# Total Maximum Daily Load for Nutrients in the Upper/Middle Charles River, Massachusetts

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## DISCLAIMER

Front Cover:
Left=Canoe on free-flowing reach of Middle Charles
Right=South Natick Dam showing excessive algae growth

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# ACKNOWLEDGEMENTS

This TMDL study was developed by the Charles River Watershed Association (CRWA) under contract with Massachusetts Department of Environmental Protection (MassDEP) and the New England Region of the United Sates Environmental Protection Agency (USEPA) with support from Numeric Environmental Services (NES) in Beverly Farms, Massachusetts under CRWA sub-contract. Water quality monitoring and data preparation were performed by CRWA. An HSPF water quality model for the Upper/Middle Charles River used for this TMDL was developed by CRWA and NES. Completion of this study depended on the generous informational and data support from the various groups. Special acknowledgement is made to the following people and organizations for the development of this TMDL.

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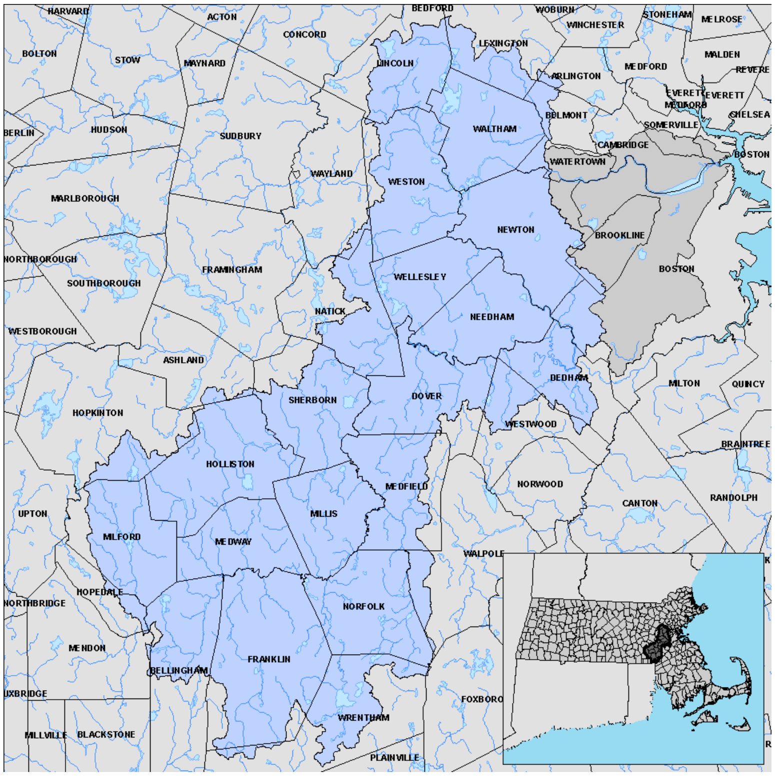
# LIST OF ACRONYMS AND UNITS

| | |
|---|---|
| ANP | – American National Power |
| BG | – Background Load Sources |
| BMP | – Best Management Practice |
| BOD | – Biochemical Oxygen Demand |
| BPJ | – Best Professional Judgment |
| CDM | – Camp Dresser and McKee |
| CFS | – Cubic Feet per Second |
| CMR | – Code of Massachusetts Regulations |
| CRPCD | – Charles River Pollution Control District |
| CRWA | – Charles River Watershed Association |
| CSO | – Combined Sewer Overflow |
| CWA | – Clean Water Act |
| DCR | – Department of Conservation and Recreation |
| GIS | – Geographic Information System |
| HRU | – Hydraulic Response Unit |
| HSPF | – Hydrologic Simulation Program – Fortran |
| IDDE | – Illicit Discharge Detection and Elimination |
| LA | – Land-area Allocation |
| LID | – Low Impact Development |
| MassDEP | – Massachusetts Department of Environmental Protection |
| MassHighway | – Massachusetts Highway Department |
| MassPike | – Massachusetts Turnpike Authority |
| MAWQS | – Massachusetts Water Quality Standards |
| MGD | – Million Gallons per Day |
| MOS | – Margin of Safety |
| MS4 | – Municipal Separate Storm Sewer System |
| MWRA | – Massachusetts Water Resources Authority |
| NPDES | – National Pollutant Discharge Elimination System |
| NRCS | – Natural Resources Conservation Service |
| PO4-P | – Orthophosphate |
| QAPP | – Quality Assurance Project Plan |
| SAP | – Sampling Analysis Plan |
| SRF | – State Revolving Fund |
| SWMP | – Storm Water Management Plan |
| TMDL | – Total Maximum Daily Load |
| TN | – Total Nitrogen |
| TORP | – Total Organic Phosphorus |
| TP | – Total Phosphorus |
| UA | – Urbanized Area |
| US-EPA | – United States Environmental Protection Agency |
| USGS | – United States Geological Survey |
| WLA | – Waste Load Allocation |
| WSGP | – Watershed-Specific General Permits |
| WWTF | – Wastewater Treatment Facility |

# SUMMARY



**Key Features**: Nutrient TMDL for an impounded river with stormwater and wastewater sources

**Location:** Towns of Hopkinton, MA to Watertown, MA - US-EPA Region 1; and surrounding watershed; Ecoregion XIV, subregion 59.

**Scope/ Size**: Upper/Middle Charles River Watershed 268 mi$^2$, 70mi mainstem segment

**Towns:** Watershed contains 5 communities in their entirety (Medway, Millis, Needham, Waltham, and Wellesley) and includes portions of 28 more (Arlington, Ashland, Bellingham, Belmont, Boston, Brookline, Dedham, Dover, Foxborough, Franklin, Holliston, Hopedale, Hopkinton, Lexington, Lincoln, Medfield, Mendon, Milford, Natick, Newton, Norfolk, Sherborn, Walpole, Watertown, Wayland, Weston, Westwood, and Wrentham).

**Land Uses**: Forest 27.9%, Water/Wetland 13.0%, Open 8.8%, Residential 42.5%, and Commercial and Industrial 7.9 % (MassGIS, 1999).

**303(d) segments:** Phosphorus/Eutrophication/Enrichment (28), Algae/Macrophytes (16), Low Dissolved Oxygen (12), DO Saturation (4) and Turbidity/Transparency (10); on 9 mainstem, 11 tributaries, and 11 connected ponds (31 segments total). One mainstem segment (MA72-04) was included as a protective TMDL.

**Data Sources:** Charles River Watershed Association (CRWA), Massachusetts Water Resources Authority (MWRA), Massachusetts Department of Environmental Protection (MassDEP), U.S. Environmental Protection Agency (USEPA), United States Geological Survey (USGS), and American National Power (ANP).

**Data Evaluation:** HSPF 12 model, Massachusetts Water Quality Standards, US-EPA Nutrient Criteria Guidance, Weight of Evidence.

**Controls:** Upgrade of wastewater treatment plants (WWTFs) and stormwater best management practices (BMPs) to reduce phosphorus from runoff.

**Monitoring Plan**: Detailed monitoring plan still to be developed.

# EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act (CWA) and the U.S. Environmental Protection Agency's Water Quality Planning and Management Regulations (Title 40 of the *Code of Federal Regulations* [CFR] Part 130) require states to identify impaired water bodies and develop Total Maximum Daily Loads (TMDLs) for each impaired segment. A TMDL establishes the amount of a given pollutant that a waterbody can assimilate without exceeding water quality standards. TMDLs provide the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources (US-EPA, 1991).

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include an implicit or explicit margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. The TMDL components for this watershed are illustrated using the following equation:

$$\text{TMDL} = [(\sum \text{WLAs} + \sum \text{LAs})\text{-System Losses}] + \text{MOS}$$

It should be noted that in addition to the MOS in this equation, an additional MOS is present with respect to the load at the Watertown Dam apportioned from the Lower Charles TMDL. System losses are as discussed on pages 47-48.

This project establishes a nutrient Total Maximum Daily Load (TMDL) and corresponding implementation plan for the Upper/Middle Charles River. The Upper/Middle Charles nutrient TMDL will address all nutrient related issues in the listed segments (MassDEP, 2008b) of the watershed above the Watertown Dam and will meet the loading requirements established in the Lower Charles TMDL (US-EPA, 2007). The Upper/Middle Charles watershed is 70 miles long, covers 268 square miles in area, and ends at the Watertown Dam where it connects to the Lower Charles. The watershed contains 5 communities in their entirety (Medway, Millis, Needham, Waltham, and Wellesley) and includes portions of 28 more (Arlington, Ashland, Bellingham, Belmont, Boston, Brookline, Dedham, Dover, Foxborough, Franklin, Holliston, Hopedale, Hopkinton, Lexington, Lincoln, Medfield, Mendon, Milford, Natick, Newton, Norfolk, Sherborn, Walpole, Watertown, Wayland, Weston, Westwood, and Wrentham). Land use in the watershed can be summarized as follows: Forest 27.9%, Water/Wetland 13.0%, Open 8.8%, Residential 42.5%, and Commercial and Industrial 7.9 %.

A TMDL is essentially a pollutant budget and establishes the maximum amount of pollutant by pollution source that can be introduced into a body of water while still attaining water quality standards. A TMDL provides a defensible basis for allocating pollutants to sources and identifying remediation responsibilities. The final TMDL load is allocated among point sources (WLAs) and non-point source (LAs) with an appropriate margin of safety (MOS).

A nutrient TMDL is required for this watershed because the Commonwealth of Massachusetts has placed many reaches in the Charles River Watershed on the Category 5 or "impaired" waters list for excessive nutrients (MassDEP 2008b). Both water quality monitoring data and visual evidence demonstrate that the Upper/Middle Charles is significantly impaired from excessive nutrients with excessive algae blooms and large extents of aquatic plant growth. The "impaired" nutrient categorization was based on available water quality monitoring data and nutrient response variables including dissolved oxygen, pH, macrophytes/algae, phosphorus, and turbidity. The listed segments include nine mainstem segments, eleven tributaries, and eleven connected ponds, for a total of 31 segments. Especially of concern is phosphorus, considered the controlling nutrient in many surface waters.

Regular occurrences of severe algal blooms during the summer months have been observed to reduce water clarity and contribute to anoxic bottom waters that do not support aquatic life. Water quality data indicate the Upper/Middle Charles River is undergoing cultural eutrophication, which is the process of producing excessive plant life due to pollutant inputs from human activities. The algal blooms in the Charles are directly responsible for degrading the aesthetic quality of the river, reducing water clarity, and impairing the designated uses. Some cyanobacteria (blue-green) species known to be toxic have been consistently observed in the Lower Charles during all summers when algal sampling has been conducted (US-EPA, 2007). The Massachusetts Water Quality Standards identify the Upper/Middle Charles River as a Class B water that is designated to support aquatic life and recreational uses. The water quality standards, that apply to the Upper/Middle Charles River and were used to set targets and calculate the total allowable loads, are presented in Table ES-1.

**Table ES-1. Massachusetts Water Quality Standards for Nutrient-Related Parameters**

| Pollutant | Criteria | Source |
|---|---|---|
| Dissolved Oxygen | Shall not be less than 6.0 mg/l in cold water fisheries and not less than 5.0 mg/l in warm water fisheries. Where natural background conditions are lower, DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. | 314 CMR: 4.05: Classes and Criteria (3)(b) 1 |
| pH | Shall be in the range of 6.5 - 8.3 standard units and not more than 0.5 units outside of the background range. There shall be no change from background conditions that would impair any use assigned to this class. | 314 CMR: 4.05: Classes and Criteria (3)(b) 3 |
| Solids | These waters shall be free from floating, suspended, and settleable solids in concentrations and combinations that would impair any use assigned to this Class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom. | 314 CMR: 4.05: Classes and Criteria (3)(b) 5. |
| Color and Turbidity | These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class. | 314 CMR: 4.05: Classes and Criteria (3)(b) 6 |
| Aesthetics | All surface waters shall be free from pollutants in concentrations or combinations 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: Classes and Criteria (5)(a) |
| Nutrients | Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established by the Department pursuant to 314 CMR 4.00. Any existing point source discharge containing nutrients in concentrations that would cause or contribute to cultural eutrophication, including the excessive growth of aquatic plants or algae, in any surface water shall be provided with the most appropriate treatment as determined by the Department, including, where necessary, highest and best practical treatment (HBPT) for POTWs and BAT for non POTWs, to remove such nutrients to ensure protection of existing and designated uses. Human activities that result in the nonpoint source discharge of nutrients to any surface water may be required to be provided with cost effective and reasonable best management practices for nonpoint source control. | 314 CMR: 4.05: Classes and Criteria (5)(c) |

The pollutant of concern for this TMDL is phosphorus as this nutrient is directly contributing to the excessive algal biomass in the Upper/Middle and Lower portions of the Charles River. Although phosphorus is ubiquitous in natural soils and vegetation, additional human inputs in the watershed are added from five active municipal wastewater treatment facilities (WWTFs) and stormwater runoff from developed land uses. Even though wastewater discharges are currently treated, they still contribute significant phosphorus loads to receiving waters. Stormwater runoff includes inputs from fertilized soils and lawns; leaf litter and other vegetative debris; car wash products and some detergents; auto exhaust, fuel, and lubricants; and pet waste. Developed land uses including high-density residential, commercial, and industrial have higher loadings of phosphorus per unit area.

The target phosphorus load for the Upper/Middle Charles River was established based on a two-tiered approach. Load scenarios were first screened to ensure the annual phosphorus load at Watertown Dam outlet met the inlet load specified by the Lower Charles TMDL. The Lower Charles TMDL specified that the average annual phosphorus load contribution from the Upper/Middle Charles River cannot exceed 15,109 kg/yr at the Watertown Dam. Second, load scenarios were screened to ensure the phosphorus loads in the Upper/Middle Charles River achieved instream water quality targets and moderate response variables linked to excess nutrients and algal biomass in the river system during extreme low flow conditions when all point sources are discharging at their current design flows. The model was also set up to evaluate instream water quality under extreme high flow conditions.

The water quality targets were developed from the water quality standards in Table ES-1, using best professional judgment (BPJ), and a “weight-of-evidence” approach. In general, targets included water quality parameters that are the most sensitive measures of nutrient impacts. The targets were selected for consistency with applicable water quality standards, the Lower Charles nutrient TMDL, US-EPA guidance documents, and MassDEP experience with nutrient TMDL development in river systems. The metrics chosen for this TMDL are listed in Table ES-2.

Since the Water Quality Standards do not contain specific numeric criteria for phosphorus, it was necessary to calculate a numerical endpoint to address the excessive algal biomass resulting from anthropogenic nutrient inputs to the Upper/Middle and Lower Charles River. To do this, targets were established for low and variable dissolved oxygen and chlorophyll-*a*. Chlorophyll-*a* served as a surrogate water quality target to define the assimilative capacity of the Upper/Middle Charles River, since chlorophyll-*a* is the photosynthetic pigment found in algae and is, therefore, a direct indicator of algal biomass. Since the eutrophication-related impairments in the Charles River are the result of excessive amounts of algae, a chlorophyll-*a* target can be used as a surrogate to reasonably define acceptable amounts of algae that will support the designated uses. The dissolved oxygen saturation targets were consistent with the numeric water quality standards and Best Professional Judgment (BPJ) applied in the Assabet River TMDL.

The chosen chlorophyll-*a* target, of 10 µg/L for the Upper/Middle Charles TMDL, is consistent with the Lower Charles TMDL and is a site-specific target for this river. The seasonal average is defined as the mean chlorophyll-*a* concentration in the Charles between April and October of each year. This period represents critical conditions when algal blooms are typically most severe in the Charles River and have the greatest impact on designated uses. The chlorophyll-*a* target was set at a level that will result in reductions in eutrophication sufficient to enable the Upper/Middle Charles River to attain all applicable Class B narrative (nutrients, aesthetics, and clarity) and numeric (dissolved oxygen and pH) standards. Achieving the seasonal average chlorophyll-*a* target will reduce algal biomass to levels that are consistent with a mesotrophic status, will address aesthetic impacts, and attain clarity standards. A maximum chlorophyll-*a* target of 18.9 µg/L was established to ensure good aesthetic quality and water clarity at times when extreme periodic algal blooms could occur during the growing season.

**ES-2. Selected Nutrient Water Quality Metrics and Guidance Values**

| Metric | Acceptable Range | Rational for Metric | Source |
|---|---|---|---|
| **Numeric Water Quality Standard** | | | |
| Dissolved Oxygen | > 5 mg/L | MassDEP Surface Water Quality Standards | MassDEP (2007b) |
| pH[1] | 6.5 – 8.3 | MassDEP Surface Water Quality Standards | MassDEP (2007b) |
| **Related Nutrient TMDLs** | | | |
| Seasonal Mean Chlorophyll-a | < 10 ug/L | Target applied in Lower Charles TMDL | US-EPA (2007) |
| Peak Chlorophyll-a | < 18.9 ug/L | Target Applied in Lower Charles TMDL | US-EPA (2007) |
| Dissolved Oxygen Saturation | < 125% | Best Professional Judgment, applied in the Assabet River Nutrient TMDLs | MassDEP (2004) |
| **Guidance** | | | |
| Total Phosphorus | < 0.025 mg/L | EPA-within lakes or reservoir | US-EPA (1986) |
| Total Phosphorus | < 0.050 mg/L | EPA-entering lakes of reservoirs | US-EPA (1986) |
| Total Phosphorus | < 0.100 mg/L | EPA- in streams or other flowing waters not discharging directly to lakes or impoundments | US-EPA (1986) |

[1] used to evaluate state of river only - not used for scenario target

Additional goals are to ensure the minimum dissolved oxygen criterion is met and to reduce the duration of dissolved oxygen supersaturation. A level of 125% dissolved oxygen saturation was used as a reasonable target for control of excessive fluctuations in dissolved oxygen. This metric is consistent with the approach used in other nutrient TMDLs (MassDEP, 2004).

Finally, a comparison was made of in-stream total phosphorus concentrations (although not a target) to US-EPA guidance to further validate the model and weight-of-evidence approach. The "Gold Book" (US-EPA, 1986) states that "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. The identified targets were used in a "weight of evidence" approach and are consistent with the TMDL evaluation for the Lower Charles TMDL.

This phosphorus TMDL project employed an HSPF (Hydrologic Simulation Program – Fortran) water quality model (Bicknell et al., 1993) that was specifically developed and calibrated to existing Upper/Middle Charles water flow and quality data (CRWA and NES, 2009). An extensive monitoring program for water quality and flow was implemented to supplement existing data and provided a sound platform to establish a well-calibrated water quality model. The HSPF model simulates water column and sediment nutrient cycling and algae dynamics coupled with one-dimensional transport in the Charles River. The calibrated HSPF model was used to evaluate nutrient reduction scenarios for the TMDL. The scenarios were evaluated relative to the approved loads for the Upper/Middle Charles established by the Lower Charles River TMDL (US-EPA, 2007) at the Watertown Dam, and selected water quality targets in the Upper/Middle Charles River.

The results from the scenario evaluation identified that an overall annual reduction in total phosphorus of 50% is required to meet the desired targets with a 6% margin of safety. To achieve this annual reduction, this TMDL assigns WLAs requiring a 66% reduction in annual phosphorus load from wastewater discharges and a 51% reduction in annual phosphorus load from stormwater (Table ES-3).

For point sources, the TMDL establishes total phosphorus (TP) wastewater discharge limits for all WWTFs at 0.1 mg/L TP during the summer months and 0.3 mg/L TP during the winter months. The summer time reductions are needed to protect the Upper/Middle Charles River from summertime algal blooms and the winter limits are necessary to achieve the loading requirement established by the Lower Charles River TMDL at the Watertown Dam. Consistent application of effluent limits will provide for equitable reductions among both the major and minor WWTFs. These limits will require total phosphorus reductions from current conditions (see Table ES-3) for major WWTFs as: Milford WWTF 66%; Charles River Pollution Control District 65%; and Medfield WWTF 66%. For minor WWTFs the reductions are: Massachusetts Correctional Institute at Norfolk 67% and Wrentham Development Center 62%. Achieving lower winter permit limits may require additional technology, chemical addition and/or a series of trials before NPDES permit limits can be permanently met. The WWTF's should be allowed a reasonable schedule, if necessary, and upon request, to test operational methods and various technologies to achieve long-term TMDL goals.

For nonpoint sources and stormwater, the TMDL sets phosphorus discharge limits by land use category. The total phosphorus reductions from current conditions (see Table ES-3) are as follows: Water/Wetland 0%; Forest 0%; Open/Agriculture 35%; Low Density Residential 45%; Medium Density Residential 65%; High Density Residential/Multi-Family 65%; Commercial/Industrial 65%; and Transportation 65%.

**Table ES-3. Annual Phosphorus WLA & LAfor the Upper/Middle Charles TMDL**

| Source | Current Load (kg/yr) | Reduction (%) | TMDL Load (kg/yr) |
|---|---|---|---|
| Milford WWTF (MA0100579) | 3,407 | 66 | 1,149 |
| CRPCD (MA0102598) | 4,278 | 65 | 1,483 |
| Medfield WWTF (MA0100978) | 1,174 | 66 | 398 |
| MCI Norfolk (MA0102253) | 406 | 67 | 132 |
| Wrentham Dev Ctr (MA0102113) | 345 | 62 | 132 |
| Pine Brook CC (MA0032212) | -- | -- | 1 |
| **WASTEWATER (WLA)** | **9,611** | **66** | **3,296** |
| | | | |
| Low Density Res. | 4,979 | 45 | 2,739 |
| Medium Density Res. | 5,505 | 65 | 1,927 |
| High Density Res./MF* | 5,964 | 65 | 2,088 |
| Commercial/Industrial* | 6,294 | 65 | 2,203 |
| Transportation | 2,167 | 65 | 759 |
| Open/Agriculture | 1,504 | 35 | 977 |
| Forest | 4,394 | 0 | 4,394 |
| **STORMWATER (WLA)** | **30,808** | **51** | **15,086** |
| | | | |
| Bentic Flux | 2,359 | 25 | 1,769 |
| Water/Wetland | 126 | 0 | 126 |
| Atmospheric Deposition | 316 | 0 | 316 |
| **NONPOINT & BACKGROUND (LA)** | **2,801** | **21** | **2,211** |

Note: Numeric differences due to decimal rounding.

Table ES-4 summarizes the annual Phosphorus Loads for current conditions and TMDL conditions (98-02) for all sources and losses. Sources are comprised of atmospheric deposition (316 kg/yr), benthic sediment release (1,769 kg/yr), water/wetland (126 kg/yr), stormwater (15,086 kg/yr), and wastewater (3,296 kg/yr) while losses are from algae uptake and settling and diversions (-5,625 kg/yr). The total annual phosphorus load (WLA and LA) is 14,968 kg which meets the allocation requirement at the Watertown Dam. The TMDL allows for an MOS of approximately 6 %. The 6% includes the additional MOS of 757 kg/yr which was apportioned from the Lower Charles TMDL.

**Table ES-4. Annual TP Loads/Losses/MOS for Current and TMDL Conditions (98-02)**

| Source | Current Load (kg/yr) | Reduction (%) | TMDL Load (kg/yr) |
|---|---|---|---|
| Wastewater | 9,611 | 66 | 3,296 |
| Stormwater | 30,808 | 51 | 15,086 |
| Nonpoint & Background | 2,801 | 21 | 2,211 |
| Other Losses* | -13,348 | 58 | -5,625 |
| **TOTAL ALLOCATION (Upper/Middle Charles Model)** | **29,872** | **50** | **14,968** |
| **MOS (Upper/Middle Charles Model)** | | | **141** |
| **TOTAL ALLOCATION (Lower Charles TMDL)** | | | **15,109** |
| **MOS (Additional Designated from Lower Charles TMDL)** | | | **757** |

Note: Numeric differences due to decimal rounding.

Reasonable assurances that the TMDL will be implemented include both application and enforcement of current regulations, availability of financial incentives including low or no-interest loans to communities for wastewater treatment facilities through the State Revolving Fund (SRF), and the various local, state and federal programs for pollution control.

# 1. INTRODUCTION

## 1.1 Description of the River

The Charles River starts above Echo Lake in Hopkinton and flows about 79 miles in a north-easterly direction to the coast. The river flows through many of the surrounding Boston communities before discharging into Boston Harbor. The river drops 310 ft in its journey to the coast and the watershed drains an area of 311 square miles. The steepest elevation change is in the headwaters with the rest of the watershed being gently sloped.

For the purposes of this report, the Upper Charles is the area above the United States Geological Survey (USGS) Dover Gauge (see Figure 1) and is slightly more than half of the drainage area (182 square miles) and half of the river length (45 miles) while the Lower Charles is the drainage area below the Watertown Dam (see Figure 1) and is about 43 square miles and 9 miles long. The Middle Charles is the 25-mile section of the river in between. The combined Upper/Middle Charles watershed is 70 miles long and covers 268 square miles in area (see Figure 1).

Inside of Interstate I-95 (Route 128) is the highly urbanized Greater Boston area, while outside of Interstate I-95 is predominantly suburban residential development with smaller urban cores and significant areas of forested landscape. The land use breakdown of the Upper/Middle Charles is as follows: Forest 27.9%, Water/Wetland 13.0%, Open 8.8%, Residential 42.5%, and Commercial and Industrial 7.9% (MassGIS, 1999). The watershed has predominantly moderately- to well-drained soils with the surficial geology being categorized as Sand and Gravel 42.6%, Till & Bedrock 51.3%, and Alluvium 6.1%.

The Upper/Middle Charles Watershed contains 5 communities in their entirety (Medway, Millis, Needham, Waltham, and Wellesley) and includes portions of 28 more (Arlington, Ashland, Bellingham, Belmont, Boston, Brookline, Dedham, Dover, Foxborough, Franklin, Holliston, Hopedale, Hopkinton, Lexington, Lincoln, Medfield, Mendon, Milford, Natick, Newton, Norfolk, Sherborn, Walpole, Watertown, Wayland, Weston, Westwood, and Wrentham).

Visual evidence and data show that the Upper/Middle Charles is significantly impaired by large extents of algae and aquatic plant growth resulting from excessive nutrients. As a result, the Upper/Middle Charles River has been listed for nutrients on the Massachusetts Integrated List thus requiring the development of this TMDL (MassDEP 2008b). Especially of concern is phosphorus, considered the controlling nutrient (see section 4.1). Although phosphorus is ubiquitous in the natural environment since it exists in natural soils and vegetation, additional inputs in the Upper/Middle Charles come from human activities and alterations to the natural hydrological system.

The principal sources of phosphorus are the five active municipal wastewater discharges (see Figure 2) and stormwater runoff. Stormwater runoff includes inputs from fertilized soils and lawns; leaf litter and other vegetative debris; car wash products and some detergents; auto exhaust, fuel, and lubricants; and pet waste. Stormwater runoff is conveyed quickly to the rivers via impervious surfaces and connected stormwater pipes. The effects of excessive nutrients are exacerbated by the numerous impoundments which are sensitive to nutrient enrichment and identified as critical reaches for this study (see Figure 2).

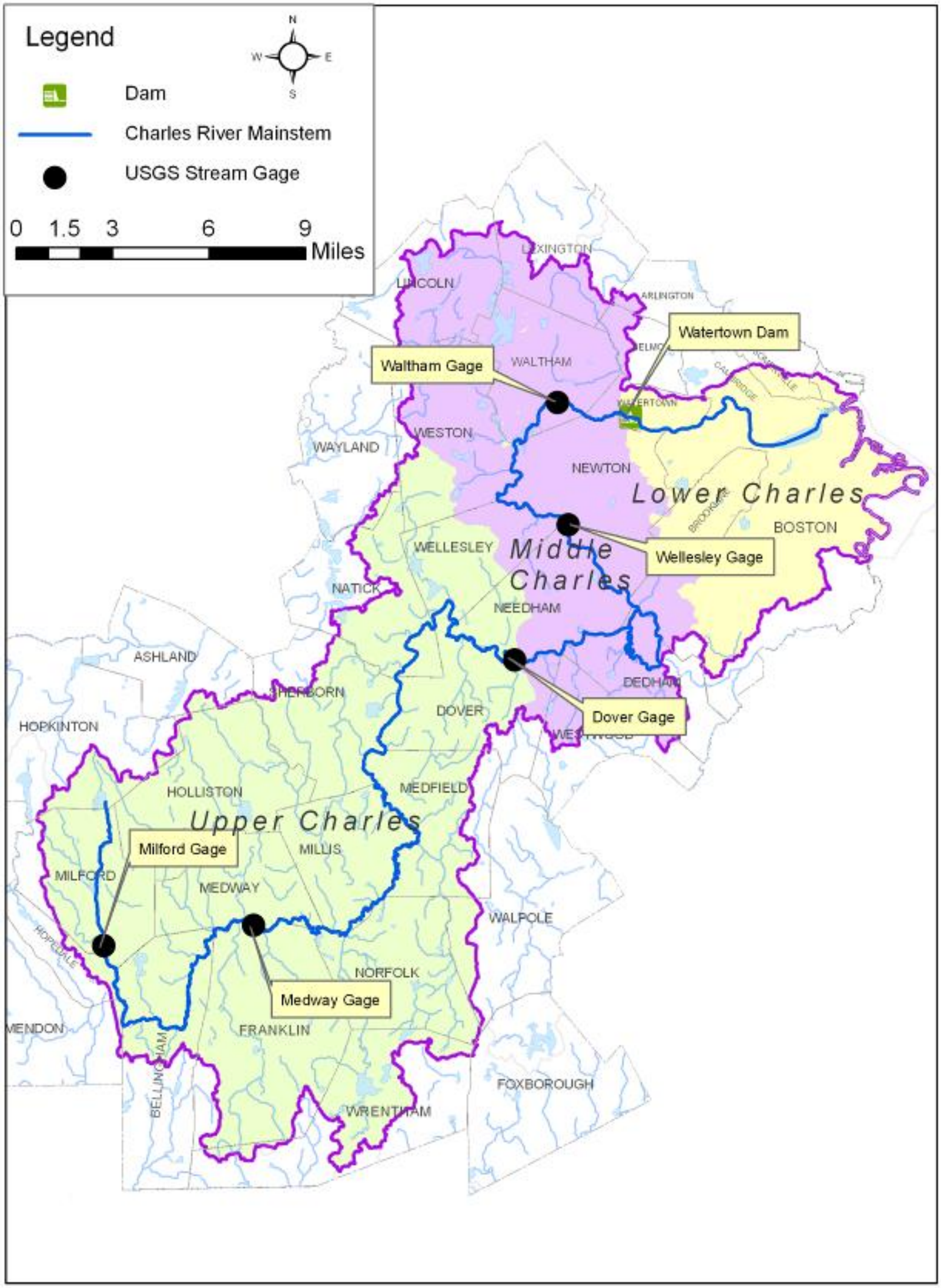


Figure 1. The Charles River Watershed

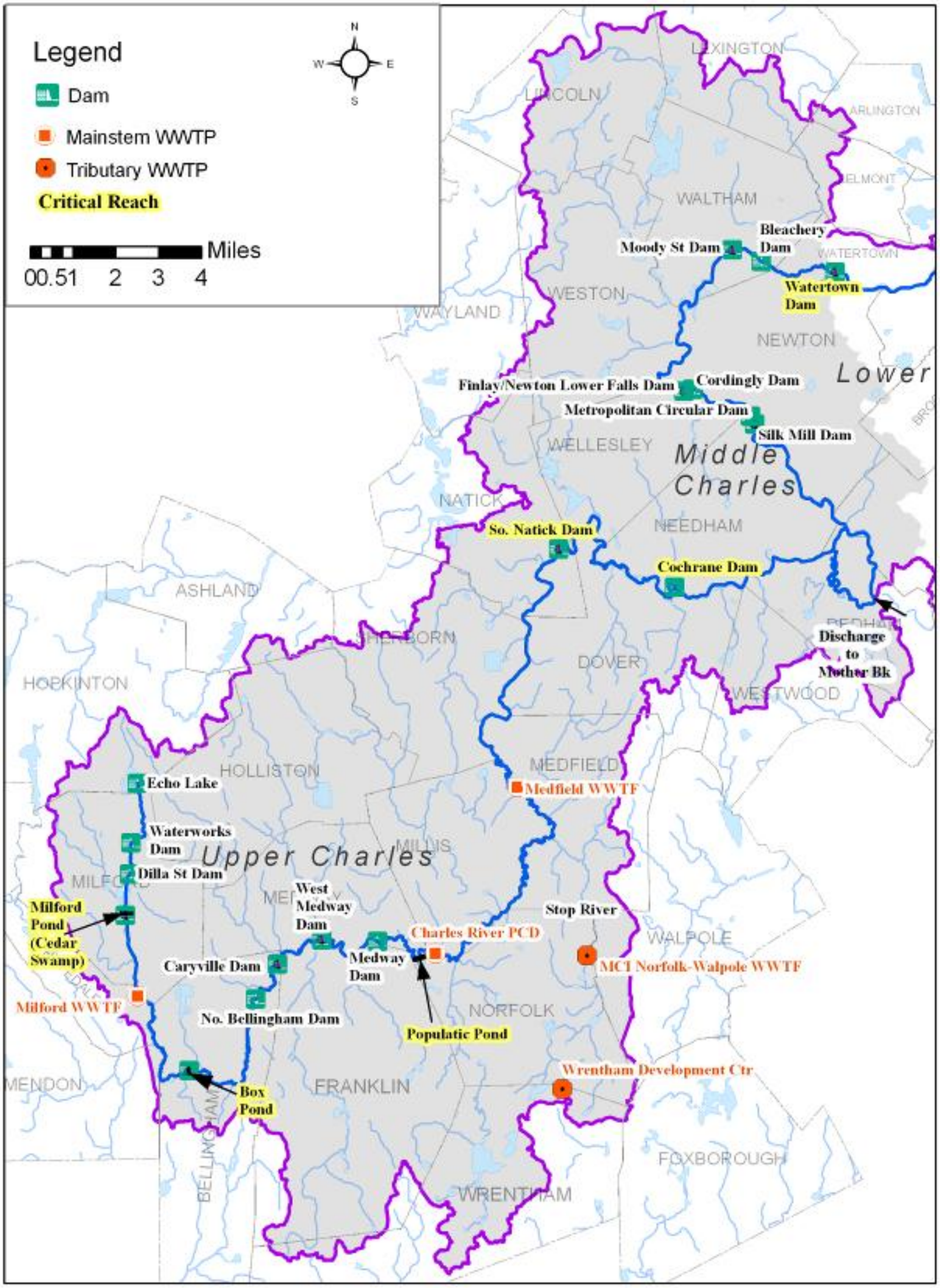


Figure 2. The Upper/Middle Charles River Watershed

## 1.2 The TMDL Process

This project establishes a nutrient Total Maximum Daily Load (TMDL) and corresponding watershed plans for the Upper/Middle Charles River and corresponding communities. The Upper/Middle Charles watershed is 70 miles long, covers 268 square miles in area, touches 33 communities, and ends at the Watertown Dam where it connects with the Lower Charles. A final nutrient TMDL has already been developed and approved for the Lower Charles (US-EPA, 2007). Under current conditions, the outlet load from the Upper/Middle watershed exceeds the target inlet load to the Lower Charles as specified in the Lower Charles TMDL. Therefore, reductions in the nutrient load from the Upper/Middle Charles watershed will be needed in order to meet the target nutrient load for the Lower Charles.

The development of a TMDL for the Upper/Middle Charles River is a high priority based on the extent of the excessive nutrients and aquatic plant growth in the river and local concerns over the water quality impacts. This priority is in accord with the Massachusetts Department of Environmental Protection (MassDEP) strategy to initiate work on significant but complicated long-term TMDLs. The large open-water extent of the Lower Charles is recognized as one of the most used public water bodies in the world for recreation (US-EPA, 2009). Recently, the Lower Charles Nutrient TMDL was completed (US-EPA-2007) and its success in reducing algae in the Lower Charles is inextricably tied to reductions in phosphorus loads from the Upper/Middle Charles River.

A TMDL is essentially a pollutant budget and establishes the maximum amount of pollutant by source that can be introduced into a body of water while attaining water quality standards. A TMDL provides a defensible basis for allocating pollutant levels among sources and designating remediation responsibilities.

Assessment of water quality by the states under the Clean Water Act, sections 303(d) and 305(b), results in an Integrated List of Waters Report that divides water bodies into one of five categories based on existing water quality. Category 5 waters are the lowest quality waters and these are placed on the “impaired” waters or 303(d) list. These “impaired” waters do not or will not meet applicable water quality standards after the application of technology-based controls and require the preparation of a TMDL. TMDLs provide the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources as well as to restore and maintain the quality of the state’s water resources (US-EPA, 1991).

A TMDL for a given pollutant and water body is composed of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include an implicit or explicit margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. The TMDL components for this watershed are illustrated using the following equation:

$$\text{TMDL} = [(\sum \text{WLAs} + \sum \text{LAs})\text{-System Losses}] + \text{MOS}$$

Where LA is the load allocation for nonpoint sources including background, WLA is the waste load allocation, and MOS is the margin of safety. System losses are as discussed on pages 47-48.

The Upper/Middle Charles River is designated as a Class B water under the Massachusetts water quality standards [314 CMR 4.05(3)b]. Class B waters are designated as capable of providing and supporting habitat for fish and other aquatic wildlife, and for primary and secondary contact recreation. Primary recreation includes any activity with prolonged or intimate contact with water, such as swimming or windsurfing. Any recreational activity where contact with the water is incidental or accidental is considered secondary contact recreation, such as boating and fishing. The goal for the river is to achieve water quality standards as defined in Massachusetts 314 CMR 4.0. The water quality standards provide numerical and narrative criteria for six-nutrient related parameters to meet the water body's designated uses (see Table 2).

The development of this nutrient TMDL addresses the issue of eutrophication, or the over-enrichment of nutrients, which results in excessive algae and aquatic plant growth and low and/or highly variable dissolved oxygen (DO) levels. Many reaches in the Upper/Middle Charles River are classified as “impaired” since they do not meet water quality standards for nutrients, dissolved oxygen (DO) and turbidity and also have high levels of algae and aquatic plants. In most freshwater systems, phosphorus is the limiting nutrient that controls eutrophication; reducing phosphorus reduces algae and could limit long-term macrophyte growth while also improving DO levels instream (Thomann and Mueller, 1987).

Water quality monitoring for the TMDL involved two rounds of dry- and wet-weather sampling and five years of flow measurements at both tributary and main stem sites. Data from the Massachusetts Water Resources Authority, Massachusetts Department of Environmental Protection and other relevant data sources were also used. Water quality monitoring data were evaluated by comparing results to the TMDL parameter action limits based on regulatory thresholds or water quality criteria and to trophic indicator criteria, which indicates the biological productivity of a water body. A weight-of evidence approach was used that considered all nutrient related parameters.

An HSPF (Hydrologic Simulation Program – Fortran) water quality model (Bicknell, et al., 1993) was developed and calibrated to existing water flow and quality data (CRWA and NES, 2009). The calibrated and validated HSPF model was used to estimate source nutrient loads and evaluate remediation scenarios by comparing simulated river nutrient concentrations, DO, and algae growth (chlorophyll-*a*) for each scenario.

The HSPF model was used to evaluate a number of management scenarios and assist in selecting the scenario that best meets the TMDL targets (see Section 5.0). The Upper/Middle TMDL must produce an outlet phosphorus load that satisfies the Lower Charles TMDL inlet load. The TMDL must also meet specific water quality targets (chlorophyll-*a*, DO, and phosphorus concentrations) for each river segment especially in the critical reaches like impoundments (e.g. Box Pond, Populatic Pond) and below wastewater treatment discharges.

To prevent further degradation in water quality and to ensure that the Upper/Middle Charles River meets state water quality standards, the nutrient TMDL requires a 50% decrease in total phosphorus loadings from current conditions. The TMDL outlines corrective actions to achieve that goal. In the Implementation Plan (Section 7.0), the two primary sources are stormwater and wastewater, and these are targeted for reductions.

Required reductions in annual stormwater loads are: 0% for water/wetland and forest; 35% for agriculture and open land; 45% for low density residential; 65% for medium/high density residential, multi-family, and commercial, industrial or transportation. Three active mainstem and two tributary wastewater treatment facilities will ultimately be required to meet summer (Apr-Oct) total phosphorus limits of 0.1 mg/L, and winter (Nov-Mar) total phosphorus limits of 0.3 mg/L%. Achieving lower winter permit limits may require additional technology, chemical addition and/or a series of trials before NPDES permit limits can be permanently met. The WWTF's should be allowed a reasonable schedule, if necessary, and upon request, to test operational methods and various technologies to achieve long-term TMDL goals.

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## 1.3 Impaired Segments

Section 303(d) of the Clean Water Act (CWA) regulation requires states to identify and list those water bodies that are not expected to meet surface water quality standards after the implementation of technology-based controls and, as such, require the development of TMDLs. Water bodies requiring TMDL development are identified under Category 5 of the Massachusetts Integrated List of Waters, which includes a listing of the specific cause(s) of the impairment (if known). Waters were listed in Category 5 if they were identified as impaired (i.e., not supporting one or more intended use), if the impairment was related to the presence of one or more "pollutants", and the source of those pollutants was not considered to be natural.

Based on the water quality data available for the Upper/Middle Charles River, the Massachusetts Department of Environmental Protection (MassDEP) has included a number of the Upper/Middle Charles River mainstem segments, tributaries, and ponds on the State's 2008 section 303(d) lists for the following pollutants (MassDEP, 2008a, b):

- Aquatic macroinvertebrate bioassessments
- Aquatic plants or Macrophytes
- Excessive algae/excess algal growth
- Non-native Aquatic Plants
- Nutrients/Eutrophication biological Indicators
- Organic enrichment/low dissolved oxygen/dissolved oxygen saturation
- Secchi disc transparency
- Sedimentation/siltation
- Taste, odor, and color
- Total Phosphorus
- Turbidity

This TMDL addresses the nutrient/eutrophication, phosphorus, and aquatic plant listings as well as associated water quality impairments such as low and variable dissolved oxygen, dissolved oxygen saturation, turbidity and Secchi disc transparency. Pathogen impairments were previously addressed in the Charles River Pathogen TMDL (MassDEP, 2007a). Increased nutrient loads to the Upper/Middle Charles contribute to excessive algal biomass and the growth of aquatic macrophytes throughout the system.

Regular occurrences of severe algal blooms during the summer months reduce water clarity and contribute to anoxic bottom waters that do not support aquatic life. Algae, or phytoplankton, are microscopic plants and bacteria that live and grow in water using energy from the sun through photosynthesis and available nutrients as food. Many species of algae contribute significantly to the base of the food web and are, therefore, a valuable part of the aquatic ecosystem. Conversely, excessive growth of algae populations can lead to a number of water quality related problems affecting both aquatic life and recreational water uses.

Algal blooms and other water quality parameters (i.e. nutrients, water clarity, chlorophyll-*a* and low or high dissolved oxygen) indicate the Upper/Middle Charles River is undergoing cultural eutrophication. Cultural eutrophication is the process of producing excessive plant life due to excessive pollutant inputs from human activities. Nutrient loads from the Upper/Middle Charles also contribute to water quality impairments in the Lower Charles. In both the Upper/Middle and the Lower Charles, the blooms are directly responsible for degrading the aesthetic quality of the river, reducing water clarity, and impairing recreational uses such as boating and swimming. Eutrophication of the Charles River also affects resident aquatic life by altering dissolved oxygen levels and producing algal species that are of little food value or, in some cases, toxic. Of particular concern to the Charles River is the potential presence of toxic algal species. Some cyanobacteria (blue-green) species known to be toxic have been consistently observed in the Lower Charles during all summers when algal sampling has been conducted (US-EPA, 2007).

The nutrient-related pollutants of concern for this TMDL study are those pollutants that are thought to be directly causing or contributing to the excessive algal biomass in the Charles River and pollutants that will or might require reductions to attain the applicable Massachusetts Water Quality Standards (MAWQS). Phosphorus is a primary pollutant of concern for contributing to excessive algal growth and the proliferation of undesirable algae species in both the Upper/Middle and Lower Charles River system.

The Upper/Middle Charles nutrient TMDL will address all nutrient related issues in the listed segments of the watershed above the Watertown Dam and will meet the loading requirements established in the Lower Charles TMDL. The mainstem and tributary segments that will be addressed by this TMDL are listed in Table 1 and mapped in Figure 3. The list includes nine mainstem segments, eleven tributaries, and eleven ponds that are connected to tributaries, for a total of 31 segments. Mainstem segments will be fully addressed since those reaches are directly modeled by HSPF, and tributaries will be addressed since they are modeled as large land segments with a connecting reach to the mainstem. The rational for including tributaries and tributary ponds is the TMDL requires nonpoint source reductions in these impaired segments in order to meet the nutrient loading requirements to achieve the water quality targets of the TMDL along with the loading requirements at the Watertown Dam.

Tributary water bodies that do not receive point source discharges are expected to meet water quality standards in a reasonable timeframe as the result of nonpoint source implementation required to meet this TMDL. Tributary water bodies (e.g., Stop River) that receive point source discharges from MCI Norfolk/Walpole and the Wrentham Development Center are expected to meet water quality standards since technology based controls will be required that are consistent with the major WWTPs. As a result, the Stop River nutrient impaired segments were included in Table 1.

# Table 1. Impaired Waters in the Upper/Middle Charles River Watershed

### Mainstem

| Waterbody | DEP ID | Description | Size | Impairments |
|---|---|---|---|---|
| Charles River (7239050) | MA72-01_2008 | Headwaters, outlet Echo Lake, | 2.5 miles | Low flow alterations |
| | | Hopkinton to Dilla Street | | Other flow regime alterations |
| | | (just upstream of Cedar Swamp Pond) | | **Dissolved Oxygen** |
| | | Milford. | | Mercury in Fish Tissue |
| Milford Pond, Charles River | MA72016_2008 | Also known as Cedar Swamp, Milford | 99.0 acres | Non-native Aquatic Plants |
| | | | | **Dissolved Oxygen** |
| Charles River (7239050) | MA72-33_2008 (formerly | Outlet Cedar Swamp Pond, Milford to | 2.0 miles | Escherichia coli |
| | | the Milford WWTF discharge, | | Physical substrate habitat alterations |
| | | Hopedale. | | **Nutrient/Eutrophication Biological Indicators** |
| Charles River (7239050) | MA72-03_2008 | Milford WWTF discharge, Hopedale to | 3.4 miles | DDT |
| | | outlet Box Pond | | **Dissolved oxygen saturation** |
| | | (formerly segment MA72008), | | Escherichia coli [5/22/2007CN156.0] |
| | | Bellingham. | | **Excess Algal Growth** |
| | | | | **Organic Enrichment Sewage Biological Indicators** |
| | | | | **Phosphorus Total** |
| Charles River (7239050) | MA72-04_2008** | Outlet Box Pond, Bellingham to inlet | 11.5 miles | Escherichia coli [5/22/2007CN156.0] |
| | | Populatic Pond, Norfolk/Medway. | | Fishes Bioassessments |
| | | | | Other flow regime alterations |
| | | | | Mercury in Fish Tissue |
| | | | | Other* |
| Populatic Pond, Chalres | MA72096_2008 | Norfolk | 41.9 acres | **Dissolved oxygen saturation** |
| | | | | **Excess Algal Growth** |
| | | | | **Dissolved Oxygen** |
| | | | | **Nutrient/Eutrophication Biological Indicators** |
| | | | | Mercury in Fish Tissue [12/20/2007NEHgTMDL] |
| Charles River (7239050) | MA72-05_2008 | Outlet Populatic Pond, | 18.1 miles | **Dissolved oxygen saturation** |
| | | Norfolk/Medway to South Natick Dam, | | **Excess Algal Growth** |
| | | Natick. | | Non-native Aquatic Plants |
| | | | | **Dissolved Oxygen** |
| | | | | **Turbidity** |
| | | | | **Nutrient/Eutrophication Biological Indicators** |
| | | | | **Phosphorus Total** |
| | | | | Mercury in Fish Tissue |
| | | | | Aquatic Macroinvertebrate Bioassessments |
| Charles River (7239050) | MA72-06_2008 | South Natick Dam, Natick to | 8.4 miles | DDT |
| | | Chestnut Street, Needham/Dover. | | Eurasian Water Milfoil, Myriophyllum spicatum |
| | | | | **Excess Algal Growth** |
| | | | | Fishes Bioassessments |
| | | | | Non-native Aquatic Plants |
| | | | | Other flow regime alterations |
| | | | | **Nutrient/Eutrophication Biological Indicators** |
| | | | | **Phosphorus Total** |
| | | | | PCB in Fish Tissue |
| | | | | Other |
| Charles River (7239050) | MA72-07_2008 | Chestnut Street, Needham to | 24.8 miles | DDT |
| | | Watertown Dam, Watertown. | | Escherichia coli [5/22/2007CN156.0] |
| | | | | FishPassage Barrier |
| | | | | Fishes Bioassessments |
| | | | | Non-native Aquatic Plants |
| | | | | Other flow regime alterations |
| | | | | **Nutrient/Eutrophication Biological Indicators** |
| | | | | **Phosphorus Total** |
| | | | | PCB in Fish Tissue |

Note: Impairments addressed in this TMDL highlighted in bold

*Does not require a TMDL

** Segment MA-72-04 included as a Protective TMDL

## Table 1. List of Impaired Waters in the Upper/Middle Charles River Watershed (cont.)

| Tributary Segments | | | | |
|---|---|---|---|---|
| **Waterbody** | **DEP ID** | **Description** | **Size** | **Impairments** |
| Alder Brook (7239475) | MA72-22_2008 | Headwaters northwest of the Route 135 and South Street intersection, Needham to the confluence with the Charles River, Needham. | 0.28 miles | **Nutrient/Eutrophication Biological Indicators**<br>Aquatic Macroinvertebrate Bioassessments |
| Beaver Brook (7239125) | MA72-28_2008 | Headwaters, north of Route 2, Lexington through culverting to Charles River, Waltham. | 5.5 miles | Escherichia coli [5/22/2007CN156.0]<br>**Excess Algal Growth**<br>Non-native Aquatic Plants<br>Other anthropogenic substrate alterations<br>Other flow regime alterations<br>**Dissolved Oxygen**<br>Sedimentation/Siltation<br>**Turbidity**<br>**Organic Enrichment Sewage Biological Indicators**<br>Taste and Odor<br>**Phosphorus Total** |
| Cheese Cake Brook (7239100) | MA72-29_2008 | Emerges south of Route 16, Newton to confluence with the Charles River, Newton. | 1.4 miles | **Dissolved oxygen saturation**<br>Escherichia coli [5/22/2007CN156.0]<br>**Excess Algal Growth**<br>Other anthropogenic substrate alterations<br>**Phosphorus Total**<br>Alteration in streamside or littoral vegetative covers |
| Fuller Brook (7239625) | MA72-18_2008 | Headwater south of Route 135, Needham to confluence with Waban Brook, Wellesley. | 4.3 miles | Escherichia coli [5/22/2007CN156.0]<br>Physical substrate habitat alterations<br>Sedimentation/Siltation<br>**Nutrient/Eutrophication Biological Indicators** |
| Rock Meadow Brook (7239500) | MA72-21_2008 | Headwaters in Fisher Meadow, Westwood through Stevens Pond and Lee Pond, Westwood to confluence with Charles River, Dedham. | 3.8 miles | **Excess Algal Growth [5/22/2007CN156.0]**<br>**Dissolved Oxygen**<br>**Nutrient/Eutrophication Biological Indicators**<br>**Phosphorus Total**<br>**Aquatic Plants Macrophytes**<br>Aquatic Macroinvertebrate Bioassessments |
| Rosemary Brook (7239325) | MA72-25_2008 | Headwaters, outlet Rosemary Lake, Needham to confluence with the Charles River, Wellesley. | 3.3 miles | **Dissolved Oxygen**<br>**Phosphorus Total** |
| Sawmill Brook (7239400) | MA72-23_2008 | Headwaters, Newton to confluence with Charles River, Boston. | 2.4 miles | Chloride<br>Escherichia coli [5/22/2007CN156.0]<br>**Dissolved Oxygen**<br>**Organic Enrichment Sewage Biological Indicators**<br>**Phosphorus Total** |
| South Meadow Brook (7239375) | MA72-24_2008 | From emergence west of Parker Street, Newton to confluence with the Charles River, Newton (sections culverted). | 1.7 miles | Debris/Floatables/Trash<br>Escherichia coli [5/22/2007CN156.0]<br>**Dissolved Oxygen**<br>Physical substrate habitat alterations<br>**Turbidity**<br>**Phosphorus Total**<br>Bottom Deposits |
| Trout Brook (7239575) | MA72-19_2008 | Headwaters, outlet Channings Pond, Dover to confluence with Charles River, Dover. | 2.8 miles | Temperature, water<br>**Nutrient/Eutrophication Biological Indicators** |
| Stop River (7239925) | MA72-09_2008 | Headwaters near Dedham Street (Route 1A), Wrentham to Norfolk-Walpole MCI discharge, Norfolk (through Highland Lake formerly segment MA72047). | 5.6 miles | **-Oxygen, Dissolved**<br>**-Phosphorus (Total)**<br>-Ambient Bioassays -- Chronic Aquatic Toxicity |
| Stop River (7239925) | MA72-10_2008 | Norfolk-Walpole MCI discharge, Norfolk to confluence with Charles River, Medfield. | 4.2 miles | -Escherichia coli [5/22/2007-CN156.0]<br>-Temperature, water<br>**-Organic Enrichment (Sewage) Biological Indicators**<br>**-Phosphorus (Total)** |

* Impairments addressed in this TMDL highlighted in bold

## Table 1. List of Impaired Waters in the Upper/Middle Charles River Watershed (cont.)

**Onstream Ponds**

| Waterbody | DEP ID | Description | Size | Impairments |
|---|---|---|---|---|
| Factory Pond, Bogastow Bk (72037) | MA72037_2008 | Holliston | 9.7 acres | Non-native Aquatic Plants |
| | | | | **Aquatic Plants Macrophytes** |
| Franklin Reservoir NE, Miller Bk (72095) | MA72095_2008 | Franklin | 21.0 acres | **Turbidity** |
| | | | | **Aquatic Plants Macrophytes** |
| Franklin Reservoir SE, Miller Bk (72032) | MA72032_2008 | Franklin | 13.1 acres | **Turbidity** |
| | | | | **Aquatic Plants Macrophytes** |
| Hardys Pond, Beaver Bk (72045) | MA72045_2008 | Waltham | 42.8 acres | **Excess Algal Growth** |
| | | | | Non-native Aquatic Plants |
| | | | | **Turbidity** |
| | | | | **Phosphorus Total** |
| Houghton Pond, Bogastow Bk (72050) | MA72050_2008 | Holliston | 17.5 acres | **Excess Algal Growth** |
| | | | | Non-native Aquatic Plants |
| | | | | **Turbidity** |
| Linden Pond, Bogastow Bk (72063) | MA72063_2008 | Holliston | 1.4 acres | **Turbidity** |
| | | | | **Aquatic Plants Macrophytes** |
| Lymans Pond, Unnamed Trib (72070) | MA72070_2008 | Dover | 4.4 acres | **Turbidity** |
| | | | | **Aquatic Plants Macrophytes** |
| Mirror Lake, Stony Bk (72078) | MA72078_2008 | Wrentham/Norfolk | 61.6 acres | Non-native Aquatic Plants |
| | | | | **Secchi disk transparency** |
| | | | | **Nutrient/Eutrophication Biological Indicators** |
| | | | | **Phosphorus Total** |
| Lake Pearl, Eagle Bk (72092) | MA72092_2008 | Wrentham | 237 acres | Eurasian Water Milfoil, Myriophyllum spicatum |
| | | | | Non-native Aquatic Plants |
| | | | | **Dissolved Oxygen** |
| Uncas Pond, Uncas Bk (72122) | MA72122_2008 | Franklin | 17.3 acres | Non-native Aquatic Plants |
| | | | | **Dissolved Oxygen** |
| Lake Winthrop, Winthrop Canal (72140) | MA72140_2008 | Holliston | 131 acres | Non-native Aquatic Plants |
| | | | | 2,3,7,8Tetrachlorodibenzopdioxin only |
| | | | | **Aquatic Plants Macrophytes** |

* Impairments addressed in this TMDL highlighted in bold

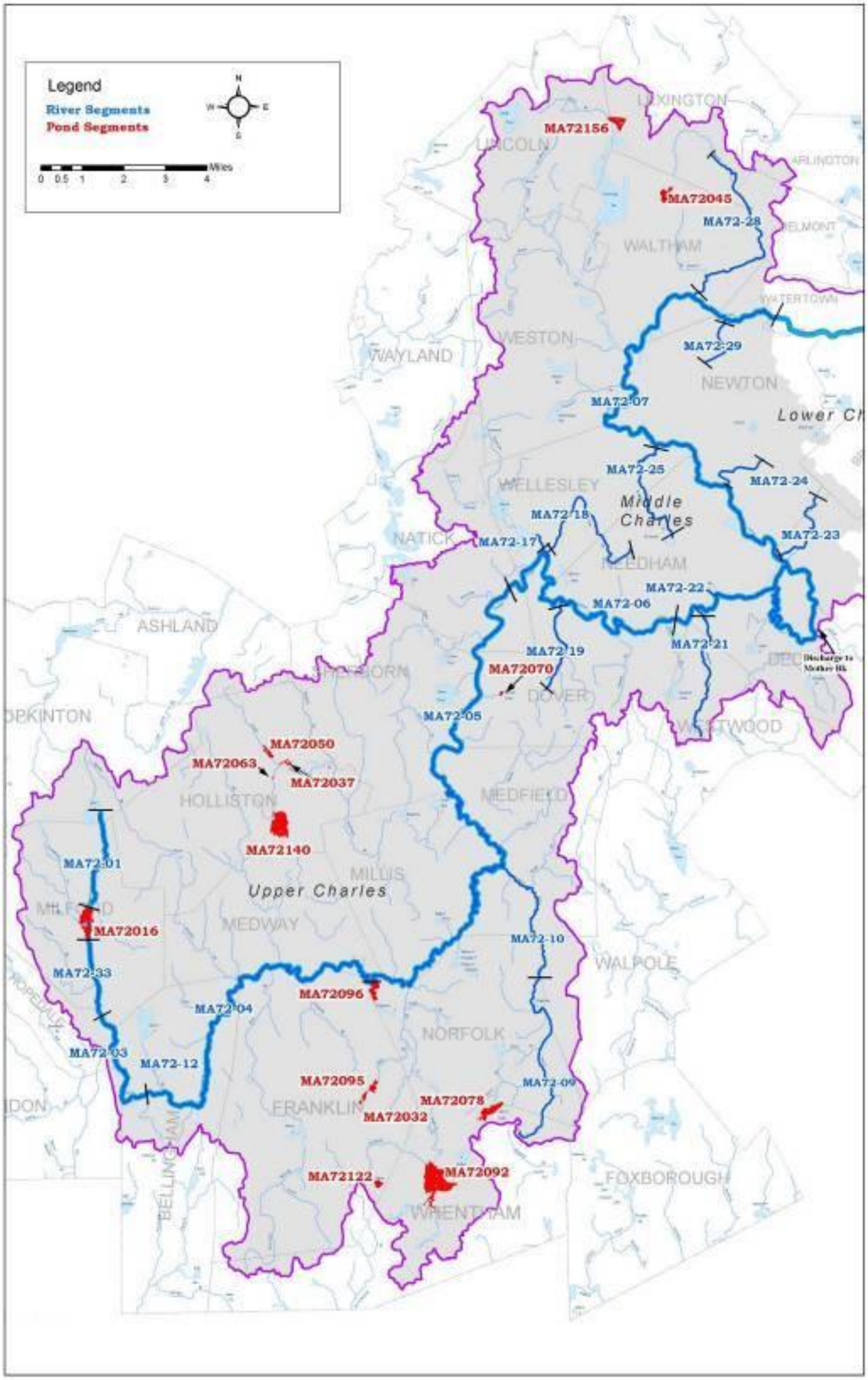


Figure 3. Impaired Waters in the Upper/Middle Charles

# 2 ASSESSING WATER QUALITY

## 2.1 Massachusetts Water Quality Standards

The Upper/Middle Charles River is designated as a Class B water under the Massachusetts Surface Water Quality Standards (MassDEP, 2007b) in section 314 CMR 4.05(3)(b). Class B waters are designated as providing and supporting habitat for fish and other aquatic wildlife and for primary and secondary contact recreation, and shall have consistently good aesthetic value. Primary recreation includes any activity with prolonged or intimate contact with the water (i.e. swimming, windsurfing, etc.). Any recreational activity where contact with the water is incidental or accidental is considered secondary contact recreation, such as boating and fishing. The goal for the river is to achieve water quality standards as defined in Massachusetts 314 CMR 4.0. The water quality standards provide numerical and narrative criteria for the six nutrient-related parameters given in Table 2.

