WWTF**
44.4	Fall Brook
44.2	USGS Leominster Gage
43.3	Wekepe Brook
36.9	Atlantic Union College
36.5	South Branch Nashua River
32.7	Still River
27.1	Catacoonamug Brook
25.9	Ice House Dam
24.9	**Ayer WWTF**
24.8	Nonacoicus Brook
24.2	Devens WWTF
23.6	Mulpus Brook
23.1	Squannacook River
21.5	Groton School Impoundment
17.2	Inlet Pepperell Pond
14.2	Outlet Pepperell Pond
14.1	USGS Gage
13.9	James River Company
13.2	Nissitissit River
13.0	Pepperell WWTF
11.3	Unkety Brook

SOUTH BRANCH NASHUA RIVER

5.0	Wachusett Reservoir Dam
4.5	Lancaster Mill Pond Dam
1.7	Clinton WWTF
1.5	Counterpane Brook
0.3	Bolton Rd. Bridge
0.0	Confluence with Nashua River

Figure 18: HSPF Projected Total Phosphorus Levels for 1999 Low Flow Week

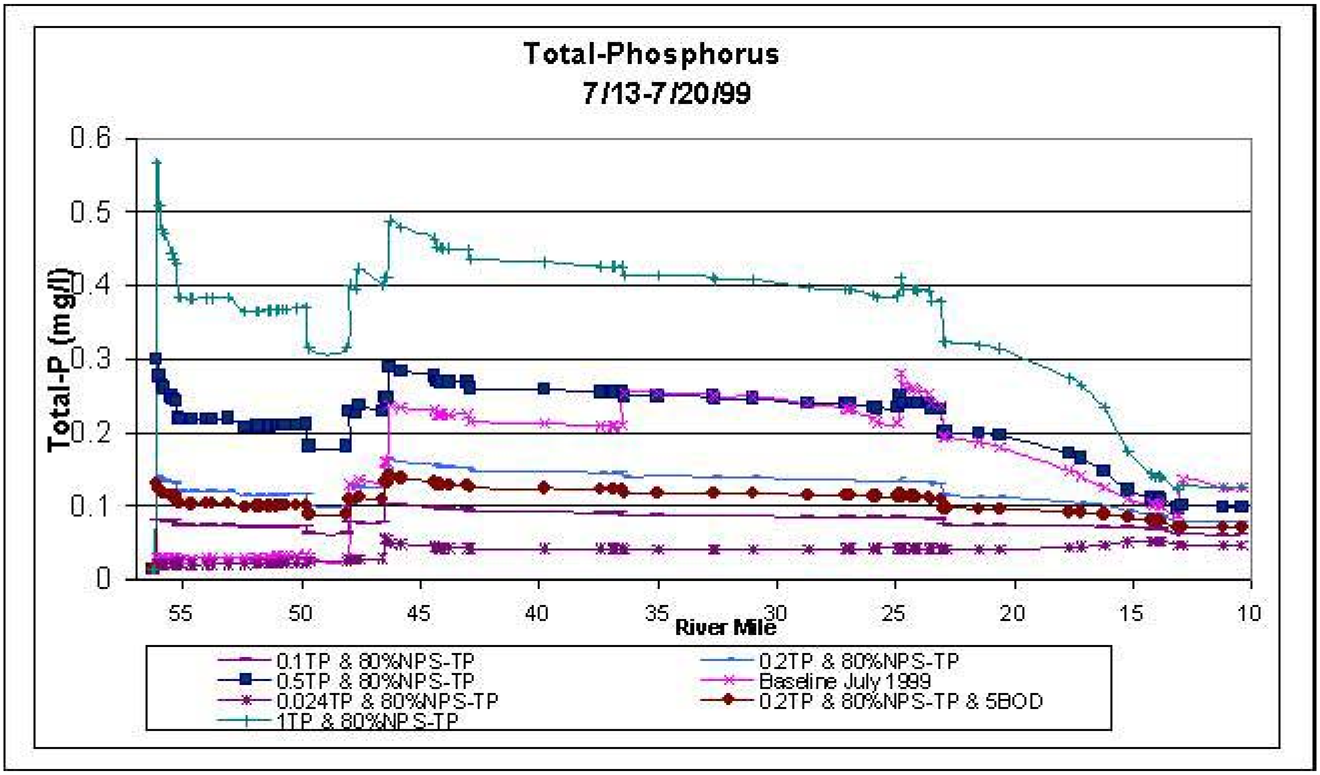


Figure 19: HSPF Projected Dissolved Phosphorus During 1999 Low Flow Week

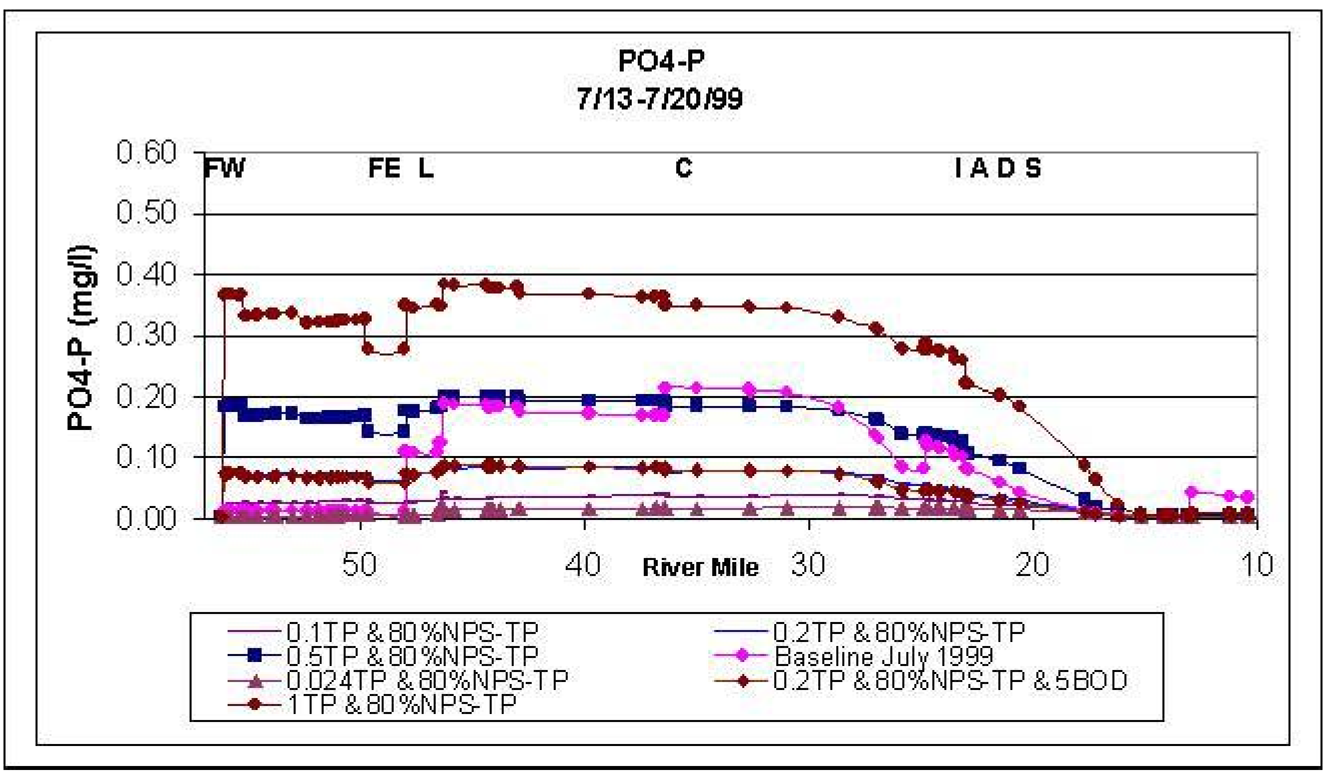


Figure 20: HSPF Projected Diurnal DO Differences During 1999 Low Flow Week

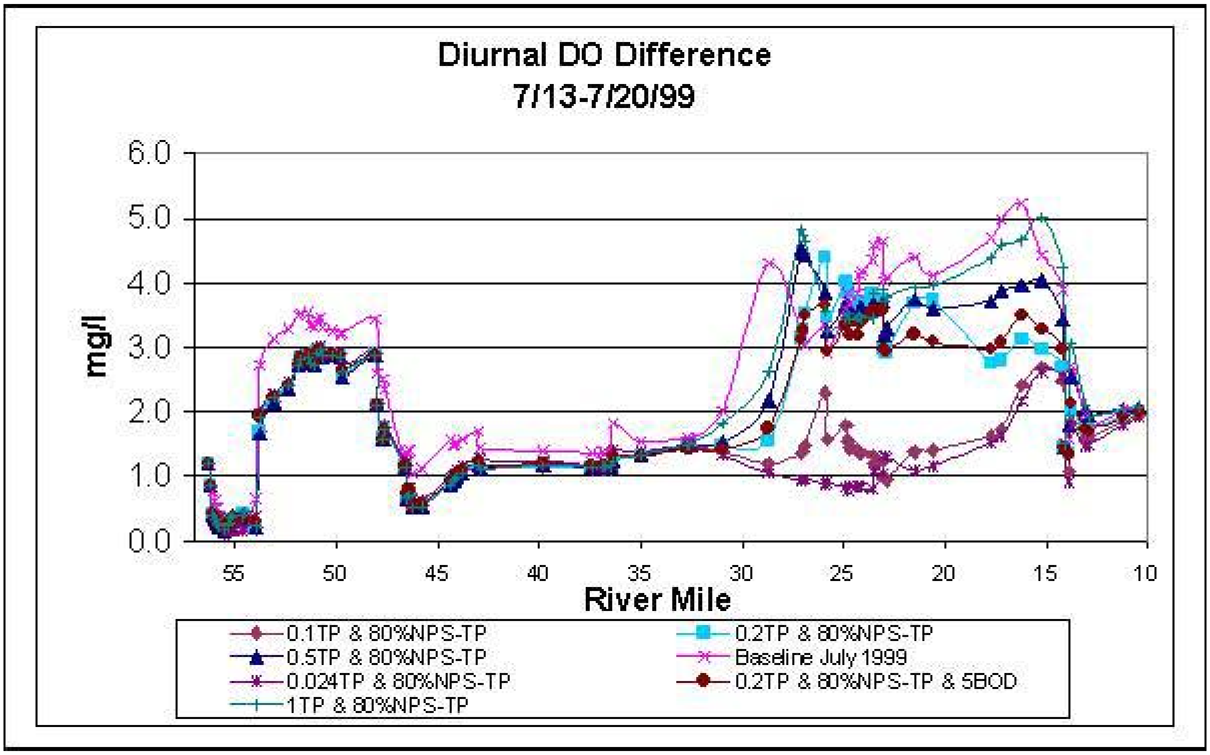


Figure 21: HSPF Projected Number of Hours DO>Saturation During 1999 Low Flow Week

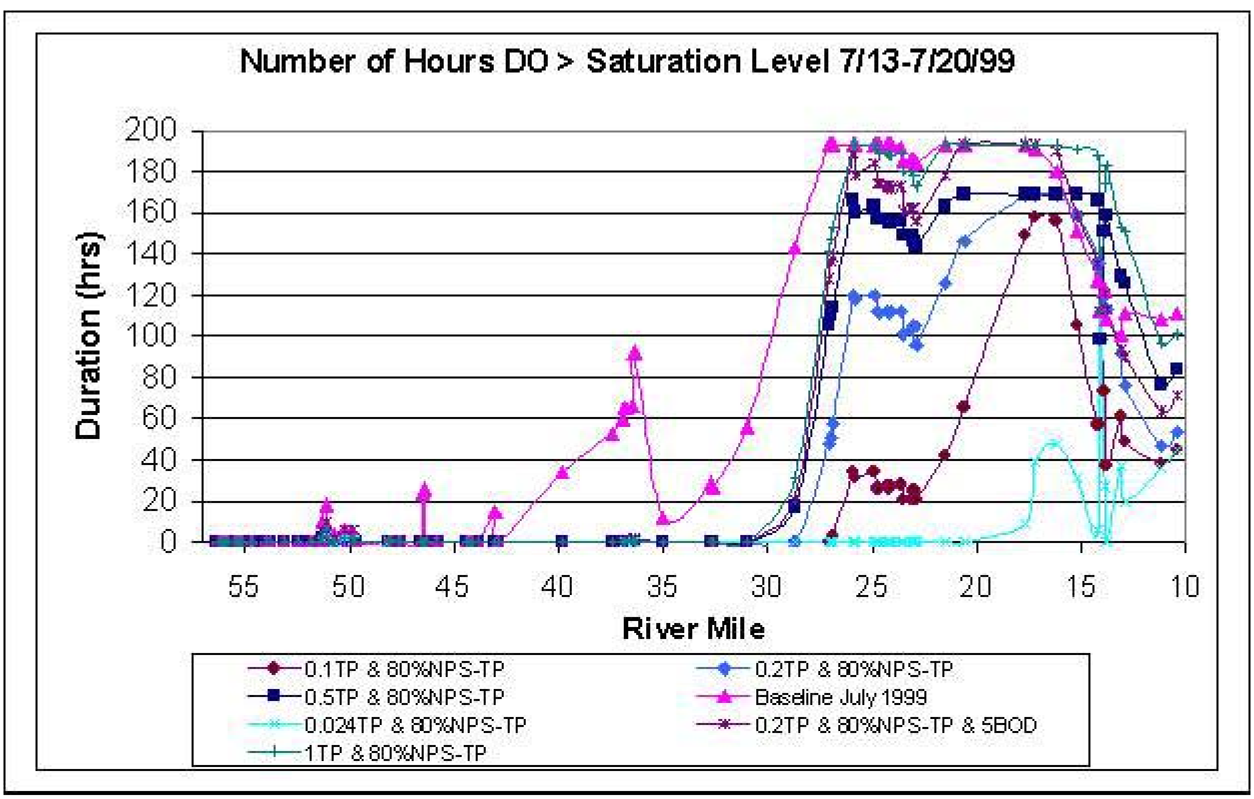


Figure 22: HSPF Projected Chlorophyll_a Levels During 1999 Low Flow Week

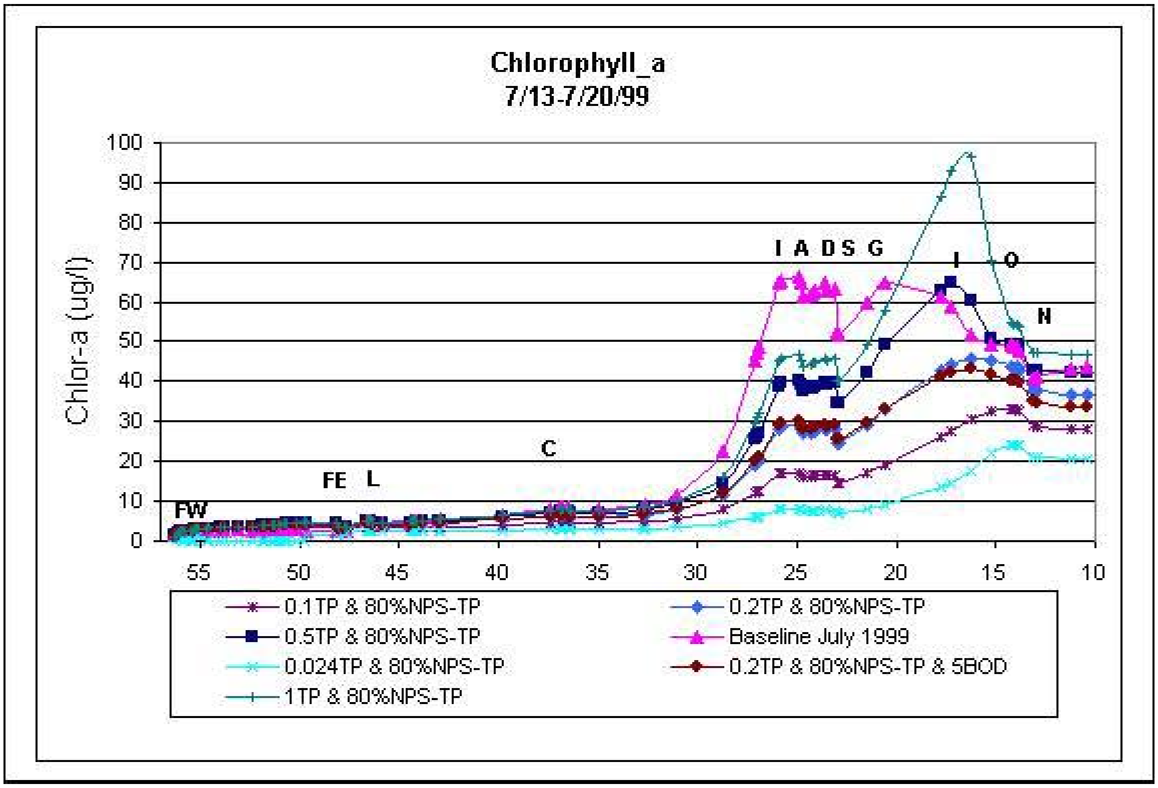
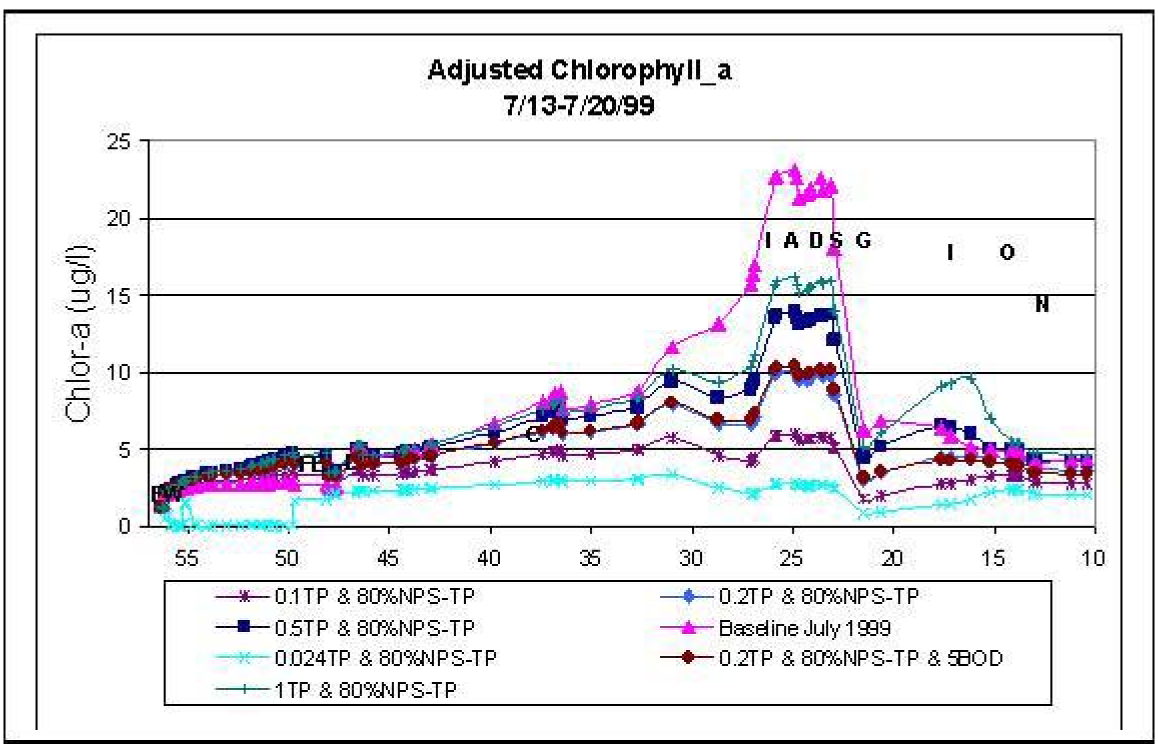


Figure 23: HSPF Adjusted Chlorophyll Values to Reflect Only Water Column Algae



Additional scenarios were run to evaluate the effect of lowering the Clinton and Ayer WWTF TP effluent to 0.5 mg/l in combination with the Fitchburg West and East WWTFs and the Leominster WWTFs at 0.2 mg/l. Figures 24-26 show the downstream incremental changes resulting from these higher levels. The scenario results indicate the instream levels for both Clinton and Ayer WWTFs at the 0.5 mg/l level or for just Clinton WWTF alone at the 0.5 mg/l TP level. In order to evaluate the effect, a comparison of instream average TP values for the river downstream of the discharge locations was added to the comparison table (Table 13). The number of hours >125% saturation, the delta DO, and the maximum chlorophyll_a showed minor impact, but likely within the margin of error for predictions.

The effect of reducing BOD in combination with reducing TP produced a slight instream benefit for TP if the levels were lowered to the 5 BOD level.

Figure 25 shows total chlorophyll_a versus river mile at low flow conditions. In order to meet a water column concentration of chlorophyll_a of 10 ug/l this would equate to a total cholorphyll_a of 49 ug/l (Figure 25 and shown in Figure 26). The objective is to achieve an adjusted chlorophyll_a concentration of approximately 10 μg/L. The water column chlorophyll_a concentration of 10 μg/L is the approximate concentration at which eutrophic conditions begin to dominate. Higher levels would not meet the narrative standard Massachusetts has described in the water quality standards. The method utilized is describe more fully on page 68. Therefore, for the Nashua TMDL recommended growing season limits are 0.2 mg/L TP for WWTFs on most of the main stem and 0.5 mg/L for the WWTF on the South Branch and for Pepperell WWTF on the mainstem. These concentrations are projected to achieve the goal of approximately 10 μg/L chlorophyll_a in the water column and should also address the floating biomass, which derives its nutrition from the water column. Little impact is expected on rooted aquatic vegetation, which derives its nutrition from the flooded soils. A management plan for zoned uses is recommended for Pepperell Pond to ensure all designated uses are met within the impoundment.

Figure 24: HSPF Instream Phosphorus Levels With Clinton and Ayer WWTFs at 0.5 mg/l TP

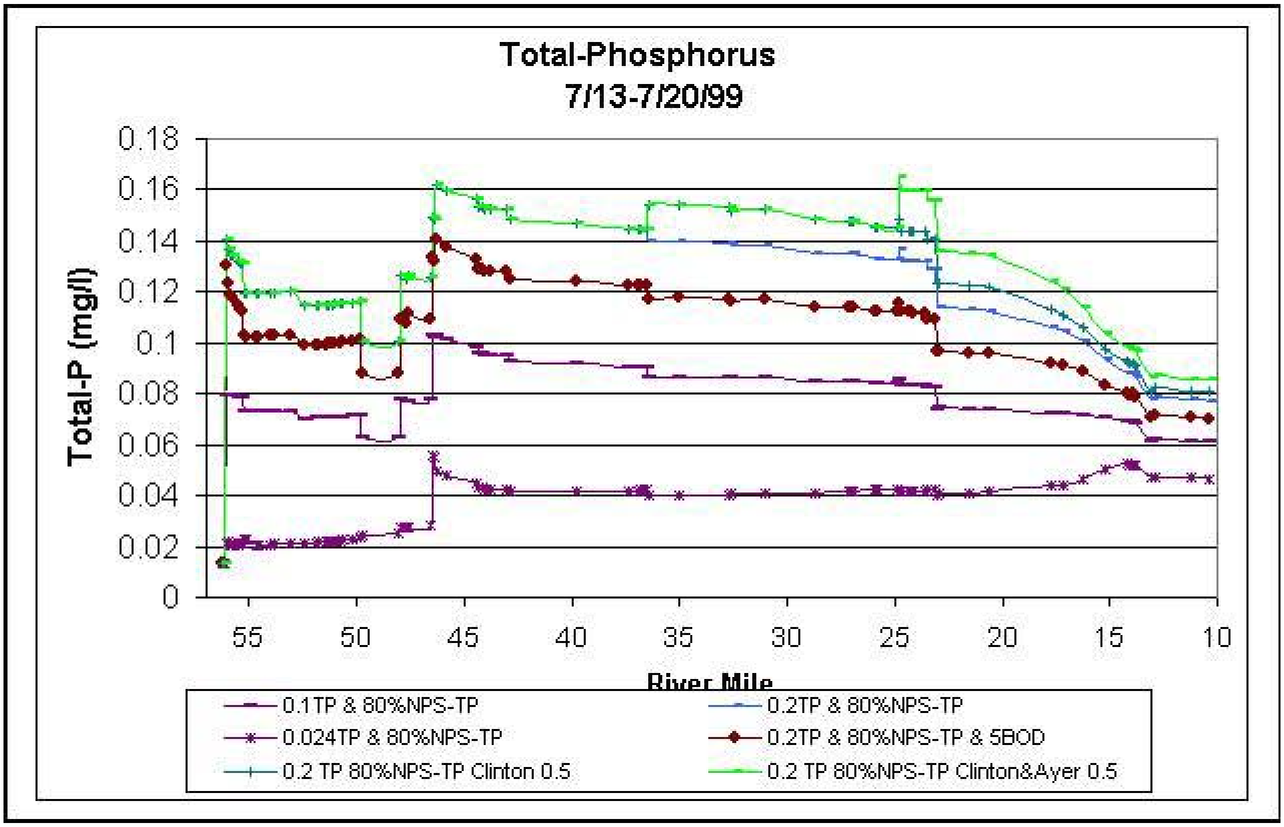


Figure 25: HSPF Instream Chlorophyll Levels With Clinton and Ayer WWTFs at 0.5 mg/l TP

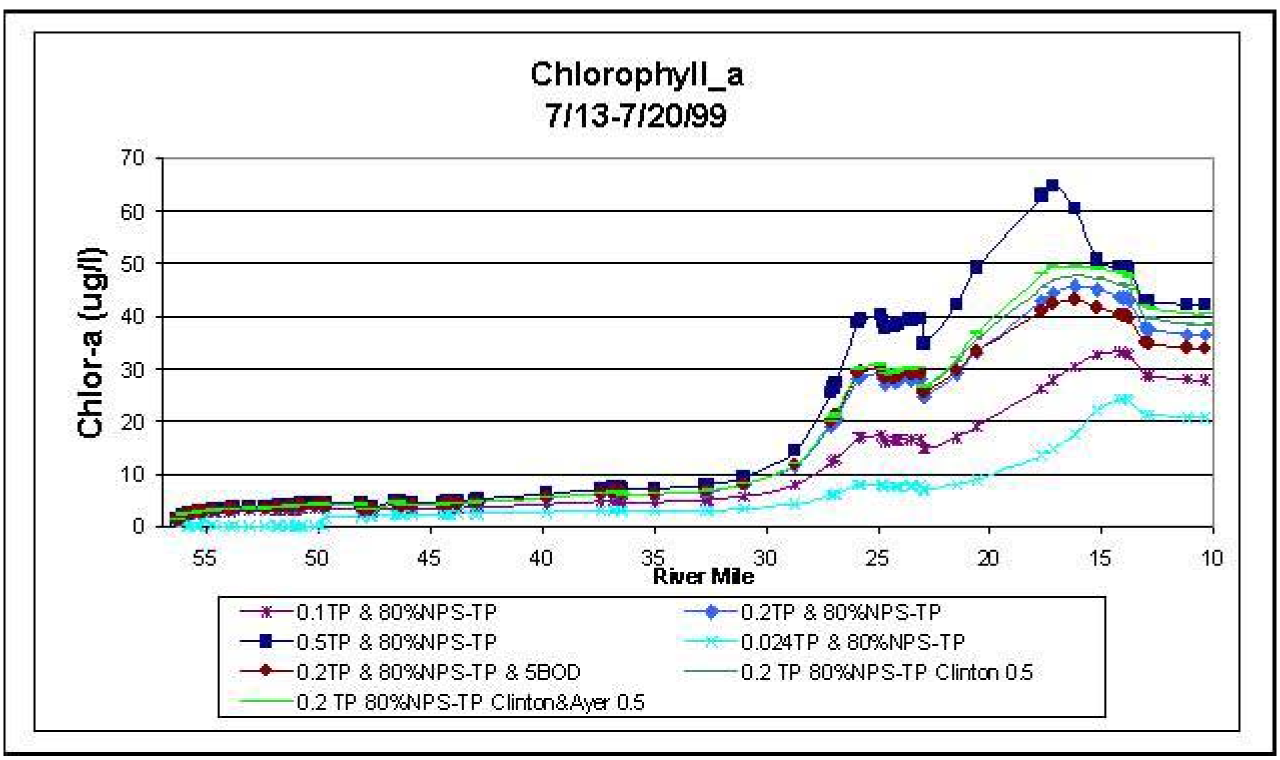
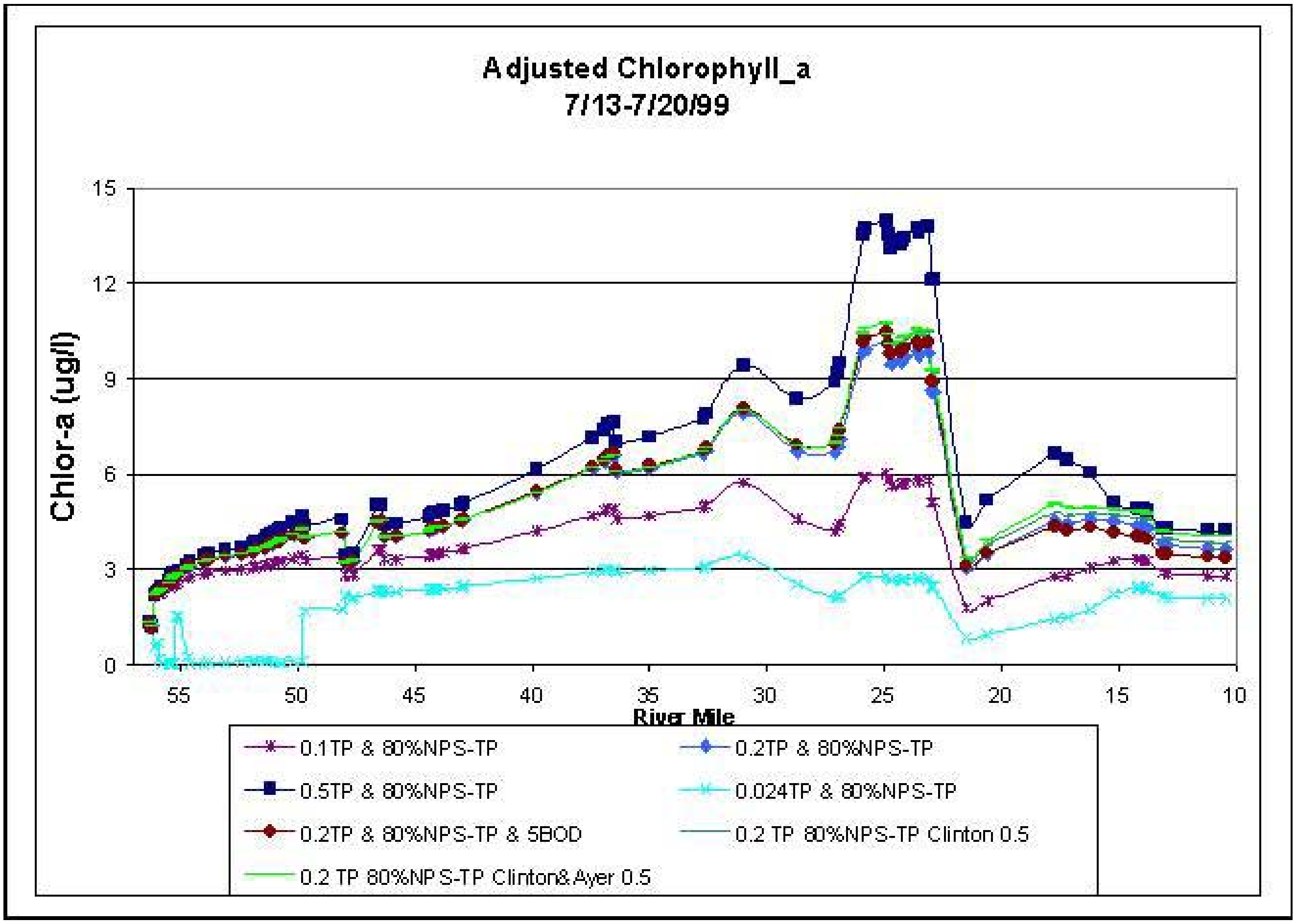


Figure 26: HSPF Instream Chlorophyll Levels With Clinton and Ayer WWTFs at 0.5 mg/l TP Adjusted to Show Only Water Column Chlorophyll



Loading Capacity

Evaluation Process

Over the last few years, water quality data have been collected on the Nashua River and a predictive model developed. These were utilized to evaluate the effects of various control strategies. If the only interest were in phosphorus concentrations, a relatively simple water quality model might suffice. Because there is no specific quantitative link between phosphorus concentrations and impacts on water quality, MassDEP believes phosphorus concentrations are of secondary importance as an indicator of meeting water quality goals. Thus, MassDEP chose to develop a model that related water quality variables and their response to different phosphorus concentrations being discharged from the WWTFs and to changing non-point source loads, as the metric by which receiving water quality goals would be measured. The system response variables that were modeled were selected jointly by MassDEP, USEPA and Numeric, the consultant to the Nashua River TMDL project. These variables include minimum and maximum dissolved oxygen, extent/duration of super-saturation of dissolved oxygen, total phosphorus concentration, and biomass, as represented by cholorophyll_a.

