Final West and East Monponsett Pond System Total Maximum Daily Loads For Total Phosphorus

(CN 446.2)

COMMONWEALTH OF MASSACHUSETTS
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Final Draft West and East Monponsett Ponds, Stetson Pond and White Oak Reservoir Total Maximum Daily Loads for Total Phosphorus

MassDEP DWM TMDL Report CN 446.2

Key Features:	Total Phosphorus TMDL for West Monponsett Pond (Segment ID # MA62182), and East Monponsett Pond (MA62218), Stetson Pond (MA62182) and White Oak Reservoir (MA62157) in Halifax, Hanson, and Pembroke MA
Data Sources:	MassDEP data, MassGIS landuse,
Data Mechanism:	Massachusetts Surface Water Quality Standards, Ambient Data, Landuse, and LLRM suite of Models
Control Measures:	Cranberry Bog BMPs, Septic System Upgrades, Stormwater Management, Aluminum Treatment.

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Executive Summary

The Massachusetts Department of Environmental Protection (MassDEP) is responsible for monitoring the waters of the Commonwealth, identifying those waters that are impaired, and developing a plan to bring them back into compliance with the Massachusetts Surface Water Quality Standards. The list of impaired waters also referred to as Category 5 of the State Integrated List of Waters or the “303d list” identifies river, lake, and coastal waters and the cause for impairment. All impaired waters listed in Category 5 require the development of a Total Maximum Daily Load (TMDL) report.

Once a water body is identified as impaired, MassDEP is required by the federal Clean Water Act (CWA) to essentially develop a “pollution budget” designed to restore the health of the impaired body of water. The process of developing this budget, generally referred to as a TMDL, includes identifying the source(s) of the pollutant from direct discharges (point sources) and indirect discharges (nonpoint sources), determining the maximum amount of the pollutant that can be discharged to a specific water body to meet water quality standards, and developing a plan to meet that goal.

This report develops total phosphorus TMDLs for an interconnected set of four waterbodies (West and East Monponsett Pond, Stetson Pond and White Oak Reservoir) in the towns of Hanson, Halifax, and Pembroke Massachusetts. East and West Monponsett Pond, Stetson Pond, and White Oak Reservoir are listed as impaired (Category 5), on the "Massachusetts 2018/2020 Integrated List of Waters" for nutrient related impairments (MassDEP, 2021). East Monponsett Pond (Segment MA62218) is listed as impaired for Chlorophyll-a and Harmful Algal Blooms. West Monponsett (Segment MA62119) is listed as impaired for Chlorophyll-a, Harmful Algal Blooms, Total Phosphorus and Transparency/Clarity. Stetson Pond (Segment MA62182) is listed as impaired for Dissolved Oxygen (DO), Harmful Algal Blooms, and Total Phosphorus (TP). White Oak Reservoir (Segment MA62157) is listed as impaired for Nutrient/Eutrophication Biological Indicators.

Stetson Pond and White Oak Reservoir were determined to be impaired by excess algal growth and for Nutrient/Eutrophication Biological Indicators (duckweed), respectively, based on data analyzed in this report. Some of the ponds are listed for other non-pollutant related impairments (TMDL not required) and these include Stetson Pond which is listed for non-native aquatic plants; East Monponsett Pond listed for non-native aquatic plants and has a completed TMDL for Mercury in Fish Tissue (EPA#33880); West Monponsett Pond MA62119 is listed for non-native aquatic plants. This report will satisfy the requirement of a phosphorus TMDL for each of the above waterbodies. In order to prevent further degradation in water quality and to ensure that each lake meets state water quality standards, the TMDL establishes phosphorus limits for the lakes and outlines actions to achieve that goal.

All four waterbodies covered in this TMDL are classified as Class A waterbodies as well as having been designated Public Water Supply and Outstanding Resource Waters (ORWs) (MassDEP 2022). The natural surface water flow pattern is from Stetson Pond south via Stetson Brook to East Monponsett Pond and then west through a culvert under Route 58 to West Monponsett Pond (Figure 1). In the northwest part of the watershed, White Oak Brook flows into White Oak Reservoir, then continues south to West Monponsett Pond. Stump Brook is the outlet on the west side of West Monponsett Pond.

Silver Lake (Pembroke, Kingston, and Plymouth MA) is the surface water supply for the City of Brockton. There is an underground pipe which allows water to be diverted from East Monponsett to Silver Lake. The City of Brockton was authorized through an emergency legislative action in 1964 to withdraw water from Silver Lake. Diversions to Silver Lake are through a pipe laid by Brockton and permitted under Ch. 91 by MassDEP. During diversions (mainly in October through May) water flows regularly in the reverse direction, flowing backward from West Monponsett to East Monponsett, potentially drawing the cyanobacteria and nutrients into Silver Lake. Action is being taken to address the cyanobacterial blooms observed in West and East Monponsett Ponds and the upstream waterbodies that are tributary to those ponds.