**Table 2. Massachusetts Water Quality Standards for Nutrient-Related Parameters**

| Pollutant | Criteria | Source |
|---|---|---|
| Dissolved Oxygen | Shall not be less than 6.0 mg/l in cold water fisheries and not less than 5.0 mg/l in warm water fisheries. Where natural background conditions are lower, DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. | 314 CMR: 4.05: Classes and Criteria (3)(b) 1 |
| pH | Shall be in the range of 6.5 - 8.3 standard units and not more than 0.5 units outside of the background range. There shall be no change from background conditions that would impair any use assigned to this class. | 314 CMR: 4.05: Classes and Criteria (3)(b) 3 |
| Solids | These waters shall be free from floating, suspended, and settleable solids in concentrations and combinations that would impair any use assigned to this Class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom. | 314 CMR: 4.05: Classes and Criteria (3)(b) 5. |
| Color and Turbidity | These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class. | 314 CMR: 4.05: Classes and Criteria (3)(b) 6 |
| Aesthetics | All surface waters shall be free from pollutants in concentrations or combinations 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: Classes and Criteria (5)(a) |
| Nutrients | Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established by the Department pursuant to 314 CMR 4.00. Any existing point source discharge containing nutrients in concentrations that would cause or contribute to cultural eutrophication, including the excessive growth of aquatic plants or algae, in any surface water shall be provided with the most appropriate treatment as determined by the Department, including, where necessary, highest and best practical treatment (HBPT) for POTWs and BAT for non POTWs, to remove such nutrients to ensure protection of existing and designated uses. Human activities that result in the nonpoint source discharge of nutrients to any surface water may be required to be provided with cost effective and reasonable best management practices for nonpoint source control. | 314 CMR: 4.05: Classes and Criteria (5)(c) |

## 2.2 US-EPA Guidance on Nutrient Criteria

Three crucial guidance documents relative to nutrient criteria for rivers and streams have been published by US-EPA in the last two decades. The first document was entitled "Quality Criteria for Water" and is commonly referred to as the "Gold Book" (US-EPA, 1986). The "Gold Book" states that, "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". This guidance provides a range of acceptable criteria for phosphorus based upon specific stream conditions (see Table 3).

The second set of documents was the "Nutrient Criteria Technical Guidance Manuals" for "Lakes and Reservoirs" (US-EPA, 2000a) and "Rivers and Streams" (US-EPA, 2000b). The purpose of these manuals was to provide scientifically defensible guidance to assist States and Tribes in developing regionally based numeric nutrient and algal criteria for rivers and streams with lakes and reservoirs. These documents describe candidate response variables that can be used to evaluate or predict the condition or degree of eutrophication in water bodies. Those variables include direct measurement of nutrient concentrations as well as observable response variables such as biomass and turbidity. The river document emphasized periphyton (attached or floating algae) as a measure for assessing nutrient enrichment. The guidance also notes the need for an adaptive management approach where uncertainty exists.

The third more specific document was the "Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion XIV" (US-EPA, 2000c). Based on statistical analyses, nutrient criteria were developed for all of Ecoregion XIV (eastern coast of the United States) and for sub-ecoregion 59 (where the Upper/Middle Charles is located). The instream total phosphorus criteria were 0.03125 and 0.02375 mg/L while the total nitrogen criteria were 0.71 and 0.57 mg/L for Ecoregion XIV and sub-ecoregion 59, respectively. The chlorophyll-*a* criterion for Ecoregion XIV was 3.75 µg/L with no criterion for sub-ecoregion 59. These criteria represent the 25th percentile of available data collected from these regions for both impaired and unimpaired waters (see Table 3).

**Table 3. US-EPA Recommended Nutrient Criteria**

| Parameter | Criteria | Source |
|---|---|---|
| Total phosphates as P within impoundment (mg/L) | 0.025 | US-EPA (1986) |
| Total phosphates as P entering impoundment (mg/L) | 0.050 | US-EPA (1986) |
| Total phosphates as P for free-flowing river (mg/L) | 0.100 | US-EPA (1986) |
| Total phosphorus (mg/L) | 0.02375 | US-EPA (2000c) |
| Total nitrogen (mg/L) | 0.57 | US-EPA (2000c) |
| Chlorophyll *a* (µg/L) | 3.75 | US-EPA (2000c) |

Although these documents are excellent resources, each has some shortcomings. The Gold Book and EcoRegion criteria were not based upon in-stream response variables or site-specific conditions which are critical to the success of any nutrient management strategy. US-EPA 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. To account for site specific conditions in the Upper/Middle Charles River, response indicators such as variable dissolved oxygen and aquatic plant biomass as measured by chlorophyll-*a* are thought to be more representative measures for assessing nutrient enrichment in some segments of the river (see Section 2.4).

## 2.3 Trophic Status

Trophic state refers to the biological production of a water body, both in terms of plant and animal life. The trophic state is generally driven by nutrient levels in the water body. There are three trophic state categories: 1) oligotrophic waters are clear with low biological productivity; 2) mesotrophic waters have intermediate biological productivity; and 3) eutrophic waters have high biological productivity relative to natural levels due to increased nutrient supply. The effects of eutrophication include increased aquatic plant growth and biomass which consequently decreases dissolved oxygen and increases turbidity and color. Total phosphorus, total nitrogen, chlorophyll-*a,* and Secchi depth are commonly used as indicators to classify the trophic state of freshwater lakes and impounded river systems. With the exception of Secchi depth, the indicators are defined in the sections above. Secchi depth is a measure of water clarity and reflects the presence of algal and non-algal particulate matter and other dissolved constituents suspended in the water column (US-EPA, 2000b).

To establish trophic levels in the Upper/Middle Charles River, water quality data from the various studies are compared to available literature values for total phosphorus and chlorophyll-*a.* Few Secchi depth data are available except for the US-EPA monitoring that measured water clarity as part of their program. Table 4 lists literature values for the mean and range of total phosphorus, chlorophyll-*a*, and peak chlorophyll-*a* for different trophic states. Peak chlorophyll-*a* values are presented because they represent instantaneous blooms which could occur even if average chlorophyll-*a* levels are acceptable.

## 2.4 Aquatic Plant Coverage

Cultural eutrophication of the Upper/Middle Charles River may be demonstrated by one or both of the following factors: elevated levels of nutrients or chlorophyll-*a* in the water column; and dense coverage and high biovolume of macrophytes and/or periphyton (attached or floating algae). Because watermeal, duckweed, and algae react very quickly to nutrient inputs and blooms occur rapidly, they are good indicators of eutrophication. Response is easily quantified by measurements of chlorophyll-*a*. On the other hand, it is more difficult to directly correlate increases of macrophytes to anthropogenic causes.

Chlorophyll-*a* concentration, for this study, only represents the phosphorus and plant biomass suspended in the water column. Where extensive coverage of periphyton and macrophytes exist, significant phosphorus and biomass amounts are tied up in these attached or floating plant groups. For those sites where periphyton and/or macrophytes dominate the system, a more qualitative approach that also looks at the amount and diversity of periphyton and macrophytes, measured by areal extent, biovolume and/or biomass, and the number of species, might be necessary to quantify the eutrophication impact.

**Table 4. Trophic Indicator Criteria**

| Variable | Oligotrophic | Mesotrophic | Eutrophic | Source |
|---|---|---|---|---|
| **Total Nitrogen (mg/l)** | | | | |
| Mean | 0.66 | 0.75 | 1.9 | US-EPA (2000a) |
| Range | 0.31 – 1.60 | 0.36 – 1.40 | 0.39 – 6.10 | US-EPA (2000a) |
| **Total Phosphorus (mg/l)** | | | | |
| Mean | 0.008 | 0.027 | 0.084 | US-EPA (2000a) |
| Range | 0.003 - 0.018 | 0.011 - 0.096 | 0.016 - 0.39 | US-EPA (2000a) |
| **Mean Chlorophyll-*a* (µg/l)** | | | | |
| Mean | 1.7 | 4.7 | 14 | US-EPA (2000a) |
| Range | 0.3 - 4.5 | 3 - 11 | 2.7 - 78 | US-EPA (2000a) |
| Range | 0.3 to 3 | 2 to 15 | >10 | Wetzel (2001) |
| Range | 0.8 to 3.4 | 3 to 7.4 | 6.7 to 31 | Ryding and Rast (1989) |
| Range | | 3.5 to 9 | - | Smith (1998) |
| Range | >10 | 4 to 10 | < 4 | Novotny and Olem (1994) |
| **Peak chlorophyll-*a* (µg/l)** | | | | |
| Mean | 4.2 | 16 | 43 | US-EPA (2000a) |
| Range | 1.3 - 11 | 5 - 50 | 10 - 280 | US-EPA (2000a) |
| Range | 2.6 - 7.6 | 8.2 – 29 | 16.9 –107 | US-EPA (2003) |

after Vollenweider and Kerekes (1980) and US-EPA (2003)

Although there are no specific biomass criteria or standards, MassDEP has suggested natural system have less than 200 mg/m$^2$ of benthic algae biomass for protection of aesthetic uses (MassDEP, 2009).

## 2.5 Evaluation Metrics

As described in 2.1 above, the Massachusetts Water Quality Standards provide numerical and narrative criteria to sustain Class B waters designated as supporting habitat for fish and other aquatic wildlife and for primary and secondary contact recreation. MassDEP has set numeric criteria for dissolved oxygen (DO>5 mg/L) and pH (6.5-8.3) (MassDEP, 2007). For nutrients, however, Massachusetts relies on narrative criteria since the relationship between nutrient concentrations and environmental responses is complex and varied. Narrative standards are aimed at controlling cultural eutrophication, including the excessive growth of aquatic plants or algae. Additional goals are designed to minimize photosynthetic effects that lead to extreme diurnal dissolved oxygen fluctuations and dissolved oxygen supersaturation.

In the absence of numeric criteria for nutrients in the Massachusetts Surface 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 water quality metrics selected for the Upper/Middle Charles are summarized in Table 5 below. These metrics will be refined into specific TMDL targets later in this report (see Section 4.3). This weight-of-evidence approach considers water quality standards, related TMDL project experience (e.g., Assabet River Phosphorus TMDL, Lower Charles River Phosphorus TMDL), as well as available guidance documents (US-EPA, 1986). A description of the rationale for numeric chlorophyll-*a*, total phosphorus and dissolved oxygen percent saturation metrics for the Upper/Middle Charles TMDL follows.

**Table 5. Selected Nutrient Water Quality Metrics and Guidance Values**

| Metric | Acceptable Range | Rational for Metric | Source |
|---|---|---|---|
| **Numeric Water Quality Standard** | | | |
| Dissolved Oxygen | > 5 mg/L | MassDEP Surface Water Quality Standards | MassDEP (2007b) |
| pH[1] | 6.5 – 8.3 | MassDEP Surface Water Quality Standards | MassDEP (2007b) |
| **Related Nutrient TMDLs** | | | |
| Seasonal Mean Chlorophyll-a | < 10 ug/L | Target applied in Lower Charles TMDL | US-EPA (2007) |
| Peak Chlorophyll-a | < 18.9 ug/L | Target Applied in Lower Charles TMDL | US-EPA (2007) |
| Dissolved Oxygen Saturation | < 125% | Best Professional Judgment, applied in the Assabet River Nutrient TMDLs | MassDEP (2004) |
| **Guidance** | | | |
| Total Phosphorus | < 0.025 mg/L | EPA-within lakes or reservoir | US-EPA (1986) |
| Total Phosphorus | < 0.050 mg/L | EPA-entering lakes of reservoirs | US-EPA (1986) |
| Total Phosphorus | < 0.100 mg/L | EPA- in streams or other flowing waters not discharging directly to lakes or impoundments | US-EPA (1986) |

[1] used to evaluate state of river only - not used for scenario target

The target value for chlorophyll-*a* was adopted from the Lower Charles River TMDL. The relationship between nutrient levels and specific response variables such as algae and macrophytes is complex and highly dependent on the physical and hydraulic characteristics of the system. Little guidance is available relative to specific response variables such as biomass and aesthetics; therefore, defining the total allowable pollutant concentration for the Upper/Middle Charles River required the interpretation of applicable narrative water quality criteria to select an appropriate numeric water quality target.

The approach used in the Lower Charles TMDL was to select a response indicator as an instream water quality metric. Chlorophyll-*a* was chosen as the surrogate water quality metric for the Lower Charles River. Chlorophyll-*a* is the photosynthetic pigment found in algae and is, therefore, a direct indicator of algal biomass. Since the eutrophication-related impairments in the Lower Charles River and Upper/Middle Charles River are the result of excessive amounts of algae, chlorophyll-*a* can be used as a surrogate metric in the Upper/Middle Charles River to reasonably define acceptable amounts of algae that will support the designated uses. The approach for developing the chlorophyll-*a* metric was defined in the Lower Charles TMDL report (US-EPA, 2007). The chosen chlorophyll-*a* target is a seasonal average of 10 µg/L (June 1 to October 1). This period represents critical conditions when algal blooms are typically most severe in the Lower Charles River and have the greatest impact on designated uses. The maximum chlorophyll-*a* value was derived from a correlation between the seasonal mean and the seasonal 90th percentile chlorophyll-*a* values. The maximum target chlorophyll-*a* value of 18.9 µg/L corresponded to the seasonal mean value of 10 µg/L. The 90th percentile value (maximum) was selected because it represents an infrequent high chlorophyll-*a* value of short duration, and also corresponds with Massachusetts' assessment protocol for water clarity, which states that no less than 90 percent of the measurements should fall below the minimum clarity threshold. Similar analysis conducted for the Upper/Middle Charles water quality data yielded comparable values for mean and 90th percentile chlorophyll-*a*; this further supports the use of these chlorophyll-*a* targets.

No single instream target concentration for total phosphorus will be established for the Upper/Middle Charles TMDL. 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 (attached macrophytes) can be removed and that some level of biomass is necessary to provide habitat to fish and other aquatic organisms. Additional goals are to also ensure the minimum dissolved oxygen criterion is met and to reduce the duration of dissolved oxygen supersaturation. A comparison of in-stream total phosphorus concentrations, although not a target, to US-EPA guidance was used to further validate the model and weight-of-evidence approach. The "Gold Book" (US-EPA, 1986) states that "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. US-EPA, 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 Upper/Middle Charles River. Additionally, a target of 125% dissolved oxygen saturation was used as a benchmark for control of excessive fluctuations in dissolved oxygen. This metric is consistent with the approach used in other nutrient TMDLs (MassDEP, 2004). The specific targets for evaluation of scenarios in the Upper/Middle Charles TMDL will be discussed further in Section 4.3.

# 3 THE STATE OF THE RIVER

## 3.1 Water Quality Monitoring Programs

All available data affecting water quality loads were reviewed to determine the present condition of the Upper/Middle Charles River. Since loads are a product of flow and concentration, both water quality concentrations and flow measurements are discussed. This section catalogs the available water quality data and describes the current state of the river based on these data by comparing the data to the evaluation metrics outlined in the previous section.

Water quality data for the Upper/Middle Charles River were obtained from Charles River Watershed Association (CRWA), Massachusetts Water Resources Authority (MWRA), Massachusetts Department of Environmental Protection (MassDEP), US Environmental Protection Agency (US-EPA), and Camp Dresser and McKee (CDM). The US-EPA data were not used as there were only two stations within the study area, the chlorophyll-*a* data were not corrected for pheophytin, and the sites were duplicated by CRWA and MWRA. The CDM data were used to validate the model results after the calibration process (CRWA, 2009) but were not used for TMDL development directly because they were collected prior to the dates used for model calibration. (CDM, 1997). Only the relevant nutrient-based water quality data, including total nitrogen, total phosphorus, chlorophyll-*a*, dissolved oxygen, and pH, are discussed here.

Total nitrogen and phosphorus are essential plant nutrients that are found in small amounts in natural waters, however, at elevated levels these elements can cause eutrophic conditions in lakes, ponds and impoundments and create excessive plant growth. Total nitrogen is the sum of organic nitrogen, ammonia, nitrate and nitrite. In some monitoring programs, total nitrogen was measured directly while in others it was computed from the individual components. Phosphorus is comprised of ortho-, poly- and organic forms and typically measured as total phosphorus and orthophosphate.

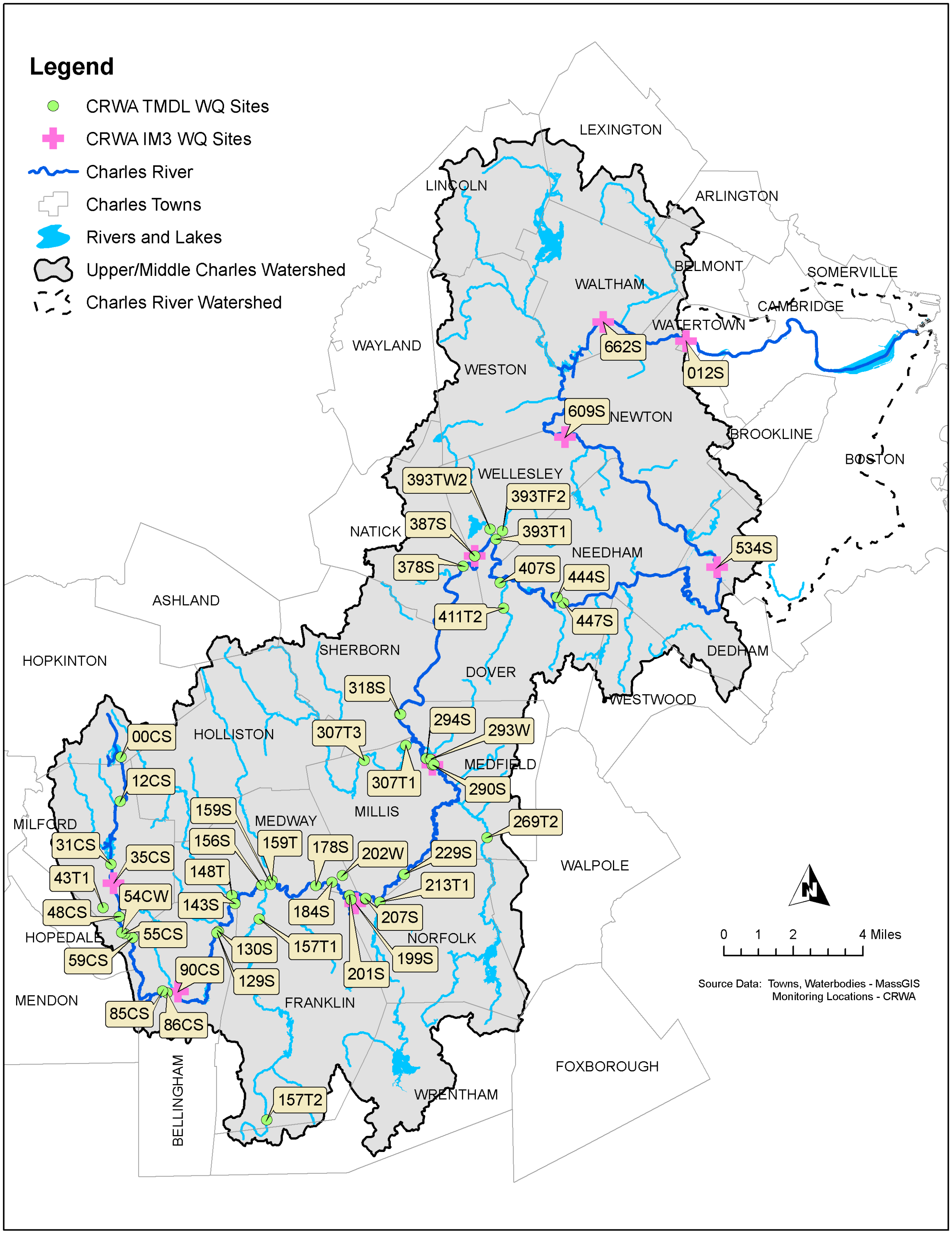
Chlorophyll-*a* is the principle photosynthetic pigment in algae and vascular plants and is an indicator of algae concentrations and over-enrichment by nutrients. Chlorophyll-*a* measures the phytoplankton algae in the water column and does not represent the plant biomass associated with either macrophytes (aquatic plants and floating algae mats) or periphyton (attached algae).

Dissolved oxygen (DO) is the most important dissolved gas in river water as it is essential to most aquatic organisms, especially fish. Oxygen is produced during photosynthesis of green plants while plants and animals use it during respiration. pH is an important water quality indicator that measures of the acidity or alkalinity of the water; pH ranges from 0 to 14. A pH equal to 7 is neutral, a pH greater than 7 is basic, and a pH less than 7 is acidic.

The water quality monitoring programs in the Upper/Middle Charles River watershed are described below. Figure 4 shows the sampling locations while Table 6 provides a comprehensive list of the sampling sites with identification numbers for all monitoring programs.

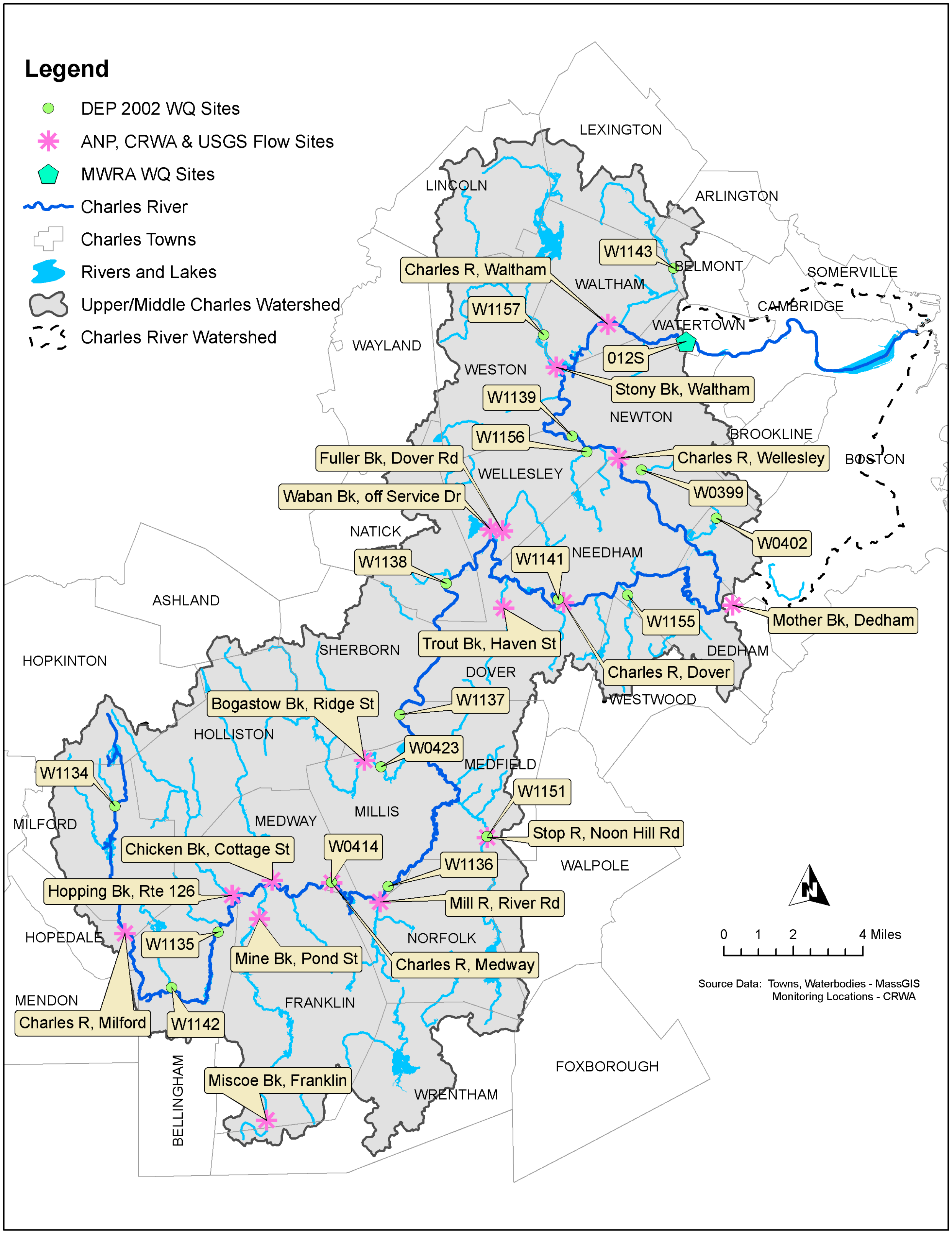
### *3.1.1 CRWA TMDL Water Quality Monitoring*

From 2002 to 2005, CRWA performed two wet-weather and two dry-weather sampling events to characterize water quality conditions in the Upper/Middle watershed. CRWA sampled 18



Source Data: Towns, Waterbodies - MassGIS
Monitoring Locations - CRWA

**Figure 4. Monitoring Sites in the Upper/Middle Charles**



Source Data: Towns, Waterbodies - MassGIS
Monitoring Locations - CRWA

**Figure 4. Monitoring Sites in the Upper/Middle Charles (cont.)**

# Table 6.  Sampling Sites in the Upper/Middle Charles

| Reach ID* | Reach Name | Town | Reach Num* | River Mile* | Main/ Trib/ WWTF | Flow | TMDL WQ | IM3 WQ | DEP WQ | CDM WQ | EPA WQ | MWRA WQ | TMDL Diurnal DO | TMDL Sonde DO | Aquatic plants | Sediment Efflux | Bathymetry & Sediment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00CS | Outlet Echo Lake | Hopkinton | 1 | 0.0 | M | | | | | | | | | X | | | |
| 12CS | Above Waterworks Dam | Milford | 3 | 1.2 | M | | X | | | | | | | | | | |
| 20CS | Waterworks to Dilla Dam | Milford | 5 | 2.0 | M | | | | W1134 | | | | | | | | |
| 31CS | Outlet Milford Pond | Milford | 7 | 3.1 | M | | X | | | | | | X | X | X | CRWA1 | X |
| 35CS | Central St Culvert | Milford | 10 | 3.5 | M | | | X | | | | | | | | | |
| 43T1 | Outlet Godfrey Brook | Milford | 213 | 4.3 | T | | X | | | | | | | | | | |
| 48CS | Howard St below Godfrey Bk | Milford | 13 | 4.8 | M | | X | | | | | | X | | | | |
| 54CW | Milford WWTF | Milford | - | 5.4 | W | | X | | | | | | | | | | |
| 55CS | Milford ANP Gage below WWTF | Hopedale/Milford | 15 | 5.5 | M | ANP | | | | | | | | | | | |
| 59CS | Mellen St | Milford | 16 | 5.9 | M | | X | | | | | | X | | | | |
| 85CS | Outlet Box Pond | Bellingham | 19 | 8.5 | M | | | | | | | | | X | X | CRWA2 | X |
| 86CS | Depot Rd | Bellingham | 20 | 8.6 | M | | X | | | | | | X | | | | |
| 88T | Outlet Beaver Brook | Bellingham | 221 | 8.8 | T | | | | W1142 | | | | | | | | |
| 90CS | N Main St / Rt 126 | Bellingham | 21 | 9.0 | M | | | X | | | | | | | | | |
| 129S | Outlet N Bellingham Dam | Bellingham | 26 | 12.9 | M | | | | | | | | | X | X | CRWA3 | X |
| 13CS | Maple St | Bellingham | 27 | 13.0 | M | | X | | W1135 | | | | X | | | | |
| 143S | Outlet Caryville Dam | Bellingham | 30 | 14.3 | M | | X | | | | | | X | | X | CRWA4 | X |
| 148T | Hopping Bk at Hartford Ave / Rt 126 | Bellingham | 232 | 14.8 | T | CRWA | X | | | | | | | | | | |
| 156S | Inlet W Medway Dam | Franklin/Medway | 32 | 15.6 | M | | X | | | | | | X | | | | |
| 157T1 | Mine Bk at Pond St | Franklin/Medway | 233 | 15.7 | T | CRWA | X | | | | | | | | | | |
| 157T2 | USGS Miscoe Bk Gage at South St | Franklin/Medway | 333 | 15.7 | T | USGS | X | | | | | | | | | | |
| 159S | Outlet W Medway Dam | Franklin/Medway | 33 | 15.9 | M | | X | | | | | | X | X | X | CRWA5 | X |
| 159T | Chicken Brook at Cottage St | Franklin/Medway | 234 | 15.9 | T | CRWA | X | | | | | | | | | | |
| 178S | Outlet Medway Dam | Franklin/Medway | 37 | 17.8 | M | | | | | | | | X | X | X | CRWA6 | X |
| 184S | USGS Medway Gage at Walker St | Medway | 38 | 18.4 | M | USGS | X | | W0414 | | | | X | | | | |
| 199S | Populatic Pond | Norfolk | 40 | 19.9 | M | | | X | | | | | | | | | |
| 201S | Outlet Populatic Pd | Medway/Norfolk | 41 | 20.1 | M | | X | | | CR-1 | | | X | X | X | CRWA7 | X |
| 202W | CRPCD WWTF | Medway | - | 20.2 | W | | X | | | CRPCD | | | | | | | |
| 207S | Below CRPCD WWTF | Millis/Norfolk | 43 | 20.7 | M | | X | | | | | | X | X | X | | |
| 213S | Above Mill River | Millis/Norfolk | 44 | 21.3 | M | | | | | CR-2 | | | | | | | |
| 213T1 | Mill River at River Rd | Millis/Norfolk | 245 | 21.3 | T | CRWA | X | | | MR-1 | | | | | | | |
| 219S | Pleasant St | Millis | 45 | 21.9 | M | | | | W1136 | | | | | | | | |
| 229S | Baltimore St/115 | Millis | 46 | 22.9 | M | | X | | | | | | X | | | | |
| 243S | Forest Rd | Medfield/Millis | 48 | 24.3 | M | | | | | CR-3 | | | | | | | |
| 269S | Above Stop River | Medfield/Millis | 53 | 26.9 | M | | | | | | | | | X | | | |
| 269T | Stop River at Causeway St | Medfield | 254 | 26.9 | T | | | | | SR-1 | | | | | | | |
| 269T2 | Stop River at Noon Hill Rd | Medfield | 254 | 26.9 | T | CRWA | X | | W1151 | | | | | | | | |
| 290S | Above Medfield WW | Medfield/Millis | 56 | 29.0 | M | | X | X | | CR-4 | | | X | | | | |
| 293W | Medfield WWTF | Medfield | - | 29.3 | W | | X | | | MWWTP | | | | | | | |
| 294S | Below Medfield WW | Medfield/Millis | 57 | 29.4 | M | | X | | | | | | | | X | | |
| 307T1 | Bogastow Bk at S End Pond | Millis | 260 | 30.7 | T | | | | | BB-1 | | | | | | | |
| 307T2 | Bogastow Bk at Orchard St | Millis | 260 | 30.7 | T | | | | W0423 | | | | | | | | |
| 307T3 | Bogastow Bk at Ridge St | Millis | 260 | 30.7 | T | CRWA | X | | | | | | | | | | |
| 318S | S Main St / Rt 27 | Medfield/Sherborn | 60 | 31.8 | M | | X | | W1137 | CR-5 | | | X | X | | | |
| 343S | Farm Rd/Bridg St | Dover/Sherborn | 64 | 34.3 | M | | | | | CR-6 | | | | | | | |
| 374S | Inlet S Natick Dam | Natick | 68 | 37.4 | M | | | | W1138 | | | | | | | | |
| 378S | Outlet S Natick Dam | Natick | 69 | 37.8 | M | | | | | CR-7 | CRBL01 | | X | X | X | CRWA8 | X |
| 387S | Cheney Bridge | Dover/Wellesley | 70 | 38.7 | M | | X | X | | | | | | | | | |
| 393T1 | Fuller / Waban Brook confluence | Wellesley | 274 | 39.3 | T | | X | | | WB-1 | | | | | | | |
| 393TF2 | Fuller  Brook at Dover St | Wellesley | 274 | 39.3 | T | CRWA | | | | | | | | | | | |
| 393TW2 | Waban Brook at Dirt Rd off Service Dr | Wellesley | 274 | 39.3 | T | CRWA | | | | | | | | | | | |
| 400S | Charles River Rd | Dover/Needham | 73 | 40.0 | M | | | | | CR-8 | | | | | | | |
| 407S | Claybrook Rd | Dover | 74 | 40.7 | M | | X | | | | | | | | X | | |
| 411T2 | Trout Bk at Haven St | Dover | 276 | 41.1 | T | CRWA | X | | | | | | | | | | |
| 444S | Outlet Cochrane Dam | Dover/Needham | 79 | 44.4 | M | | | | | CR-9 | | | | X | X | CRWA9 | X |
| 447S | USGS Dover Gage below Cochrane Dam | Dover/Needham | 80 | 44.7 | M | USGS | X | | W1141 | | | | X | | | | |
| 469T | Rock Meadow Bk at Dedham CC | Dedham | 284 | 46.9 | T | | | | W1155 | | | | | | | | |
| 524T | USGS Mother Bk gage/discharge at Rt 1 | Dedham | 292? | 52.4 | T | USGS | | | | | | | | | | | |
| 534S | Inlet Silk Mill Dam / Rt 109 | Dedham/W Roxbury | 93 | 53.4 | M | | | X | | | | | | | | | |
| 548T | Vine / Sawmill Bk above Baker St | Newton | 296 | 54.8 | T | | | | W0402 | | | | | | | | |
| 582T | S Meadow Bk below Needham St | Newton | 299 | 58.2 | T | | | | W0399 | | | | | | | | |
| 591S | USGS Wellesley Gage, outlet Circular Dam | Newton/Wellesley | 101 | 59.1 | M | USGS | | | | | | | | | | | |
| 607T | Rosemary Bk above Barton St | Wellesley | 304 | 60.7 | T | | | | W1156 | | | | | | | | |
| 609S | Outlet Finlay Dam | Newton/Wellesley | 106 | 60.9 | M | | | X | W1139 | | | | | | | | |
| 642T | USGS Stony Brook Gage below Reservoir | Waltham | 309 | 64.2 | T | USGS | | | W1157 | | | | | | | | |
| 662S | Outlet Moody St Dam | Waltham | 110 | 66.2 | M | | | X | | | | | | | | | |
| 666S | USGS Waltham Gage | Waltham | 111 | 66.6 | M | USGS | | | | | | | | | | | |
| 668T | Beaver Bk above Mill Pond | Waltham | 311 | 66.8 | T | | | | W1143 | | | | | | | | |
| 012S | Outlet Watertown Dam | Watertown | 113 | 69.1 | M | | | X | | | CRBL02 | X | | | | | |
| 743S | Western Ave | Boston/Cambridge | 117 | 74.3 | M | | | X | | | | | | | | | |
| 763S | Massachusetts Ave | Boston/Cambridge | 118 | 76.3 | M | | | X | | | | | | | | | |
| 784S | Outlet New Charles Dam | Boston | 121 | 78.4 | M | | | X | | | | | | | | | |

*** Reach ID is the CRWA reach identification label, Reach Num is the reach number for the HSPF model, River Mile is the miles downstream from the outlet of Echo Lake**

mainstem and 10 tributary sites in the Upper/Middle Charles (Table 6). All these data were summarized in two detailed data reports (CRWA, 2003a; CRWA, 2006).

Wet-weather samples were collected over multiple days. An ideal wet weather flow regime was defined in the TMDL Quality Assurance Project Plan (QAPP) (CRWA, 2002) as greater than 1.0 inch of rainfall for wet soil, greater than 1.5 inches of rain for dry soil, or greater than 2 cfsm of runoff at the tributary gauges. Measurements were made for ammonia, nitrate, nitrite, total Kjeldahl nitrogen, orthophosphate, total phosphorus, chlorophyll-*a*, temperature, dissolved oxygen, and pH.

The results from the dry and wet weather monitoring events were combined as one sample set because the differences in nutrient concentrations between dry and wet weather events were relatively small. In general, there is greater variation between concentrations between seasons than between different weather conditions in the same season because the permit levels for treated effluent discharges from the WWTFs change from season to season.

CRWA performed a number of additional dissolved oxygen (DO) surveys to help define DO levels and diurnal range. Water quality sondes were used to measure continuous DO at nine impoundment and three river sites in August and September 2002 to better define the daily DO fluctuation in the Upper/Middle Charles. In addition, CRWA measured both the horizontal and vertical variability of DO at the 12 sites by performing five depth profiles across each impoundment. CRWA also measured diurnal DO fluctuations at 18 sites on two separate occasions to document diurnal range of DO concentrations from the morning to the afternoon.

CRWA surveyed nine impoundments and ponds to determine bathymetry and sediment thickness during summer and fall of 2002 and the summer of 2003. The bathymetric survey determined the storage capacity and quantified the thickness of sediments in each impoundment and pond. In the summer of 2005, an aquatic plant survey was conducted in the same nine impoundments plus three river sites to measure number of aquatic plant species, areal extent, and biomass.

CRWA contracted UMass-Dartmouth in 2005 to design and conduct a sediment nutrient and oxygen flux study in the Upper/Middle watershed. The goal was to obtain rates of sediment nutrient release and oxygen demand to support the parameterization of the water quality model. The same nine impoundment sites were studied. Sediment cores were collected at two to five stations at each site and were incubated to determine both aerobic and anaerobic nutrient release rates and sediment oxygen demand.

CRWA and contracted laboratories followed the procedures and guidelines outlined in the approved TMDL QAPP (CRWA, 2002). UMass-Dartmouth worked under an approved Sampling Analysis Plan (SAP) approved general QAPP for the sediment testing.

### *3.1.2 CRWA IM3 Water Quality Monitoring*

Since 1996, as part the Integrated Monitoring, Modeling, and Management (IM3) program (CRWA, 1997), CRWA has routinely sampled the entire river on a monthly basis for bacteria. On a quarterly basis, nine locations in the Upper/Middle Charles River were also monitored for a suite of nutrient parameters including ammonia, nitrate+nitrite, total nitrogen, orthophosphate, total phosphorus, chlorophyll-*a*, pheophytin, temperature, and pH (Table 6).

Quarterly nutrient monitoring occurs every March, June, September and December. A dry weather event is defined as less than 0.1 inches of total rainfall in the previous 72 hours. Total rainfall equal to or greater than 0.1 inches over the past 72 hours is considered a wet weather event. CRWA collected all data in accordance with an approved QAPP (CRWA, 2001; CRWA, 2007).

### *3.1.3 MWRA Water Quality Monitoring*

Since 1996, MWRA has routinely sampled the outlet of the Watertown Dam (Site 012S) on a weekly basis for several nutrient-related parameters including ammonia, nitrate+nitrite, total nitrogen, orthophosphate, total phosphorus, chlorophyll-*a*, pheophytin, temperature, DO, and pH (Table 6). This weekly sampling at the downstream boundary of the Upper/Middle Charles River provides an excellent record of nutrient loads at the lower boundary for the model. Over 350 samples were collected year-round in both dry and wet weather. MWRA collected their data in accordance with an approved QAPP.

### *3.1.4 MassDEP Water Quality Monitoring*

MassDEP conducts watershed assessments throughout the State on a five-year cycle. In 2002, MassDEP collected water quality data from the Charles River watershed at eight mainstem sites and 10 tributaries located in the Upper/Middle Charles River (Table 6). A total of 14 surveys were conducted in 2002; of which, five included analyses of nutrients. Measurements of ammonia, total phosphorus, temperature, DO, and pH were made.

## 3.2 Current Water Quality Conditions

To characterize water quality conditions of the Upper/Middle Charles River watershed, CRWA calculated several summary statistics (mean, median, range and number of samples) of the available nutrient-related water quality data collected by CRWA, MWRA, MassDEP, and US-EPA and compared them to Massachusetts surface water quality standards, US-EPA's nutrient guidance levels , trophic indicator criteria, and the ratio of nitrogen to phosphorous which is used to determine the limiting nutrient of concern . A qualitative assessment of aquatic plants extent, biovolume, and species is also included.

### *3.2.1 Total Nitrogen Data*

Nitrogen in surface waters is typically not the limiting nutrient controlling plant growth. When the ratio of nitrogen-to-phosphorus exceeds 7.2 on a weight basis, phosphorus becomes the limiting nutrient (Chapra, 1997). The ratios of nitrogen-to-phosphorus in the Upper/Middle Charles watershed generally far exceed this value (see Section 4.1).

Since nitrogen does not control algal growth, the limitation of nitrogen concentrations is not expected to reduce algal growth in the Upper/Middle Charles, thus it will not be the focus of this nutrient TMDL. The concentration of nitrogen could be important to water quality at the outlet of the Charles River when it discharges into the Bay of Massachusetts, since nitrogen is generally the limiting nutrient in marine waters.

Nitrogen concentrations in the Upper/Middle Charles are high relative to most nutrient or eutrophic criteria, averaging about 2.3 mg/L, with extreme values up to 20 mg/L. MWRA sampling for total nitrogen at the Watertown dam (012S) revealed an average of approximately 1.0 mg/L with a flat trend observed over time.

### *3.2.2 Total Phosphorus Data*

Table 7 summarizes the mean, minimum, and maximum concentrations with the number of samples for total phosphorus at each site for all the monitoring programs in the Upper/Middle Charles river watershed. The table is ordered by river mile from the top of the watershed. The main stem wastewater discharge sites are the Milford WWTF (5.4 miles), Charles River Pollution Control District or CRPCD (20.2 miles), and the Medfield WWTF (29.3 miles).

Most of the total phosphorus samples and statistics exceed the US-EPA nutrient guidance values except for a few sample sites in the uppermost part of the watershed in Milford. The MWRA samples at the Watertown dam (012S) show a flat trend until 2004 then a downward trend probably reflecting new WWTF permit discharge for phosphorus. Summer limits for phosphorus discharge were lowered to 0.2 mg/L in late 2000 and additional winter limits of 1.0 mg/L were imposed for all but one treatment plant in 2005.

The individual monitoring programs can be summarized as follows:

1. CRWA TMDL Data (2002-2005) – 31 sites
    a. Only 2 sites (31CS, 43T1) had means less than 0.025 mg/L
    b. No sites had means above 0.10 mg/L
    c. 21 sites had minimums less than 0.025 mg/L
    d. 5 sites had maximums above 0.10 mg/L

2. CRWA IM3 Data (1996-2006) – 9 sites
    a. All sites had means much greater than 0.025 mg/L
    b. No sites had means greater than 0.10 mg/L
    c. 2 sites had minimums below the 0.025 mg/L
    d. All 9 sites had maximums above the 0.10 mg/L
    e. Concentrations were lowest in March, highest in summer, then decreased in fall

3. MWRA Data (1997-2007) – 1 site at Watertown Dam
    a. Mean greater than 0.025 mg/L
    b. Minimum below the 0.025 mg/L
    c. Maximum above the 0.10 mg/L
    d. Decreasing trend since 2004

4. MassDEP Data (2002) – 18 sites
    a. All sites had means greater than 0.025 mg/L
    b. 3 sites (269T2, 469T, 548T) had means greater than 0.10 mg/L
    c. 4 sites had minimums below the 0.025 mg/L
    d. 6 sites had maximums above the 0.10 mg/L
    e. Concentrations lowest in April and highest in summer

# Table 7. Total Phosphorus Data from Upper/Middle Charles Monitoring

| Name | CRWA ID | Site ID | River Mile | Years | Mean (mg/L) | Min (mg/L) | Max (mg/L) | Num. Samples | Site Description |
|---|---|---|---|---|---|---|---|---|---|
| TMDL | 31CS | 31CS | 3.1 | 02-05 | 0.020 | 0.013 | 0.032 | 8 | Outlet Milford Pond |
| TMDL | 43T1 | 43T1 | 4.3 | 02-05 | 0.018 | 0.011 | 0.027 | 3 | Outlet Godfrey Brook |
| TMDL | 48CS | 48CS | 4.8 | 02-05 | 0.057 | 0.027 | 0.120 | 8 | Howard St below Godfrey Bk |
| TMDL | 59CS | 59CS | 5.9 | 02-05 | 0.090 | 0.036 | 0.267 | 8 | Mellen St |
| TMDL | 86CS | 86CS | 8.6 | 02-05 | 0.038 | 0.029 | 0.051 | 8 | Depot Rd |
| TMDL | 13CS | 13CS | 13.0 | 02-05 | 0.037 | 0.020 | 0.064 | 8 | Maple St |
| TMDL | 143S | 143S | 14.3 | 02-05 | 0.035 | 0.029 | 0.044 | 8 | Outlet Caryville Dam |
| TMDL | 148T | 148T | 14.8 | 02-05 | 0.051 | 0.026 | 0.077 | 6 | Hopping Bk at Hartford Ave / Rt 126 |
| TMDL | 156S | 156S | 15.6 | 02-05 | 0.037 | 0.028 | 0.046 | 8 | Inlet W Medway Dam |
| TMDL | 157T1 | 157T1 | 15.7 | 02-05 | 0.048 | 0.033 | 0.075 | 6 | Mine Bk at Pond St |
| TMDL | 157T2 | 157T2 | 15.7 | 02-05 | 0.026 | 0.018 | 0.045 | 6 | USGS Miscoe Bk Gage at South St |
| TMDL | 159S | 159S | 15.9 | 02-05 | 0.050 | 0.030 | 0.082 | 8 | Outlet W Medway Dam |
| TMDL | 159T | 159T | 15.9 | 02-05 | 0.080 | 0.046 | 0.180 | 6 | Chicken Brook at Cottage St |
| TMDL | 184S | 184S | 18.4 | 02-05 | 0.044 | 0.026 | 0.051 | 8 | USGS Medway Gage at Walker St |
| TMDL | 201S | 201S | 20.1 | 02-05 | 0.054 | 0.039 | 0.075 | 8 | Outlet Populatic Pd |
| TMDL | 207S | 207S | 20.7 | 02-05 | 0.053 | 0.043 | 0.072 | 8 | Below CRPCD WWTF |
| TMDL | 213T1 | 213T1 | 21.3 | 02-05 | 0.038 | 0.019 | 0.106 | 6 | Mill River at River Rd |
| TMDL | 229S | 229S | 22.9 | 02-05 | 0.038 | 0.023 | 0.054 | 8 | Baltimore St/115 |
| TMDL | 269T2 | 269T2 | 26.9 | 02-05 | 0.089 | 0.038 | 0.131 | 6 | Stop River at Noon Hill Rd |
| TMDL | 290S | 290S | 29.0 | 02-05 | 0.041 | 0.030 | 0.048 | 8 | Above Medfield WW |
| TMDL | 294S | 294S | 29.4 | 02-05 | 0.062 | 0.041 | 0.100 | 8 | Below Medfield WW |
| TMDL | 307T3 | 307T3 | 30.7 | 02-05 | 0.066 | 0.041 | 0.098 | 6 | Bogastow Bk at Ridge St |
| TMDL | 318S | 318S | 31.8 | 02-05 | 0.053 | 0.038 | 0.069 | 8 | S Main St / Rt 27 |
| TMDL | 387S | 387S | 38.7 | 02-05 | 0.046 | 0.031 | 0.060 | 8 | Cheney Bridge |
| TMDL | 393T1 | 393T1 | 39.3 | 02-05 | 0.052 | 0.027 | 0.084 | 6 | Fuller / Waban Brook confluence |
| TMDL | 407S | 407S | 40.7 | 02-05 | 0.049 | 0.037 | 0.056 | 8 | Claybrook Rd |
| TMDL | 411T2 | 411T2 | 41.1 | 02-05 | 0.030 | 0.018 | 0.054 | 6 | Trout Bk at Haven St |
| TMDL | 447S | 447S | 44.7 | 02-05 | 0.042 | 0.029 | 0.057 | 8 | USGS Dover Gage below Cochrane Dam |
| | | | | | | | | | |
| IM3 | 35CS | 35CS | 3.5 | 96-06 | 0.057 | 0.012 | 0.240 | 36 | Central St Culvert |
| IM3 | 90CS | 90CS | 9.0 | 96-06 | 0.077 | 0.027 | 0.296 | 37 | N Main St / Rt 126 |
| IM3 | 199S | 199S | 19.9 | 96-06 | 0.063 | 0.000 | 0.102 | 21 | Populatic Pond |
| IM3 | 290S | 290S | 29.0 | 96-06 | 0.089 | 0.035 | 0.356 | 36 | Above Medfield WW |
| IM3 | 387S | 387S | 38.7 | 96-06 | 0.091 | 0.028 | 0.335 | 35 | Cheney Bridge |
| IM3 | 534S | 534S | 53.4 | 96-06 | 0.070 | 0.025 | 0.133 | 38 | Inlet Silk Mill Dam / Rt 109 |
| IM3 | 609S | 609S | 60.9 | 96-06 | 0.072 | 0.031 | 0.131 | 33 | Outlet Finlay Dam |
| IM3 | 662S | 662S | 66.2 | 96-06 | 0.063 | 0.026 | 0.115 | 38 | Outlet Moody St Dam |
| IM3 | 012S | 012S | 69.1 | 96-06 | 0.068 | 0.034 | 0.121 | 37 | Outlet Watertown Dam |
| | | | | | | | | | |
| MWRA | 012S | 012S | 69.1 | 97-06 | 0.068 | 0.022 | 0.214 | 374 | Outlet Watertown Dam |
| | | | | | | | | | |
| DEP | 20CS | W1134 | 2.0 | 02 | 0.029 | 0.021 | 0.041 | 4 | Waterworks to Dilla Dam |
| DEP | 88T | W1142 | 8.8 | 02 | 0.026 | 0.024 | 0.030 | 4 | Outlet Beaver Brook |
| DEP | 13CS | W1135 | 13.0 | 02 | 0.051 | 0.037 | 0.068 | 4 | Maple St |
| DEP | 184S | W0414 | 18.4 | 02 | 0.038 | 0.029 | 0.055 | 4 | USGS Medway Gage at Walker St |
| DEP | 219S | W1136 | 21.9 | 02 | 0.042 | 0.028 | 0.061 | 4 | Pleasant St |
| DEP | 269T2 | W1151 | 26.9 | 02 | 0.111 | 0.100 | 0.140 | 4 | Stop River at Noon Hill Rd |
| DEP | 307T2 | W0423 | 30.7 | 02 | 0.064 | 0.043 | 0.089 | 4 | Bogastow Bk at Orchard St |
| DEP | 318S | W1137 | 31.8 | 02 | 0.059 | 0.035 | 0.086 | 4 | S Main St / Rt 27 |
| DEP | 374S | W1138 | 37.4 | 02 | 0.069 | 0.045 | 0.120 | 4 | Inlet S Natick Dam |
| DEP | 447S | W1141 | 44.7 | 02 | 0.059 | 0.023 | 0.100 | 5 | USGS Dover Gage below Cochrane Dam |
| DEP | 469T | W1155 | 46.9 | 02 | 0.113 | 0.034 | 0.170 | 5 | Rock Meadow Bk at Dedham CC |
| DEP | 548T | W0402 | 54.8 | 02 | 0.137 | 0.067 | 0.190 | 5 | Vine / Sawmill Bk above Baker St |
| DEP | 582T | W0399 | 58.2 | 02 | 0.090 | 0.076 | 0.110 | 4 | S Meadow Bk below Needham St |
| DEP | 607T | W1156 | 60.7 | 02 | 0.080 | 0.041 | 0.120 | 5 | Rosemary Bk above Barton St |
| DEP | 609S | W1139 | 60.9 | 02 | 0.066 | 0.038 | 0.077 | 4 | Outlet Finlay Dam |
| DEP | 642T | W1157 | 64.2 | 02 | 0.027 | 0.022 | 0.036 | 5 | USGS Stony Brook Gage below Reservoir |
| DEP | 668T | W1143 | 66.8 | 02 | 0.070 | 0.046 | 0.098 | 5 | Beaver Bk above Mill Pond |

░ 0.025 to 0.05 mg/L ▒ 0.05 to 0.10 mg/L ▓ Exceeds 0.10 mg/L

### *3.2.3 Chlorophyll-a Data*

Table 8 summarizes the mean, minimum, and maximum chlorophyll-*a* concentrations with the number of samples at each site for all the monitoring programs in the Upper/Middle Charles river watershed. The table is ordered by river mile from the top of the watershed. The main stem wastewater discharge sites are the Milford WWTF (5.4 miles), CRPCD (20.2 miles), and the Medfield WWTF (29.3 miles).

The MWRA samples at the Watertown dam (012S) show a decline until 2002, an increase until 2004, then a further decline after 2004. The later decline probably reflects new WWTF permit limits for phosphorus. Summer limits for phosphorus discharge were lowered to 0.2 mg/L in late 2000 and additional winter limits of 1.0 mg/L were imposed for all but one treatment plant in 2005. Minimum chlorophyll-*a* concentrations are expected to be low because algae die off in the winter.

The individual monitoring programs can be summarized as follows:

1. CRWA TMDL Data (2002-2005) – 31 sites
    a. All sites had means less than 10 µg/L
    b. All sites had minimums less than 10 µg/L
    c. 3 sites had maximums above 18.9 µg/L
    d. High chlorophyll-*a* concentrations occurred downstream of the CRPCD WWTF and in the Stop River tributary (269T2) which has 2 small WWTFs

2. CRWA IM3 Data (1996-2006) – 9 sites
    a. 4 sites had means greater than 10 µg/L
    b. All sites had minimums below 10 µg/L
    c. All sites had maximums above 18.9 µg/L
    d. Trend of increasing chlorophyll-*a* with increasing distance downstream

3. MWRA Data (1997-2007) – 1 site
    a. Mean less than 10 µg/L
    b. Mean less than 10 µg/L
    c. Maximum above 18.9 µg/L
    d. Decreasing trend from 1998-2005

4. MassDEP Data (2002)
    a. No chlorophyll-*a* data were collected

# Table 8. Total Chlorophyll-*a* Data from Upper/Middle Charles Monitoring

| Name | CRWA ID | Site ID | River Mile | Years | Mean (µg/L) | Min (µg/L) | Max (µg/L) | Num. Samples | Site Description |
|---|---|---|---|---|---|---|---|---|---|
| TMDL | 31CS | 31CS | 3.1 | 02-05 | 3.3 | 1.4 | 7.8 | 8 | Outlet Milford Pond |
| TMDL | 43T1 | 43T1 | 4.3 | 02-05 | 1.6 | 0.6 | 3.6 | 3 | Outlet Godfrey Brook |
| TMDL | 48CS | 48CS | 4.8 | 02-05 | 4.6 | 0.6 | 6.0 | 8 | Howard St below Godfrey Bk |
| TMDL | 54CW | 54CW | 5.4 | 02-05 | 0.6 | 0.6 | 0.6 | 4 | Milford WWTF |
| TMDL | 59CS | 59CS | 5.9 | 02-05 | 3.3 | 0.6 | 10.4 | 8 | Mellen St |
| TMDL | 86CS | 86CS | 8.6 | 02-05 | 5.0 | 2.4 | 10.2 | 8 | Depot Rd |
| TMDL | 13CS | 13CS | 13.0 | 02-05 | 3.3 | 0.6 | 5.9 | 8 | Maple St |
| TMDL | 143S | 143S | 14.3 | 02-05 | 1.8 | 0.6 | 3.1 | 8 | Outlet Caryville Dam |
| TMDL | 148T | 148T | 14.8 | 02-05 | 2.2 | 0.6 | 5.7 | 6 | Hopping Bk at Hartford Ave / Rt 126 |
| TMDL | 156S | 156S | 15.6 | 02-05 | 1.9 | 0.6 | 3.3 | 8 | Inlet W Medway Dam |
| TMDL | 157T1 | 157T1 | 15.7 | 02-05 | 2.6 | 0.6 | 5.3 | 6 | Mine Bk at Pond St |
| TMDL | 157T2 | 157T2 | 15.7 | 02-05 | 2.9 | 0.6 | 12.6 | 6 | USGS Miscoe Bk Gage at South St |
| TMDL | 159S | 159S | 15.9 | 02-05 | 2.9 | 1.2 | 5.4 | 8 | Outlet W Medway Dam |
| TMDL | 159T | 159T | 15.9 | 02-05 | 6.1 | 0.6 | 18.4 | 6 | Chicken Brook at Cottage St |
| TMDL | 184S | 184S | 18.4 | 02-05 | 3.3 | 0.6 | 6.0 | 8 | USGS Medway Gage at Walker St |
| TMDL | 201S | 201S | 20.1 | 02-05 | 7.4 | 0.6 | 24.4 | 8 | Outlet Populatic Pd |
| TMDL | 202W | 202W | 20.2 | 02-05 | 0.6 | 0.6 | 0.6 | 4 | CRPCD WWTF |
| TMDL | 207S | 207S | 20.7 | 02-05 | 7.2 | 0.6 | 22.3 | 8 | Below CRPCD WWTF |
| TMDL | 213T1 | 213T1 | 21.3 | 02-05 | 2.1 | 0.6 | 7.6 | 6 | Mill River at River Rd |
| TMDL | 229S | 229S | 22.9 | 02-05 | 3.8 | 1.2 | 7.0 | 8 | Baltimore St/115 |
| TMDL | 269T2 | 269T2 | 26.9 | 02-05 | 5.5 | 0.6 | 19.4 | 6 | Stop River at Noon Hill Rd |
| TMDL | 290S | 290S | 29.0 | 02-05 | 3.9 | 1.4 | 8.8 | 8 | Above Medfield WW |
| TMDL | 293W | 293W | 29.3 | 02-05 | 1.3 | 0.6 | 2.2 | 4 | Medfield WWTF |
| TMDL | 294S | 294S | 29.4 | 02-05 | 3.6 | 1.5 | 8.8 | 8 | Below Medfield WW |
| TMDL | 307T3 | 307T3 | 30.7 | 02-05 | 1.2 | 0.6 | 2.8 | 6 | Bogastow Bk at Ridge St |
| TMDL | 318S | 318S | 31.8 | 02-05 | 3.9 | 1.8 | 11.3 | 8 | S Main St / Rt 27 |
| TMDL | 387S | 387S | 38.7 | 02-05 | 3.1 | 1.8 | 5.3 | 8 | Cheney Bridge |
| TMDL | 393T1 | 393T1 | 39.3 | 02-05 | 3.6 | 1.2 | 7.0 | 6 | Fuller / Waban Brook confluence |
| TMDL | 407S | 407S | 40.7 | 02-05 | 4.9 | 1.6 | 17.1 | 8 | Claybrook Rd |
| TMDL | 411T2 | 411T2 | 41.1 | 02-05 | 1.3 | 0.6 | 3.7 | 6 | Trout Bk at Haven St |
| TMDL | 447S | 447S | 44.7 | 02-05 | 4.5 | 1.8 | 12.3 | 8 | USGS Dover Gage below Cochrane Dam |
| | | | | | | | | | |
| IM3 | 35CS | 35CS | 3.5 | 96-06 | 4.2 | 0.0 | 50.0 | 33 | Central St Culvert |
| IM3 | 90CS | 90CS | 9 | 96-06 | 4.3 | 0.0 | 21.0 | 34 | N Main St / Rt 126 |
| IM3 | 199S | 199S | 19.9 | 96-06 | 14.3 | 2.0 | 64.0 | 17 | Populatic Pond |
| IM3 | 290S | 290S | 29 | 96-06 | 5.2 | 1.0 | 34.0 | 33 | Above Medfield WW |
| IM3 | 387S | 387S | 38.7 | 96-06 | 4.9 | 1.0 | 22.0 | 30 | Cheney Bridge |
| IM3 | 534S | 534S | 53.4 | 96-06 | 10.2 | 1.0 | 70.0 | 37 | Inlet Silk Mill Dam / Rt 109 |
| IM3 | 609S | 609S | 60.9 | 96-06 | 10.9 | 2.0 | 84.0 | 31 | Outlet Finlay Dam |
| IM3 | 662S | 662S | 66.2 | 96-06 | 12.5 | 1.0 | 67.0 | 36 | Outlet Moody St Dam |
| IM3 | 012S | 012S | 69.1 | 96-06 | 7.4 | 1.0 | 79.0 | 34 | Outlet Watertown Dam |
| | | | | | | | | | |
| MWRA | 012S | 012S | 69.1 | 97-06 | 7.5 | 0.6 | 47.0 | 370 | Outlet Watertown Dam |

▨ Average exceeds 10.0 µg/L or Maximum exceeds 18.9 µg/L

### *3.2.4 pH Data*

Table 9 summarizes the mean, minimum, and maximum pH data with the number of samples at each site for all the monitoring programs in the Upper/Middle Charles river watershed. The table is ordered by river mile from the top of the watershed. As previously noted the main stem wastewater discharge sites include the Milford WWTF (5.4 miles), CRPCD (20.2 miles), and the Medfield WWTF (29.3 miles).

Water column pH is also an indicator of eutrophic conditions. Like dissolved oxygen, a water body's pH can vary diurnally and typically increases during the daylight hours as carbon dioxide is taken up by photosynthesis and decreases at night when algal respiration releases carbon dioxide to the water. The changes in carbon dioxide concentrations affect the equilibria of the overall carbonate system thus causing changes in pH (US-EPA, 2007). During periods of excessive aquatic plant growth, pH values can often exceed 8.3, the maximum limit of the range of pH allowed in the MA Water Quality Standards.

The individual monitoring programs can be summarized as follows. Not all the sites in the IM3 program were summarized, only those that also had nutrient data.