The application used, HSPF, v. 12, is a complex, time variable (dynamic) model that simulates hydrology generated from precipitation and specified land uses in the watershed. The model predicts in-stream water quality for several variables. HSPF was used to develop, calibrate, and verify a model for the Nashua River based on conditions monitored in 1998 and 2003-4. During the lowest flow week used in the model, July 13-20, 1999, river flow was near 7Q10 and wastewater total phosphorus effluents ranged from 0.01 mg/l to close to 4 mg/l. Three of the 6 WWTFs did not have phosphorus limits.

Once the model was calibrated and verified, various runs were made to evaluate improvements from reduced phosphorus loads on several response variables including minimum and maximum dissolved oxygen, percent dissolved oxygen saturation (indicator of biomass), in-stream phosphorus concentrations and chlorophyll_a levels. The output from the calibrated model for the low flow week of July 1999 was used as the baseline. Output from each scenario was compared to the baseline. While it should be recognized that predicting biomass response is on the edge of the state of the art to model, MassDEP believes large predicted differences are qualitatively correct. Therefore, these differences are important and significant in assessing whether overall water quality goals are predicted to be met and designated uses achieved.

Many model runs were made to evaluate the system response variables using different assumptions. WWTF effluent concentrations for total phosphorus were varied from those observed in 1999 down to the water quality standard of 0.024 mg/l. Additional projections were made using design WWTF flows and effluent phosphorus concentrations to assess the relative difference in water quality response variables that would result from increasing flows and phosphorus loads from 1999 to fully permitted conditions. A summary of conditions and results from all scenarios are presented in Table 13.

Model Results

The model results, as summarized in Table 13, indicate that an order of magnitude reduction in WWTF total phosphorus concentrations combined with a reduction in non-point source inputs (NPS) would be expected to meet water quality objectives. As previously discussed, MassDEP came to this conclusion based not on one single factor but rather on a combination of response variables in the model using a "weight-of-evidence" approach. The following summarizes model predictions for each of the individual response variables identified above, however, it is the combination of these results that form the basis of the Department's position.

Phosphorus

As previously discussed the Commonwealth of Massachusetts presently does not have numeric water quality criteria for phosphorus. In its absence MassDEP considered all available guidance and information and best professional judgment in make permitting decisions. In this regard MassDEP consulted the previously cited USEPA 2000 guidance relative to in stream phosphorus concentrations that included a suggested in-stream phosphorus criteria during the summer months in Ecoregion XIV (encompasses most of the eastern coast of the United States) of 31.25 µg/l and for sub-ecoregion 59 (where the Nashua is located) of 23.75 µg/l (0.024 mg/l). In addition, 1986 "Gold Book" criteria previously developed by USEPA, recommended total phosphates as phosphorus (P) should not exceed 0.05 mg/l in any stream at the point where it enters any lake or reservoir, 0.025 mg/l within the lake or reservoir, and 0.1 mg/l in flowing waters not discharging directly to lakes or impoundments.

Model results predicting in-stream concentrations of total phosphorus by river milepoint are presented in Table 14, and, based upon these predictions, the following observations can be made:

1. Background concentrations (above the Fitchburg West WWTF) are expected to be around 0.014 mg/l.

2. WWTF reductions in phosphorus effluent concentrations to 0.2 mg/l or less for the mainstem without any reduction in non-point source phosphorus all exceed the recommended guidance in multiple reaches of the Nashua River.

TABLE 13 Summary of Scenarios for Water Quality Target Model Output

Nashua River TMDL Modeling

Summary of Predicted DO, TP and Chlorophyll for 1 week in July,1999 Low Flow Week

Alternatives	Flows	Chlorophyll Max (ug/l)	Avg (ug/l)	Miles >20ug/l	Dissolved Oxygen Max (mg/l)	Min (mg/l)	Delta (mg/l)	< 5	>Sat	>125%Sat	Phosphorus MaxP (mg/l)	Avg P (mg/l)	Avg P (mg/l) belowAyer
								(percent of hrs during low flow week)					
Baseline and Permit Loads													
Baseline-Load for Surveys July 1998	existing	63.5	24.7	19.0	13.59	5.70	4.65	0.0	41.1	21.7	0.281	0.156	0.175
Baseline-Permit Lds P=1mg/l & 80% NPS-TP (7/99)	permit	96.3	23.9	18.1	13.55	5.20	5.02	0.0	41.8	18.9	0.489	0.358	0.268
Point Source and NonPoint Source Reductions 7/99													
Pont Source at 0.5 mg/l TP													
Permit Loads P=0.5 mg/l & 80%NPS-TP	permit	64.6	20.3	16.1	13.45	5.20	4.52	0.0	34.9	16.0	0.288	0.215	0.172
Pont Source at 0.2 mg/l TP													
Permit Loads P=0.2 mg/l & 80% NPS TP	permit	45.8	16.0	11.1	12.46	5.19	4.39	0.0	26.1	5.9	0.162	0.124	0.107
Point Sources at 0.2 mg/l with BOD Reductions													
Permit Loads P=0.2 mg/l & 80% NPS TP & 5 BOD	permit	43.1	15.1	10.5	12.62	5.43	3.66	0.0	36.7	10.3	0.140	0.107	0.093
Point Sources at 0.1 mg/l TP													
Effluents Set at Water Quality Standards													
Permit Loads P=0.024 mg/l & 80%NPS-TP	permit	24.3	6.2	5.0	10.36	5.18	3.00	0.0	12.0	0.0	0.056	0.038	0.045
Pont Source at 0.2 mg/l TP Higher TP at Clinton and Ayer													
Permit Loads P=0.2 mg/l & 80%NPS-TP C&A=0.5TP	permit	49.6	17.2	10.5	13.26	5.19	4.21	0.0	29.0	9.4	0.165	0.132	0.126
Permit Loads P=0.2 mg/l & 80%NPS-TP C=0.5TP	permit	47.7	16.8	10.5	13.06	5.19	4.21	0.0	28.4	8.1	0.162	0.129	0.115

Legend
BASELINE--1999 Loads
BASELINE--Current Permit Loads 1 mg/l P
WWTFs at 0.5mg/l P
WWTFs at 0.2 mg/l P
WWTFs at lower BOD
Preferred Alternatives to Date
EPA water quality standards TP=0.024mg/l

NOTE: table does not include upper 1.5 miles of North Branch

Table 14: Predicted In-stream TP Concentrations by River Milepoint per Model Run

	TOTAL PHOSPHORUS							CI @ 0.5	CI&Ay 0.5
Rivermile	Baseline	0.024	0.1	0.2	0.5	0.2 & 5 BOD	1.0	0.2	0.2
56.3	0.014	0.013	0.014	0.014	0.014	0.013	0.013	0.014	0.014
56.2	0.014	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
56.1	0.029	0.022	0.079	0.141	0.300	0.130	0.566	0.141	0.141
56.0	0.029	0.022	0.079	0.137	0.276	0.123	0.510	0.137	0.137
55.9	0.029	0.021	0.079	0.135	0.262	0.119	0.476	0.135	0.135
55.8	0.029	0.021	0.079	0.134	0.260	0.118	0.470	0.134	0.134
55.5	0.029	0.021	0.079	0.132	0.249	0.114	0.445	0.132	0.132
55.4	0.030	0.021	0.079	0.131	0.245	0.113	0.435	0.131	0.131
55.3	0.030	0.021	0.079	0.131	0.243	0.113	0.429	0.131	0.131
55.2	0.028	0.023	0.073	0.119	0.219	0.103	0.385	0.119	0.119
55.1	0.028	0.023	0.073	0.119	0.218	0.102	0.384	0.119	0.119
54.7	0.028	0.021	0.073	0.119	0.218	0.102	0.382	0.119	0.119
54.6	0.028	0.020	0.073	0.119	0.218	0.102	0.382	0.119	0.119
54.0	0.029	0.021	0.073	0.120	0.218	0.103	0.383	0.120	0.120
53.8	0.029	0.021	0.073	0.120	0.218	0.103	0.383	0.120	0.120
53.1	0.030	0.021	0.073	0.120	0.219	0.103	0.384	0.120	0.120
52.4	0.029	0.021	0.070	0.114	0.208	0.099	0.364	0.114	0.114
51.9	0.030	0.022	0.070	0.115	0.208	0.099	0.365	0.115	0.115
51.8	0.030	0.022	0.070	0.115	0.208	0.099	0.365	0.115	0.115
51.4	0.030	0.022	0.071	0.115	0.209	0.099	0.366	0.115	0.115
51.3	0.031	0.022	0.071	0.115	0.209	0.100	0.366	0.115	0.115
51.1	0.031	0.022	0.071	0.115	0.209	0.100	0.367	0.115	0.115
51.0	0.031	0.022	0.071	0.115	0.209	0.100	0.367	0.115	0.115
50.8	0.032	0.022	0.071	0.115	0.210	0.100	0.368	0.115	0.115
50.7	0.032	0.023	0.071	0.115	0.210	0.100	0.368	0.115	0.115
50.2	0.033	0.023	0.071	0.116	0.211	0.101	0.369	0.116	0.116
49.8	0.034	0.023	0.071	0.116	0.211	0.101	0.370	0.116	0.116
49.7	0.029	0.024	0.063	0.100	0.180	0.088	0.315	0.100	0.100
48.1	0.030	0.025	0.063	0.101	0.181	0.088	0.316	0.101	0.101
48.0	0.129	0.027	0.078	0.126	0.229	0.109	0.401	0.126	0.126
47.7	0.127	0.027	0.077	0.125	0.226	0.108	0.396	0.125	0.125
47.6	0.136	0.027	0.077	0.127	0.238	0.111	0.423	0.127	0.127
46.6	0.131	0.028	0.078	0.126	0.229	0.109	0.401	0.126	0.126
46.5	0.159	0.056	0.103	0.149	0.247	0.133	0.412	0.149	0.149
46.4	0.159	0.055	0.102	0.148	0.246	0.132	0.410	0.148	0.148
46.3	0.236	0.049	0.103	0.162	0.288	0.140	0.489	0.162	0.162
45.8	0.233	0.048	0.101	0.160	0.283	0.138	0.480	0.160	0.160
44.4	0.230	0.045	0.098	0.156	0.276	0.133	0.464	0.156	0.156
44.3	0.224	0.043	0.096	0.153	0.270	0.129	0.452	0.153	0.153
44.2	0.224	0.043	0.096	0.153	0.269	0.129	0.452	0.153	0.153
44.1	0.224	0.043	0.095	0.153	0.269	0.128	0.450	0.153	0.153
43.8	0.224	0.043	0.095	0.153	0.268	0.128	0.450	0.153	0.153

Rivermile	TOTAL PHOSPHORUS Baseline	0.024	0.1	0.2	0.5	0.2 & 5 BOD	1.0	CI @ 0.5 0.2	CI&Ay 0.5 0.2
43.8	0.224	0.043	0.095	0.153	0.268	0.128	0.450	0.153	0.153
43.0	0.224	0.043	0.095	0.152	0.268	0.128	0.448	0.152	0.152
42.9	0.214	0.042	0.092	0.148	0.260	0.125	0.436	0.148	0.148
39.8	0.212	0.042	0.092	0.147	0.258	0.124	0.432	0.147	0.147
37.4	0.208	0.042	0.091	0.145	0.254	0.123	0.426	0.145	0.145
36.9	0.209	0.042	0.091	0.145	0.255	0.123	0.426	0.145	0.145
36.8	0.209	0.042	0.091	0.145	0.255	0.123	0.426	0.145	0.145
36.5	0.209	0.042	0.091	0.145	0.255	0.123	0.426	0.145	0.145
36.4	0.253	0.040	0.087	0.140	0.249	0.117	0.414	0.154	0.154
35.0	0.253	0.040	0.087	0.140	0.250	0.118	0.415	0.154	0.154
32.7	0.251	0.040	0.087	0.139	0.248	0.117	0.412	0.153	0.153
32.6	0.248	0.041	0.086	0.138	0.246	0.117	0.408	0.152	0.152
31.0	0.249	0.041	0.086	0.139	0.246	0.117	0.408	0.152	0.152
28.7	0.239	0.041	0.085	0.135	0.240	0.114	0.397	0.149	0.149
27.1	0.234	0.042	0.085	0.135	0.239	0.114	0.395	0.148	0.148
27.0	0.233	0.042	0.085	0.135	0.239	0.114	0.395	0.148	0.148
26.9	0.233	0.042	0.085	0.135	0.239	0.114	0.395	0.148	0.148
25.9	0.219	0.042	0.084	0.133	0.234	0.113	0.386	0.146	0.146
25.8	0.216	0.043	0.084	0.133	0.233	0.112	0.385	0.146	0.146
24.9	0.216	0.042	0.084	0.133	0.233	0.113	0.385	0.146	0.146
24.8	0.282	0.042	0.085	0.137	0.248	0.116	0.412	0.149	0.165
24.7	0.266	0.042	0.083	0.132	0.239	0.113	0.396	0.144	0.160
24.3	0.262	0.042	0.083	0.132	0.239	0.112	0.395	0.144	0.160
24.2	0.260	0.042	0.083	0.132	0.239	0.112	0.394	0.144	0.160
24.1	0.258	0.042	0.083	0.132	0.239	0.112	0.393	0.144	0.160
23.6	0.254	0.042	0.083	0.132	0.239	0.112	0.392	0.144	0.160
23.5	0.241	0.042	0.082	0.129	0.232	0.109	0.379	0.141	0.156
23.1	0.239	0.042	0.082	0.129	0.232	0.109	0.378	0.140	0.156
23.0	0.196	0.040	0.074	0.114	0.201	0.097	0.325	0.123	0.136
22.9	0.194	0.041	0.074	0.114	0.200	0.097	0.323	0.123	0.136
21.5	0.187	0.041	0.074	0.113	0.198	0.096	0.319	0.122	0.135
20.6	0.181	0.041	0.074	0.112	0.195	0.096	0.314	0.122	0.134
17.7	0.148	0.044	0.073	0.106	0.171	0.092	0.274	0.113	0.124
17.2	0.140	0.044	0.072	0.104	0.165	0.091	0.263	0.111	0.121
16.2	0.124	0.046	0.072	0.101	0.148	0.089	0.233	0.106	0.114
15.2	0.109	0.050	0.071	0.093	0.121	0.084	0.175	0.098	0.104
14.2	0.103	0.052	0.069	0.088	0.111	0.080	0.143	0.093	0.098
14.1	0.102	0.052	0.069	0.088	0.110	0.080	0.140	0.092	0.098
13.9	0.102	0.052	0.069	0.088	0.110	0.080	0.140	0.092	0.098
13.8	0.100	0.052	0.068	0.087	0.109	0.079	0.139	0.091	0.096
13.1	0.086	0.047	0.061	0.078	0.097	0.071	0.122	0.081	0.086
12.9	0.136	0.047	0.062	0.079	0.100	0.072	0.129	0.082	0.087
11.2	0.125	0.047	0.061	0.077	0.098	0.071	0.125	0.081	0.086
10.4	0.124	0.047	0.061	0.077	0.098	0.070	0.124	0.081	0.085
min	0.028	0.020	0.061	0.077	0.097	0.070	0.122	0.085	0.085
max	0.282	0.056	0.103	0.200	0.500	0.140	1.000	0.200	0.200
average	0.180	0.044	0.078	0.117	0.194	0.100	0.311	0.130	0.130

Biomass/Chlorophyll_a

As noted previously, the model has a greater uncertainty associated with the results related to biomass, represented in the model by chlorophyll_a concentration, than other model predictions. Despite this uncertainty and because of its importance to achieving designated uses, MassDEP believes the model can be used to predict order of magnitude differences.

The model runs using permitted (design) effluent flows near 7Q10 in-stream conditions predicted that very strict effluent limits at the WWTFs only (i.e. without a reduction in non-point source phosphorus), even limits of low total phosphorus, resulted in very large biomass reductions when compared to 1999 levels (see Table 13) but still did not meet water quality standards. This indicates the need to include assessment of NPS abatement measures to meet water quality goals. As WWTF total phosphorus concentrations were reduced to 0.2 mg/l and NPS was reduced by 20% the total biomass as peak chlorophyll_a was reduced to a 50% reduction of biomass from that predicted for July 1999. As previously mentioned, although the biomass portion of the model has more uncertainty associated with the results, a 50 % or more reduction is considered significant by MassDEP, since it directly relates to a reduction of biomass within the water column itself.

Dissolved Oxygen

There are two issues of concern when assessing the model results relative to dissolved oxygen. The first is that Massachusetts Water Quality Standards set a minimum criterion of 5.0 mg/l in-stream to protect warm water fish. This standard must be met at all times when flow is greater than or equal to 7Q10 and becomes of particular importance during low-flow conditions observed during the summer months when water temperatures increase and the ability of the water to hold oxygen decreases. The second concern is large fluctuations in dissolved oxygen concentration and the amount of time supersaturated conditions exist. Large daily dissolved oxygen fluctuations result from lower dissolved oxygen concentrations in the early morning hours followed by supersaturated and extremely high concentrations in the late afternoon. This condition is directly related to eutrophication and the amount of both floating and rooted biomass in the system and is indicative of excessive biomass.

Predictive modeling conducted for the Nashua watershed included evaluating both these concerns. First, the model output tracked the number of hours, at 100 stations throughout the river during one week of low flow conditions approximating 7Q10, that the dissolved oxygen was predicted to be less than 5.0 mg/l (see Table 13). Second, although the diurnal fluctuation at each location was estimated, the output was evaluated for the amount of time dissolved oxygen exceeded saturation concentrations during that low flow week to provide an indirect measurement of the impacts and the amount of biomass in the system.

As previously noted, data were collected during the summer of 1998 and used to calibrate the model. Projections were then made for 1999 near 7Q10 conditions with full permitted flows and loads. Daily average flows at the Leominster USGS gage during July 13-20, 1999 were near 40 cubic feet per second (cfs). The 7Q10 flow at the Leominster USGS gage was 32.8 cfs.

The calibrated model run (1), simulating the baseline July 1998 conditions, estimated that except for the low flow headwaters condition, minimum dissolved oxygen violations occurred during that week 0% of the time, and dissolved oxygen was above 125% saturation 22% of the time and maximum phosphorus at 0.28 mg/l. When the low flow summer conditions were then adjusted to full WWTF loads, as in model run (2), the minimum DO conditions still remained above the state standard for water quality, except in the low flow headwaters section, however, the maximum phosphorus increased to 0.49 mg/l. This model run also used a 20% reduction in nonpoint source and was used as the baseline to evaluate the changes in water quality targets with changes in WWTF loads.

An additional metric that was used to assess the impact of phosphorus discharges on water quality was the amount of time dissolved oxygen concentrations exceeded saturation levels. This metric was used as a surrogate to estimate the biomass response to various control measures. In addition, diurnal fluctuations in dissolved oxygen were, on average, reduced even further throughout the system when both NPS and point sources were reduced. The largest improvement in dissolved oxygen fluctuations occurred from river mile 25.9 to river mile 21.7 to river mile 14.2 (Ice House Dam, through Groton School area, through Pepperell Impoundment). These results indicate significantly less photosynthetic and respiratory activity resulting from less biomass.

The results of all the simulated scenarios indicate that phosphorus load reductions from sources other than WWTFs also are necessary to meet water quality standards.

Summary of Model Results

The primary general conclusions from analyzing all the model results are as follows:

- To achieve the water quality goals of reducing biomass by at least 50% based on 1999 projected conditions, and reducing the duration of dissolved oxygen super-saturation by approximately 57% require that total phosphorus concentration in WWTF effluents be no greater than 0.2 mg/l and 0.5 mg/l during the growing season and that the NPS inputs be reduced by 20%.
- A reduction of the Fitchburg West, Fitchburg East, Leominster, and Ayer WWTFs to 0.2 mg/l and the Clinton and Pepperell WWTFs to 0.5 mg/l TP with a 20% watershed-wide NPS reduction resulted in the following. In-stream maximum TP concentrations were reduced to less than 0.16 mg/l from 0.49 mg/l in the free flowing sections of the upper reaches, and were reduced to 0.11 mg/l from 0.26 mg/l prior to entering the impoundment at Pepperell, and were also reduced from 0.40 mg/l to 0.15 mg/l entering Ice House Impoundment.
- MassDEP set the target for both the free flowing and impounded part of the river based on the response variable of chl_a. However, there are few data for chl_a

from periphyton data for the river. Because of this void, MassDEP compared the modeled phosphorus concentration for the free flowing portion to EPA's general guidance for nutrients (red book), that suggests for flowing waters, a concentration of 0.1 mg/L TP be attained. The in-stream concentration predicted through modeling approaches this concentration during low flow and is likely to be at or lower than this at higher flows. Given that the standing crop of periphyton represents the integration of conditions over periods of time longer than a week, MassDEP considers the concentrations predicted from the model as acceptable. This also appears to be a reasonable conclusion since the free flowing areas of the Nashua have not exhibited large fluctuations of DO nor has the minimum standard of 5.0 mg/l been violated during the surveys conducted.

In the case of the major impoundment, Pepperell Pond, chl_a data are available, so this preferred indicator can be used to set a water quality target because the model incorporates all of the DO impacts from chl_a, for both rooted and water column chl_a. The rooted plants obtain nutrients from the sediment and are considered not to be directly affected by the water column TP. Field water column data were used to estimate the fraction of the concentration predicted by the model that would be from the water column. For all Pepperell Pond data for July-August 1998, the average was 20% based on a total of 4 samples. The target chosen is 10 ug/l chl_a in the water column. This value is reflective of mesotrophic conditions and MassDEP considers this an appropriate target as an average during the growing season for a flooded meadow such as Pepperell Pond. To reach the target of 10 ug/l, chl_a, model predictions of 50 ug/l or lower would be acceptable using the 20% conversion factor. The TMDL of 0.5 mg/l from Clinton and Pepperell WWTFs and 0.2 mg/l TP from all other WWTFs is projected to produce a peak total concentration of chl_a in Pepperell Pond of 49 ug/L, which translates to approximately 10 ug/L in the water column and thus meets the water quality target.

- Reducing the Clinton and Pepperell WWTFs to 0.2 mg/l did not show a significant decrease in the mainstem TP, and was not enough to justify the increased cost for the incremental improvements.
- A reduction in TP from WWTF discharges, by itself, is not sufficient to meet the minimum DO standard, and does not reduce biomass enough to meet water quality standards and USEPA guidance.
- Biomass reductions of 50% below the baseline 1999 full permitted loads are obtained when NPS phosphorus is reduced 20% in combination with WWTF TP effluent concentrations.
- Reductions in NPS phosphorus, coupled with reductions in WWTF discharges of TP, are necessary to significantly reduce biomass, significantly reduce the percentage of time of super-saturation, and to approach the USEPA guidance for in-stream P concentrations.

TMDL

Total Maximum Daily Loads (TMSL) can be defined by the equation:

TMDL = BG + WLAs +LAs +MOS

Where

TMDL = loading capacity of receiving water
BG = natural background
WLAs = portion allotted to point sources
LAs = portion allotted to (cultural) NPS
MOS = margin of safety

And consideration must also be given to seasonal variability and to growth.

Based upon the detailed data collection and predictive water quality modeling conducted and in consideration of all of the evidence and analysis previously discussed, MassDEP is establishing in accordance with 314 CMR 4.05(5)(c) an effluent limit of 0.2 mg/l TP at design flows during the growing season for Fitchburg West, Fitchburg East, Leominster, and Ayer WWTFs, and 0.5 mg/l TP limit for the Clinton WWTF and Pepperell WWTF, plus a goal of 20% reduction in NPS P input. These limits and reductions to nutrient inputs are necessary to control accelerated and cultural eutrophication in the Nashua River so that it can meet its designated uses. Reducing the Clinton WWTF and Pepperell WWTFs to 0.2 mg/l did not show a significant decrease in the mainstem TP, and the results are likely to be within the predictive limits of the current model. Therefore effluent limits less than 0.5 mg/l P for these two discharges are considered not warranted at this time. Pepperell WWTF is downstream of the Impoundment.

As previously noted, during the non-growing season, effluent limits for P are not proposed; however, MassDEP and USEPA are concerned that the discharge of particulate phosphorus during the non-growing months may settle in downstream impoundments and slow moving reaches of the river. Therefore, the NPDES permit will require that the WWTFs optimize the removal of particulate phosphorus and monitor both total and dissolved P to determine if there is a need for non-growing season limits.

As noted above, the model simulations indicate that a combination of reductions of phosphorus at the WWTFs and from NPS inputs is necessary to meet water quality standards and designated uses. The model predicts that the limits identified above will result in the following:

1. in-stream TP concentrations are expected to drop from an average concentration projected for 1999 of about 0.36 mg/l to an average concentration of 0.13 mg/l based on the modeling and weight-of-evidence approach.