The Lake Loading Response Model (LLRM) suite of lake models was used for this TMDL. The LLRM is a spreadsheet based model which uses an annual steady state suite of models to estimate nutrient loadings. These estimated nutrient loadings along with pond morphometric and physical characteristics are then used to predict in-pond nutrient concentrations using a suite of well accepted lake models for phosphorus predictions. The successful calibration of the model was based on relatively high nutrient export rates from specific landuses that discharge directly to surface waters (cranberry bogs, stormwater and natural forested wetlands), combined with estimates of export from septic systems and internal sediment recycling of phosphorus. These estimates for each waterbody were simultaneously adjusted with the LLRM suite of lake models until they approximated the observed in-lake surface concentrations in each lake. The major sources of phosphorus to the lakes were cranberry bogs, runoff from developed areas, internal release from sediments, and natural wetlands.

Ignoring sediment sources, the largest controllable watershed sources of phosphorous are cranberry bog inputs and runoff associated with residential development. In the case of West Monponsett Pond, internal loading or recycling of phosphorus from lake sediments is a major source of phosphorus during the summer growing season. Implementation is already underway to address the cranberry bog inputs. The large commercial bogs north of Stetson Pond were retired in 2008 and that pond already shows a reduction in TP concentrations. The Morse Brothers Winebrook bogs and "bog #19" near West Monponsett Pond and White Oak Reservoir have implemented reduced phosphorus fertilizer rates as recommended by the University of Massachusetts (UMass) Cranberry Experiment Station. West Monponsett Pond has also shown significant reductions in TP concentrations coincident with the fertilizer reductions. In addition, a Section 319 grant (#12-02/319) was previously awarded in 2012 to assist in implementation and monitoring of new experimental filters for cranberry bog discharge waters, with monitoring being conducted by the UMass Cranberry Station. Funding support to aid implementation of this TMDL is available on a competitive basis under various state programs including the U.S. Environmental Protection Agency (USEPA) Section 319 Grant Program administered by MassDEP.

It is recommended to first reduce external loads to the extent possible before addressing the internal loads, but due to health concerns regarding the potentially toxic cyanobacterial blooms in West Monponsett, the Town of Halifax funded treatments with a light dose of aluminum in 2013, 2015, and 2016. With 319 funding, the Town of Halifax applied aluminum doses in 2017, 2018 and 2019. Light aluminum doses were applied in small amounts over the summer months to avoid potential impacts to the rare state listed freshwater mussels in the pond. The sediment source of phosphorus is presumably due to historic inputs of phosphorus, largely from anthropogenic sources.

Implementation will include continued effort to reach out to remaining cranberry growers to use the most current recommended practices on their bogs. Implementation can be achieved by a combination of best management practices (BMPs) including reducing the phosphorus fertilizer rates, reducing volumes of discharge water and reducing concentrations of total phosphorus in the discharge water. Further implementation of stormwater and septic system upgrades are encouraged. Aluminum treatment of West Monponsett Pond totals an applied dose of 50 g/m^2. Treatment of the other ponds in the system is also encouraged with potential funding through the Section 319 Grant Program. The Town of Halifax received a Section 319 grant in 2017 to help fund alum treatment of West Monponsett through 2019.

Additionally, a substantial reduction in TP loads (50% - 60%) from stormwater will be required for Stetson Pond, East Monponsett, White Oak Reservoir, and West Monponsett Pond watersheds to meet this TMDL. These substantial reductions in TP loads from stormwater will be implemented through Municipal Separate Storm Sewer Systems (MS4) permits associated with designated urban areas in the towns of Halifax, Hanson and Pembroke.

In summary, the four waterbodies were modeled with a mass balance approach using a combination of landuse areas multiplied by phosphorus export coefficients and the resulting phosphorus loads for each pond were modeled using a suite of lake models to match the observed (2009 or 2015) TP concentrations. Target TP concentrations were chosen to attain recovery of the ponds and a set of TMDL loads were established to meet those targets. The reductions in loads required to reach the targets ranged from 30% to 73% as shown in Table ES-1 below. Although the TMDL must be expressed as a daily load, the implementation and administrative decisions should rely on achieving the annual TMDL load which is more appropriate for these waterbodies.

Table ES-1 Summary of Targets and Load Reductions for Ponds

Waterbody	Current TP ppb used in model	Current TP Load kg/yr	Target TP ppb	TMDL Load kg/yr	TMDL Load kg/day	Percent TP Load Reduction
Stetson Pond	15	69	13	48	0.13	30%
East Monponsett	34	345	18	182	0.53	47%
White Oak Brook Reservoir	50*	76	23	35	0.10	54%
West Monponsett	68	676	18	186	0.50	73%

*Measured TP was 35 ppb (see text).

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Programmatic Background and Rationale

Section 303(d) of the Federal Clean Water Act requires each state to (1) identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. TMDLs may also be applied to waters threatened by excessive pollutant loadings. The TMDL establishes the allowable pollutant loading from all contributing sources that is necessary to achieve the applicable water quality standards. TMDL determinations must account for seasonal variability and include a margin of safety (MOS) to account for uncertainty of how pollutant loadings may impact the receiving water's quality. This report will be submitted to the USEPA as a TMDL under Section 303d of the Federal Clean Water Act, 40 CFR 130.7. After public comment and final approval by the USEPA, the TMDL can be used as a basis for state and federal permitting and regulatory decisions. The report will also serve as a general guide for future implementation activities such as grant funding of best management practices (BMPs). Information on watershed planning in Massachusetts is available on the MassDEP website at https://www.mass.gov/guides/watershed-planning-program.