1. CRWA TMDL Data (2002-2005) – 27 sites
   a. 2 sites (157T1, 157T2) had means less than the lower limit of 6.5
   b. 5 sites had minimums less than the lower limit
   c. 4 sites had maximums above the Upper/Middle limit of 8.3

2. CRWA IM3 Data (1996-2006) – 9 sites
   a. No sites had means less than the lower limit of 6.5
   b. 8 sites had minimums less than the lower limit
   c. 3 sites had maximums above the Upper/Middle limit of 8.3

3. MWRA Data (1997-2007) – 1 site
   a. Mean not less than lower limit of 6.5
   b. Minimum less than the lower limit
   c. Maximum above the Upper/Middle limit of 8.3

4. US-EPA Data (1998-2006) – 2 sites
   a. No sites had means less than the lower limit of 6.5
   b. 2 sites had minimums less than the lower limit
   c. No sites had maximums greater than the Upper/Middle limit of 8.3

5. MassDEP Data (2002)
   a. 2 sites (20CS, 88T) had means less than the lower limit of 6.5
   b. 5 sites had minimums less than the lower limit
   c. 1 site (20CS) had maximum less than the lower limit
   d. 1 site (374S) had maximum greater than the Upper/Middle limit of 8.3

# Table 9. pH Data from Upper/Middle Charles River Monitoring

| Name | CRWA ID | Site ID | River Mile | Years | Mean (-) | Min (-) | Max (-) | Num. Samples | Site Description |
|---|---|---|---|---|---|---|---|---|---|
| TMDL | 31CS | 31CS | 3.1 | 02-05 | 6.8 | 6.3 | 7.7 | 9 | Outlet Milford Pond |
| TMDL | 43T1 | 43T1 | 4.3 | 02-05 | 7.2 | 6.5 | 7.8 | 3 | Outlet Godfrey Brook |
| TMDL | 48CS | 48CS | 4.8 | 02-05 | 7.1 | 6.9 | 7.6 | 9 | Howard St below Godfrey Bk |
| TMDL | 59CS | 59CS | 5.9 | 02-05 | 7.1 | 6.8 | 7.6 | 9 | Mellen St |
| TMDL | 86CS | 86CS | 8.6 | 02-05 | 7.5 | 6.6 | 8.0 | 9 | Depot Rd |
| TMDL | 13CS | 13CS | 13 | 02-05 | 7.3 | 6.7 | 7.8 | 9 | Maple St |
| TMDL | 143S | 143S | 14.3 | 02-05 | 7.5 | 7.3 | 7.7 | 5 | Outlet Caryville Dam |
| TMDL | 148T | 148T | 14.8 | 02-05 | 7.1 | 6.6 | 8.3 | 7 | Hopping Bk at Hartford Ave / Rt 126 |
| TMDL | 156S | 156S | 15.6 | 02-05 | 7.2 | 6.7 | 7.4 | 7 | Inlet W Medway Dam |
| TMDL | 157T1 | 157T1 | 15.7 | 02-05 | 6.3 | 5.5 | 7.1 | 6 | Mine Bk at Pond St |
| TMDL | 157T2 | 157T2 | 15.7 | 02-05 | 6.0 | 5.5 | 6.9 | 5 | USGS Miscoe Bk Gage at South St |
| TMDL | 159S | 159S | 15.9 | 02-05 | 7.1 | 6.7 | 7.4 | 8 | Outlet W Medway Dam |
| TMDL | 159T | 159T | 15.9 | 02-05 | 6.9 | 6.2 | 7.9 | 6 | Chicken Brook at Cottage St |
| TMDL | 184S | 184S | 18.4 | 02-05 | 7.6 | 6.9 | 8.8 | 7 | USGS Medway Gage at Walker St |
| TMDL | 201S | 201S | 20.1 | 02-05 | 8.0 | 7.2 | 9.5 | 6 | Outlet Populatic Pd |
| TMDL | 207S | 207S | 20.7 | 02-05 | 7.6 | 7.2 | 8.3 | 6 | Below CRPCD WWTF |
| TMDL | 213T1 | 213T1 | 21.3 | 02-05 | 7.3 | 6.8 | 7.8 | 5 | Mill River at River Rd |
| TMDL | 229S | 229S | 22.9 | 02-05 | 7.4 | 7.1 | 7.8 | 6 | Baltimore St/115 |
| TMDL | 269T2 | 269T2 | 26.9 | 02-05 | 7.0 | 6.8 | 7.4 | 6 | Stop River at Noon Hill Rd |
| TMDL | 290S | 290S | 29 | 02-05 | 7.5 | 7.0 | 8.1 | 6 | Above Medfield WW |
| TMDL | 294S | 294S | 29.4 | 02-05 | 7.4 | 7.1 | 7.8 | 6 | Below Medfield WW |
| TMDL | 307T3 | 307T3 | 30.7 | 02-05 | 6.9 | 6.6 | 7.4 | 6 | Bogastow Bk at Ridge St |
| TMDL | 318S | 318S | 31.8 | 02-05 | 7.3 | 7.0 | 8.2 | 8 | S Main St / Rt 27 |
| TMDL | 387S | 387S | 38.7 | 02-05 | 7.3 | 7.0 | 7.5 | 8 | Cheney Bridge |
| TMDL | 393T1 | 393T1 | 39.3 | 02-05 | 7.2 | 6.7 | 7.7 | 7 | Fuller / Waban Brook confluence |
| TMDL | 407S | 407S | 40.7 | 02-05 | 7.5 | 7.1 | 8.5 | 9 | Claybrook Rd |
| TMDL | 411T2 | 411T2 | 41.1 | 02-05 | 6.8 | 6.3 | 7.6 | 7 | Trout Bk at Haven St |
| TMDL | 447S | 447S | 44.7 | 02-05 | 7.5 | 7.1 | 8.4 | 9 | USGS Dover Gage below Cochrane Dam |
| | | | | | | | | | |
| IM3 | 35CS | 35CS | 3.5 | 96-06 | 6.9 | 6.0 | 7.8 | 65 | Central St Culvert |
| IM3 | 90CS | 90CS | 9 | 96-06 | 7.2 | 6.1 | 7.9 | 64 | N Main St / Rt 126 |
| IM3 | 199S | 199S | 19.9 | 96-06 | 7.4 | 6.5 | 9.1 | 48 | Populatic Pond |
| IM3 | 290S | 290S | 29 | 96-06 | 7.0 | 6.1 | 8.1 | 59 | Above Medfield WW |
| IM3 | 387S | 387S | 38.7 | 96-06 | 7.2 | 6.2 | 8.0 | 65 | Cheney Bridge |
| IM3 | 534S | 534S | 53.4 | 96-06 | 7.3 | 6.2 | 8.9 | 72 | Inlet Silk Mill Dam / Rt 109 |
| IM3 | 609S | 609S | 60.9 | 96-06 | 7.2 | 6.3 | 8.1 | 68 | Outlet Finlay Dam |
| IM3 | 662S | 662S | 66.2 | 96-06 | 7.3 | 6.2 | 8.6 | 66 | Outlet Moody St Dam |
| IM3 | 012S | 012S | 69.1 | 96-06 | 7.1 | 6.3 | 7.4 | 59 | Outlet Watertown Dam |
| | | | | | | | | | |
| MWRA | 012S | 012S | 69.1 | 97-06 | 7.2 | 4.3 | 9.3 | 209 | Outlet Watertown Dam |
| | | | | | | | | | |
| DEP | 184S | W0414 | 18.4 | 02 | 7.2 | 6.2 | 8.3 | 18 | USGS Medway Gage at Walker St |
| DEP | 20CS | W1134 | 2 | 02 | 5.7 | 5.3 | 6.1 | 9 | Waterworks to Dilla Dam |
| DEP | 13CS | W1135 | 13 | 02 | 7.2 | 6.6 | 8.0 | 10 | Maple St |
| DEP | 219S | W1136 | 21.9 | 02 | 7.3 | 6.8 | 7.9 | 10 | Pleasant St |
| DEP | 318S | W1137 | 31.8 | 02 | 7.3 | 6.6 | 8.3 | 10 | S Main St / Rt 27 |
| DEP | 374S | W1138 | 37.4 | 02 | 7.3 | 6.6 | 8.5 | 10 | Inlet S Natick Dam |
| DEP | 609S | W1139 | 60.9 | 02 | 7.3 | 6.9 | 8.0 | 10 | Outlet Finlay Dam |
| DEP | 447S | W1141 | 44.7 | 02 | 7.2 | 6.8 | 7.9 | 10 | USGS Dover Gage below Cochrane Dam |
| DEP | 582T | W0399 | 58.2 | 02 | 6.8 | 6.6 | 7.0 | 17 | S Meadow Bk below Needham St |
| DEP | 548T | W0402 | 54.8 | 02 | 6.7 | 6.5 | 7.1 | 16 | Vine / Sawmill Bk above Baker St |
| DEP | 307T2 | W0423 | 30.7 | 02 | 6.8 | 6.5 | 7.1 | 10 | Bogastow Bk at Orchard St |
| DEP | 88T | W1142 | 8.8 | 02 | 6.4 | 6.1 | 6.6 | 9 | Outlet Beaver Brook |
| DEP | 668T | W1143 | 66.8 | 02 | 6.7 | 6.4 | 6.9 | 10 | Beaver Bk above Mill Pond |
| DEP | 269T2 | W1151 | 26.9 | 02 | 6.8 | 6.5 | 7.0 | 11 | Stop River at Noon Hill Rd |
| DEP | 469T | W1155 | 46.9 | 02 | 6.5 | 6.2 | 6.9 | 9 | Rock Meadow Bk at Dedham CC |
| DEP | 607T | W1156 | 60.7 | 02 | 6.7 | 6.5 | 7.1 | 10 | Rosemary Bk above Barton St |
| DEP | 642T | W1157 | 64.2 | 02 | 6.8 | 6.6 | 7.4 | 12 | USGS Stony Brook Gage below Reservoir |

░ Below pH 6.5

▓ Exceeds pH 8.3

### *3.2.5 Dissolved Oxygen Data*

Dissolved oxygen (DO) data were analyzed differently from the previous data sets. The statistics presented include the average diurnal DO range (mg/L), minimum DO (mg/L), and the maximum percent DO saturation (%). Diurnal DO range is given for information purposes only and is not used as a target. Only summary data from the TMDL DO measurements are presented. The TMDL sonde (identified as TMDLS in Table 10) measurements were made by deploying a DO sonde in selected river reaches for a number of days and were considered the highest priority so all sites are summarized. The TMDL diurnal range (identified as TMDLD in Table 10) measurements were made early morning and mid-afternoon at selected sites and are only summarized for sites not in the TMDLS data set. The remaining TMDL DO measurements (TMDL) were made at the time that the water quality samples were collected and are only summarized for sites not in the TMDLS and TMDLD data sets.

Table 10 summarizes the above statistics with the number of samples for DO at each site for all the monitoring programs in the Upper/Middle Charles river watershed. The table is ordered by river mile from the top of the watershed. For reference, the main stem wastewater discharge sites are the Milford WWTF (5.4 miles), CRPCD (20.2 miles), and the Medfield WWTF (29.3 miles).

About half of the DO mean diurnal ranges exceed 2.0 mg/L. These sites were selected to be critical slow-moving sites for DO fluctuation so other river reaches will have less diurnal range. Minimum DO was observed to fall to less than the 5 mg/L standard primarily in selected tributaries. About one-third of the maximum DO saturation values exceeded the 125% guidance value.

The individual monitoring programs can be summarized as follows:

1) CRWA TMDLS Data (2002) – 12 sites
    a) 1 site (31CS) had minimum DO below the minimum limit (5.0 mg/L)
    b) 4 sites had maximum DO saturation greater than 125 %

2) CRWA TMDLD Data (2005) – 14 sites excluding TMDLS sites
    a) 1 site (157T1) had minimum DO below the minimum limit of 5.0 mg/L
    b) 1 site had maximum DO saturation greater than 125%

3) CRWA TMDL Data (2002-2005) – 9 sites excluding TMDLS/TMDLD sites
    a) 4 tributary sites had minimum DO below the minimum limit (5.0 mg/L)
    b) 1 site (294S) had maximum DO saturation greater than 125%

4) MassDEP Data (2002) – 16 sites
    a) 8 tributary and 2 main stem sites had minimum DO below the minimum limit (5.0 mg/L)
    b) 3 sites had maximum DO saturation greater than 125%

5) MRWA (1997-2007) – 1 site
    a) No DO data

# Table 10. Dissolved Oxygen Data from Upper/Middle Charles Monitoring

| Name | CRWA ID | Site ID | River Mile | Years | Mean DO Diff (mg/L) | Min DO (mg/L) | Max DOsat (%) | Num. Samples | Site Description |
|---|---|---|---|---|---|---|---|---|---|
| TMDLS | 00CS | 00CS | 0 | 02 | 0.5 | 7.8 | 106.1 | 5 | Outlet Echo Lake |
| TMDLS | 31CS | 31CS | 3.1 | 02 | 0.1 | 2.0 | 44.0 | 5 | Outlet Milford Pond |
| TMDLS | 85CS | 85CS | 8.5 | 02 | 2.2 | 8.85 | 153.3 | 7 | Outlet Box Pond |
| TMDLS | 129S | 129S | 12.9 | 02 | 3.4 | 5.3 | 122.6 | 5 | Outlet N Bellingham Dam |
| TMDLS | 159S | 159S | 15.9 | 02 | 2.2 | 5.8 | 102.5 | 5 | Outlet W Medway Dam |
| TMDLS | 178S | 178S | 17.8 | 02 | 1.2 | 5.6 | 99.0 | 7 | Outlet Medway Dam |
| TMDLS | 201S | 201S | 20.1 | 02 | 3.5 | 8.8 | 162.7 | 4 | Outlet Populatic Pd |
| TMDLS | 207S | 207S | 20.7 | 02 | 3.5 | 8.0 | 152.7 | 4 | Below CRPCD WWTF |
| TMDLS | 269S | 269S | 26.9 | 02 | 2.2 | 6.8 | 113.9 | 5 | Above Stop River |
| TMDLS | 318S | 318S | 31.8 | 02 | 0.4 | 7.0 | 127.4 | 5 | S Main St / Rt 27 |
| TMDLS | 378S | 378S | 37.8 | 02 | 0.9 | 5.8 | 117.6 | 6 | Outlet S Natick Dam |
| TMDLS | 444S | 444S | 44.4 | 02 | 0.8 | 6.3 | 101.5 | 6 | Outlet Cochrane Dam |
| | | | | | | | | | |
| TMDLD | 43T1 | 43T1 | 4.3 | 05 | -0.2 | 7.79 | 89.9 | 1 | Outlet Godfrey Brook |
| TMDLD | 48CS | 48CS | 4.8 | 05 | -0.1 | 5.11 | 67.6 | 2 | Howard St below Godfrey Bk |
| TMDLD | 59CS | 59CS | 5.9 | 05 | 2.0 | 6.42 | 102.5 | 2 | Mellen St |
| TMDLD | 86CS | 86CS | 8.6 | 05 | 0.2 | 5.81 | 80.6 | 2 | Depot Rd |
| TMDLD | 13CS | 13CS | 13 | 05 | 3.7 | 7.3 | 134.7 | 1 | Maple St |
| TMDLD | 143S | 143S | 14.3 | 05 | 0.0 | 6.59 | 80.8 | 2 | Outlet Caryville Dam |
| TMDLD | 148T | 148T | 14.8 | 05 | -0.1 | 6.55 | 74.1 | 1 | Hopping Bk at Hartford Ave / Rt 126 |
| TMDLD | 156S | 156S | 15.6 | 05 | 1.6 | 7.17 | 106.5 | 1 | Inlet W Medway Dam |
| TMDLD | 157T1 | 157T1 | 15.7 | 05 | 2.1 | 4.75 | 82.9 | 1 | Mine Bk at Pond St |
| TMDLD | 159T | 159T | 15.9 | 05 | -0.2 | 6.49 | 74.4 | 1 | Chicken Brook at Cottage St |
| TMDLD | 184S | 184S | 18.4 | 05 | 0.5 | 8.12 | 105.9 | 2 | USGS Medway Gage at Walker St |
| TMDLD | 229S | 229S | 22.9 | 05 | 2.2 | 6.83 | 104.5 | 1 | Baltimore St/115 |
| TMDLD | 290S | 290S | 29 | 05 | 0.7 | 8.42 | 109.2 | 1 | Above Medfield WW |
| TMDLD | 447S | 447S | 44.7 | 05 | 1.2 | 8.34 | 114.9 | 1 | USGS Dover Gage below Cochrane Dam |
| | | | | | | | | | |
| TMDL | 157T2 | 157T2 | 15.7 | 02-05 | - | 2.7 | 66.8 | 6 | USGS Miscoe Bk Gage at South St |
| TMDL | 213T1 | 213T1 | 21.3 | 02-05 | - | 4.2 | 109.9 | 5 | Mill River at River Rd |
| TMDL | 269T2 | 269T2 | 26.9 | 02-05 | - | 4.2 | 82.9 | 5 | Stop River at Noon Hill Rd |
| TMDL | 294S | 294S | 29.4 | 02-05 | - | 5.8 | 128.7 | 7 | Below Medfield WW |
| TMDL | 307T3 | 307T3 | 30.7 | 02-05 | - | 4.1 | 111.3 | 6 | Bogastow Bk at Ridge St |
| TMDL | 387S | 387S | 38.7 | 02-05 | - | 5.3 | 81.6 | 8 | Cheney Bridge |
| TMDL | 393T1 | 393T1 | 39.3 | 02-05 | - | 6.3 | 120.2 | 6 | Fuller / Waban Brook confluence |
| TMDL | 407S | 407S | 40.7 | 02-05 | - | 5.9 | 101.8 | 8 | Claybrook Rd |
| TMDL | 411T2 | 411T2 | 41.1 | 02-05 | - | 5.0 | 86.6 | 6 | Trout Bk at Haven St |
| | | | | | | | | | |
| DEP | 20CS | W1134 | 2 | 02 | - | 1.6 | 97.5 | 9 | Waterworks to Dilla Dam |
| DEP | 88T | W1142 | 8.8 | 02 | - | 4.9 | 90.2 | 9 | Outlet Beaver Brook |
| DEP | 13CS | W1135 | 13 | 02 | - | 5.6 | 127.6 | 10 | Maple St |
| DEP | 184S | W0414 | 18.4 | 02 | - | 7.3 | 123.1 | 10 | USGS Medway Gage at Walker St |
| DEP | 219S | W1136 | 21.9 | 02 | - | 7.0 | 122.1 | 10 | Pleasant St |
| DEP | 269T2 | W1151 | 26.9 | 02 | - | 3.0 | 111.6 | 11 | Stop River at Noon Hill Rd |
| DEP | 307T2 | W0423 | 30.7 | 02 | - | 5.2 | 90.9 | 10 | Bogastow Bk at Orchard St |
| DEP | 318S | W1137 | 31.8 | 02 | - | 6.7 | 133.1 | 10 | S Main St / Rt 27 |
| DEP | 374S | W1138 | 37.4 | 02 | - | 2.7 | 131.9 | 10 | Inlet S Natick Dam |
| DEP | 447S | W1141 | 44.7 | 02 | - | 3.7 | 105.0 | 10 | USGS Dover Gage below Cochrane Dam |
| DEP | 469T | W1155 | 46.9 | 02 | - | 0.5 | 88.5 | 9 | Rock Meadow Bk at Dedham CC |
| DEP | 548T | W0402 | 54.8 | 02 | - | 2.2 | 89.3 | 10 | Vine / Sawmill Bk above Baker St |
| DEP | 582T | W0399 | 58.2 | 02 | - | 3.5 | 75.0 | 9 | S Meadow Bk below Needham St |
| DEP | 607T | W1156 | 60.7 | 02 | - | 3.6 | 80.0 | 10 | Rosemary Bk above Barton St |
| DEP | 609S | W1139 | 60.9 | 02 | - | 5.6 | 117.5 | 10 | Outlet Finlay Dam |
| DEP | 642T | W1157 | 64.2 | 02 | - | 5.5 | 91.0 | 9 | USGS Stony Brook Gage below Reservoir |
| DEP | 668T | W1143 | 66.8 | 02 | - | 4.4 | 84.8 | 10 | Beaver Bk above Mill Pond |

▨ Minimum DO below 5.0 mg/L or DO Saturation exceeds 125%

In addition, CRWA measured both the horizontal and vertical variability of DO at the TMLDS sites by performing five depth profiles across each impoundment. In general, the sites could be divided into two categories - uniform profile versus non-uniform profile. Sites such as Populatic Pond (201S), Echo Lake (00CS), Milford Pond (31CS), below CRPCD WWTF outfall (207S), and Box Pond (85CS) had non-uniform profiles with significant decreases of DO concentrations (greater than 2.0 mg/L) and temperature with increasing water depth (CRWA, 2004). Echo Lake is a very deep and clean water body so this decrease in DO is probably due to vertical stratification and inadequate mixing or lack of light penetration and subsequent drop in photosynthetic activity. The sediment oxygen demand was high at the other sites (CRWA, 2006). Many of these sites also violated the minimum DO standard at depths greater than three feet. In contrast, West Medway Dam, South Natick Dam, South Main St./Rte. 27 in Medfield (318S) Cochrane Dam, Stop River/Charles River confluence, North Bellingham Dam and Medway Dam showed more uniform profiles of DO concentrations and temperature, indicating they are well-mixed impoundments with minimal stratification and/or sediment oxygen demand.

### *3.2.6 Flow Data*

Flow data for the Upper/Middle Charles River watershed were obtained from the United States Geological Survey (USGS), American National Power (ANP), and Charles River Watershed Association (CRWA). Figure 4 shows all of the Upper/Middle watershed streamflow monitoring locations.

USGS operates a number of streamflow gauges in the Upper/Middle watershed of which five mainstem gauges and three tributary gauges were used in this study. American National Power measures streamflow at a railroad bridge near South Howard Street, just upstream of the Mellon Street bridge in Milford (IM3/TMDL Site 59CS). See Table 11 for a list of USGS and ANP streamflow monitoring stations.

CRWA also installed and operated nine tributary gauges for this study (Table 11). Rating curves were developed at each site by simultaneously measuring streamflow and water levels under different flow regimes. In 2002, CRWA installed depth loggers at the tributaries to measure water level and streamflow continuously.

More information about streamflow monitoring methodology and data collected for the Upper/Middle TMDL is available from the Phase I Final Report (CRWA, 2004) and the Phase II Final / Phase III Data Report (CRWA, 2006).

### *3.2.7 Ponds and Impoundments*

As part of the Upper/Middle Charles River TMDL Project, CRWA performed several studies in the nine ponds and impoundments in the Upper/Middle watershed with a summary of results listed in Table 12. More details are provided in the project data reports (CRWA, 2003a; 2006).

## Table 11. Streamflow Monitoring Stations in the Upper/Middle Charles

| Name | Site ID | River Mile | Years | River / Tributary | Communities | Station Description |
|---|---|---|---|---|---|---|
| ANP | 55CS | 5.5 | 95-05 | Charles River | Hopedale/Milford | Milford ANP Gage below WWTF |
| USGS | 157T2 | 15.7 | 97-05 | Miscoe Brook | Franklin/Medway | USGS Miscoe Bk Gage at South St |
| USGS | 184S | 18.4 | 97-05 | Charles River | Medway | USGS Medway Gage at Walker St |
| USGS | 447S | 44.7 | 37-05 | Charles River | Dover/Needham | USGS Dover Gage below Cochrane Dam |
| USGS | 524T | 52.4 | 31-05 | Mother Brook | Dedham | USGS Mother Bk gage/discharge at Rt 1 |
| USGS | 591S | 59.1 | 59-05 | Charles River | Newton/Wellesley | USGS Wellesley Gage, outlet Circular Dam |
| USGS | 642T | 64.2 | 99-05 | Stony Brook | Waltham | USGS Stony Brook Gage below Reservoir |
| USGS | 666S | 66.6 | 31-05 | Charles River | Waltham | USGS Waltham Gage |
| | | | | | | |
| CRWA | 148T | 14.8 | 02-05 | Hopping Brook | Bellingham | Hopping Bk at Hartford Ave / Rt 126 |
| CRWA | 157T1 | 15.7 | 02-05 | Mine Brook | Franklin/Medway | Mine Bk at Pond St |
| CRWA | 159T | 15.9 | 02-05 | Chicken Brook | Franklin/Medway | Chicken Brook at Cottage St |
| CRWA | 213T1 | 21.3 | 02-05 | Mill River | Millis/Norfolk | Mill River at River Rd |
| CRWA | 269T2 | 26.9 | 02-05 | Stop River | Medfield | Stop River at Noon Hill Rd |
| CRWA | 307T3 | 30.7 | 02-05 | Bogastow Brook | Millis | Bogastow Bk at Ridge St |
| CRWA | 393TW2 | 39.3 | 02-05 | Waban Brook | Wellesley | Waban Brook at Dirt Rd off Service Dr |
| CRWA | 393TF2 | 39.3 | 02-05 | Fuller Brook | Wellesley | Fuller Brook at Dover St |
| CRWA | 411T2 | 41.1 | 02-05 | Trout Brook | Dover | Trout Bk at Haven St |

The studies included a bathymetry and sediment thickness survey, an aquatic plant survey, and a sediment nutrient flux and oxygen demand study. Water volume, plant biovolume (water volume occupied by plants), and nutrient efflux rates from sediments were used as inputs to the TMDL model. Aquatic plants extent and biovolume were used to assess aesthetic and designated use impacts. High biovolume means that the water column is choked with plants and could have impaired recreational use, lowered aesthetic value, and low and/or variable DO.

## Table 12. Pond and Impoundment Data in the Upper/Middle Charles

| Site ID | Description | Area (ac) | Water (ft) | Sed-iments (ft) | Bio-volume (%) | Top Biovolumes Species |
|---|---|---|---|---|---|---|
| 31CS | Milford Pond | 118.4 | 2.0 | 5.4 | 50.2 | Variable milfoil, White water lily, Cattail |
| 85CS | Box Pond | 42.6 | 2.3 | 1.2 | 33.8 | Algae-floating, Waterweed, Floating-leafed pondweed |
| 129S | North Bellingham Dam | 3.3 | 1.0 | 0.9 | 29.8 | Phragmites, Burreed-emergent, Purple loosestrife |
| 143S | Caryville Dam | 6.1 | 1.2 | 0.5 | 38.0 | Phragmites, Cattail, Waterweed |
| 159S | West Medway Dam | 11.8 | 2.0 | 0.8 | 12.7 | Purple loosestrife, Waterweed, Pondweed |
| 178S | Medway Dam | 4.9 | 3.0 | 0.3 | 0.0 | Purple loosestrife, Yellow water lily, Pickerelweed |
| 201S | Populatic Pond | 49.1 | 5.7 | 5.4 | 2.2 | Algae-submerged, Algae-floating, Yellow water lily |
| 378S | South Natick Dam | 13.5 | 3.5 | 1.0 | 6.5 | Coontail, Big-leaf pondweed, Algae-floating |
| 444S | Cochrane Dam | 10.4 | 4.5 | 0.8 | 7.1 | Algae-floating, White water lily, Purple loosestrife |

Biovolume decreased downstream from 50% at Milford Pond to 0% at the Medway Dam then increased again to 7.1% at the Cochrane Dam. Milford Pond, the largest pond in area, had the highest percent biovolume of aquatic plants. The small impoundment upstream of Caryville Dam in Bellingham was also densely vegetated with a percent biovolume of 38%. The large Box Pond and the small impoundment upstream of North Bellingham Dam also had extensive vegetation throughout them with percent biovolumes of 34% and 30%, respectively. The remaining five sites had percent biovolumes ranging from 0% at Medway Dam to 12.7% at West Medway Dam. The impoundment upstream of Medway Dam was sparsely vegetated, which may have been largely due to the small volume of sediments and deep waters as compared to the other sites.

Twenty-three different species of vegetation were identified in Milford Pond with the top three biovolume species being variable milfoil (*Myriophyllum heterophyllum)*, white water lily (*Nymphaea odorate*), and cattail (*Typha sp.)*. The top plant species near Caryville Dam were common reed (*Phragmites australis*), cattail (*Typha sp.)* and waterweed (*Elodea nuttallii)*. The top three plant species found throughout Box Pond were algae-floating (*Lyngbya sp.*), waterweed (*Elodea nuttallii)*, and floating-leafed pondweed (*Potamogeton natans*) and common reed (*Phragmites australis*), burreed-emergent (*Sparganium sp.*), and purple loosestrife (*Lythrum salicaria*) were observed near North Bellingham Dam. Purple loosestrife (*Lythrum salicaria*) and algae-floating (*Lyngbya sp.*) were observed in three out of the five remaining sites.

Box Pond, Populatic Pond, and Cochrane Dam had significant quantities of floating algae while Populatic Pond also had significant areas of submerged algae. Floating and submerged algae can have large diurnal effects on dissolved oxygen concentrations over and above those caused by algae in the water column as measured by chlorophyll-*a*. Macrophytes and periphyton (attached or floating algae) can also sequester large amounts of phosphorus from the water column during the growing season and release it later when they senesce.

### *3.2.8 Aesthetics and Fisheries*

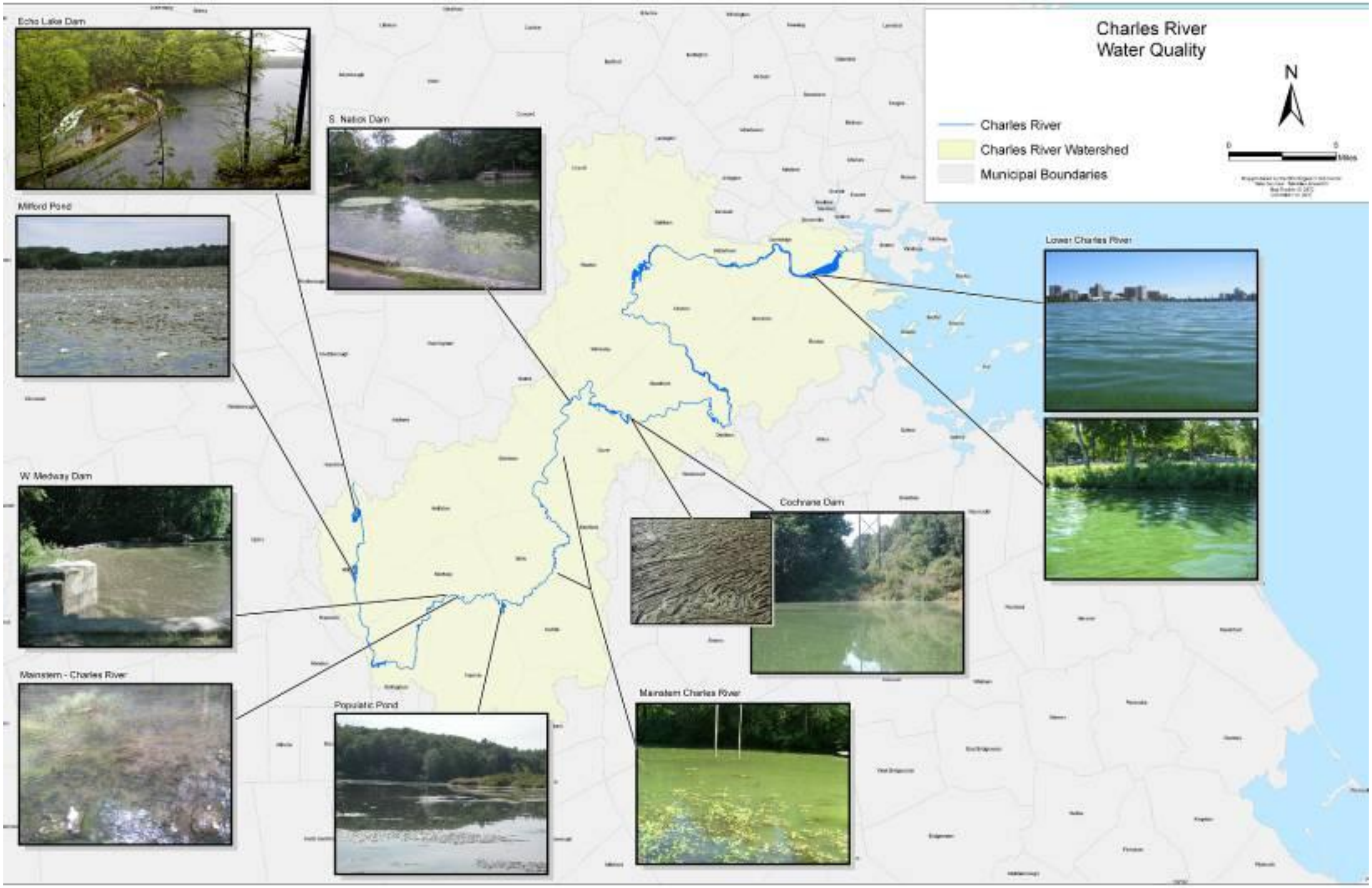
Sections of the Upper/Middle Charles River watershed, especially in the ponds and impoundments, have poor aesthetic quality. This poor quality is largely a result of nutrients and other pollutants that cause objectionable algal blooms, deposits, and scum. Excessive biomass often produces objectionable odors, color and turbidity. These conditions support less desirable species of aquatic life and contribute to non-attainment of Massachusetts WQS by impairing designated uses.

As part of the Nutrient TMDL for the Lower Charles River, the relationship between algae levels and aesthetic impacts were evaluated through the review of user perception-based studies conducted in other water bodies. Most of the studies reviewed for the Lower Charles TMDL indicated that chlorophyll-*a* concentration higher than 20 µg/L have consistently resulted in perceived aesthetic impairments among users (US-EPA, 2007). Individual chlorophyll-*a* measurements greater than 20 µg/L have been consistently measured each summer in the Upper/Middle watershed and more frequently in the Lower Charles.

The extensive nature of aquatic plants in the Upper/Middle watershed can create an unattractive appearance of the river. This situation is observed in Populatic Pond, where although percent plant biovolume was very low (2%), algae scum was prevalent throughout the pond in the summertime. Dense stands of aquatic plants can also impede recreational passage in the river, for example, in any of the Upper/Middle four impoundments. Figure 5 shows photographs of the type and extent of aquatic plants in some areas of the Charles River watershed. Aquatic plants also directly affect water clarity since they obstruct light penetration and contribute to turbidity. Although water clarity was not quantified using a Secchi disk, CRWA has observed high turbidity in the river on numerous occasions in the summer and early fall.

Sediments also have a significant impact on aesthetics in the river. Sediments are deposited onto the river bottom creating thick, mucky and obnoxious conditions. At several locations including Milford Pond, Box Pond, Populatic Pond, and South Natick Dam, mean sediment depths were measured to range between one to five feet deep. Upon disturbance of the bottom sediments, turbidity increases in the surrounding water column and objectionable odors may be emitted.

Impaired river water quality has created poor habitat for fish affecting the types and numbers of fish found in the river. A recent study by Massachusetts Division of Fish and Wildlife and CRWA found that 98% of the fish in the river are comprised of macrohabitat generalists, fish species that can live in a wide range of habitats including lakes, streams and reservoirs and do not require free-flowing water for any part of their life cycle (CRWA, 2003b). Examples of common macrohabitat generalists in the Charles River are common carp, largemouth bass, and redbreast sunfish. Many of these macrohabitat generalist species are also considered to be pollutant tolerant species (MassWildlife, 2009).



a) *Spatial Extent of the Problem*

**Figure 5. Photographs of Degraded Water Quality in the Charles River Watershed (05-07)**

*b) White water lilies in Milford Pond in September 2005*

*c) Phragmites and cattails above Caryville Dam in September 2007*

**Figure 5. Degraded Water Quality in the Upper/Middle Charles (05-07) (cont.)**

*d) Floating algae above South Natick Dam in August 2007*

*e) Dense floating algae and duckweed above Cochrane Dam in September 2005*

**Figure 5. Degraded Water Quality in the Upper/Middle Charles (05-07)**

# 4 WATER QUALITY SUMMARY AND TARGETS

## 4.1 Pollutant of Concern

Phosphorus or nitrogen, two primary plant nutrients, may limit or control aquatic plant growth depending on their relative amounts in the aquatic system. Other environmental factors, such as light penetration, temperature, and residence time, may also play a role in plant growth. While phosphorus and nitrogen are both nutrients, phosphorus generally is the one judged to be limiting in freshwater (see Section 3.2.1). Some organisms can convert atmospheric nitrogen into a useable form of nitrogen thereby creating a nearly limitless supply.

To identify which nutrient is a 'limiting' factor that controls aquatic plant growth, the ratios of the total nitrogen (TN) and total phosphorus (TP) can be calculated. A typical biomass ratio of nitrogen to phosphorus is approximately 7.2 by weight (Chapra, 1997). A TN:TP ratio less than 7.2 suggests that nitrogen is the limiting factor while a ratio higher than 7.2 indicates that phosphorus will limit plant growth.

Available phosphorus and nitrogen data for the Upper/Middle Charles (Section 3) yielded ratios of TN:TP of 18.3–178 for the TMDL program and 3.65-145 for the IM3 data. From these ratios one can conclude that phosphorus is the limiting nutrient and the pollutant of concern for this nutrient TMDL.

## 4.2 Phosphorus Sources and Loads

Although phosphorus is ubiquitous in the natural environment, additional inputs to a watershed come from combined sewer overflows (CSOs), wastewater discharges, stormwater runoff, accumulated organic sediments on the river bottom, and some groundwater sources. There are no known CSOs in the Upper/Middle Charles study area and groundwater sources of phosphorus, including septic tank return flows from functioning systems, are normally very small because phosphorus is highly adsorbed to soil.

The primary human sources of phosphorus in the Upper/Middle Charles are wastewater, stormwater, and benthic sediments. Treated municipal wastewater is discharged from wastewater treatment facilities (WWTFs) that are regulated by the MassDEP and US-EPA National Pollutant Discharge Elimination System (NPDES) permits. Stormwater runoff occurs during rainfall or snowmelt events and conveys phosphorus from land surfaces to the river system. In the fall, dead plant material and algae settle to the river bottom and the following growing season these benthic sediments release nutrients through organic decay.

The three largest WWTFs (flows reported here for 1998-2002) are on the mainstem of the Charles and include the Milford WWTF (3.5 mgd), the Charles River Pollution Control District or CRPCD in Medway serving four communities (4.4 mgd), and the Medfield WWTF (1.0 mgd). Part of the Milford discharge (0.34 mgd) is used consumptively for cooling by the Milford American National Power Plant. The three smaller WWTFs are on the Stop River and include the Caritas Hospital which ceased discharging in 2003 (0.02 mgd), the Massachusetts Correctional Institution at Norfolk (0.4 mgd), and the Wrentham Development Center (0.1 mgd). Phosphorus from wastewater discharges are mainly in the form of orthophosphate (50-80%) which is highly available for aquatic growth. Discharge is continuous so the impact is augmented in the summertime when river flows are low (less dilution) and water temperatures are high (high aquatic plant growth rates). Permitted summer limits for phosphorus discharge were lowered to 0.2 mg/L in late 2000 and winter limits of 1.0 mg/L were imposed for all but one treatment plant in 2005.

Stormwater runoff occurs from rainfall or snowmelt events when the infiltration capacity of the surface is exceeded. Much of the stormwater runoff originates from impervious surfaces like rooftops, driveways, and roadways but stormwater runoff may also come from vegetated areas, especially if the soil is compacted or saturated. The stormwater runoff carries phosphorus that is adsorbed to sediment and dissolved in the water, and might also come from wastewater sources. Wastewater enters the stormwater system illicitly via wastewater pipes that incorrectly connected to the stormwater drainage system.

Many human activities exacerbate the level of phosphorus in stormwater─ lawn fertilizers; car wash products; vegetative debris such as lawn clippings; some detergents; car exhaust and other oil byproducts, and pet waste. Urbanized zones have large extents of impervious area that produce considerable volumes of stormwater runoff that are directly connected to surface waters. Intensity of development increases phosphorus loads from stormwater both through the increase in impervious area and also the intensity of the land use. High density residential and commercial or industrial activities have higher phosphorus loads than low or medium density residential land uses (Horner et al, 1994).

Organic benthic sediment accumulates at the end of the growing season when aquatic plants senesce and settle to the bottom of the river creating a potential source of nutrients that are re-released the following growing season when the organic matter begins to decay with the increase in water temperature. Years of accumulation of organic matter on the river bottom, especially if the historic period had high phosphorus discharges from WWTFs, can create a significant source of nutrients that can be released to the water column long after the water column has been cleaned up.

Losses of phosphorus throughout the system include diversions and internal transient losses like uptake and settling. Streamflow is diverted from the Charles River at Mother Brook into the Neponset River for flood control purposes. The diversions averages about 38 mgd and can result in significant reductions in phosphorus load at the Watertown Dam outlet, especially during the high-flow periods when releases are highest. Internal growth processes result in phosphorus loss via uptake by phytoplankton and benthic algae during the growing season and a phosphorus gain at the end of the growing season from respiration and settling.

An analysis of Upper/Middle Charles total loads and losses was performed for the period 1998-2002 using the calibrated HSPF model. The predicted phosphorus loads were summed over the summer months (Apr-Oct, lb/period) and the full year (Jan-Dec, lb/yr). This five-year period was chosen to match the period used for the load calculations in the Lower Charles TMDL. All flows mentioned in this section are also for that period.

The total wastewater phosphorus load to the Upper/Middle watershed was estimated by summing the daily loads from the six WWTFs. The daily load time series were created from actual daily flows and daily concentrations estimated between measurements using step interpolation. The product of flow and concentration gave the daily load for each WWTF. Daily loads (lbs/d) were then summed to get summer, winter, and annual loads. The final wastewater loads were then converted to metric units (kg/time period).

The total stormwater phosphorus load to the Upper/Middle watershed was estimated from the hydrologic response units (HRUs) by using the calibrated HSPF model to generate the monthly phosphorus loads for groundwater and surface runoff components then accumulating across months and HRUs. Since sediments were not simulated explicitly in the HSPF, the dissolved nutrient components were used to predict the combined dissolved and particulate loads for runoff. The model generated monthly HRU loads (lb/ac/month) for orthophosphate (PO4-P) and degradable organic matter represented by biochemical oxygen demand (BOD) for the 21 pervious HRUs (3 soils x 7 land uses) and the two impervious HRUs (residential and commercial). Monthly total phosphorus (TP) loads for each HRU were calculated as the sum of the PO4-P, labile organic P (BOD/165.8), and refractory organic P (0.5*BOD/165.8) loads. Stormwater TP loads for the summer, winter, and annual (lb/period) periods were calculated using the HRU loads (lb/ac/month) and HRU areas (ac) and summing across the months and HRUs. The final stormwater loads were then converted to metric units (kg/period).

The predicted loads of total phosphorus from the Watertown Dam and Mother Brook were estimated from the hourly flow (cfs) and hourly loads (lb/hr) of PO4-P and TORP (total organic phosphorus) and converted to kg/period or kg/yr. Other total phosphorus loads and losses were also estimated from the HSPF model by turning on/off certain model components. Sources are comprised of atmospheric deposition, benthic sediment release, stormwater, and wastewater while losses are from algae uptake and settling, and diversions. The final loads and losses for the summer (Apr-Oct), winter (Nov-Mar), and whole year are summarized in Table 13. The simulated annual outlet phosphorus load from the Watertown Dam was 28,262 kg/yr which is close to the measured load of 28,925 kg/yr (EPA, 2007; CRWA, 2009).

**Table 13. Calibration Phosphorus Loads and Losses in the Upper/Middle Charles (98-02)**

| **TP Loads (kg/yr)** | | | | | |
|---|---|---|---|---|---|
| **Period** | **Atmos. Deposition** | **Sed Release** | **Stormwater** | **Wastewater** | **Total** |
| Apr-Oct | 162 | 982 | 16,454 | 3,333 | 20,931 |
| Nov-Mar | 154 | 1,377 | 14,480 | 4,518 | 20,529 |
| Annual | 316 | 2,359 | 30,934 | 7,851 | 41,460 |
| **TP Losses (kg/yr)** | | | | | |
| **Period** | **Benth Algae** | **Settling** | **Mother Brook** | **Watertown Dam** | **Total** |
| Apr-Oct | 6 | 5,250 | 2,238 | 13,273 | 20,767 |
| Nov-Mar | 15 | 3,208 | 2,359 | 14,989 | 20,571 |
| Annual | 21 | 8,458 | 4,597 | 28,262 | 41,338 |

Figure 6 shows an annual breakdown of the sources. Stormwater load is the largest source (74%) and includes both developed (48%) and background (forested) stormwater load (26%). Wastewater is 19% and benthic sediment is 6% while atmospheric deposition contributes only 1% of the total source load. Winter wastewater loads were a higher percentage of the total load than summer (22% vs. 16%) because of the higher winter discharge limits for phosphorus. Correspondingly, stormwater loads were a slightly higher percentage in the summer (78%) than the winter (70%).

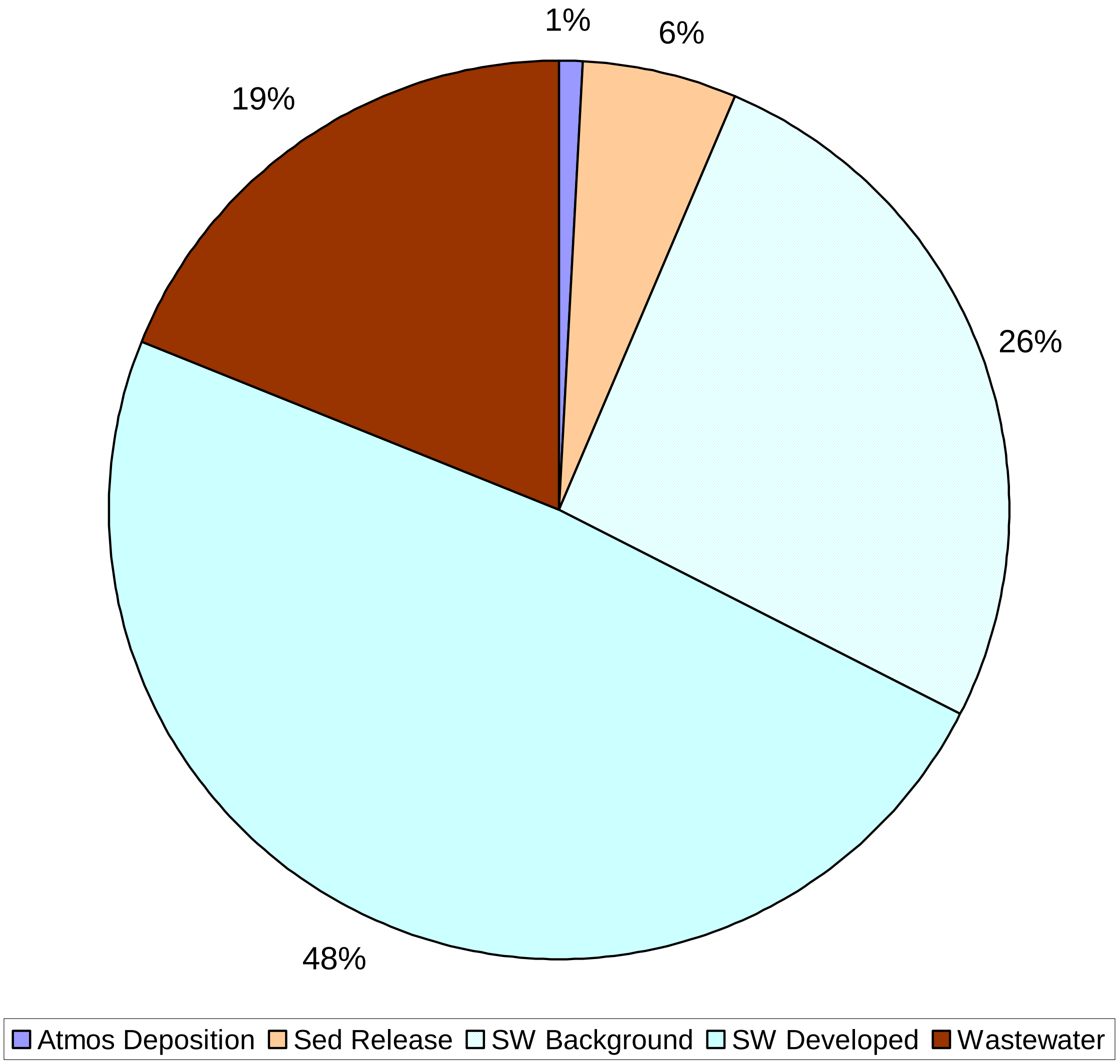


**Figure 6. Phosphorus Loads in the Upper/Middle Charles (98-02)**

Figure 7 shows the monthly variation of the principal source loads from stormwater and wastewater. The stormwater nutrient loads are highest in the spring and early summer when the soils are wettest and runoff occurs readily with any rainfall event. Although significant runoff events can occur during any wet period in the summer, they are much more likely to occur in the spring. The phosphorus nutrient load from WWTFs is usually highest in the winter and lowest in the summer. This pattern occurs because both the waste flows and permitted effluent concentrations are low in the summer. Waste flow variation is governed mostly by groundwater infiltration into the pipes and the groundwater levels follow the same seasonal pattern as streamflow, highest in the winter/spring and lowest in the summer/fall. Permitted phosphorus effluent concentrations are highest in the winter and lowest in the summer.

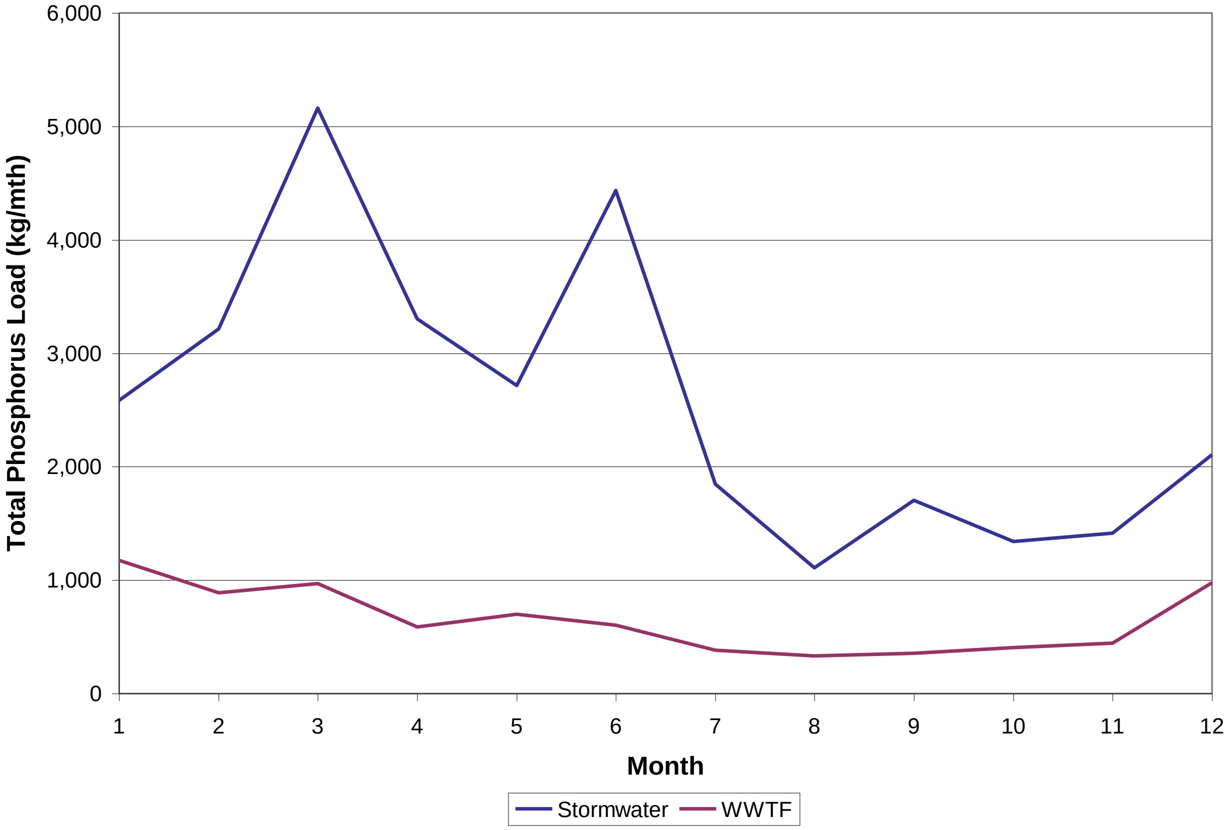


**Figure 7. Monthly Trends of Key Phosphorus Loads in the Upper/Middle Charles (98-02)**

Table 14 partitions the total predicted stormwater load for the Upper/Middle Charles TMDL by land use and perviousness then compares the loads to the Lower Charles TMDL. The Lower TMDL used literature-based export coefficients (Horner, 1994) and adjusted these coefficients to match the total observed watershed phosphorus load. In general, these Lower TMDL loads were lower than those used in the Upper/Middle TMDL because the Lower Charles TMDL model used the measured load input at the Watertown Dam. As such it did not have to consider additional losses that were occurring in the Upper/Middle sections of the system. Therefore in order to account for upstream losses and still match the measured load at the Watertown Dam further adjustments to the final phosphorus export coefficients were necessary and are provided in Table 14. In general, the final export coefficients for the Upper/Middle TMDL were the lowest for Water/Wetland and Forest, intermediate for Open/Agriculture, increasing from Low Density Residential to High Density Residential, and highest for Commercial/Industrial. The same export coefficient for impervious area is repeated for all three residential categories because only one HRU is used in the HSPF model for all residential impervious areas. The adjusted export coefficients for impervious fractions of the land use fall well within the range of values cited in the literature for urban (0.19-6.23 kg/ha/yr), commercial (0.1-7.6 kg/ha/yr) and industrial (0.4-4.1 kg/ha/yr) land uses (Loehr et. al. 1989, US-EPA 1983).

**Table 14. Stormwater Phosphorus Loads by Land Use and TMDL (98-02)**

| Land Use | TP Load (kg/yr) | | TP Load (kg/ha/yr) | |
|---|---|---|---|---|
| | Upper/Middle | Lower | Upper/Middle | Lower |
| Open/Agric | 1,504 | 1,441 | 0.24 | 0.17 |
| Forest | 3,656 | 4,130 | 0.17 | 0.13 |
| Forested Wetland | 738 | - | 0.13 | - |
| Water/Wetland | 126 | 0 | 0.12 | 0.00 |
| Low Density Res | 4,979 | 520 | 0.38 | 0.05 |
| Pervious | 3,995 | - | 0.31 | - |
| Impervious | 985 | - | 2.22 | - |
| Medium Density Res | 5,505 | 3,826 | 0.62 | 0.57 |
| Pervious | 4,225 | - | 0.50 | - |
| Impervious | 1,280 | - | 2.22 | - |
| High Density Res | 5,029 | 5,674 | 1.11 | 1.13 |
| Pervious | 2,730 | - | 0.78 | - |
| Impervious | 2,299 | - | 2.22 | - |
| Multi-Family | 935 | - | 1.51 | |
| Pervious | 664 | - | 1.33 | |
| Impervious | 271 | - | 2.22 | |
| Commercial/Industrial* | 8,461 | 6,277 | 2.03 | 1.54 |
| Pervious | 2,231 | - | 1.32 | - |
| Impervious | 6,230 | - | 2.51 | - |
| Average/Total | 30,934 | 21,868 | 0.47 | 0.32 |

* includes Transportation defined by MassGIS as airports, docks, divided highway, freight, storage, and railroads

## 4.3 Water Quality Target Selection and Evaluation

The target evaluation for the Upper/Middle Charles River was based on a two-tiered evaluation approach. First, the annual phosphorus load at Watertown Dam outlet must meet the inlet load specified by the Lower Charles TMDL. Second, the phosphorus loads must be low enough to achieve instream water quality targets and control response variables for excess nutrients and algal biomass in the river system during low flow conditions and WWTF design flows.

The Upper/Middle Charles River model was specifically developed for this TMDL to simulate instream nutrient and algal dynamics in the Upper/Middle Charles River from Echo Lake to the Watertown Dam in response to pollutant loadings from watershed sources. The model simulates water column and sediment nutrient cycling and algae dynamics coupled with one-dimensional transport in the Charles River. Water quality target selection and evaluation involved analysis of predicted water quality both spatially along the length of the Upper/Middle Charles River system as well as temporally during critical periods of low and high flow.

The following section summarizes the rational for setting water quality targets in the Upper/Middle Charles watershed as well as the basis for analysis of instream predictions with respect to the critical river segments and critical periods.

### 4.3.1 Watertown Dam Target

As part of the two-tiered approach, scenarios were first screened for their ability to meet the phosphorus load at Watertown Dam that was derived in the Lower Charles Phosphorus TMDL. As specified in the Lower Charles TMDL, the average annual phosphorus load contribution from the Upper/Middle Charles River cannot exceed 15,109 kg/yr at the Watertown Dam (US-EPA, 2007). This target is the maximum load allocation for phosphorus from the Upper/Middle Charles River watershed that can exit over the Watertown Dam in order to achieve the phosphorus TMDL for the Lower Charles. The five-year period of 1998-2002 for this TMDL was chosen to match the same period used for load calculations in the Lower Charles TMDL.

### 4.3.2 Water Quality Targets Selection

The water quality targets were developed from metrics identified in Section 2.5 using best professional judgment (BPJ) and a “weight-of-evidence” approach. In general, targets include water quality parameters that are the most sensitive measures of nutrient impacts. The targets were selected for consistency with applicable water quality standards, the Lower Charles phosphorus TMDL, US-EPA guidance documents, and MassDEP experience with nutrient TMDL development in river systems. The metrics chosen for this TMDL are given in Table 15.

**Table 15. Water Quality Targets for the Upper/Middle Charles TMDL**

| Water Quality Targets (Apr-Oct 2002) | Min/Max 7-d Avg | 10/90th percentile | Average |
|---|---|---|---|
| Minimum daily dissolved oxygen | >5 mg/L | >5 mg/L | >5 mg/L |
| Maximum daily dissolved oxygen saturation | < 125% | < 125% | < 125% |
| Mean daily total phosphorus in flowing waters | <0.1 mg/L | <0.1 mg/L | <0.1 mg/L |
| Mean daily total phosphorus on entering | <0.05 mg/L | <0.05 mg/L | <0.05 mg/L |
| Mean daily total phosphorus in impounded reaches | <0.025 mg/L | <0.025 mg/L | <0.025 mg/L |
| Mean daily chlorophyll-*a* | < 18.9 µg/L | < 18.9 µg/L | < 10 µg/L |

Instream predictions of hourly water quality were generated for each reach using the calibrated HSPF model. To eliminate some of the data outliers, the hourly values were processed into daily values and the final metrics deliberately avoided overall minimum and maximum statistics. To evaluate extremes, the daily percentiles and minimum 7-day average statistics were used. A 10th percentile of daily values is expected to be lower only 10% of the days while the a 90th percentile is expected to be higher only 10% of the days. The 7-day minimum and maximum represent the lowest and highest average over seven consecutive days within the year. Only the dissolved oxygen target uses the minimum statistics, while the other targets use the maximum statistics.

To evaluate the effect of different years on worst case conditions, the model was run for two periods – a single low-flow year (2002) and a ten-year period (1996-2005). The targets in Table 15 were used to compare the predicted conditions of each reach for the two periods. Output from the model was also manipulated to give the date that worst case condition occurred as well as the associated flow for each parameter of interest. This approach captured the worst case water quality predictions under both extreme low flow and high flow conditions. A comparison of the results from the two simulation periods revealed no significant differences in output. As a result it was concluded that 2002 would be the most appropriate period to use in further scenario evaluations.

The most deleterious effects of excessive nutrients are usually manifested during the summer growing season as the lower flows and warmer temperatures create conditions that result in more rapid algae and aquatic plant growth. However, the analysis was expanded to include the late spring runoff in April when high stormwater loads can also contribute to early algal growth. The period of evaluation for the Upper/Middle Charles TMDL analysis was therefore set from April to October.

For each scenario (April to October 2002), the river segments where water quality targets were not achieved were tallied and the results presented in tables as river miles and percent of river. The following sections describe how the targets chosen will achieve the desired water quality objectives.

#### *4.3.2.1 Aesthetic and Water Clarity Impacts*

A seasonal average chlorophyll-*a* target of 10 µg/L for the Upper/Middle Charles TMDL is consistent with the Lower Charles TMDL and is a site-specific target for this river. The chlorophyll-*a* target is set at a level that is expected to result in reductions in eutrophication sufficient to enable the Upper/Middle Charles River to attain all applicable Class B narrative (nutrients, aesthetics, and clarity) and numeric (dissolved oxygen and pH) standards. Achieving the seasonal average chlorophyll-*a* target will reduce algal biomass to levels that are consistent with a mesotrophic status, and will ultimately address aesthetic impacts, and attain clarity standards.

Excessive algae often results in poor aesthetic quality because of coloration and reduced clarity. To evaluate the extreme levels of algae that might be encountered during a growing season, the 90th percentile of the daily average value (the value that is expected to be exceeded only 10% of days) was estimated for the period April to October. A strong relationship between the seasonal mean and the seasonal 90th percentile values ($R^2=0.94$) was demonstrated in the Lower Charles TMDL. For the Lower Charles, a linear regression was used to establish the 90th percentile chlorophyll target of 18.9 µg/L for a seasonal mean chlorophyll-*a* concentration of 10 µg/L. The regression analysis was repeated for the Upper/Middle Charles and yielded similar results.

#### *4.3.2.2 Harmful Algal Blooms*

The goal of achieving the seasonal average chlorophyll-*a* target concentration of 10 µg/L is to move the Upper/Middle Charles River from a eutrophic to mesotrophic status. A mesotrophic status for the Upper/Middle Charles River would indicate intermediate nutrient availability and biological production (US-EPA, 1990) without having an adverse impact from harmful algal blooms on the aquatic system (US-EPA, 2000a). Analysis of the patterns in algal taxonomic composition across temperate lakes of differing nutrient status (Watson et al., 1997) showed that cyanobacteria (blue-green biomass) increases markedly with increasing total phosphorus concentrations between 30 and 100 µg/L. Thus, reductions in phosphorus to achieve the 10 µg/L chlorophyll-*a* target in the Upper/Middle Charles River should result in reductions in both cyanobacteria (blue-green) biomass and the potential for nuisance and toxic blooms. Thus, achieving the seasonal average chlorophyll-*a* concentration of 10 µg/L should be adequately protective for both public health and water quality (US-EPA, 2007).