   This reduction in phosphorus will provide improvements in the response variables as follows:

2. the minimum DO criterion of 5.0 mg/l will be maintained during low flow conditions in all reaches of the Nashua River below the WWTFs thus meeting the requirements of 314 CMR 4.05(3)(b)1(a).
3. the amount of time in-stream DO levels exceed 125% saturation levels will be reduced by approximately 57% indicating a significant amount of biomass reduction. This biomass reduction will be seen in the water column.
4. peak biomass is expected to be reduced by 50% in the system over 1999 projected conditions which should meet the state criteria for "aesthetics" in 314 CMR 4.05(5)(a) and address most of the public concerns about excessive floating aquatic vegetation.
5. chl_a levels will be reduced in the water column reducing surface algal mats.

Implementation of a management plan for Pepperell Pond will reduce rooted aquatic plants through mechanical means such as harvesting or hydroraking. Reduction in plant coverage will in turn reduce diurnal dissolved oxygen swings. Reduction in rooted plants will also reduce the amount of nutrients being pumped from the sediments and moved into plant biomass and improve access and safety for boating and swimming.

Focusing on reductions in NPS pollution watershed-wide will also maintain instream improvements resulting through changes in WWTF effluent quality. There is the possibility of improvements being reduced as the watershed develops and NPS TP inputs increase. A strong NPS control program is integral to implementation of this TMDL.

Waste Load Allocation

The WLA for TP is summarized in Table 15 along side the LA for NPS and the MOS, both of which will be discussed in the next sections. In the WLA no room was provided for increases over plant design flow or for other dischargers to be added.

Table 15
TMDL for Total Phosphorus
NASHUA RIVER

			WWTF Effluent Limits Total Phosphorus, mg/L April 1 – October 31[1]		WWTF Effluent Limits Total Phosphorus, mg/L November 1 – March 31
WWTF	**NPDES**	**Design Flow, MGD**	**mg/L**	**lbs/day @ design flow**	**mg/L and lbs/day**
Fitchburg West	**MA0101281**	**10.5**	**0.20**	**17.5**	**Optimize for particulate phosphorus removal and monitor and report for total and dissolved**
Fitchburg East	**MA1010986**	**12.4**	**0.20**	**20.7**	
Leominster	**MA0100617**	**9.3**	**0.20**	**15.5**	

Clinton	**MA0100404**	**3.0**	**0.50**	**12.5**	**phosphorus concentration**
Ayer	**MA0100013**	**1.8**	**0.20**	**3.0**	
Pepperell	**MA0032034**	**1.1**	**0.50**	**4.6**	
TMDL					
WLA				**73.8**	
LA				**177**	
MOS				**2.0**	**Separation of Fitchburg CSOs**
	Model-conservative assumptions of higher wwtf design loads with lowest river flow; NPS based on avg annual & avg monthly flow during lowest river flows			**IMPLICIT**	
TMDL				**252.8**	

The TMDL is based on a weight-of-evidence approach using a number of response variables to various levels of P. With the TMDL based on a TP of 0.2 mg/l in the effluents from the WWTFs on the mainstem above Pepperell Impoundment, and 0.5 mg/l for the Clinton and Pepperell WWTFs, plus a 20% reduction in NPS TP concentrations in the Nashua River fully realized, predicted TP concentrations in the Nashua River near the point of discharge of these treatment facilities are less than 0.16 mg/l. Based on the above, the MassDEP considers the proposed loads from these sources to be acceptable in terms of water quality as expressed in the response variables for the mainstream Nashua River. For the response variables, the amount of time during the low flow week in which the percent saturation is above 125% will be reduced 57% thereby also reducing the large diurnal swings of dissolved oxygen and raising the minimum dissolved oxygen. The response variable of chl_a will also be reduced by 50% representing a reduction in the biological productivity.

Load Allocation

The results from the HSPF model include two explicit sources of non-point source phosphorus: runoff and groundwater. Runoff combined with groundwater can be separated into two components: natural background and cultural. To estimate the natural background portion, an export coefficient was used which assumes the watershed is entirely forested. An export coefficient of 0.13 kg/ha/yr was used based on the range of values summarized by Reckhow et al.(1980). Assuming the entire watershed is forested yields:

0.13 kg/ha/yr X 520 sq mi X 640 acres/sq mi X 1/2.47 acres/ha X 2.2 lbs/kg = 38,535 lbs P/yr

This load represents the natural background portion of phosphorus associated with runoff and groundwater. (There are not sufficient data to disaggregate these two components.) To apportion this load over the year 1999, daily stream flow from the USGS gage in Leominster (110 sq mi at the gage) was used to prorate the annual load on a daily time scale. The estimated daily natural background P load is assumed to be proportional to the percentage of average annual flow volume represented by each day's mean flow. For the May through October permit period, this amounted to 10,000 lbs or 54 lbs/day. The HSPF model predicts approximately 50,680 lbs during the 6 month growing season or 275 lbs/day of P from non-point sources during this same period. Thus the calculated cultural contribution during this low flow period is estimated to be 221 lbs/day.

During the growing season, when phosphorus from runoff is at its minimum, the principal source of phosphorus is still from the dissolved, readily available point source phosphorus discharged by the treatment plants. The NPS load allocation is expressed as a reduction in phosphorus by 20% from the 1999 values that results in a target load allocation of 177 lbs/day for this source.

Margin of Safety

TMDLs must provide a margin of safety to address uncertainties in the technical analysis. In the case of the Nashua a margin of safety is provided in two ways. First, and perhaps most significant, the margin of safety is implicit with conservative assumptions used in the model. The HSPF12 model was developed (USEPA, 2000; Baker, 2001,2002) using the higher design flows and loadings in the permits versus the actual lower flows and loadings discharged by the WWTFs. All scenario comparisons were conducted near 7Q10 flows. For example, the scenarios include very low point source phosphorus loads during the entire growing season and not just during the low flow period actually modeled. Second, the Department is requiring that all WWTFs on the mainstem above Pepperell Impoundment achieve an effluent limit of 0.2 mg/l total phosphorus to account for model uncertainties and provide a margin of safety that reductions predicted by the model will actually occur. This is relevant particularly to the model predictions of biomass reductions that are the most critical issue on the Nashua River. Additionally, the City of Fitchburg is under Administrative Order from the USEPA to have complete CSO separation. The reduction in nutrients as a result of the CSO changes will provide additional MOS.

A report by Numeric Environmental (Baker, 2002) discussed the annual phosphorus loading from the Fitchburg CSOs based on event mean concentrations measured in the field at the CSOs during 1996. Total annual CSO loads were estimated to be 33,421 pounds of CBOD5, 2, 492 pounds of ammonia-N and 796 pounds of total phosphorus. The Numeric reports state that these annual loads account for approximately 1% of the total non-point source annual pollutant loadings for pollutants, but that the use of EMCs for typical urban stormwater and CSOs from the literature suggests that the total annual CSO loads due to the Fitchburg CSO may be higher than those measured in Fitchburg during 1996 by up to a factor of 3.

The limit for total phosphorus of 0.2 mg/l for the WWTFs on the mainstem above Pepperell Impoundment and 0.5 mg/l for the WWTF on the South Branch and for the Pepperell WWTF is predicted to meet the minimum dissolved oxygen criterion when combined with a reduction of 20% nonpoint source total phosphorus input. However, the purpose of this TMDL is also to address eutrophication issues in the river and not just minimum dissolved oxygen. Therefore, other factors also must be considered. The results of simulating the 1999 flows with 0.5 mg/l from the point sources were close to meeting standards, but did not meet all of the goals and therefore is not considered to meet the TMDL. However, the difference between the results for the scenarios with WWTF effluent concentrations at 0.5 mg/l and the scenario with effluent concentration at 0.2 mg/l, both with a 20% reduction in NPS total phosphorus, for 1999 and design flows are not dramatically different. This suggests that at these relatively stringent effluent limits, changes have gradual impacts on water quality. Hence, using the results from the scenario with 0.2 mg/l as a baseline to set the upper limit (and upper limit is emphasized) on the margin of safety seems within reason. While the EPA guidance phosphorus concentration was approached under these scenarios at all locations, there is uncertainty about the model's prediction of biomass, and there is a question whether or not a 20% reduction in nonpoint source phosphorus can be completely achieved. At the same time, using average monthly and average annual flows to calculate the NPS P load during low flow periods likely overstates these loads and represents part of the qualitative or implicit margin of safety. Therefore, the Department believes effluent limits as stated for total phosphorus for the mainstem WWTFs are necessary as a component of the margin of safety. In addition, the margin of safety takes into consideration the fact that all communities have not completed a comprehensive facility planning process nor have they completed the MEPA process at this time therefore future needs have not yet been finalized.

Overall then, the conservative assumptions are difficult to estimate quantitatively, so they represent and are best expressed as an implicit margin of safety.

Recommended Loads and Actions for Nashua River

The above information and modeling conducted to date indicates that both WWTF facility improvements and nonpoint source reductions are necessary to achieve water quality goals. The proposed TMDL loads are listed below with the implementation strategies for reducing point and nonpoint source pollution in the Nashua River watershed as follows.

- NPDES permit program: reissuance of 5 municipal MA WWTF permits including Ayer WWTF, Fitchburg West WWTF, Fitchburg East WWTF, Leominster WWTF, Pepperell WWTF, and Clinton WWTF with new limits tied to instream water quality to reduce levels of nutrients as selected from the Scenario Comparison Table 13 for HSPF results.

- Summer monthly average limits are as follows:
  Fitchburg West NPDES Permit No. MA 0101281
  (17.5 lbs/day) (8 mg/l BOD, 0.2 mg/l TP)
  Fitchburg East NPDES Permit No. MA0100986
  (20.7 lbs/day) (8 mg/l BOD, 0.2 mg/l TP)
  Leominster NPDES Permit No. MA0100617
  (15.5 lbs/day) (15 mg/l BOD, 0.2 mg/l TP)
  Clinton NPDES Permit No. MA0100404
  (12.5 lbs/day) (20 mg/l BOD, 0.5 mg/l TP)
  Ayer NPDES Permit No. MA 0100013
  (3.0 lbs/day) (30 mg/l BOD, 0.2 mg/l TP)
  Pepperell NPDES Permit No. MA 0100064
  (4.6 lbs/day) (29 mg/l BOD, 0.5 mg/l TP)

- Stormwater Runoff Program:

Issuance of Phase 2 Stormwater Permits, to reduce nonpoint loading of nutrients to the tributaries and mainstem. Grant programs exist through MassDEP to encourage grants tied to NPS reductions in targeted watershed;
Phase1 and Phase 2 stormwater permitting is targeted to control runoff from additional watershed communities. Massachusetts, over the last several years, has instituted a comprehensive stormwater management plan. The goal of this program is to reduce nonpoint source runoff and associated impacts. The towns of Ayer, Boylston, Clinton, Fitchburg, Gardner, Groton, Holden, Lancaster, Leominster, Lunenburg, Paxton, Rutland, Shirley, Sterling, Townsend, West Boylston, and Westminster are under the Phase 2 program. The towns of Bolton, Dunstable, Harvard, and Pepperell were granted waivers from the program by USEPA. Details of the program and requirements be fulfilled by the cities and towns are listed in Appendix F.

- CSO NPDES permit reissuance and planning improvements to provide complete separation of flows in the City of Fitchburg. Addressing the CSOs in Leominster would also provide added benefit.
- Development of Lakes' TMDLs for phosphorus control in the watershed to assist with proposed 20% NPS-total phosphorus reduction. At present one TMDL for Bare Hill Pond in the Nashua Watershed has been completed. During the summer of 2003 a number of additional lakes had TMDL surveys conducted with future plans for development of TMDLs for nutrients reductions. Additionally, a number of bacteria TMDLs have been completed for the Nashua watershed. A by-product of reducing bacterial contamination will be reduction of the associated nutrient inputs. Also, the Massachusetts Nonpoint Source Management Plan, Volume IV, Action Strategies, 2001, provides a compilation by each river segment for each major watershed, showing 303(d) water quality impacts, important water quality issues, data and information sources, and provides specific recommendations to address the water quality impacts.
- Development of a zoned use management plan for Pepperell Impoundment, which would specify areas of recreation, habitat protection for wildlife, and include structural controls for macrophytes in order to promote these uses. This plan would

be developed by the towns in combination with the NRWA through a grant submitted to the 319 Implementation Program for funding development and implementation.

- Mass DEP has also developed a web based Watershed Based Plan http://host.appgeo.com/MADEPWatershed/Map.aspx which identifies, maps, and models land use with its corresponding contribution of pollutant loads, and provides nonpoint source remediation information.

Seasonal Variation

In the case of eutrophication for systems with relatively short retention times such as shallow impoundments, the growing season is the critical time. This suggests that nutrient loads to a flowing water system are most relevant during that period.

During 1998 and 2003, a number of water quality surveys were conducted to evaluate nutrient loadings to enhance understanding of the nature and extent of nutrient sources to the Nashua River. Total phosphorus loadings were estimated using concurrently measured flows and total phosphorus concentrations from point sources and from tributaries, which represents non-point sources. The evaluation of nutrient loadings during the field surveys found that point sources contributed the majority of nutrient loadings to the Nashua River during most surveys. Point sources were found to be the dominant source of biologically available phosphorus (i.e. dissolved phosphorus).

The dissolved form of phosphorus from the point source loading is not only available for direct uptake by the plant community but also will not settle. As a result there is assumed to be little likelihood that WWTF discharges of dissolved phosphorus during the non-growing season and particularly during high flow months will be retained in the system for use during the growing season.

Therefore, seasonal phosphorus removal at the WWTFs is justified and effluent limits for total phosphorus will be applicable from April 1 through October 31. During the non-growing season, November 1 through March 31, effluent limits for phosphorus will not be in effect; however, due to concerns that particulate phosphorus, if discharged, may potentially settle in downstream impoundments during this timeframe, optimization for particulate phosphorus removal will be required and effluent monitoring for both total and dissolved phosphorus will be required to support future permitting decisions. The further question of whether dissolved phosphorus might adsorb to particulate matter and settle to later become biologically active is also open and will be addressed through future monitoring programs.

Monitoring Plan for the TMDL Developed Under an Adaptive Management Approach

In order to assess the progress in and success of obtaining the TMDL’s water quality goals, a systematic monitoring plan needs to be established. Data necessary to determine whether water quality goals have been met through the implementation of one or a combination of control mechanisms provided for in the TMDL need to be collected and evaluated. The actual design of the monitoring program will be developed during the first permit cycle. The design will incorporate and expand upon available programs such as the ones listed below.

The MassDEP Central Regional Office in Worcester (CERO) has developed a strategic monitoring plan in the Nashua River watershed to sample 5 stations on a bimonthly program. The goal of the program is to measure long-term water quality trends at strategic and representative stations. Measurements include: total phosphorus, dissolved oxygen, pH, temperature, conductivity, total dissolved solids, total suspended solids, ammonia, nitrate/nitrite, TKN, hardness, alkalinity, chlorides, turbidity, and TSS. The stations included in the MassDEP monitoring program are:

- North Nashua: below all municipal treatment plants; below USGS gage, Leominster, mile 43.8, (NN12)
- South Nashua: Bolton Road Bridge, below the Clinton WWTF, mile 36.5, 1.6, (NS19)
- Inlet to Pepperell Pond: the boat launch in Groton, north/downstream of the Rte. 119 Bridge, (station name=INLTPEPPD)
- Mainstem Nashua: Railroad crossing below Covered Bridge, Pepperell, downstream of Pepperell Pond, mile 13.7 (NM29A)
- Squannacook River: off Townsend Road below gage, Shirley-Groton, mile 23.0, 3.5 (NT60A)

Additionally, the MassDEP Division of Watershed Management (DWM) has instituted a program of watershed surveys in 5 groups of revolving watersheds within the state, during which each watershed is targeted for intensive survey work every 5 years. Once the new NPDES permits become effective and loads of introduced pollutants are being reduced, the DWM monitoring program will be used to measure levels of improvements through expansion of the CERO program to include chlorophyll samples, benthic algae, and additional stations on a rotating schedule. The intensive program, carried out in 1998 was augmented by data collected in 2003 with expansion into the un-assessed tributaries for non-point source monitoring. A Quality Assurance Project Plan developed for the 2003 monitoring program, prepared by MassDEP (Connors, 2002), details this monitoring plan. The next 5-year sampling will be conducted in 2008.

The Nashua River Watershed Association, under a 104(b)(3) grant from the MassDEP has expanded and upgraded their volunteer monitoring program to evaluate the mainstem as well as tributaries that are presently un-assessed. Their sampling includes: total coliform, fecal coliform, E. coli, dissolved oxygen, temperature, pH, and alkalinity. Appendix C includes selected summary results from the NRWA monitoring program. The data are complementary to and support the MassDEP efforts. During 2000 and again in 2002, this program included total phosphorus sampling at 10 locations.

TMDL Implementation

Implementation of the TMDL will be assured primarily through the NPDES permit process inasmuch as the point discharges are the principal source of phosphorus to the Nashua River during the period of concern (growing season). Nonpoint source controls will also be needed in order to reduce watershed inputs of phosphorus. The TMDL includes adaptive management. Monitoring of the Nashua's response to incremental controls will allow refinement of the modeling predictions and determine whether the water quality goals have been achieved. If further control efforts are needed, both implementation of additional nonpoint source reductions and more stringent effluent limits will be evaluated. Additionally, a management plant would be developed and implemented for Pepperell Pond for zoned uses.

Proposed Tasks and Responsibilities

Table 16 lists the proposed tasks and responsibilities for this TMDL to assure completion of each task. The TMDL recognizes uncertainty in the modeling approach, and in the prediction of what the final level will be in percentage exceedance of target levels. The TMDL supports that by utilizing an adaptive implementation approach these point source reductions at the treatment plants, and CSO elimination along with some reductions in nonpoint source inputs, will be enough to achieve standards. An integral part of this TMDL will be the promotion of a structured management plan to address the macrophytes through a zoned use designation for Pepperell Impoundment. The monitoring programs incorporated as part of this TMDL will determine if more reductions are needed in the future.

Table 16: Proposed Tasks and Group(s) Responsible for Implementation

Tasks	**Responsible Group**
TMDL development	MassDEP
Address Public Comments on TMDL	MassDEP, Consultants
Organization, contacts with Stakeholder Groups	NRWA
NPDES Permit issuance and response to comments	USEPA, MassDEP
Public Meetings on Permits	USEPA, MassDEP
Facility Upgrades and CWMP	Communities
Include proposed remedial actions in NRWA Management Plans	Communities, NRWA
Monitoring	MassDEP (year 2 of cycle) NRWA volunteer monitoring USEPA
NPDES Stormwater Management Program	USEPA, MassDEP, Communities
Development of Pepperell Pond Management Plan through a proposed 319 Grant	NRWA, Towns, working with consultants and MassDEP
Organize and implement TMDL education, outreach	NRWA, Towns working with

programs	consultants
CSO elimination in Fitchburg	USEPA, MassDEP, City
Pass town bylaws to control NPS. See http:/www.umass.edu/masscptc/bylaws	Town Selectmen, town meeting
Implement other remedial measures for discrete NPS pollution outside of Phase II	See Table 17

Ideas for NPS pollution control in the watershed are listed below and also in the Clean Water Toolkit, also called the Massachsuetts Nonpoint Source Pollution Management Manual. This manual is a comprehensive, electronically-based resource that outlines appropriate BMPs for remediation of NPS, organized by specific land use category. The manual can be accessed at **http://mass.gov/dep/water/resources/nonpoint.htm** .

Table 17:. Guide to Nonpoint Source Control of Phosphorus and Erosion

Type of NPS Pollution	**Whom to Contact**	**Types of Remedial Actions**
Agricultural		
Erosion from Tilled Fields	Landowner and NRCS	Conservation tillage (no-till planting); contour farming; cover crops; filter strips; etc.
Fertilizer leaching	Landowner and NRCS and UMass Extension	Conduct soil P tests; apply no more fertilizer than required. Install BMPs to prevent runoff to surface waters.
Manure leaching	Landowner and NRCS and UMass Extension	Conduct soil P tests. Apply no more manure than required by soil P test. Install manure BMPs.
Erosion and Animal related impacts	Landowner and NRCS	Fence animals away from streams; provide alternate source of water.
Construction		
Erosion, pollution from development and new construction.	Conservation Commission, Town officials, planning boards	Enact bylaws requiring BMPs and slope restrictions for new construction, zoning regulations, strict septic regulations. Enforce Wetlands Protection Act
Erosion at construction sites	Contractors, Conservation Commission, Building Inspector	Various techniques including seeding, diversion dikes, sediment fences, detention ponds etc.
Resource Extraction		
Timber Harvesting	Landowner, logger, Regional DEM forester	Check that an approved forest cutting plan is in place and BMPs for erosion are being followed
Gravel Pits	**Pit owner, Regional DEP, Conservation Commission**	**Check permits for compliance, recycle wash water, install sedimentation ponds and berms. Install rinsing ponds.**
Residential, urban areas		
Septic Systems	Homeowner, Lake associations, Town Board of Health, Town officials	Establish a septic system inspection program to identify and replace systems in non-compliance with Title 5. Discourage garbage disposals in septic systems.
Lawn and Garden fertilizers	Homeowner, Lake associations	Establish an outreach and education program to encourage homeowners to eliminate the use of phosphorus fertilizers on lawns, encourage perennial plantings over lawns.
Runoff from Housing lots	Homeowner, Lake associations	Divert runoff to vegetated areas, plant buffer strips between house and lake
Urban Runoff	Landowner, Town or city Dept. Public Works	Reduce impervious surfaces, institute street sweeping program, batch basin cleaning, install detention basins etc.

Highway Runoff	MassHighway,	Regulate road sanding, salting, regular sweeping, and installation of BMPs.
Unpaved Road runoff	Town or city Dept. Public Works or other owner	Pave heavily used roads, divert runoff to vegetated areas, install riprap or vegetate eroded ditches.
Other stream or lakeside erosion	Landowner, Conservation Commission	Determine cause of problem; install riprap, plant vegetation.

Reasonable Assurance/ Water Quality Standards Attainment Statement

Reasonable assurance, that the TMDL will be implemented, is effected through enforcement of current regulations, availability of financial resources, and state, local, and federal pollution control programs. MassDEP and USEPA possess the statutory and regulatory authority, through the water quality standards and the State and Federal Clean Water Acts, to implement and to enforce the provisions of the TMDL, through requirements for total phosphorus loading reductions from NPDES permittees. Regulation enforcement for point sources includes National Pollution Discharge Permits (NPDES. Reasonable assurance also includes the stormwater NPDES permit coverage, which will address the discharges regulated under this program. Regulation enforcement for nonpoint sources includes local enforcement of the Wetlands Protection Act, the Rivers Protection Act, Title 5 for septic systems, and local regulations governing zoning among others. Financial programs include federal money available through the 319 NonPoint Source Program, the 604 and 104b programs, which are included as part of the MassDEP and USEPA Performance Partnership Agreements. Funding is also available through the Title 5 upgrade low interest loans, State Revolving Fund Clean Water Act money and cost sharing for agricultural BMPs through the Federal NRCS program. The point system for receiving grants has been modified for most grants to promote projects which have completed and approved TMDLs.

Reasonable assurance exists given the extensive HSPF and QUAL2 modeling efforts together with the field data which show that once the NPDES permit limits are implemented at the municipal treatment plants in Massachusetts and nonpoint source control implementation is included, water quality standards will be attained and uses affected by these parameters will be restored. That standards will be attained is supported by the concurrent development and implementation of nutrient watershed TMDLs for phosphorus level reductions in lakes in the Nashua River drainage area, thereby assisting with reductions in NPS levels. NPS levels will also be reduced through the Phase 2 stormwater permit program for cities and towns, to encourage best management practices (BMPs). The review and reissuance of the CSO permits for the Cities of Fitchburg and Leominster, with complete separation of CSOs for Fitchburg will further reduce contributions of nutrients. Complete separation of CSOs in the city of Fitchburg is governed by an Administrative Consent Order between the USEPA and the City of Fitchburg.

Public Participation

MassDEP and the USEPA attended meetings on a regular basis over a number of years with the then existent Executive Office of Environmental Affairs EOEA Nashua River Watershed Team. The EOEA team was composed of representatives from various agencies, planning associations, and stakeholders. At the meetings MassDEP and the consultants presented various aspects of the data collection, assessment, and modeling throughout the course of the project and responded to comments and received input on the process. These meetings together with the public commenting aspect of the NPDES permitting process for the permit renewals in 2000 and again during 2005 and 2006, and with a meeting on this TMDL are considered the public input requirement of this TMDL. Year 1 of the MassDEP watershed cycle also requires public meetings, which will be used as a method of meeting the TMDL requirements for public involvement during the implementation process.

Public Comment and Reply

The NPDES permitting process will address the public comments on the proposed effluent limits, which are the major target of this TMDL. Additionally, public comments received at the public meetings, and comments received in writing within a 30-day comment period following the public meeting, will be considered by the Department. The final version of the TMDL report will include both a summary of comments and the Department's response. The final TMDL report will be sent to USEPA Region 1 in Boston for final approval.

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Appendix A
Nashua River Watershed Land Use

Part 1: Land Area Per Subwatershed; Massachusetts Protected Land, MADEP NPDES Permits in each subwatershed, Total Watershed Priority Habitat

PRIORITY HABITAT FOR ENTIRE WATERSHED
Total of 13.8 square miles declared Priority Habitat

SUBWATERSHEDS
Square miles include MA and NH subwatershed portions;
Protected areas include only MA portion of watershed;
NPDES includes only MA permits

<u>Nashua River Mainstem</u> – 78.4 sq miles 9.8%
3611 acres Permanently Protected
1324 acres Chapter 61A Forestry Ag, (temporary protection)
3 NPDES major
4 NPDES minor

<u>South Nashua</u> - 12.6 sq miles 7.9%
597.21 acres Permanently Protected
43.89 acres Chapter 61A Forestry Ag, (temporary protection)
1 NPDES major
3 NPDES minors

<u>Mulpus Brook</u> – 15.9 sq miles 32%
1682 acres Permanently Protected
1585 acres Chapter 61A Forestry Ag, (temporary protection)
24.63 miles streams, lakes upstream

<u>Catacoqnamug Brook</u> – 20.0 sq miles 20%
1249 acres Permanently Protected
1335 acres Chapter 61A Forestry Ag, (temporary protection)
1 NPDES minor
31.9 miles streams, lakes upstream

<u>Nonacious Brook</u> – 18.8 sq miles 9.4%
1013 acres Permanently Protected
128 acres Chapter 61A Forestry Ag, (temporary protection)
1 NPDES minor
1 NPDES major

<u>Still River</u> – 5.5 sq miles 34%
914 acres Permanently Protected
294 acres Chapter 61A Forestry Ag, (temporary protection)

James Brook – 4.3 sq miles 12%
348 acres Permanently Protected
no Chapter 61A Forestry Ag, (temporary protection)

Unkety Brook – 6.9 sq miles 26%
619 acres Permanently Protected
534 acres Chapter 61A Forestry Ag, (temporary protection)

Wachusett Reservoir - 21.7 sq miles 38%
4680 acres (7.3 sq miles) Permanently Protected
655 acres Chapter 61A Forestry Ag (temporary prot)
no NPDES discharges

Wekepeke Brook – 11.5 sq miles 20%
1448 acres (13.4 sq miles) Permanently Protected
18 acres (4.8 sq miles) Chapter 61A (temporary)
no NPDES discharges

Flag Brook - 12.66 sq miles 32%
2105 acres Permanently Protected
558 acres Chapter 61A (temporary)
1 Minor NPDES
1 Major NPDES

Fall Brook - 7.1 sq miles 14%
545 acres Permanently Protected
104 Chapter 61A (temporary)
no NPDES discharges

North Nashua River - 65.8 sq miles less than 1%
1453 acres Permanently Protected
57 aces chapter 61A (temporary)
2 Minor NPDES
4 Major NPDES

Monoosnoc Brook -11.38 sq miles 24%
3.72 acres Chapter61A (temporary)
1799 acres (2.8 sq miles) Permanently protected
1 Minor NPDES discharge
no major discharges

Phillips Brook - 15.82 sq miles 15%
1040 acres Permanently Protected
481 acres Chapter61A (Temporary)
1 Minor NPDES discharge

Whitman River - 28.25 sq miles 26%
3299 acres (5.1 sq miles) Permanently protected
1516 acres Chapter61A (Temporary)
no NPDES discharges

Quinapoxet River - 57.17 sq miles 48%
11396 acres (17.8 sq miles) Permanently Protected
6219 acres (9.7 sq miles) Chapter61A (temporary)
3 NPDES Minor discharges

Stillwater River - 39.3 sq miles 47%
8778 acres (13.6 sq miles) Permanently Protected
3126 acres (4.8 sq miles)) Chapter61A (Temporary
no NPDES discharges

Squannacook River - 73.15 sq miles 18.3%
7902 acres (12.3 sq miles) Permanently Protected (in Mass)
705 acres Chapter61A (Temporary)
1 Major NPDES discharge

Nissitissit River - 60.5 sq miles 7%
1583 acres (2.4 sq miles) Permanently Protected
1259 acres Chapter 61A (temporary)
no NPDES discharges

Fallulah Brook – 16 sq miles 14%
1313 acres Permanently protected
201 acres Chapter61A (temporary)
no NPDES discharges

Appendix B
City of Fitchburg Combined Sewer Overflows
Summary of Reports prepared by Fitchburg's Consultant Dufresne & Henry, Inc.