The Massachusetts Surface Water Quality Standards (SWQS), 314 Code of Massachusetts Regulations (CMR) 4.0, define conditions required to support designated uses. The standards are largely narrative as they apply to nutrients:

314CMR 4.05 (3) b: ….These waters are designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. ....These waters shall have consistently good aesthetic value.

> 1. Dissolved Oxygen: a. 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.

and

314CMR 4.05 (5)(a) 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.

and

314CMR 4.05 (5)(c) 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 including, but not limited to, those established in 314 CMR 4.06(6)(c): Table 28: Site-specific Criteria. 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.

Section 314 CMR 4.05(3)(b) 6 also states:
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.

In addition to the criteria above the SWQS also include an anti-degradation policy under 314 CMR 4.04:

4.04: Antidegradation Provisions
(1) Protection of Existing Uses. In all cases existing uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.
(2) Protection of High Quality Waters. High Quality waters are waters whose quality exceeds minimum levels necessary to support the national goal uses, low flow waters, and other waters whose character cannot be adequately described or protected by traditional criteria. These waters shall be protected and maintained for their existing level of quality unless limited degradation by a new or increased discharge is authorized by the Department pursuant to 314 CMR 4.04(5). Limited degradation also may be allowed by the Department where it determines that a new or increased discharge is insignificant because it does not have the potential to impair any existing or designated water use and does not have the potential to cause any significant lowering of water quality.
(3) Protection of Outstanding Resource Waters. The quality of Outstanding Resource Waters shall be protected and maintained.

(a) Any person having an existing discharge to these waters shall cease said discharge and connect to a POTW, unless it is shown by said person that such a connection is not reasonably available or feasible. Existing discharges not connected to a POTW shall be provided with the highest and best practical method of waste treatment determined by the Department as necessary to protect and maintain the outstanding resource water.

(b) A new or increased discharge to an Outstanding Resource Water is prohibited unless:

1. the discharge is determined by the Department to be for the express purpose and intent of maintaining or enhancing the resource for its designated use and an authorization is granted as provided in 314 CMR 4.04(5). The Department's determination to allow a new or increased discharge shall be made in agreement with the federal, state, local or private entity recognized by the Department as having direct control of the water resource or governing water use; or

2. the discharge is dredged or fill material for qualifying activities in limited circumstances, after an alternatives analysis which considers the Outstanding Resource Water designation and further minimization of any adverse impacts. Specifically, a discharge of dredged or fill material is allowed only to the limited extent specified in 314 CMR 9.00: 401 *Water Quality Certification for Discharge of Dredged or Fill*

Material, Dredging, and Dredged Material Disposal in Waters of the United States within the Commonwealth and 314 CMR 4.06(1)(d). The Department retains the authority to deny discharges which meet the criteria of 314 CMR 9.00, but will result in substantial adverse impacts to the physical, chemical, or biological integrity of surface waters of the Commonwealth.

(4) Protection of Special Resource Waters. The quality of Special Resource Waters shall be protected and maintained. No new or increased discharge to an SRW, and no new or increased discharge to a tributary to an SRW that would result in lower water quality in the SRW, may be allowed, except where:

(a) the discharge results in temporary and short term changes in the quality of the SRW, provided that the discharge does not permanently lower water quality or result in water quality lower than necessary to protect uses; and

(b) an authorization is granted pursuant to 314 CMR 4.04(5).

(5) Authorizations.

(a) An authorization to discharge to waters designated for protection under 314 CMR 4.04(2) may be issued by the Department where the applicant demonstrates that:

1. The discharge is necessary to accommodate important economic or social development in the area in which the waters are located;

2. No less environmentally damaging alternative site for the activity, receptor for the disposal, or method of elimination of the discharge is reasonably available or feasible;

3. To the maximum extent feasible, the discharge and activity are designed and conducted to minimize adverse impacts on water quality, including implementation of source reduction practices; and

4. The discharge will not impair existing water uses and will not result in a level of water quality less than that specified for the Class.

(b) An authorization to discharge to the narrow extent allowed in 314 CMR 4.04(3) or 314 CMR 4.04(4) may be granted by the Department where the applicant demonstrates compliance with 314 CMR 4.04(5)(a)2. through 4.

(c) Where an authorization is at issue, the Department shall circulate a public notice in accordance with 314 CMR 2.06: *Public Notice and Comment*. Said notice shall state an authorization is under consideration by the Department, and indicate the Department's tentative determination. The applicant shall have the burden of justifying the authorization. Any authorization granted pursuant to 314 CMR 4.04 shall not extend beyond the expiration date of the permit (d) A discharge exempted from the permit requirement by 314 CMR 3.05(4) (discharge necessary to abate an imminent hazard) may be exempted from 314 CMR 4.04(5) by decision of the Department.

(e) A new or increased discharge specifically required as part of an enforcement order issued by the Department in order to improve existing water quality or prevent existing water quality from deteriorating may be exempted from 314 CMR 4.04(5) by decision of the Department.

(6) The Department applies its Antidegradation Implementation Procedures to point source discharges subject to 314 CMR 4.00.

(7) Discharge Criteria. In addition to the other provisions of 314 CMR 4.00, any authorized discharge shall be provided with a level of treatment equal to or exceeding the requirements of 314 CMR 3.00: *Surface Water Discharge Permit Program*. Before authorizing a discharge, all

appropriate public participation and intergovernmental coordination shall be conducted in accordance with 314 CMR 2.00: *Permit Procedures*.