#### *4.3.2.3 Dissolved Oxygen*

Dissolved oxygen levels have been observed to fall below the minimum dissolved oxygen criterion of 5 mg/L in the water column of the Upper/Middle Charles River (see Table 10). As a result of algal photosynthetic activity, dissolved oxygen concentrations can vary considerably during the day and result in high super-saturated dissolved oxygen levels (see Table 10). Reducing the seasonal mean chlorophyll-*a* concentration to achieve the target of 10 µg/L will result in less algal biomass and, therefore, reductions in diurnal dissolved oxygen variations and super-saturated dissolved oxygen concentrations.

#### *4.3.2.4 Phosphorus Levels*

Presently the Massachusetts Water Quality Standards do not contain numeric in-stream phosphorus criteria. As such no specific in-stream target concentration for total phosphorus was established for the Upper/Middle Charles TMDL, however, published guidance values (US-EPA, 1986; 2000a; 2000b; 2000c) were considered. Under the weight-of-evidence approach all available information was 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, like macrophytes, can be removed and that some level of biomass is necessary to provide habitat to fish and other aquatic organisms. A comparison of relative in-stream total phosphorus concentrations, although not a target, to US-EPA guidance was used as part of the weight-of-evidence in the scenario selection process. Specifically, the “Gold Book” (US-EPA, 1986) criteria were used to provide a relative comparison of the modeled scenarios impact on reducing instream water quality predictions for total phosphorus. This guidance recommends that total phosphorus not exceed 50 µg/L in any stream at the point where it enters any lake or impoundment, nor exceed 25 µg/L within the lake or reservoir. A desired goal for the prevention of plant nuisance instream or in flowing waters not discharging directly to lakes or impoundments is 100 µg/L total phosphorus. This guidance provided a range of acceptable guidance values for phosphorus based upon specified conditions.

### *4.3.3 Critical and Excluded Reaches*

Instream water quality predictions were made for the entire length of the Upper/Middle Charles River starting at Echo Lake and ending at the Watertown Dam. Table 16 provides a summary of reaches and river miles that were identified as critical during model development. More focus was given to the analysis and interpretation of water quality predictions in these reaches. All reaches were evaluated except the excluded reaches (the first 0.4 miles above Echo Lake plus river miles 0-3.1 and river miles 49.1-58.9).

Two river segments where water quality targets were exceeded were excluded from the reach analysis. The segment starting at the headwaters to the start of the Milford Main Street Culvert (0.4 miles above Echo Lake plus river miles 0-3.1) was excluded from the analysis of instream predictions (a total of 3.5 miles). Water quality impairments in this section of the river were not related to nutrient enrichment. Although low dissolved oxygen levels were found, those levels remained consistently low and did not fluctuate a great deal. It appears that the low dissolved oxygen condition in this area is a function of natural conditions resulting from bordering vegetative wetlands and low flow conditions in the headwater reaches. Massachusetts WQS (314CMR 4) allow for exclusions from standards that are due naturally occurring conditions.

The river segment from the start of the Dedham Canal just above Mother Brook to the Silk Mill Dam (river mile 49.5-59.4) was also excluded from analysis (a total of 9.9 miles) due to limited dissolved oxygen data available for calibration of the model in this portion of the river. Decision-making was not based on the model output in this section of the river due to the lower confidence in the predicted instream water quality conditions.

In summary, 13.3 miles were excluded from the detailed instream water quality evaluation.

### *4.3.4 Critical Low Flow and High Flow Periods*

The dynamic nature of streamflow, loads, impoundments, and residence time in the Upper/Middle Charles River makes it difficult to pick a single "critical" flow period. Early analysis of individual reaches showed that each reach had its own "critical" period. Since instream water quality impacts are often a result of extreme conditions, the Upper/Middle Charles TMDL instream predictions were evaluated over a range of low and high flow conditions.

**Table 16. Critical Reaches Evaluated in the Upper/Middle Charles TMDL**

| Critical Reach | Description | Label | River Mile |
|---|---|---|---|
| Below Milford WWTP Outfall | WWTP inputs | MilfWW | 5.5 |
| Box Pond Outlet | Increased residence time in impounded reach can result in degraded water quality | BoxPnd | 8.5 |
| Populatic Pond | Depressed dissolved oxygen attributed to backwater effects from CRPCD effluent | PopPnd | 20.1 |
| Below Charles River Pollution Control District (CRPCD) Outfall | WWTP inputs | CRPCD | 20.7 |
| Below Stop River confluence | Tributary inputs including minor WWTF input | StopR | 27.6 |
| Below Medfield WWTP Outfall | WWTP inputs | MedWW | 29.4 |
| South Natick Dam | Increased residence time in impounded reach | SNatDm | 37.8 |
| Cochran Dam | Increased residence time in impounded reach | CochDm | 44.4 |
| Watertown Dam | Total phosphorus load to Lower Charles Rivdr evaluated | WatDm | 69.1 |

Average monthly streamflow varies largely in response to seasonal evaporation from high streamflow in the winter/spring to low streamflow in the summer/fall. The lowest flow conditions usually occur during a dry period in the late summer/fall while the highest flows usually occur during a wet period in the late winter/spring.

The phosphorus nutrient load from WWTFs is usually highest in the winter and lowest in the summer. This pattern occurs because both the waste flows and permitted effluent concentrations are low in the summer. The stormwater nutrient loads are highest in the spring and early summer when the soils are wettest and runoff occurs readily with any rainfall event (see Figure 7).

The residence time of the river system from Echo Lake to the Watertown Dam varies from weeks to months depending on the streamflows. An algae bloom might start in an upstream reach during a warm low flow period then move downstream as flows increase. Additionally, impoundments have long residence times and are more susceptible to algae and plant growth so they might respond to a loading source many miles upstream.

Water quality response of the river to the dynamic nature of the phosphorus loads is mostly confined to the plant growth season. Even though nutrient loads are much higher in the winter, eutrophication responses like algae and aquatic plant growth and dissolved oxygen depletion or fluctuation are muted in the cooler temperatures. The analysis is therefore confined to the growing season of April to October (see Section 4.3.2).

Massachusetts Water Quality Standards set a minimum dissolved oxygen criterion of 5.0 mg/L instream to protect warm water fish. Large fluctuations in dissolved oxygen concentration and the amount of time supersaturated conditions exist are also pronounced during low flow conditions. Large daily dissolved oxygen fluctuations result from extremely low 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.

Massachusetts's water quality standards are devised to provide for the protection of water quality during low flow conditions that satisfy a certain statistical condition designated as 7Q10. This 7Q10 condition is the lowest flow averaged for a consecutive 7-day period with a recurrence interval of 10 years and is determined from continuous gauging station records. Utilizing only this low-flow approach makes sense when the river contamination is dominated by WWTF loads but not when stormwater loads are also a significant source.

The low-flow approach was therefore adapted by identifying the worst seven-day water quality condition by reach under all flow situations in a given period, for each water quality target under evaluation. The analysis was performed for both a one year (Apr-Oct, 2002) and a ten-year (1996-2005) period. The analysis extracted the date when the worst case condition occurred as well as the associated flow for each target of interest and reach. This approach enabled worst case water quality predictions under both extreme low flow and high flow conditions to be evaluated. A comparison of the two simulation periods (one-year and ten-year) revealed no significant difference in predicted outcomes. As a result it was concluded that the 2002 simulation period was appropriate for further scenario evaluations.

# 5 WATER QUALITY MODEL RESULTS

An HSPF model (Bicknell, et al., 1993) was developed and calibrated for use in this Upper/Middle Charles TMDL study. Details on the model construction and calibration are summarized in the Phase III Calibration Report (CRWA, 2009). The model was calibrated to field conditions for the period 2002-2005 and validated by comparing it with continuous DO data from a prior survey (CDM, 1997).

## 5.1 Scenarios Modeled

The purpose of this evaluation was to determine the impact of various point source and nonpoint source reductions on water quality in the critical reaches of the Upper/Middle Charles River and their ability to meet the load requirement at the Watertown Dam necessary to protect the Lower Charles River Basin.

The Upper/Middle Charles HSPF model was run for 18 scenarios (see Table 17). All scenarios presented here are modifications of the calibrated model. The major wastewater treatment facilities (WWTFs) are Milford WWTF, Charles River Water Pollution District (CRPCD), and Medfield WWTF while the minor systems are MCI Norfolk, Wrentham Development Center, and Southwood Caritas Hospital (operated until June 2003).

Scenarios 1-6A investigate the effect of phosphorus reductions from wastewater only, while 7-12A looked at the effect of phosphorus reductions from both wastewater and stormwater along with some reductions in phosphorus release from benthic sediments. The reductions in phosphorus loads from stormwater are consistent with the reductions required in the Lower Charles TMDL. The reductions applied to wastewater and stormwater sources represent the maximum extent practicable for current control technology. Benthic efflux rates were reduced to 75% of the calibration values to simulate the expected sediment response to the total phosphorus load reductions.

The current (existing WWTP permit conditions) and all forested condition scenarios represent baselines for comparison of scenarios.

The following briefly describes each scenario that was investigated. All scenarios were run for the period 1998-2002 to be consistent with the scenario period used for the Lower Charles TMDL (US-EPA, 2007).

**Calibration Scenario**

The calibrated model used 1999 land use to predict stormwater flows and loads, actual WWTF flow and loads, actual pump withdrawals and return flows, and actual Mother Brook diversions. In 2001, the discharge permits for all WWTFs lowered the summer limits for phosphorus discharge from 1.0 mg/L to 0.2 mg/L while winter limits remained unrestricted. For this run only, the Southwood Caritas Hospital WWTF was operational.

**Current Scenario**

This scenario represents current permitted conditions with permitted flows and discharge concentrations for WWTFs. For the Milford, Medfield, and Wrentham WWTFs, the phosphorus discharge limits were 0.2 mg/L (Apr-Oct) and 1.0 mg/L (Nov-Mar). For CRPCD and MCI Norfolk the same summer limits apply but winter effluent concentrations were based on actual values (sometimes less than permitted). All WWTFs discharge flows were set to the 12-month rolling average permit flow and seasonally varied according to the average observed monthly waste flow pattern for 1998-2002 (see Figure 7). Additionally, CRPCD summer flows were restricted to its permitted summertime flow. The permitted flows were: CRPCD=5.7 mgd with 4.5 mgd Jul-Sep, Milford=4.3 mgd, Medfield=1.52 mgd, MCI Norfolk=0.464 mgd, Wrentham Development Center=0.454 mgd, and Southwood Caritas Hospital=0 mgd)

**Scenario 1 (WWTF reductions only)**

This scenario represents the effect of setting the discharge phosphorus concentrations for all the major WWTFs to a low value year-round. All parameters were kept the same as the current condition except phosphorus discharge limits for major WWTFs were set at 0.2 mg/L year-round and minors at 0.1/1.0 mg/L for summer/winter.

**Scenario 2 (WWTF reductions only)**

This scenario represents the effect of setting the discharge phosphorus concentrations for the major WWTFs lower in the summer than the winter. All parameters were kept the same as the current condition except phosphorus discharge limits for major WWTFs were set at 0.2/0.5 mg/L and minors at 0.1/1.0 mg/L for summer/winter.

**Scenario 3 (WWTF reductions only)**

This scenario represents the effect of setting the discharge phosphorus concentrations for all the major WWTFs to a very low value year-round. All parameters were kept the same as the current condition except phosphorus discharge limits for major WWTFs were set at 0.1 mg/L year-round and minors at 0.1/1.0 mg/L for summer/winter.

**Scenario 4 (WWTF reductions only)**

This scenario represents the effect of setting the discharge phosphorus concentrations for Milford WWTF to a very low value year-round and other the major WWTFs to a low value year-round. All parameters were kept the same as the current condition except phosphorus discharge limits for Milford WWTF was set at 0.1 mg/L year-round, other major WWTFs at 0.2 mg/L year-round, and minors at 0.1/1.0 mg/L for summer/winter.

**Scenario 5 (WWTF reductions only)**

This scenario represents the effect of setting the discharge phosphorus concentrations for Milford WWTFs to a very low value year-round and setting other major WWTFs lower in the summer than the winter. All parameters were kept the same as the current condition except phosphorus discharge limits for Milford WWTF was set at 0.1 mg/L year-round, other major WWTFs at 0.2/0.5 mg/L for summer/winter, and minors at 0.1/1.0 mg/L for summer/winter.

**Scenario 6 (WWTF reductions only)**

This scenario represents the effect of setting the discharge phosphorus concentrations for Milford WWTF lower than the other major WWTFs and also setting the summer lower than the winter. All parameters were kept the same as the current condition except phosphorus discharge limits for Milford WWTF were set at 0.1/0.5 mg/L for summer/winter, other major WWTFs at 0.2/0.5 mg/L for summer/winter, and minors at 0.1/1.0 mg/L for summer/winter.

**Scenario 6A (WWTF reductions only)**

This scenario represents the effect of setting the discharge phosphorus concentrations for the major WWTFs low in the summer and relatively high in the winter. All parameters were kept the same as the current condition except phosphorus discharge limits for major WWTFs were set at 0.2/1.0 mg/L for summer/winter and minors at 0.1/1.0 mg/L for summer/winter.

**Scenario 7 (WWTF + SW reductions)**

This scenario represents the effect of setting the discharge phosphorus concentrations for all the major WWTFs to a low value year-round and applying the Lower Charles TMDL stormwater reductions. Same as Scenario 1 with stormwater phosphorus reductions as follows: Open/Agriculture (35%), Low Density Residential (45%), Medium and High Density Residential (65%) and Commercial/Industrial (65%). Sediment efflux rates were reduced to 75% of calibration to represent the adjustment to load reductions.

**Scenario 8 (WWTF + SW reductions)**

This scenario represents the effect of setting the discharge phosphorus concentrations for the major WWTFs lower in the summer than the winter and applying the Lower Charles TMDL stormwater reductions. Same as Scenario 2 with stormwater phosphorus reductions as follows: Open/Agriculture (35%), Low Density Residential (45%), Medium and High Density Residential (65%) and Commercial/Industrial (65%). Sediment efflux rates were reduced to 75% of Calibration to represent the adjustment to load reductions.

**Scenario 9 (WWTF + SW reductions)**

This scenario represents the effect of setting the discharge phosphorus concentrations for all the major WWTFs to a very low value year-round and applying the Lower Charles TMDL stormwater reductions. Same as Scenario 3 with stormwater phosphorus reductions as follows: Open/Agriculture (35%), Low Density Residential (45%), Medium and High Density Residential (65%) and Commercial/Industrial (65%). Sediment efflux rates were reduced to 75% of Calibration to represent the adjustment to load reductions.

**Scenario 10 (WWTF + SW reductions)**

This scenario represents the effect of setting the discharge phosphorus concentrations for Milford WWTFs to a very low value year-round and other the major WWTFs to a low value year-round and applying the Lower Charles TMDL stormwater reductions. Same as Scenario 4 with stormwater phosphorus reductions as follows: Open/Agriculture (35%), Low Density Residential (45%), Medium and High Density Residential (65%) and Commercial/Industrial (65%). Sediment efflux rates were reduced to 75% of Calibration to represent the adjustment to load reductions.

**Scenario 11 (WWTF + SW reductions)**

This scenario represents the effect of setting the discharge phosphorus concentrations for Milford WWTFs to a very low value year-round and setting other major WWTFs lower in the summer than the winter and applying the Lower Charles TMDL stormwater reductions. Same as Scenario 5 with stormwater phosphorus reductions as follows: Open/Agriculture (35%), Low Density Residential (45%), Medium and High Density Residential (65%) and Commercial/Industrial (65%). Sediment efflux rates were reduced to 75% of Calibration to represent the adjustment to load reductions.

### Scenario 12 (WWTF + SW reductions)

This scenario represents the effect of setting the discharge phosphorus concentrations for Milford WWTF lower than the other major WWTFs and also setting the summer lower than the winter and applying the Lower Charles TMDL stormwater reductions. Same as Scenario 6 with stormwater phosphorus reductions as follows: Open/Agriculture (35%), Low Density Residential (45%), Medium and High Density Residential (65%) and Commercial/Industrial (65%). Sediment efflux rates were reduced to 75% of Calibration to represent the adjustment to load reductions.

### Scenario 12A (WWTF + SW reductions)

This scenario represents the effect of setting the discharge phosphorus concentrations for the major WWTFs low in the summer and relatively high in the winter and applying the Lower Charles TMDL stormwater reductions. Same as Scenario 6A with stormwater phosphorus reductions as follows: Open/Agriculture (35%), Low Density Residential (45%), Medium and High Density Residential (65%) and Commercial/Industrial (65%). Sediment efflux rates were reduced to 75% of Calibration to represent the adjustment to load reductions.

### Lower Final TMDL Scenario (WWTF + SW reductions)

This scenario was not run but represents the Lower Charles TMDL. Similar to Scenario 12A but with both major and minor WWTFs set at 0.2/1.0 mg/L phosphorus for summer/winter and WWTF flows set to (lower) actual flows not permitted flows. The Lower TMDL also used lower stormwater export coefficients but there was no diversion from Mother Brook, no sediment efflux, and no internal uptake.

### All Forested Scenario

This scenario represents near-natural conditions for water quality. All the open/agricultural, residential and commercial/industrial loads were converted to forest loads. WWTF discharges were removed completely. All pumping withdrawals and return flows were turned off but the Mother Brook diversion was retained. Sediment efflux rates were reduced to 10% of Calibration to represent near-natural conditions. All dams remained in place.

# Table 17. Descriptions of Modeled Scenarios and Annual Phosphorus Loads (98-02)

| **Description** | | **Major WWTFs** | | | | | | **Minor discharges** | | | | | | **Watertown Dam** | **Reduction from Permitted** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Milford** | | **CRPCD** | | **Medfield** | | **MCI Norfolk** | | **Wrentham Dev** | | **Southwood** | | | |
| **Permitted Flow (MGD)** | | 4.3 MGD<br>12-mth Rolling Monthly Seasonal Flow Variations | | 5.7 MGD Oct-Jun, 4.5 MGD Jul-Sep<br>12-mth Rolling Avg Seasonal Flow variations | | 1.52 MGD<br>12-mth Rolling Avg Seasonal Flow Variations | | 0.484 MGD<br>12-mth Rolling Avg Seasonal Flow Variations | | 0.454 MGD<br>12-mth Rolling Avg Seasonal Flow variations | | 0.055 MGD<br>12-mth Rolling Avg Seasonal Flow variations | | | |
| **Scenario** | **Description** | **WLA-Summer (mg/L)** | **WLA-Winter (mg/L)** | **WLA-Summer (mg/L)** | **WLA-Winter (mg/L)** | **WLA-Summer (mg/L)** | **WLA-Winter (mg/L)** | **WLA-Summer (mg/L)** | **WLA-Winter (mg/L)** | **WLA-Summer (mg/L)** | **WLA-Winter (mg/L)** | **WLA-Summer (mg/L)** | **WLA-Winter (mg/L)** | **TP Load (kg/yr)** | **TP Load (%)** |
| Calibration | Model calibrated to the period 2002-2005 then run for the simulatiion period | 1.0/0.2 | - | 1.0/0.2 | - | 1.0/0.2 | - | 1.0/0.2 | - | 1.0/0.2 | - | 1.0/0.2 | - | 28,261 | 5.4 |
| Current Permits | Current permitted conditions applied to the simulation period | 0.2 | 1.0 | 0.2 | - | 0.2 | 1.0 | 0.2 | - | 0.2 | 1.0 | 0.0 | 0.0 | 29,872 | 0.0 |
| 1 | WWTFs: at 0.2 mg/L TP year-round, all major plants. | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 25,653 | 14.1 |
| 2 | WWTFs: 0.2 mg/L TP growing season and 0.5 mg/L TP non-growing all major plants | 0.2 | 0.5 | 0.2 | 0.5 | 0.2 | 0.5 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 27,223 | 8.9 |
| 3 | WWTFs: at 0.1 mg/L TP year-round, all major plants. | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 24,755 | 17.1 |
| 4 | WWTFs: Milford at 0.1 mg/L TP all year, Other major WWTFs (CRPCD/Medfield) at 0.2 mg/L TP year-round. | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 25,354 | 15.1 |
| 5 | WWTFs: Milford at 0.1 mg/L TP year-round and other major (CRPCD/Medfield) at of 0.2 mg/L TP growing season and 0.5 mg/L TP for non-growing season. | 0.1 | 0.1 | 0.2 | 0.5 | 0.2 | 0.5 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 26,361 | 11.8 |
| 6 | WWTFs: Milford at 0.1 mg/L TP growing season, and 0.5 mg/L TP non-growing season, Other WWTFs (CRPCD/Medfield) at 0.2 mg/L TP growing season and 0.5 mg/L TP for non-growing season. | 0.1 | 0.5 | 0.2 | 0.5 | 0.2 | 0.5 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 27,109 | 9.2 |
| 6A | WWTFs: 0.2 mg/L TP growing season and 1 mg/L TP non-growing all major plants | 0.2 | 1.0 | 0.2 | 1.0 | 0.2 | 1.0 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 29,868 | 0.0 |
| 7 | WWTFs: at 0.2 mg/L TP year-round, all major plants. + SW50 + SED75* | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 15,099 | 49.5 |
| 8 | WWTFs: 0.2 mg/L TP growing season and 0.5 mg/L TP non-growing all major plants + SW50 + SED75[1] | 0.2 | 0.5 | 0.2 | 0.5 | 0.2 | 0.5 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 16,681 | 44.2 |
| 9 | WWTFs: at 0.1 mg/L TP year-round, all major plants. + SW50 + SED75[1] | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 14,181 | 52.5 |
| 10 | WWTFs: Milford at 0.1 mg/L TP all year, Other major WWTFs (CRPCD/Medfield) at 0.2 mg/L TP year-round. + SW50 + SED75[1] | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 14,794 | 50.5 |
| 11 | WWTFs: Milford at 0.1 mg/L TP year-round and other major (CRPCD/Medfield) at 0.2 mg/L TP growing season and 0.5 mg/L TP for non-growing season. + SW50 + SED75[1] | 0.1 | 0.1 | 0.2 | 0.5 | 0.2 | 0.5 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 15,809 | 47.1 |
| 12 | WWTFs: Milford at 0.1 mg/L TP growing season, and 0.5 mg/L TP non-growing season, Other WWTFs (CRPCD/Medfield) at 0.2 mg/L TP growing season and 0.5 mg/L TP for non-growing season. + SW50 + SED75[1] | 0.1 | 0.5 | 0.2 | 0.5 | 0.2 | 0.5 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 16,564 | 44.6 |
| 12A | WWTFs: 0.2 mg/L TP growing season and 1 mg/L TP non-growing all major plants + SW50 + SED75[1] | 0.2 | 1.0 | 0.2 | 1.0 | 0.2 | 1.0 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 0.0 | 19,340 | 35.3 |
| Lower TMDL | WWTFs: 0.2 mg/L TP growing season and 1 mg/L TP non-growing all major plants (with actual not permitted flows) + SW50 | 0.2 | 1.0 | 0.2 | 0.1 | 0.2 | 1.0 | 0.2 | 1.0 | 0.2 | 1.0 | 0.0 | 0.0 | 15,109 | 49.4 |
| All Forested | This scenario represents a near-natural condition with no withdrawals/discharges, sediment flux at 10% of measured values and no Benthic Algae. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10,350 | 65.4 |

[1] Stormwater loads were set at 65% of actual loads for Commercial/Industrial, Multi-family Residential; High and Medium Density Residential; 45% for Low Density Residential; and 35% for open/agricultural land uses. Phosphorus sediment flux was set to 75% of the rates used were for the Actual Conditions Scenario to reflect a moderate decline in sediment efflux rates following the wastewater and stormwater reductions.

2 Grey cells for average annual phosphorus load at the Watertown Dam load meet the Lower TMDL requirement of 15,109 kg/yr

## 5.2 Scenario Results

All the results presented here are the average over the five-year period that spans 1998-2002.

The total phosphorus loadings (kg/yr) at the Watertown Dam for the different load reduction options are provided in Table 17 and Figure 8 along with the target phosphorus load from the Lower Charles River TMDL (15,109 kg/yr). The differences in the scenario loads can be summarized as follows:

- All scenario loads fall between All Forested (10,350 kg/yr) and Current (29,872 kg/yr).
- The Current Scenario is higher than the Calibration Scenario because it uses permitted flows in place of actual flows for the WWTFs, and represents a worst case load.
- Scenarios 1-6A, which have only WWTF reductions, result in less loading than the Current Scenario but are still significantly above the Lower TMDL target.
- Scenario 6A is similar to Current Scenario because actual winter phosphorus discharge concentrations from CRPCD and Norfolk are similar to the permitted winter value used in Current Scenario.
- Scenarios 7-12A, which have both WWTF and stormwater reductions, result in much less loading than Scenarios 1-6A, and all approximate the Lower Charles TMDL target load.
- Only the loads from Scenarios 7, 9, and 10 fall below the Lower Charles River TMDL target load (highlighted in Table 17).

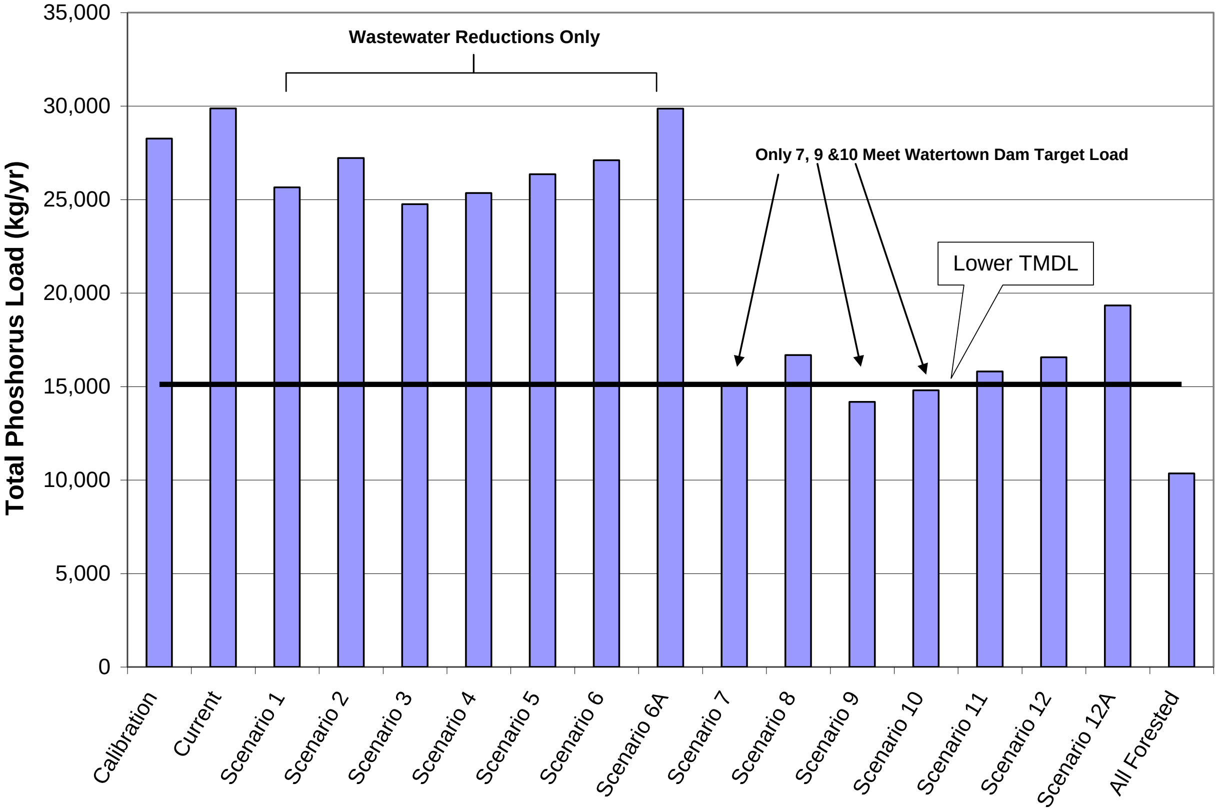


**Figure 8. Total Phosphorus Loads at the Watertown Dam by Scenario (98-02)**

For those scenarios that meet the Lower Charles River TMDL load target in Table 17 (Scenarios 7, 9, and 10), a detailed analysis of water quality impacts was performed on individual reaches for the period from April to October in 2002 (see table 18). This season and year were chosen as the critical period for the Upper/Middle Charles TMDL (see Section 4). All reaches were evaluated except the excluded reaches (the first 0.4 miles above Echo Lake plus river miles 0-3.7 and river miles 49.5-59.4 discussed in section 4.3.3). This analysis summarizes the impacts as the total river miles and percent of river miles that exceed the water quality targets in Table 15.

The results in Table 18 show that Scenario 9 is clearly the scenario that meets the targets most consistently. For mean chlorophyll-*a*, zero miles exceeded the 10.0 µg/L target and similarly for the 90th percentile and 7-day maximum chlorophyll-a, no miles exceeded the 18.9 µg/L target. Scenario 9 was the only scenario that achieved zero exceedance for chlorophyll-*a* other than the All Forested Scenario. For dissolved oxygen, there were no differences among the three scenarios but all resulted in only 0.5 miles below the 5 mg/L target for the 7-day minimum (a relatively small violation–see discussion of Figure 10) and zero miles for the other targets. For dissolved oxygen saturation, Scenario 9 had the lowest river miles exceeding the target of 125% but the number of impacted river miles was still predicted to be higher than the All Forested Scenario. Although not all reaches in Scenario 9 were reduced below the DO saturation target, in some critical reaches the DO saturation was dramatically reduced from about 170% to 130% for mean conditions and from around 200% to 160% for low flow conditions.

For total phosphorus, Scenario 9 and the All Forested Scenarios did not have any exceedances of the 0.1 mg/L instream target. For the 0.05 mg/L lake-entry target, Scenario 9 had 3.6-16.4 miles in exceedance depending on the statistic, somewhat higher than All Forested, but significantly lower than the other two scenarios. For the 0.025 mg/L lake-exit target, there were few differences in the impacted river miles among the load reduction scenarios and only some (2%) of the reaches evaluated met this target. Only the All Forested Scenario met this 0.025 mg/L target.

Figures 9-12 plot the results from Scenario 9 as longitudinal profiles for each parameter versus river mile and also show the critical and excluded reaches. Figure 9 shows the mean chlorophyll-*a* does not exceed the target mean of 10.0 µg/L for the entire river length while the 90th percentile and 7-day maximums are also below the target maximum of 18.9 µg/L. Additional longitudinal plots for Scenarios are included in Appendix A2 for reference.

In Figure 10, the mean dissolved oxygen is above target minimum of 5 mg/L for the entire length while the 90th percentile and 7-day maximums are also above that target except for a single 7-day minimum value of 4.95 mg/L at mile 44.4 (within a critical reach Cochrane Dam). While this prediction could be perceived as a violation of a MassDEP Water Quality Standards, it is a relatively small excursion from the Standard that occurs only within a single reach, during a 7-day minimum period. The excursion was deemed acceptable since the difference between the predicted value and the standard (5 mg/L) is well within the expected error of the analysis.

Figure 11 shows the mean dissolved oxygen saturation does not exceed the target maximum of 125% for the vast majority of the river length except for a critical reach downstream of the CRPCD outfall. For the 90th percentile and 7-day maximums, there are two critical reaches where the target is exceeded, namely, Box Pond and downstream of the CRPCD outfall. However, it should be noted that although these areas are above the 125% target, they have been dramatically reduced from the value predicted for the current scenario (200%).

The final Figure 12 shows that Scenario 9 did not have any exceedances of the 0.1 mg/L instream target for total phosphorus. For the 0.05 mg/L lake-entry target, the mean predicted concentration was below 0.05 mg/L in most reaches throughout the river and entering critical impounded reaches. The only exception to this was in the section from the Milford WWTP to Box Pond which was slightly higher than the 0.05 mg/L target. Under extreme conditions (90th percentile and 7-day maximum of the mean daily values), the 0.05 mg/L target was exceeded in the sections from the Milford WWTP to about river mile 16.4 and in a short stretch below the Charles River Pollution Control District (which did not exceed 0.06 mg/L). These excursions were found to be acceptable, however, because they did not result in exceedances of the chlorophyll-*a* or dissolved oxygen targets. The figure also shows that all the total phosphorus statistics exceeded the lake-exit target of 0.025 mg/L for most of the river length except a small section of river above Milford WWTF. Finally, it should be noted that the average total phosphorus concentration for the All Forested Scenario (completely forested conditions) was about 0.018 mg/L.

## 5.3 Fine-Tuning the Final TMDL Phosphorus Load

The objective of this section is to investigate whether it is possible to use slightly higher winter TP discharge limits for the WWTFs and still meet the Lower TMDL phosphorus load but make it more feasible that the treatment plants will consistently meet the more stringent discharge limits under the colder winter conditions.

The above analyses point to Scenario 9 as the only option evaluated that meets both the Lower Charles TMDL target phosphorus load and the selected water quality targets. This scenario has a phosphorus load of 14,181kg/yr at the Watertown Dam, that is, well below the Lower TMDL target of 15,109 kg/yr by 928 kg/yr. The phosphorus load could be increased to approximate the Lower Charles TMDL target load by adjusting the winter WWTF limits with little effect on the summer water quality performance.

Table 19 presents the calculations used to estimate the total phosphorus load at the Watertown Dam for a range of winter phosphorus discharge limits for the major and minor WWTFs (Scenario 9A, 9B, 9C, 9D). Only scenarios that had the same WWTF discharge limits for summer and different discharge limits for winter were used in this estimation procedure since they would have the same winter flows and diversions from Mother Brook.

# Table 18. Summary of Water Quality Performance by Preferred Scenario (Apr-Oct, 2002)

| RIVER MILES EXCEEDED (13.3 mi excluded) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chlorophyll-a | | | Dissolved Oxygen | | | Dissolved Oxygen Saturation | | | Total Phosphorus | | | | | | | | |
| Scenario | Mean >10.0 ug/L | 90th pctl >18.9 ug/L | 7-d Mx >18.9 ug/L | Mean< 5 mg/L | 10th pctl <5 mg/L | 7-d Mn <5 mg/L | Mean >125% | 90th pctl >125% | 7-d Mx >125% | Mean >0.025 mg/L | 90th pctl >0.025 mg/L | 7-d Mx >0.025 mg/L | Mean >0.05 mg/L | 90th pctl >0.05 mg/L | 7-d Mx >0.05 mg/L | Mean >0.10 mg/L | 90th pctl >0.10 mg/L | 7-d Mx >0.10 mg/L |
| All Forested | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| S7 | 24.3 | 11.1 | 16.2 | 0 | 0 | 0.5 | 2.1 | 4.9 | 5.1 | 55.1 | 55.9 | 56.2 | 24.5 | 43.2 | 53.9 | 2.2 | 4.7 | 7.5 |
| S9 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0.6 | 3.1 | 3.7 | 55.1 | 55.9 | 56.2 | 3.6 | 13 | 16.4 | 0 | 0 | 0 |
| S10 | 2.1 | 5.6 | 10.6 | 0 | 0 | 0.5 | 1.2 | 4.7 | 4.7 | 55.1 | 55.9 | 56.2 | 13.6 | 29.3 | 34.7 | 0 | 0 | 0 |
| Current | 51.7 | 45.6 | 51.7 | 0 | 0 | 3.3 | 3.9 | 6 | 11.8 | 56.2 | 56.2 | 56.2 | 55.1 | 55.9 | 55.9 | 3.6 | 11.4 | 29.2 |

| PERCENT RIVER MILES EXCEEDED (13.3 mi excluded) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chlorophyll-a | | | Dissolved Oxygen | | | Dissolved Oxygen Saturation | | | Total Phosphorus | | | | | | | | |
| Scenario | Mean >10.0 ug/L | 90th pctl >18.9 ug/L | 7-d Mx >18.9 ug/L | Mean< 5 mg/L | 10th pctl <5 mg/L | 7-d Mn <5 mg/L | Mean >125% | 90th pctl >125% | 7-d Mx >125% | Mean >0.025 mg/L | 90th pctl >0.025 mg/L | 7-d Mx >0.025 mg/L | Mean >0.05 mg/L | 90th pctl >0.05 mg/L | 7-d Mx >0.05 mg/L | Mean >0.10 mg/L | 90th pctl >0.10 mg/L | 7-d Mx >0.10 mg/L |
| All Forested | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 | 3.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| S7 | 43.2 | 19.8 | 28.8 | 0.0 | 0.0 | 0.9 | 3.7 | 8.7 | 9.1 | 98.0 | 99.5 | 100.0 | 43.6 | 76.9 | 95.9 | 3.9 | 8.4 | 13.3 |
| S9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 1.1 | 5.5 | 6.6 | 98.0 | 99.5 | 100.0 | 6.4 | 23.1 | 29.2 | 0.0 | 0.0 | 0.0 |
| S10 | 3.7 | 10.0 | 18.9 | 0.0 | 0.0 | 0.9 | 2.1 | 8.4 | 8.4 | 98.0 | 99.5 | 100.0 | 24.2 | 52.1 | 61.7 | 0.0 | 0.0 | 0.0 |
| Current | 92.0 | 81.1 | 92.0 | 0.0 | 0.0 | 5.9 | 6.9 | 10.7 | 21.0 | 100.0 | 100.0 | 100.0 | 98.0 | 99.5 | 99.5 | 6.4 | 20.3 | 52.0 |

* pctl=percentile, 7-d=7-day, mx=maximum, mn=minimum

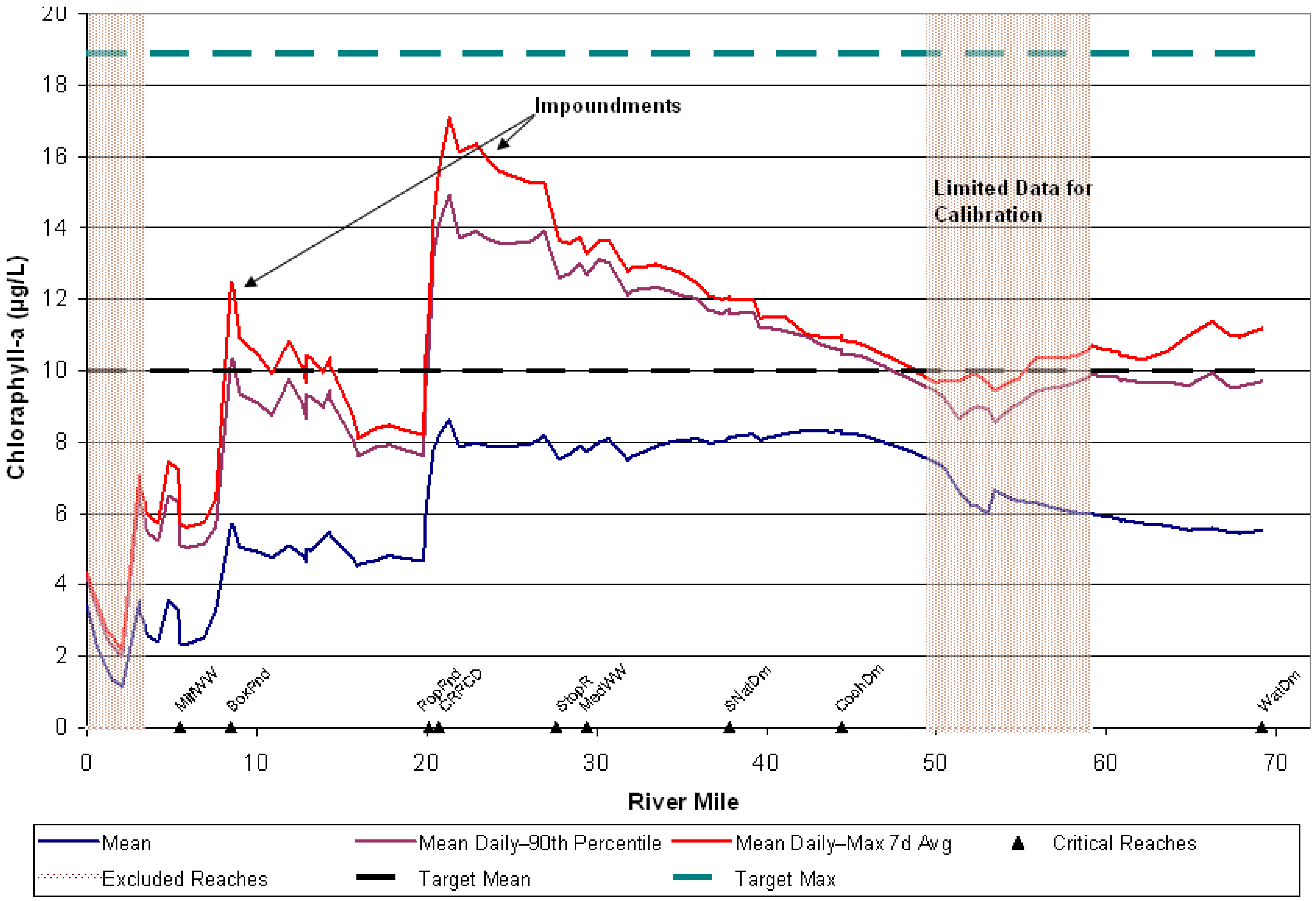


Figure 9. Longitudinal Profile of Chlorophyll-a for Scenario 9

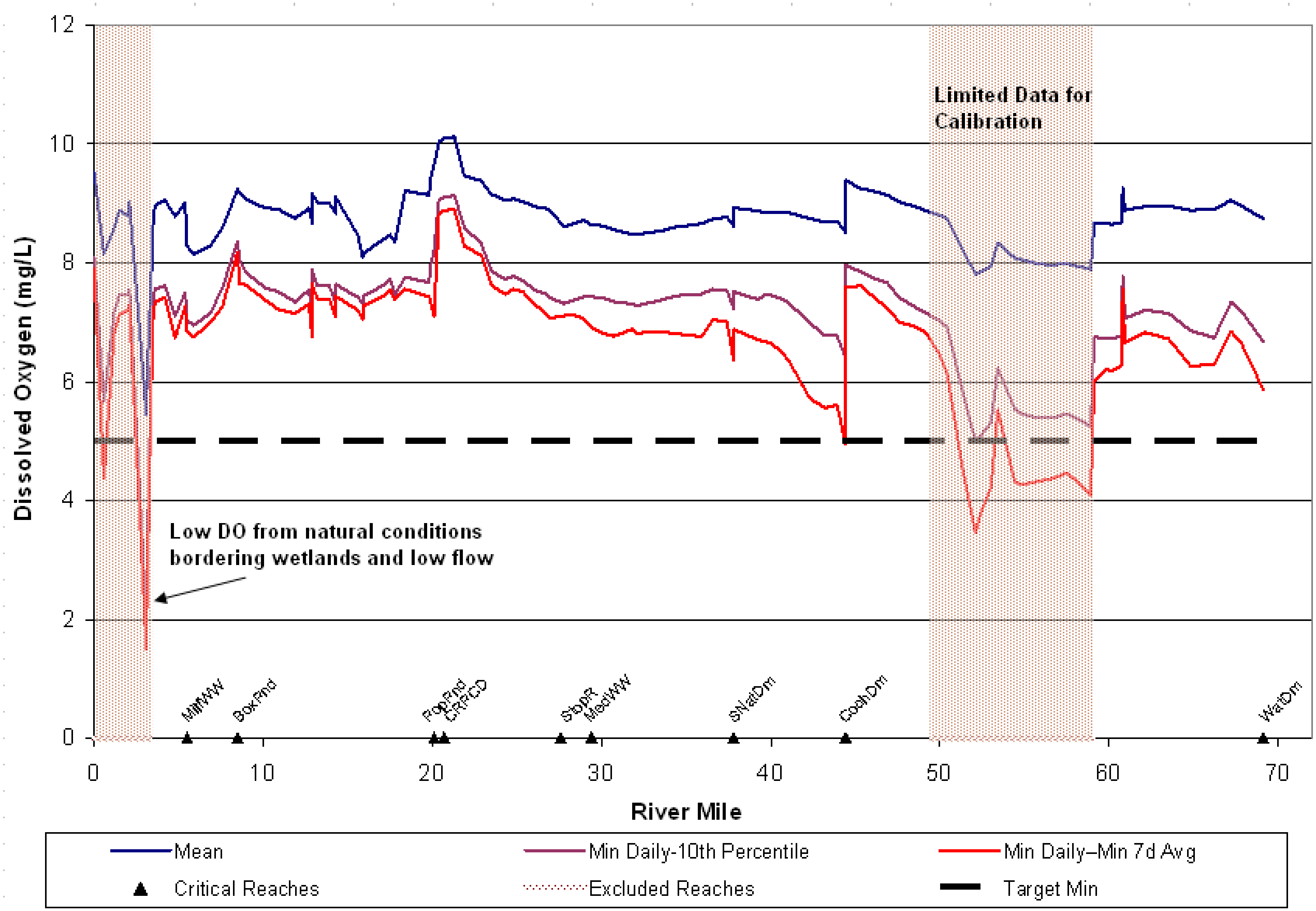


**Figure 10. Longitudinal Profile of Dissolved Oxygen for Scenario 9**

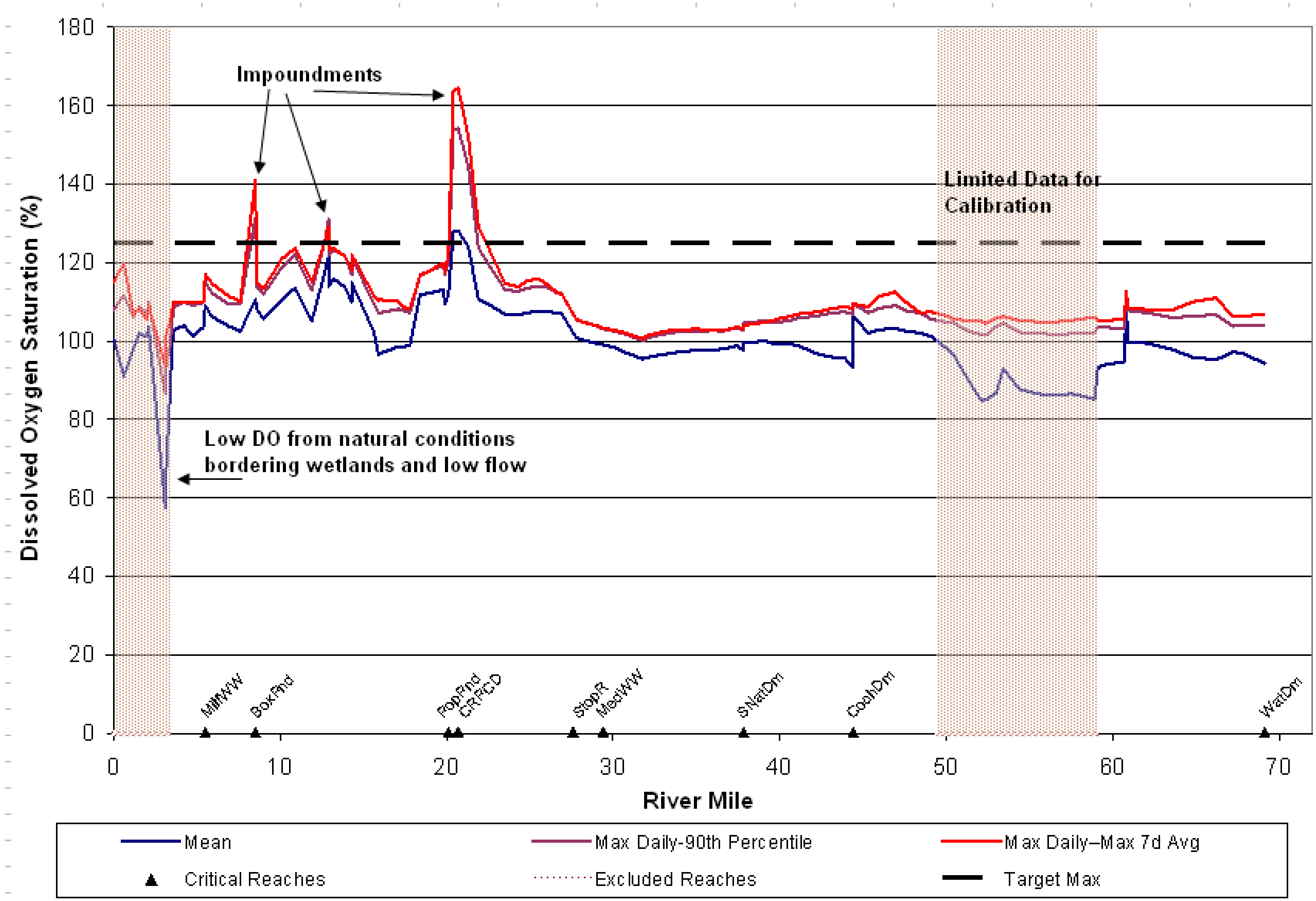


Figure 11. Longitudinal Profile of Dissolved Oxygen Saturation for Scenario 9

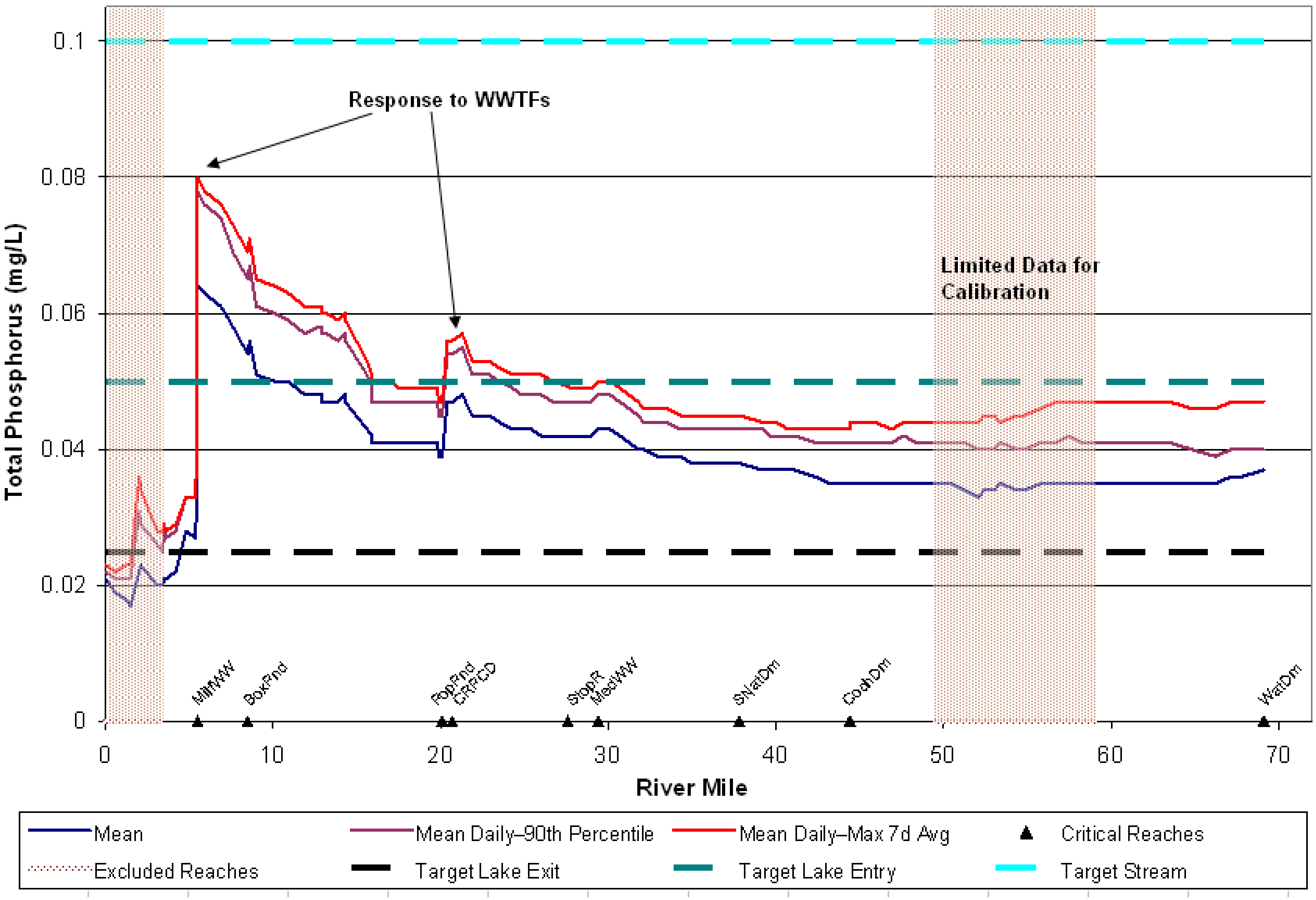


Figure 12. Longitudinal Profile of Total Phosphorus for Scenario 9

**Table 19. Estimated Total Phosphorus Load for Various WWTF Winter Discharge Limits**

| Scenario | Majors | | Minors | | Total Load (kg/yr) | WWTF Load (kg/yr) |
|---|---|---|---|---|---|---|
| | Summer TP (mg/L) | Winter TP (mg/L) | Summer TP (mg/L) | Winter TP (mg/L) | | |
| 9A | 0.1 | 0.2 | 0.1 | 1.0 | 14,710 | 2,944 |
| 9B | 0.1 | 0.25 | 0.1 | 1.0 | 14,974 | 3,303 |
| 9C | 0.1 | 0.3 | 0.1 | 1.0 | 15,238 | 3,663 |
| 9D | 0.1 | 0.3 | 0.1 | 0.3 | 14,968 | 3,295 |

Scenarios 9A, 9B, 9C, and 9D evaluated winter TP limits for major WWTFs of 0.2, 0.25, 0.3 mg/L and 0.3 mg/l, respectively. Scenario 9A, 9B, and 9C had TP limits for the minor facilities were set at 0.1 mg/L summer and 1 mg/L winter. Only 9D set the minor TP limit at 0.1 mg/L summer and 0.3 mg/L winter. The total phosphorus loads at the Watertown Dam for Scenarios 9A, 9B, 9C, and 9D were estimated as 14,710, 14,974, and 15,238 and 14,968 kg/yr, respectively.

The final Scenario 9D load of 14,968 kg/yr meets the Lower Charles TMDL target phosphorus load of 15,109 kg/yr. This scenario was chosen for implementation since the calculated load is below the Lower Charles River TMDL target of 15,109 at the Watertown Dam. This scenario also represents equitable effluent limits for both major and minor wastewater treatment facilities**.**

## 5.4 Summary and Final TMDL Scenario

The above analysis of the annual total phosphorus loads and water quality performance showed that only Scenario 9 met both the Lower Charles TMDL target phosphorus load and the selected Upper/Middle Charles River water quality targets. Post-processing analysis revealed that the winter discharge limits of 0.1 mg/L for the major WWTFs in Scenario 9 could be raised slightly to the more achievable winter value in Scenario 9D of 0.3 mg/L while still approximating the Lower Charles TMDL target at the Watertown Dam with a watershed load of 14,968 kg/yr.

Scenario 9D will now be referred to as the Final TMDL Scenario in the rest of the document. In summary, this scenario has phosphorus WWTF discharge limits for summer/winter for majors and minors at 0.1/0.3 mg/L with stormwater phosphorus reductions as follows: Open/Agriculture (35%), Low Density Residential (45%), Medium and High Density Residential (65%) and Commercial/Industrial (65%).

# 6 TMDL ANALYSIS

## 6.1 Final TMDL Loads

The Upper/Middle Charles TMDL assessed the phosphorus loads from wastewater treatment facilities (WWTFs), stormwater, and accumulated benthic sediments. An HSPF (Hydrologic Simulation Program – Fortran) water quality model (Bicknell, et al., 1993) was developed and calibrated to existing water flow and quality data (CRWA and NES, 2009). The calibrated HSPF model was used to evaluate numerous remediation scenarios by comparing simulated total phosphorus load and instream concentrations of phosphorus, dissolved oxygen, and chlorophyll-*a* (algae).

Average phosphorus loads (kg/yr) for all sources were predicted for the period 1998-2002 using the HSPF model. This period was chosen to match the load calculations for the Lower Charles TMDL. A detailed loading analysis for calibrated conditions was presented in Section 5 in Table 13. This analysis was repeated for the Current and Final TMDL Scenario to compute the percent change under permitted conditions. The Current Scenario represents the current permitted condition. The Final TMDL Scenario approximates the Lower TMDL phosphorus load requirement at the Watertown Dam with a watershed load of 14,968 kg/yr and also meets the desired water quality targets in all reaches of interest.

Stormwater loads include discharges from piped infrastructure as well as non-point source discharges from overland flow. All land use types contribute phosphorus loads through stormwater runoff including forests and wetlands. Stormwater loads also include any sanitary flows that enter the river through storm drains via illicit cross connections. The HSPF model was developed and calibrated for flow and water quality at many monitoring locations with differing upstream land uses (CRWA, 2009). The HSPF model was designed specifically to include land use as a part of the hydrological response units (HRUs). Stream reaches receive flows and loads from upland areas based on HRUs and weather inputs. Stormwater loads by land use type were then adjusted to match the measured phosphorus load at the Watertown Dam and measured instream water quality responses. The HSPF model thus provides a sound basis on which to estimate and allocate stormwater loads based on land use type.

The HSPF model was used to evaluate 18 management scenarios and assist in selecting the scenario that best meets the TMDL targets (see Section 5). The Upper/Middle Charles TMDL must produce an outlet phosphorus load that is less than Lower Charles TMDL inlet load of 15,109 kg/yr. The TMDL must also meet specific water quality targets (chlorophyll-*a*, dissolved oxygen, dissolved oxygen saturation, and phosphorus concentrations—see Table 15) especially in the critical reaches and below wastewater treatment discharges (see Table 16).

Table 20 provides the annual phosphorus source loads for the Current and TMDL conditions. Under the Current Scenario, total annual phosphorus load to the Upper/Middle Charles River is 29,872 kg/year while the TMDL load is 14,968 kg/yr. Thus, a 50% reduction in annual phosphorus load is required in order to meet water quality standards in the Upper/Middle Charles River. New development will need to minimize or offset phosphorus loads.

**Table 20/ES-4. Annual TP Loads/Losses/MOS for Current and TMDL Conditions (98-02)**

| Source | Current Load (kg/yr) | Reduction (%) | TMDL Load (kg/yr) |
|---|---|---|---|
| Wastewater | 9,611 | 66 | 3,296 |
| Stormwater | 30,808 | 51 | 15,086 |
| Nonpoint & Background | 2,801 | 21 | 2,211 |
| Other Losses* | -13,348 | 58 | -5,625 |
| **TOTAL ALLOCATION (Upper/Middle Charles Model)** | **29,872** | **50** | **14,968** |
| **MOS (Upper/Middle Charles Model)** | | | **141** |
| **TOTAL ALLOCATION (Lower Charles TMDL)** | | | **15,109** |
| **MOS (Additional Designated from Lower Charles TMDL)** | | | **757** |

Note: Numeric differences due to decimal rounding.

* Other losses include algae uptake and settling, and diversions including Mother Brook. Please refer to pages 47-48for the complete discussion. MOS includes 141 kg/yr from the Upper/Middle TMDL and 757 kg/yr apportioned from the Lower Charles TMDL.

Figure 13 graphically displays the daily phosphorus loads (98-02) by comparing the Current and Final TMDL conditions. The graph shows that the TMDL waste load reductions must be applied uniformly and consistently throughout the year under all load conditions.