The ***Plan of Study for Engineering Service CSO***, *1995* details the work to be conducted under the study and the timetable for completion. The plan of study is represented by five individual tasks: response to the Administrative Order, system characterization, sewer system modeling and analysis, water quality evaluation, and long-term control plan development. The ***Environmental Notification Form*** for the CSO study was filed on July 31, 1996.

Report on ***Dry Weather Overflow Analysis, CSO Study***, DPW, Fitchburg, May, 1995.
This report details surveys at all CSO regulators, dye studies, preparation of maps and sketches, and delineation of tributary drainage areas. The report states there are 38 CSO regulators that lead to 27 outfall points at surface waters. Of these, 7 dry weather overflows discharge raw sewage intermittently to the Nashua River.

The Report on ***Nine Minimum controls to Reduce CSO Overflows***, *1996*, documents the City of Fitchburg's actions to meet EPA's CSO Control Policy whereby municipalities are required to implement the Nine Minimum controls by December 31, 1996. These controls are:

- Proper operation and regular maintenance for the sewer system and CSO outfalls.
- Maximum use of the collection system for storage.
- Review and modification of pretreatment requirements to ensure that CSO impacts are minimized.
- Maximization of flow to the WWTP for treatment.
- Elimination of CSOs during dry weather.
- Control solid and floatable materials in CSOs.
- Pollution prevention programs to reduce contaminants in CSOs.
- Public notification to the Public of CSO occurrences and impacts.
- Monitoring to effectively characterize CSO impacts and the efficiency of CSO controls.

The SWMM model (version 4.3) was applied by HydroAnalysis, Inc. and reported in the ***CSO Master Plan SWMM Model Development, Calibration and Application Report***, 1998. This model computes the combined sewage flow for 12.3 miles of combined sewer system tributary to 58 CSO regulators (42 or which discharge directly to the Nashua River or tributaries thereto, and 11 combinations in which storm water and sanitary sewerage may commingle), and 7.7 miles of the Main Truck Line sewer. Over 20 miles of sewer line are represented. The model was used to predict performance of the CSO system for the 2.1-inch rainstorm of 11/15/95. This approximates the one-year 24-hour storm, which is used for evaluating CSO proposals. The model was calibrated against field measurements in 1995, 1996, and 1997. The model is being used to determine the magnitude of overflows and evaluate control strategies.
The model reports the following:

- for the 24-hour storm, about half reaches the East Fitchburg WWTF and half is discharged to surface waters via overflows;
- infiltration continues for several days after a large storm, however, only the short term response of surface runoff creates the overflow situation;
- The model predicts higher peak flow and faster flow recession than actually occurs.

The model will be used to evaluate structural and nonstructural components of reduction methods to produce a phased plan.

CSO Master Plan Water Quality Evaluation, DPW Fitchburg, 1998.
This study is a computer simulation of Fitchburg's CSO system under varying storm events, and predicts the pollution loads which discharge into the Nashua River as the result of the CSO overflows. The study modeled the 3-month, 6 month, 1 year, and 5-year rainstorms, which are the typical year's rainstorm.

- 58 regulators end at 37 outfalls into the Nashua River and tributaries.
- 96% of the combined sewage overflow occurring in the 3-month storm came from 10 of the 37 outfalls with the remainder coming from 17 outfalls. Thirteen outfalls provide no overflow and 17 produce only 2%.
- Pollution loads are significantly lower than for other similar systems.
- BOD and SS loads from urban stormwater runoff are much greater than for the Fitchburg CSOs.

Water samples were obtained during storm event from 5 of the CSO regulators for **the *Flow Gauging Report Combined Sewer Overflows***, (1997). Grab samples were collected during the first 30 minute first-flush, and composite samples for the event duration, and analyzed for BOD, TSS, ammonia, phosphorus, copper, lead, and fecal coliform. Weighted average mean concentrations of pollutants for each CSO were calculated for the first flush and for the event. Loads were then calculated for the 3 and 6 month, 1 and 5 year return period single-event storms. A continuous simulation model was then used to calculate for all the 1986 rainstorms the pollutant loads from each CSO. Literature values for BOD, TSS, lead, and fecal coliform are higher than the field data, while TP are about equal or higher, and copper values were not evaluated. Data are available on disc.

The report states that the majority of CSOs begin to activate at the 3-month storm event. For the design storms and the year-long simulation, between 91% to 99% of the CSO volume is discharge to the receiving waters by the same 6 to 10 CSOs which account for almost all the pollutant loads into the Nashua River. The report states that the mitigation by storage or treatment of these overflows would significantly reduce the pollutant loads to the Nashua River. The ten most active CSO regulators generate 96.5% of CSO volume.

Task 5: CSO Master Plan, DPW Fitchburg, 1998

The report proposes modifications to 24 of the 58 CSO regulators, which discharge to the Nashua River and tributaries, via 38 outfalls. The other 24 regulators, which do not activate for the 3-month storm, have no modifications proposed. This proposal will reduce CSOs to no more than 4 times per year at 11 of the outfalls at a cost of 3 million. Additionally, to reduce effects on the East Fitchburg WWTF, an additional 5.5 million proposal for constructed facilities to equalize wet weather flows is proposed. The East Fitchburg WWTF will receive an additional 4.8 million gallons of wet weather flows for the 2-month storm. During the 3-month storm, 3.8 million gallons will be discharged as CSO from 17 regulators, and convey 5 million gallons for treatment.

The John Fitch Interceptor I/I Study sewage flow metering program was reported in the ***City-wide Infiltration/Inflow Study Task 1 John Fitch Interceptor Flow Gauging 1999***, DPW, Fitchburg, MA. This study was conducted between March and August 1999. Eight meters collected information every 15 minutes. The purpose of the study was to define, by tributary area, sewer system flow rates and volumes under a range of operating conditions including: dry weather versus wet weather; high groundwater versus low groundwater; and daily minimum versus daily peak flows in order to define base sanitary sewage flows and extraneous flow of I/I.

Results of the study indicated that infiltration rates averaged over 3,000 gpd/in-mile, which is much greater than the DEP guideline of 2,500, and was not evenly distributed over the entire system. The report states that there is 500,000 gpd average infiltration into the JFI system.

Combined Sewer Separation and Environmental Impact Report and CSS Separation Engineering and Final Reports, Dufresne-Henry, 2001-2004
Thes reports describe a “phased-in” CSS program and other related projects. 15 annual project to be completed including the separation of combined sewers by constructing 20 miles of new drains at a cost of $26 million. Reports describe final design, implementation and schedules.

Appendix C
Part 1: 1998 Water Sampling, Sediment Sampling, WWTF Sampling

In 1998, the Massachusetts' DEP in combination with the USEPA and the Nashua River Watershed Association, conducted a sampling program of the Nashua River and selected tributaries. The sampling was conducted in order to document existing water quality and biological conditions in the river; to determine the current impact of present discharges on the river; and to provide data for modeling new or increased discharges to the river for determining maximum allowable organic nutrient loadings. A team approach was implemented. MADEP conducted the instream water quality and toxicity testing, hydrological measurements, and assessment of the biology and habitat of the river and tributaries. The USEPA conducted the WWTF effluent monitoring, the diurnal dissolved oxygen measurements, the sediment oxygen demand testing and the sediment chemistry and toxicity testing. The Nashua River Watershed Association conducted some complimentary sampling through a volunteer monitoring program, and the municipal WWTFs sampled their effluent for the nitrogen series and for total phosphorus, as well as sampling upstream and downstream of the facility for dissolved oxygen and temperature.

DEP sampled 11 water quality stations. The sampling stations are listed below. These stations were sampled once per month from May through October, 1998, for alkalinity, hardness, chloride, suspended solids, turbidity, ammonia, nitrate, total phosphorus, fecal coliform, dissolved oxygen, temperature, pH, conductivity, and total dissolved solids. E. coli was added for the month of May 1998 only. Additionally, the July and August sampling included dissolved phosphorus and BOD, to coincide with the placement of diurnal oxygen samplers, and 4 additional stations were added for these 2 months for total and dissolved phosphorus and chlorophyll only. The USEPA sampled 4 stations for diurnal DO (Pepperell Pond inlet and outlet, Groton School, and Ice House impoundment). The USEPA additionally sampled 5 stations for sediment chemistry and toxicity and 8 stations for sediment oxygen demand.

Sampling was continued annually for some of these water quality stations as part of the strategic monitoring program. The strategic monitoring stations were sampled every other month by DEP subsequent to the intensive May-October, 1998 sampling round as follows: (4/7/99, 5/5/99, 7/7/99, 8/4/99, 9/1/99, 11/3/99, 4/5/2000, 6/7/2000, 8/2/2000). These stations are indicated by an asterisk in the list below. Sampling at these strategic monitoring stations has continued on a schedule of nearly every other month up to the present.

Water Quality Sampling Stations

Nashua North

NN01	Fitchburg	Whitman River, Route 31
NN09	Fitchburg	Falulah Road
NN12 #	Lancaster	Route 190 bridge

Nashua South

NS17	Clinton	Route 110, upstream Clinton WWTP
NS19 #	South Bolton Rd Lancaster.	

Nashua Mainstem

NM21 #	Lancaster/Tank Bridge @Still River Road	
	Harvard	south of Oxbow Nat'l Wildlife Refuge
NM21A	Harvard	Rte. 2 ramp at Jackson Road
NM25, 25(A)	Shirley/Ayer	Route 2A, (upstream/downstream bridge)
NM29A#	Pepperell	downstream of Covered Bridge, Groton St.

Nashua Tributaries

NT60A#	Groton	Squannacook River, Townsend Rd. across from Candice Lane
NT68	Pepperell	Nissitissit River, Mill St.

Diurnal Sampling

Diurnal sampling was conducted at 4 stations, all located on the Nashua River mainstem, as listed below. Diurnal samplers were placed instream from July 16-24, and August 10-13, 1998, to record in 15-minute intervals the pH, temperature, conductivity, and dissolved oxygen. Sampling times were selected to coincide as much as possible with the July and August, 1998 water quality sampling rounds, which also included total and dissolved phosphorus, and chlorophyll-a.

Station	EPA Reference Station No.	Station Description
GROTSCH	(N4)	Groton School
ICEHSEDM	(N1) (NR3)	Ice House Dam
INLTPEPPD	(N6)	Pepperell Impoundment, Inlet
OUTPEPPD	(N8) (NR5)	Pepperell Impoundment, Outlet-above dam

Water Column Toxicity

Water column toxicity was measured by MADEP using Microtox chronic testing at 11 stations in May, 1998 at 9 stations in June, and at 6 stations in July and August (NM29A, NM25, NM21A, NM21, NS17, NS19). The Microtox test utilized a marine bioluminescent bacterium *Vibrio fisheri* in contact with a substance over 22 hours to determine the potential effect of substances on aquatic biota. Results are expressed as IC (inhibitory concentration), LOEC (lowest observable effect concentration) and NOEC (no observable effect concentration).

Hydrology

Flows were measured at 2 stations by MADEP, and data collected from 5 USGS continuous gage stations in the watershed. These 7 stations are listed below.

5 USGS stations	*2 DWM flow stations during 1998 surveys*
North Nashua, Fitchburg	Nashua Tank Bridge, Harvard
North Nashua, Leominster	Nashua, Rte 2A, Ayer
Stillwater, Sterling	
Squannacook, West Groton	
Nashua, East Pepperell	

Weather Conditions

Weather conditions were recorded for the surveys as follows:

May 27---15 days prior to survey little to no rain

June 17----four days prior to survey received about 5 inches of rain

July 22-----19 days prior to survey received little to no rain
August 12 ----day prior and day of survey received a total of 1 inch of rain
September 9---2 days prior to survey received 0.2 inches of rain
October 7---11 days prior to survey received little to no rain

Review of these conditions indicated that the surveys conducted in May, July, and September, 1998 could be characterized as dry weather surveys, and the surveys in June and August, 1998 could be characterized as impacted by wet weather events.

Biological and Habitat Sampling

Biological sampling was also included as part of the survey work. Fish toxics were assessed at Snows Millpond, Fitchburg/Westminster and Whalom Lake, Lunenburg. Biological assessments were conducted at 14 stations. Sampling of invertebrates by DEP-DWM, utilized RBPIII with kicknet in 100m sections. Habitat evaluations were conducted concurrently at these same stations. Periphyton analyses were conducted at 9 locations in the wadeable part of the mainstem Nashua, and in one of the tributaries. These were done in conjunction with macroinvertebrate and habitat assessment to provide a qualitative assessment of in-stream water quality and habitats. Stations for macroinvertebrate, habitat, and periphyton sampling are listed below. Locations indicated with an asterisk in table below indicate the periphyton sampling stations. Periphyton samples were also collected at NT34 Whitman River, Fitchburg.

Macroinvertebrate, Phytoplankton, and Habitat Sampling Station Locations

STATION	**TOWN**	**LOCATION**
NN03	Fitchburg	North Nashua River downstream from Mill #9 bridge
NN09*	Fitchburg	North Nashua River downstream from Falullah Rd.
NN10A	Leominster	North Nashua River upstream from Rte. 2Searstown Mall
NN13*	Lancaster	North Nashua River upstream from bridge Ponakin Mill
QP00	Holden	Quinapoxet River downstream from River St. Canada Mills
SL00	West Boylston	Stillwater River upstream from Crowley Rd.
NS17*	Clinton	South Nashua River upstream from MWRA Clinton WWTF
NS19	Lancaster	South Nashua River upstream from Bolton Rd.
NM23B*	Ayer/Shirley	Nashua River downstream from McPhearson Rd. RR bridge
NT61	Shirley/Groton	Squannacook River downstream from Route 225
NM29*	Pepperell	Nashua River downstream from covered bridge
NM30*	Hollis, NH	Nashua River downstream from Rte. 111
NT67*	Pepperell	Nissitissit River downstream from Prescott St.
NT68*	Pepperell	Nissitissit River downstream from Mill St.

Periphyton Sampling Stations

STATION	**TOWN**	**LOCATION**
NT34	Fitchburg	Whitman River
NN09	Fitchburg	North Nashua, Falulah Rd.

NN13	Lancaster	North Nashua, Ponakin Mill
NS17U	Clinton	South Branch
NM23B	Ayer/Shirley	Mainstem, downstream from McPheasrson Rd. RR bridge
NM29	Pepperell	Mainstem-downstream covered bridge
NM30	Hollis, NH	Mainstem, downstream from Rte. 111
NT67	Pepperell	Prescott Rd.
NT68	Pepperell	Nissitissit River

Sediment Toxicity

Sediment toxicity testing was conducted at 5 locations on March 16, 1999 by the USEPA. Measurements included: grain size, TOC, SEM/AVS, cyanide, and total metals (Ag, As, Ba, Be, Cd, Co, Cr, Ni, Pb, Sb, Se, Tl, V, Zn, Hg).   Sediment bioassays for toxicity used a chronic 10-day test.

Stations sampled:

1. NR1 upstream of Tank Bridge, 1 meter off of west bank upstream of RR bridge
2. NR2 just downstream of tank bridge (NM21) 1 meter off of west bank across from boat landing in Oxbow NWR
3. NR3 3 meters from south bank and 30 m upstream of Ice House dam
4. NR4 near abandoned Fort Devens air strip
5. NR5 above Pepperell Pond Dam

Sediment Oxygen Demand (SOD)

Sediment oxygen demand measurements were made at 8 locations during November, 1998. Five cores were taken at each site and measurements were made of SOD in g/m^2/day. The stations selected for sampling are listed below with water quality stations listed adjacent as reference.

		SOD Results		
Station	Mean	Range	Description	Date
N1 NR3	1.34	1.08-1.73	Ice House Dam	11/18/98
N2 NR2 NM21	0.81	0.59-1.04	Tank Bridge and RR	11/18/98
N3 NR4 NM25	1.90	1.51-2.16	Route 2A Bridge	11/18/98
N4 GROTSCH	1.43	1.15-1.68	Groton School	11/17/98
N5	1.73	1.40-2.10	Rte. 225 Bridge	11/17/98
N6 INLTPEPPD	2.70	1.97-3.13	Inlet Pepperell Pond	11/16/98
N7 OUTPEPPD	1.50	1.26-1.98	Midpoint Pepperell Pond	11/16/98
N8 NR5	1.22	1.00-1.40	Pepperell Pond Dam	11/20/98

WWTF Sampling

Six municipal wastewater treatment plants discharge directly to the Nashua River including to the North and South Branches. Of these 6 facilities, only 5 are located above the impaired segments, and therefore only these will be included in the TMDL discussion. Additionally, the Devens site, which is also connected to the impaired segment, discharges presently to groundwater. The following table lists the 5 municipal surface water discharge facilities together with the permit flow, actual flow, 7Q10, and dilution factors. The discharges, from these facilities, are regulated by NPDES permits. The permits for Ayer, Clinton, Leominster, and Fitchburg West were renewed in 2000. The Fitchburg East permit was renewed in 2001, due to the CSO issue, which required additional evaluation and discussion. Ayer was again renewed in 2006.

The 5 WWTFs (Fitchburg East and West, Leominster, Clinton, Ayer) were sampled during August, 1998 by the USEPA for BOD, TSS, TP, NH_3, NO_3, NO_2 and metals.

SELECTED WWTFs PERMIT LIMITS

	FITCHBURG WEST	**FITCHBURG EAST**	**LEOMINSTER**	**CLINTON**	**AYER**
PERMIT FLOW	**10.5 MGD 16.24 CFS**	**12.4 MGD 19.18 CFS**	**9.4 MGD 14.39 CFS**	**3.01 MGD 4.66 CFS**	**1.79 MGD 2.77 CFS**
ACTUAL SUMMER FLOW	**5.3 MGD**	**5.5 MGD**	**4.7 MGD**	**2.0 MGD**	**1.6 MGD**
7Q10	**2.02 MGD 3.13 CFS**	**17.25 MGD 26.7 CFS**	**22.5 MGD 34.9 CFS**	**1.8 MGD' 2.79 CFS**	**30.8 MGD 47.6 CFS'**
DILUTION FACTOR	**1.2**	**2.4**	**3.4**	**1.6**	**18**
LOCATION	**NORTH NASHUA**	**NORTH NASHUA**	**NORTH NASHUA**	**SOUTH NASHUA**	**MAINSTEM**

In order to characterize and quantify the discharge, the agencies requested the facilities expand their self-monitoring program to include the nitrogen series (ammonia, nitrate, TKN), as well as total phosphorus, once per month during the DEP/USEPA 1998 sampling program. The facilities sampled for these during part of 1998 and 1999. This information was combined with information provided through the monthly Discharge Monitoring Reports and Toxicity Monitoring Reports, required by the NPDES permits, to produce a spreadsheet with monthly discharge data for all parameters required in the HSPF model. Prior to 2000, only 3 facilities (Fitchburg West, Fitchburg East, and Leominster) had phosphorus limits.

Appendix C
Part 2: Water and Sediment Quality Results of 1998 Sampling

In general the WWTF discharges of solids and nutrients decreased significantly from 1977 to 1998. These reductions translated into measurable improvements in instream water quality for BOD, dissolved oxygen, nutrients and solids. Although no dissolved oxygen levels were measured below 5 mg/l, super-saturation of dissolved oxygen and higher chlorophyll-a levels were measured in Pepperell Pond. These values, combined with high sediment oxygen demand (SOD) values at the same location, indicated a nutrient enrichment issue. Higher bacteria levels were exhibited during and after rain events. All these assessments were conducted at present effluent flows, and not at the higher permitted flows.

Water Quality Results

Water quality sampling results indicated no dissolved oxygen levels below water quality criteria, with DO levels above 6.5 mg/l during the morning surveys at all stations. Percent saturation values were all below 100% in the 70-90% range, with NS17 and NM21 and NM21A showing the lowest values between 70 and 75% for the 11 water quality stations. However, diurnal dissolved oxygen from the diurnal samplers showed characteristic diurnal cycles with elevated levels during the day, and lower levels at night. No night values were below the 5 mg/l dissolved oxygen criteria. Percent saturation showed a large swing to above 150% in Pepperell Pond. pH values were all within range with NT60A showing levels in the low 6 range. The pH values also showed the diurnal fluctuations characteristic of productivity effects.

Conductivity values at some stations showed elevated values at NN9, NN12, NM21, NM29A of above 250 umhos/cm indicating effects of urbanization.

The volunteer monitoring data for 1998 collected by the Nashua River Watershed Association confirmed the DEP data. The NRWA data showed only one excursion for dissolved oxygen below the water quality standards on the mainstem. The percent saturation showed fluctuations above 100% indicating effects of eutrophication. In comparison, the data for 1997 showed a number of samples below the water quality standards, with the lowest values in August coinciding with consistently low summer flows all summer. Base flows during 1997 were very low with little rain.

In general, 1998 flows were higher, about twice 7Q10, and very close to the August 1977 flows. The 1996 flow values were also very low. Instream sampling by the Clinton WWTF above the facility showed low levels of dissolved oxygen, at 3-4 mg/l.

Chemical and Nutrient Data

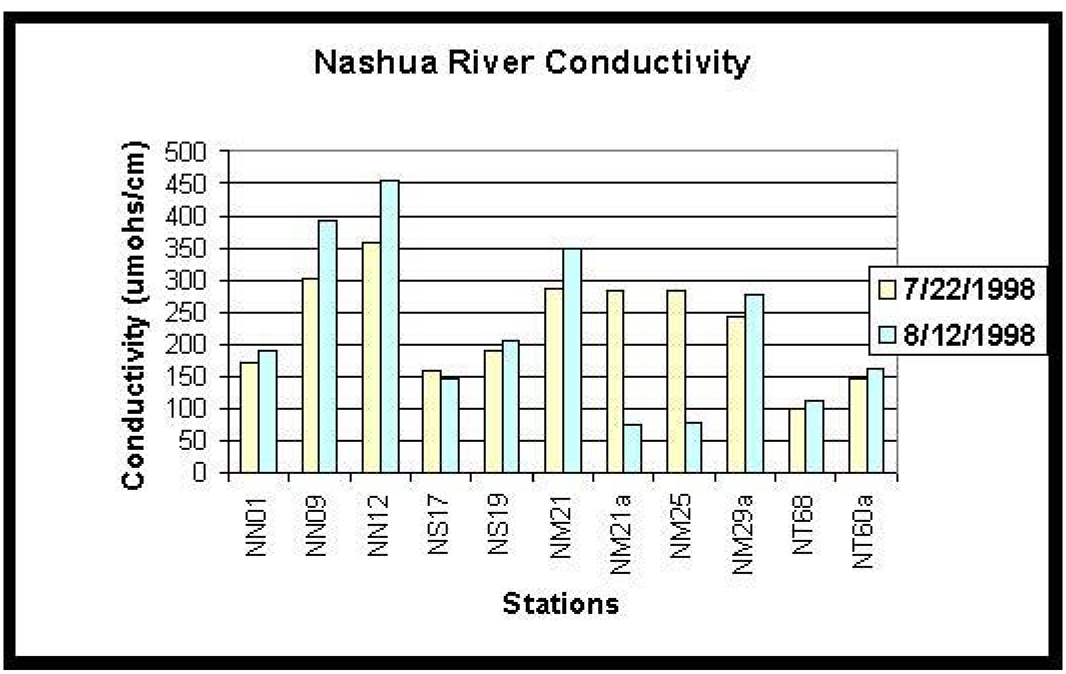
The water quality of the South Branch of the Nashua River, downstream of the Clinton treatment plant, showed elevated phosphorus and nitrate levels. The water quality above the treatment plant showed elevated nitrate levels. The effect of the June,1998 rains were significant on total phosphorus levels in the South Branch of the Nashua River.

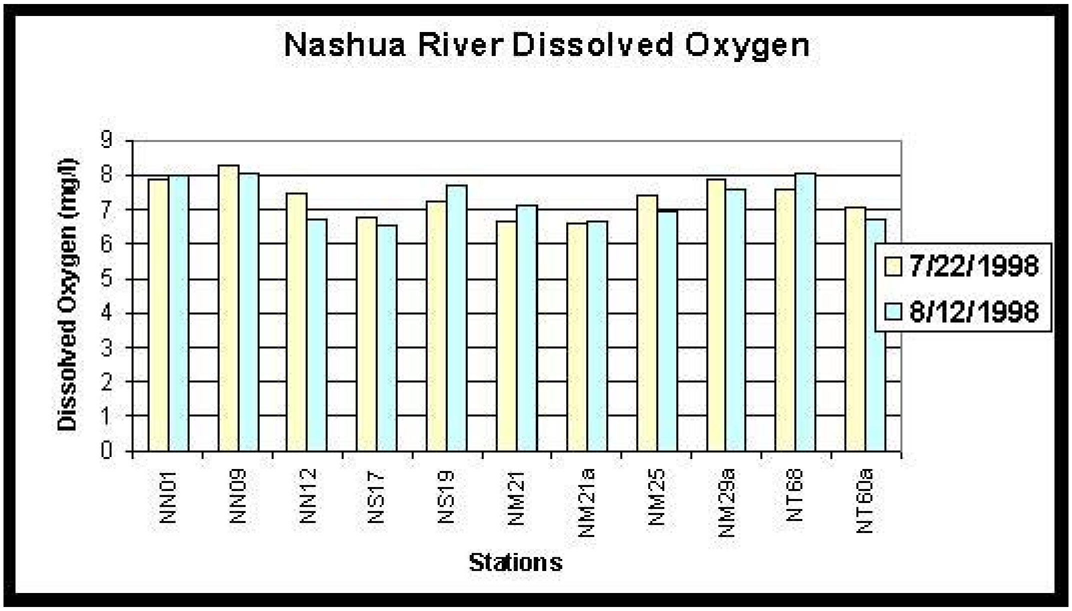
The upper reaches of the North Branch of the Nashua River showed good water quality. However, at station NN9 some parameters were elevated. Suspended solids, phosphorus, and nitrate showed some effects from the Fitchburg area, but the water quality would still be considered good. At station NN12, the cumulative effects from the Fitchburg and Leominster areas showed instream elevated levels of chlorides to 50-60 umhos/cm, suspended solids of 3-7 mg/l, turbidity values of 1-2 mg/l, ammonia levels of 1-5 mg/l, and nitrate levels of 2-5 mg/l. Total phosphorus levels were high at 0.1-0.2 mg/l, but were much less than those levels measured in the South Branch of the Nashua River.

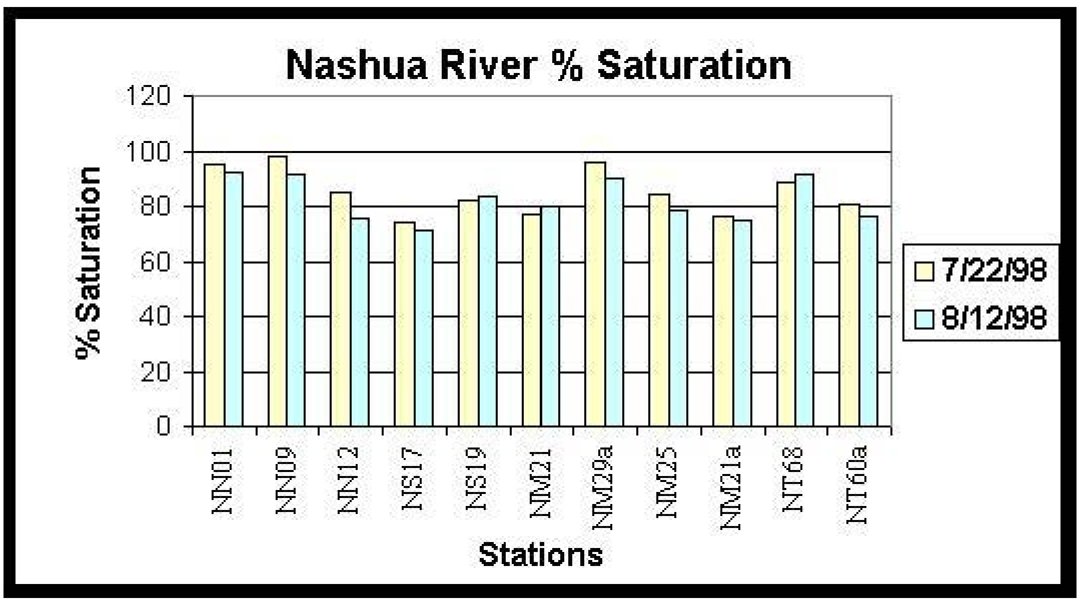
Overall, good water quality was measured in the Nissitissit River even after the high rains in June1998. Phosphorus levels were very low in this tributary, less than 0.01 mg/l at all times. The Squannacook River also displayed good water quality in June, although the nitrate and chloride levels were generally higher than in the Nissitissit River. Phosphorus levels were still very good with most being less than 0.02 mg/l.