The programmatic background summary given below is intended to be general in nature and the issues described may or may not apply to the specific water body in question. The management of eutrophic freshwater lakes is typically based on a study of the nutrient sources and loads to the lakes and usually focuses on phosphorus as the important (or limiting) nutrient (Cooke et al., 2005). For TMDLs, the phosphorus loads estimated from the study can be compared to total phosphorus loadings estimated from a suite of different published lake models. A target concentration is selected, and a target load of phosphorus is calculated for the lake to control eutrophication in the water column, however additional plant management may be needed. A total phosphorus TMDL is established to meet Massachusetts narrative WQS. Although nutrient criterion does not exist in Massachusetts, water quality parameters which respond to nutrients can be used to assess the health of a water body. Guidance values for these parameters are detailed in MassDEP's Consolidated Assessment and Listing Methodology (CALM, see MassDEP, 2016). The CALM is used to translate the narrative nutrient criteria. As detailed in the CALM, lakes and pond should maintain a minimum of 4-foot visibility in surface waters for safe recreational use (which is equivalent to the 1.2 m Secchi disc transparency), a 16 ppb max monthly chlorophyll *a* concentration (a measure of algae and cyanobacterial biomass), limiting non-rooted macrophyte (i.e. duckweed) to 25% or less coverage, maintaining minimum dissolved oxygen (generally 5 mg/l for warm water) and to limit potentially toxic cyanobacterial blooms (less than 70,000 cells/mL).

The successful implementation of this TMDL will require cooperative support from the public including lake and watershed associations, local officials and municipal governments in the form of education, funding and local enforcement. In some cases, additional funding support is available under various state programs including the MassDEP Section 319 Grant Program (nonpoint source grants) and the State Revolving Fund Program (SRF); see Water Resources Grants and Financial Assistance on MassDEP web site.

Nutrient Enrichment: Nutrients are a requirement of life, but in excess they can create water quality problems. Lakes are ephemeral features of the landscape and over geological time most tend to fill with sediments and associated nutrients as they make a transition from lake to marsh to dry land. However, this natural successional ("aging") process can be and often is accelerated through the activities of humans, especially through development in the watershed. For some highly productive lakes with developed watersheds, it is not easy to separate natural succession from "culturally induced" effects. Nonetheless, all feasible steps should be taken to reduce the impacts from cultural activities. The following discussion summarizes the current understanding of how nutrients influence the growth of algae and macrophytes (aquatic plants), the time scale used in the studies, the type of models applied, and the data collection methods used to create a nutrient budget. A brief description of the rationale for choosing a target load (the TMDL) as well as a brief discussion of implementation and management options is presented. A more detailed description of fertilizer and water usage in commercial cranberry bogs is provided in Appendix D, *Guidelines for Total Maximum Daily Loads of Phosphorus from Commercial Cranberry Bog Discharges in Massachusetts*.

A detailed description of the current understanding of limnology (the study of lakes and freshwaters) and management of lakes and reservoirs can be found in Wetzel (2001), Cooke et al., (2005) and Holdren et al., (2001). To prevent cultural enrichment it is important to examine the nutrients required for growth of phytoplankton (algae) and macrophytes. The limiting nutrient is typically the one in shortest supply relative to the nutrient requirements of the plants. The ratio of nitrogen (N) to phosphorus (P) in both algae and macrophyte biomass is typically about 7 by weight or 16 by atomic ratio (Vallentyne, 1974). Observations of relatively high N/P ratios in water suggests P is most often limiting and careful reviews of numerous experimental studies have concluded that phosphorus is a limiting nutrient in most freshwater lakes (Likens, 1972; Schindler and Fee, 1974). Most diagnostic/feasibility studies of Massachusetts lakes also indicate phosphorus as the limiting nutrient. Even in cases where excess phosphorus has led to nitrogen limitation, previous experience has shown that it is easier, more cost-effective and more ecologically sound to control phosphorus than nitrogen. The reasons include the fact that phosphorus is related to terrestrial sources and does not have a significant atmospheric source as does nitrogen (e.g., nitrates in precipitation). Thus, nonpoint sources of phosphorus can be managed more effectively by best management practices (BMPs). In addition, phosphorus is relatively easy to control in point source discharges. Finally, phosphorus does not have a gaseous phase, while the atmosphere is a nearly limitless source of nitrogen gas that can be fixed by some blue-green algae, (i.e. cyanobacteria) potentially resulting in toxic blooms. For all the reasons noted above, phosphorus is chosen as the critical element to control freshwater eutrophication, particularly for algal dominated lakes or in lakes threatened with excessive nutrient loading.