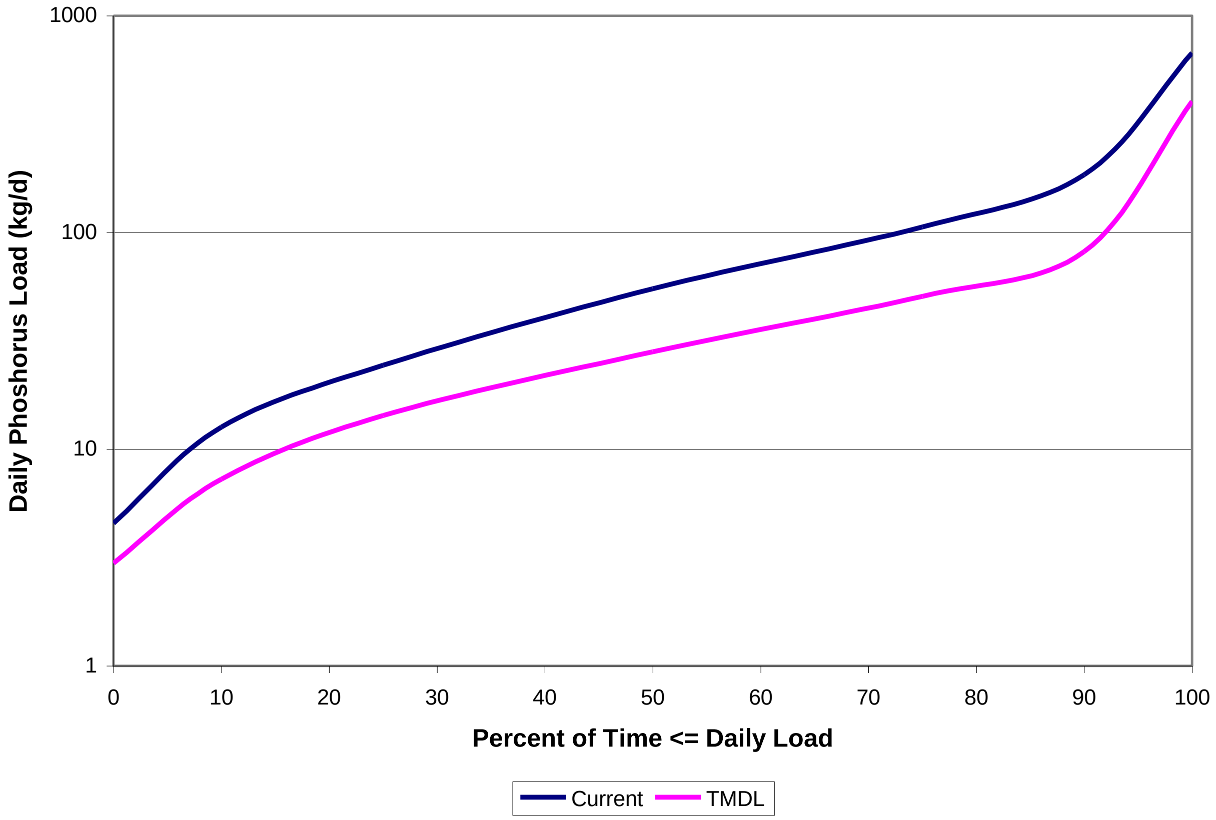


**Figure 13. Daily Phosphorus Load Frequency for Current and TMDL Conditions (98-02)**

## 6.2 Waste Load and Load Allocations

A TMDL for a given pollutant and water body is composed of the sum of land-area load allocations for nonpoint sources, individual waste load allocations for point sources, and natural background levels. In addition, the TMDL must include an implicit or explicit margin of safety to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. The TMDL components for this watershed are illustrated using the following equation:

$$TMDL = [(LA + WLA) - System\ Losses] + MOS$$

where LA is the load allocation for nonpoint sources including background, WLA is the waste load allocation, and MOS is the margin of safety. System losses are as discussed on pages 47-48.

US-EPA regulations require that point sources of pollution (discharges from discrete pipes or conveyances) subject to National Pollutant Discharge Elimination System (NPDES) permits receive WLAs specifying the amount of a pollutant they can release to the water body. Non-point sources of pollution and point sources not subject to NPDES permits receive LAs specifying the amount of a pollutant that they can release to the water body.

In the case of stormwater, it is often difficult to identify and distinguish between point source discharges that are subject to NPDES regulation, and those that are not. Therefore, US-EPA has stated that where it is not possible to distinguish between point source discharges that are subject to NPDES regulation and those that are not, it is permissible to include all point source storm water discharges in the WLA portion of the TMDL.

### *6.2.1 Load Allocation*

Both nonpoint sources of phosphorus and unregulated stormwater drainage systems exist throughout the Upper/Middle Charles River watershed. The major nonpoint source categories that contribute phosphorus to the river are diffuse overland runoff, including runoff from forest, open space and wetlands and water, and groundwater recharge to the river and tributaries. Also, there are many stormwater drainage systems in the watershed that are currently not regulated by the NPDES permit program. These systems include privately owned drainage systems serving commercial areas, small construction sites less than an acre in size, certain industrial uses, and municipal drainages systems in more rural portions of the watershed.

The level of information available for this TMDL through the specific HRU setup in the HSPF model makes it suitable for quantifying total phosphorus loadings from watershed areas by land use. Stormwater from these land uses include regulated stormwater and non-stormwater point sources, nonpoint sources, and unregulated stormwater point sources. Currently, there is insufficient information available to confidently apportion the total phosphorus loading from the various land use types to the regulated and non-regulated stormwater source categories within the watershed areas. As a result, this TMDL has assigned LAs to benthic flux, water/wetland areas and atmospheric deposition.

### *6.2.2 Waste Load Allocation*

NPDES regulated point sources in the Upper/Middle Charles River Watershed that contribute phosphorus loads include both WWTF and stormwater sources. The majority of the watershed is comprised of communities that are subject to the Phase II NPDES stormwater regulations governing municipally owned separate stormwater sewer systems (MS4s). NPDES permits are also required for stormwater associated with construction activities disturbing greater than one acre of land and stormwater associated with certain industrial activities.

Currently, there is insufficient information available to confidently apportion the total watershed phosphorus loading from the various land use types to the regulated and non-regulated stormwater source categories within the watershed areas. For this reason, the WLAs for this TMDL include regulated NPDES point sources, and stormwater point sources that are not currently regulated under the NPDES program. The WLA values are estimates that can be refined in the future as more information becomes available.

The top of Table 21 contains the total phosphorus WLAs for the six WWTFs that discharge to the Upper/Middle Charles as calculated from the Current and Final TMDL scenarios. Current NPDES permits set the total phosphorus discharge limits at Milford WWTF, Medfield WWTF, and Wrentham Development Center to 0.2 mg/L in the summer (Apr-Oct) and 1.0 mg/L for the winter (Nov-Mar). Charles River Pollution Control District (CRPCD) in Medway and the Massachusetts Correctional Institute (MCI) at Norfolk only have a summer season limit of 0.2 mg/L but do not yet include the winter season limits. This TMDL sets phosphorus WWTF discharge goals for summer/winter for both majors and minors at 0.1/0.3 mg/L. These wastewater reductions are needed for two specific reasons 1) additional summer time reductions were necessary over current permitted loads in order to address water quality problems in critical reaches of the Upper/Middle Charles River Watershed, and 2) winter time reductions are necessary to meet the Lower Charles TMDL load requirement at the Watertown Dam. The Lower Charles TMDL sets an annual cap on loads from the treatment facilities upstream, which must be met at the Watertown Dam. Since the treatment facilities can discharge up to their currently permitted flows the increase in load from existing to permitted flows has to be accounted for in this TMDL. Achieving lower winter permit limits may require additional technology, chemical addition and/or a series of trials before NPDES permit limits can be permanently met. The WWTF's should be allowed a reasonable schedule, if necessary, and upon request, to test operational methods and various technologies to achieve long-term TMDL goals.

The middle portion of Table 21 contains the stormwater WLAs for total phosphorus by land use type as calculated from the Current and Final TMDL Scenarios. All intense land uses like Medium Density Residential, High Density Residential, Multi-Family Residential, Commercial/Industrial, and Transportation have a 65% reduction requirement.
In Table 21, the modeled Commercial/Industrial/Transportation land use was split into Commercial/Industrial and Transportation categories. The Transportation category applies to transportation land uses defined by MassGIS (airports, docks, divided highway, freight, storage, railroads). Other infrastructure receives the same WLA as the land use type they are within.

The lower portion of Table 21 contains the nonpoint source and background LAs for total phosphorus assigned to atmospheric deposition, water/wetland area, and benthic flux.

Figure 14 graphically shows the reductions from current conditions to the Final TMDL loads. The Final TMDL loads are the WLAs and LAs. All loads are the average over 1998-2002 (kg/ha).

The subtotals of the loads for wastewater (3,296 kg/yr), stormwater (15,086), and nonpoint/background (2,211) from Table 21 appear in the top three rows of Table 20/Table ES-4 (shown previously), which summarizes the annual total phosphorus loads for current conditions and TMDL conditions (98-02) for all sources and losses. As shown, sources also include system losses from algae uptake and settling, and diversions (-5,625 kg/yr). Most importantly, Table 20/Table ES-4 also shows that the total annual phosphorus load (WLA + LA- system losses), is 14,968 kg/yr, a loading which meets the allocation requirement at the Watertown Dam (15,109 kg/yr). The TMDL allows for a total MOS of approximately 6%. The 6% includes the additional MOS of 757 kg/yr which was apportioned from the Lower Charles TMDL.

## Table 21/ES-3. Annual Phosphorus WLA and LA for the Upper/Middle Charles TMDL

| Source | Current Load (kg/yr) | Reduction (%) | TMDL Load (kg/yr) |
|---|---|---|---|
| Milford WWTF (MA0100579) | 3,407 | 66 | 1,149 |
| CRPCD (MA0102598) | 4,278 | 65 | 1,483 |
| Medfield WWTF (MA0100978) | 1,174 | 66 | 398 |
| MCI Norfolk (MA0102253) | 406 | 67 | 132 |
| Wrentham Dev Ctr (MA0102113) | 345 | 62 | 132 |
| Pine Brook CC (MA0032212) | -- | -- | 1 |
| **WASTEWATER (WLA)** | **9,611** | **66** | **3,296** |
| | | | |
| Low Density Res. | 4,979 | 45 | 2,739 |
| Medium Density Res. | 5,505 | 65 | 1,927 |
| High Density Res./MF* | 5,964 | 65 | 2,088 |
| Commercial/Industrial* | 6,294 | 65 | 2,203 |
| Transportation | 2,167 | 65 | 759 |
| Open/Agriculture | 1,504 | 35 | 977 |
| Forest | 4,394 | 0 | 4,394 |
| **STORMWATER (WLA)** | **30,808** | **51** | **15,086** |
| | | | |
| Bentic Flux | 2,359 | 25 | 1,769 |
| Water/Wetland | 126 | 0 | 126 |
| Atmospheric Deposition | 316 | 0 | 316 |
| **NONPOINT & BACKGROUND (LA)** | **2,801** | **21** | **2,211** |

Note: Numeric differences due to decimal rounding.

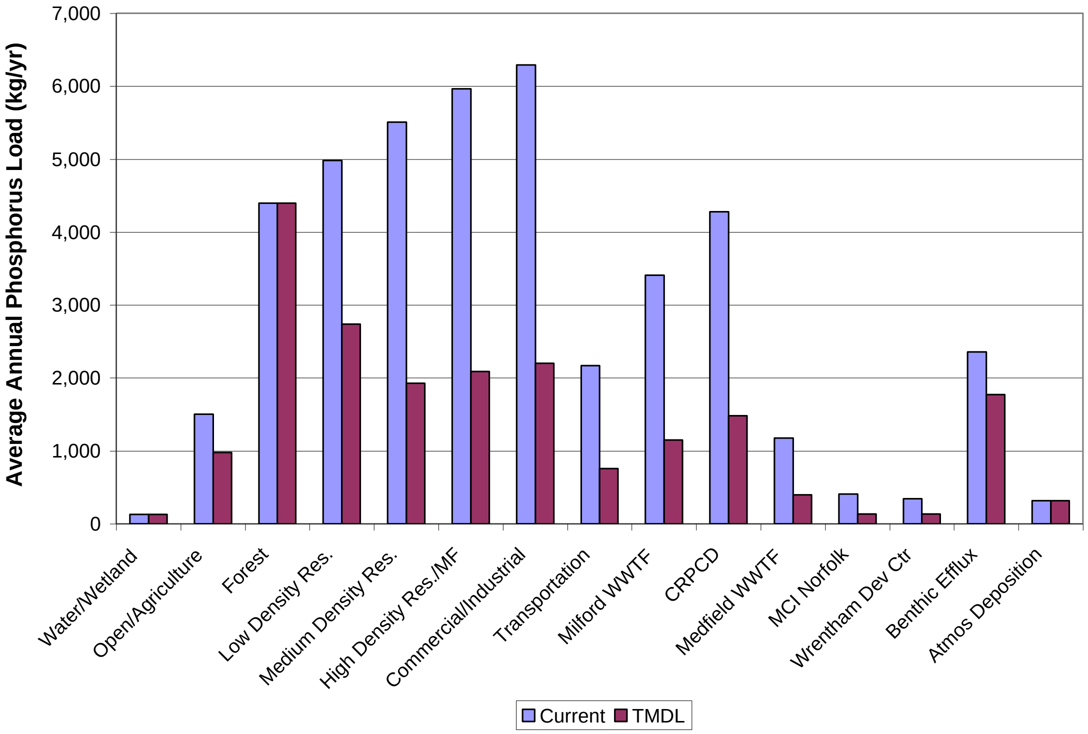


**Figure 14. Annual Phosphorus WLAs for the Upper/Middle Charles TMDL**

## 6.3 Margin of Safety

Both section 303(d) of the Clean Water Act and the regulations at 40 CFR 130.7 require that TMDLs include a margin of safety (MOS). The MOS is the portion of the pollutant loading reserved to account for any uncertainty in the data. There are two ways to incorporate the MOS (1) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations or (2) implicitly incorporate the MOS by using conservative model assumptions to develop allocations. For this TMDL analysis, the MOS is consistent with the Lower Charles TMDL. The TMDL maintains the 5% explicit margin of safety, and achieves an additional MOS of 1% through conservative model assumptions.

The Upper/Middle Charles TMDL is constrained by the Lower Charles TMDL load at the Watertown Dam and the Lower Charles TMDL included an explicit 5% margin of safety. A portion of that margin of safety for the Lower Charles also applies to the Upper/Middle Charles TMDL. The Lower Charles TMDL margin of safety was explicitly set at 979 kg/yr for a total load of 19,544 kg/yr for the Lower Charles. The margin of safety for the Lower Charles needs to be applied proportionally to account for the Upper/Middle Charles watershed load to the Watertown Dam of 15,109 kg/yr. The Upper/Middle Charles TMDL therefore inherits an explicit margin of safety from the Lower Charles TMDL of 757 kg/yr. Additionally, the Final TMDL for the Upper/Middle Charles is 14,968 kg/yr which is below the Lower Charles TMDL load allocation limit (15,109 kg/yr). This provides for a total explicit MOS of 898 kg/yr or 6% (141 kg/yr from the Upper/Middle Charles TMDL and 757 kg/yr from the Lower to the Upper/Middle TMDL).

The Final TMDL Scenario also includes several conservative assumptions that provide an additional safety factor. First, the model assumes a reduction of the sediment efflux rate for phosphorus of only 25%. Since the total reduction of total phosphorus load for the TMDL is 50%, the long-term efflux rate is expected to eventually be higher than this number. The difference in the assumed reduction and the expected long-term reduction in sediment efflux rates for phosphorus is considered an additional implicit safety factor.

Second, because each reach was analyzed individually for the mean, 90th percentile, and 7-day extreme value for the target water quality parameters, the analysis methodology provided for an additional implicit margin of safety as compared to a TMDL that looks at averages over multiple reaches. The Final TMDL Scenario was selected to provide the best possible protection for all reaches since it consistently meets the defined water quality targets.

Third, the methods of analysis for determining annual average phosphorus load and achieving water quality targets in all reaches was based on a worst case condition. The target annual phosphorus load was based on an average of 1998-2002 and this period is considered representative of a much longer flow period with low flows slightly lower than average (see Figures 5-4 and 5-5 in US-EPA, 2007). The analysis period used for the reaches was 2002 which is considered to be representative of low flow or near-7Q10 conditions (see Section 4.3.4) and should capture the worst case conditions associated with WWTF discharges.

In summary, this TMDL provides for both an explicit (6%) and an implicit margin of safety.

## 6.4 Seasonal Variation

The federal regulations at 40 CFR 130.7 require that TMDLs include seasonal variations and take into account critical conditions for stream flow, loading, and water quality parameters. For this TMDL, nutrient loadings were determined on an hourly basis, and then accumulated to an annual figure, thus accounting for seasonality. Phosphorus sources to Upper/Middle Charles River waters arise from a mixture of dry- and wet-weather sources. The biologic response to nutrient inputs from multiple sources throughout the length of the river is complex and dependent on the loads as well as the physical and hydraulic characteristics of the receiving stream.

The Upper/Lower Charles TMDL model is a dynamic water quality model that simulates hourly water flow and quality data in response to time-varying inputs of land-derived stormwater and wastewater. The model was run for the period 1994-2005 and focused on the period 1998 to 2002 for phosphorus loads and April to October, 2002 for reach responses. The 1998-2002 period was carefully selected to represent the variability in flow conditions while the summer of 2002 was chosen to represent the worst-case water quality response. These two approaches cover the widest possible range of seasonal variability that could be encountered in the Upper/Middle Charles River watershed.

The Upper/Middle Charles TMDL model was used to simulate a frequency distribution of allowable daily phosphorus loadings (see Section 6.1) as estimations of allowable maximum daily loads to the Lower Charles. Combining the frequency distribution of allowable daily loads with the allowable annual load requires that phosphorus controls should be in place throughout the year in order to meet both the allowable annual load and the water quality targets.

# 7 TMDL IMPLEMENTATION PLAN

## 7.1 Overview and Approach

The Upper/Middle Charles River does not currently meet Massachusetts Water Quality Standards, and is impaired by excessive nutrients, organic enrichment/low dissolved oxygen and noxious aquatic plants, among other impairments. Water quality standards are established to assure that beneficial uses of the river and tributaries, such as boating, swimming, fishing and fish consumption, are protected. When water quality standards are not met, the federal Clean Water Act requires a Total Maximum Daily Load (TMDL) to be established. A TMDL determines the current amount of pollution entering a water body, identifies the sources of that pollution, and quantifies how much that pollution needs to be reduced in order to meet water quality standards. The TMDL then assigns a maximum allowable pollutant load to the major sources (an allocation) so that water quality standards will be met. The TMDL Implementation Plan (Plan) lays out a recommended approach to achieve allocated loads. The purpose of this plan is to outline an adaptive management process that identifies immediate implementation activities, as well as a framework for making continued progress in reducing pollutant loads to the Upper Charles River over the long term.

The Upper/Middle Charles River Nutrient TMDL has identified phosphorus as the pollutant of concern and determined the magnitude and extent of phosphorus-related water quality impairments in the Upper/Middle Charles River and tributaries. The sources contributing to those impairments and the required phosphorus pollutant reductions from these sources to achieve water quality standards and protect beneficial uses have also been ascertained. This TMDL has established that significant reductions in phosphorus loading are necessary.

The Upper/Middle Charles Nutrient TMDL was conducted following the approval of the Lower Charles River Basin Nutrient TMDL, which provided a maximum phosphorus allocation to the Upper/Middle Charles River at the Watertown Dam. The Upper/Middle Charles River Nutrient TMDL was thus developed to achieve water quality standards in the Upper/Middle Charles River with the constraint of also meeting the allocation established in the Lower Charles TMDL.

To achieve the required reductions in phosphorus loading, decreases from both the two main sources of phosphorus to the Upper/Middle Charles River are necessary including the wastewater treatment facilities (WWTFs) and stormwater. The waste load allocations (WLAs) in this TMDL require:

1) reductions in phosphorus effluent limits at the three major WWTFs and the three minor WWTFs to achieve a summer time limit of 0.1 mg/L, and wintertime limit of 0.3 mg/L. Achieving lower winter permit limits may require additional technology, chemical addition and/or a series of trials before NPDES permit limits can be permanently met. The WWTF's should be allowed a reasonable schedule if necessary, and upon request, to test operational methods and various technologies to achieve long-term TMDL goals;
2) reductions in stormwater phosphorus loads based upon land use, as identified.

Model predictions indicate that these load reductions will attain most of the TMDL targets for the Upper/Middle Charles River and achieve Massachusetts Water Quality Standards. These load reductions will also achieve the annual phosphorus load reductions required in the Lower

Charles River Basin Nutrient TMDL.

## 7.2 Management Strategies

This Upper/Middle Nutrient TMDL has established that there are numerous sources of phosphorus to the river that are contributing to water quality impairments. The most significant sources of phosphorus, WWTF discharges and stormwater, account for 93% of the total annual phosphorus load to the Upper/Middle Charles River. Figure 6 in Section 5 showed the annual phosphorus loads to the Upper/Middle Charles River from the main sources for the period 1998-2002.

Based on the magnitude of phosphorus reductions called for in this TMDL, a watershed-wide implementation plan is needed. This plan requires the control and/or elimination of several nutrient sources to the Charles River including stormwater runoff from drainage systems, illicit discharges to stormwater drainage systems, and reductions in annual and seasonal phosphorus loadings from both private and publicly-owned treatment works.

TMDL implementation-related tasks are presented in Table 22. The MassDEP working with the watershed communities, US-EPA, MRWA, CRWA, and other stakeholders in the watershed will make every reasonable effort to assure implementation of this TMDL. These stakeholders can provide valuable assistance in defining hot spots and sources of nutrient contamination as well as the implementation of mitigation or preventative measures.

The TMDL Implementation Plan targets the two primary sources of phosphorus for reductions consistent with the WLAs for stormwater and WWTFs. Because of the complexity of the system being modeled, the inherent difficulties in modeling phytoplankton, and the difficulty of defining and installing necessary stormwater BMPs, an adaptive management approach is proposed, which allows for a process that is implemented in stages over time.

Achieving the Upper Charles River nutrient TMDL will require an iterative process that sets realistic implementation goals and schedules that are adjusted as warranted based on ongoing monitoring and assessment of control activities. The total phosphorus allocations presented in the TMDL represent reductions that will require substantial time and financial commitment to be attained. A comprehensive control strategy is needed to address the numerous sources of nutrients in the Charles River watershed that contribute to nutrient impairments in both the Upper and Lower Charles River.

In 2009, MassDEP, the US EPA and Tetra Tech Inc., along with local officials from the towns of Bellingham, Franklin and Milford, conducted a pilot study in the Upper Charles River Basin to determine the optimal combination of structural best management practices (BMPs) to meet the phosphorus reduction targets of the Charles River Total Maximum Daily Load (TMDL). The Pilot combined hydrologic and water quality modeling, with management scenarios and an optimization routine called the BMP Decision Support System (BMPDSS). The study was designed to answer the following question: Given the actual conditions in these towns and reasonable management scenarios what is the most cost effective collection of BMPs needed to reach the TMDL Goal? The results indicate a significant cost difference between near-optimal solutions versus requiring MS4s to meet the same reduction objectives. Specifically, it is far more effective to concentrate phosphorus removal efforts where conditions are favorable for removal and loading rates are high, though some phosphorus removal is required virtually everywhere it is possible. Implementing a near-optimal phosphorus reduction program implies making tradeoffs between favorable and un-favorable sites, as well as between privately owned sources of stormwater and publicly managed stormwater, as well as new institutions to make that possible. Additionally, non-structural measures to reduce phosphorus have the potential for significant savings by avoiding the construction costs of structural BMPs. The report can be found at: http://www.mass.gov/dep/water/resources/tmdls.htm#charlesdp.

EPA has proposed a new draft permit, known as the "North Coastal Small Municipal Separate Storm Sewer System (MS4) General Permit," which updates pollution control measures to help control excessive pollution from stormwater runoff. The draft permit would apply to 84 communities in eastern Massachusetts including communities in the Charles River watershed. The draft MS4 permit would require communities to continue to implement stormwater management programs already in place that are designed to reduce pollutants discharged from municipal storm systems to rivers, lakes and bays. The new permit builds upon work the communities started under the previous MS4 permit, issued in 2003. The proposed permit includes "best management practices" such as removing illegal sewage connections to storm systems, street sweeping, public education, and steps to expand the infiltration of stormwater rather than diverting stormwater into sewer systems. These measures will help prevent water pollution caused by stormwater in Massachusetts.

The report is at: http://www.epa.gov/region01/npdes/stormwater.

### *7.2.1 Stormwater*

Aggregate WLAs for stormwater discharges to the Upper/Middle Charles River were established for sources that contribute phosphorus loads. The aggregation of sources into gross or lumped allocations by land use is consistent with the level of data and information available for this TMDL. While there is reasonable confidence in the overall magnitude of the total nutrient loadings to the Upper/Middle Charles River from the identified major land use areas, there are only limited data available to determine the magnitudes of loads from individual sources. This uncertainty is due to several factors including the typical high variability associated with drainage system discharges, the lack of nutrient and flow monitoring data for specific stormwater sources, and many of the drainage system sources are influenced, to varying degrees, by illicit sewage discharges.

## Table 22. Upper/Middle Charles TMDL Implementation Tasks

| Task | Responsible Organization |
|---|---|
| TMDL Public Meeting | CRWA, MassDEP, and US-EPA |
| Response to Public Comment | MassDEP |
| Issue Final TMDL | MassDEP |
| Review and approve Final TMDL | US-EPA |
| Integration of TMDL with appropriate regulatory programs | Charles River Watershed Municipalities, MassDEP, and US-EPA |
| Identify comprehensive stormwater management strategy including cost estimates and potential funding sources | Charles River Watershed Municipalities, WWTFs, and other relevant NPDES permit holders including non-municipal MS4 permit holders (e.g. MassHighway, MassPike, and DCR) where appropriate |
| Develop and implement stormwater management programs including BMP implementation | Charles River Watershed Municipalities, WWTFs, and other relevant NPDES permit holders including non-traditional MS4 permit holders (e.g. MassHighway, MassPike, and DCR) where appropriate |
| Illicit discharge detection and elimination | Charles River Watershed Municipalities, WWTFs, and other relevant NPDES permit holders including non-municipal MS4 permit holders (e.g. MassHighway, MassPike, and DCR) where appropriate |
| Modification of WWTFs permits and operations to meet TMDL | WWTFs, MassDEP, and US-EPA |
| Organize and implement education and outreach program | MassDEP, CRWA, and Charles River Watershed Communities |
| Ongoing surface water monitoring | US-EPA, MWRA, MassDEP, and CRWA |
| Provide periodic status reports on implementation of remedial activities | Charles River Watershed Municipalities, WWTFs, and other relevant NPDES permit holders including non-traditional MS4 permit holders (e.g. MassHighway, MassPike, and DCR) |
| If necessary, identify future programs to reduce phosphorus loads in targeted seasons/locations | Charles River Watershed Municipalities, WWTFs, and other relevant NPDES permit holders including non-traditional MS4 permit holders (e.g. MassHighway, MassPike, and DCR) |

These WLAs were expressed in terms of both loadings and relative percent reductions. This implementation plan emphasizes the relative percent annual phosphorus load reductions needed for each land use type, which are as follows:

1. Commercial/Industrial/Transportation – 65%
2. High Density / Medium Density / Multi-family Residential – 65%
3. Low Density Residential – 45%
4. Open Space / Agriculture – 35%
5. Forest / Forested Wetlands – 0%
6. Open Water / Wetlands – 0%

These reductions are the same as those called for in the Lower Charles Nutrient TMDL. The reductions provide guidance as to the relative importance of land use categories for contributing phosphorus to the Upper/Middle Charles River. The magnitude of the loading estimates for each of the land-cover categories is based on Geographic Information system (GIS) land cover categories and literature based phosphorus export loading rates. Although this information was extremely useful in helping to calibrate and validate the HSPF water quality model it is not accurate enough to be applied at the individual site or parcel level. There is no substitute for phosphorus source assessments in each of the communities. It is possible, because of local site conditions such as soils, slope, drainage patterns, vegetative cover, and site use or activity that the actual phosphorus loading from urban sites may be less than or higher than the estimates from this analysis. Similarly, actual phosphorus loadings from less developed areas in the watershed may be higher than estimated in this analysis and should not be overlooked for control opportunities. Examples of high phosphorus loading sources in less developed areas that may be easily and cost effectively controlled include soil erosion from forested areas and construction sites. Also, open parklands adjacent to waterways may be areas where excessive fertilizers are applied and/or where waterfowl congregate and generate high phosphorus wastes in close proximity to receiving waters. Leaf litter from tree lined streets in low and medium density residential areas served with piped drainage systems may also represent relatively easy to control high source loading areas as well.

This Plan recommends that owners of stormwater drainage system discharges to the Charles River undertake an iterative approach of managing their discharges. Briefly, this approach would involve adopting initial controls to reduce phosphorus while at the same time collecting information that will better characterize their sources so that subsequent control activities can be prioritized to achieve the greatest phosphorus load reductions in the most efficient and cost effective manner.

### *7.2.2 Management of Stormwater from Drainage Systems*

Storm water runoff can be categorized in two forms; 1) point source discharges (from discrete conveyance, including piped systems) and 2) non-point source discharges (includes sheet flow runoff). Many point source storm water discharges are regulated under the NPDES Phase I and Phase II permitting programs when discharged to waters of the United States. Municipalities that operate regulated municipal separate storm sewer systems (MS4s) must develop and implement a storm water management plan (SWMP) which must employ, and set measurable goals for the following six minimum control measures:

1. public education and outreach particularly on the proper disposal of pet waste,
2. public participation/involvement,
3. illicit discharge detection and elimination,
4. construction site runoff control,
5. post construction runoff control, and
6. pollution prevention/good housekeeping.

All or portions of the towns in this watershed are classified as Urban Areas (UAs) by the United States Census Bureau and are subject to the Stormwater Phase II Final Rule.

The NPDES permits which EPA has issued in Massachusetts to implement the Phase II Stormwater program do not establish numeric effluent limitations for storm water discharges. Rather, they establish narrative requirements, including best management practices, to meet the six minimum control measures and to meet State Water Quality Standards.

Portions of some of the municipalities in the watershed are not currently regulated under the Phase II program. It is recommended that those municipalities consider expanding some or all of the six minimum control measures and other BMPs throughout their jurisdiction in order to minimize storm water contamination.

Some stormwater point sources may not be the responsibility of the municipal government and may have to be addressed through other regulatory vehicles available to EPA and MassDEP, including, but not limited to EPA's exercise of its residual designation authority to require NPDES permits, depending upon the severity of the source. The data included in this TMDL, including wasteload allocations, demonstrates that additional controls may well be needed on many storm water discharges.

With respect to stormwater, existing stormwater management programs need to be expanded to include more specific control and monitoring activities related to nutrients (discussed below). The draft TMDL recommended consideration of one or more targeted watershed-specific general permits (WSGP) for drainage systems that discharge to the Charles River and its tributaries. Presently there are three regulatory activities intended to address this issue. They include the MS4 General permit, which encompasses all towns in the watershed either in whole or in part, the application of EPA's Residual Designation Authority (RDA) in the Towns of Milford, Franklin, and Bellingham, and the proposed statewide stormwater regulation and permit for private commercial, industrial and institutional properties.  Experience gained from the implementation of these approaches will help guide future decisions on the best regulatory vehicles to address stormwater discharges throughout the watershed.  WSGPs may still be an efficient approach to accomplish improved levels of nutrient control from stormwater drainages systems and if necessary, expand permit coverage to drainage systems that are presently not covered and should be considered in the future.

Requirements for permitted entities to conduct specific nutrient-related monitoring and control activities are necessary to achieve the specified large nutrient load reductions from sources in the contributing watersheds. A regulatory mechanism will be important to ensure that steps will be taken by watershed communities and other owners of permitted drains to make continued progress in reducing nutrient loadings and identifying/prioritizing other actions that are needed to achieve the water quality goals of the Charles River.

A list of the municipalities in Massachusetts regulated by the Phase II Rule can be viewed at http://www.epa.gov/region01/npdes/stormwater/2003-permit-archives.html along with the Notices of Intent for each municipality.

Stormwater discharges represent a major source of nutrients to the Upper/ Middle Charles River and the current level of control is inadequate to protect both the Upper/Middle and Lower Charles River system. Initially, the owners of regulated municipal drainage systems, including communities, Massachusetts Highway Department (MassHighway), Department of Conservation and Recreation (DCR), and Massachusetts Turnpike Authority (MassPike), will need to collect source monitoring data and additional drainage area information to better target source areas for controls and evaluate the effectiveness of on-going control practices. Also, while their sources are being better characterized, their existing stormwater management programs should be enhanced to optimize reductions in nutrient loadings with initial emphasis on source controls and pollution prevention practices.

Phosphorus load reductions from stormwater may be undertaken using a combination of good housekeeping practices, structural and nonstructural Best management Practices (BMPs), reductions in impervious cover, and other Low Impact Development (LID) techniques. Other approaches can also aid in this process including establishing outreach and education programs for homeowners to encourage proper lawn and garden care as well as practices for the proper disposal of pet waste. Each of these actions can significantly reduce nutrient loads. Municipal good housekeeping practices should also be adopted, including regular street sweeping and proper operation and maintenance of stormwater infrastructure, maintenance of parks and public lands, and best management practices at all municipal facilities. Adoption of local regulations and bylaws can require sediment and erosion controls, and can encourage low impact development and other infiltration practices that also mitigate flooding. Information about regulatory and non-regulatory tools can be found in The Massachusetts Clean Water Toolkit at http://www.mass.gov/dep/water/resources/nonpoint.htm on MassDEP's Nonpoint Source Pollution web page. The Toolkit provides a comprehensive resource about nonpoint source pollution, appropriate best management practices, and appropriate strategies to support development of an effective TMDL implementation program.

Although the TMDL presents quantified WLAs, EPA and MassDEP do not intend to initially include numeric effluent limitations in NPDES stormwater permits based on this TMDL. As discussed in the LA and WLA sections, all of the allocations except for WWTFs represent aggregated loads from many regulated and unregulated sources, including nonpoint sources that contribute to the overall watershed load presented. Individual source data are limited, and therefore at the present time, it is not feasible to estimate appropriate numeric effluent limitations for regulated storm water drainage systems. In the future, as more source information is developed it may become feasible to establish effluent limits for permitted drainage system discharges.

The current intention is to have the stormwater permits require best management practices (BMP-based permits) that will require permittees to develop and implement comprehensive stormwater management programs involving source monitoring to identify and prioritize pollutant source areas and to implement BMPs. MassDEP and EPA believe that BMP-based permits will initially provide an appropriate framework for developing comprehensive stormwater management programs with specific emphasis on phosphorus that contributes to the existing water quality impairment.

Comprehensive programs will be necessary to achieve the phosphorus reduction and water quality goals of this TMDL. Programs should build upon existing stormwater management to accomplish the following tasks:

- characterize the drainage areas that contribute to discharges requiring permit coverage under the Permittee's jurisdiction
- implement a comprehensive Illicit Discharge Detection and Elimination (IDDE) program (where appropriate)
- prioritize source areas for stormwater management and control
- identify site-specific and regional opportunities for implementation of BMPs
- include the necessary structural and non-structural best management practices (BMPs) that, upon implementation, will achieve reductions in phosphorus loadings from the NPDES covered drainage areas that are consistent with the phosphorus load reductions identified in this TMDL

More detail is discussed below.

1. Drainage Area Characterization
    - A. Prepare map of drainage areas showing:
        - i. Outfall locations;
        - ii. Pipe/drainage system network with all catch basins, underdrains, and common manholes;
        - iii. Sanitary sewer system and or on-site sewage disposal systems;
        - iv. Impervious cover;
        - v. Land cover categories;
        - vi. Parking lots ;
        - vii. Vegetated areas where fertilizers are applied; and
        - viii. Areas with trees bordering paved areas (i.e., trees lined streets).
    - B. Divide drainage area into logical/manageable sub-drainage areas or subcatchments;
    - C. Report the following information for each outfall and/or subcatchment area:
        - a. Drainage area;
        - b. Impervious cover area;
        - c. Parking lot area;
        - d. Area in each MassGIS land cover category;
        - e. Vegetated areas that receive fertilizer applications;
        - f. Number of catch basins;

    g. Number of common manholes serving both the drainage and sanitary sewer systems; and
    h. Length of roadways.

2. Conduct Illicit Discharge Detection and Elimination (IDDE) Program (where appropriate)
    A. Drainage system investigations;
    B. Dry and wet-weather monitoring;
    C. Prioritize sources for elimination;
    D. Elimination of illicit sources; and
    E. Post-removal confirmation.

3. Develop and implement Baseline Storm Water Management Plan (SWMP) or good housekeeping plan to reduce phosphorus loading. The baseline SWMP must include the following components:
    A. Education:
        i. Fertilizer and grounds keeping management;
        ii. Pet waste control;
    B. Leaf litter collection/disposal program;
    C. Catch basin cleaning;
    D. street-sweeping of parking lots and roadways using vacuum assisted sweepers; and
    E. maintenance plan for existing BMPs.

4. Prioritize sources using drainage area characteristics, IDDE information, and monitoring data. Each source should be assigned a numerical ranking based on consideration of the magnitude of the phosphorus loading from the source and the likely nature of the control remedy. The ranking should indicate the priority in which sources will be addressed.

5. Develop and implement an enhanced SWMP to achieve the phosphorus loading reduction goals of TMDL. The SWMP would be improved using the information developed from the drainage area characterization task together with guidance on BMP pollutant removal performance. Currently EPA Region I is finalizing a project to develop BMP pollutant removal performance information that would be suitable for estimating phosphorus removal credits for various BMPs. The enhanced SWMP should consider the BMPs identified and discussed further below in this section.

    A. Prepare a revised SWMP to achieve TMDL phosphorus reduction goals.
        i. Identify phosphorus reduction goals;
        ii. Consider infiltration practices, bio-retention/filtration practices and other structural controls that have been shown to be consistently reliable for removing phosphorus in storm water runoff;
        iii. Consider high-efficiency street sweeping program;
        iv. Provide supporting documentation to show that the enhanced SWMP will achieve TMDL phosphorus reduction goals;
        v. Provide implementation schedule to address each ranked sources.

    B. Design and install structural and/or nonstructural BMPs to achieve TMDL phosphorus reduction goals;
    C. Provide detailed operation and maintenance plan for all BMPs including detailed schedule for all implementation activities;
    D. Maintenance plan for existing BMPs.

6. Prepare a post-implementation assessment of the enhanced SWMP. The permittee will track and assess the pollutant reductions achieved during implementation of the SWMP and document whether or not it appears to be meeting the reduction goals of the TMDL. Best estimates of phosphorus capture of the various non-structural and structural BMPs should be provided. Estimates need to be based on quantifiable measures to the maximum extent practicable. Examples include the amount of dust and dirt collected by street sweeping and catch basin cleanings, cubic yards of leaf litter collected, weight of dog waste bags collected from designated receptacles, amount of fertilizer applied, and amount of sediment deposition in structural BMPs.

In addition to the above, municipalities should explore the use of local ordinances to address potentially high pollutant source areas that are not directly covered by NPDES permits (shopping centers, malls, etc.).

Considering the large extent of urbanized area in the Charles River watershed, non-structural BMPs are likely to be important components of the management programs. The efficiencies of some of the more commonly used structural controls, such as detention basins and sedimentation basins, at removing smaller sized particles is often limited. Non-structural BMPs emphasize source controls such as public education, use of alternative products, street cleaning, catch basin cleaning, general maintenance, and land use controls (CGER-OSB, 2000).

Current research indicates that some of the most effective means to reduce phosphorus loads from stormwater involve infiltration practices. Phosphorus loading rates are directly related to impervious cover and how well-connected that impervious cover is to drainage systems. Not only are infiltration practices highly effective at removing phosphorus, they offer the added benefit of recharging groundwater which in turn contributes base-flow to streams and receiving waters. The added baseflow from stormwater/groundwater recharge improves aquatic habitats, increases pollutant assimilative capacity of the receiving waters, and helps to offset withdrawals from public water supplies.

Bioretention/filtration practices are another class of BMPs that hold great promise for removing phosphorus and other pollutants in storm water runoff in the Charles River watershed. Unlike infiltration practices, the implementation of bioretention practices are not limited by soil conditions and can be installed almost anywhere where space exists. Bioretention/filtration practices provide a filter media and vegetation to treat runoff. Where subsoils are poor for drainage, underdrains are used to collect treated runoff after it has passed through the vegetation and filter media.

The first step in the stormwater management program will be source monitoring and drainage area characterization. Permittees will need to map their stormwater drainage systems and characterize the drainage area (i.e., area, land uses, percent imperviousness, street miles, etc). They will also need to prioritize their nutrient sources by drainage system and identify high source areas (e.g., highly impervious areas, high erosion areas, golf courses, etc), in order to effectively focus management options. Permittees that own and operate a single separate storm sewer system will not need to go through the prioritization step. As indicated owners of permitted separate storm sewer systems in the watershed should first develop a baseline stormwater management plan that follows the aforementioned steps to reduce nutrient loading to the Charles River through source controls.

Disturbed land and construction activities continue to be significant potential sources of phosphorus loading. Regulation and enforcement of erosion and sedimentation control practices should be evaluated and expanded if appropriate to reduce phosphorus loads.

In some areas, stream bank management activities may be contributing to phosphorus loading. The use of culverts, retaining walls, rip rap and other armored stream bank treatments can increase stream velocities and increase the rate of sediment deposition in downstream areas. These practices may also lead to larger flood events which transport significant volumes of phosphorus and other pollutants to receiving waters. Stream bank restoration utilizing vegetated banks and shallow wetland shelves can significantly reduce phosphorus loads and improve water quality without increasing flood risk.

Additional activities such as the identification and removal of illicit sanitary flows from storm drains and the correction of failing septic systems will contribute to the reduction in phosphorus loading as well as address fecal contamination problems. Non-structural BMP programs such as source control programs, landscape maintenance and management programs, high-efficiency, high frequency sweeping programs for streets and parking lots, no-idling and emissions reduction programs, and public education campaigns may also provide some reduction in phosphorus loading.

### *7.2.3 Management of Illicit Discharges to Stormwater Drainage Systems*

Both dry- and wet-weather water quality monitoring of municipal stormwater drainage system discharges to the Charles River, show that the quality of these discharges is highly variable and that they are likely to be contaminated with illicit sources of sewage (see Lower Charles TMDL). Past and on-going investigations of stormwater drainage systems that discharge to the Lower Charles River indicated illicit sources of sewage are prevalent in tributary stormwater drainage systems and represent a substantial source of nutrient loading. Because of the presence of sewage in the stormwater drainage systems, it is difficult to determine how much of the nutrient loading is due to illicit sources and how much is due to stormwater runoff. This is likely the case in urban areas in the Upper/Middle Charles River as well.

Illicit discharges of sewage to the Charles River through the municipal stormwater drainage system represent a substantial source of nutrients that contributes to water quality problems in the Upper/Middle Charles River as well as excessive algal biomass in the Lower Charles. Not only are illicit discharges a concentrated source of nutrients, but they pose a direct risk to human health because of the potential presence of pathogens in the discharges. Illicit discharges are prohibited in the watershed and must be eliminated to protect human health and to reduce algal biomass in the Charles River System. Since illicit discharges are associated with the stormwater drainage systems, Phase II Municipal Separate Storm Sewer System (MS4) permits are also the vehicles for implementation of controls on illicit discharges.

Individual sources must be first identified in the field before they can be abated. Pinpointing sources will require extensive monitoring of the stormwater drainage systems during both dry- and wet-weather conditions. A comprehensive program is needed in all of the Charles River watershed communities to ensure that illicit sources are identified and that appropriate actions will be taken to eliminate them. Some communities that are actively investigating illicit discharges currently sample for bacteria in their drainage system monitoring. These sampling efforts need to be expanded to include nutrients.

Guidance for implementing an illicit discharge detection and elimination program is available from several documents. EPA New England developed a specific plan for the Lower Charles River to identify and eliminate illicit discharges (both dry and wet weather) to their separate storm sewer systems (US-EPA 2004). This protocol represents just one of the approved methodologies available. More generic guidance is provided in a document prepared for EPA by the Center for Watershed Protection and the University of Alabama entitled Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments which can be downloaded from:
http://cfpub.epa.gov/npdes/docs.cfm?program_id=6&view=allprog&sort=name

In addition, practical guidance for municipalities is provided in a New England Interstate Water Pollution Control Commission publication entitled Illicit Discharge Detection and Elimination Manual, A Handbook for Municipalities available at: http://www.neiwpcc.org/iddemanual.asp. Implementation of the protocol outlined in these guidance documents satisfies the Illicit Discharge Detection and Elimination requirement of the NPDES program.

In general, the IDDE programs implemented in the Charles River watershed should contain the following components:

- Conduct comprehensive system-wide assessments of drainage systems to identify illicit sewage sources. Methodology must be consistent, at a minimum, with the protocol presented in the Appendix.
    - Conduct dry- and wet-weather nutrient sampling throughout each drainage system
    - Conduct physical inspections and investigations (e.g., manhole inspections, dye testing, videoing drains, etc.)
- Eliminate “easy to fix” sources (i.e., direct pipe connections)
- Develop prioritized plans with schedules for eliminating more complex illicit sources such as those occurring from deteriorating sewers and drain pipes and sewer underdrain connections
- Conduct on-going confirmatory monitoring program to document the elimination of illicit sources. Program shall include dry- and wet-weather sampling of drains.
- Prepare annual progress reports (to be submitted to MassDEP and US-EPA)

As with stormwater management, any monitoring or pilot studies should be well-designed and consistent throughout the watershed.

The detection and elimination of illicit discharges to the Charles River is a high priority for US-EPA and MassDEP. Tracking down episodic illicit discharges to storm drainage systems can be a challenging endeavor that requires repeated water quality monitoring, aggressive source tracking techniques, and committed local resources.

### *7.2.4 Wastewater Treatment Facilities*

There are six active Wastewater Treatment Facilities (WWTFs) discharging treated sewage into the Upper/Middle Charles River watershed, three on the main stem of the Charles River plus two on the Stop River, and one on Pine Brook, both a tributaries to the Charles River. Each of these facilities has a National Pollutant Discharge Elimination System (NPDES) permit which establishes phosphorus limits for the facility.

Under this Implementation Plan, regulation of WWTFs must establish effluent limits to achieve water quality standards and thus the WLAs established in this TMDL. The WLAs for these WWTFs were selected to meet the Lower TMDL total phosphorus load at the Watertown Dam and also to meet the target water quality criteria in all reaches in the Upper /Middle Charles River.

The following permit limits are recommended for phosphorus:

> Milford WWTF, Charles River Water Pollution Control District, the Medfield WWTF, and the minor WWTFs (MCI-Norfolk, Wrentham Development, and Pine Brook Country Club) must reduce their phosphorus discharge levels to 0.1 mg/L in the summer (Apr-Oct) and 0.3 mg/L in the winter (Nov-Mar). Achieving lower winter permit limits may require additional technology, chemical addition and/or a series of trials before NPDES permit limits can be permanently met. The WWTF's should be allowed a reasonable schedule, if necessary, and upon request, to test operational methods and various technologies to achieve long-term TMDL goals.

## 7.3 Potential Future Management Activities

Control of stormwater runoff from drainage systems will require a significant amount of time and effort to accomplish. Given the magnitude of annual phosphorus load reductions required of many land use types, the existing level of development in the Upper/Middle Charles River watershed, and potential constraints on some sites, it is possible that some sites will be unable to achieve the total annual reductions needed to meet the TMDL. Through the adaptive management approach ongoing monitoring will be conducted and will indicate if water quality standards are being met. If this does not occur other management activities would have to be identified and considered to reach to goals outlined in this TMDL.

Potential management activities that could be considered include, but are not limited to, the following:

- Relocating WWTF outfalls to different river segments
- Reducing the phosphorus load from the WWTF and/or considering converting WWTF surface water discharges to treated groundwater discharges

- Consider a pollutant trading program
- macrophyte and benthic algae treatment
- removal or stabilization of benthic sediments
- baseflow augmentation
- the removal of select dams

Each of these potential alternatives would have to be fully investigated and considered prior to further implementation.

### *7.3.1 Ongoing Monitoring*

Water quality and flow monitoring programs in the Upper/Middle Charles River should be continued in order to assess progress towards and success of obtaining the TMDL's water quality goals. This monitoring is necessary to determine whether water quality goals are met through the implementation of the activities. Pilot projects should include water quality monitoring to determine their effectiveness at removing phosphorus. Instream monitoring programs should be designed to capture spatial, seasonal and climatic variability. In the Upper/Middle Charles River, periodic vegetative surveys should be conducted to determine the impacts of phosphorus reduction on biomass in critical reaches.

### *7.3.2 Refinement of the Watershed Model*

The HSPF model used to develop the nutrient TMDL for the Upper/Middle Charles River must be kept "active" as part of the implementation plan and data collected in ongoing water quality monitoring programs and be utilized to update the model on a regular basis. This will allow ongoing evaluation of new stormwater and wastewater controls as they are implemented and also permit the development of additional scenarios to help prioritize implementation strategies in the future.

Periodic modeling activity is important in the Upper/Middle Charles River given some of the uncertainties of the response of nutrient reduction activities and the potential need to consider greater reductions. In an adaptive management approach, load reductions are implemented, the effects on the receiving water quality are evaluated, and further reductions are then implemented if they are deemed necessary. This process is repeated until water quality goals are met.

### *7.3.3 Funding/Community Resources*

A complete list of funding sources for implementation of nonpoint source pollution is provided in Section VII of the Massachusetts Nonpoint Source Management Plan Volume I available on line at http://mass.gov/dep/water/resources/nonpoint.htm#plan. This list includes specific programs available for nonpoint source and stormwater management and resources available for communities to manage local growth and development. The State Revolving Fund (SRF) provides low interest loans to communities for certain capital costs associated with building or improving wastewater treatment facilities. In addition, many communities in Massachusetts sponsor low cost loans through the SRF for homeowners to repair or upgrade failing septic systems.

# 8 REASONABLE ASSURANCE

Reasonable assurances that the TMDL will be implemented include both application and enforcement of current regulations, availability of financial incentives including low or no-interest loans to communities for wastewater treatment facilities through the State Revolving Fund (SRF), and the various local, state and federal programs for pollution control. Storm water NPDES permit coverage is designed to address discharges from municipal owned storm water drainage systems. Some stormwater sources may not be the responsibility of the municipal government. These, and in cases in which efforts under Phases I and II fail to achieve water quality standards, may have to be addressed through other regulatory vehicles available to MassDEP and US-EPA through federal and state Clean Water Acts depending upon the severity of the impact.

MassDEP also is evaluating monitoring data collected by the agency and others in order to help set priorities for abating impacts from storm water. Enforcement of regulations controlling non-point discharges includes local enforcement of the state Wetlands Protection Act and Rivers Protection Act Title 5 (http://www.mass.gov/dep/water/laws/regulati.htm) regulations for septic systems and various local regulations including zoning regulations. Financial incentives include Federal monies available under the CWA Section 319 Nonpoint Source program and the CWA Section 604 and 104b programs, which are provided as part of the Performance Partnership Agreement between MassDEP and the US-EPA. Additional financial incentives include state income tax credits for Title 5 upgrades, and low interest loans for Title 5 septic system upgrades through municipalities participating in this portion of the state revolving fund program. A brief summary of many of MassDEP's tools and regulatory programs is presented below.

A review of historical grant projects in the Charles River watershed over the last few years shows an on-going commitment to fund projects in the watershed to reduce nonpoint source phosphorus. This includes six 319 projects of close to $2.8 million dollars dedicated to the Charles River watershed, with an additional $400,000 from other funding sources to address other nonpoint source issues in the watershed. Projects include a pilot Online Phosphorus Trading System to facilitate cost effective solutions with the intent to expand to the entire Charles River watershed.

Specifically in the Charles River Watershed, the Department has issued 319 grants to develop and implement stormwater treatment systems and collect additional data for the TMDL development. The implementation projects will result in the installation of stormwater treatment systems to protect Hammond Pond in Newton and to treat and reduce discharges to the Charles River off Plymouth Road in Bellingham, Cold Spring Brook in Wellesley, stormwater retrofit in Franklin, and an LID Program at Jackson Square. The 319 program also provides additional assistance in the form of guidance. MassDEP is in the process of updating the Massachusetts' Nonpoint Source Management Manual that will provide detailed guidance in the form of BMPs by land use to address various water quality impairments and associated pollutants.

## 8.1 Overarching Tools

### *8.1.1 Massachusetts Clean Water Act*

The Massachusetts Clean Water Act (M.G.L. Chapter 21, sections 26-53) provides MassDEP with specific and broad authority to develop regulations to address both point and non-point sources of pollution. There are numerous regulatory and financial programs, including those identified in the preceding paragraph, that have been established to directly and indirectly address nutrient impairments throughout the state. Several of them are briefly described below. The Massachusetts Clean Water Act can be found at http://www.mass.gov/legis/laws/mgl/gl-21-toc.htm.

### *8.1.2 Surface Water Quality Standards*

The Massachusetts Surface Water Quality Standards (314 CMR 4.0) assign designated uses and establish water quality criteria to meet those uses. Water body classifications (Class A, B, and C, for freshwater and SA, SB, and SC for marine waters) are established to protect each class of designated uses. The Massachusetts Surface Water Quality Standards can be found online at http://www.mass.gov/dep/water/laws/regulati.htm#wqual.

### *8.1.3 Ground Water Quality Standards*

The Massachusetts Ground Water Quality Standards (314 CMR 6.0) consist of groundwater classifications, which designate and assign the uses for various groundwaters of the Commonwealth that must be maintained and protected. Like the surface water quality standards the groundwater standards provide specific ground water quality criteria necessary to sustain the designated uses and/or maintain existing groundwater quality. The Massachusetts Ground Water Quality Standards can be found at http://www.mass.gov/dep/water/laws/regulati.htm#gwp.

### *8.1.4 River Protection Act*

In 1996 Massachusetts passed the Rivers Protection Act. The purposes of the Act were to protect the private or public water supply; to protect the ground water; to provide flood control; to prevent storm damage; to prevent pollution; to protect land containing shellfish; to protect wildlife habitat; and to protect the fisheries. The provisions of the Act are implemented through the Wetlands Protection Regulations, which establish up to a 200-foot setback from rivers in the Commonwealth to control construction activity and protect the items listed above. Although this Act does not directly reduce nutrient discharges it indirectly controls many sources of nutrients close to water bodies. More information on the Rivers Protection Act can be found on MassDEP's web site at http://www.mass.gov/dep/water/laws/regulati.htm.#t5regs.

### *8.1.5 Surface Water Discharge Permitting Program Regulations*

The Massachusetts Surface Water Discharge Permitting Program Regulations (314 CMR 3.0) allow MassDEP to take action whenever it determines that a discharge from a storm drain or other source is a significant contributor of pollutants to waters of the Commonwealth. US-EPA and MassDEP have the authority to designate the discharge as a significant contributor of pollutants and require the discharger to obtain an individual surface water discharge permit and/or require through a general permit or an enforcement action that the discharger undertake additional control measures, BMPs, or other actions to ensure compliance with a general permit or water quality standards, or to protect the public health and the environment. Through its regular watershed sampling or its own investigations in response to complaints or inspections, MassDEP can determine that certain discharges from municipal storm drain systems are significant contributors of pollutants to surface waters. In that event, MassDEP can and has issued a Notice of Noncompliance to the municipality requesting that the municipality develop and implement a plan for removing illicit sanitary connections to the storm drain system. The Massachusetts Surface Water Discharge Permitting Program Regulations can be found at http://www.mass.gov/dep/water/laws/regulati.htm.

### *8.1.6 Stormwater Regulations*

Stormwater is regulated through both federal and state programs. Those programs include, but are not limited to, the federal and state Phase I and Phase II NPDES stormwater program, and, at the state level, the Wetlands Protection Act MGL Chapter 130, Section 40), the state water quality standards, and the various permitting programs previously identified.

Existing stormwater discharges are regulated under the Federal and State Phase 1 and Phase II Stormwater Program. In Massachusetts there are two Phase 1 communities, Boston and Worcester. Both communities have been issued individual permits to address stormwater discharges. In addition, 237 communities in Massachusetts, and all 35 communities in the Charles River Watershed are covered by Phase II (the only exception is Boston which is covered under Phase 1). Phase II is intended to further reduce adverse impacts to water quality and aquatic habitat by instituting use controls on the unregulated sources of stormwater discharges that have the greatest likelihood of causing continued environmental degradation including those from municipal separate storm sewer systems (MS4s) and discharges from construction activity.

Other storm water discharges regulated under Phases I and II include storm water associated with industrial activities and storm water associated with construction activities. In addition, US-EPA has the authority to require non-regulated point source storm water discharges to obtain NPDES permits if it determines that such storm water discharge causes or contributes to a water quality violation, or is a significant contributor of pollutants, or where controls are needed based on a waste load allocation in an US-EPA approved TMDL (See 40 CFR § 122.26(a)(9)(i)).

The Phase II Final Rule, published in the Federal Register on December 8, 1999, requires permittees to determine whether or not stormwater discharges from any part of the MS4 contribute, either directly or indirectly, to a 303(d) listed waterbody. Operators of regulated MS4s are required to design stormwater management programs to 1) reduce the discharge of pollutants to the “maximum extent practicable” (MEP), 2) protect water quality, and 3) satisfy the appropriate water quality requirements of the Clean Water Act. Implementation of the MEP standard typically requires the development and implementation of BMPs and the achievement of measurable goals to satisfy each of the six minimum control measures. Those measures include 1) public outreach and education, 2) public participation, 3) illicit discharge detection and elimination, 4) construction site runoff control, 5) post-construction runoff control, and 6) pollution prevention/good housekeeping. In addition, each permittee must determine if a TMDL has been developed and approved for any water body into which an MS4 discharges. If a TMDL has been approved then the permittee must comply with the TMDL including the application of BMPs or other performance requirements. The permittees must report annually on all control measures currently being implemented or planned to be implemented to control pollutants of concern identified in TMDLs. The data included in this TMDL, including wasteload allocations, demonstrates that additional controls may well be needed for many storm water discharges in segments with high bacteria concentrations and nutrient loads particularly during wet weather. Finally, the Department has the authority to issue an individual permit to achieve water quality objectives. Links to the MA Phase II permit and other stormwater control guidance can be found at http://www.mass.gov/MassDEP/water/wastewater/stormwat.htm. A full list of Phase II communities in MA can be found at: http://www.mass.gov/MassDEP/brp/stormwtr/stormlis.htm

In addition to the Phase I and II programs described above, the Massachusetts Department of Environmental Protection proposed new "Stormwater Management Regulations," in the spring of 2009 that will establish as statewide general permit program aimed at controlling the discharge of stormwater runoff from certain privately-owned sites containing large impervious surfaces.

The proposed regulations are being revised based on public comment and should be available soon. The proposed regulations are available on the DEP website at (http://www.mass.gov/dep/service/regulations/newregs.htm#storm) require private owners of land containing five or more acres of impervious surfaces to apply for and obtain coverage under a general permit; implement nonstructural best management practices (BMPs) for managing stormwater; install low impact development (LID) techniques and structural BMPs at sites undergoing development and redevelopment; and submit annual compliance certifications to the Department.

Where the Department has determined that stormwater runoff is causing or contributing to violations of the Massachusetts Surface Water Quality Standards, the proposed regulations would allow MassDEP to impose the same requirements on certain private owners or land with less than 5 acres of impervious surfaces and require owners to such land to design and implement the LID techniques and stormwater BMPs needed to address these violations.

The MassDEP Wetlands regulations (310 CMR 10.0) direct issuing authorities to enforce the MassDEP Stormwater Management Policy, place conditions on the quantity and quality of point source discharges, and to control erosion and sedimentation. The Stormwater Management Policy was issued under the authority of the 310 CMR 10.0. The policy and its accompanying Stormwater Performance Standards apply to new and redevelopment projects where there may be an alteration to a wetland resource area or within 100 feet of a wetland resource (buffer zone). The policy requires the application of structural and/or non-structural BMPs to control suspended solids, which have associated co-benefits for nutrient removal. A stormwater handbook was developed to promote consistent interpretation of the Stormwater Management Policy and Performance Standards: Volume 1: Stormwater Policy Handbook and Volume 2: Stormwater Technical Handbook can be found along with the Stormwater Policy at http://www.mass.gov/dep/water/wastewater/stormwat.htm#swpwet

### *8.1.7 Septic System Regulations*

MassDEP has Septic System (Title 5) Regulations in place that require minimum standards for the design and performance of individual septic systems. Those regulations ensure, in part, protection for nearby surface and groundwaters from bacterial contamination. The regulations also provide minimum standards for replacing failed and inadequate systems. The Department has established a mandatory requirement that all septic systems must be inspected and upgraded to meet Title 5 requirements at the time of sale or transfer of the each property.

## 8.2 Financial Tools

**Nonpoint Source Control Program**: MassDEP has established a non-point source control and grant program to address non-point source pollution sources statewide. The Department has developed a Nonpoint Source Management Plan that sets forth an integrated strategy and identifies important programs to prevent, control, and reduce pollution from nonpoint sources and more importantly to protect and restore the quality of waters in the Commonwealth. The Clean Water Act, Section 319, specifies the contents of the management plan. The plan is an implementation strategy for BMPs with attention given to funding sources and schedules. Statewide implementation of the Management Plan is being accomplished through a wide variety of federal, state, local, and non-profit programs and partnerships. It includes partnering with the Massachusetts Coastal Zone Management on the implementation of Section 6217 program. That program outlines both short and long term strategies to address urban areas and stormwater, marinas and recreational boating, agriculture, forestry, hydro modification, and wetland restoration and assessment. The CZM 6217 program also addresses TMDLs and nitrogen sensitive embayments and is crafted to reduce water quality impairments and restore segments not meeting state standards.

In addition, the state is partnering with the Natural Resource Conservation Service (NRCS) to provide implementation incentives through the national Farm Bill. As a result of this effort, NRCS now prioritizes its Environmental Quality Incentive Program (EQIP) funds based on MassDEP's list of impaired waters. Over the last several years EQIP funds have been used throughout the Commonwealth to address water quality goals through the application of structural and non-structural BMPs.

MassDEP, in conjunction with US-EPA, also provides a grant program to implement nonpoint source BMPs that address water quality goals. The section 319 funding provided by US-EPA is used to apply needed implementation measures and provide high priority points for projects that are designed to address 303d listed waters and to implement TMDLs.

Additional information related to the non-point source program, including the Management Plan can be found at: http://www.mass.gov/dep/water/resources/nonpoint.htm.

The **State Revolving Fund (SRF) Program** provides low interest loans to eligible applicants for the abatement of water pollution problems across the Commonwealth. Since July 2002 the MassDEP has issued millions of dollars for the planning and construction of combined sewer overflow (CSO) facilities and to address stormwater pollution. Loans have been distributed to municipal governments statewide to upgrade and replace failed Title 5 systems. These programs all demonstrate the State's commitment to assist local governments in implementing the TMDL recommendations. Additional information about the SRF Program can be found at http://www.mass.gov/MassDEP/water/wastewater/wastewat.htm.