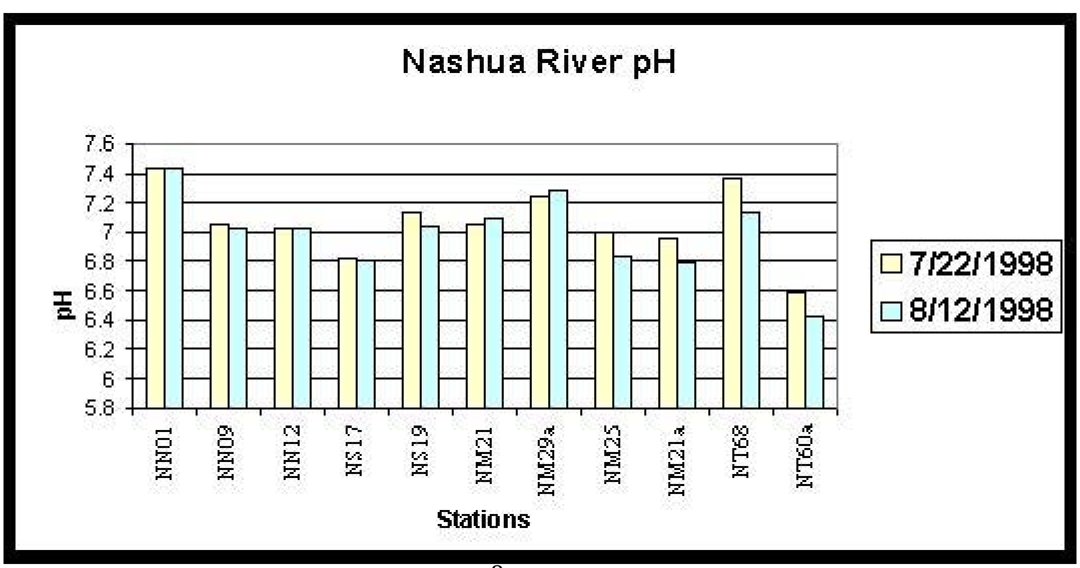
WWTF phosphorus data showed levels for the Clinton WWTF between 1-4 mg/l, and Ayer WWTF levels around 2-3 mg/l. The other WWTFs had phosphorus levels below 1 mg/l, with the levels discharged from the Fitchburg West WWTF below 0.1 mg/l. The Clinton WWTF and the Ayer WWTF did not have phosphorus limits in their NPDES permits prior to 2000. Levels of ammonia from the Fitchburg West WWTF ranged between 0.8 mg/l and 3.9 mg/l. The Fitchburg East ammonia levels were 0.5-2.0 mg/l.

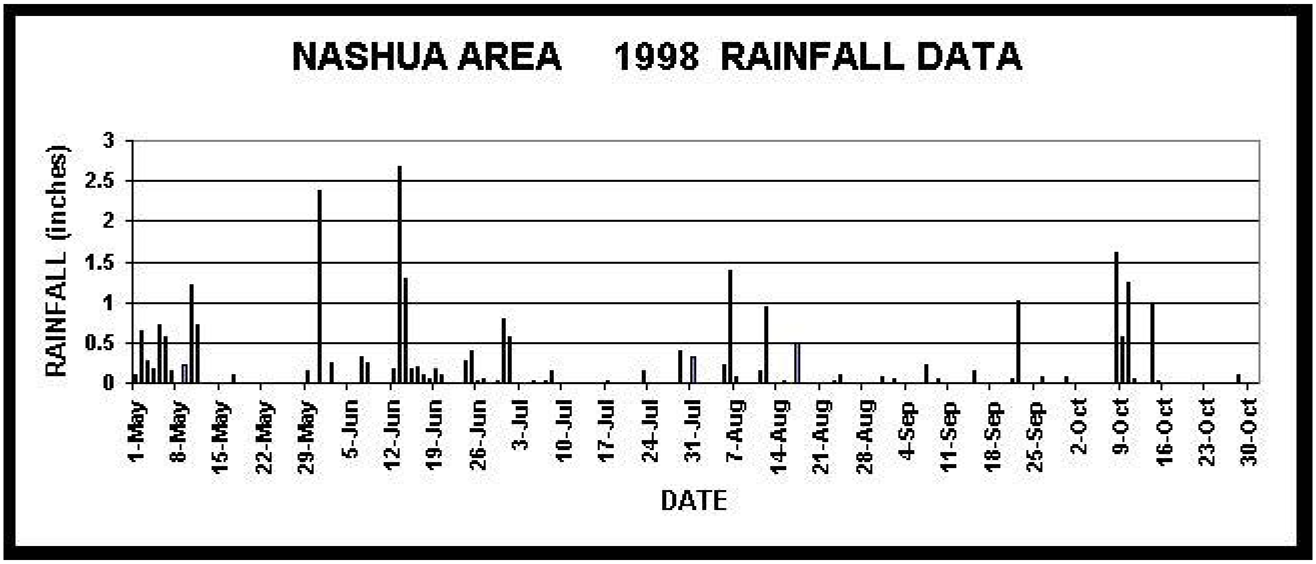
A comparison was made of the 1977 instream water quality with the 1998 water quality. The NPDES limits produced significant improvements in water quality through reductions in solids and nutrients and BOD at all 5 wastewater treatment facilities from 1977 to 1998. These improvements have translated into measurable improvements in instream water quality from BOD, DO, nutrients, and solids. The graphs following show the decrease in effluent concentrations between 1977 and 1998.

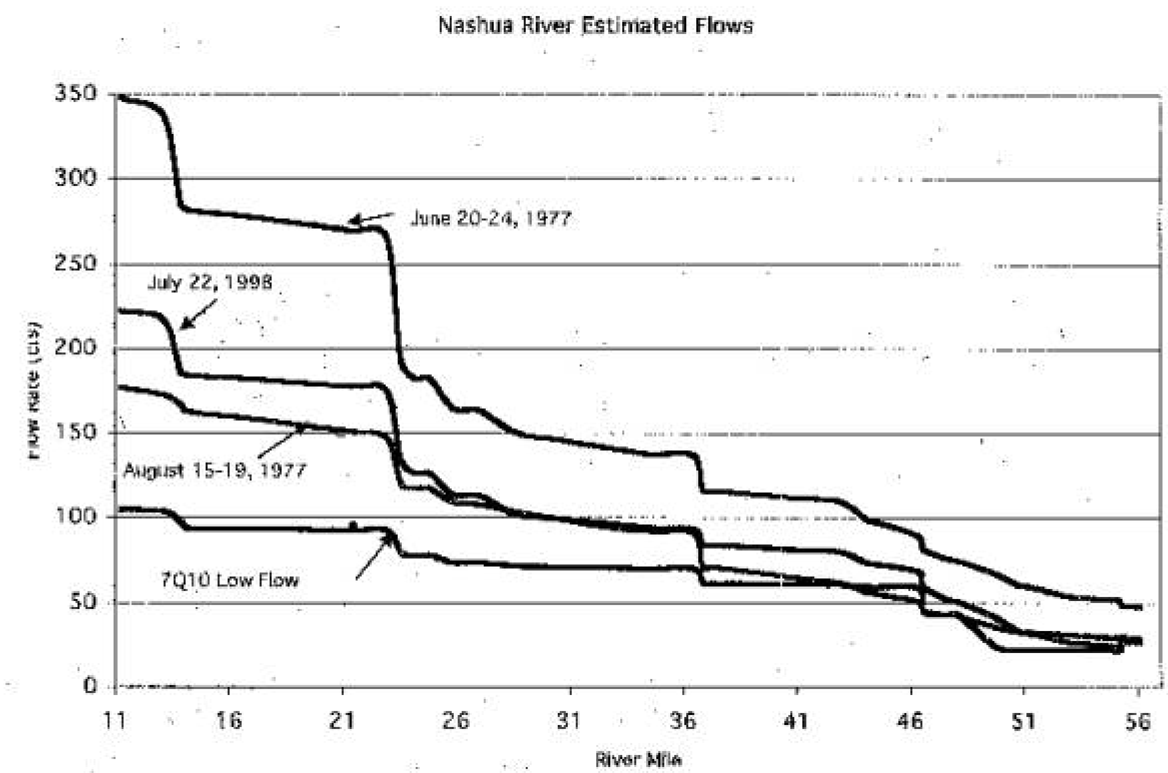


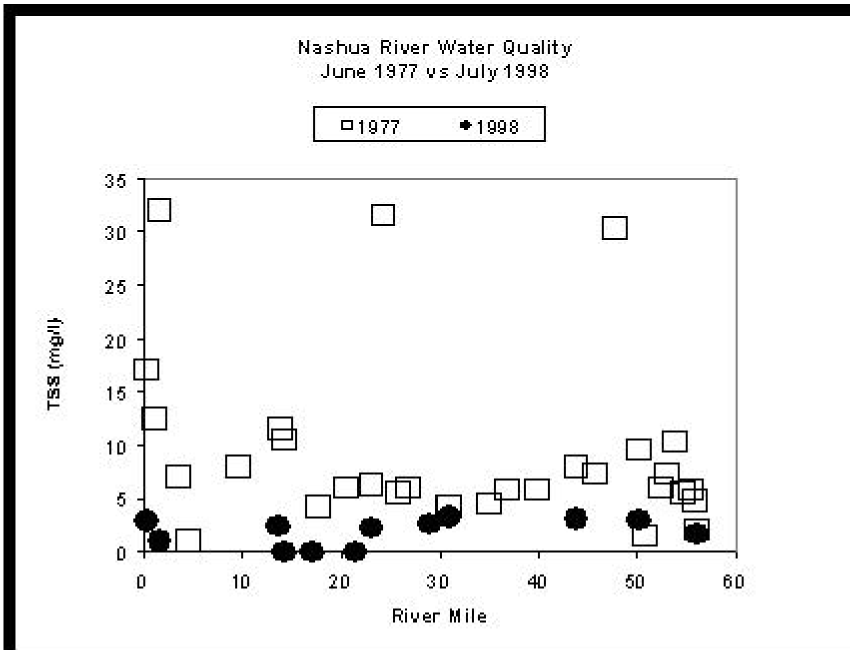

Nashua River Dissolved Oxygen
Dissolved Oxygen (mg/l)
9
8
7
6
5
4
3
2
1
0
NN01
NN09
NN12
NS17
NS19
NM21
NM21a
NM25
NM29a
NT68
NT60a
Stations
7/22/1998
8/12/1998

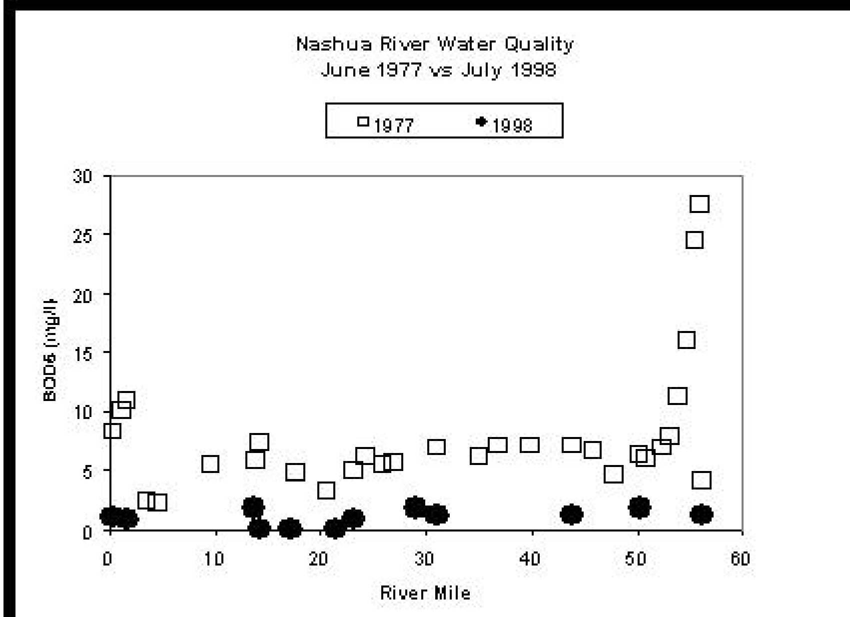

Nashua River % Saturation
% Saturation
120
100
80
60
40
20
0
NN01
NN09
NN12
NS17
NS19
NM21
NM29a
NM25
NM21a
NT68
NT60a
Stations
7/22/98
8/12/98

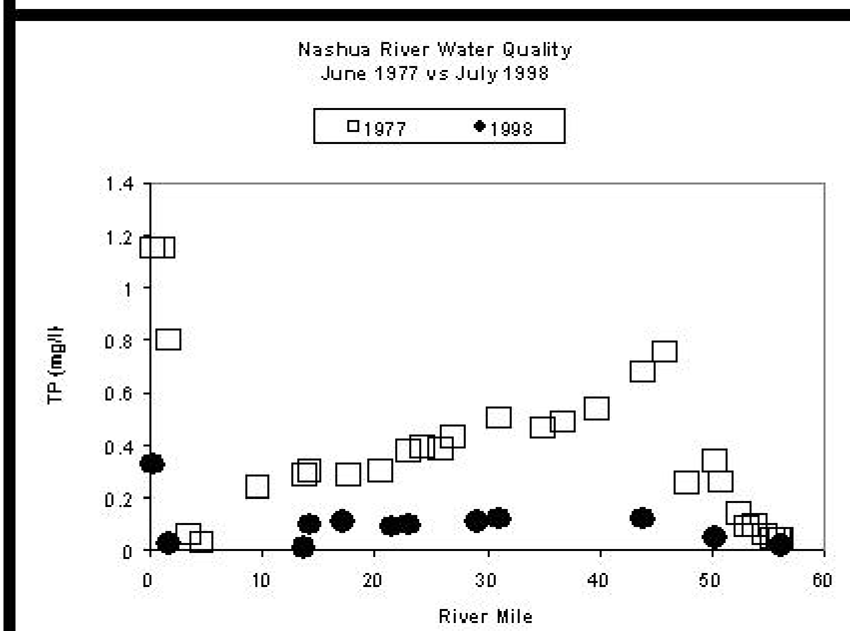

Nashua River pH
pH
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
5.8
NN01
NN09
NN12
NS17
NS19
NM21
NM29a
NM25
NM21a
NT68
NT60a
Stations
7/22/1998
8/12/1998

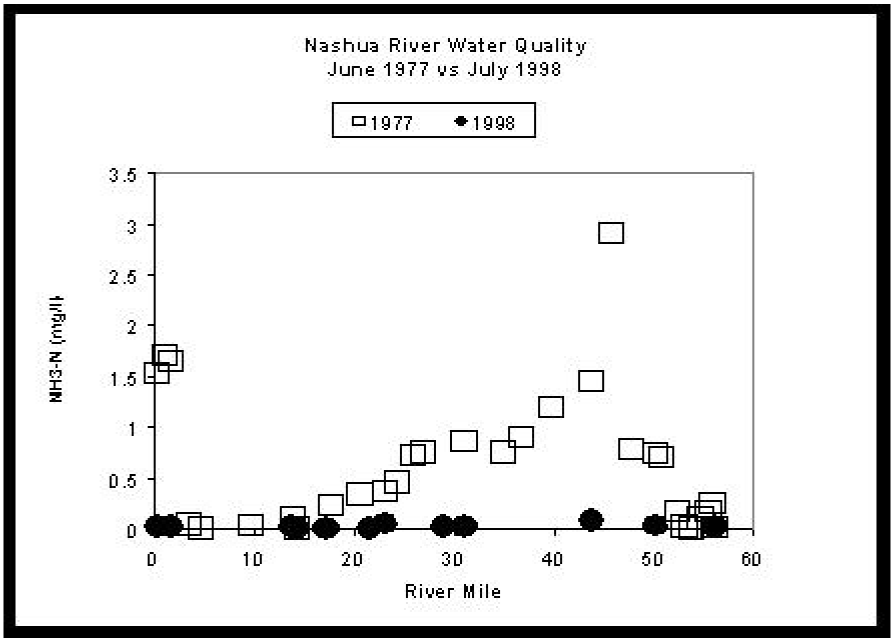

NASHUA AREA 1998 RAINFALL DATA
RAINFALL (inches)
0
0.5
1
1.5
2
2.5
3
1-May
8-May
15-May
22-May
29-May
5-Jun
12-Jun
19-Jun
26-Jun
3-Jul
10-Jul
17-Jul
24-Jul
31-Jul
7-Aug
14-Aug
21-Aug
28-Aug
4-Sep
11-Sep
18-Sep
25-Sep
2-Oct
9-Oct
16-Oct
23-Oct
30-Oct
DATE

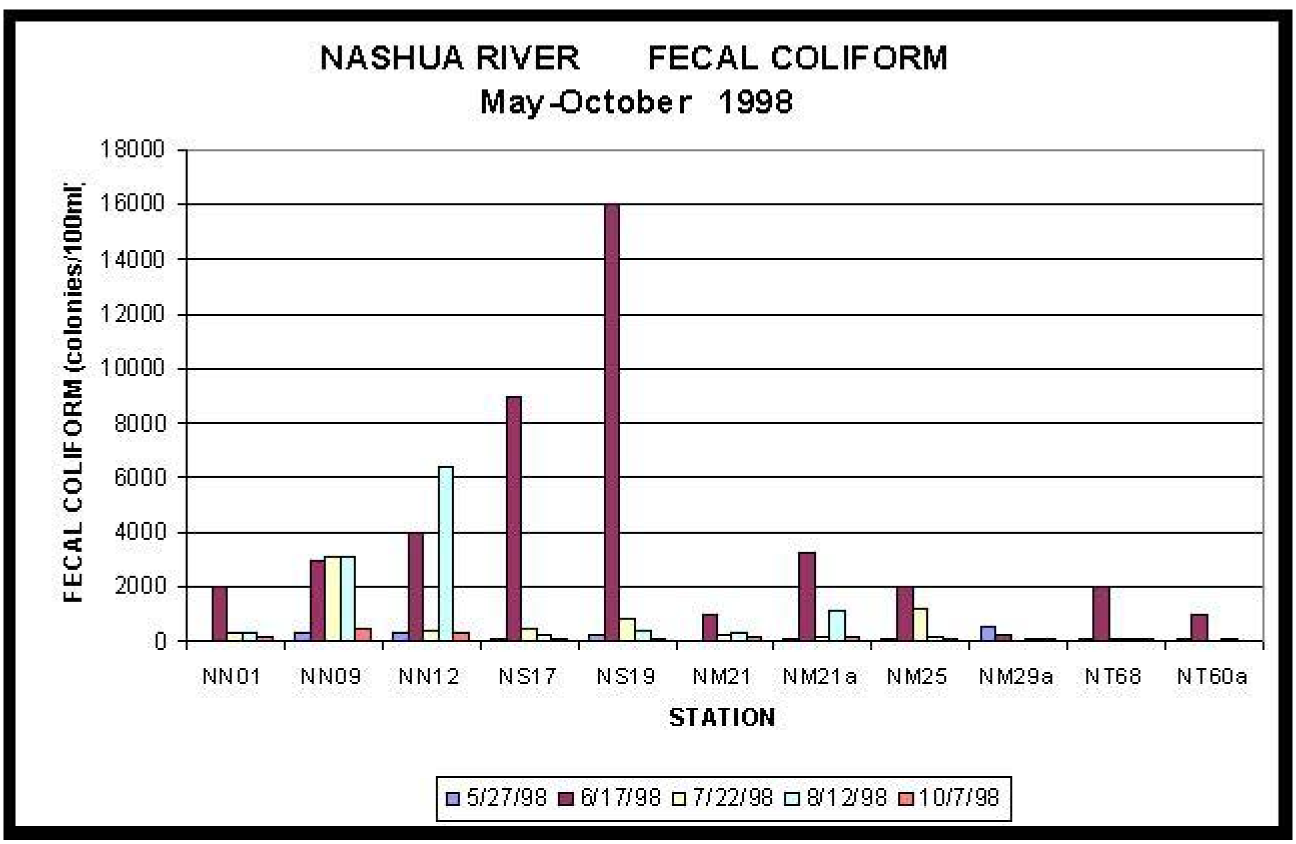

Nashua River Estimated Flows
0
50
100
150
200
250
300
350
June 20-24, 1977
July 22, 1998
August 15-19, 1977
7Q10 Low Flow
11
16
21
26
31
36
41
46
51
56
River Mile

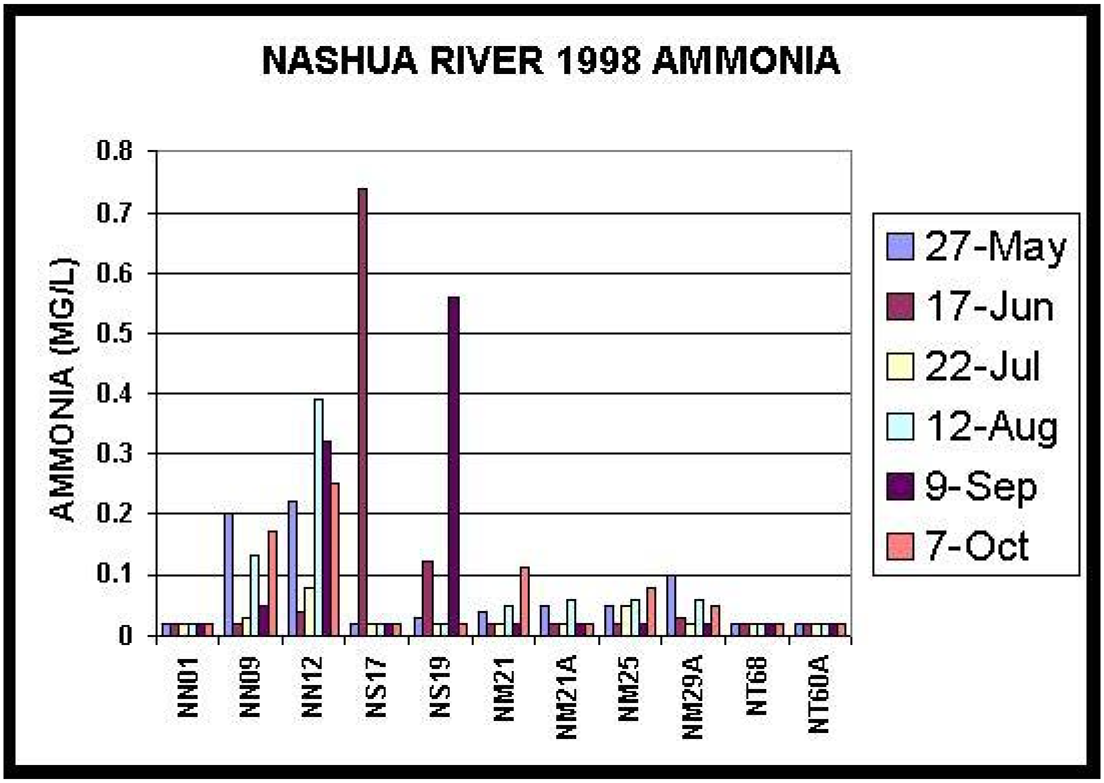

Nashua River Water Quality
June 1977 vs July 1998
1977
1998
TSS (mg/l)
River Mile

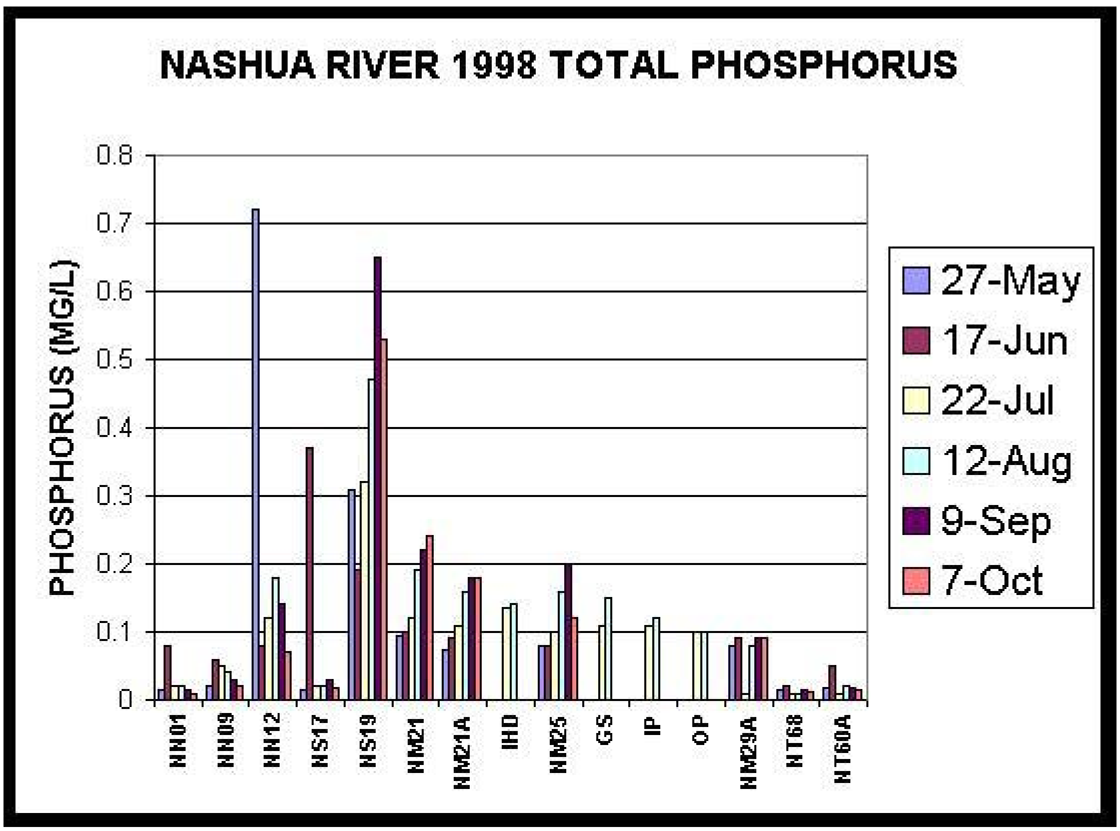

Nashua River Water Quality
June 1977 vs July 1998
1977
1998
BOD5 (mg/l)
River Mile


Nashua River Water Quality
June 1977 vs July 1998
1977
1998
TP (mg/l)
River Mile


Nashua River Water Quality
June 1977 vs July 1998
1977
1998
3.5
3
2.5
2
1.5
1
0.5
0
NH3-N (mg/l)
0
10
20
30
40
50
60
River Mile


NASHUA RIVER FECAL COLIFORM
May-October 1998
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
FECAL COLIFORM (colonies/100ml)
NN01
NN09
NN12
NS17
NS19
NM21
NM21a
NM25
NM29a
NT68
NT60a
STATION
5/27/98
6/17/98
7/22/98
8/12/98
10/7/98


NASHUA RIVER 1998 AMMONIA
AMMONIA (MG/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
NN01
NN09
NN12
NS17
NS19
NM21
NM21A
NM25
NM29A
NT68
NT60A
27-May
17-Jun
22-Jul
12-Aug
9-Sep
7-Oct


NASHUA RIVER 1998 TOTAL PHOSPHORUS
PHOSPHORUS (MG/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
NN01
NN09
NN12
NS17
NS19
NM21
NM21A
IHD
NM25
GS
IP
OP
NM29A
NT68
NT60A
27-May
17-Jun
22-Jul
12-Aug
9-Sep
7-Oct

Sediment Chemistry and Toxicity Testing Results

Sediment sampling results from the 1998 surveys conducted in the Nashua River are detailed in the USEPA, 1999 report entitled, *Nashua River Sediment Toxicity Study*, by David McDonald. This report indicates that inorganic Cd, Cr, Cu, Pb, Hg were high at all stations with Ice House Impoundment and Pepperell Pond Impoundments the highest. No cyanide was found at any station. Although the station metal results were elevated, the binding capacity due to high AVS (acid volatile sulfides) and TOC (total organic carbon) in the sediment, provide a high binding capacity and therefore a low potential for toxicity and effect on aquatic biota. This was confirmed with the preliminary toxicity testing.

Sediment Oxygen Demand

Of the five cores at each of the 8 stations, ranges were from a low of 0.18 g/m^2/day at Tank Bridge to a high of 3.13 g/ m^2/day at the Pepperell Pond impoundment. Average values from the USEPA manual show the following:

- WWTF outfall 6 g/m^2/day
- WWTF downstream 1.5 g/m^2/day
- Sandy soils 0.5 g/m^2/day
- Mineral soils 0.07 g/m^2/day

SOD Results

Station	Mean	Range	Description	Date
N1 NR3	1.34	1.08-1.73	Ice House Dam	11/18/98
N2 NR2 NM21	0.81	0.59-1.04	Tank Bridge and RR	11/18/98
N3 NR4 NM25	1.90	1.51-2.16	Route 2A Bridge	11/18/98
N4 GROTSCH	1.43	1.15-1.68	Groton School	11/17/98
N5	1.73	1.40-2.10	Rte. 225 Bridge	11/17/98
N6 INLTPEPPD	2.70	1.97-3.13	Inlet Pepperell Pond	11/16/98
N7 OUTPEPPD	1.50	1.26-1.98	Midpoint Pepperell Pond	11/16/98
N8 NR5	1.22	1.00-1.40	Pepperell Pond Dam	11/20/98

Periphyton Assessment

STATION	ASSESSMENT
NT34	No evidence NPS, large amounts of Spriogyra and Fragilaria
NN09	Visual NPS impacts and sewage smell, diatoms covered the cobbles
NN13	Thin layer of diatoms
NS17U	Hypolimnetic discharge from Wachusett Reservoir, red alga present
NM23B	Obvious NPS pollution and sewage smell, turbid, high bacteria counts
NM29	NPS runoff from horse farm; turbid and opaque;
NM30	
NT67	No distinctive periphyton community; cold water habitat;
NT68	Green filamentous alga dominated although amounts were low; cold water habitat

Microtox Chronic Test

Of the 11 water quality stations sampled in May 1998, 7 stations in June 1998, and 6 stations in July and August 1998, none showed any significant toxicity issues.