There is a direct link between phosphorus loading and algal biomass (expressed as chlorophyll *a)* in algae dominated lakes (Vollenweider, 1975). The situation is more complex in macrophyte-dominated lakes where the rooted aquatic macrophytes may obtain most of the required nutrients from the sediments. In organic, nutrient-rich sediments, the plants may be limited more by light or physical constraints such as water movement than by nutrients. In such cases, it is difficult to separate the effects of sediment deposition, which reduce depth and extend the littoral zone, from the effects of increased nutrients, especially phosphorus, associated with the sediments. In Massachusetts, high densities of aquatic macrophytes are typically limited to depths less than ten feet and lakes where organic rich sediments are found (Mattson et al., 2004). Thus, the response of rooted macrophytes to reductions in nutrients in the overlying water will be much weaker and much slower than the response of algae or non-rooted macrophytes, which rely on the water column for their nutrients. In algal or non-rooted macrophyte dominated systems, nutrient reduction in the water column can be expected to control growth with a lag time related to the hydraulic flushing rate of the system. In lakes dominated by rooted macrophytes, additional, direct control measures such as harvesting, herbicides or drawdowns will be required to realize reductions in plant biomass within a reasonably short time scale. In both cases, however, nutrient control is essential since any reduction in one component (either rooted macrophytes or phytoplankton) may result in a proportionate increase in the other due to the relaxation of competition for light and nutrients. In addition, it is critical to establish a TMDL so that future development around the lake will not impair water quality. It is far easier to prevent nutrients from causing eutrophication than to attempt to restore a eutrophic lake. The first step in nutrient control is to calculate the current nutrient loading rate or nutrient budget for the lake.

Nutrient budgets: Nutrient budgets and loading rates in lakes are determined on a yearly basis because lakes tend to accumulate nutrients as well as algal and macrophyte biomass over long time periods compared to rivers which constantly flush components downstream. In cases of short retention time reservoirs (less than 14 days), nutrient budgets may be developed on a shorter time scale (e.g. monthly budgets from wastewater treatment plants) but the units are expressed on a per year basis in order to be comparable to nonpoint sources estimated from land use models. Nutrients in lakes can be released from the sediments into the bottom waters during the winter and summer and circulated to the surface during mixing events (typically spring and fall in deep lakes and spring, summer and fall in shallow lakes). Nutrients stored in shallow lake sediments can also be directly used by rooted macrophytes during the growing season. In Massachusetts lakes, peak algal production, or blooms, may begin in the spring and continue during the summer and fall, while macrophyte biomass peaks in late summer. The impairment of uses is usually not severe until summer when macrophyte biomass reaches the surface of the water interfering with boating and swimming. Also, at this time of year the high daytime primary production and high nighttime respiration can cause large fluctuations in dissolved oxygen with critical repercussions for sustaining aquatic life. In addition, oxygen is less soluble in warm summer water as compared to other times of the year. The combination of these factors can drive oxygen to low levels during the summer and may cause fish kills. For these reasons the critical period for use impairment is during the summer, even though the modeling is done on a yearly basis for the reasons explained above.

There are three basic approaches to estimating current nutrient loading rates: the measured mass balance approach; the land use export modeling approach; and modeling based on the observed in-lake concentration. The measured mass balance approach requires frequent measurements of all fluvial inputs to the lake in terms of flow rates and phosphorus concentrations. The yearly loading is the product of flow (liters per year) times concentration (mg/l), summed over all sources (i.e., all streams and other inputs) and expressed as kg/year. The land use export approach assumes phosphorus is exported from various land areas at a rate dependent on the type of land use. The yearly loading is the sum of the product of land use area (Ha) times the export coefficient (in kg/Ha/yr). In some cases a combined or modified approach using both methods is used. In-lake phosphorus models provide an indirect method of estimating loading but do not provide information on the sources of input; however, this approach can be used in conjunction with other methods to validate results. Although the mass balance method is more time consuming and more costly due to the field sampling and analysis, it is generally considered to be more accurate. For this reason, the mass balance results are used whenever possible. If a previous diagnostic/ feasibility study or mass balance budget is not available, then a land use export model, such as Reckhow et al., (1980) or the NPSLAKE model (Mattson and Isaac, 1999) can be used to estimate nutrient loading.

Target Load: Once the current nutrient loading rate is identified, a new, lower rate of nutrient loading must be established which will meet surface water quality standards for the lake. This target load or TMDL can be set in a variety of ways. Usually a target concentration in the lake is established and the new load must be reduced to achieve the lower concentration. This target nutrient concentration may be established by a water quality model that relates phosphorus concentrations to water quality required to maintain designated uses. Alternatively, the target concentration may be set based on concentrations observed in background reference lakes for similar lake types or from concentration ranges found in lakes within the same ecological region (or sub-ecoregion). In cases of impoundments or lakes with rapid flushing times (e.g., less than 14 days), somewhat higher phosphorus targets may be used because the planktonic algae and nutrients are rapidly flushed out of the system and typically do not have time to grow to nuisance conditions in the lake or accumulate in the sediments. In the case of seepage lakes (with no inlet streams) they may naturally have lower phosphorus targets, particularly if the lakes are clear water rather than dark or tea colored lakes.

Various models (equations) have been used for predicting productivity or total phosphorus concentrations in lakes from analysis of phosphorus loads. These models typically take into consideration the water body's hydraulic loading rate and some factor to account for settling and storage of phosphorus in the lake sediments. Among the more well-known metrics are those of Vollenweider (1975), Kirchner and Dillon (1975), Chapra (1975), Larsen and Mercier (1975) and Jones and Bachmann (1976). These models are used to calculate the Total Maximum Daily Load or TMDL, in kilograms of the nutrient per day or per year that will result in the target concentration in the lake being achieved. The TMDL must account for the uncertainty in the estimates of the phosphorus loads from the sources identified above by including a "margin of safety". The margin of safety can be specifically included, and/or included in the selection of a conservative phosphorus target, and/or included as part of conservative assumptions used to develop the TMDL. In addition, a simple mass balance equation (model) of total load divided by total water input, may also be used to establish the minimum load (assuming no settling or loss of phosphorus) that could explain the observed concentration in the lake.