## 8.3 Watershed Specific Strategies

In summary, MassDEP's approach and existing programs set out a wide variety of tools both MassDEP and local communities can use to address nutrient sources to the Charles River (e.g., illicit discharges and stormwater runoff). While there are relatively few categories of nutrient sources to the Charles River, the highly variable characteristics associated with these sources make it necessary for the TMDL implementation program to include intensive investigations, reconnaissance, and characterization of nutrient sources from the watershed. This work will identify illicit sources for elimination and help to prioritize other sources for additional controls. Also, the effectiveness and potential of various control programs to reduce nutrient loadings to the Charles River such as high-efficiency street sweeping, illicit discharge detection and elimination, nutrient management, and public education will require ongoing iterations of investigation, evaluation, and revision. Local stormwater management plans will need to evolve as new information on sources and the effectiveness of controls becomes available.

The specific strategy that US-EPA and MassDEP intend to apply to the Charles River watershed to reduce nutrient loading involves the use of the NPDES stormwater permitting program in an iterative process. Through the permitting process, IDDE programs will be developed/refined, stormwater management plans will be regularly evaluated and updated, source specific information will be collected, and control practices will be tested, evaluated and implemented. Ongoing water quality monitoring by MassDEP, US-EPA, MWRA, and the CRWA will be used to monitor progress in improving reducing algal blooms and improving water quality. Moreover, MassDEP recommends that the existing water quality model of the Charles River be maintained and used to evaluate progress as it will be help to distinguish water quality impacts associated with climatic conditions and nutrient loading.

It is MassDEP's goal to work closely with US-EPA, municipalities, CRWA, and other interested public to develop an overall implementation framework to address significant nutrient contributors and monitor progress at reducing nutrient loading to the Charles River. To accomplish this, MassDEP will consult their internal databases, as well as local data that are available and review NPDES stormwater permit annual submittals. MassDEP has the authority under M.G.L. c.21 to designate a source where necessary (or use US-EPA's authority) to require quicker action than would otherwise be achieved under existing schedules or require additional controls if it is determined that Phase II activities are insufficient to solve the problem. To aid in the collection of critical data and information, MassDEP will provide grant opportunities to collect the data necessary to prioritize nutrient source areas. Once a significant source is found, MassDEP will coordinate with the owner of the discharge to "go up the pipe" to identify illicit connections and undertake additional controls as necessary.

MassDEP's authority combined with the programs identified above provide sufficient reasonable assurance that implementation of remedial actions will take place.

# 9 PUBLIC PARTICIPATION

## 9.1 Public Meeting

A public meeting was held on October 29, 2009 from 4 to 7 PM at the Mass Horticultural Society Elm Bank Reservation Wellesley, MA (http://www.masshort.org/directions). The Draft Total Maximum Daily Load for Nutrients in the Upper/Middle Charles River, Massachusetts (Control Number CN 272.0) was distributed for public review and solicitation of comments on September 30, 2009. Comments in the Draft document were accepted until November 30, 2009.

## 9.2 Response to Comments

Please see Appendix A-1 for the response to comments.

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# Appendix A1 – Response to Comments

# Total Maximum Daily Load for Nutrients in the Upper/Middle Charles River, Massachusetts

## Response to Comments

## September 2010

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| Public Meeting Announcement Published in the Monitor | 9/15/09 |
| Public Meeting Location | Elm Bank, Wellesley, MA |
| Date: | 10/29/09 |
| Time: | 4 to 7 PM |
| Close of Public Comment Period | 11/30/09 |

| Attendee Name | Affiliation |
|---|---|
| Rick Dunn | MassDEP, Worcester |
| Nigel Pickering | CRWA |
| Kate Bowditch | CRWA |
| Richard Baker | NES |
| Elaine Hartman | MassDEP, Worcester |
| Mark Voorhees | USEPA, Boston |
| Kimberley Groff | MassDEP, Worcester |
| Bob Zimmerman | CRWA |

| Attendee Name | Affiliation |
|---|---|
| Fred Civian | MassDEP |
| Susan Welby | Rep. Harkins Office |
| Jane Madden | CDM |
| Cheri Cousens | CRPCD |
| David Dobrzynski | CRWA Volunteer |
| John Bersley | Natick |
| Eric Las | Beals and Thomas, Inc. |
| David Nyman | CEI |
| Catherine Daly Woodbury | DPW, City of Cambridge |
| Patrick McHallam | 11 Phillips St., Medway |
| Bob Bois | 13 E. Central St., Natick |
| Kurt Tramposch | 2 Weir Meadow Path, Wayland MA |
| Tom Ryder | DPW, Town of Needham |
| Mark Coviello | DPW, Town of Natick |
| Rosalie Starvish | Boston BEC, Inc. |
| Kevin Keith | DPW, Town of Needham |
| Karen Patterson Greene | Charles River Conservancy |

**Notice to Reviewers:** The following pages provide MassDEP's response to questions and issues raised on the Department's Draft Total Maximum Daily Load for Nutrients in the Upper/Middle Charles River, Massachusetts (Report CN 272.0), September, 2009. A public meeting was held on October 29, 2009, at Elm Bank, Wellesley, MA and the public comment period ended on November 30, 2009. The comments listed below were extracted from letters received during the comment period. Original letters can be viewed at the following address.

DEP, Division of Watershed Management
627 Main St., 2nd Floor
Worcester, MA 01608

Comments and responses are provided below from each agency, group, municipality, or individual that commented. To aid you in your review, comments are provided in bold and responses are provided in italics.

## A. CONSERVATION LAW FOUNDATION

1. **Question**: **Implementation Plan**
**a. Wintertime Limits, b. Stormwater, c. Reasonable Assurance**

**Comment: In general, the implementation plan fails to provide a clear and concise plan for achieving the required reductions within a reasonable time period. CLF submits the following specific comments with respect to the implementation plan and reasonable assurance:**

**1a. Question: Wintertime Limits**
**Although the WLAs for large WWTFs in the Draft TMDL are based on effluent limitations of 0.1 mg/l in the summer and 0.3 mg/l in the winter, the implementation plan suggests a two-step process with initial winter limits of 0.5 mg/l for the next permit renewal and re-evaluation after the first five-year period to attain the 0.3 mg/l limit. CLF objects to the statements in the implementation plan to the effect that "the plan envisions a transitional period for major WWTFs by setting an interim winter limit of 0.5 mg/L phosphorus which should be reevaluated after the first 5-year period to attain to [sic] the final 0.3 mg/L winter limit for total phosphorus. A permit with a winter effluent limitation of 0.5 mg/l would not be "consistent with the assumptions and requirements of any available wasteload allocation", as required by 40 CFR 122.44(d)(1)(vii)(B). Furthermore, given the lack of an assimilative capacity in the Charles River, EPA does not have the authority to pursue a phased approach.**

**1a. Response:** *Language in Section 7.2.4 of the TMDL Implementation Plan has been revised to delete references to "a transitional period for major WWTFs" and "setting an interim winter limit of 0.5 mg/l phosphorus" because the permitting authority may provide a compliance schedule if necessary.*

**1b. Question: Stormwater**
**It is not clear how the required reductions will be achieved for unregulated stormwater sources. The Draft TMDL seems to place the burden of achieving the reductions largely on municipalities, but also acknowledges that some stormwater point sources may need to be "addressed through other regulatory vehicles….including, but not limited to EPA's exercise of its residual designation authority to require NPDES permits…" The implementation plan should set forth specific measures and timeframes, including an enforceable retrofit program and appropriate low-impact development requirements for new construction and new development, which will ensure the required reductions, are achieved.**

**1b. Response: The HSPF model used to develop the TMDL is sufficient to evaluate the water quality impacts in the Charles River from different land use categories however the scale is too large to properly evaluate site-specific stormwater remediation efforts which would need to be done at a much finer scale.** *In the interest of achieving water quality improvements as soon as possible and to finalize the TMDL, the site specific details of stormwater reductions will need to be addressed as part of an implementation strategy using available and evolving tools once the TMDL is approved. Detailed analysis on a lot-by-lot basis will be needed to determine the most cost effective solutions. Clearly, such an analysis is beyond the scope of this TMDL. Additionally, the stormwater program is still evolving both on a federal and state level. Keeping this in mind, there are a number of activities taking place concurrently intended to address the discharge of pollutants from either private or public stormwater systems. A brief review of some of these activities follows.*

*The Commonwealth has been developing a state stormwater permit to address unregulated existing sources. Comments received on proposed draft regulations are being evaluated to revise and finalize the state stormwater permit.*

*Additionally, EPA is in the process of applying its Residual Designation Authority (RDA) to designate additional sites within the Charles River Watershed in Milford, Bellingham, and Franklin with two acres or more of impervious surface for NPDES stormwater permitting. EPA has also issued a draft general storm water permit for these properties. The draft permit is located at: http://www.epa.gov/ne/npdes/charlesriver/pdfs/DraftRDAGeneralPermit.pdf.*

*To better understand the scope and potential management approaches for achieving the necessary stormwater phosphorus reductions, MassDEP and EPA funded a demonstration project in the three upstream most Charles River communities, Milford, Bellingham, and Franklin to develop optimized stormwater control strategies for achieving the phosphorus reductions identified for each community in the EPA approved Lower Charles phosphorus TMDL. This project addresses all stormwater phosphorus sources from both municipal and private properties within the Charles River Watershed of these three communities. The intent of the demonstration project was to provide the MassDEP, EPA and the communities with workable ideas for implementing controls to achieve the needed phosphorus reductions in the most cost-effective manner. The final report for this project is located at: http://www.mass.gov/dep/water/resources/tmdls.htm#charles*

*In addition, EPA has also issued a draft MS4 permit for some of the coastal watersheds and the Charles River watershed is included in this new draft permit. This draft permit proposes that each of the Charles River communities develop phosphorus control plans to achieve phosphorus load reductions identified in the Lower Charles River TMDL for each community. Information on the permit is located at:* http://www.epa.gov/region01/npdes/stormwater

*Also at the federal level, the USEPA is modifying the 2008 stormwater construction general permit, extending the permit by one year to June 30, 2011. The Construction General Permit can be found at: http://cfpub.epa.gov/npdes/stormwater/cgp.cfm. The permit applies only where EPA is the permitting authority which includes Massachusetts. The permit regulates the discharge of stormwater from construction sites that disturb one acre or more of land and from smaller sites that are part of a larger, common plan of development. The permit requires construction site operators to comply with stormwater discharge requirements that are intended to prevent sediment loss, soil erosion and other pollution issues at active construction sites.*

*The extension of the 2008 construction general permit is needed to allow USEPA sufficient time to incorporate the new federal effluent requirements for the construction and development industry, which was announced by EPA on December 1, 2009. These effluent limitations guidelines (ELGs) and new source performance standards (NSPS) to control the discharge of pollutants from construction sites can be found at: http://www.epa.gov/guide/construction/. As a summary, EPA is proposing effluent limitations guidelines (ELGs) and new source performance standards (NSPS) to control the discharge of pollutants from construction sites. These would require construction sites to implement a range of erosion and sediment control measures to control pollutants in stormwater discharges. In addition, for certain large sites located in areas of the country with high rainfall intensity and soils with high clay content, stormwater discharges* *from the construction site would be required to meet a numeric limit on the allowable level of turbidity.*

*Currently, the USGS is also carrying out a cooperative project with the City of Cambridge, MA to evaluate the potential effectiveness of a high-efficiency sweeping technology to remove pollutant loading from city streets. This project is funded jointly by the MassDEP, USGS, and EPA, and will develop a calibrated sweeping model to evaluate the potential phosphorus load reduction credits that can be earned for a variety of sweeping program. The project's intensive data collection phase began in early April of 2010.*

*In summary, there are many implementation activities underway intended to address stormwater contributions to the Charles River. Since any approach would require a detailed site-by-site evaluation it does not seem logical to suspend the submittal or approval of this TMDL until those activities are completed. In addition, since the stormwater program is evolving on both a federal and state level, the specifics on an implementation plan would need to be developed on a more localized basis with updates as the new parts of the program become completed.*

*The goal of this TMDL was to identify what the needed reductions would have to be to meet water quality standards and to outline a generalized implementation approach to guide future implementation activities. As stated in the TMDL, the agencies believe that a combination of illicit source elimination, phosphorus source controls, and implementation of non-structural and structural BMPs has the potential to achieve large reductions in annual phosphorus loadings even from already urbanized areas. However, further investigation will be needed and identified as part of the implementation process to identify the optimal storm water management programs for various types of drainage areas. These investigations should involve detailed characterization of drainage areas, identification of illicit sources, and pilot applications of non-structural and structural BMPs.*

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**1c. Question: Reasonable Assurance**

**The reasonable assurance section of the Draft TMDL discusses application and enforcement of current regulations, financial incentives, and local, state and federal programs for pollution control. The majority of these are pre-existing programs, and thus their ability to provide reasonable assurance is questionable. The only promising new program is the proposed state stormwater regulations, but these are still being developed and in CLF's view as proposed are not comprehensive enough to achieve the required load reductions.**

**1c. Response:** *The Department respectfully disagrees with the commenter that pre-existing programs are ineffective to address stormwater problems***.** *The state and federal grant programs have proven effective in the past in designing and implementing innovative as well as tried and true methods for watershed remediation programs. The agencies believe as long as funding is available in the future these programs will continue to be implemented in order to provide reasonable assurance in obtaining watershed remediation. This is not to say that new programs aren't needed or that current programs would not have to be adjusted in time to more effectively address stormwater impacts in this evolving area. Some of the existing programs available to municipalities are as follows:*

***Nonpoint Source Control Program****: MassDEP has established a non-point source control and grant program to address non-point source pollution sources statewide. The Department has* *developed a Nonpoint Source Management Plan that sets forth an integrated strategy and identifies important programs to prevent, control, and reduces pollution from nonpoint sources and more importantly to protect and restore the quality of waters in the Commonwealth. The Clean Water Act, Section 319, specifies the contents of the management plan. The plan is an implementation strategy for BMPs with attention given to funding sources and schedules. Statewide implementation of the Management Plan is being accomplished through a wide variety of federal, state, local, and non-profit programs and partnerships. It includes partnering with the Massachusetts Coastal Zone Management on the implementation of Section 6217 program. That program outlines both short and long term strategies to address urban areas and stormwater, marinas and recreational boating, agriculture, forestry, hydro modification, and wetland restoration and assessment. The CZM 6217 program also addresses TMDLs and nitrogen sensitive embayments and is crafted to reduce water quality impairments and restore segments not meeting state standards.*

*In addition, the state is partnering with the Natural Resource Conservation Service (NRCS) to provide implementation incentives through the national Farm Bill. As a result of this effort, NRCS now prioritizes its Environmental Quality Incentive Program (EQIP) funds based on MassDEP's list of impaired waters. Over the last several years EQIP funds have been used throughout the Commonwealth to address water quality goals through the application of structural and non-structural BMPs.*

*MassDEP, in conjunction with US-EPA, also provides a grant program to implement nonpoint source BMPs that address water quality goals. The section 319 funding provided by US-EPA is used to apply needed implementation measures and provide high priority points for projects that are designed to address 303d listed waters and to implement TMDLs.*

*Specifically in the Charles River Watershed, from 2001 to September 2009, the Department has issued 319 grants totaling $ $1,493,494 (not including local match) to develop and implement stormwater treatment systems and collect additional data for TMDL development. The projects will result in the installation of stormwater treatment systems to protect Hammond Pond in Newton and to treat and reduce discharges to the Charles River off Plymouth Road in Bellingham, Cold Spring Brook in Wellesley, stormwater retrofit in Franklin, and an LID Program at Jackson Square.. The 319 program also provides additional assistance in the form of guidance. The Department has updated the Massachusetts' Nonpoint Source Management Manual (The Clean Water Toolkit), which provides detailed guidance in the form of BMPs by land use to address various water quality impairments and associated pollutants The Department has updated the Massachusetts' Nonpoint Source Management Manual (The Clean Water Toolkit), which provides detailed guidance in the form of BMPs by land use to address various water quality impairments and associated pollutants.*

*Additional information related to the non-point source program, including the Management Plan can be found at: http://www.mass.gov/dep/water/resources/nonpoint.htm.*

*The* ***State Revolving Fund (SRF) Program*** *provides low interest loans to eligible applicants for the abatement of water pollution problems across the Commonwealth. Since July 2002 the MassDEP has issued millions of dollars for the planning and construction of combined sewer overflow (CSO) facilities and to address stormwater pollution. Loans have been distributed to municipal governments statewide to upgrade and replace failed Title 5 systems. These programs all demonstrate the State's commitment to assist local governments in implementing the TMDL recommendations. Additional information about the SRF Program can be found at http://www.mass.gov/MassDEP/water/wastewater/wastewat.htm.*

*Many of the proposed requirements in draft stormwater permits for the MS4s in the Charles River watershed and the residually designated sites within Milford, Bellingham, and Franklin are specifically intended to address needed phosphorus load reductions. Once these permits are finalized, they will provide significant reasonable assurance that needed phosphorus load reductions will be achieved.*

*In order to achieve the large reductions in stormwater runoff necessary to bring the Charles River into compliance with water quality standards an intensive and integrated watershed remediation effort will be necessary to complete over time.*

### 2. TMDL Other Losses

**Question: A category called "other losses" is placed in the TMDL table on page 71 without any explanation in the text. Presumably these relate to the losses discussed in Section 4.2, but EPA and MassDEP need to explain this term and its basis for inclusion in the calculation of the TMDL more fully. This term reflects a very significant portion of the total load, and appears to describe some type of reductions or removal of phosphorus inputs from the system that are projected to decrease over time. It is crucial that the term and the rationale for those projections are fully explained.**

**Response***: Text and a table explaining other losses are found on page 17, Table 13. For ease of reading, a reference and footnote will be placed on page 71 for the reader to refer to this text and table as they appear spatially removed in the report. Other losses include Benthic Algae, Settling, losses from the Mother Brook diversion, and losses over the Watertown Dam. These losses are presented for three time periods, April-Oct, Nov-Mar, and Annual. Totals across these time frames are also included in the table.*

### 3. WLAs for Stormwater Sources

**Question: The Draft TMDL uses aggregate WLAs by land-use category and aggregates together regulated and unregulated sources. While we agree with the determination that all point sources, including stormwater dischargers that are as-yet unregulated, must be placed in the WLA, the WLA is impermissibly aggregated. Aggregation to this degree is not permitted under the regulations as 40 CFR 130.2(h) defines a wasteload allocation as "[t]he portion of a receiving water's loading capacity that is allocated to *one* of its existing or future point sources of pollution" (emphasis added). CLF believes that the state has GIS data (including watershed GIS analyses required to be performed by MS4s) which would enable MassDEP to identify all parcels in the Upper/Middle Charles watershed by land use category. Using this information, MassDEP could allocate wasteload allocations (and percent reductions required) to each individual parcel, as required under the regulation.**

**Footnote 2 page 3: 40 C.F.R. § 130.2(h). In the proposed 1999 revisions to the water quality planning and management regulations, EPA stated that "current regulations require a wasteload allocation for *each* existing or future point source" (emphasis added). The proposed regulations would have amended this requirement and allowed allocations to categories or subcategories of point sources subject to a general permit and to categories or subcategories of sources where the pollutant load does not need to be reduced in order to meet water quality standards. However, the proposed regulations were withdrawn in**

**March 2003, before they were to have gone into effect. Therefore, the regulations continue to require a wasteload allocation for *each* existing or future point source.**

**Response:** *Presently there are not enough data on a parcel by parcel-by-parcel basis to provide dis-aggregation at a greater level. The EPA 2002*[1] *guidance available at the time this TMDL was prepared states that, " NPDES-regulated storm water discharges must be addressed by the wasteload allocation component of a TMDL….It may be reasonable to express allocations for NPDES-regulated storm water discharges from multiple sources as a single categorical wasteload allocation when data and information are insufficient to assign each source or outfall individual WLAs." Additionally, during the implementation process, individual site evaluations will be necessary to determine the most cost effect solution.*

*The time involved and cost associated with developing and incorporating a parcel by parcel land use analysis into this TMDL is well beyond the scope of this project and would create significant delays in the TMDL being reviewed and approved and therefore significant delays in implementing any aspect of the TMDL. The agencies believe that this type of detailed land use analyses would be more prudent as part of the implementation process whereby the agencies and municipalities could partner in evaluating the most cost effective methods for acquiring land use nutrient reductions. The parcel- by- parcel application would unnecessarily constrain actions to attain the goal of watershed reductions.*

*Additionally, the former EOEA watershed teams developed detailed build-out scenarios. This information is available to the town to use in reaching their NPS reductions through identification of current and potential future land uses and a combination of more stringent local by-laws and BMPs and working with permitees through the present Stormwater Regulations. The buildout maps are located at:* *http://commpres.env.state.ma.us/content/buildout.asp*

### 4. Effluent Limitations for Large WWTFs

**Question: The Draft TMDL chooses scenario "9C" and sets effluent limitations for major WWTFs at 0.1 mg/l in the summer and 0.3 mg/l in the winter. However, the resulting total discharge of phosphorus is 15,238 kg/year, which exceeds the Lower Charles TMDL target load at the Watertown Dam by 129 kg/year. The TMDL states that exceeding the Lower Charles TMDL target load is acceptable because the Lower Charles TMDL target load contained an explicit margin of safety of 979 kg/year. The chosen scenario effectively and improperly reduces the explicit margin of safety in the Lower Charles TMDL without providing additional analyses or support for such reduction. As we noted in our comments to the Lower Charles TMDL in April 2007 (with which MassDEP and EPA explicitly agreed in responses to our comments), it is important that the MOS be retained in light of uncertainty about the current loading conditions and unknown effects of climate change and other factors on water quality conditions of the Charles River in the future. The final TMDL should use Scenario 9, 9A or 9B, any of which would result in a total discharge of phosphorus below the Lower Charles TMDL target load and thus not erode the MOS in the Lower Charles TMDL.**

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[1] EPA memorandum titled "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs" by Robert H. Wayland and James A. Hanlon of EPA (11/22/02)

**Response:** *MassDEP and USEPA have done a thorough review of all of the comments and questions both at the Public Meeting and in written response to the agency, and have conducted further evaluations of the selected scenario. After careful consideration of all comments, the agencies has decided to resolve all the issues raised by all stakeholders, by adding an additional scenario (Scenario 9D) which provides for 0.1 mg/l TP effluent limit in the summer and 0.3 mg/l effluent limit in the winter for all WWTFs, including the minors. The total phosphorus load at the Watertown Dam would then be 14,968 kg/yr, well below the Lower Charles allocation of 15,109 kg/yr.*

## 5. Margin of Safety (MOS)

**Question: Section 6.2 includes a relatively brief discussion of assumptions about sediment efflux rate, and the fact that each reach was independently analyzed based on different flow parameters. The Agencies (MassDEP and USEPA) have made significant advancements in understanding, quantifying, and projecting the effects of climate change on freshwater ecosystems, yet it is not clear that the full breadth of this research and knowledge is reflected in the TMDL limits and MOS.**
**EPA and MassDEP should more fully explain how, based on data and information currently known to the agencies about the impacts of climate change on rainfall frequency and intensity, stream flow, and pollutant levels in freshwater streams in the Northeast U.S., the TMDL and MOS will be protective of nutrient-related water quality standards throughout the implementation period of the TMDL into the future.**

**Response:** *The effect of climate change on this TMDL cannot be accurately determined. Increased rainfall could either create instream dilution of nutrients, which could allow the WWTFs to discharge more, or it could on the other hand create increased nutrient runoff. Without an accepted site-specific method to calibrate and verify the effects, the agencies have taken an approach of using current climate conditions to predict instream effects. The studies conducted to date on climate change are on a more global or regional scale but this has not been reduced to a watershed or segment-by-segment scale to date and therefore are not yet useful for the development of TMDLs at this scale. Additionally, with the selection of the new Scenario 9D, the MOS will be substantially higher than previously proposed, and will have the capacity to provide additional buffer for climate changes along with changes from other sources not yet quantitatively well defined.*

## 6. Ongoing Monitoring and Adjustments

**Question: Ongoing monitoring of instream phosphorus levels, phosphorus loading, temperature, chlorophyll *a* levels, pH and dissolved oxygen will be critical as a phosphorus control program is implemented. The HSPF water quality model should be kept active so that new data can be incorporated and assumptions tested. The Draft TMDL establishes with certainty that significant phosphorus reduction is required across the entire watershed, for virtually all developed land use categories. The impacts of temperature are clearly significant and more detailed data collection and monitoring are needed in order to ensure that nutrient reductions achieve water quality goals, and are not offset by increasing temperatures.**

**CLF recommends adding a provision for reopening the TMDL in light of new data. The Draft TMDL repeatedly expresses that it relies on an iterative process, where goals and schedules will be set based on ongoing monitoring and assessment of control activities. A**

**reopener provision would allow new data to inform more precise loading reduction targets or other adjustments to the TMDL.**

**Response:** *MassDEP, USEPA, and CRWA have contributed significant staff and monetary resources to the development of the HSPF model and TMDL development and are committed to maintaining and improving the HSPF Charles River model and the TMDL as budgetary constraints allow. MassDEP believes that a re-opener clause is not necessary as MassDEP has the ability to re-open a TMDL at any time. A reopener clause is also part of all NPDES permits.*

### 7. CLF Statement of Support and Approval for the Upper Charles TMDL

**CLF Comment on TMDL: In conclusion, the Draft TMDL is a solid building block towards achieving improvements in water quality in the Upper/Middle Charles, and CLF supports its approval. CLF appreciates the work that has gone into producing the Draft TMDL, and we expect that MassDEP and EPA will commit to providing the rigorous analysis and robust enforcement measures necessary to correct these significant water quality impairments on the ground.**

**Response:** *The agencies and CRWA are interested in utilizing these tools in the future as new watershed data show changes to the system. The agencies appreciate CLFs support of these efforts.*

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## B. CHARLES RIVER CONSERVANCY COMMENT LETTER

### 8. Statement:

**As cited: "The Charles River Conservancy is writing in support of the proposed Total Maximum Daily Load for Nutrients In the Upper/Middle Charles River. ………One of the projects the Conservancy is currently working on is the effort to return public access swimming to the Lower Charles River. Thus we are particularly concerned that the water quality of the Lower Charles continue to be improved through the effective implementation of both the TMDL for the Lower Charles, established in 2007, and the adoption and implementation of the proposed TMDL for the Upper and Middle Charles River."**

**Response:**
*MassDEP, USEPA, and the CRWA thank the Charles River Conservancy for their review of the Upper/Middle Charles River TMDL and their support of the conclusions of the study and recommendations for action.*

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## C. MASS COALITION FOR CHARLES RIVER STEWARDSHIP COMMENT LETTER

**9. Comment/Question**: **Watershed Credits and Trading**. **The TMDL and wasteload allocations established in the draft report are based on the technical feasibility of phosphorus control for POTW and stormwater sources.**
**While this is one way to approach the development of the phosphorus load that the Charles River can absorb, it does not mean that wasteload allocations should follow suit. This is particularly true in basins such as the Charles, where 75% of the phosphorus is from stormwater and 25% from POTWs. At the very least, all sources should be held to a common percentage reduction, and mechanisms for exchanging phosphorus removal "credits" between POTWs and stormwater should be created. To do as the draft TMDL requires – that the POTWs bear a proportionately greater share of the reduction – sends the wrong economic signal and encourages land use practices that appear to be difficult to control.**

**Response:** *The commenter is correct that stormwater contributes a greater amount of phosphorus to the system both annually and seasonally. However, it also needs to be noted that during the critical period (during the summer) when in-stream flows are low and detention times are high the POTWs discharge primarily orthophosphorus to the river, which is readily available for uptake for plant growth.*

*As noted the Department chose to consider and include the ability of technology to achieve the desired water quality goals. Doing so provides reasonable assurance that the water quality goals will be met. This approach does not however rule out the possibility of watershed credits and trading but it does recognize the inherent difficulties of developing and implementing a project of this magnitude. To do so at this time would significantly delay implementation of any instream improvements. In addition, and as noted above tradeoffs may not attain the results expected since point sources and non-point sources provide different types of phosphorus and provide these at different times of the year effecting differing instream water quality changes. It is for this reason that a dynamic model such as HSPF was developed and utilized for this TMDL. It provides a tool, which can be used to evaluate how point source and non point source inputs each affect the instream water quality and to determine how these could be exchanged if possible. These trades are shown in the report as the different scenarios.*

*Finally, a system would need to be set up and in place for NPS and PS trading. However, none is in place at present.*

**10. Comment/Question**: **Dam Removal Study. The TMDL should evaluate the water quality impacts of dam removal. Here, as elsewhere, dams create opportunities for algal growth. It may be that water quality objectives – and other environmental objectives – can best be met by dam removal.**

**Response:** *The question of dam removal is complex. Issues of contaminated sediment movement, impact on adjacent wetlands and loss of habitat, as well as flooding issues in an urban environment all compound to provide a potentially difficult and costly project to analyze for instream improvements. A study is currently being funded by the agencies to look at dam removal in the Assabet River and these complex and costly issues are being looked at in that watershed. Results from this study could be evaluated as part of the implementation part of this TMDL to determine if a similar project was cost effective for the Charles River watershed. However, significant funding would be needed to carry out a study of this magnitude. The preliminary cost estimates for a project of this sort in the Assabet is around $1 million and there was limited public acceptance for the cost for dam removal.*

**11. Comment/Question: Implementation. We are encouraged that the implementation section sets out a phased plan for implementing the TMDL. We think, however, that the implementation plan should be mindful of the capital and operating expense associated with the POTW improvements. To account for this, and where significant expenditures on the POTW are necessary, the schedule should match the expected reductions in stormwater loads.**

**Response:** *As with all regulatory projects, certain aspects may take longer than others to design and implement, however, regulations do not provide for the delay of one part of the project to meet necessary delays in another part of the project. The MassDEP plan is mindful of capital operating expenses and the TMDL provides flexibility in selecting the most cost effective solution.*

## D. NAIOP THE COMMERCIAL REAL ESTATE DEVELOPMENT ASSOCIATION COMMENT LETTER

**12. Comment/Question: While the draft report does look for source reductions from residential properties, we urge the Department to be equitable with all land uses when considering how these reductions will be achieved. As the report notes, phosphorous in stormwater runoff is from fertilizers, car washing, leaf litter, pet waste and detergents - all things that could be reduced with source controls by all property types, including residential users. Source control for all land uses that spreads out the obligations over a larger base is critical to a solution that is equitable to all.**

**Response:** *In general MassDEP agrees with your comment however it must also be recognized that different types of land uses also contribute different loads of phosphorus to the system on a per acre basis. However, we agree that a watershed wide approach, with consideration of all land use types, should be considered in the implementation of the non point source reductions that are necessary to meet the goals of this TMDL.*

**13. Comment/Question: The draft report recognizes that site specific data is not available to establish appropriate effluent limits so numeric effluent limitations will not be included in the NPDES stormwater permits based on this TMDL. However, in lieu of effluent targets, the report establishes the requirement for the implementation of BMPs to achieve the target phosphorus reductions.**

**As with the Draft Stormwater General Permit Regulations issued in late 2008, NAIOP urges the Department to balance the goals of reducing phosphorous with the economic impact such BMPs would have on businesses. It is imperative that the Department carefully consider the cost/benefit of potential BMPs, similar to the Department's approach with the SIP for Clean Air. There are some BMPs that are significantly more cost effective (and efficient) than others. With limited private and public resources, these BMPs should be given priority. NAIOP would be happy to provide additional input to the Department on specific BMPs as well as a reasonable timeline for implementation.**

**Response:** *MassDEP recognizes that some BMPs can be more cost effective than others and that selection of the most cost erective BMP is very site specific. Therefore, the selection of the BMP will be up to individual owners to determine. The agencies are not specifying which BMPs should be applied as these would be site specific. The agencies agree with utilizing the best cost/benefit approach and effectiveness in meeting state and federal regulatory requirements and instream water quality standards and goals. These will be applied in the decision making process for selection and implementation of any BMPs for protection and remediation as implementation goes forward.*

*You may also be aware that a pilot project was funded by MassDEP and the USEPA working in combination with TetraTech and the three Charles River watershed headwater towns of Franklin, Bellingham, and Milford. The pilot project evaluated BMP stormwater controls in those towns. The pilot project utilizes GIS applications as part of a Decision Making Tool (DMT) developed by TetraTech to provide rapid assessment of all possible combinations of BMPs that could be utilized in each town. The DMT exports graphical analyses of percentage removal versus total costs (construction). Preliminary data show that in general a cooperative town wide or regional authority would provide more cost effective methods and opportunities due to availability of good BMP sites, since soils with high infiltration rates are one of the most important factors in controlling phosphorus removal, and costs shared with a larger basis lessen the impact on individual parcels and landowners. The pilot project shows that it takes site specific analysis to determine the best solution. A copy of the study is available at:* *http://www.mass.gov/dep/water/resources/tmdls.htm#charlesdp*

*MassDEP has recommended an iterative adaptive management process involving detailed source characterization and prioritization to identify the optimal solutions for achieving reductions. A goal of this process will be to identify the most cost-effective and optimal management plan to achieve the overall reductions. The agencies expect that appropriate frameworks for implementing the necessary controls, consisting of regulatory and/or non-regulatory aspects, will become apparent once the storm water management plans are developed. The agencies also recognize that a coordinated and full effort from all responsible and interested parties will be required to achieve the water quality goals projected in both the Upper/Middle and Lower TMDL.*

**14. Comment/Question: Finally, much of the draft report relies on the proposed Storm Water Management General Permit Program (314 CMR 21.00). We understand that a new draft of the regulations will be available soon. Given that the initial draft unfairly imposed on commercial and industrial facilities the bulk of the cost and burden of reducing phosphorous loading into surface water bodies, NAIOP once again urges the Department to significantly revise the regulations before moving forward with the implementation of this report**.

**Response:** *Although the regulations for Storm Water Management General Permit are being revised to take into account the public and agency comments, these regulations will only affect specifics of the implementation part of the project and how implementation aspects are designed. The proposed new regulations will not affect the approval of the overall TMDL report. Please refer to Response 1.b. for additional information on the stormwater issues.*

## E. MASSACHUSETTS DEPARTMENT OF TRANSPORTATION COMMENT LETTER

### General Comments

**15. Comment/Question: Illicit discharge requirements are excessive: The TMDL recommends conducting an extensive illicit discharge detection effort that may be unwarranted (TMDL Section 7.2.3, Page 86-87). Data from previous MassDOT efforts indicates that illicit discharges from our storm water outfalls are not a significant source of water quality concerns. An assessment of 289 outfalls within the Lower Charles River Watershed performed for MassDOT did not identify any illicit connections. The efforts to conduct illicit discharge are costly. Therefore, comprehensive illicit discharge detection from MassDOT's storm water system is not a cost-effective approach to reducing pollution from storm water systems. Rather, a targeted effort to assess areas with a higher potential for illicit discharge is more appropriate.**

**The TMDL recommends that as part of the illicit discharge detection efforts, wet weather and dry weather sampling for nutrients should be conducted (TMDL Section 7.2.3, Page 86-87). This is not consistent with the standard approaches to identifying illicit discharges, which do not include sampling for nutrients. In addition, the nature of storm water is such that the nutrient concentrations are highly variable within a storm event and throughout the year. Therefore, results from sampling efforts are unlikely to be valuable for assessing the contribution of specific areas if based on a limited number of samples. More comprehensive sampling efforts for such a large number of outfalls would be cost prohibitive. The basis for this recommendation is unclear; given the increased costs involved, this effort likely is unwarranted.**

**Response:** *The concerns of the DOT are noted. This recommendation was targeted more at municipal systems than those controlled by MassDOT. Although the Lower Charles had a smaller number of illicit discharges, it is anticipated that the much larger and more complex Upper/Middle Charles watershed could be different. If illicit discharges are not found to be prevalent an alternative plan targeting areas deemed to have a higher potential for the discharge of phosphorus should be developed and implemented. The fundamental goal of this TMDL is to identify and eliminate sources of phosphorus to the Charles River system, whether those sources include illicit discharges or not.*

*During the feasibility/implementation process, prior reports and studies should be taken into account to determine the most cost effective method of assessing and monitoring discharges for a matrix of issues including proximity to water bodies and potential impacts. The Department questions how DOT would prioritize discharges, quantify their phosphorus contribution and track remediation efforts without a significant monitoring program. The above matrix could be used to prioritize where sampling should begin. MassDEP still believes however, that illicit discharges from municipal systems still exist and work needs to continue to remove them from the municipal systems where feasible. MassDEP also believes that other alternative approaches could be acceptable, provided they show a clear path to prioritize sources of phosphorus for remediation but it will be incumbent upon MassDOT to develop a plan acceptable to MassDEP.*

**17. Comment/Question: Use and need for drainage area information unclear: The TMDL recommends defining the drainage area and a wide range of related characteristics for each outfall or subcatchment (page 83). MassDOT has hundreds of outfalls within the TMDL area and defining and assessing the drainage areas would be very expensive and time**

**consuming. It is not clear how this information would be used for prioritizing areas for BMP installation. In addition, there may be other more efficient ways of prioritizing outfalls for BMPs. These may include the location of the outfall relative to the impaired water body, the size of the outfall (which may be useful as a surrogate for the drainage area and flow while being easily obtained), and the land use of the area near the outfall. Permittees should have significant flexibility in their approach for assessing their drainage areas and prioritizing them for BMP implementation. This flexibility will allow permittees to implement the most cost-effective approaches and maximize the improvement in water quality achieved within limited budgets. Implementing a cook book approach to large, diverse, storm water systems is not efficient. In addition, the flexibility in prioritization and BMP implementation will avoid unnecessary delays that may be caused by compiling the details of MassDOT's drainage systems.**

**Response:** *The ideas of the MassDOT to incorporate flexibility into the approaches utilized to identify and prioritize the most important outfalls and to maximize the improvements in water quality while keeping budgetary constraints in mind, in order to implement the most cost-effective approaches, are noted. The ideas stated above were incorporated into the management and implementation discussion section of the TMDL. Some of the information requested by the TMDL should already be available to MassDOT as that information would be required to complete other projects or to meet MS4 requirements.*

*In order to achieve the large reductions in stormwater runoff necessary to bring the Charles River into compliance with water quality standards, an intensive and integrated watershed remediation effort will be necessary to complete over time.*

*This may be allowed if MassDOT develops a detailed plan for Department approval.*

**18. Comment/Question**: **Overlap with MS4 permit not defined: The draft TMDL contains many recommendations that are duplicative of the requirements of the MS4 Phase II Permit. However, the TMDL does not acknowledge that compliance with the MS4 permit will achieve many of these recommendations. For example, the TMDL recommends developing and implementing Storm Water Management Plans to reduce phosphorus loading. Developing a separate SWMP for consistency with this TMDL would be duplicative of the SWMP developed for compliance with the MS4 permit. Therefore, the recommendations that are duplicative of MS4 requirements should be identified, and many of the requirements can be incorporated into the SWMP developed for compliance with the existing Phase II MS4 permit.**

**Response:** *The TMDL is a technical document. The intent of the TMDL is not to create a duplication of work but rather to provide an overall framework that discusses the problems in the watershed, what the causes of those problems are, and what methods could be employed to address those problems. One of the most important methods to improve overall watershed water quality is the MS4 Permit and the requirements set forth in that permit. It is not MassDEP's intent to require additional SWMP's where they already exist. Our goal is to utilize existing tools like the MS4 Phase II Permit to address the sources of water quality impairments in the river is primary to meeting stormwater reductions. It must be recognized however that these permits will and SWMPs will likely need to be updated to include a prioritization system to address and remediate phosphorus sources. The MS4 Permit itself includes a requirement to meet the water quality goals set forth in any approved TMDLs. This TMDL sets forth those goals and once finalized and approved by EPA, future stormwater NPDES permits are required to be consistent with the wasteload allocations of any approved applicable TMDL.*

**19. Comment/Question: Watershed specific permits unnecessary: The TMDL recommends an evaluation of developing watershed specific general permits (WSGP) within the Charles River watershed (page 81). The existing statewide MS4 general permit is comprehensive and allows implementation of measures to address local water quality concerns through a number of mechanisms, including compliance with TMDLs. Therefore, a WSGP would not have significant advantages for the water quality of the Charles River over application of the current permit framework. In addition, the development of a WSGP would create a duplicative administrative burden for permittees that operate systems that cross the boundaries of the Charles River Watershed.**

**Response:** *The TMDL recommends conducting a study that would evaluate the usefulness of developing a WSGP as a tool to facilitate implementation of the goals of the TMDL if the TMDL and current efforts fail. A study is necessary to evaluate the extent of additional improvements that could be obtained and what the level of those improvements would be as well as potential costs. This study would be necessary for making an informed decision if water quality goals are not met.*

**Comment/Question: Load and Reduction Comments**

**20. Transportation loads are over-estimated: The data indicate that the load of phosphorus from MassDOT roads represents only a small portion of the overall load to the upper Charles River. Preliminary findings from work being conducted by the USGS estimate a loading rate of 1.8 kg/ha/yr estimated with data from the Highway-Runoff Database Version 1.0.0a (Federal Highway Administration, 2009). These data represent runoff directly from roadway surfaces. This loading rate is significantly less than the 2.51 kg/ha/yr used in the model for impervious surfaces in the Commercial/Industrial/Transportation land use (Table 14, page 50). This demonstrates that the model is over-estimating the impacts of transportation land uses.**

**Response:** *See Draft Report, Table 14, page 50. Also please refer to our response to Q23 for more detail.*

*The phosphorus export rate of 2.51 kg/ha/yr represents an aggregation of impervious surface for land uses within the industrial land use category not just highways. The agencies appreciate MassDOT data collection efforts to characterize stormwater pollutant characteristics but do not agree that it should be concluded that DOT's calculated rate of 1.8 kg/ha/yr is necessarily representative of all highways throughout the upper-middle watershed and for the same loading conditions used in the TMDL analysis.*

*Experience in the stormwater monitoring field consistently shows high variability of stormwater quality within land uses at single sites and at among different sites within the same land use category. Experience shows that the longer the averaging period used to characterize quality from a particular stormwater source the less variability there is among sites of a given land use. The approach used in this TMDL was to match watershed loads with simulated instream water quality for over a five year period in order to reduce variability associated with numerous factors particularly year to year variations in climatic conditions. The TMDL analysis did not attempt to characterize loadings for individual sites or from subsets within broader land use categories.*

*The primary objective was to estimate total loading while recognizing that some stormwater sources of phosphorus (particularly highly impervious areas) are more potent than others.*

*Also, for implementation purposes, this TMDL emphasizes the* ***relative*** *reductions that are needed to achieve the water quality goals. The significance of emphasizing relative reductions is that the absolute value of actual loads is less important than the relative reduction. For example, if the Lower Charles phosphorus TMDL applied a uniform load reduction rate among all of the controllable land use categories (all except forested) the reduction required would be 63.7%. For the more impervious surface such as highways, MassDEP is confident that a reduction on the order of 65% is needed to achieve the water quality goals for the Charles River regardless of whether its absolute loading rates is 1.5 or 2.5 kg/ha/yr. MassDEP has determined from this TMDL analysis as was determined in the Lower TMDL analysis that the land use categories with higher loading rates (medium density residential, high density residential, industrial, and commercial) all require reductions of 65% to achieve the water quality goals of the Charles River. MassDEP is confident that the phosphorus loading from highways is well with the within the various loadings from this group of land uses. Since the Charles River TMDL uses actual instream water quality data to back calculate runoff levels, the data in this study are more relevant to the upper –middle Charles River watershed for the TMDL analysis period than the more focused monitoring efforts provided by MassDOT.*

*Our consultant, Numeric, indicated that the TP average annual export coefficients given in Table 14 were calculated using the hourly HSPF predicted unit area phosphorus loads discharged from pervious and impervious fractions and the total of each land category, during the 5-year period between 1998 and 2002. Although the calculated value of 2.5 kg/ha/yr for the impervious fraction of the Commercial/Industrial/Transportation land use is higher than that attributed to a preliminary analysis by USGS (1.8), it falls well within the range of values cited in the literature for urban (NURP range = 0.19-6.23), commercial (Loehr et al, 1989, range = 0.1-7.6) and industrial (Loehr et al. ,1989, range = 0.4-4.1) land uses. In the China Lake TMDL (Maine DEP, 2001), the Maine DEP utilized TP export coefficients of 3.9 and 2.9 kg/ha/yr, for lake shoreline and non-shoreline roadways, respectively. The official Maine DEP Method for determining phosphorus load allocations within altered urban and suburban landscapes (Dennis, et al. ,1989) utilizes TP export coefficients of 5.9 and 4.2 kg/ha/yr for road surfaces and impervious urban surfaces, respectively. The values used by Maine DEP serve to further bracket those given in Table 14 as being well within the range of values cited in the literature. Official stormwater management manuals for several other states similarly contain TP export coefficients for highways that are similar to or significantly higher than the values calculated from the HSPF results of this study.*

*An important finding of the NURP studies was that event-mean TP concentrations for runoff from all urban land uses were similar, with median and mean EMC concentrations of 0.26 and 0.33 mg/l TP, respectively. Application of the widely accepted Simplified Method (Shoeler, 1987), using the recommended average annual rainfall depth of 41.5 inches for coastal New England and the NURP urban median EMC for TP yields an export coefficient of 2.5 kg/ha/yr for impervious surfaces. This result is essentially identical to the TP export coefficient determined using the calibrated HSPF model for the impervious component of the commercial/industrial/transportation land uses, within the Upper/Middle Charles River watershed.*

**21. Comment/Question: The TMDL indicates that the level of reduction applied to each land use when developing the Waste Load Allocation (WLA) is reflective of the relative**

**importance of that land use. In addition, the TMDL applies greater reductions to the major wastewater treatment facilities (WWTFs) than to the minor WWTFs. Despite this, the TMDL requires the highest level of reduction (65%) from transportation land use even though it only represents a small fraction (7%) of the storm water phosphorus load to the Charles River (Figure 14, page 74). Further, MassDOT represents only a fraction of the load from the transportation land use with approximately 200 road miles (as calculated from former MassHighway roads) out of the total 2,400 road miles in the watershed. Based on the loading rate developed with the USGS data and an estimated impervious area (from formerly MassHighway roads) of 400 hectares, we estimate that 730 kg/yr of phosphorus runs off these impervious areas within the Charles River watershed. This is less than two percent of the overall load to the Charles River (40,545 kg/yr). Since MassDOT is such a small fraction of the overall load, and therefore has a relatively minor impact on the Charles River Water quality, a lower requirement for phosphorus reduction attributable to transportation land use is appropriate.**

**Response:** *Please see also the response to question 20.*

*All NPS received the same across the board reduction and there are differences between the MassDOT model and the agencies' model in that the MassDOT model only estimates the amount coming from the impervious surface while this model combines transportation with other categories of land use and considered both impervious and pervious areas (therefore the higher runoff coefficient). Impervious areas as compared with pervious areas, by definition, have direct runoff without any attenuation or infiltration. The relative magnitude of the impact from impervious areas can be substantial on a percentage basis in comparing actual runoff levels versus potential runoff levels. Additionally, roadways tend to follow the river system and are located in the buffer zone of the waterway with proximity to the river and its tributaries being quite high. Therefore, the potential for reductions of runoff from these roadways can be quite substantial with correspondingly large reductions in instream effects. An evaluation of the roadways as specified in the TMDL implementation/management section would provide further refinement in the information necessary to a determination of importance.*

*The 65% was based on all transportation and was consistent with all stormwater reductions across the board, and 65% was the amount the Department felt was achievable based on BMPs. The TMDL does not break out MassDOT versus other roadways. When dealing with stormwater pollutant loadings in a large watershed like the Charles, it is necessary to address literally thousands of individual sources that when considered individually each source can seem insignificant. However, the cumulative effect of all the sources combined is not insignificant. MassDEP is very confident that impervious surfaces when considered collectively are a very significant and substantial source of phosphorus to the Charles River.*

*Numeric indicated that the TP stormwater loads and export coefficients determined with the HSPF model are the result of its calibration to a large amount of recent site-specific stream flow and water quality data for the Upper and Middle Charles River and its watershed. As such, they are likely much more representative of actual current conditions within the Charles River watershed than transportation TP loads estimated by USGS using a nation-wide database. The HSPF TMDL modeling indicates that TP stormwater loads from urban impervious surfaces, including roadways, are a significant source of TP to the Charles River and its tributary streams. In addition, stormwater TP loads discharged from these impervious road surfaces are often directly connected to the stream network, with very little load attenuation.*

**22. Comment/Question: In addition, only a minority of the runoff from the MassDOT (formerly MassHighway) roads discharge directly to the Charles River. The volume and concentration of phosphorus in runoff from roads that do not discharge directly to the Charles River will be reduced substantially by a number of factors, including existing BMPs which facilitate infiltration, detention, and plant absorption. BMPs such as these have been shown to reduce phosphorus loads from 20 to 90 percent (MA DEP Stormwater Policy, 2008). As a result, the phosphorus load from MassDOT roads in the watershed to the Charles River is likely much lower than predicted. Therefore, MassDOT is a minor contributor of phosphorus to the Charles River.**

**Response:** *In a 2010 assessment of Spruce Pond brook, a one-square-mile subwatershed in Franklin, CRWA found that few stormwater BMPs had been installed prior to 2000, the base year for the TMDL land use. Of the 50 potential BMP sites, only 7 had active stormwater BMPs, and most of these BMPs were not designed to remove much phosphorus. These 7 BMPs only accounted for 2.5% of the required TMDL reduction for the subwatershed, and that estimate assumed the BMPs were being maintained.*

*A comprehensive mapping of these outfalls and an identification of the drainage areas together with a decision matrix of factors used to prioritize the importance of these outfalls would be the most logical way of determining whether the outfalls are a major or minor contributor. From the information contained in this letter, it appears that MassDOT already has a large amount of the information necessary for a project this type.*

*MassDEP and EPA envision that the permitting process will allow MassDOT to get phosphorus reduction credits for existing well functioning BMPs. As part of the permitting process, MassDEP expects that MassDOT will have the opportunity to document post-constructional details of existing BMPs and provide supporting information to justify phosphorus removal credits for complying with phosphorus load reduction permit requirements. To assist permittees in assigning phosphorus removal credits for BMPs, Tetra Tech, under contract to EPA, conducted a BMP performance assessment project that provides long-term cumulative phosphorus load reductions for eight types of structural BMPs based on varying design storage capacities. The final report for this project is located at: http://www.epa.gov/region1/npdes/stormwater/assets/pdfs/BMP-Performance-Analysis-Report.pdf*

**23. Comment/Question: Storm water loads are over-estimated: From our analysis of the draft TMDL narrative, it appears that the ultimate allocation of loads under this TMDL attribute too much of the existing phosphorus load to surface runoff (distributed over the several categories of land uses). The concern is that the resulting TMDL action strategy places too heavy an emphasis on reducing phosphorus from land uses, including transportation (e.g., by application of non-structural and structural BMPs), and too little emphasis on identification and correction of other significant sources.**

**The Upper/Middle Charles TMDL is based in part on achieving a load allocation stipulated in the Lower Charles TMDL. In the Lower Charles TMDL study, the analytical model was based on land use literature-based export coefficients, and the model was calibrated by adjusting the literature coefficients by about 1%. It appears that this adjustment was applied uniformly over all the land use classes. The model used for the Draft TMDL study**

**of the Upper/Middle Charles, resulted in a further adjustment to the export coefficients (see Table 14 and the narrative on page 49). These further adjusted values average 47% greater than the aggregate coefficient for all land uses.**

**At the October 29, 2009 public hearing, the DEP offered that this adjustment was made essentially to calibrate the model. The modeling consultant indicated that the coefficients were "back-calculated" from modeling results. By either explanation, the adjusted loading rates differ so significantly from literature values and from values used in the Lower Charles TMDL, that further analysis is warranted to explain or justify the difference.**

**From the last row of Table 14, one can infer that if export coefficients by land use category had been set equal to those used for the Lower Charles, then the storm water load would be 21,868 lbs instead of 30,974 lbs. This would mean the model would not account for about 9,106 lbs of phosphorus (annual load).**

**Response:** *The Draft Report explains why the land use export coefficients used in the Lower Charles TMDL were too low and had to be increased for this TMDL as follows:*

*"The Lower TMDL used literature-based export coefficients (Horner, 1994) and adjusted these coefficients to match the total observed watershed phosphorus load. In general, these Lower TMDL loads were lower than those used in the Upper/Middle TMDL because the Lower Charles TMDL model used the measured load input at the Watertown Dam. As such it did not have to consider additional losses that were occurring in the Upper/Middle sections of the system Therefore in order to account for upstream losses and still match the measured load at the Watertown Dam further adjustments to the final phosphorus export coefficients were necessary and are provided in Table 14."*

*The net phosphorus losses of about 10,500 kg/yr that are mentioned in the above paragraph (also see Table 14, page 50) are mostly due to the Mother Brook diversion and settling of algae. Because the Lower TMDL did **not** consider these losses in its more general analysis, the stormwater phosphorus load for this TMDL **must be** increased as part of the calibration process.*

*In addition to raising all export coefficients, the low density residential loading factor used in the lower TMDL appeared too low (lower than forest), so it was increased from 0.05 to 0.38 kg/ha/yr. That value for the low density residential land use corresponded well with numbers used in another MassDEP report (Mattson, M.D. and Isaac, R.A., 1999. Calibration of phosphorus export coefficients for Total Maximum Daily Loads of Massachusetts's Lakes. Lake Reservoir Management, 15:209-219).*

*In the HSPF model, there are no export coefficient parameters, so the buildup, washoff, interflow, and groundwater coefficients were set to literature values, then the model was run, and effective export coefficients (kg/ha/yr) were calculated from simulated output for all the pervious and impervious land segments. This process was repeated iteratively by changing model parameters until the export coefficients seemed reasonable relative to one another and the total phosphorus load at the Watertown Dam matched the observed load for the calibration conditions.*

*Numeric indicated that stormwater TP loads were developed based on an iterative calibration of the HSPF model, using a large amount of recent site-specific flow and water quality data. The calibrated model accounts for all of the important processes controlling flow and water quality constituent loadings to the river, as well as internal sources and losses of flow and water quality constituents from the stream network. Internal sources and losses simulated by the model include:*

*bottom sediment nutrient releases, algal settling and the Mother Brook flow diversion. The simplified export coefficient approach used in the Lower Charles TMDL neglected these significant internal TP losses, resulting in land use TP export coefficients which were within the relatively wide literature ranges, but somewhat lower than found using the much more comprehensive HSPF modeling approach. Citing an export coefficient value as being "from the literature" should not lend it more credibility or validity than an export coefficient determined with a fully calibrated, comprehensive model such as HSPF.*

*The biggest change was due to the fact that the Upper Charles had to account for losses from Mother Brook where the Lower Charles focused only on what was coming over the dam. The bottom line is that both used Mass Balance based on data.*

*Additionally, literature values can be extensively different from actual site-specific values as literature values are taken from nationwide databases where study sites may not be comparable. All studies begin with literature values as the first step. These literature values may be appropriate for locations in which the land uses in the study area database are similar to the land uses in the actual study area. This is the case for the Lower Charles. The Lower Charles is a more uniform urban area than the Upper/Middle Charles and using land use values from the database showed a good fit with only a small fraction of a change needed in order to match the instream values with the runoff values.*

*However, the Upper/Middle Charles has a much more complex land use and therefore required more extensive changes from the literature values in order to generate and simulate observed instream water quality values. To have land use runoff values back-calculated from actual instream data is many orders of magnitude more accurate than using literature values from areas much different and geographically far removed from the study area.*

**24. Comment/Question: Other unaccounted significant sources: The unaccounted for phosphorus load raises the question whether there are other significant sources that should be considered under a separate category from surface runoff, such as:**

- **Illicit connections or undocumented CSOs**
- **Groundwater contributions (e.g., failing septic systems or septic systems located in close proximity to surface waters)**
- **Populations of resident waterfowl**[2]
- **Erosion of disturbed sites**
- **Channel erosion associated with watershed streams**

**Section 4.2 indicates that flows from functioning septic systems are normally very small. There is no discussion of failing septic systems, or of "apparent" functioning systems that may be close enough to water resources that they may "short circuit." Is there sufficient evidence to eliminate septic systems as a potential phosphorus source?**

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[2] This potential source should not be underestimated. If the Canada geese population in the watershed is proportional to the 1997 goose population estimated by MassWildlife for the state, then the watershed is home to at least 1200 of these waterfowl, each of which can produce up to an estimated 2 lbs. of phosphorus per year.

**Response:** *Please refer to question 35 for additional discussion. Although additional data is always beneficial MassDEP believes the current modeling effort has adequately captured the major sources and their impact on water quality within the Upper/Middle Charles River. There is not enough data on all smaller sources which are minor compared to the other sources.*

**a. Illicit connections or undocumented CSOs**

*a. MassDEP does not believe there are any CSO in the middle and upper watershed but are aware of the presence of illicit sanitary sewage discharges and sanitary sewer overflows (SSOs). These discharges are highly variable and difficult to estimate their contribution to the Charles because most have yet to be identified and/or quantified. However, MassDEP and EPA envision the permitting process for achieving the stormwater phosphorus load reductions will allow municipalities to take credit for the elimination of documented illicit discharges and SSO. To earn such credit towards the municipality's overall reduction requirement will require the municipality to quantify the volume of illicit discharge eliminated. For example, the Boston Water and Sewer Commission (BWSC) has had a long running IDDE program. When BWSC eliminates illicit discharges it reports the annual volume eliminated based on public water usage records. Using these volumes and representative phosphorus concentrations of untreated sanitary sewage, the corresponding phosphorus load eliminated can be estimated.*

**b. Groundwater contributions (e.g., failing septic systems or septic systems located in close proximity to surface waters)**

*b. Failed septic systems are likely a very minor source of phosphorus to the water shed. Phosphorus mobility is highly limited in soils and usually moves only under surface breakout conditions. Therefore the input was determined to be relatively minor. However, under the implementation phase, the towns in the upper watershed could evaluate this issue and possible solutions as part of the BMP implementation plans. Although these are expected to be small they may assist in meeting the total nutrient reductions requested as part of this TMDL. A large portion of the watershed is already sewered.*

**c. Populations of resident waterfowl**[3]

*c. MassDEP agrees that waterfowl can be a contributor to phosphorus in localized areas. Therefore, this would be more logical to deal with on a town by town site specific basis,. Although these are expected to be small they may assist in meeting the total nutrient reductions requested as part of this TMDL.*

**d. Erosion of disturbed sites**

*d. Erosion of disturbed sites should be a minor contributor to the overall phosphorus load if required erosion control techniques are employed as required. Nonetheless, they may be a contributor to phosphorus in localized areas and should be addressed on a town-by-town basis.*

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[3] This potential source should not be underestimated. If the Canada geese population in the watershed is proportional to the 1997 goose population estimated by MassWildlife for the state, then the watershed is home to at least 1200 of these waterfowl, each of which can produce up to an estimated 2 lbs. of phosphorus per year.

*Although these are expected to be small they may assist in meeting the total nutrient reductions requested as part of this TMDL.*

**e. Channel erosion associated with watershed streams**

*e. Same response as for c and d.*

**25. Comment/Question**: **Build-out conditions not considered: The TMDL does not appear to account for build-out conditions, other than future growth anticipated in the design flows of the wastewater treatment plants. If the study assumes that new development will control phosphorus levels to equal "background" (i.e., forest loading rates), then the required removal rates may be unrealistic for sites where infiltration BMPs cannot be installed. The lack of build-out analysis does not appear to be a realistic approach to addressing long-term water quality goals.**

**Response:** *It is anticipated that current regulations for building requirements and proposed new stormwater regulations for existing sites will control increases in future nutrient runoff. Build-out analyses have been conducted in the past by EOEEA watershed teams and these GISs based maps are available for the town to use in meeting their regulatory requirements. These maps are located at*: *http://commpres.env.state.ma.us/content/buildout.asp. Please see Response 1.b. for additional stormwater issues.* .