Fish Toxics Monitoring

The edible fillets from Snows Millpond (Fitchburg/Westminster) and Lake Whalom (Lunenburg) showed no metals levels above standards for Cd, As, Hg, Pb, and Se. Additionally, PCBs were not detected, nor were pesticides.

SMART Monitoring

The Massachusetts DEP Central Regional Office conducts a strategic monitoring program at 5 locations in the Nashua River watershed with sampling every other month as indicated earlier. A summary of data from this program is listed in the following table for 1999-2000, the years in which modeling was conducted. Data from this program was utilized as part of the calibration for model development.

Macroinvertebrate and Habitat Assessment

Sampling indicates moderate improvements in the Nashua River and tributaries since 1985 at most sites. On the South Branch, the health of the aquatic community downstream of the Clinton WWTF has improved. Station NS19, below the Clinton WWTF, improved from the 1977 description of a grayish color, a septic odor, with mostly worms and chironomids, to good water clarity and no odors, no worms, and more diversity, with of clean water organisms and chironomids in 1998. The community at NS17, above the Clinton WWTF, has also improved in diversity although still impacted.

Station NN09 on the North Branch showed improvement but still moderate impairment due to the combined effects of effluents and urban runoff. North Branch station NN03, the most upstream station, improved from a slime covered bottom in 1977 with a community of mostly chironomids, to a site with only sparse algal coverage and no obvious sludge deposits, and a community mostly of clean water organisms and more diversity. North Branch, station NN10/10A showed a shift to more diversity although still impacted.

On the mainstem, in 1998, stations NM23B and NM29 had sewage odors and extreme turbidity, and moderately impacted communities. Station NM30 showed some improvement in diversity although still impacted.

Nashua River 1999-2000 Data From DEP CERO Monitoring Program (Kimball and Beaudoin)

Station	Date	Temp	DO	Cond	TDS	pH	%sat	SS	NH3	TKN	NO3	TP	ALK	Turb	Cl	Hrdns
		Celcius	mg/l		mg/l			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	NTU	mg/l	mg/l
NN12	4/7/99	10.03	10.47	279	0.179	6.7	91.5	4.1	1.2	1.4	0.44	0.060	19	2	58	33
	5/5/99	13.4	8.83	334	0.214	6.79	83.1	8.2	2	2.2	0.77	0.230	28	1.6	62	40
	7/7/99	24.48	6.4	399	0.255	6.93	75.8	7.6	0.32	0.79	2.5	0.170	32	4.9	65	56
	8/4/99	21.52	7.52	576	0.368	7.27	83.6							4.8		
	9/1/99	18.34	7.87	545	0.349	7.06	81.6	5.7	0.29	1.3	7	0.180	38	3.1	86	75
	11/3/99	14.17	8.88	206	0.132	6.6	86.2	20	0.03	0.8	0.45	0.170	14	4.8	40	26
	4/5/00	8.94	10.96	235	0.151	6.63	94.5	5.8	0.43	0.71	0.32	0.064	11	2.2	50	24
	6/7/00	11.71	10.51	104.9	0.067	6.35	95.4	13	0.05	0.45	0.23	0.120	6	7.8	19	12
	8/2/00	18.6	8.71	241	0.154	6.67	91.3	7.4	0.11	0.5	0.88	0.098	14	3.9	51	28
	10/18/00	11.77	9.16	403	0.258	6.82	82.3	3.1	0.07	0.63	3.6	0.120	30	1.7	75	48
	12/6/00	1.82	12.61	324	0.208	6.58	89.4	11	0.32	0.88	1.9	0.210	20	2.7	61	37

Station	Date	Temp	DO	Cond	TDS	pH	%sat	SS	NH3	TKN	NO3	TP	ALK	Turb	Cl	Hrdns
		Celcius	mg/l		mg/l			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	NTU	Cl	mg/l
NS19	4/7/99	10.23	10.62	169	0.108	6.79	93.2	1.6	0.02	0.39	1.4	0.210	22	1	24	35
	5/5/99	12.56	9.84	185	0.118	6.89	90.8	2.2	0.03	0.42	2.6	0.420	27	1.6	23	35
	7/7/99	22.67	6.89	219	0.14	6.79	78.9	3.4	0.1	0.54	5	0.950	23	2.8	22	37
	8/4/99	20.19	7.31	273	0.175	7.24	79							16		
	9/1/99	16.35	8.11	268	0.171	7.17	80.7	2.4	0.04	0.47	4	0.760	49	2.3	30	35
	11/3/99	13.69	7.25	159	0.102	6.45	69.7	23	0.02	0.38	1.1	0.260	24	2.7	19	32
	4/5/00	9.19	10.31	147	0.094	6.78	89.3	3.6	1.2	1.3	0.55	0.210	22	2.1	20	28
	6/7/00	11.79	9.76	90.6	0.058	6.52	88.7	4.7	0.12	0.63	0.59	0.200	14	4.4	10	19
	8/2/00	19.08	8.19	180	0.115	6.79	86.7	3.5	0.04	0.44	1.8	0.290	27	2	23	33
	10/18/00	11.75	8.17	203	0.13	6.8	73.3	1.9		0.38	3.3	0.420	29	1.7	24	37
	12/6/00	1.93	12.14	197	0.124	6.77	86	4.3		0.3	2	0.250	30	2.3	26	35

Station	Date	Temp	DO	Cond	TDS	pH	%sat	SS	NH3	TKN	NO3	TP	ALK	Turb	Cl	Hrdns
		Celcius	mg/l		mg/l			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	NTU	mg/l	mg/l
NM21	4/7/99	10.72	9.31	256	0.164	6.76	82.7	4	0.99	1.2	0.76	0.080	19	0.95	51	35
	5/5/99	12.97	7.7	291	0.186	6.76	71.8	3.3	1.3	1.6	1.5	0.180	25	1.3	54	38
	7/7/99	25.41	5.87	375	0.24	7.06	70.8	6.2	0.08	0.53	2	0.320	35	3.2	58	56
	8/4/99	21.66	6.79	368	0.235	7.26	75.3							2.8		
	9/1/99	17.21	7.83	435	0.278	7.15	79.3	6.4	0.06	0.9	4	0.210	37	3.3	68	66
	11/3/99	13.67	7.86	248	0.159	6.67	75.5	15	0.02	0.6	1.6	0.240	26	3.3	43	37
	4/5/00	10.35	9.33	231	0.148	6.63	83.2	9.4	0.57	0.96	0.45	0.120	14	4.8	46	27
	6/7/00	11.97	9.02	105.6	0.068	6.35	82.4	30	0.06	0.74	0.28	0.200	10	108	20	17
	8/2/00	18.72	7.63	212	0.135	6.58	80.2	16	0.03	0.56	1	0.180	17	5	41	27
	10/18/00	10.98	7.79	318	0.204	6.76	68.7	2.1	0.07	0.61		0.160	27	2.4	56	45
	12/6/00	0.95	11.99	256	0.164	6.59	82.6	1.7	0.16	0.5	1.4	0.130	20	1.7	20	34

Nashua River 1999-2000 Data From CERO Monitoring Program (Kimball and Beaudoin)

Station	Date	Temp	DO	Cond	TDS	pH	%sat	SS	NH3	TKN	NO3	TP	ALK	Turb	Cl	Hrdns
		Celcius	mg/l		mg/l			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	NTU	mg/l	mg/l
NT60A	4/7/99	10.41	10.5	121.7	0.078	6.36	92.5	1	0.02	0.2	0.24	0.020	6	0.55	26	14
	5/5/99	13.51	8.84	148.8	0.095	6.41	83.4	1.2	0.02	0.37	0.4	0.030	9	1.1	31	16
	7/7/99	26.54	5.57	149	0.095	6.45	68.5	2.5	0.04	0.27	0.24	0.030	11	1.3	28	17
	8/4/99	23.76	4.82	181	0.116	6.6	55.8							1.6		
	9/1/99	19.61	5.56	176	0.112	6.49	59.1	2.3	0.02	0.31	0.21	0.018	15	1	38	21
	11/3/99	10.67	9.47	140.2	0.09	6.18	84.9	10	0.02	0.25	0.31	0.022	6	0.85	29	16
	4/5/00	9.09	10.88	120.3	0.077	6.19	94	1.4	0.02	0.2	0.2	0.017	4	1	26	12
	6/7/00	11.87	9.95	94.4	0.06	6.04	90.6	9.6	0.02	0.44	0.12	0.066	4	3.5	21	9.3
	8/2/00	17.61	8.27	79.4	0.051	5.95	84.9	3.5	0.02	0.4	0.08	0.039	4	2	16	9.1
	10/18/00	10.24	7.74	155	0.099	6.31	67.1	6.8		0.47	0.41	0.054	8	1.2	33	18
	12/6/00	0.57	12.85	131.7	0.084	6.21	87.6				0.44	0.031	8	1.1	28	14

Station	Date	Temp	DO	Cond	TDS	pH	%sat	SS	NH3	TKN	NO3	TP	ALK	Turb	Cl	Hrdns
		Celcius	mg/l		mg/l			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	NTU	mg/l	mg/l
NM29A	4/7/99	10.75	11.25	198	2	6.9	100	0.127	0.26	0.71	0.51	0.080	15	1.1	40	30
	5/5/99	14.71	10.35	249	0.16	6.95	100.2	3.9	0.23	0.77	1	0.090	23	2.1	47	37
	7/7/99	27.74	4.96	322	0.206	6.99	62.3	3.3	0.2	0.83	0.82	0.120	34	2.5	55	48
	8/4/99	25.57	5.81	391	0.128	7.3								2.4		
	9/1/99	21.76	5.94	407	0.26	7.25	65.9	5	1.4	2	1.3	0.360	51	3.4	64	60
	11/3/99	12.13	9.34	257	0.164	6.74	86.7	3.3	0.08	0.7	0.98	0.092	25	2.6	46	59
	4/5/00	10.54	10.22	211	0.135	6.69	91.5	13	0.2	0.57	0.44	0.055	14	1.7	40	29
	6/7/00	14.76	9.19	209	0.134	6.76	89.3	8.2	0.07	0.58	0.68	0.140	18	4.8	38	30
	8/2/00	19.06	7.25	155	0.099	6.47	76.7	3.4	0.07	0.56	0.46	0.091	13	2.9	30	22
	10/18/00	12.01	7.69	257	0.165	6.81	69.5	4.7	0.1	0.66	1.1	0.120	26	10	45	41
	12/6/00	1.17	12.84	229	0.147	0.7	89	1.2	0.25	0.6	0.9	0.140	18	2	42	31

Nashua River Watershed Association Volunteer Monitoring Program

The Nashua River Watershed Association has been conducting a volunteer monitoring program since 1998. Following is data from their program for the summer of 2000. Samples were collected once per month from April to October except for the month of September during which time an oil spill interfered with sampling. A total of 38 stations were sampled for fecal coliform, E. *coli*, temperature, dissolved oxygen, percent saturation, pH, and alkalinity, with relative flow recorded. Twelve additional stations were sampled for total phosphorus. Data tables were produced by the NRWA with statistics including geometric mean, and percent of samples over standard. NRWA data tables may be obtained from the NRWA.

12 stations were reviewed by DEP: eight on the Nashua River, and four on the North Nashua. Data for the mainstem indicated an overall drop in DO during August for NM01, NM02, NM03, NM04, and NM05, with all 5 stations below 2 mg/l. NM01 also was low during May 2000. For NM06, NM07, and NM08, all stations were above the 5 mg/l standard for all dates except for NM07, which was just above 2 mg/l in October 2000. All four stations on the North Nashua showed DO levels above 5 mg/l for all dates. The percent saturation values for the Nashua River mainstem stations for dates listed above reflected the low dissolved oxygen values with the August values reaching below 20% saturation, and the October sampling event reaching to just above 20% saturation. Although the DO values for NN09 and NN10 were good, the percent saturation was only moderate for NN09 in July, and NN10 in October.

The data showed very significant increases in instream phosphorus below the Clinton WWTF, the Ayer WWTF, and the Pepperell WWTF, as compared with instream phosphorus levels above these facilities. The Nissitissit River phosphorus levels were very low. Levels below Fitchburg East, and below Leominster were comparable to values sampled upstream. Subsequent to the year 2000 phosphorus sampling, the Clinton and Ayer NPDES permits included a 1mg/l limit for phosphorus. The NRWA is considering re-sampling for phosphorus above and below these facilities to evaluate the reduction in phosphorus levels instream as a result of the reduction of phosphorus levels being discharged. A copy of the rainfall graph produced by NRWA is included. The sampling dates were 5/20, 6/17, 7/15, 8/19, 9/16 and 10/14/2000.

	Nashua Watershed Year 2000 Sampling Stations		
NM01	Nashua River	Nashua, NA	mouth of Nashua River
NM02	Nashua River	Nashua, NA	Mine Falls Park
NM03	Nashua River	Hollis, NH	upstream of Rte. 11 bridge
NM04	**Nashua River**	**Pepperell, MA**	downstream of confluence with Nissitissit
NM05	**Nashua River**	**Pepperell, MA**	upstream of covered bridge
NM06	**Nashua River**	**Lancaster, MA**	canoe launch off of Rte. 117
NM07	**Nashua River**	**Lancaster, MA**	Night Pasture
NM08	**Nashua River**	**Lancaster, MA**	Mill St.

NN01	**North Nashua River**	**Lancaster, MA**	Main St. RR bridge
NN02	**North Nashua River**	**Lancaster, MA**	Cook powerline crossing
NN09	**North Nashua River**	**Fitchburg, MA**	McDonald's parking lot
NN10	**North Nashua River**	**Fitchburg, MA**	upstream of Depot St. bridge

Appendix D
Part 1: Calculation and Selection of Low Flow Numbers (7Q10)

In the development of models to evaluate the effects of instream pollutants on the water quality and ecology of the river system, the calculation and subsequent selection of low flow numbers are paramount. The following summary from CDM developed for the Nashua inflow/outflow study provides a listing of the available flow records for the watershed.

USGS STATION NAME	**DRAINAGE AREA IN SQUARE MILES**	**STREAMFLOW DATA TYPE**	**PERIOD OF RECORD**
North Nashua River Fitchburg, MA	63.4	Continuous	1972 to present
North Nashua River Leominster, MA	110	Continuous	1935 to present
Nashua River East Pepperell, MA	316	Continuous	1935 to present
Squannacook River West Groton, MA	63.7	Continuous	1949 to present
Quinapoxet River Canada Mills Holden, MA	44.4	Continuous	1996 to present
Stillwater River Sterling, MA	31.6	Continuous Low flow partial record	1994 to present 1971-73, 1991-93
Rocky Brook Sterling, MA	1.95	Peak	1946 to 1967
Easter Brook North Leominster, MA	0.92	Peak	1964 to 1974
Trapfall Brook Ashby, MA	5.89	Low flow partial record	1993 to 1995
Trout Brook Holden, MA	6.79	Low flow partial recofd	1971-73, 1991-93
Philips Brook Fitchburg, MA	15.8	Low flow partial record	1994-1996
Whitman River Westminster, MA	21.7	Low flow partial record	1973-74, 1991-93
Unkety Brook Pepperell, MA	6.84	Low flow partial record	1971-74, 1991-93
Reedy Brook E. Pepperell, MA	1.92	Low flow partial record	1971-73, 1991-93

In 1984, the United States Geological Survey (Wandle, 1984) produced a report on the flow records in the Merrimack River Basin. Flow statistics were prepared detailing the gages and summary statistics for these gages. As part of the Nashua River TMDL project, Numeric Environmental Services (NES) compiled an updated version of data for three of these stations to include data up to September, 1999. NES utilized FFALOW, a USGS Pearson III.exe file to calculate the new 7Q10 numbers and the return flows for different frequencies. This procedure of incorporating the revised 7Q10 numbers reduced the 7Q10 by 10% if the 1931-1999 USGS flows were used. The 7Q1s increase until the mid-1960s then decreased significantly, especially in the Leominster area and above the Fitchburg East gage.

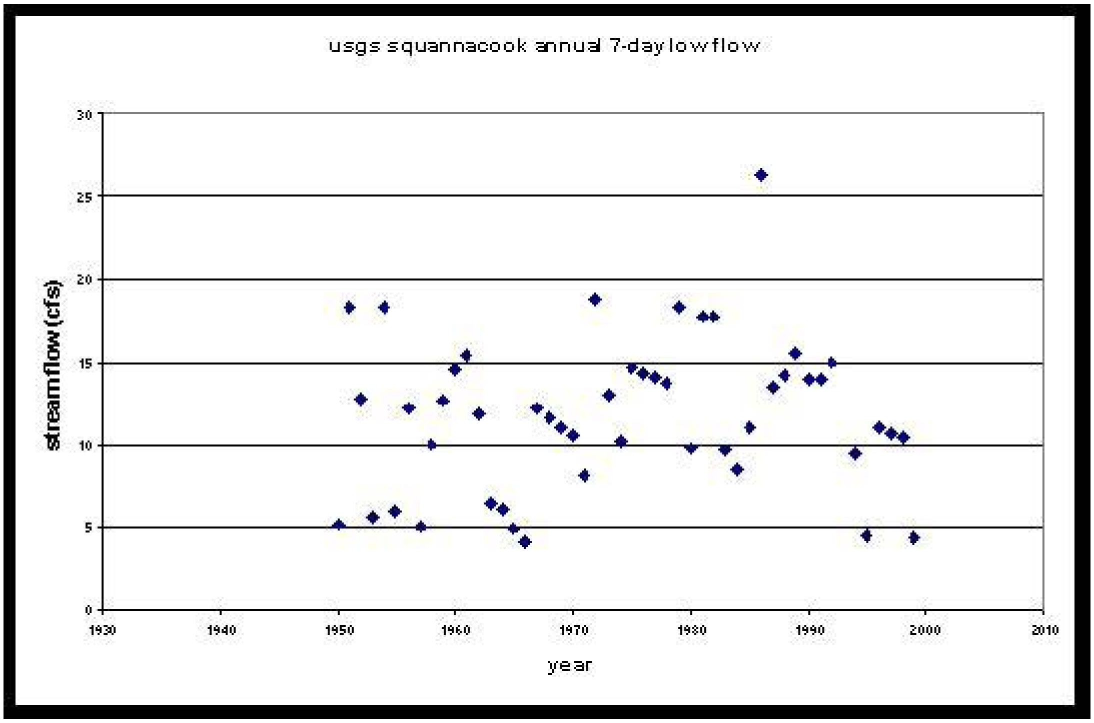
An additional effect on the flows in the mainstem of the Nashua River and in the South Branch of the river may be related to the reduction, although small, in the minimum release from Wachusett Reservoir. The minimum release is legislated for 12 million gallons per week. Prior to June 1991 the release was 1.8-2.0 mgd. Beginning in June 1991, the release was dropped to 1.6 mgd. MDC has readjusted the outlflow to 1.8 mgd.

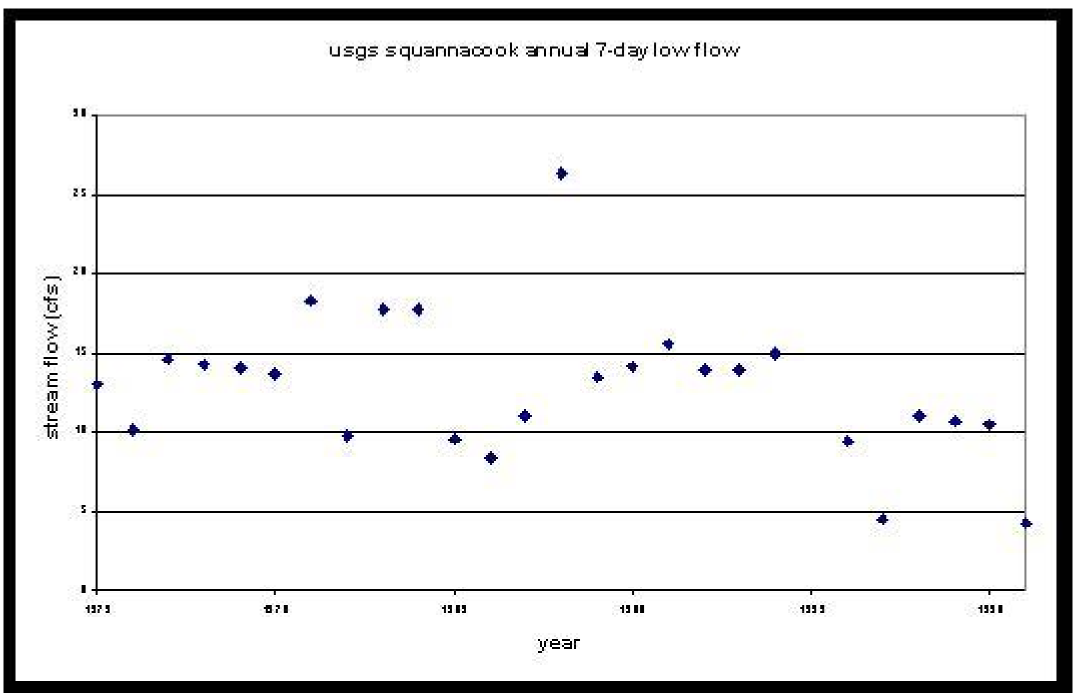
The three gaged stations are: (1) North Nashua, Fitchburg; (2) North Nashua, Leominster; and (3) Squannacook, West Groton. Dates of records include: (1) September 17, 1935 to September 30, 1999; (2) October 1, 1972 to September 30, 1999; and (3) October 1, 1949 to September 9, 1999, respectively. NES calculated annual 7-day low flow statistics utilizing a running average for each year of record and then graphing the minimum values for each year. Representative graphs are included which show the trends from 1935-1999, and from 1973 to 1999. The second set of graphs are more reflective of current conditions, of water use and withdrawals, and "resending" of the water back to the river system.

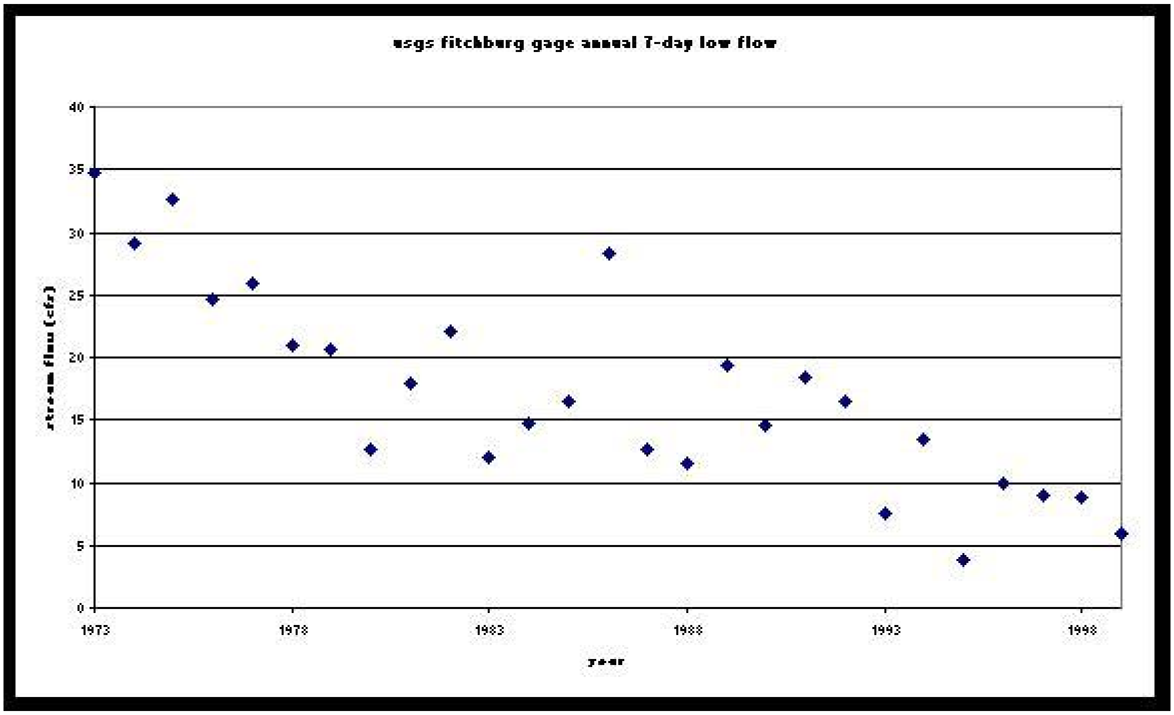
Flow Statistics as cited in Wandle, 1984, for these sites are listed in the table below. The gage at East Pepperell on the mainstem of the Nashua River, as the river leaves Massachusetts is given for comparison.

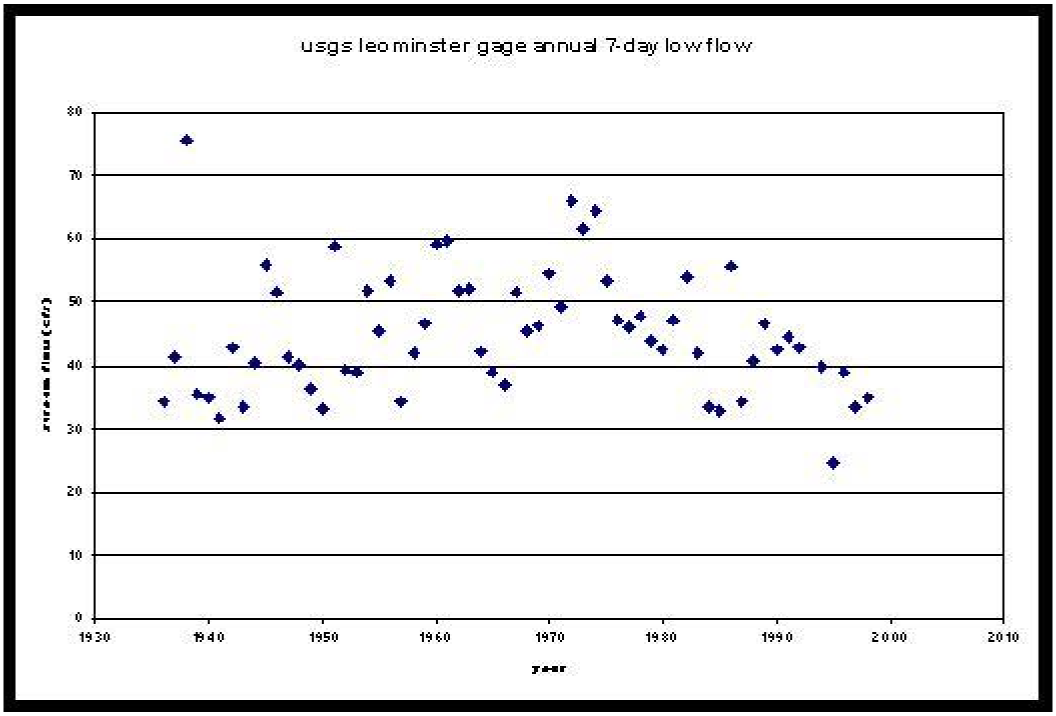
Gage	**7Q10**	**7Q2**	**Mean Annual Discharge**
North Nashua, Fitchburg	--	--	--
North Nashua, Leominster	35.3	45.4	191 cfs s.d. 48.7
Squannacook	5.5	12.9	109 cfs s.d. 1.37 cfs
Nashua River, East Pepperell	46.0	93.3	558 cfs s.d. 166 cfs

7Q10 is the annual minimum 7-day mean discharge for 10-year recurrence interval.
7Q2 is the annual minimum 7-day mean discharge for 2-year recurrence interval.