After the target TMDL has been established, the allowed loading of nutrients is apportioned to various sources that may include point sources as well as nonpoint sources such as private septic systems and runoff from various land uses within the watershed. In Massachusetts, few lakes receive direct point source discharges of nutrients. In cases where significant point sources regulated through the National Pollutant Discharge Elimination System (NPDES) program exist upstream of a lake or impoundment, the point source will in most cases be required to use the Highest and Best Practical Treatment (HBPT) to reduce total phosphorus loading. The existing loads for NPDES point sources are calculated based on current data, not on the permitted discharge loading. New discharge mass loading limits at a treatment plant may be computed by applying the percent reduction required to meet the TMDL to the current loads. The new permitted concentrations of total phosphorus can then be calculated based on total mass loading divided by permitted flow rate for the discharge.

The nutrient nonpoint source analysis generally will be related to land use that reflects the extent of development in the watershed. This effort can be facilitated using geographic information systems (GIS) digital maps of the area that can summarize land use categories within the watershed. This is then combined with nutrient export factors which have been established in numerous published studies. The targeted reductions must be reasonable given the reductions possible with the best available technology and Best Management Practices (BMPs). The first scenario for allocating loads will be based on what is practicable and feasible for each activity and/or land use to make the effort as equitable as possible.

Seasonality: As the term implies, TMDLs must be expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms as well. For most lakes, it is appropriate and justifiable to express a nutrient TMDL in terms of allowable annual loadings. The annual load should inherently account for seasonal variation if it is protective of the most sensitive time of year. The most sensitive time of year in most lakes occurs during summer, when the frequency and occurrence of nuisance algal blooms and macrophyte growth are typically greatest. The phosphorus TMDL was established to be protective of the most environmentally sensitive period (i.e., the summer season), therefore it will also be protective of water quality during all other seasons. Additionally, the targeted reduction in the annual phosphorus load to lakes will result in the application of phosphorus controls that also address seasonal variation. For example, certain control practices such as stabilizing eroding drainage ways or maintaining septic systems will be in place throughout the year while others will be in effect during the times the sources are active (e.g., application of lawn fertilizer).

Implementation: The implementation plan or watershed management plan to achieve the TMDL reductions will vary from lake to lake depending on the type of point source and nonpoint source loads for a given situation. For nonpoint source reductions the implementation plan will depend on the type and degree of development in the watershed. While the impacts from development cannot be eliminated, they can be minimized by prudent "good housekeeping" practices, known more formally as best management practices (BMPs). Among these BMPs are control of runoff and erosion, well-maintained subsurface wastewater disposal systems and reductions in the use of fertilizers in residential areas, parks, cemeteries and golf courses and agriculture. Activities close to the water body and its tributaries merit special attention for following good land management practices. In addition, there are some statewide efforts that provide part of an overall framework. These include the legislation that curbed the phosphorus content of many cleaning agents, regulate application of plant nutrients on agricultural lands, turf, and lawns (330 CMR 31.0), revisions to regulations that encourage better maintenance of subsurface disposal systems (Title 5 septic systems), and the Rivers Protection Act that provides for greater protection of land bordering water bodies. In some cases, structural controls, such as detention ponds, may be used to reduce pollution loads to surface waters.

Although the land use approach gives an estimate of the magnitude of typical phosphorus export from various land uses, it is important to recognize that nonpoint source phosphorus pollution comes from many discrete nonpoint sources within the watershed. Perhaps the most common phosphorus sources in rural areas are associated with soil erosion and use of phosphorus fertilizers. Soils tend to erode most rapidly following land disturbances such as construction, gravel pit operations, tilling of agricultural lands, overgrazing, and trampling by animals or vehicles. Erosion from unpaved roads is also a common problem in rural areas. Soils may erode rapidly where runoff water concentrates into channels and erodes the channel bottom. This may occur where impervious surfaces such as parking lots and roadways direct large volumes of water into ditches which begin to erode from either excessive water drainage or poorly designed ditches and culverts. An unvegetated drainage way is a likely source of soil erosion. Cesspools or home septic systems that do not meet Title 5 requirements may also be a source if located close to surface waters.

Discrete sources of nonpoint phosphorus in urban, commercial and industrial areas include a variety of sources that are lumped together as ‘urban runoff’ or ‘stormwater’ and may be considered as point sources under wasteload allocations. As many of these urban sources are difficult to identify the most common methods to control such sources include reduction of impervious surfaces, infiltration, street sweeping and other non-structural BMPS as well as treatment of stormwater runoff by structural controls such as detention ponds when this becomes necessary.

Other sources of phosphorus include phosphorus-based lawn fertilizers used in residential areas, parks, cemeteries and golf courses and fertilizers used by agriculture. Manure from animals, especially dairies and other confined animal feeding areas, is high in phosphorus. In some cases, the manure is inappropriately spread or piled on frozen ground during winter months and the phosphorus can wash into nearby surface waters. Over a period of repeated applications of manure to local agricultural fields, the phosphorus in the manure can saturate the ability of the soil to bind phosphorus, resulting in phosphorus export to surface waters. In some cases, cows and other animals including wildlife such as flocks of ducks and geese may have access to surface waters and cause both erosion and direct deposition of feces to streams and lakes.