**Compliance Comments**

**26. Comment/Question: Need for BMPs in not-direct discharges: MassDOT understands the need for phosphorus reduction for direct discharges to the Charles River and its tributaries but feels that discretion should be provided for determining if discharges do not directly discharge to any of these waterbodies. By focusing on the direct discharges, the limited budgets for BMP construction will most effectively be utilized for phosphorus reduction.**

**Response:** *MassDEP agrees with your comment. This is the reason the TMDL recommends that all entities including MassDOT prioritize each source. The importance of prioritizing which sources should be targeted first in order to achieve the most improvement instream should be emphasized in any implementation/management plan.*

**27. Comment/Question: Accounting for BMPs: The existing MassDOT storm water system includes BMPs that reduce the phosphorus loads to the Charles River. For example, when I-495 was built (around the late 1960s), a vast array of drainage attenuation basins and swales also were built. BMPs like these should be factored into all of the phosphorus loading calculations, i.e., considered when assessing compliance with the WLA and reductions that this TMDL requires. Furthermore, it is not clear that the effectiveness of existing BMPs would be considered when determining compliance with the TMDL. Compliance with the TMDL should be determined based on the implementation of BMPs where practicable. In some cases, it is likely that the MassDOT system already has sufficient BMPs to achieve the required reductions in phosphorus loading.**

**Response:** ***See Response to Question 22.*** *The purpose of this TMDL is to identify sources and loads of phosphorus to the Charles River system, their impact on water quality, and to define the load reductions necessary to meet the state Water Quality Standards. The TMDL also attempts to provide general guidelines for implementation but it does not attempt to identify which activities should and should not receive credit nor how much credit should be granted. The reason it did not attempt this is because the amount of reduction is highly site specific and depends on many factors including, but not limited to: 1) the type of BMP (including whether it is structural or non-structural), 2) the location, 3) the effectiveness of the BMP to remove phosphorus and 4) how well the BMP is maintained over time. The water quality conditions observed during the development of this TMDL should reflect the reductions achieved by BMP implementation prior to TMDL development however this is highly dependent on the factors identified above especially whether or not the BMP has been well maintained. Clearly, any new BMPs that have been applied subsequent to the development of this TMDL should receive credit to partially meet the overall reductions specified in this TMDL but the method for assigning and tracking that credit was beyond the scope of the TMDL and should be evaluated through other processes.*

*The USEPA is presently in the process of evaluating this issue and has recently developed, and issued for public comment, a pilot program permit using their Clean Water Act, Residual Designation Authority (RDA) for stormwater discharged from the Towns of Bellingham, Franklin, and Milford. That permit has proposed alternative ways to provide credit for both structural and non-structural BMP applications. For further information please refer to the EPA web site at http://www.epa.gov/region1/npdes/charlesriver/index.html.*

**28. Comment/Question: In addition, compliance should take into account the highly variable nature of storm water systems and the constraints at certain sites that would make certain structural BMPs not feasible. Therefore, the TMDL should account for these variations and acknowledge that implementing structural BMPs for reducing phosphorus loads is not feasible at all outfalls. In addition, flexibility should be allowed for implementing BMPs in areas where they will be most effective and the greatest reductions in phosphorus loading will be achieved. This will ensure the most prudent use of tax dollars for reducing phosphorus loading to the river.**

**Response:** *The TMDL provides an overall goal for phosphorus reductions to meet water quality standards but is not sufficient to allocate loads on a parcel by parcel basis. It is for this reason the Department has recommended site-specific evaluations and prioritizations. The importance of prioritizing which sources should be targeted first in order to achieve the most improvement instream, together with a feasibility study which includes evaluation of installation and access, should be emphasized in any management plan.*

**29. Comment/Question: The EPA has developed performance curves for a few of the available structural BMPs (*Stormwater Best Management Practices Performance Analysis,* December 2008). Will the EPA and DEP permit MassDOT to rely on this reference to document effectiveness of BMPs for controlling phosphorus? Will the EPA or DEP be supplementing this document with data on other structural BMPs discussed in the Massachusetts Stormwater Handbook? Will guidance be available for the performance efficacy of non-structural practices, such as street sweeping, fertilizer application, and leaf litter control?**

**Response:** *The* Stormwater Best Management Practices Performance Analysis *is one tool which the agencies have made available for use in projects such as these. This report is located at:* [http://www.epa.gov/region1/npdes/stormwater/assets/pdfs/BMP-Performance-Analysis-Report.pdf](http://www.epa.gov/region1/npdes/stormwater/assets/pdfs/BMP-Performance-Analysis-Report.pdf). *For the permitting program EPA envisions that the performance information from this project may be used by permittees to demonstrate compliance with phosphorus reduction requirements by calculating phosphorus reduction credits for BMPs that are designed, constructed, and maintained in accordance with the MA SW Handbook. For other BMPs, not included in the BMP performance project, the permittee will need to provide and justify estimates of reduction credits. For the draft RDA general permit, EPA has included methodologies for calculating phosphorus reduction credits for both non structural ( sweeping, CB cleaning, phosphorus free fertilizer use, and leaf litter management) and structural BMPs., The Agencies would like to expand the scope of BMPs for which long-term cumulative phosphorus reduction estimates are provided. However, no plans currently exist; as such work is dependent on having both available funding and adequate BMP performance data. As indicated in RTC 1b, the USGS with funding by MassDEP and EPA is carrying out a high efficiency street sweeping project in the City of Cambridge for the goal of developing estimates of phosphorus reduction credits for various sweeping programs.*

## Modeling Comments/Questions

**30. Comment/Question: Sediment releases: The analytical model used to develop the TMDL includes a component for sediment nutrient release. Section 3.1.1 describes a study which characterized sediment nutrient and oxygen release rates in nine watershed impoundments. The narrative does not appear to relate how this information was used. Does the model account for sediment release from the impoundments only, or from the entire river reach within the study area?**

**The TMDL report (e.g., Section 4.2, page 46) notes the potential significance of nutrient release from sediment accumulated on the river bottom. The study mentions no characterization of river sediments, or how phosphorus from the river sediments enters the water column. Has characterization and evaluation of nutrient release within the river been conducted? Has sediment transport from the river to the impoundments, and subsequent contribution to impoundment sediment/water interaction, been evaluated?**

**Response:** *For each of the nine impoundments, average model parameters were determined from the four samples per impoundment. The parameters used in the HSPF model were the sediment oxygen demand, ammonia efflux rate, and phosphate efflux rate* ($g/m^2/hr$)*. Because the measured organic efflux rates were low, the BOD rates in HSPF were set to near zero values. The measured average rates were used in each of the nine impoundment reaches and interpolated between impoundments for flowing reaches between them. Because these rates are area-dependent* ($g/m^2/hr$) *and the flowing reaches do no have much bottom area, the actual rates (g/hr) are very low, so the model is not sensitive to the accuracy of these values for the flowing reaches.*

*The study referred to was conducted by UMASS Dartmouth. The data indicated those 36 sediment samples were collected in 9 impoundments, with 4 samples per impoundment. Each sample was measured for sediment oxygen demand (SOD) and nutrient release rates under both aerobic and anaerobic conditions. The SOD data showed little variability. Aerobic and anaerobic release rates were averaged for the impoundments and incorporated into the model. Sediment flux data collected by UMass Dartmouth (CRWA, 2006) indicated that NO3-N is lost* *from the water column within these impoundments. Denitrification was activated within the HSPF model for these reaches during warm-weather periods when predicted water column DO levels decrease. Sediment processes like erosion were not explicitly modeled since suspended solids concentrations are very low in the Charles River*

*Excerpts from the Upper/Middle Charles River Phase III Calibration Report (CRWA, Numeric, 2009) are as follows:*

*"CRWA surveyed nine impoundments and ponds to determine bathymetry and sediment thickness during summer and fall of 2002 and the summer of 2003. The bathymetric survey determined the storage capacity and quantified the thickness of sediments in each impoundment and pond……..*

*CRWA contracted UMass-Dartmouth in 2005 to design and conduct a sediment nutrient and oxygen flux study in the Upper/Middle watershed. The goal was to obtain rates of sediment nutrient release and oxygen demand to support the parameterization of the water quality model. The same nine impoundment sites were studied. Sediment cores were collected at two to five stations at each site and were incubated to determine both aerobic and anaerobic nutrient release rates and sediment oxygen demand."*

*Phosphorus from the river sediments can enter the river system in a number of ways including scouring and resuspension of the sediments into the water column or through chemical changes in the surface sediments that take place when dissolved oxygen in the water column reaches a low enough level to dissolve the layer which seals off the sediment nutrients from moving into the water column. A determination can be made of the composition of the sediments and the level of dissolved oxygen in the water column over these sediments, however, these types of studies are prohibitively expensive, but they were funded for this project.*

*Information from these studies was incorporated into the HSPF model.*

*Numeric indicated that measured phosphorus flux rates from bottom sediments and oxygen loss rates to bottom sediments were both included within each reach of the HSPF river model. The measured phosphorus (orthophosphorus) and nitrogen (ammonium and nitrate) flux rates, in grams per square foot per day, were extracted from the impoundment sediment study and assigned to the corresponding impoundment reaches in the HSPF model. HSPF calculates the bottom surface area of each reach, during each 1-hour time step. The measured impoundment rates were linearly interpolated over the length of river to determine values used in non-impounded, free flowing reaches. Flux values were measured for both aerobic and anaerobic (low dissolved oxygen) conditions within overlying waters and these different values were also used in the model. Anaerobic phosphorus flux rates were generally greater than those measured under aerobic conditions. HSPF predicted water column dissolved oxygen levels at each time step were then used by the model to select either the aerobic (DO greater than 2 mg/l) flux rate or the anaerobic (DO less than 2 mg/l) flux rate, during each time step. It is important to note that although linearly interpolated impoundment values for flux rates were used in free flowing river reaches, very little flux of nutrient or dissolved oxygen mass occurs within them, due to their low water residence times.*

**31. Comment/Question: TP settling: In Table 13, how was the "settling" component of "TP Losses" estimated? Does this include both river and impoundment components?**

**Response:** *Numeric indicated that the HSPF model simulated the loss of algae and organic phosphorus to bottom sediments via settling, within all reaches, including both impounded and free flowing portions of the river main-stem and its tributaries. Since algae contain phosphorus, their settling results in a loss of phosphorus from the water column. Similarly, the HSPF model simulated the loss of both the refractory (non-reactive) and labile (reactive) portions of the water column organic phosphorus to bottom sediments via settling of refractory organic phosphorus and biochemical oxygen demand, respectively.*

*A sensitivity analysis was conducted by turning various processes on and off to look at the response instream in order to provide an idea of the internal responses Coefficients were adjusted based on the results of the sensitivity analysis.*

**32. Comment/Question: Groundwater contributions: The Section 4.2 introductory paragraph states that groundwater sources of phosphorus are normally very small. Has this statement been corroborated by field data obtained within the study area? How do background groundwater phosphorus levels compare to the EPA criteria for phosphorus listed in Table 3?**

**Response:** *A buildup and washoff process was used for surface water with EMCs for groundwater input on a monthly basis. The total phosphorus used for groundwater was 0.01 mg/l for all months and all* PERLND*s. This is directly comparable to the USEPA recommended nutrient numbers listed in Table 3, pg. 19.*

*Numeric indicated that HSPF was used in this study to simulate subsurface flow in two regions. The upper region nearest to the ground surface, termed the interflow region, can receive rainfall that infiltrates downward. Below this region exists the groundwater. During an HSPF simulation, phosphorus concentrations are assigned to the flows discharging from each of these regions into the stream network. Although no interflow and groundwater phosphorus concentration data were available for the land uses within the watershed, values were assigned based on best professional judgment. Groundwater phosphorus concentrations for all land uses were set to 0.01 mg/l. Interflow phosphorus concentrations were set to 0.01 for forested wetland and water wetland land uses, 0.06 mg/l for open and forested land uses and 0.16 mg/l for all residential land uses and the commercial/industrial/transportation land use. The higher interflow concentrations used for the developed land uses were meant to capture all unknown subsurface sources, such as failing septic systems.*

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## F. COMPREHENSIVE ENVIRONEMENTAL INCORPORATED COMMENT LETTER On behalf of the Towns of Franklin and Millis

**33. Comment/Question: Model Calibration Methodology and its Effect on Allocation of the Annual Phosphorus Loads**

**From our analysis of the Draft TMDL, we are concerned that the ultimate allocation of loads ascribes too much of the existing phosphorus load to surface runoff, distributed over the several categories of land uses. This allocation is derived from the modeling**

**assumptions and calibration. With the allocation by land use proposed under the TMDL, the importance of other contributing sources has been masked. The action plan for reducing phosphorus can then result in too much emphasis on reducing phosphorus from land uses, and too little effort to identify, characterize, and address these other sources.**

**As a result, affected communities could expend considerable resources on regulating land uses or implementing BMP retrofits to capture and treat runoff from individual sites, only to find after years of effort that the Charles River is still impaired because of significant loads from other sources that were insufficiently characterized in this TMDL.**

**The basis of this concern is as follows:**
**The Draft Nutrient TMDL uses existing water quality and flow data within the watershed to develop a model to define phosphorus loadings to the Upper/Middle Charles River, calibrated to the water quality data at the Watertown Dam that served as the basis for the Lower Charles River Final Nutrient TMDL.**

**In the Lower Charles TMDL, the analytical model estimated phosphorus loads from surface runoff from various categories of land uses for the entire watershed, based on literature values of export coefficients. After accounting for wastewater treatment facilities and CSOs, the modeling effort found that the estimated load based on these coefficients was within 1% of the load computed from water quality and flow data. The Lower Charles TMDL model was therefore calibrated by adjusting the export coefficients by about 1%. It appears that this adjustment was applied uniformly over all the land use classes. The results of this analysis established existing and allocated loads of phosphorus at the Watertown Dam. These loads have been carried forward into the development of the Draft Upper Middle Charles TMDL.**

**In the Draft Upper/Middle Charles TMDL, the narrative (page 49) states that "*further adjustments to the final phosphorus export coefficients were necessary.*" The adjusted coefficients are presented in Table 14 and compared to the values used for the Lower Charles study. The Upper Charles TP loading rates (expressed in kg/ha/yr) differ from the lower Charles an average of 47% for the aggregate coefficient for all land uses. Individual land-use adjustments vary widely, from minus 2% (high density residential) to plus 660% (low density residential).**

**The DEP indicated at the public hearing that the coefficients were adjusted, essentially to calibrate the model. Also at the public hearing, a representative of the consultant who developed the TMDL model stated that the coefficients were "back-calculated" from modeling results. Whatever method was used to result in these adjusted loading rates, the fact remains that they differ significantly from literature values, and from the values used in the Lower Charles TMDL study. The Draft TMDL narrative does not explain or justify this substantial difference.**

**If the export coefficients by land use category were set to equal the ones used for the Lower Charles, then the stormwater phosphorus loads would be 21,868 lbs, instead of the 30,974 lbs established in the Draft TMDL (bottom row of Table 14). This means that the model would then not account for approximately 9,106 lbs of annual phosphorus contribution at Watertown Dam. This raises the question whether there are other significant sources that could account for over 9,100 lbs (almost 30% of the load that the TMDL would allocate to "stormwater").**

***Response:*** *Also refer to responses to questions 21 and 23.*

*When the Lower Charles TMDL was developed a certain number of generalized assumptions were made for the watershed above the Watertown Dam, with the focus of the Lower Charles study on the areas it encompassed. Therefore, the finer definition of sources and sinks of nutrients above the Watertown Dam was left to be undertaken during the Upper/Middle Charles TMDL study with a load allocation provided for water quality at the dam which was required to be met. The Lower Charles did not look in detail at the more complex watershed issues above the Watertown Dam including the Mother Brook diversion, sediment issues, particularly in the impounded sections of the river, and a number of other factors which had to be addressed . These sources were defined in greater detail under this study and therefore as these items were defined a more detailed and accurate apportioning of the load was developed. (See below)*

*Numeric Inc. indicated that the Lower Charles TMDL export coefficient loading calculations failed to account for the phosphorus loss from the Mother Brook Diversion. The Mother Brook diversion results in a major loss of point (wastewater treatment facilities), non-point source (stormwater, interflow and groundwater) and internal bottom sediment release TP loading from the upstream watershed. The Lower Charles TMDL export coefficient loading calculations also neglected internal TP losses to bottom sediments described in the response to Q31. Had these major losses been recognized during the Lower Charles TMDL, their export coefficients would have been set higher, but still within the range of acceptable literature values, which is quite large. The literature values used in the Lower Charles TMDL should not be interpreted as site-specific or as from the center of the range of acceptable values. The export coefficients determined using the HSPF model of the Upper/Middle Charles River are much more accurate because they fall within the literature range of acceptable values and were determined using a more comprehensive modeling tool calibrated with extensive site-specific field observations of current conditions throughout the river system.*

**34. Comment/Question: This further prompts the following related questions:**

- **a. What is the rationale in general for adjusting coefficients for the land-use categories, instead of calibrating the model in an alternative fashion? For example, the TMDL could have carried a category consisting of "other sources" for both the modeling and the eventual allocation of loads.**

- **b. What is the rationale for the differential treatment of land use categories, rather than a uniform adjustment?**

- **c. If there is such a substantial difference between predicted loads from stormwater by land-use literature coefficient, and the observed load after accounting for other inputs and losses, why does the TMDL study not further explore potential reasons for this difference?**

***Response (a, b & c):*** *Please also refer to our response to Question 23.*

*(a) The aggregation of sources into gross or lumped allocations by land use is consistent with the level of data and information available for this TMDL. While there is reasonable confidence in the overall magnitude of the total nutrient loadings to the Upper/Middle Charles River from the identified major land use areas, there are only limited data available to determine the*

*magnitudes of loads from other individual sources. This uncertainty is due to several factors including the typical high variability associated with drainage system discharges, the lack of nutrient and flow monitoring data for specific stormwater sources, and because as stated above, many of the drainage system sources are influenced, to varying degrees, by illicit sewage discharges. Because of the presence of sewage in the stormwater drainage systems, it is difficult to determine how much of the nutrient loading is due to illicit sources and how much is due to stormwater runoff, therefore a method of evaluating and remediating the presence of illicit discharges was recommended as part of the implementation portion of the TMDL. The ability of carving out the amount of this under an 'other' category is limited at this time and funds would be better directed at remediation. Therefore, aggregate WLAs for stormwater discharges to the Upper/Middle Charles River were established for sources that contribute phosphorus loads. It should also be noted that there are no CSO's in the Upper/Middle section of the Charles River.*

*(b) The amount of phosphorus in storm water discharges from various land uses (excepting, agricultural, forest and open space land uses) is directly and proportionally related to the percent imperviousness of that land use; and the Charles River watershed is reflective of general trends when considering the relationship between land use and degree of imperviousness. Each land use category has a different amount of impervious land use and therefore requires differential treatment.*

*(c) The ranges in percent impervious values for various land uses can be quite large if data is extracted from a nationwide database (Schueler, 1987). However for the Charles River watershed, the percent imperviousness was directly calculated for each land use by MassGIS in 2007, providing site specific information which could be used to specify numbers for this TMDL. Subsequently, the land use numbers were then recalibrated to actual instream water quality values providing a direct link both to actual GIS land use and actual instream water quality. However, there is no substitute for further phosphorus source assessments in each of the communities as part of the implementation of this TMDL.*

*For these reasons, a comprehensive control strategy needs to be developed by each contributor as part of the implementation process to address the numerous sources of nutrients in the Charles River watershed that contribute to impairments in both the Upper and Lower Charles River. Also, the specified reductions in the TMDL will provide guidance as to the relative importance of land use categories for contributing phosphorus to the Upper/Middle Charles River.*
*Other potential loads such as septic tanks, animal waste especially from geese, illicit connections, and erosion from disturbed sites were considered, but not included for the following reasons.*

*Contamination from septic tanks usually occurs in the form of nitrogen or bacteria which are both highly mobile constituents. In contrast, phosphorus has a high retardation coefficient in soils, and is mostly confined to the leaching field. Failed septic tanks could contribute to some phosphorus loading, depending upon their location but are likely minimal in terms of overall phosphorus loading as compared to other sources.*

*Animal feces, especially from geese, could contribute to phosphorus loading and could be a significant input. However, the unknown number and types of animals, their temporal and spatial location, and poor data availability on feces quantity per animal per day, make quantifying these sources accurately almost impossible. The TMDL implicitly included these animal feces load in the land use loading rates.*

*Illicit connections could also be a significant source of phosphorus loads because they are usually continuous even during the dry periods. Again, the unknown number of connections,* *their spatial location, and the unknown load per connection, make quantifying these sources difficult. The TMDL implicitly included these illicit connection loads in the land use loading rates. Much of the stormwater concentration data and derived export coefficients in the literature rely on measured data in areas where there were existing illicit connections so the numbers are already biased high by their presence.*

*Erosion from disturbed sites could also be a significant source of phosphorus loads especially during the wet season when surface runoff is greater. Because these sites tend to be temporary in nature, we did not explicitly consider them in the HSPF model but we did model all open areas, including agriculture and mining, and as Open Land, using appropriate parameter values. Finally, the HSPF reach model was not configured to model inorganic sediment transport since the Charles is a relatively flat river and there is little inorganic sediment transport. The reach model did, however, model the transport of organic and inorganic nutrients, including phosphorus.*

*Numeric indicated that the approach used in the HSPF watershed modeling of individual land uses has been used successfully in a large number of nutrient TMDL studies across the US. A large literature database exists of model parameters used successfully, in the past, to predict the observed phosphorus export from the different land use categories. It is important to note that the observations are for total export from each land use, which includes the unknown "other sources".*

**35. Comment/Question: Does this difference warrant additional data collection, analysis, and documentation regarding potential other pollutant sources that individually or collectively contribute significant phosphorus loading, such as: See question 24.**

*Although additional data is always beneficial MassDEP believes the current modeling effort has adequately captured the major sources and their impact on water quality within the Upper/Middle Charles River.*

**a. Illicit connections or undocumented CSOs;**

***See Response to Question 24.***

**b. Groundwater contributions (e.g., from failing septic systems, or systems located in close proximity to existing receiving waters);**

*b. Failed septic systems are likely a very minor source of phosphorus to the water shed. Phosphorus mobility is highly limited in soils and usually moves only under surface breakout conditions. Therefore the input was determined to be relatively minor. However, under the implementation phase, the towns in the upper watershed could evaluate this issue and possible solutions as part of the BMP implementation plans. Although these are expected to be small they may assist in meeting the total nutrient reductions requested as part of this TMDL. A large portion of the watershed is already sewered.*

**c. populations of resident waterfowl;**

*c. Waterfowl can be a contributor to phosphorus in localized areas. Therefore, this would be more logical to deal with on a town by town, site specific basis, though controlling waterfowl in critical proximity areas and dealt with under the nonpoint source identification and reduction* *part of the TMDL projects. Although these are expected to be small they may assist in meeting the total nutrient reductions requested as part of this TMDL.*

**d. Erosion of disturbed sites;**

*d. Erosion of disturbed sites may also be a contributor to phosphorus in localized areas but should be controlled at construction sites through implementation of the Wetlands Protection Act.*

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**e. Channel erosion associated with watershed streams?**

*e. Same response as for c and d.*

**Overall Response for a-d:** *Since the Charles River TMDL uses actual instream water quality data to back calculate runoff levels, the data in this study are more site specific and therefore would be more accurate than data extracted from a database. Anytime site specific data can be used to refine less localized data acquired from a database, the more accurate the data.*

*Literature values can be extensively different from actual site-specific values as literature values are taken from nationwide databases where study sites may not be comparable. All studies begin with literature values as the first step. These literature values may be appropriate for locations in which the land uses in the study area database are similar to the land uses in the actual study area. This is the case for the Lower Charles. The Lower Charles is a more uniform urban area than the Upper/Middle Charles and using land use values from the database showed a good fit with only a small fraction of a change needed in order to match the instream values with the runoff values for the Lower Charles.*

*However, the Upper/Middle Charles has a much more complex land use and therefore required more extensive changes from the literature values in order to generate the actual instream water quality values. To have land use runoff values back-calculated from actual instream data is many orders of magnitude more accurate than using literature values from areas much different and geographically far removed from the study area.*

*Additionally, because of the complexity of the system being modeled, an adaptive management approach is proposed, which allows for a process that is implemented in stages over time, and this will allow for continued refinement of the process as it proceeds.*

**36. Comment/Question: Communities such as Franklin and Millis have been proactive in adopting land use controls that require on-site infiltration of runoff and other stormwater BMPs that would control phosphorus inputs from development. The TMDL narrative does not state how existing stormwater management practices have been accounted in the modeling. Has an effort been made to account for existing stormwater management controls in the development of the TMDL, or is the assignment of pollutant loading made strictly on the basis of impervious surface, without regard for whether existing phosphorus controls may be in place? If stormwater management practices have not been accounted for in the modeling, then we believe the TMDL may be further overstating the pollutant loading from surface runoff.**

**Response:** *The HSPF model simulates watershed and water quality conditions from 1998 to 2005 and is therefore based upon the land uses existing at that time.* **.** *The model simulates hydrology based on the observed climatic conditions during that period and simulates pollutant transport by accounting for known sources and sinks throughout the system thus resulting in a* *mass balance through each segment. Therefore, by definition, the model reflects the improvements of BMPs that were installed prior to the instream water quality sampling used to develop this TMDL. However, the percentage reductions in nutrient runoff from the BMPs installed subsequent to that time could be used to partially meet the overall reductions specified in this TMDL as credit for these newly installed BMPs*

*For any implementation completed since 2005, the benefits of the towns' efforts should be revealed during future water quality data collections. Towns should track the efforts they have completed and continue to make towards meeting water quality goals.*

**37. Comment/Question: Modeling and Supporting Data: The analytical model used to develop the TMDL includes a component for sediment nutrient release. Section 3.1.1 describes a study which characterized sediment nutrient and oxygen release rates in nine watershed impoundments. The narrative does not clearly state how this information was used.**

a. **Does the model account for sediment release from the impoundments only, or from the entire river reach within the study area?**

b. **The TMDL report (e.g., Section 4.2, page 46) notes the potential significance of nutrient release from sediment accumulated on the river bottom. If the river sediment is a significant source of nutrient cycling, how does the model account for it? The study mentions no characterization of river sediments, or how the contribution of phosphorus from these sediments is realized. Is phosphorus released directly from the river segments? Is the sediment from the rivers mobilized to the impoundments, contributing to release in the impoundments?**

c. **In Table 13, how was the "settling" component of "TP Losses" estimated? Does this include both river and impoundment components?**

d. **Does the model account for direct phosphorus input from within the river and its tributaries, as a result of sediments from the stream incision that typically occurs in developed and developing urban areas?**

**Response (37 a, b, c, d):** *See response to Questions 30 & 31.*

**38. Comment/Question:**
**The introductory paragraph of Section 4.2 states that groundwater sources of phosphorus are normally very small.**

**a. Has this statement been corroborated by field data obtained within the study area?**

**b. How do background groundwater phosphorus levels compare to the EPA criteria for phosphorus listed in Table 3?**

**c. Section 4.2 indicates that flows from functioning septic systems are normally very small. There is no discussion of failing septic systems, or of "apparent" functioning systems that may be close enough to water resources that they may**

**"short circuit." Is there sufficient evidence to eliminate septic systems as a potential phosphorus source?**

**Response:** *See previous responses to questions 30, 32, &37.*

**a. & b.** *A buildup and washoff process was used for surface water with EMCs for groundwater input on a monthly basis. The total phosphorus used for groundwater was 0.01 mg/l*

***b***. *This is directly comparable to the USEPA recommended nutrient numbers listed in Table 3, pg. 19.*

**c.** *During the modeling, slightly elevated interflow TP concentrations specified for the developed land uses were used in an attempt to account, in a general way, for some failing septic systems and other unknown subsurface sources.*

*With phosphorus, however, the question of importance is related to its mobility in soils. Phosphorus mobility is highly limited in soils and usually moves only under surface breakout conditions. Therefore the input was determined to be relatively minor.*

**39. Comment/Question: The TMDL does not appear to account for build-out conditions. At the public hearing, presenters indicated that build-out is reflected to some degree in the use of the design flows for the Waste Water Treatment Facilities, rather than current flows. Also, it was indicated that new development would be anticipated to employ stormwater management practices.**

**Using the Lower Charles export coefficients, new commercial/industrial and high density residential development would need to employ practices capable of removing 84 to 89% of the phosphorus in stormwater runoff, to achieve background levels (i.e., equivalent to the forest export coefficient). This seems unrealistic, especially in areas where infiltration systems are not feasible. We believe the TMDL does not adequately anticipate future conditions.**

**Response:** *For purposes of TMDL development you are correct that build out was in part anticipated by assessing the phosphorus loading using the design flows rather than existing flows at the POTWs. It was also assumed that current and new regulations for building requirements will control increases in future nutrient runoff. Build-out analyses have been conducted in the past by EOEEA watershed teams and these GISs based maps are available for the town to use in meeting their regulatory requirements and evaluating future build-out of their town and where to apply for example, further zoning regulations, land use and building requirements or land purchases for water quality protection. These build-out maps are located at*: [http://commpres.env.state.ma.us/content/buildout.asp](http://commpres.env.state.ma.us/content/buildout.asp)

**Comment/Question: TMDL Implementation Strategy**

**The Draft TMDL identifies two major categories subject to management for the reduction of phosphorus loads: wastewater treatment plant discharges, and stormwater. The stormwater components of load are allocated by land use category.**

**Relative to the management of the stormwater components, the TMDL suggests a rather broad and generally defined program of source controls (e.g., public education, housekeeping practices), implementation of BMPs, and illicit discharge detection and elimination (IDDE).**

**40. Comment/Question: The proposed IDDE program bears no direct relationship to the load allocation. While the number of illicit discharges might be expected to be higher in areas of greater land use intensity, we expect no direct correlation of such discharges to the areas or loadings in each land use category listed in Table 21. It is not clear how decision makers will be able to track the relative effects of removing illicit discharges in comparison to other phosphorus control efforts associated with the land-use categories.**

**Response:** *Also please refer to response number 24.*

*Although it is difficult to quantify the resulting load reductions it is clear that the elimination of illicit connections will result in a direct reduction of phosphorus to the Charles River. To quantify these reductions a method of tracking the removal of illicit discharges and estimating the relative amount and effects of removing illicit discharges would need to be developed as part of the management/implementation plan. The TMDL recommended an IDDE program since removal of illicit connections will result in phosphorus reductions however we also recognize that this recommendation may be appropriate for some communities and not others. Due to the presence of sewage in the stormwater drainage systems, it is difficult to determine how much of the nutrient loading is related to illicit sources and how much to stormwater runoff, therefore a method of evaluating and remediating the presence of illicit discharges is key to the implementation of the TMDL.*

**41. Comment/Question: The land use based allocation does not account for stormwater management practices already in place. Proactive communities with a lot of stormwater controls in place may have lower phosphorus loadings than others with little or no practices in place. It is not clear in the TMDL action plan how communities will be credited for programs in place.**

**Response:** *As previously discussed, the purpose of this TMDL is to identify sources and loads of phosphorus to the Charles River system, their impact on water quality, and to define the load reductions necessary to meet the state Water Quality Standards. The TMDL also attempts to provide general guidelines for implementation but it does not attempt to identify which activities should and should not receive credit nor how much credit should be granted. The reason it did not attempt this is because the amount of reduction is highly site specific and depends on many factors including, but not limited to: 1) the type of BMP (including whether it is structural or non-structural), 2) the location, 3) the effectiveness of the BMP to remove phosphorus and 4) how well the BMP is maintained over time. The water quality conditions observed during the development of this TMDL should reflect the reductions achieved by BMP implementation prior to TMDL development however this is highly dependent on the factors identified above especially whether or not the BMP has been well maintained. Clearly, any new BMPs that have been applied subsequent to the development of this TMDL should receive credit to partially meet the overall reductions specified in this TMDL but the method for assigning and tracking that credit was beyond the scope of the TMDL and should be evaluated through other processes.*

*The USEPA is presently in the process of evaluating this issue and has recently developed, and issued for public comment, a pilot program permit using their Clean Water Act Residual Designation Authority (RDA) for storwmater discharged from the Towns of Bellingham,* *Franklin, and Milford. That permit has proposed alternative ways to provide credit for both structural and non-structural BMP applications. For further information please refer to the EPA web site at:* *http://www.epa.gov/region1/npdes/charlesriver/*

**42. Comment/Question: The EPA has issued a Residual Designation for several communities in the Upper/Middle Charles Watershed, including Franklin. The Residual Designation will impose stormwater controls on properties with impervious surfaces of 2 acres or more, with the objective of achieving significant reductions in phosphorus. The Draft TMDL does not reconcile the phosphorus load allocations established in that Residual Designation with the load allocations proposed by the TMDL. Further, the Draft TMDL does not indicate how the communities affected by this designation will be credited for actions taken under the Residual Designation, or for actions taken previously by the communities to require developments to incorporate BMPs (such as infiltration practices) that control phosphorus.**

**Response:** *The TMDL establishes the overall reductions based on water quality conditions prior to 2005. As such it was not the Departments intent to reconcile the two studies. Please see our response to question number 41 above for more discussion on this subject.*

**43. Comment/Question: A major part of the effort to address contribution of pollutants from surface water runoff associated with individual land uses will be the application of non-structural and structural Best Management Practices (BMPs). The EPA has developed performance curves for a few of the universe of structural BMPs available (*Stormwater Best Management Practices Performance Analysis,* December 2008). This document can be used to estimate the effectiveness of some BMPs for controlling phosphorus.**

a. **Will this document be supplemented with data on other structural BMPs discussed in the Massachusetts Stormwater Handbook?**
b. **Will guidance be available for the performance efficacy of non-structural practices (e.g., street sweeping, fertilizer application, leaf litter control)?**

**Response:** *See Response to Question 42.*

*Presently, as noted, the Stormwater Best Management Practices Performance Analysis is one tool which the agencies have made available for estimating performance for different types of structural BMPs. This report is located at: http://www.epa.gov/region1/npdes/stormwater/assets/pdfs/BMP-Performance-Analysis-Report.pdf. At the present time there are no plans to supplement this document with other structural BMPs however this might be possible if future funding becomes available.*

*Additional resources and guidance are however available from several other sources for both structural and non-structural BMP applications. Two of the sources used by many stormwater practitioners include the Center for Watershed Protection in Maryland and EPA.*

*The Center for Watershed Protection's (CWP) mission is, in part, to advance, synthesize and widely disseminate watershed science by translating this knowledge into practical tools and techniques. They use a collaborative approach and integrate multiple disciplines, jurisdictions, and issues into a comprehensive watershed approach to assist in the development and implementation of the most effective stormwater and watershed management practices. Among* *other guidance, the CWP maintains a "Stormwater Manager's Resource Center" that provides various tools for assessing and analyzing stormwater BMP performance. They also provide reference and guidance materials and performance criteria for various BMP applications and technologies. The Stormwater Manager's Resource Center can be found on the web at: http://www.stormwatercenter.net/.*

*The USEPA also provides resources on BMP design and performance. One of those resources, which is cosponsored by EPA, is the International Stormwater BMP Database. This database evaluates over 300 BMP studies, and provides performance analysis results, tools for use in BMP performance studies, monitoring guidance and other study-related information and publications. The overall purpose of the project is to provide scientifically sound information to improve the design, selection and performance of BMPs. This site can be found at http://www.bmpdatabase.org/BMPPerformance.htm.*

*The USEPA also provides additional guidance and web links to various studies related to stormwater. These can be found on at: http://cfpub.epa.gov/npdes/stormwatermonth.cfm.*

*Although there is no one specific source of performance data associated with nonstructural BMPs there are many individual studies that can be reviewed to provide such information. For instance, a detailed discussion of the removal efficiencies of different types of street sweepers with additional references can be found in the Lower Charles River Phosphorus TMDL http://www.mass.gov/dep/water/resources/tmdls.htm#charles.*

*Most of the pollutant load in stormwater is associated with very small particle sizes (Pitt et al. 2004). Investigations conducted by Sartor and Boyd (in Walker et al. 1999) on street dirt characteristics have shown that most particulates found on street surfaces are in the fractions of sand and gravel, while only approximately 6 percent of particles are in the silt and clay soil size (i.e., < 63 microns). However, it is the silt and clay size particles that were found to contain over half of the phosphorus and 25 percent of other pollutants (Walker et al. 1999).*

*With respect to nutrients, the collection of the fine-sized particles from paved surfaces by high-efficiency sweeping has the benefit of removing these pollutants before they become incorporated into stormwater.*

*It is likely that mechanical broom type sweepers are most commonly used in the watershed at present. These types of sweepers are capable of collecting coarse-sized sediments and litter, but the high-efficiency sweepers are more efficient at collecting the smaller particle sizes that are most associated with nutrients. Furthermore, mechanical broom sweepers might make the finer particles and associated phosphorus more available for washoff during rain events. Studies by Pitt and Sutherland (in Walker et al. 1999) indicated that a significant portion of the larger dirt particle sizes picked up by these sweepers are not easily transported by rainfall and that removal of these particles tends to expose the smaller sheltered particles for transport. The results of monitoring studies conducted in the late 1970s and early 1980s to evaluate the effectiveness of mechanical broom sweepers did not find them to be very effective in reducing stormwater pollutant loads (Center for Watershed Protection 1999).*

*Recently an additional investigation of the relative performance of two types of street sweepers (mechanical broom and high-efficiency vacuum type sweepers) was conducted by the USGS in conjunction with the City of New Bedford, Massachusetts (Residential Street-Dirt Accumulation Rates and Chemical Composition, and Removal Efficiencies by Mechanical-and Vacuum-Type Sweepers, New Bedford, Massachusetts, 2003–04, Breault et al. 2005). The results of four* *sweeping experiments (two for each type of sweeper) clearly show that the vacuum sweeper was about three times more efficient than the mechanical broom sweeper. With respect to picking up silt and clay sized particles, the vacuum sweeper was three and six times more efficient than the mechanical broom sweeper. More detailed information on this study can be found at USGS http://pubs.usgs.gov/sir/2005/5184/.*

*There are also many other studies developed to assess the performance of non-structural BMPs. Many can be identified and accessed by searching the web for the "nonstructural BMP performance data". For example, one report which could be referred to is the 'Residential Street-Dirt Accumulation Rates and Chemical Composition, and Removal Efficiencies by mechanical and Vacuum-Type Sweepers' New Bedford, Massachusetts, 2004- http://pubs.usgs.gov/sir/2005/5184/.*

*Finally, the USEPA is presently in the process of evaluating this issue and has recently developed, and issued for public comment, a pilot program permit using their Clean Water Act Residual Designation Authority (RDA) for storwmater discharged from the Towns of Bellingham, Franklin, and Milford. That permit has proposed alternative ways to provide credit for both structural and non-structural BMP applications. For further information please refer to the EPA web site at http://www.epa.gov/region1/npdes/charlesriver/*

**44. Comment/Question: Franklin and Millis have been proactive in implementing stormwater management practices, both through land use controls and through construction of municipal facilities. Millis Stormwater Regulations first went into effect in 1994, and Franklin has had such regulations in place since about 1999; both communities have amended the regulations since. As the TMDL proposes continued reliance on similar practices, and given that stormwater controls have been aggressively pursued at both the local and state levels, at least since the implementation of the DEP Stormwater Management Policy in 1996, has the water quality data for the Charles River been examined for evidence of the impacts of these controls? Is there water quality evidence based on actions to date, which support the TMDL's recommendation for further investment in these measures?**

**Response:** *Water quality studies over the last decade have shown continual improvement in the river system with implementation of both stricter WWTF effluent limits and implementation of watershed controls. Since these took place concurrently it is difficult to separate out site specific controls and their individual effect on in-stream quality. The agencies therefore rely on the extensive literature available and independent and governmental studies which evaluate ranges of potential improvements instream with each remedial action. The true measure however is water quality data collection in the river itself over time.*

*In order to include credit for new additional work, verification of post-construction BMP design and effectiveness and O&M will be necessary to allocate credit.*

**45. Comment/Question: The TMDL allocation by land use does not provide a useful means to measure progress of attainment of the TMDL objective. Various courses of action are suggested, and ways to measure the action are suggested, but no means for measuring results correlated with such actions. Level of effort can be documented (e.g., measuring pounds of street sweepings) but it is not clear how decision makers will measure *results* (actual reductions in phosphorus in the river) in a manner that can be correlated with *specific practices*.**

c. **How will anyone know which, if any, actions are effective in reducing phosphorus loading? How will municipal decision makers know that resources they spend to address the TMDL are achieving real results, let alone cost-effective ones?**

d. **How will decision makers at the state and federal level be able to credit communities for attaining TMDL objectives?**

e. **The proposed TMDL action strategy seems to have no specified end point. How will any community know when it has completed its share of the tasks needed to address the TMDL?**

**Response:** *Final evaluation of effectiveness will be determined through measuring instream results to see if water quality standards and guidelines are met. Development of a decision matrix for evaluating and prioritizing potential watershed improvements based upon previously tried methods as documented in watershed improvement manuals and the literature will be key to focusing on the most cost effective solutions. Each source should be assigned a numerical ranking based on consideration of the magnitude of the phosphorus loading from the source and the likely nature of the control remedy. The ranking should indicate the priority in which sources will be addressed. Implementation should be followed by tracking and documenting level of effort, as the effects instream are cumulative and so it would not be logical to try to expend money to measure the site specific improvements of each implementation item. Periodic water quality studies will show when sections of the river are responding and therefore, which watershed areas are meeting required reductions. The HSPF model developed as part of this project will be available to provide a further tool for the evaluation of instream improvements as related to watershed areas. Pilot projects could also be developed for water quality monitoring to determine site specific effectiveness of various methods for removing phosphorus. Instream monitoring programs, if considered, should be designed to capture spatial, seasonal and climatic variability.*

*Since there is no timeline for an end to development and watershed changes it is anticipated that this effort will continue in an adaptive manner. The total phosphorus allocations presented in the TMDL represent reductions that will require substantial time and financial commitment to be attained. Achieving the goals of the Upper Charles River nutrient TMDL will require an iterative process that sets realistic implementation goals and schedules that are adjusted as warranted based on ongoing monitoring and assessment of control activities.*

**46. Comment/Question: The implementation strategy includes the collection of source monitoring data to better target controls for source areas. The TMDL should clearly indicate that the collection of monitoring data should be a watershed effort initiated by DEP and local watershed groups, rather than individual communities, to promote the consistent collection of data and to target areas that would help enhance future modeling runs by DEP.**

**Response:** *MassDEP is of the opinion that there are two primary monitoring activities associated with implementation activities. Those include ambient monitoring generally conducted by MassDEP in concert with watershed associations and source monitoring, which would be conducted to prioritize which systems should be addressed and the effectiveness of controls.*

*This Plan recommends that owners of stormwater drainage system discharges to the Charles River undertake an iterative approach of managing their discharges. Briefly, this approach would involve adopting initial controls to reduce phosphorus while at the same time collecting information that will better characterize their sources so that subsequent control activities can be prioritized to achieve the greatest phosphorus load reductions in the most efficient and cost effective manner.*

**47. Comment/Question: The implementation strategy includes measures that are duplicative of the requirements that Phase II communities must meet under their MS4 permit coverage. It is not clear that compliance with the MS4 permit will be considered compliance with the TMDL. We request that the TMDL action plan clearly state that the management measures are integral with the communities' MS4 program, and that the TMDL does <u>not</u> require a separate program encompassing the management measures outlined in the Draft document.**

**Response:** *The intent of the TMDL is not to create a duplication of work but rather to provide an overall framework that discusses what the problems are in the watershed, what the causes of those problems are, and what methods could be employed to address those problems. One of the most important methods to improve overall watershed water quality is the MS4 Permit and the requirements set forth in that permit. Utilizing the tool of the MS4 Phase II Permit to address the sources of water quality impairments in the river is primary to meeting stormwater reductions. The MS4 Permit itself includes a requirement to meet the water quality goals set forth in any approved TMDLs. This TMDL sets forth those goals. The TMDL is intended to also cover other entities or areas not presently covered under the MS4 permit program.*

*The purpose of the TMDL plan is to outline an adaptive management process that identifies immediate implementation activities, as well as a framework for making continued progress in reducing pollutant loads to the Upper Charles River over the long term.*

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## G. CAMP DRESSER MCKEE COMMENT LETTER
**On behalf of the Charles River Pollution Control District**

**48. Statement: Load Allocation: The draft TMDL establishes waste load allocations for a variety of sources to meet the TMDL target. Stormwater represents approximately 75 % of the controllable phosphorus load on the system, with treatment plants reflecting the remaining 25 %. It appears that the wasteload allocations were based on assumed achievable reductions in phosphorus loadings from stormwater sources, as well as application of limit of technology treatment at wastewater treatment plants. As compared to the baseline wasteload allocations, the stormwater sources are required to reduce their loads by some 51 % and the wastewater treatment plants by 62 %.**

**We believe that the waste load allocation should reflect the relative contribution of the various sources of phosphorus, rather than the ability of those sources to achieve preset reductions or level. Thus, if the watershed needs an overall reduction of x %, then all sources should be required to achieve reductions of that same amount. Sources that cannot achieve the necessary reduction through control of their own sources should be required to obtain offsets from elsewhere to achieve the necessary reductions. This can be accomplished through trading programs, such as that implemented by the State of**

**Connecticut, or offset programs such as those that DEP suggests for water and sewer banks. This would be more appropriate for the following reasons:**

**The method used in the draft TMDL effectively subsidizes and enables land use practices that are known to be significant sources of phosphorus. In the TMDL, low density residential land use contributes almost 5,000 kg/yr of phosphorus, and is provided a waste load allocation of 45 % reduction. Since the watershed requires an aggregate reduction of more than 45 %, the draft TMDL effectively enables low density development by requiring it to bear a proportionately lower share of the reduction.**

**The method used in the draft TMDL is inequitable because it forces some classes of users to do more, in order that others can do less. For example, in contrast to low density residential land uses, high density and commercial land uses and POTW's are expected to reduce phosphorus loads by 65 %. It is not clear why these classes of user should bear a proportionally larger share of the remediation effort.**

***Response:*** *Point and non-point source trades are not a 1 to 1 proposition as the impact from the point sources is greater than the non-point sources during the summer months when instream flows and runoff are low. The TMDL, however, does not exclude the potential for future trading options or focus on the most cost effective solutions for achieving water quality improvements in the watershed , but since no program or structure is in place today, the TMDL established reductions are based on what was considered to be technologically achievable and still meet water quality standards. Regardless of the approach chosen communities still need to move forward with developing a decision matrix for selection and implementing watershed improvements. Reductions at point sources, as well as non-point sources, need to move forward concurrently and therefore there would be no need to delay approval or implementation of the TMDL. Development and implementation of a trading program, although possible, would take considerable time and effort possibly delaying implementation of the TMDL.*

*For residential versus other land use types: The final report for the EPA-funded BMP Decision Support System (DSS) assessment for the Upper Charles was released in January, 2009. Essentially, the results show that there can be significant cost savings associated with using optimization techniques to identify the most cost effective BMP solutions to meet the phosphorus TMDL targets. This can be done by systematically considering the many important factors that affect BMP selection such as site conditions, source areas, space limitations, and widely varying BMP pollutant removal efficiencies.*

*Additionally, low density residential has significantly lower phosphorus export coefficients along with significantly lower impervious areas, than high density residential, commercial, and industrial, etc.*

**49. Comment/Question: Additionally, we do not understand why state owned facilities are given more lenient limits in this analysis. Both MCI-Norfolk and Mass Development are given higher wintertime phosphorus limits than other pubic treatment plants. We would have expected that state agencies would receive the same limit as other POTW's, and would lead by example.**

**Response:** *WWTF limits are given based upon the results of effectiveness of improvements instream as determined by the output of the HSPF model results. Initially, it was assumed that reductions at the minor POTWs in the watershed would have minimal effect on water quality in the Charles River. However, in response to this comment and others received at the public* *meeting and in writing during the public comment period, MassDEP and USEPA have conducted further evaluations of the selected scenario. After careful consideration of all comments and in consideration that the receiving water (namely the Stop River) is also included on the state Integrated List of Waters, the agencies re-evaluated the impacts and potential benefits of additional reductions to those POTWs as well (now identified in the report as scenario 9D). The results indicate that further reductions to the minor facilities would not only help to address water quality impacts on the Stop River as well as the Charles River downstream, but also would be necessary to ensure compliance with the load allocation of 15,109 kg/yr set by the lower Charles TMDL at the Watertown Dam. As a result, the TMDL has been revised to now require the minor facilities to achieve the same effluent limits as the majors (0.1 mg/l TP effluent limit in the summer and 0.3 mg/l effluent limit in the winter). By requiring these reductions the total phosphorus load at the Watertown Dam would be 14, 968 kg/yr which is less that the 15, 109 kg/yr required as part of the lower Charles TMDL.*

**50. Comment/Question: Finally we should point out that there are potential contradictions between the waste load allocations contained in this TMDL and the waste load allocations contained in the Lower Charles TMDL. The WLAs specifically listed for the POTWs in table 5-7 of the Lower Charles TMDL differ from the WLAs in the Upper Charles TMDL by a factor of almost 3. The differences have nothing to do with the total assimilative capacity of the river, since the total loads are the same. Rather, the discrepancies result from different and inconsistent policy choices about who should bear the burden of compliance. Where these two TMDLs are based upon the same water quality criteria and same total load for the same river, the inconsistency is arbitrary and capricious.**

**Response:** *The WWTF limits in the Lower Charles TMDL are based upon meeting not only the load requirements at the Watertown Dam but also the water quality requirements in the Lower Charles. The additional and lower WWTF effluent limits in the Upper/Middle Charles TMDL are based upon meeting additional instream water quality standards in the upper and middle reaches of the Charles River.*

**51. Comment/Question: Moreover, if permits are issued to reflect the site-specific limits calculated in the two TMDLs, stormwater dischargers may be held to the implicit limits of the lower Charles TMDL, while wastewater Dischargers would be held to the upper Charles TMDL. The result would be reduction of phosphorus below the level needed to maintain water quality. In that case, the new phosphorus limits would over-regulate, that is, they would be unwarranted and unnecessary as a scientific matter.**

**Response:** *The lower limits for the WWTFs are necessary to meet instream water quality standards in the upper and middle reaches of the river. These limits maintain, but do not reduce the loads at the Watertown Dam proposed in the Lower Charles TMDL. As noted above the lower Charles TMDL evaluation also didn't consider future treatment plant loads based on their design flows thus further reductions were needed to address future anticipated flows and to account for other sources and sinks in the upper/middle Charles sections of the river above the Watertown Dam.*

**52. Comment/Question: TMDL metrics: The TMDL uses a variety of metrics to assess the efficacy of various control strategies. These include pH, Dissolved Oxygen (both concentration and percent saturation), various chlorophyll a concentrations (peak and seasonal mean concentrations) and Total Phosphorus concentrations. Dissolved Oxygen and pH are included in the Massachusetts Water Quality Standards (314 CMR 4), and the chlorophyll a metrics as used in this TMDL are designed to protect designated uses and**

**aesthetics, and as a measure of cultural eutrophication. Since TMDL's are intended to establish limits to meet water quality standards, these are appropriate to include as metrics in the TMDL document.**

**However, total phosphorus concentrations by themselves are inappropriate to use as metrics in the TMDL. As the TMDL document states, because the relationship between nutrient concentrations and environmental responses is complex and varied, there are no numeric standards for phosphorus in Massachusetts, but rather narrative standards designed to prevent cultural eutrophication and protect designated uses. A simple perusal of Table 18 of the TMDL clearly makes the point that concentration is an inadequate predictor of water quality compliance. Since the other metrics used in the TMDL are already effective measures of compliance with water quality standards, it is unnecessary and inappropriate to include total phosphorus as a TMDL metric. To do otherwise effectively turns the concentration values used into water quality standards. While we understand that the weight of evidence approaches needs to be applied in various instances, the approach needs to be rationally and logically grounded. Since the same water quality standards are being applied to the same river, the TMDLs for the upper and lower Charles River should use a consistent methodology. To do otherwise would be arbitrary and capricious.**

**Response***: It is not the Departments intent to regulate in-stream phosphorus concentration. It is the Department's intent to use a weight of evidence approach because of the issues identified above. Also, the Department disagrees that evaluating phosphorus in the TMDL effectively turns the values into water quality standards. WQS would need to go through another formal review process to establish new standards. The standards clearly state in 314 CMR 4.05 (5), "unless naturally occurring, all surface waters shall be free from nutrients in the concentrations that would cause or contribute to impairment of existing of designated uses." As such it is appropriate to include them in this evaluation. Total phosphorus was included as one of the metrics in the weight-of-evidence evaluation conducted on the cause and effect of eutrophication in the Charles River. Literature studies show the direct relationship between phosphorus and enhanced growth with corresponding links to low and widely fluctuating dissolved oxygen levels instream, which has a numeric standard. To eliminate phosphorus from the weight-of-evidence scenario comparison would not be, in our opinion logical.*

**53. Comment/Question: Recognition of Uncertainty in the Analysis: All models are inherently inaccurate; the innumerable variables that are a work in the real world, can only be approximated in the modeled world. For that reason, we believe that it is important to acknowledge these uncertainties in applying the model. We note, from the calibration report, for example, that the mean error for various parameters varies from 5 % for temperature in the mainstem, to over 100 % for chlorophyll a in the mainstem. We generally agree with the conclusion of the calibration report that**

> **"…the water quality calibration appears to be adequate given the complexity of the 70-mile long river and the sparse temporal data available at some of the reaches in the Middle Charles. The predicted constituents visually fit the observed values and the calculated errors, even somewhat high, are still within the acceptable published limits…"**

**This does not, however, mean that we should ignore uncertainty when applying the model. We should be careful about attributing significance to small differences between results, as we know that the model is likely inadequate to truly resolve these small differences. Among**

**other things, this leads us to ask for some greater presentation of scenario results, as described further below.**

**Response**: *MassDEP agrees that all models have a certain level of inherent uncertainty. For this reason, the agencies look at the relative improvements instream from comparing one scenario to another. This scenario to scenario comparison along with a weight-of evidence approach has proven to be the most effective method of dealing with model uncertainty. Additionally, absolute numbers with respect to meeting water quality standards are used but only after an extensive evaluation through comparison with average, minimum, maximum and 90th and 95th percentiles together with how these cause and effect variables are linked.*

*In addition, a margin of safety was applied during the TMDL calculations in order to account for the levels of modeling uncertainty (mean error) found comparing modeling results and field observations. Also, a weight of evidence approach was taken when interpreting the modeling results for the various scenarios.*

**54. Comment/Question: TMDL Implementation: The section on TMDL implementation discusses the strategy for moving forward to achieve water quality standards in the River. It properly characterizes the difficult task facing the implementation of the stormwater and POTW phosphorus controls. It acknowledges that additional efforts on the part of the District will be necessary to meet the ultimate permit limits, and that the difficulty in reaching the stormwater wasteload allocations is a reason for implementing phased limits at the District's facilities.**

**We should point out, however, that it is the summertime limit of 0.1 mg/l that will likely require additional capital investments on the part of the District, not the winter time limit of 0.3 as the report indicates.**

**Using the basic logic as set out in the Draft TMDL, we suggest that our initial permit be set at 0.2 mg/l in the summer and 0.5 mg/l in the winter. These limits represent almost 50% of the reduction sought in the TMDL. At the next permit cycle – 5 years hence, an assessment can be made of the progress moving forward with the stormwater implementation, and the need for further adjustment in our limit can be assessed. The five years of staged implementation will also provide an opportunity for us to consider the benefits of changing treatment technologies that are emerging to respond to ever more stringent nutrient control strategies.**

**Response**: *The issue noted above would better be discussed during the permitting process rather than the TMDL process since any decision is highly dependent upon the individual circumstances at each facility. With that said however delaying the implementation of the effluent limits for up to 10 years could have a significant detrimental effect on the river as more nutrients are introduced into the river over a longer period of time. Fate and transport of those nutrients may produce additional effects that would require changes to these proposed limits which could be even more stringent should the implementation be delayed.*

**55. Comment/Question: Scenarios: The Draft TMDL contains a scenario described as "natural conditions". Yet, that scenario includes the several dams that exist in the watershed. We suggest that this alternative be re-titled to "Pre-colonial land use" or similar, since it is not natural. Also, because dams play an important role in the water quality of the river by increasing the residence time in impoundments, and providing enhanced opportunity for algal growth, the TMDL should evaluate dam removal as a**

**strategy for restoring water quality in the Charles. While we understand that dam removal is fraught with multiple problems that cannot be addressed in the context of this study, the contribution of these dams to water quality problems should be evaluated in this study.**

**Response:** *The replacement name 'all forested' has now replaced r the scenario name 'natural conditions' in the final report to recognize the presence of the dams in the river system.*

*The question of dam removal is complex. Issues of contaminated sediment movement, impact on adjacent wetlands and loss of habitat as well as flooding issues in an urban environment all compound to provide a potentially difficult and costly project to analyze for instream improvements. A similar study was recently conducted on the Assabet River at a cost of approximately 1 million dollars. Although the Department is not opposed to such an evaluation it is well beyond the present scope of work and budget and would significantly delay implementation efforts.*

**56. Comment/Question: Scenario Results: The document presents longitudinal plots of various metrics for scenario 9 in figures 9 through 12. We find these most informative, because they graphically represent the location, extent and magnitude of the excursions from the metric, which cannot be fully captured in the tabular format of Table 18. For this reason, the report should include an appendix containing longitudinal plots for scenarios 1 though 11. All scenarios for a single metric should be plotted on the same page, to the extent feasible.**

**Response***:* *Plots for some of the more important parameters for the last several scenarios have been added in Appendix A2 for comparison. The first several scenarios were not included since all scenarios that did not include stormwater reductions clearly did not meet the loads at the Watertown Dam.*

**57. Comment/Question: Seasonal Evaluations: We note that a 0.2 mg/l limit on Total Phosphorus applied year round to the District's effluent essentially meets the waste load allocation as presented in Table 21 (1,483 kg/yr WLA vs. 1,495 kg/year computed at 0.2). Thus, the summer limit of 0.1 mg/l is driven by conditions in the upper watershed. In addition to the scenario plots requested above, it would be useful to have time series plots for 2002 at the critical reaches that compel the lower limit. All scenarios for a single metric should be plotted on the same page, to the extent feasible.**

**Response:** *Meeting the load allocation at the Watertown Dam is only one part of the requirement. Reaching and maintaining instream water quality in the Upper and middle portion of the watershed is also a regulatory requirement. A total phosphorus limit of 0.1 mg/l in the summer was necessary to maintain instream water quality.*

*Additional graphs have been added to the report for comparison.*

**Detailed Questions**

**58. Comment/Question: Populatic Pond and CRPCD: Table 16 suggests that the CRPCD discharge is the cause of low DO in Populatic Pond. Is there a reference (and corroborating information) to support this? Is the model properly configured to account for this, and do the simulations validate the statement?**

**Response:** *HSPF cannot simulate reverse flow within the river. However, this portion of the river is relatively flat and it is possible for a portion of the plant discharge to back-up or mix into Populatic Pond, during low river flow conditions. This backflow condition as well as an upstream gradient in algal levels has been observed between the plant discharge and Populatic Pond, suggesting that this phenomenon occurs.*

**59. Comment/Question: Simulation Time Period: At the bottom of page 55 there is a discussion concerning the time period used to simulate various water quality scenarios and responses. The paragraph concludes that the April through October, 2002 period was appropriate for scenario evaluations. Do we take this to mean that except where otherwise noted, the scenario results presented are for that period in 2002? In particular, the longitudinal plots in figures 9 through 12.**

**Response**: *Yes. All simulations and plots were for April – October, 2002.*

**60. Comment/Question: Figure 13: Could you explain how the curves in Figure 13 were developed?**

**Response**: *Figure 13 is a frequency distribution curve of the loads at the Watertown Dam. Daily output of total phosphorus loads for the period 98-02 were ranked and plotted as a percentage. Values for Scenario 9 were output and then adjusted for Scenario 9c loads. The figure shows that there is little difference between the high flow and the low flow curves when comparing current to TMDL frequency distribution loads, and therefore the TMDL reductions must be implemented under all flow conditions.*

**61. Comment/Question: Residence Time: It would be useful to have some graphic representing residence time in the River under various high and low flow conditions. Similar information was presented in the Lower Charles TMDL Final Report.**

**Response:** *Several runs of the HSPF model were made to investigate the propagation of a slug of conservative tracer injected at the Milford Wastewater Treatment Facility discharge (Reach 15), during 2002 and during low flow conditions in August of 2005. Results suggested that during low flow, the slug took several weeks to reach the Watertown Dam. Flow information from these studies and HSPF runs appear in the following graphs. The first two graphs show the flows and the next four graphs show the peaks for movement of dye during 2002 and 2005.*

*The two flow graphs, one for 2002 and one for 2005, show both low and high flow conditions from June through October for these years. In the Lower Charles TMDL this type of information was provided to show that the lower section of the river acts more like a lake than a river system, as compared with the Upper/Middle Charles which has a combination of both riverine stretches and ponded areas.*

*Note that in the graphs, R16 to R113 represent Charles River reaches in the water quality model from below the Milford WWTF (R16) to the Watertown Dam (R113).*

*The time of travel results developed from the 2002 to 2005 dye injection studies are presented in a table after the graphs.*

Figures 1 and 2 represent the 7-day average stream flows for the summers of 2002 and 2005.