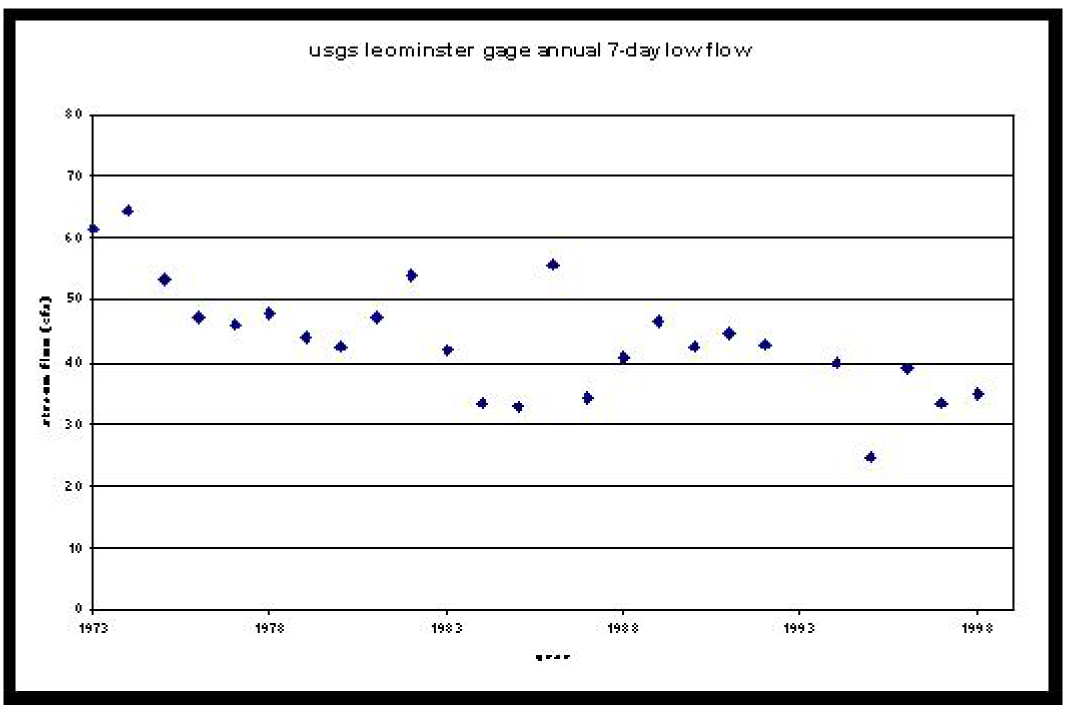

usgs squannacook annual 7-day low flow
streamflow (cfs)
0
5
10
15
20
25
30
1930
1940
1950
1960
1970
1980
1990
2000
2010
year


usgs squannacook annual 7-day low flow
stream flow (cfs)
year


usgs fitchburg gage annual 7-day low flow
stream flow (cfs)
year
0
5
10
15
20
25
30
35
40
1973
1978
1983
1988
1993
1998

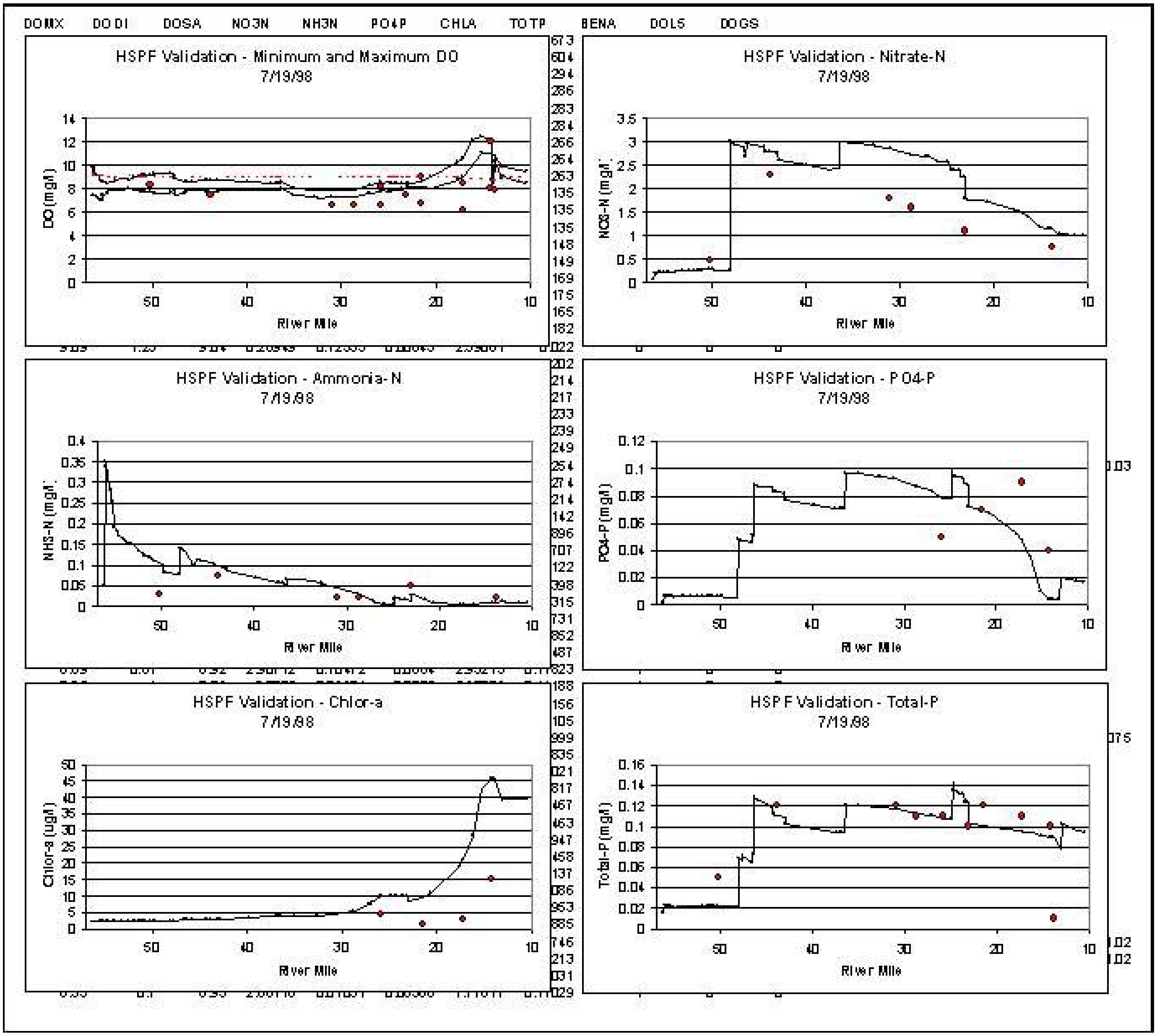


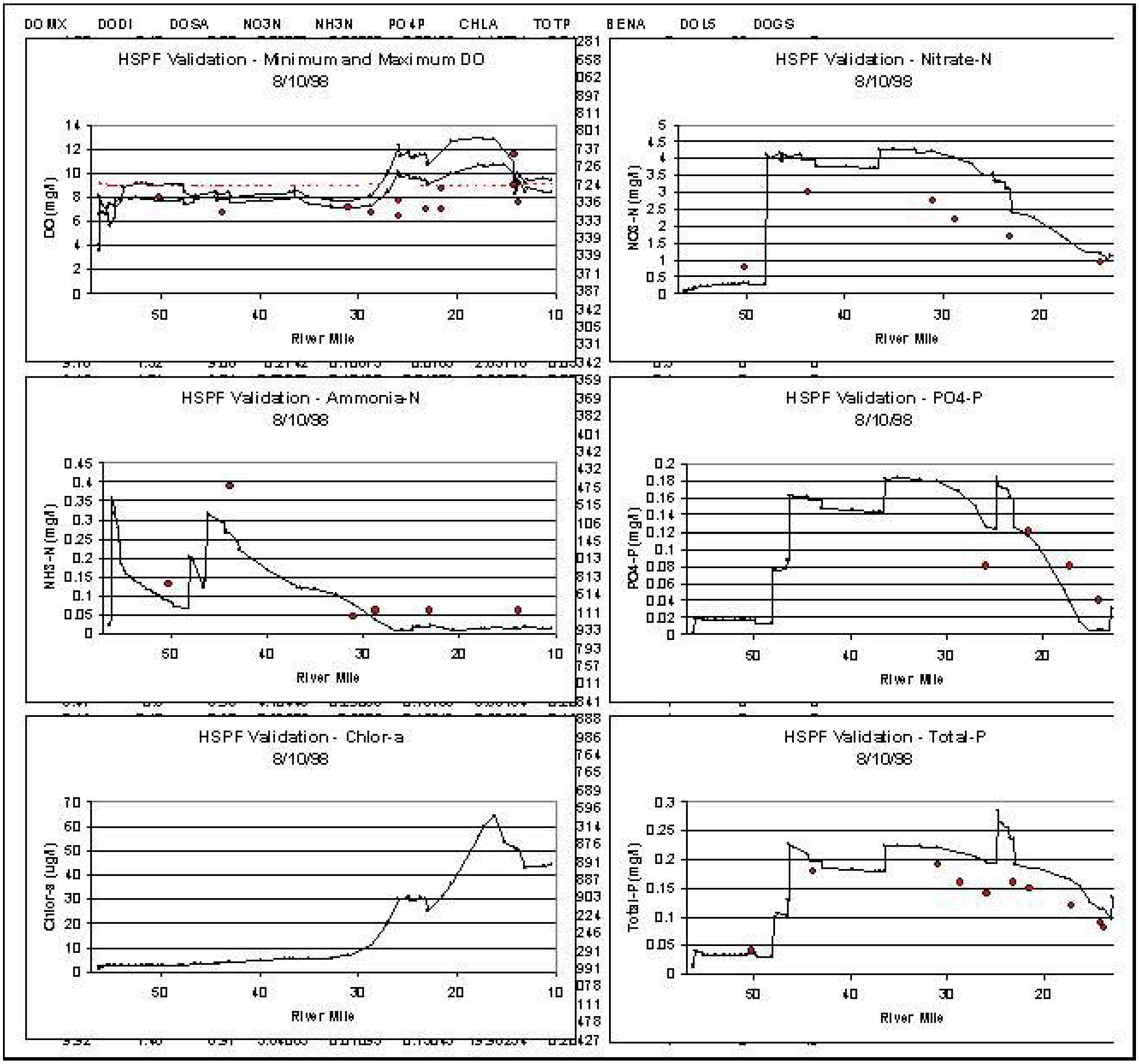
usgs leominster gage annual 7-day low flow
stream flow (cfs)
year



usgs leominster gage annual 7-day low flow
stream flow (cfs)
year

Appendix D
Part 2: HSPF Validation

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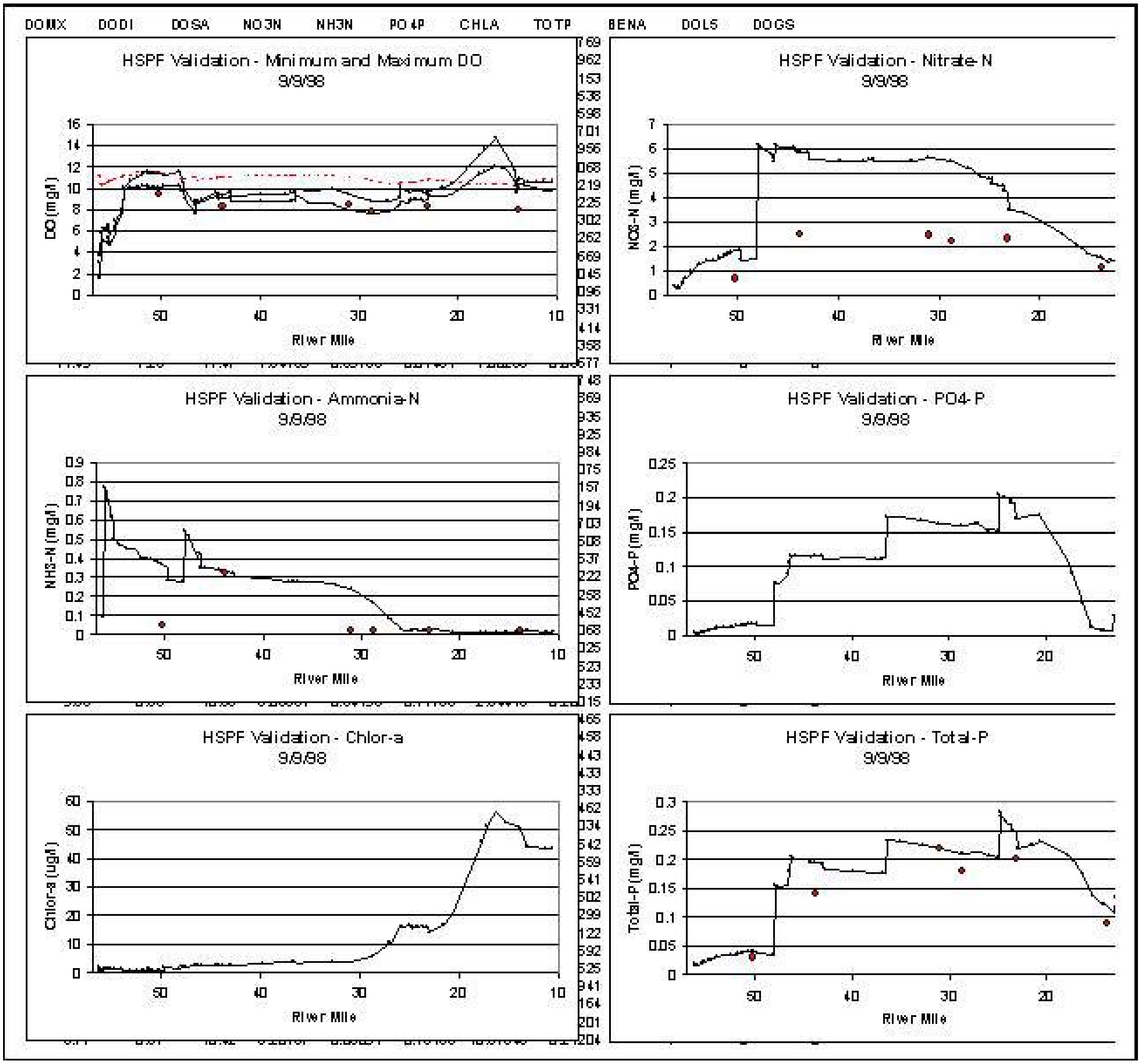
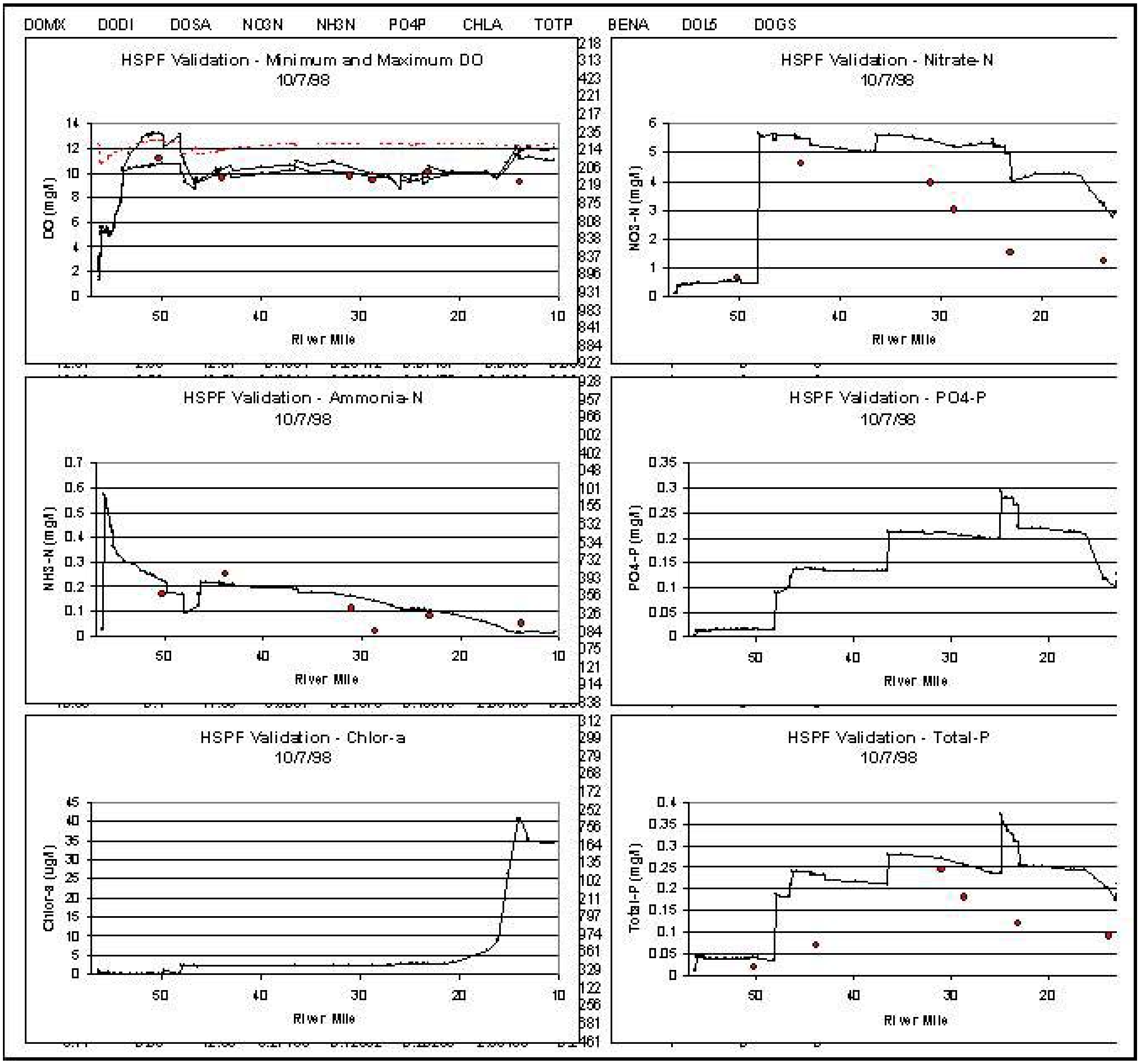
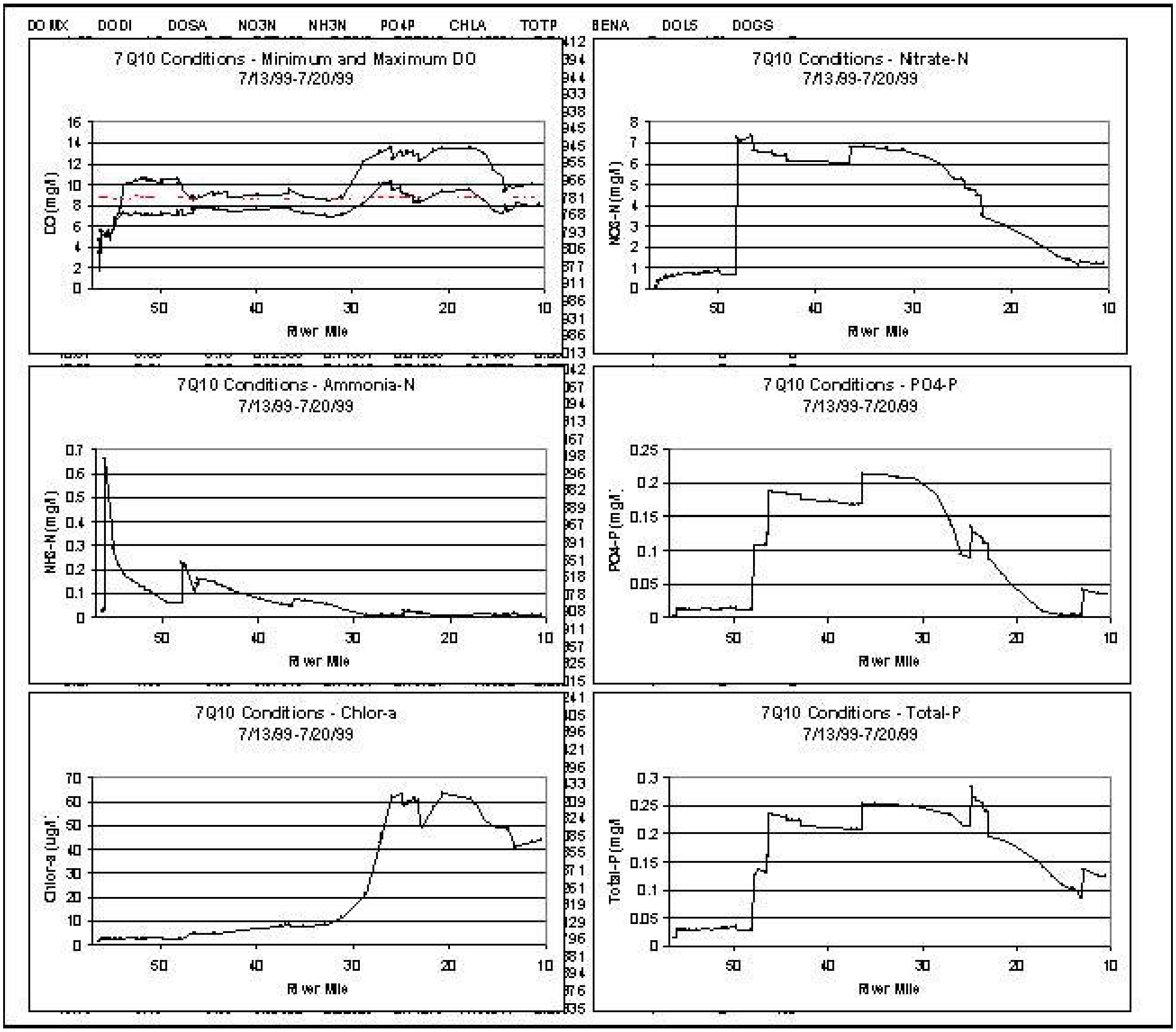
HSPF Validation - Minimum and Maximum DO
8/10/98
DO (mg/l)
River Mile
HSPF Validation - Nitrate-N
8/10/98
NO3-N (mg/l)
River Mile
HSPF Validation - Ammonia-N
8/10/98
NH3-N (mg/l)
River Mile
HSPF Validation - PO4-P
8/10/98
PO4-P (mg/l)
River Mile
HSPF Validation - Chlor-a
8/10/98
Chlor-a (ug/l)
River Mile
HSPF Validation - Total-P
8/10/98
Total-P (mg/l)
River Mile


DOMX DODI DOSA NO3N NH3N PO4P CHLA TOTP BENA DOLS DOGS
HSPF Validation - Minimum and Maximum DO
9/9/98
DO (mg/l)
River Mile
HSPF Validation - Nitrate-N
9/9/98
NO3-N (mg/l)
River Mile
HSPF Validation - Ammonia-N
9/9/98
NH3-N (mg/l)
River Mile
HSPF Validation - PO4-P
9/9/98
PO4-P (mg/l)
River Mile
HSPF Validation - Chlor-a
9/9/98
Chlor-a (ug/l)
River Mile
HSPF Validation - Total-P
9/9/98
Total-P (mg/l)
River Mile


DOMX DODI DOSA NO3N NH3N PO4P CHLA TOTP BENA DOL5 DOGS
HSPF Validation - Minimum and Maximum DO
10/7/98
DO (mg/l)
River Mile
HSPF Validation - Nitrate-N
10/7/98
NO3-N (mg/l)
River Mile
HSPF Validation - Ammonia-N
10/7/98
NH3-N (mg/l)
River Mile
HSPF Validation - PO4-P
10/7/98
PO4-P (mg/l)
River Mile
HSPF Validation - Chlor-a
10/7/98
Chlor-a (ug/l)
River Mile
HSPF Validation - Total-P
10/7/98
Total-P (mg/l)
River Mile


DO MX DO DI DOSA NO3N NH3N PO4P CHLA TOTP BENA DOL5 DOGS
7Q10 Conditions - Minimum and Maximum DO
7/13/99-7/20/99
DO (mg/l)
River Mile
7Q10 Conditions - Nitrate-N
7/13/99-7/20/99
NO3-N (mg/l)
River Mile
7Q10 Conditions - Ammonia-N
7/13/99-7/20/99
NH3-N (mg/l)
River Mile
7Q10 Conditions - PO4-P
7/13/99-7/20/99
PO4-P (mg/l)
River Mile
7Q10 Conditions - Chlor-a
7/13/99-7/20/99
Chlor-a (ug/l)
River Mile
7Q10 Conditions - Total-P
7/13/99-7/20/99
Total-P (mg/l)
River Mile

Appendix E
QUAL2E Model Development and Wasteload Allocation

A QULA2E model was developed by Numeric (Numeric, 2000) based upon the Massachusetts Stream 7B, 1977 wasteload allocation model (MADEP, 1977). Attached is a brief review of the QUAL2E model developed by NUMERIC followed by a synopsis of the instream effects of wasteload allocation runs developed by DEP.

This Appendix presents the following:

- Summary text on QUAL2E model development, including calibration, verification, and 7Q10;
- Comparison of results of DEP wasteload allocation runs at 7Q10 with different effluent discharge scenarios and baseline scenario;
- Graphs of minimum and maximum dissolved oxygen and chlorophyll_a for 3 scenarios (2000 permit limits, final suggested effluent concentrations, and a less stringent set of effluent changes);
- Comparison of global and reach specific algal coefficients for calibration, verification, and 7Q10 input files;
- Effluent numbers for year 2000 permit limits;
- Comparison of WWTF effluent values for calibration, verification, and 7Q10 files;
- Listing of QUAL2E input and output files received from Numeric; and
- Results of additional WLA runs using 2 additional 7Q10 input files (no algae effect; only planktonic algae).

The results indicated that values of 10 mg/l BOD, 1 mg/l NH_3 and 0.2 mg/l P would improve water quality with a corresponding decrease in diurnal DO fluctuations and moderate instream levels of chlorophyll-a.

QUAL2E Development, Calibration, Verification, 7Q10, and Preliminary Results

The QUAL2E Nashua model development was based upon the Massachusetts' DEP STREAM7B Nashua calibrated and verified model developed in1977, and the input data file for the 7Q10 STREAM7B low flow waste load allocation run. (Numeric, 2001; MADEP, 1977) Reach designations remained the same on model conversion.

Physical Representation

The Nashua River was divided into 48 reaches, with computational elements of 0.1 mile in length. The schematic shows river miles versus reach element designations. Each reach represents a portion of the river with similar hydraulic or chemical characteristics. The basic hydraulics were based upon the Stream7B low flow wasteload allocation model originally developed by the MADEP, and retains the original DEP reach designations. Numeric additionally updated and expanded the hydraulics using FEMA HEC2 cross-section data to calculate depth and velocity power functions. Ftables were developed from the HEC2 data, for depth, surface area, and volume versus stream flow.

Water budget and flows

A water budget spreadsheet was developed. The spreadsheet utilized measured point source, tributary, and USGS gage data for generating distributed inflows for surface water and groundwater, and also provided a graphical comparison of the flows for the June, August, and 7Q10 flows. The August 15-19, 1977 flows were less than twice 7Q10 and the June 20-24,1977 flows were about three times 7Q10.

Meteorological data

Climatological data was a combination of NOAA/NCDC solar and meteorological data from 1961-90 (SAMSON), and hourly US Weather Observations (1990-95). A spreadsheet format was utilized to input LCD data into QUAL2E. Solar radiation at ground level was based upon the radiation outside the atmosphere as adjusted in the model for cloud cover. Radiation outside the atmosphere was based upon the day of year start time, and the latitude and longitude, which varies daily and seasonally. In a dynamic simulation, when temperature was simulated also, the temperature and cloud cover were then used to calculate hourly photosynthetically active radiation.

Calibration

The model was calibrated using the June1977 water quality data and was run in the dynamic mode for heat, algae, ultimate biochemcial oxygen demand, and the phosphorus and nitrogen cycles. The point source and tributary inflows and loads were constant in time. The model calibrated well for temperature, total phosphorus, chlorophyll_a, average dissolved oxygen, total suspended solids, ammonia, and 5-day biochemical oxygen demand. Nitrate calibration was fair. The QUAL2E model field data is contained in the file Calobs, with the solar radiation data Cal77.lcd, to produce the Cal77.dat input file.

Validation

The model was validated using the August 15-19, 1977 data set. A 15-day period was required to reach steady-state, indicating time of travel from the headwaters to the mouth of the river under 7Q10 flow conditions. The model verification was good for temperature, average DO, Chl_a, TP, NO_3, TSS, BOD_5, and NH_3. The Ver77.dat input file utilized the solar radiation data in Cal77.lcd.

The QUAL2E model was successfully developed and tested for 1977 conditions with steady flows and loads. Numeric additionally developed a set of modeling tools and utilities.

Re-Calibration/Validation

The QUAL2E model was subsequently updated and tested by Numeric using the 1998 water quality and flow data collected by the MADEP (20 years subsequent to the original development and calibration). Meteorological (MET) data was obtained from Cornell. River flow data was obtained from the USGS. Wastewater treatment facility data was obtained from MADEP and USEPA. July 16-24, 1988 was selected for verification. The flows for the July 22, 1998 survey were about twice 7Q10 and higher than the August 15-19, 1977 initial calibration run.

Two files were developed. Cal98.dat is calibrated to the average dissolved oxygen and utilizes a chlorophyll_a to biomass ratio of 50. Cal98alg.dat is calibrated to reflect a diurnal DO fluctuation due to primary productivity and utilizes a chl_a to biomass ratio of 10. The solar radiation file is Cal98.lcd

7Q10 Models

Two 7Q10 models were then developed based upon the two 1998 calibrated models. Wla.dat reflects the average daily DO and chl_a to biomass ratio of 50 and is utilized to determine the effects instream of NH_3 and BOD without the benefits of algal production of oxygen. WlaAlg.dat reflects the diurnal DO fluctuations with a chl_a to biomass ratio of 10 and is developed to determine instream effects of phosphorus once ammonia and BOD are excluded. The solar radiation file for the wasteload allocation run is 7Q10.lcd. Given the limited data available along the steam the model calibrated well.

An additional 7Q10 run was developed with the algae turned off for photosynthesis and respiration. The abundance of phosphorus in the system would predict very high chlorophyll_a levels and extensive algal populations if the algae were not turned off. However, in the Nashua system the populations were mostly macrophytes.