Perhaps the most difficult source of phosphorus to account for is the phosphorus recycled within the lake, from the lake sediments. In most stratified north temperate lakes, phosphorus that accumulated in the bottom waters of the lake during stratification is mixed into surface waters during spring and fall turnover when the lake mixes. Phosphorus release from shallow lake sediments may be a significant input for several reasons. These reasons include higher microbial activity in shallow warmer waters that can lead to sediment anoxia and the resultant release of iron and associated phosphorus. Phosphorus release may also occur during temporary mixing events such as wind or powerboat caused turbulence or bottom feeding fish, which can resuspend phosphorus rich sediments. Phosphorus can also be released from nutrient ‘pumping’ by rooted aquatic macrophytes as they extract phosphorus from the sediments and excrete phosphorus to the water during seasonal growth and senescence (Cooke et al., 2005; Horne and Goldman, 1994). Shallow lakes also have less water to dilute the phosphorus released from sediment sources and thus the impact on lake water concentrations is higher than in deeper lakes.

The most important factor controlling macrophyte growth appears to be light (Cooke et al., 2005). Due to the typically large mass of nutrients stored in lake sediments, reductions in nutrient loadings by themselves are not expected to reduce macrophyte growth in many macrophyte-dominated lakes, at least not in the short-term. In such cases additional in-lake control methods are generally recommended to directly reduce macrophyte biomass. Lake management techniques for both nutrient control and macrophyte control have been reviewed in “Eutrophication and Aquatic Plant Management in Massachusetts. Final Generic Environmental Impact Report” (GEIR) and the accompanying “Practical Guide” (Mattson et al., 2004; Wagner, 2004) https://www.mass.gov/service-details/lakes-and-ponds-program-publications .

The MassDEP will support in-lake remediation efforts that are cost-effective, long-term and meet all environmental concerns, however, instituting such measures will be aided by continued Federal (via U.S. Environmental Protection Agency, or EPA), and State grant support.

Financial support for various types of implementation is potentially available on a competitive basis through both the nonpoint source (319) grants and the State Revolving Fund (SRF) loan program. The 319 grants require a 40 percent non-federal match of the total project cost although the local match can be through in-kind services such as volunteer efforts. Other sources of funding include the 604b Water Quality Management Planning Grant Program and the Community Septic Management Loan Program. Information on these programs is available on the MassDEP website: Water Resources Grants and Financial Assistance.

Because the lake restoration and improvements can take a long period of time to be realized, follow-up monitoring is essential to measure interim progress toward meeting the water quality goal and guide additional BMP implementation. This can be accomplished through a variety of mechanisms including volunteer efforts. Recommended monitoring may include Secchi disk readings, lake total phosphorus, macrophyte mapping of species distribution and density, visual inspection of any structural BMPs, coordination with Conservation Commission and Board of Health activities and continued education efforts for citizens in the watershed.

Description of Waterbodies and Problem Assessment

All waterbodies covered in this study are classified by MassDEP as public water supplies and outstanding resource waters. The waterbodies in the study area, their class and 2018/2020 Integrated List information are presented in Table 1. West Monponsett Pond is a 125 Ha (308 acre) *hypereutrophic* pond located in Halifax/Hanson, MA. The pond is at an elevation of 52 feet above mean sea level (AMSL). West Monponsett Pond has been suffering the symptoms of a eutrophic lake with cyanobacteria blooms and is on the 2018/2020 Integrated List for Chlorophyll-a, Harmful Algal Blooms, Phosphorus (Total), Transparency/Clarity and several non-native aquatic plants (a non-pollutant). The high levels of total phosphorus (TP) result in excessive algal growth and impair designated uses of the waters. The lake is naturally tea colored due to the high amount of dissolved organic material in the lake, presumably due to the large areas of wetlands and forested wetlands in the watershed. The federal Clean Water Act requires that such waters be listed on the 303d list in Category 5 (impaired) and that a Total Maximum Daily Load report be developed and submitted to the EPA. The modeling approach and implementation in this report follow the approach used in the previously approved TMDL for White Island Pond (MassDEP, 2010a).

East Monponsett Pond is a 110 Ha (272 acre) pond also located in the Town of Halifax, MA at an elevation of 52 feet (AMSL). This waterbody is included in the TMDL for mercury in fish tissue (Northeast States, 2007). East Monponsett Pond is a mesotrophic tea colored pond that is experiencing some cultural eutrophication but is generally in better condition than the west basin. It also suffers from occasional blooms and is listed as impaired for Chlorophyll-a, Harmful Algal Blooms, and several non-native aquatic plants (a non-pollutant, not requiring a TMDL)

Stetson Pond is a 38.1 hectare pond located in Pembroke, MA. Stetson Pond is tributary to East Monponsett Pond via Stetson Brook, and as such is part of the Monponsett Pond system. The pond is at an elevation of 61 feet (AMSL). The pond was listed on the 2018/2020 Integrated List (MassDEP 2021) for Dissolved Oxygen, Harmful Algal Blooms, Phosphorus (Total), and several non-native aquatic plants (a non-pollutant). The Massachusetts Department of Public Health (MassDPH) posted signage warning people to avoid contact with the water for 37 days in 2010 due to elevated concentrations of cyanobacteria.