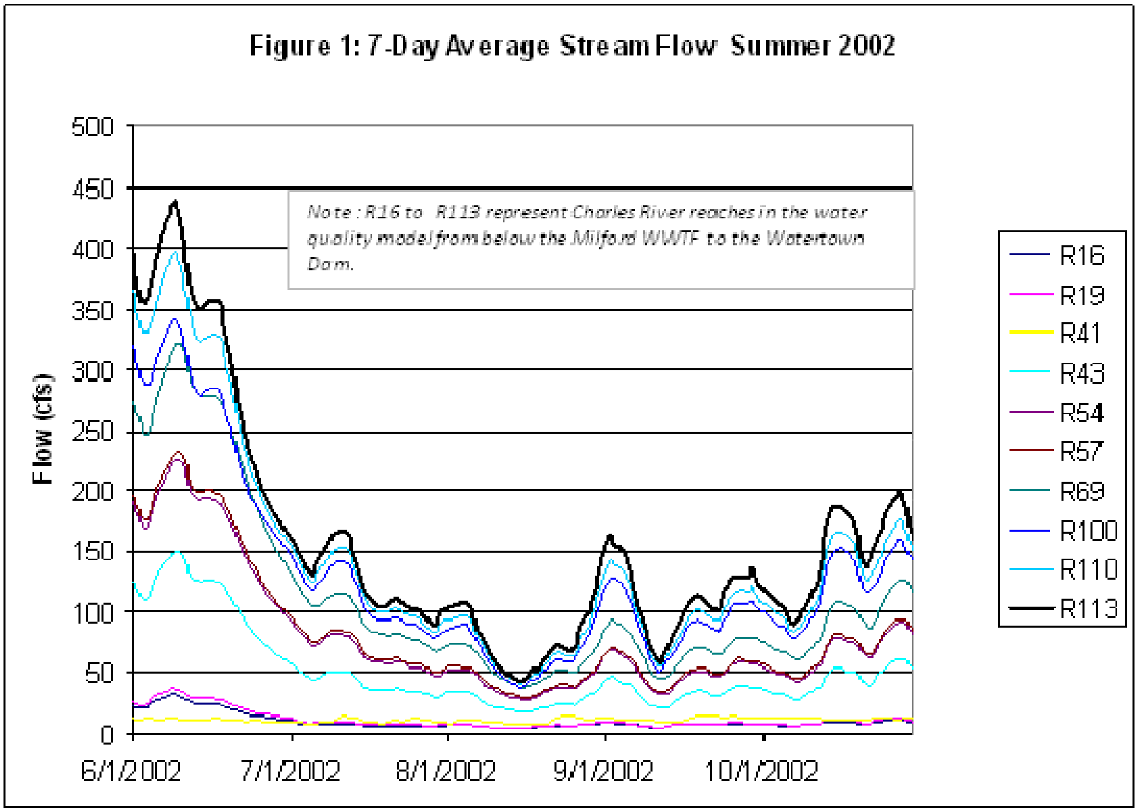


Figure 1: 7-Day Average Stream Flow Summer 2002

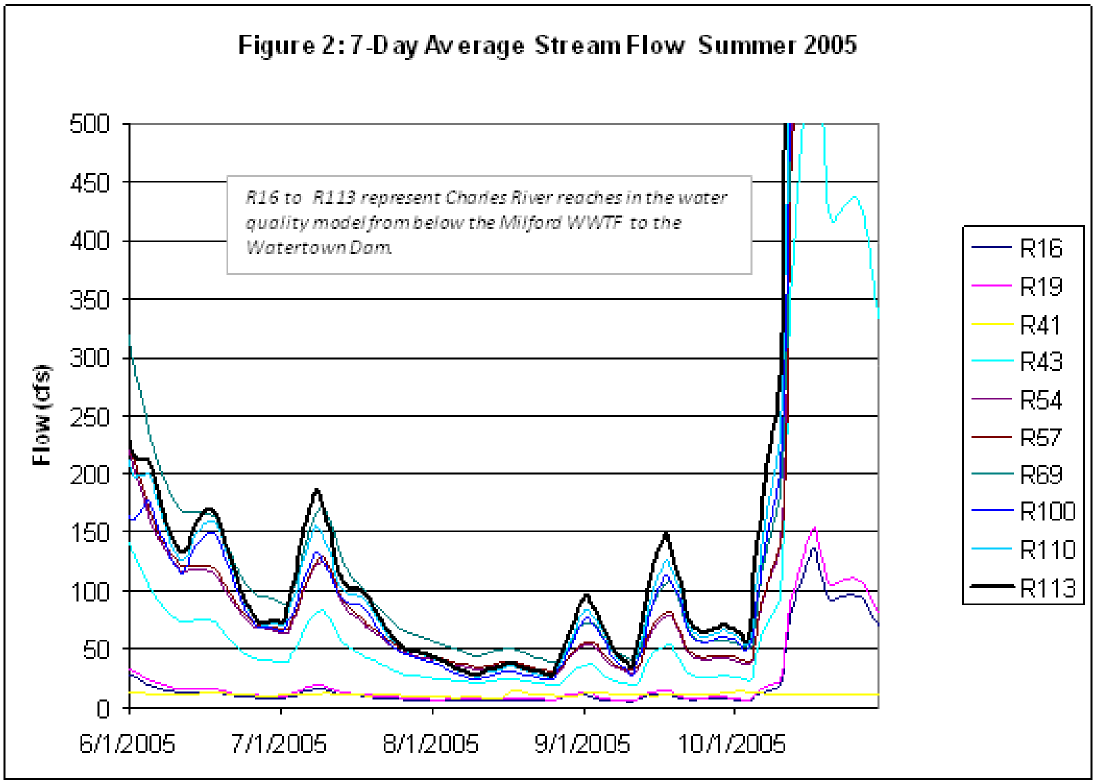
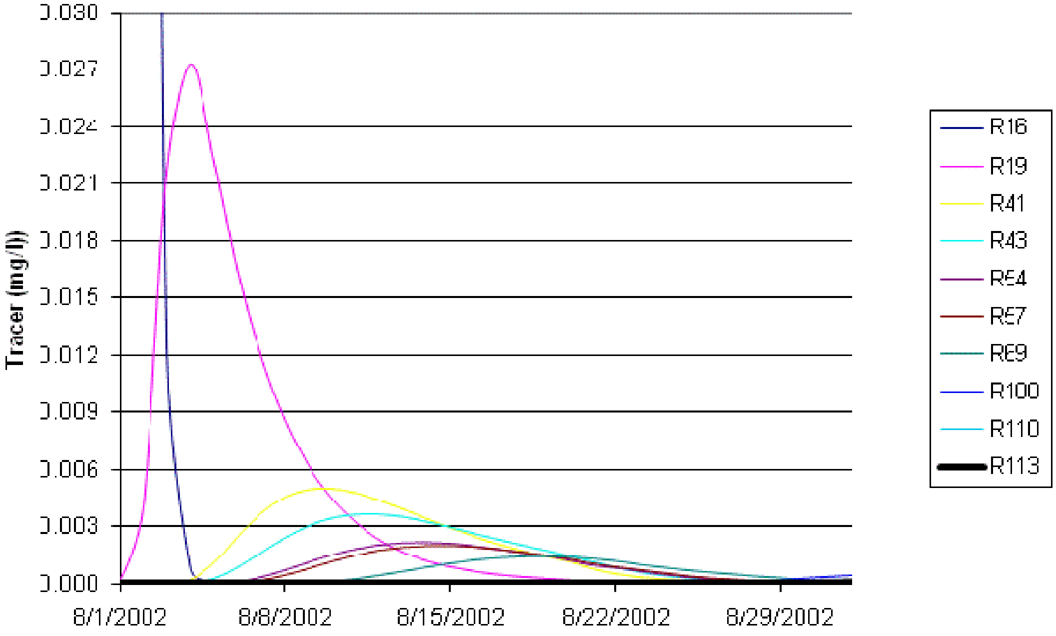
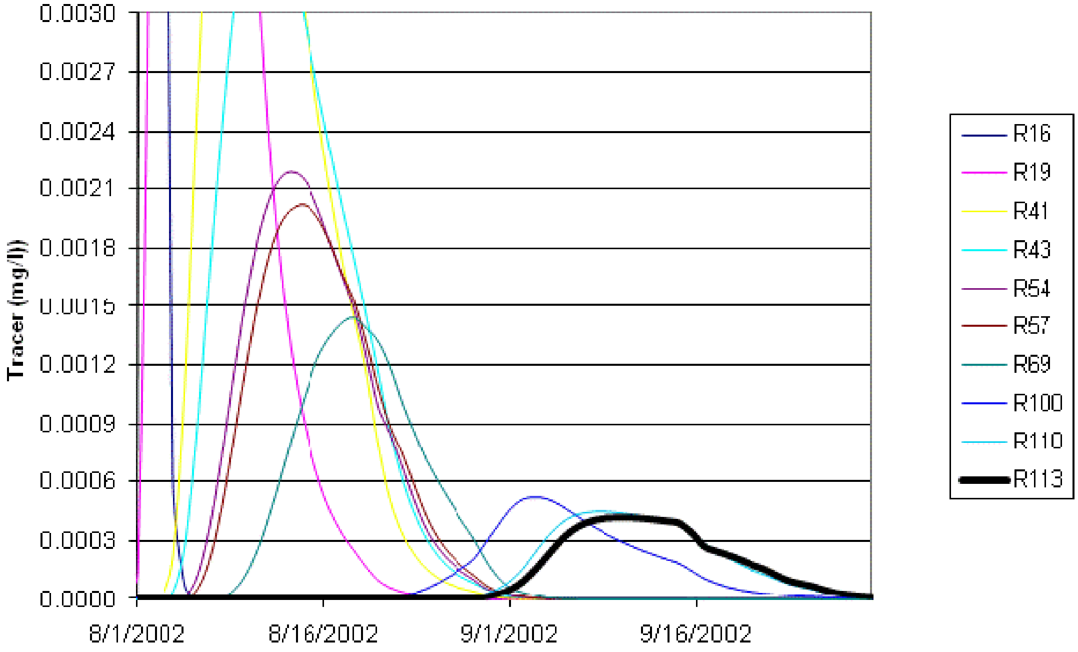


Figure 2: 7-Day Average Stream Flow Summer 2005

## Figure 3 - Travel-Times for Tracer Injected at Milford POTW
August 1, 2002



## Figure 4 - Travel-Times for Tracer Injected at Milford POTW
August 1, 2002 (higher resolution)



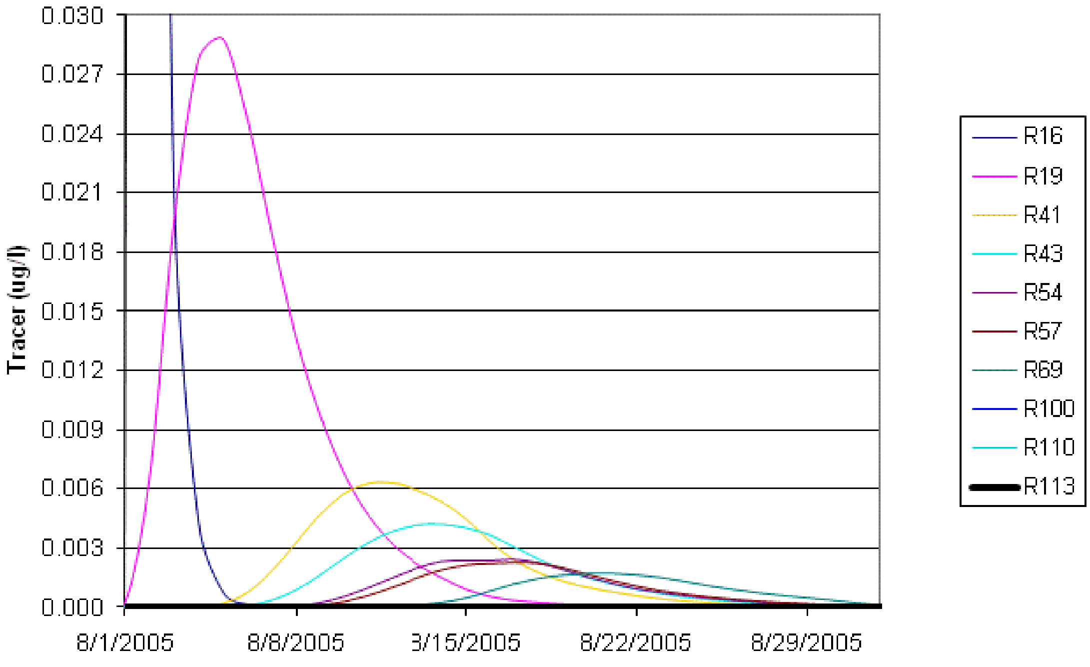


**Figure 5 - Travel-Times for Tracer Injected at Milford POTW**
**August 1, 2005**

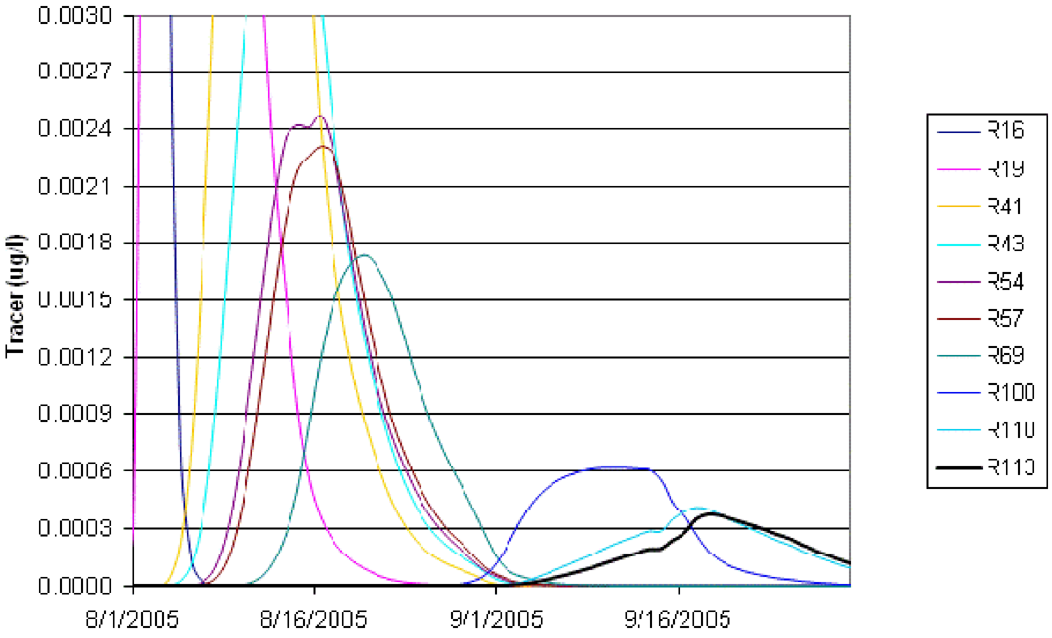


Figure 6 - Travel-Times for Tracer Injected at Milford POTW
August 1, 2005 (higher resolution)

### Table 1 Time of Travel Results from 2002 and 2005 Numeric Dye Studies
### Low Flow Time Frame

| | | 2002 | 2005 |
|---|---|---|---|
| Reach | | TOT (days) | TOT (days) |
| 15 | Milford WWTF injection site | | |
| 16 | Downstream Milford WWTP | 1 | 1 |
| 19 | Outlet Box Pond | 3 | 4 |
| 41 | Populatic Pond | 9 | 11 |
| 43 | Below CRPCD | 11 | 13 |
| 54 | Above Medfield WWTF | 13 | 15 |
| 57 | Below Medfield WWTF | 14 | 16 |
| 69 | Outlet So. Natick Dam | 18 | 20 |
| 100 | Just above Circular Dam Wellesley & USGS gage | 33 | 41 |
| 110 | Outlet Moody St Dam | 39 | 48 |
| 113 | Outlet Watertown Dam | 41 | 50 |

**62. Comment/Question: WWTFs and Nonreactive Phosphorus: As we approach lower and lower phosphorus limits, we are sometimes finding that there is a component of some wastewater discharges that is not amenable to removal and is not bioavailable. To the extent that a discharger has this nonreactive phosphorus in their discharge, we assume that their permit effluent limits will be adjusted accordingly.**

**Response:** *HSPF models total phosphorus which includes all the components of dissolved, organic and nonreactive phosphorus. The scenarios reflect these components and this information is then used to develop limits. Should a WWTF believe that their system has an unusual situation, the facility could submit data to document this and the data would be considered during the NPDES permit renewal.*

# Appendix A2 – Longitudinal Profiles

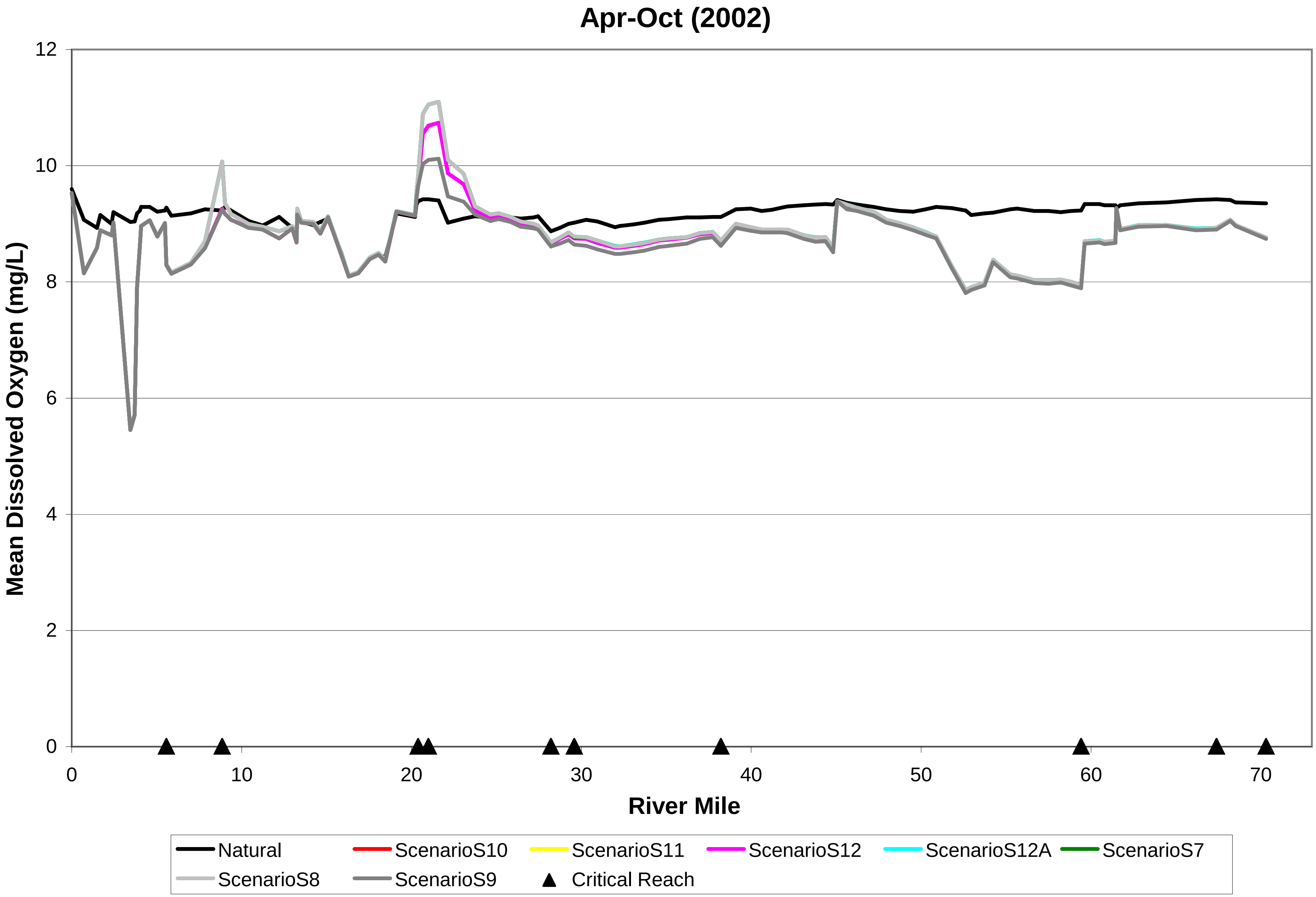


Figure A1. Longitudinal Profile for Mean Dissolved Oxygen Scenarios 7 to 12A.

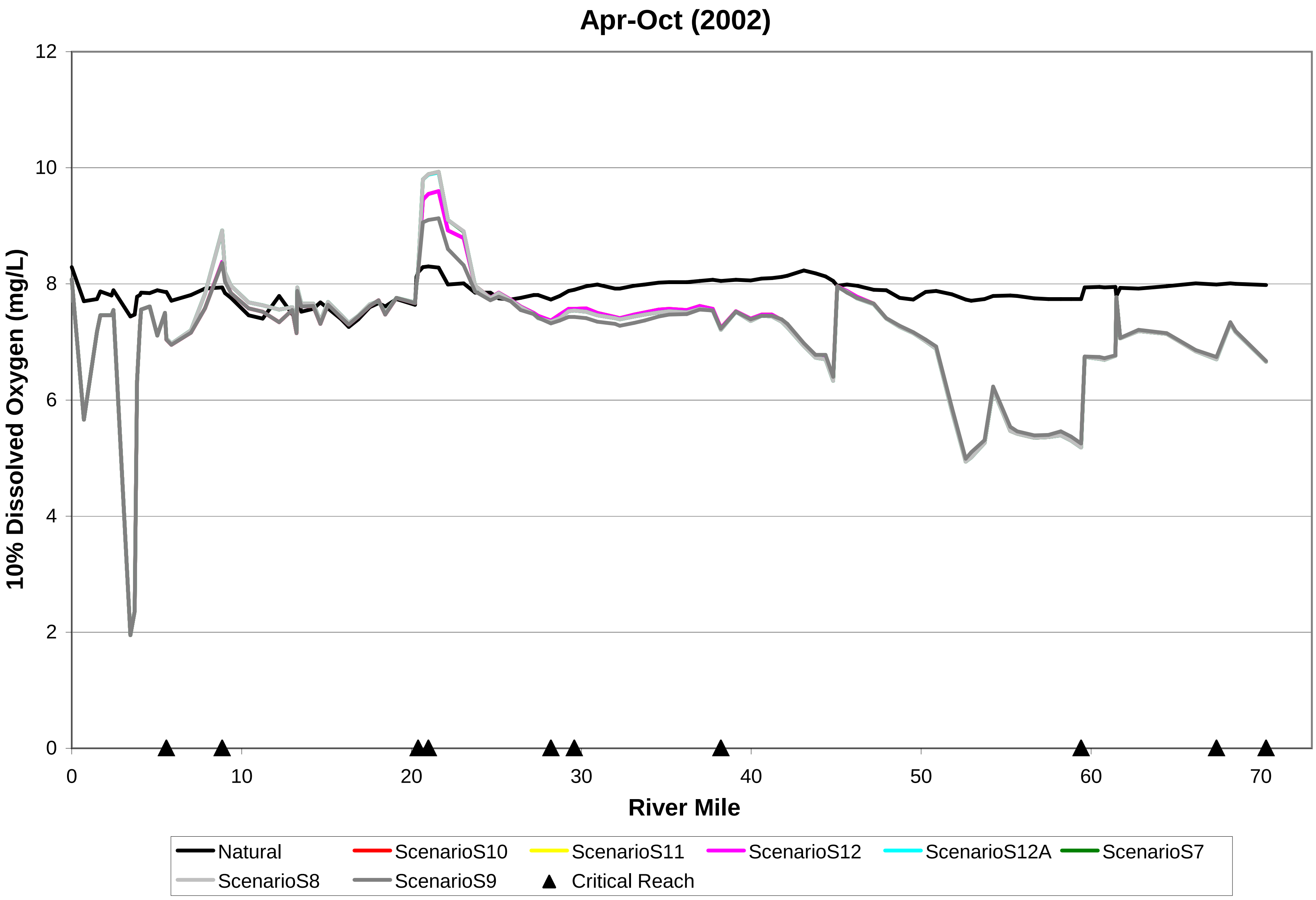


Figure A2. Longitudinal Profile for Minimum Dissolved Oxygen (10th percentile) Scenarios 7 to 12A.

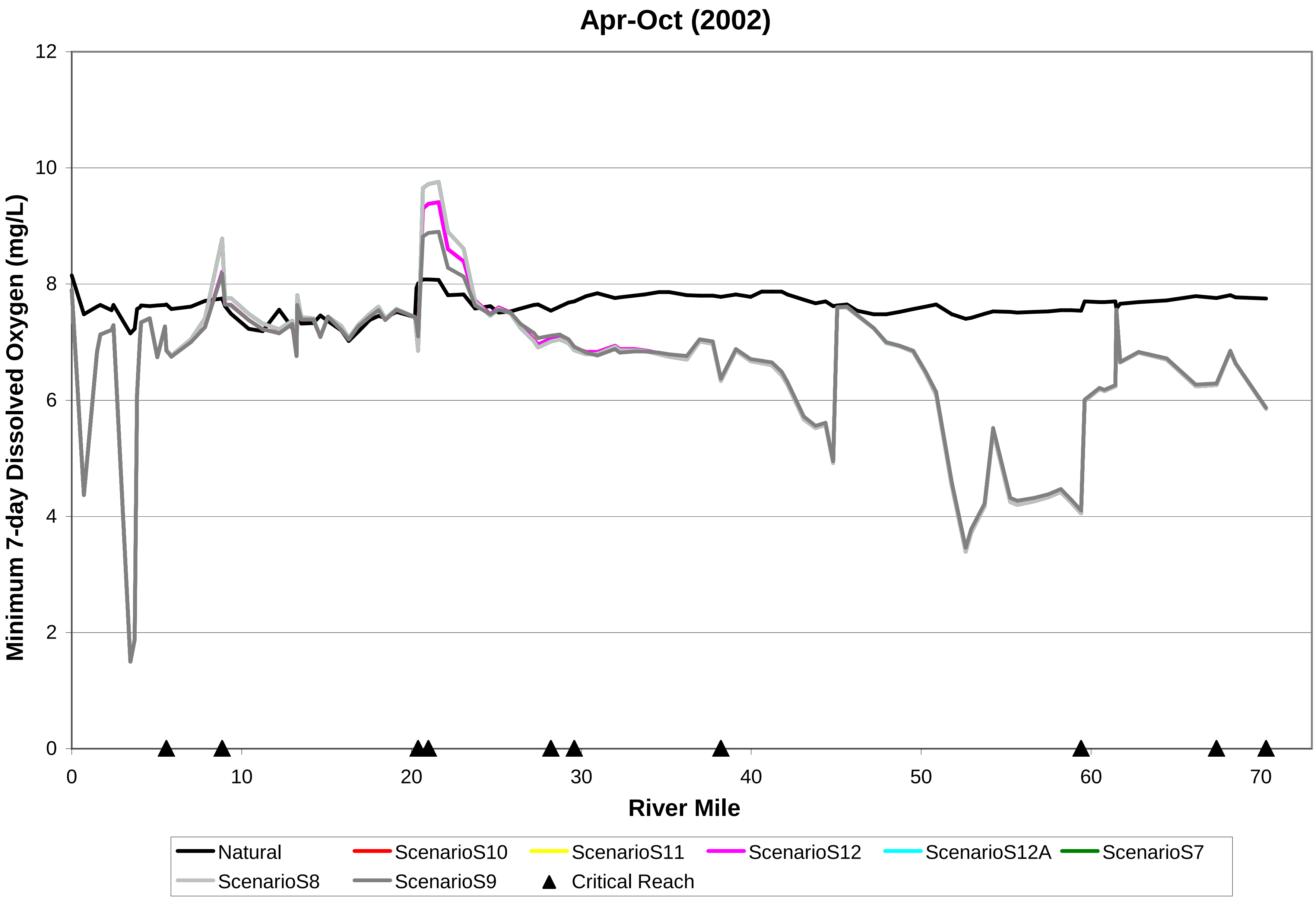


Figure A3. Longitudinal Profile Minimum 7-day Average Dissolved Oxygen Scenarios 7 to 12A.

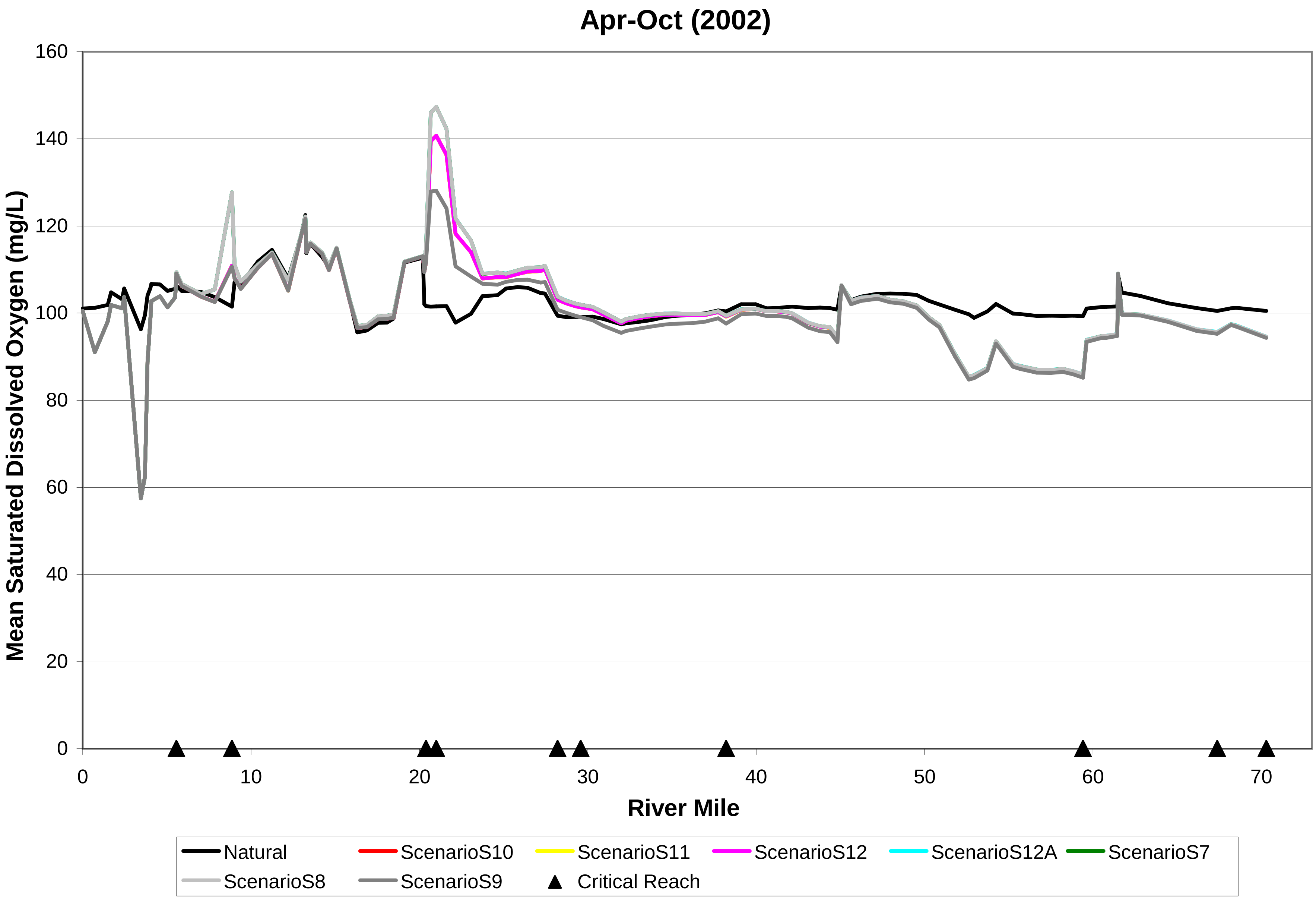


Figure A4. Longitudinal Profile Mean Dissolved Oxygen Saturation Scenarios 7 to 12A.

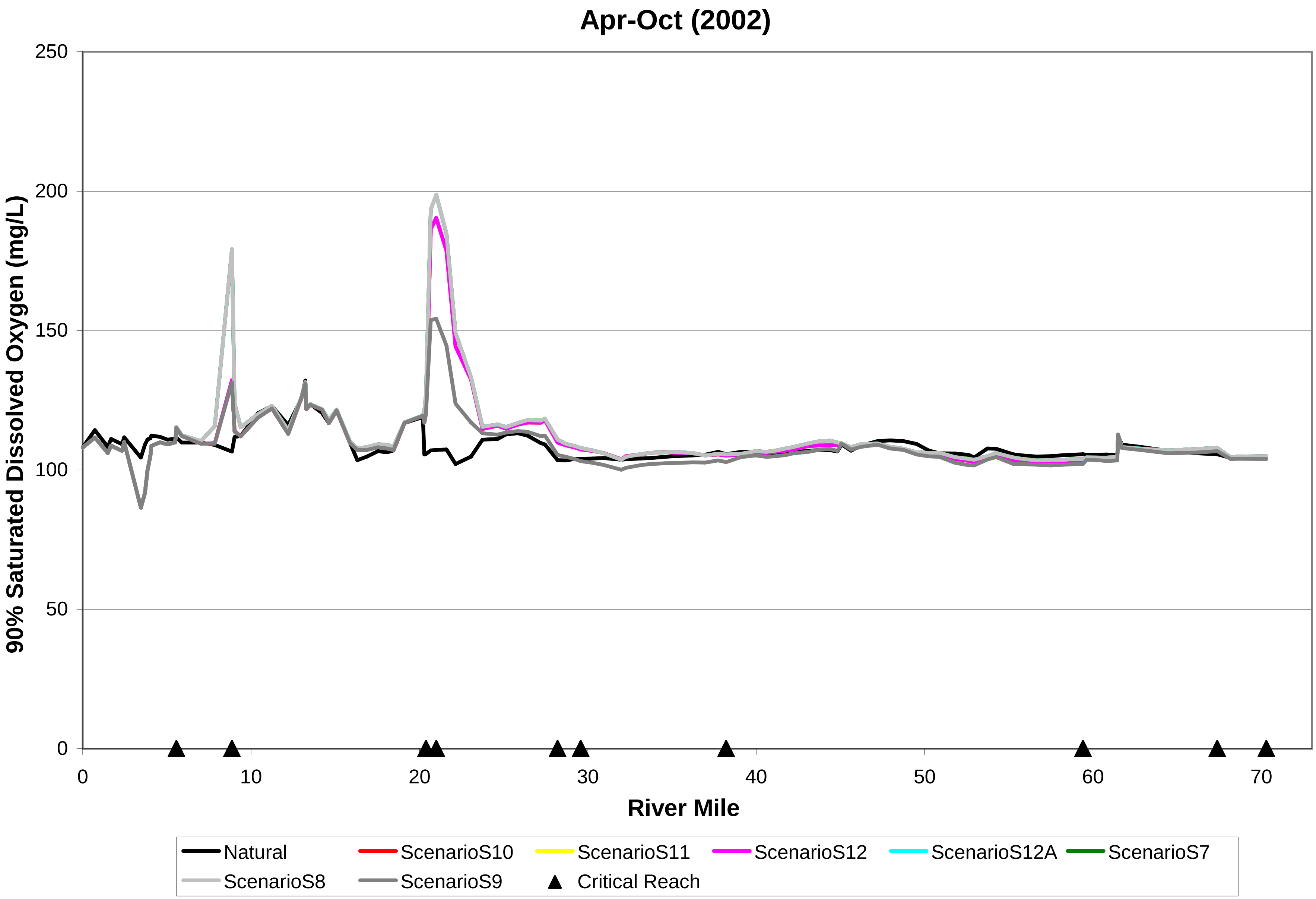


Figure A5. Longitudinal Profile for Maximum Dissolved Oxygen Saturation (90th percentile) Scenarios 7 to 12A.

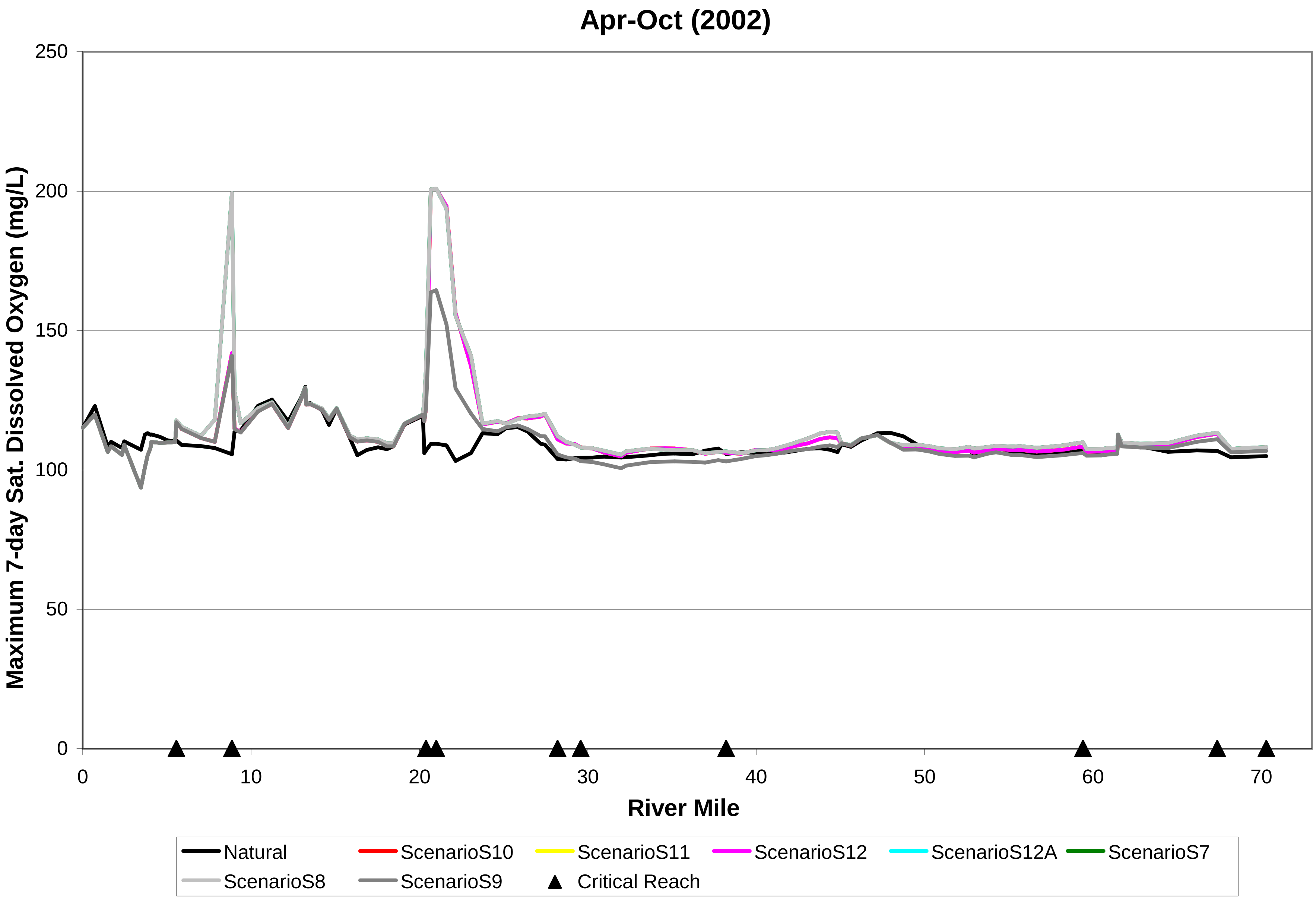


Figure A6. Longitudinal Profile Maximum 7-day Dissolved Oxygen Saturation Scenairo 7- 12A.

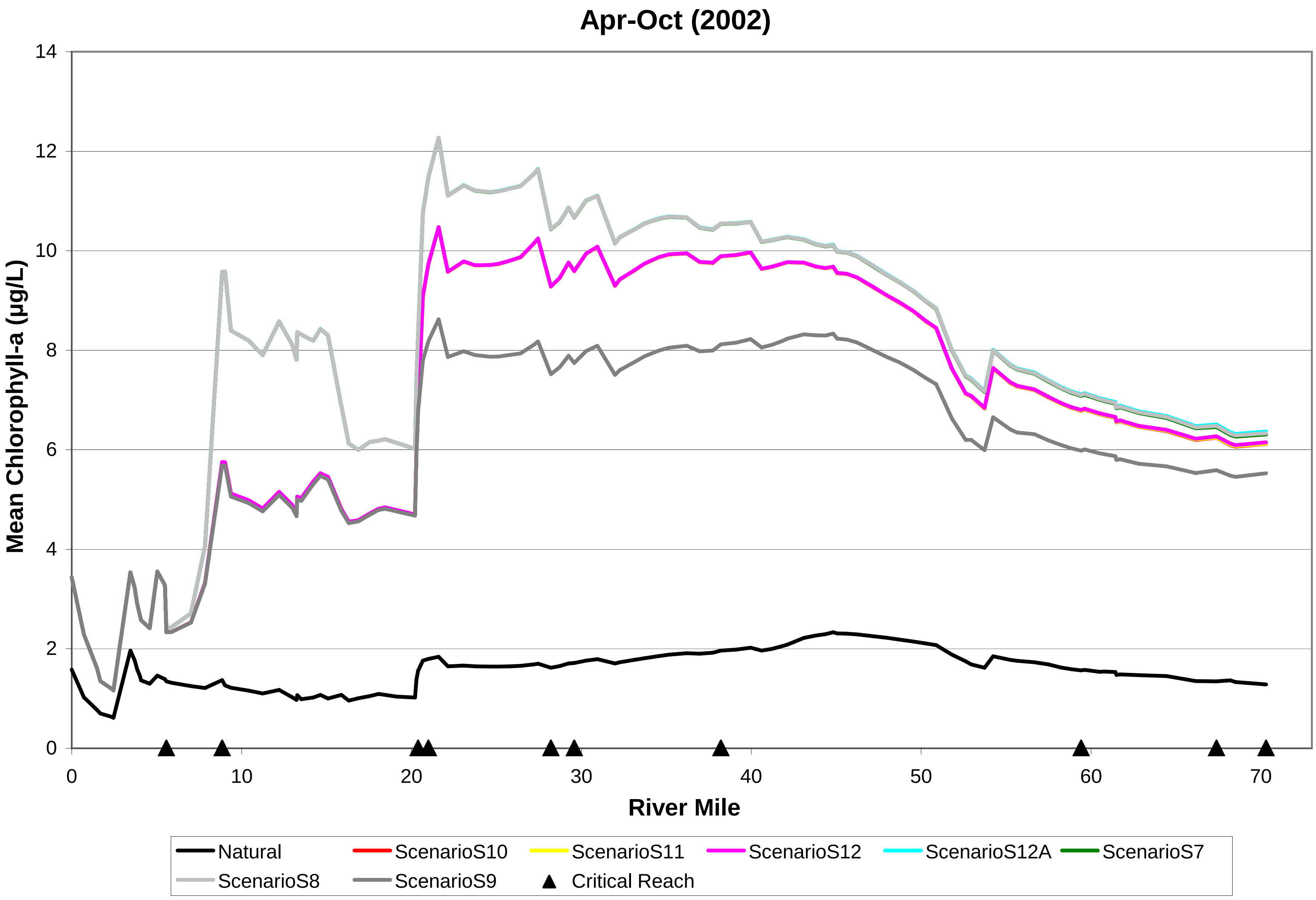


Figure A7. Longitudinal Profile Mean Chlorophyll-a Scenarios 7 to 12A.

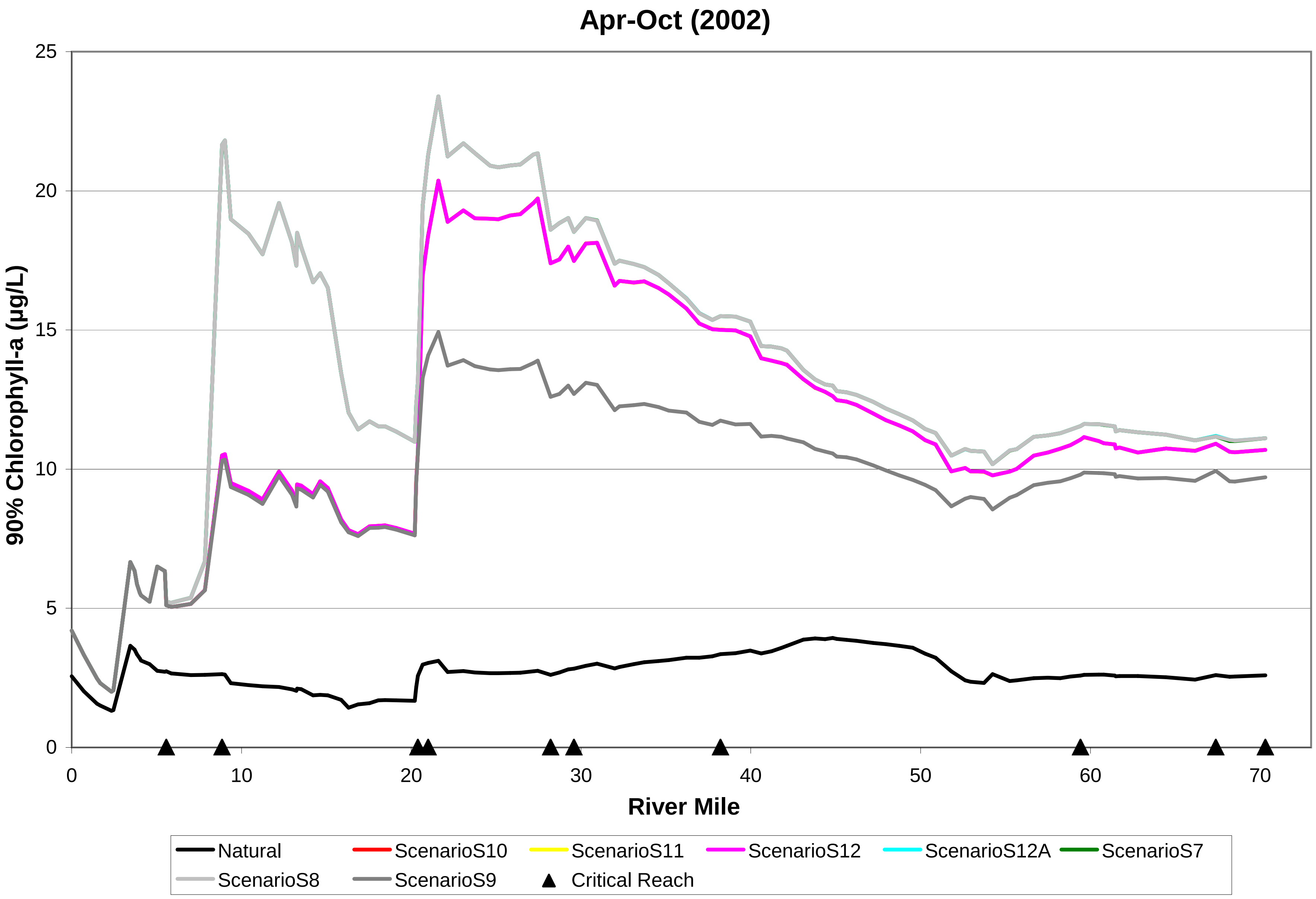


Figure A8. Longitudinal Profile Maximum Chlorophyll-a (90th percentile) Scenario 7 to 12A.

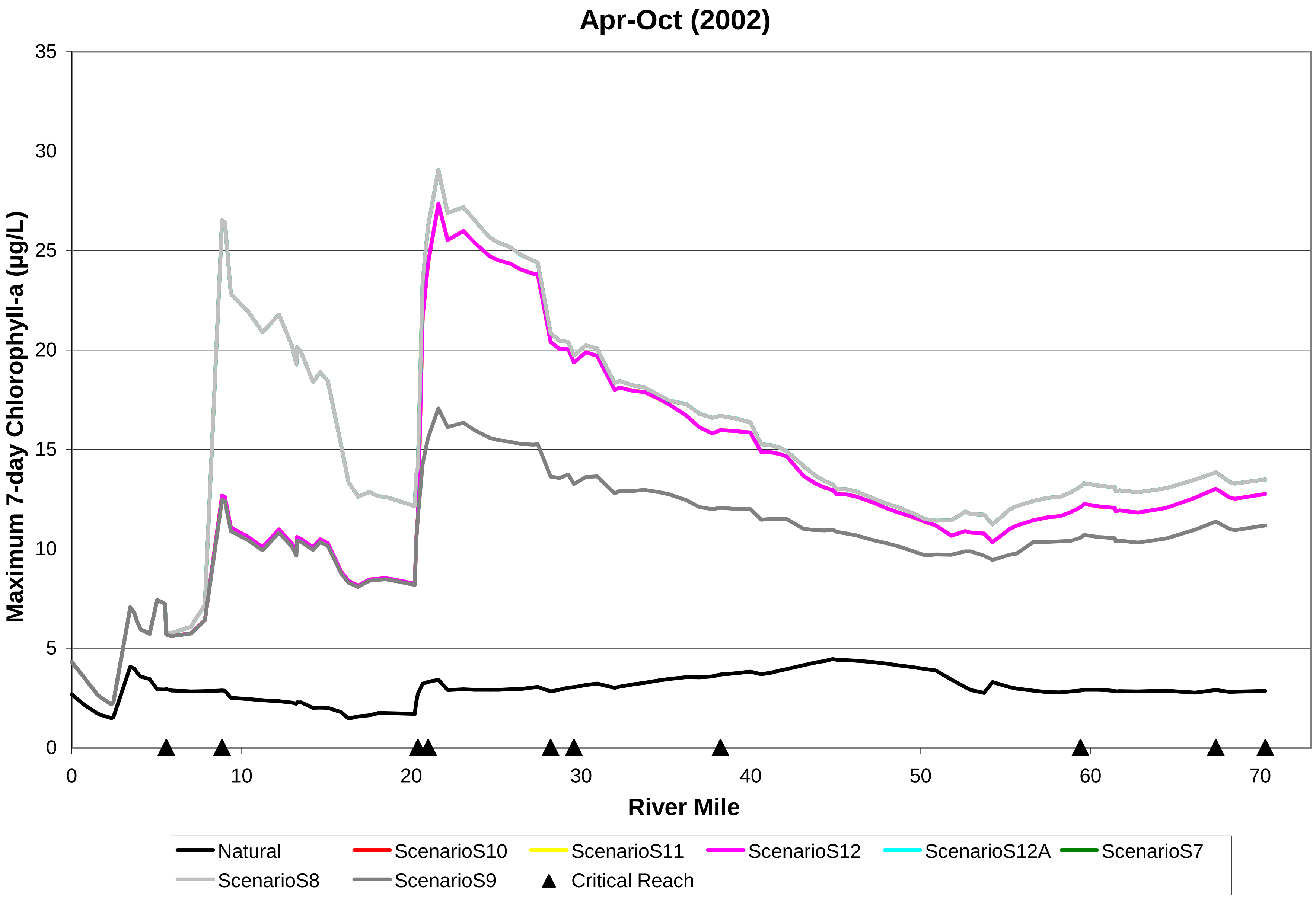


Figure A9. Longitudinal Profile Maximum 7-day Chlorophyll-a Scenarios 7 to 12A.

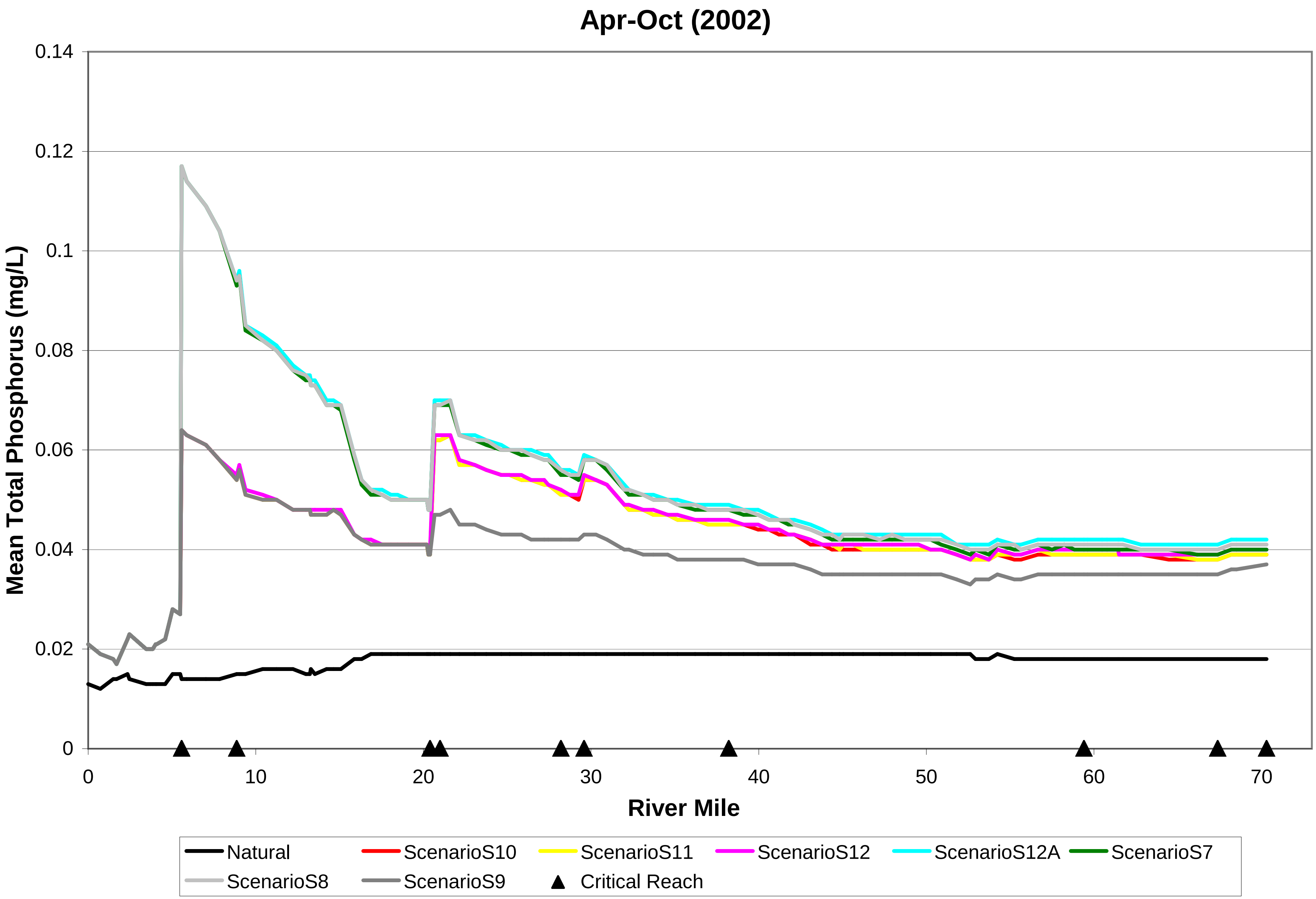


Figure A10. Longitudinal Profile Mean Total Phosphorus Scenario 7 to 12A.

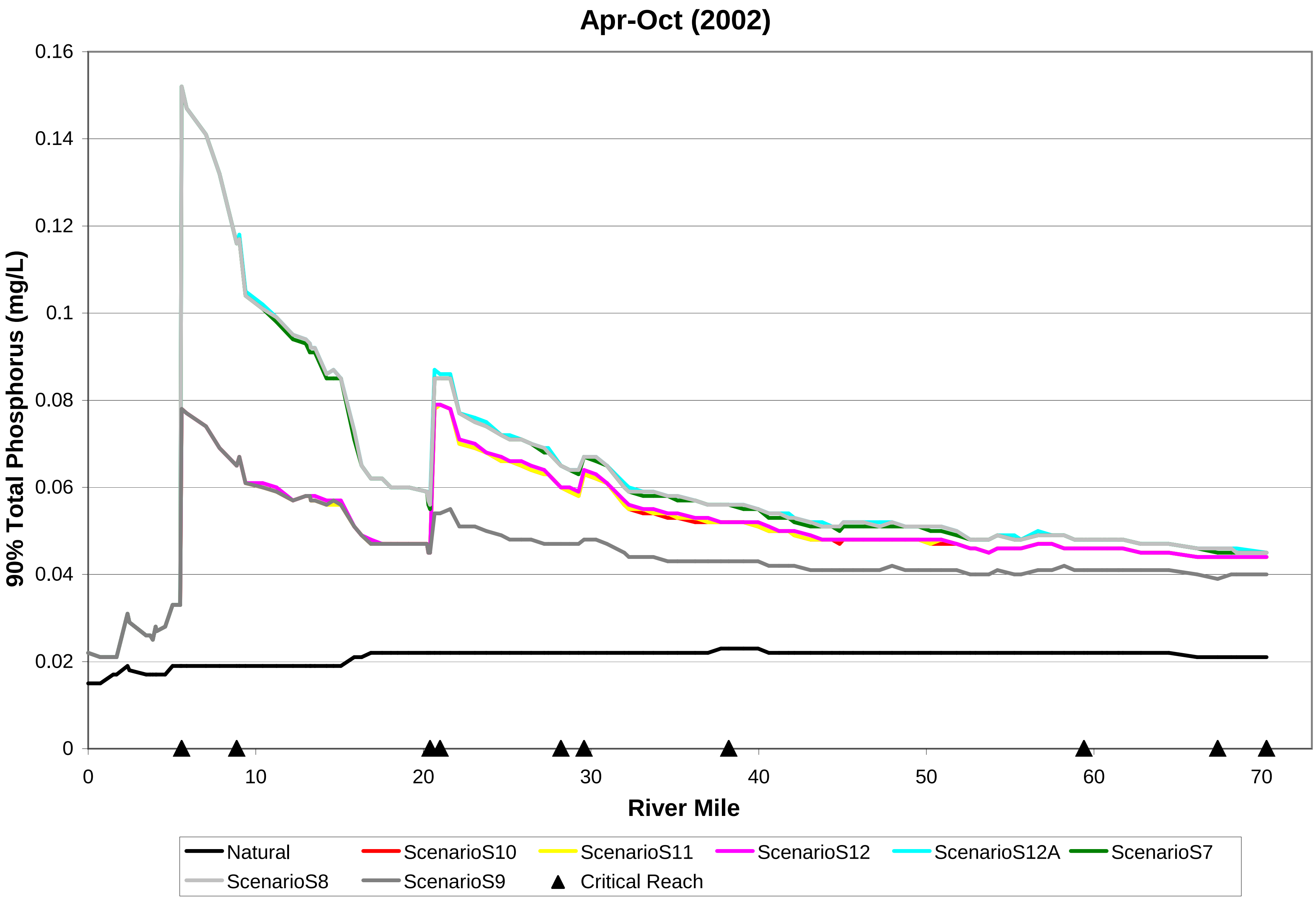


Figure A11. Longitudinal Profile Maximum Total Phosphorus (90th percentile) Scenario 7 to 12A.

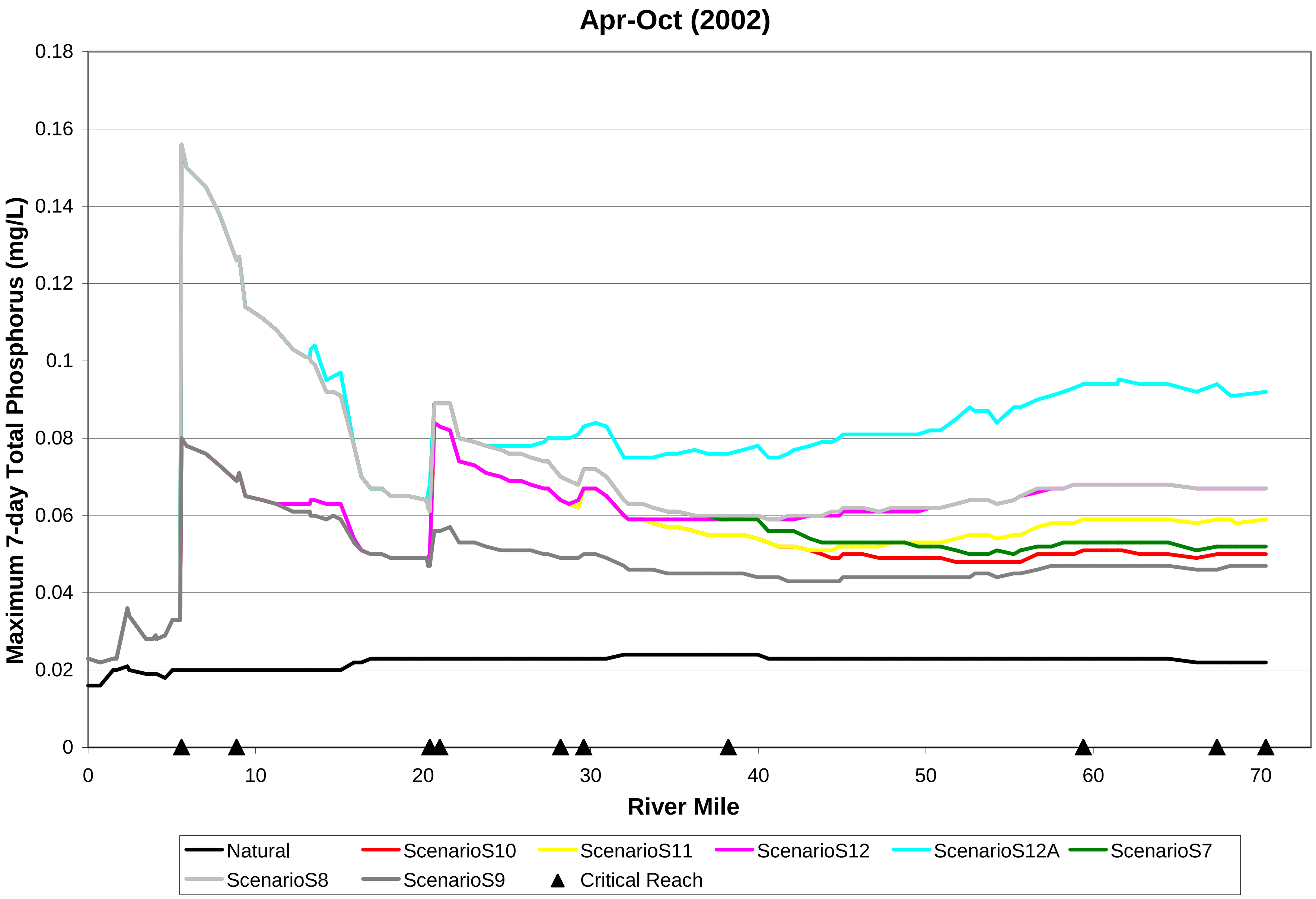


Figure A12. Longitudinal Profile Maximum 7-day Total Phosphorus Scenario 7 to 12A.