A decision was required with regard to which model would best represent the Nashua system. The assumption was made that the high chl_a levels represent the chlorophyll and primary productivity for both the planktonic and macrophytic populations, thereby using the WlaAlg.dat 7Q10 model input file for development of water quality scenarios.

New 7Q10 flow figures were developed utilizing the last 20 years of USGS flow data. These new flows should be evaluated to determine if they should replace the full historical record in a revised 7Q10 model.

Dynamic simulation

The final stages of the calibration process were the simulations of chlorophyll_a. The model was run in a dynamic mode to look at the diurnal variations in dissolved oxygen from algal productivity and respiration, as nitrates and phosphates were taken up by the algae.

Once the photosynthetically active solar radiation was set, all parameters were set at average values to determine output. Since a number of the parameters required in the algal simulations were not measured, values were selected from a range of values in the QUAL2 manual. The model was then run for a time that equaled the time of travel in the river.

The initial underpredictions of algal growth were increased by increasing the growth rate u. In this model the chlorophyll_a is directly proportional to biomass with a conversion factor determining the amount of chlorophyll per unit of biomass.

ug/l Chlor-a/Liter = (ug Chlr-a/mg.Algae) X (mg algae/Liter).

The change in biomass over time = growth rate – respiration – settling.

The method for determining growth rate in the model was multiplicative.

The algal component was regulated globally for most variables, and regulated reach-by-reach for the chl-a to biomass ratio, and the settling coefficients. The ratio of chl-a to biomass controlled the uptake of nitrates and phosphates and this affected the growth factor. As the ratio became larger, and more chl_a was found per cell, the uptake of nitrates and phosphates became less, and the algal affect on DO became less. The production and respiration of algae was related to the amount of algal biomass. The algal ratio of chl_a to biomass, the algal growth rate, and the respiration rate were then adjusted in an iterative process to reflect actual instream values.

Adjustments were then made to reflect the consumption of nutrients by adjusting the algal fractions of nitrogen and phosphorus. Since nutrient concentrations affected algal growth rate, this was also an iterative process and included the settling rate. An included table provides a comparison of the algal input parameters in the calibration and verification runs.

Table Showing Algal Input Parameters for QUAL2 Runs

Table showing algal input parameters for QUAL2 runs by Numeric

	Calibration	*Calibration*	**Re-Calibration**	*7Q10*	*7Q10*
	Jun-77	***Aug-77***	**Jul-98**	***mid-May***	***mid-May***
	CAL77.DAT	***VER77.DAT***	***CAL98.DAT***	***WLA.DAT***	***WLAALG.DAT***
O UPTAKE BY NH3 OXID(MG O/MG N)	**3.5**	**3.5**	**3.1**	**3.1**	**3.1**
O PROD BY ALGAE (MG O/MG A)	**1.6**	**1.6**	**1.6**	**1.6**	**1.8**
N CONTENT OF ALGAE (MG N/MG A)	0.085	0.085	0.085	0.085	0.085
ALG MAX SPEC GROWTH RATE(1/DAY)	**2.3**	**1.6**	**2.5**	**2.5**	**3**
N HALF SATURATION CONST (MG/L)	0.3	0.3	0.3	0.3	0.3
LIN ALG SHADE CO (1/H-UGCHA/L)	**0.0088**	**0.0088**	**0.0088**	**0.0088**	**0.01**
LIGHT FUNCTION OPTION (LFNOPT)	1	1	1	1	1
DAILY AVERAGING OPTION (LAVOPT)	3	3	3	3	3
NUMBER OF DAYLIGHT HOURS (DLH)	14	14	14	14	14
ALGY GROWTH CALC OPTION(LGROPT)	1	1	1	1	1
ALG/TEMP SOLR RAD FACTOR(TFACT)	0.45	0.45	0.45	0.45	0.45
O UPTAKE BY NO2 OXID(MG O/MG N)	**1.20**	**1.20**	**1.07**	**1.07**	**1.07**
O UPTAKE BY ALGAE (MG O/MG A)	**2.00**	**2.00**	**2.00**	**2.00**	**2.3**
P CONTENT OF ALGAE (MG P/MG A)	0.012	0.012	0.012	0.012	0.012
ALGAE RESPIRATION RATE (1/DAY)	0.2	0.2	0.2	0.2	0.2
P HALF SATURATION CONST (MG/L)	0.04	0.04	0.04	0.04	0.04
NLIN SHADE (1/H-(UGCHA/L)**2/3)	**0.0540**	**0.0540**	**0.0165**	**0.0165**	**0.0165**
1 LIGHT SATURATION COEF (INT/MIN)	0.03	0.03	0.03	0.03	0.03
LIGHT AVERAGING FACTOR (AFACT)	0.92	0.92	0.92	0.92	0.92
TOTAL DAILY SOLAR RADTN (INT)	2400	2400	2400	2400	2400
ALGAL PREF FOR NH3-N (PREFN)	0.9	0.9	0.9	0.9	0.9
NITRIFICATION INHIBITION COEF	0.6	0.6	0.6	0.6	0.6
CHLOROPHYLL-A TO BIOMASS RATIO	**50**	**50**	**50**	**50**	**10**

		Bowie (1985)	**Qual2e**
Ratio of chl-a to algal biomass	ug chla/mg/A	2.5-100	10-100
Nitrogen content of algal biomass	mg N/mg A	0.06-0.16	0.07-0.09
Phosphorus content of algal biomass	mg P/mg A	0.002-0.05	0.01-0.02
Maximum algal growth rate	day-1	0.58-9.2	1.0-3.0
Algal respiration	day-1	0.02-0.92	0.05-0.50

Scenarios

Eight scenarios were run by MADEP utilizing the QUAL2 model developed by Numeric. Comparative scenarios were run at 7Q10 flow conditions and maximum effluent discharge flow, utilizing a chlorophyll_a/biomass ratio of 10, as follows:

Scenario 1: Baseline with 1998 permits.
Scenario 2: 2000 permit limits.
Scenario 3: 2000 permit limits, 1 mg/l ammonia,
Scenario 4: 2000 permit limits, 1 mg/l ammonia. 0.5 mg/l phosphorus
Scenario 5: 2000 permit limits, 1 mg/l ammonia, 0.5 mg/l phosphorus, 10 mg/l BOD.
Scenario 6: 2000 permit limits, 1 mg/l ammonia, 0.2 mg/l phosphorus, 10 mg/l BOD.
Scenario 7: 2000 permit limits, 1 mg/l ammonia, 0.1 mg/l phosphorus, 10 mg/l BOD.

Scenario 8: 2000 permit limits with a chlorophyll_a/biomass ratio of 50 with no photosynthesis and respiration.

Scenario 9: 2000 permit limits with a chlorophyll_a/biomass ratio of 50 with photosynthesis and respiration on.

The NPDES year 2000 permit limits are listed in Table 3.

Table 3
Scenario 1 WWTF Effluent Input Numbers from Year 2000 NPDES Permits or Monitoring

	FTBG-W*	**FTBG-E**	**LEOM***	**CLINTON***	**AYER***	**PEPL**
FLOW (cfs)	16.2	19.2	14.4	4.7	2.8	1.1
FLOW (mgd)	10.5	12.5	9.3	3.0	1.8	0.7
BOD (mg/l)	8	8	15	20	30	30
NH3 (mg/l)	1	1	1.3	2	1	
NO3 (mg/l)	0.42	5.1	5.8	13	**2.9**	
TKN (mg/l)	4.7	3.8	2.5	1.4	**1.7**	
TOTAL-P (mg/l)	1	1	1	1	1	
TSS (mg/l)	10	10	20	20	30	30
DO (mg/l)	6	6	6	6	6	

TKN, NO3 numbers from EPA monitoring in 1998

Results
A comparion of results is tabulated. Graphical comparison is also provided Results indicated that values of 10 mg/l BOD, 1 mg/l NH_3 and 0.1 mg/l TP would improve water quality with a corresponding decrease in diurnal DO fluctuations and moderate instream levels of chlorophyll_a.   Chlorophyll_a maximums would be reduced from a high value to 25 ug/l. Dissolved oxygen minimums would rise from 0.88 mg/l to 5.88 mg/l, with "miles not meeting standards" being reduced from 1.5 miles to 0 miles.

The model results indicated that more stringent effluent numbers would be required for the wastewater treatment facilities than presently exit in the NPDES year 2000 permits. However, QUAL2, although regarded as an excellent model for handling the many dams on the Nashua River and modeling diurnal dissolved oxygen, was not as well equipped to model impoundments. Therefore, the TMDL modeling was scoped to include modeling using nonpoint source effects and point source effects on the systems through HSPF. This modeling was conducted using HSPF to determine if reductions in nonpoint sources would translate into corresponding increases in water quality instream, and if corresponding values would be indicated in the impoundments.

Table 1 Nashua River QUAL2 Stream Reach Information

North Branch						
STREAM REACH	2.0RCH=	FROM	55.9	TO	55.5	JAMES RIVER POWER STATION DAM TO CROCKER BURBANK MILL 9
STREAM REACH	3.0RCH=	FROM	55.5	TO	55.3	CROCKER BURBANK MILL 9 TO WATER INTAKE
STREAM REACH	4.0RCH=	FROM	55.3	TO	55.2	WATER INTAKE TO FITCHBURG PAPER COMPANY MILL 4
STREAM REACH	5.0RCH=	FROM	55.2	TO	54.7	FITCHBURG PAPER CO. MILL 4 TO FITCHBURG PAPER CO. MILL 1
STREAM REACH	6.0RCH=	FROM	54.7	TO	54.0	FITCHBURG PAPER CO. MILL 1 TO DANIEL STREET BRIDGE
STREAM REACH	7.0RCH=	FROM	54.0	TO	52.9	DANIEL STREET BRIDGE TO FITCHBURG GAS AND ELECTRIC CO.
STREAM REACH	7.1RCH=	FROM	52.9	TO	51.9	DANIEL STREET BRIDGE TO FITCHBURG GAS AND ELECTRIC CO.
STREAM REACH	8.0RCH=	FROM	51.9	TO	51.4	FITCHBURG GAS AND ELECTRIC CO. TO ARDEN MILL DAM
STREAM REACH	9.0RCH=	FROM	51.4	TO	51.1	ARDEN MILL DAM TO DUCK MILL DAM
STREAM REACH	10.0RCH=	FROM	51.1	TO	50.8	DUCK MILL DAM TO BEMIS ROAD DAM
STREAM REACH	11.0RCH=	FROM	50.8	TO	49.8	BEMIS ROAD DAM TO FALULAH BROOK
STREAM REACH	12.0RCH=	FROM	49.8	TO	48.1	FALULAH BROOK TO FITCHBURG EASTERLY WWTP
STREAM REACH	13.0RCH=	FROM	48.1	TO	47.7	FITCHBURG EASTERLY WWTP TO WHEELRIGHT PAPER CO. DAM
STREAM REACH	14.0RCH=	FROM	47.7	TO	46.6	WHEELWRIGHT PAPER CO. DAM TO MONOOSNOC BROOK
STREAM REACH	15.0RCH=	FROM	46.6	TO	46.4	MONOOSNOC BROOK TO LEOMINSTER WWTP
STREAM REACH	16.0RCH=	FROM	46.4	TO	44.4	LEOMINSTER WWTP TO FALL BROOK
STREAM REACH	17.0RCH=	FROM	44.4	TO	44.2	FALL BROOK TO USGS GAGING STATION
STREAM REACH	18.0RCH=	FROM	44.2	TO	43.0	USGS GAGING STATION TO WEKEPEKE BROOK
STREAM REACH	19.0RCH=	FROM	43.0	TO	41.1	WEKEPEKE BROOK TO PERKINS SCHOOL
STREAM REACH	19.1RCH=	FROM	41.1	TO	39.3	WEKEPEKE BROOK TO PERKINS SCHOOL
STREAM REACH	19.2RCH=	FROM	39.3	TO	37.4	WEKEPEKE BROOK TO PERKINS SCHOOL
STREAM REACH	20.0RCH=	FROM	37.4	TO	36.9	PERKINS SCHOOL TO ATLANTIC UNION COLLEGE
STREAM REACH	21.0RCH=	FROM	36.9	TO	36.5	ATLANTIC UNION COLLEGE TO CONFLUENCE WITH SOUTH BRANCH N
South Branch						
STREAM REACH	21.1RCH=	FROM	4.5	TO	3.1	OUTLET OF LANCASTER MILLPOND TO CLINTON WWTP
STREAM REACH	21.2RCH=	FROM	3.1	TO	1.7	OUTLET OF LANCASTER MILLPOND TO CLINTON WWTP
STREAM REACH	21.3RCH=	FROM	1.7	TO	1.5	CLINTON WWTP TO COUNTERPANE BROOK
STREAM REACH	21.4RCH=	FROM	1.5	TO	0.0	COUNTERPANE BROOK TO CONFLUENCE WITH MAINSTEM
Mainstem						
STREAM REACH	22.0RCH=	FROM	36.5	TO	34.6	SOUTH BRANCH NASHUA TO STILL RIVER
STREAM REACH	22.1RCH=	FROM	34.6	TO	32.7	SOUTH BRANCH NASHUA TO STILL RIVER
STREAM REACH	23.0RCH=	FROM	32.7	TO	30.7	STILL RIVER TO SHIRLEY PRE-RELEASE CENTER
STREAM REACH	23.1RCH=	FROM	30.7	TO	28.7	STILL RIVER TO SHIRLEY PRE-RELEASE CENTER
STREAM REACH	24.0RCH=	FROM	28.7	TO	27.1	SHIRLEY PRE-RELEASE CENTER TO CATACOONAMUG BROOK
STREAM REACH	25.0RCH=	FROM	27.1	TO	25.9	CATACOONAMUG BROOK TO ICE HOUSE DAM
STREAM REACH	26.0RCH=	FROM	25.9	TO	24.9	ICE HOUSE DAM TO AYER WWTP
STREAM REACH	27.0RCH=	FROM	24.9	TO	24.2	AYER WWTP TO FORT DEVENS WWTP
STREAM REACH	28.0RCH=	FROM	24.2	TO	23.6	FORT DEVENS WWTP TO MULPUS BROOK
STREAM REACH	29.0RCH=	FROM	23.6	TO	23.0	MULPUS BROOK TO SQUANNACOOK RIVER
STREAM REACH	30.0RCH=	FROM	23.0	TO	21.5	SQUANNACOOK RIVER TO THE GROTON SCHOOL
STREAM REACH	31.0RCH=	FROM	21.5	TO	20.1	THE GROTON SCHOOL TO THE INLET TO PEPPERELL POND
STREAM REACH	31.1RCH=	FROM	20.1	TO	18.6	THE GROTON SCHOOL TO THE INLET TO PEPPERELL POND
STREAM REACH	31.2RCH=	FROM	18.6	TO	17.2	THE GROTON SCHOOL TO THE INLET TO PEPPERELL POND
STREAM REACH	32.0RCH=	FROM	17.2	TO	15.7	THE INLET TO PEPPERELL POND TO THE OUTLET AT EAST PEPPERELL
STREAM REACH	32.1RCH=	FROM	15.7	TO	14.2	THE INLET TO PEPPERELL POND TO THE OUTLET AT EAST PEPPERELL
STREAM REACH	33.0RCH=	FROM	14.2	TO	13.9	EAST PEPPERELL DAM TO JAMES RIVER-PEPPERELL PAPER CO.
STREAM REACH	34.0RCH=	FROM	13.9	TO	13.2	JAMES RIVER-PEPPERELL PAPER CO. TO THE NISSITISSIT RIVER
STREAM REACH	35.0RCH=	FROM	13.2	TO	11.3	THE NISSITISSIT RIVER TO UNKETY BROOK
STREAM REACH	36.0RCH=	FROM	11.3	TO	10.4	UNKETY BROOK TO THE MASS-NH STATE LINE

WWTF EFFLUENT NUMBERS FROM NPDES YEAR 2000 PERMITS

	FTBG-W	**FTBG-E**	**LEOM**	**CLINTON**	**AYER**	**PEPL**
FLOW (cfs)	16.2	19.2	14.4	4.7	2.8	1.4
FLOW (mgd)	10.5	12.5	9.3	3.0	1.8	0.9
BOD	8	8	15	20	30	30
NH3	1	1	1.3	2	2	0.56
NO3 (no number in permit)	1.4	8	8	1.3	2.9	5.1
TOTAL-P	1	1	1	1	1	
TSS	10	10	20	20	30	
DO	6	6	6	6	6	

COMPARISON OF RESULTS OF WLA RUNS AT 7Q10 FLOWS WITH EACH EFFLUENT DISCHARGE SCENARIO

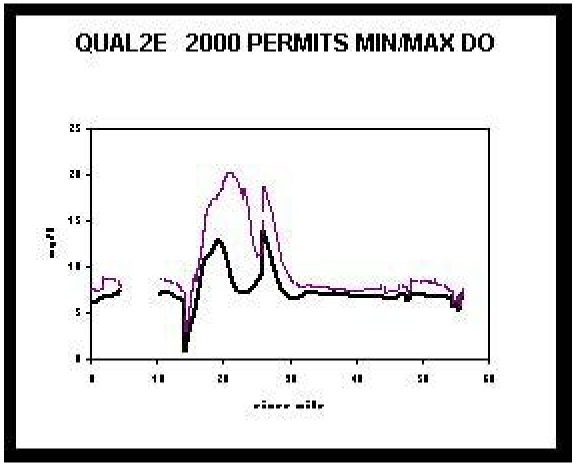
	C:\7Q10 *WlaAlg2a.dat*	*WlaAlg3a.dat*	*WlaAlg4a.dat*	*WlaAlg5a.dat*	*WlaAlg6a.dat*	*WlaAlg7a.dat*
Chl_a to Biomass = 10				**10 (mg/l) BOD**	**10 (mg/l) BOD**	**10 (mg/l) BOD**
(planktonic and macrophytic algae)			**0.5 (mg/l) P**	**0.5 (mg/l) P**	**0.2 (mg/l) P**	**0.1 (mg/l) P**
		1 (mg/l) NH3	**1 (mg/l) NH3**	**1 (mg/l) NH3**	**1 (mg/l) NH3**	**1 (mg/l) NH3**
	2000 Permits	**2000 Permits**	**2000 Permits**	**2000 Permits**	**2000 Permits**	**2000 Permits**
24 Hour Minimums						
Miles Not Meeting Standards	1.5	1.5	**2.7**	**2.5**	1.8	0
Minimum Dissolved Oxygen	0.88	1	1.93	**2.2**	4.67	5.88
Chl_a Max	213	212	**129**	**129**	53	25
Location (mile points)	15.6 to 14.2	15.6 to 14.2	**16.8** to 14.2	**16.7** to 14.3	16.0 to 14.3	DO @ 27.8 Chl_a @ 16.4
24 Hour Maximums						
Miles Not Meeting Standards	0.5	0.5	**2.3**	**2.2**	0	0
Minimum Dissolved Oxygen	3.1	3.2	3.16	3.37	5.18	5.18
Maximum Dissolved Oxygen	21.2	20.17	21.1	**16.2**	10.45	8.73
Location (mile points)	14.7 to 14.3	14.7 to 14.3	**16.5** to 14.3	**16.5** to 14.3	DOmax @ 26.0 mi	DOmax @ 1.8 mi

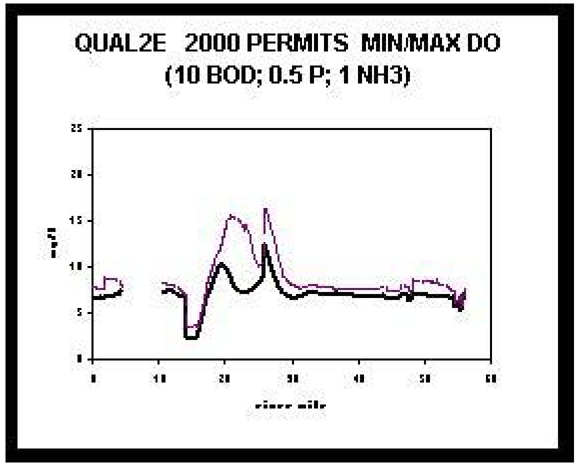
Additional WLA Runs Using Different Input Files

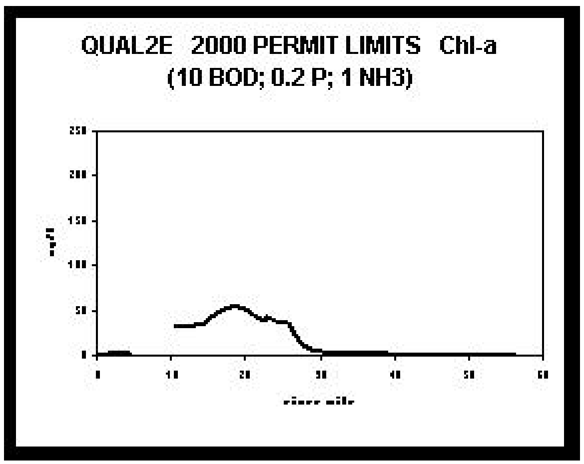
(HIGHER CHLA TO BIOMASS RATIO WITH AND WITHOUT P &R)

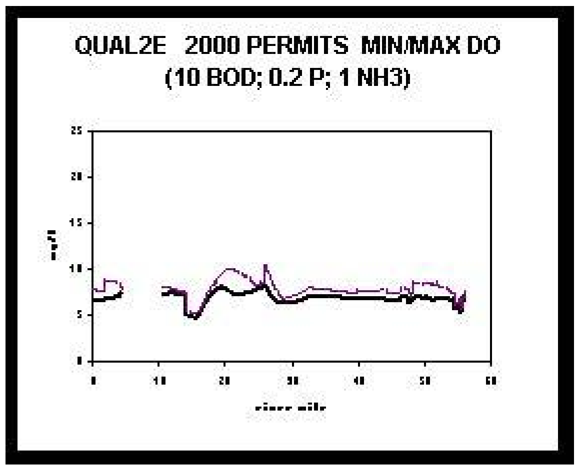
	WLA0.dat	***WLA2.dat***
Chl_a to Biomass Ratio	50	50
	(no P & R)	**(with P & R)**
	(no algae)	**(only planktonic algae)**
	2000 Permits	**2000 Permits**
24 Hour Minimums		
Miles Not Meeting Standards	0.7	0
Minimum Dissolved Oxygen	4.92	5.39 @ 27.9
Chl_a Max	0.41	346 @ 10.5 mi
Location (mile points)	26.6 to 26.1	
24 Hour Maximums		
Miles Not Meeting Standards	0.6	0
Minimum Dissolved Oxygen	4.94	5.61 @ 28.4
Maximum Dissolved Oxygen	8.74	8.71 @ 13.2 mi
Location (mile points)	26.5 to 26.1	

Graphical Comparison of Selected Scenario Results









Appendix F
Massachusetts Stormwater Control Program

In Massachusetts, over the last several years, comprehensive stormwater management programs have been instituted. Stormwater discharges to surface waters cause water use impairments in water bodies across the state. The development of better storm water controls through state and federal stormwater regulations will lessen the impact to surface waters through better controls implemented at the local level. A summary of these programs follows.

In 1987, the Clean Water Act authorized EPA and states, when delegated the authority by EPA, to regulate point sources that discharge pollutants into waters of the U.S. through the National Pollutant Discharge Elimination System (NPDES) permit program. EPA is the permitting authority for the NPDES program in Massachusetts. The NPDES Phase I Storm Water Program, in place since 1990, addressed sources of stormwater runoff that had the greatest potential to negatively impact water quality: municipalities with populations over 100,000 that own and operate a municipal separate storm water system (MS4); discharges associated with certain categories of industrial operations; and, large construction activities that disturb five acres or more of land. These permits required the implementation of storm water management plans and programs to protect and improve water quality. Nationally, municipalities that operated MS4s were permitted under individual permits while construction activities and some industrial categories were issued permit coverage under general permits. In Massachusetts, only Boston and Worcester are included in the municipal category. The City of Worcester was issued an individual stormwater permit in 1998 for a five-year permit term, and was required to develop, implement and enforce a stormwater management program to reduce, to the maximum extent practicable, the discharge of pollutants from the MS4 to receiving waters identified in the permit. Worcester's NPDES Phase I stormwater permit will be reissued in 2006, and will require the continuation of many of the components of the stormwater management program established during the first permit term, along with new elements.

The Phase II Final Rule, published on December 8, 1999, expanded the NPDES permit program to include operators of small municipal separate storm sewer systems (small MS4s) and discharges from construction activity disturbing one acre or more of land. Under the Phase II program, the definition of "municipal" includes Massachusetts communities, U.S. military installations, state or federal owned facilities such as hospitals, prison complexes, state colleges or universities and state highways. The Phase II Rule also ended an exemption from stormwater permitting of industrial activities owned and operated by municipalities with populations of less than 100,000 people.

The Phase II Rule automatically designated (either in full or part) certain Massachusetts communities based on the urbanized area delineations from the 2000 U.S. Census. As a result of the census mapping, 17 communities in the Nashua River Watershed applied to EPA and MassDEP for coverage under the Phase II stormwater general permit, issued May 1, 2003.
The communities are Ayer, Boylston, Clinton, Fitchburg, Gardner, Groton, Holden, Lancaster, Leominster, Lunenburg, Paxton, Rutland, Shirley, Sterling, Townsend, West Boylston, and Westminster. The towns of Bolton, Dunstable, Harvard, and Pepperell were granted waivers from the program by EPA.
The general permit requires operators of regulated MS4s to develop and implement a storm water management program (SWMP) to reduce the discharge of pollutants from the storm drainage system to the Maximum Extent Practicable (MEP) and to protect water quality. In order to achieve

pollutant reduction and water quality protection, the permit required MS4s to develop a program consisting of the following six minimum measures:

1. public education and outreach;
2. public participation and involvement;
3. detection and elimination of illicit discharges;
4. construction site runoff control;
5. post-construction runoff control; and,
6. good housekeeping/pollution prevention practices in municipal operations.

Implementation of the program involves the identification of best management practices (BMPs) for the control measures and measurable goals for each BMP. In the context of storm water, a BMP is a technique, measure or structural control that is used for a given set of conditions to manage the quantity and improve the quality of storm water runoff in the most cost-effective manner. EPA's current policy for storm water permitting states that using best management practices rather than conforming to numeric discharge limits, is generally the most appropriate control unless adequate information exists to establish more specific requirements. The development of TMDL's will in some cases provide the needed information.

Municipalities that are totally regulated must implement the requirements of the Phase II permit in the entire town, while communities that are partially regulated need to comply with the Phase II permit only in the mapped Urbanized Areas (see http://www.epa.gov/region01/npdes/stormwater/ma.html for detailed maps for each community and copies of the Notices of Intent). EPA and MassDEP issued Stormwater general permits jointly after administrative review by EPA. Annual reports will be submitted to EPA and MassDEP by the permittees on May 1st in years 2004 through 2008 (inclusive). Phase II stormwater general permits will expire on May 1, 2008.

Stormwater discharges from construction activities are regulated in Massachusetts by federal, state and municipal law. The Phase II Rule lowered the threshold of land disturbance needing permitting under EPA's NPDES General Permit for Construction Activities. The Construction General Permit program requires construction sites disturbing one acre or more of land, either by itself or as part of a larger development plan, to apply for coverage under the permit. The operator of the site must file a Notice of Intent with EPA and develop a storm water pollution prevention plan (SWPPP) that describes how to control stormwater runoff from the site. The plan must include a narrative plan, a site map, erosion and sedimentation controls, temporary and permanent stabilization techniques, construction sequence, proper waste disposal, post-construction storm water management, inspection and maintenance during construction, and a plan for post-construction operation and maintenance of the storm water system.

Construction project oversight of stormwater discharges in Massachusetts also occurs at the municipal level. Municipalities may have local drainage, sewer, and wetland bylaws and ordinances that regulate stormwater for new development and redevelopment projects.

In 1996, recognizing that stormwater runoff and discharges were large contributors to the water quality problem in Massachusetts rivers, streams, and marine waters, the MassDEP, in coordination with the Massachusetts Office of Coastal Zone Management (CZM), developed stormwater management standards and a strategy for their implementation. *The Stormwater Handbook and Best Management Practices Manual* require stormwater management systems be implemented when new construction or reconstruction projects are reviewed by issuing authorities under the Wetlands Protection Act, M.G.L. C. 131 §40. The stormwater standards apply to industrial, commercial, institutional, residential subdivision, and roadway projects, including site preparation, construction, redevelopment, and on-going operation.

EPA oversees the permitting of stormwater discharges from industrial facilities in Massachusetts. The Stormwater Multisector General Permit for Industrial Activities (MSGP) provides facility-specific requirements for many types of industrial facilities within one general overall permit. The permit outlines steps that facility operators must take prior to being eligible for permit coverage, including development and implementation of a stormwater pollution prevention plan (SWPPP). Operators of industrial facilities that are not included in coverage under the MSGP must submit an individual permit application to EPA if they discharge or have the potential to discharge stormwater to a municipal separate storm sewer system (MS4) or directly to waters of the United States. The individual permit application process is considerably more lengthy than the general permit.