White Oak Reservoir, an impoundment along White Oak Brook, is 6 hectares in size, a maximum depth of 2.3m (7.5 feet) and is located at an elevation of approximately 60 feet (AMSL). The stream was impounded sometime in the early 20th century to provide water for nearby cranberry bogs. In surveys of White Oak Reservoir by MassDEP it was noted that the pond exceeds the 25% threshold, as established in the CALM (MassDEP 2016) for non-rooted macrophyte cover (duckweed). White Oak Reservoir is listed as impaired for Nutrient/Eutrophication Biological Indicators and Phosphorus (Total) in the 2018/2020 Integrated List (MassDEP 2021). This TMDL will include loading limits for White Oak Reservoir, which is tributary, via White Oak Brook to West Monponsett Pond.

Table 1.Description of waterbodies in study area and 2018 Integrated List information

Waterbody Name	Water Body Segment	Description and Location	Size (acres)[1]	Class	Qualifier	303d Cat.	2018/2020 Integrated List Impairment Causes
Stetson Pond	MA62182	Pembroke	88.0	A	PWS\ORW	5	Harmful Algal Blooms, Oxygen, Dissolved, Phosphorus (Total), Curly-Leaf Pondweed[3], Eurasian Water Milfoil[3], Myriophyllum Spicatum[3], Fanwort, Water Chestnut
Monponsett Pond	MA62218	[East Basin] Halifax	247	A	PWS\ORW	5	Chlorophyll-a, Harmful Algal Blooms, Mercury in Fish Tissue[2], Curly-Leaf Pondweed[3], Eurasian Water Milfoil[3], Myriophyllum Spicatum[3], Fanwort[3], Non-Native Aquatic Plants[3]
White Oak Reservoir	MA62157	Hanson	13.00	A	PWS\ORW	5	Nutrient/Eutrophication Biological Indicators, Phosphorus (Total), Fanwort[3]

Waterbody Name	Water Body Segment	Description and Location	Size (acres)[1]	Class	Qualifier	303d Cat.	2018/2020 Integrated List Impairment Causes
Monponsett Pond	MA62119	[West Basin] Halifax/ Hanson	283.00	A	PWS\ORW	5	Chlorophyll-a, Harmful Algal Blooms, Phosphorus (Total), Transparency/ Clarity, Eurasian Water Milfoil[3], Myriophyllum Spicatum[3], Fanwort[3]
Additional waters outside of study area							
Silver Lake	MA94143	Pembroke/ Plympton/ Kingston	616.00	A	PWS\ORW	4c	Dissolved Oxygen, Fish Passage Barrier[3], Flow Regime Modification[3]
Jones River	MA94-12	Headwaters, outlet Silver Lake, Kingston to former dam (NATID:MA 00396) near Wapping Road, Kingston.	4.10 mile	B		5	Algae, Aquatic Plants (Macrophytes), Dissolved Oxygen Turbidity, Dewatering[3], Fish-Passage Barrier[3],
Stump Brook[4]	--	--	--	--	--	--	--

1- note these sizes are regulatory sizes used by MassDEP in the 303d list, for purposes of TMDL modeling the 1:25,000 Hydrography layer areas were used.
2 -TMDL approved for mercury in fish (Northeast States 2007). EPA TMDL #33880.
3- Not a pollutant, no TMDL required.
4-Stump Brook has not been assessed.

Flow Issues

The natural surface water flow pattern is from Stetson Pond south via Stetson Brook to East Monponsett Pond and then west through a culvert under Route 58 to West Monponsett Pond (Figure 1). In the northwest part of the watershed, White Oak Brook flows into White Oak Reservoir, then continues south to West Monponsett Pond. Stump Brook is the outlet on the west side of West Monponsett Pond (Figure 1).

The City of Brockton was authorized to use Silver Lake as a public water supply (PWS) as far back as 1899. In 1964 the Massachusetts Legislature approved Act 371 to allow a diversion from Monponsett Pond to Silver Lake (Figure 1) to supplement the water supply with some restrictions. Diversions occur generally only in the fall, winter and spring between October and June. During times of diversion the natural flow direction between the ponds (from East Monponsett Pond to West Ponponset Pond) may be reversed (West Monponsett Pond to East Monponset Pond). There are concerns that the potentially toxic cyanobacterial blooms and excess nutrients in West and East Monponsett Ponds will flow into Silver Lake and the altered hydrology may impact both West and East Monponsett Ponds as well as their downstream outlet, Stump Brook which suffers from low flows (Princeton Hydro, 2013; Horsley Witten, 2015). In addition, the use of Silver Lake as a PWS results in only brief outflows to the Jones River (Princeton Hydro, 2013). The hydraulic diversions result in less Silver Lake water to be discharged to the headwaters of the Jones River, which itself is listed as impaired on the 303d list of impaired waters due to low flows. In 1995 MassDEP and the City of Brockton signed an Administrative Consent Order (ACO) which required the City to develop a Comprehensive Water Management Plan and a strategy to reduce environmental impacts. Both ponds are highly influenced by both their surrounding landuse and the ponds use as a public water supply source. The diversion of water from East Monponsett Pond affects the hydrology of both West and East Monponsett Ponds and increases the risk of introducing cyanobacteria to the public water supply source, Silver Lake.

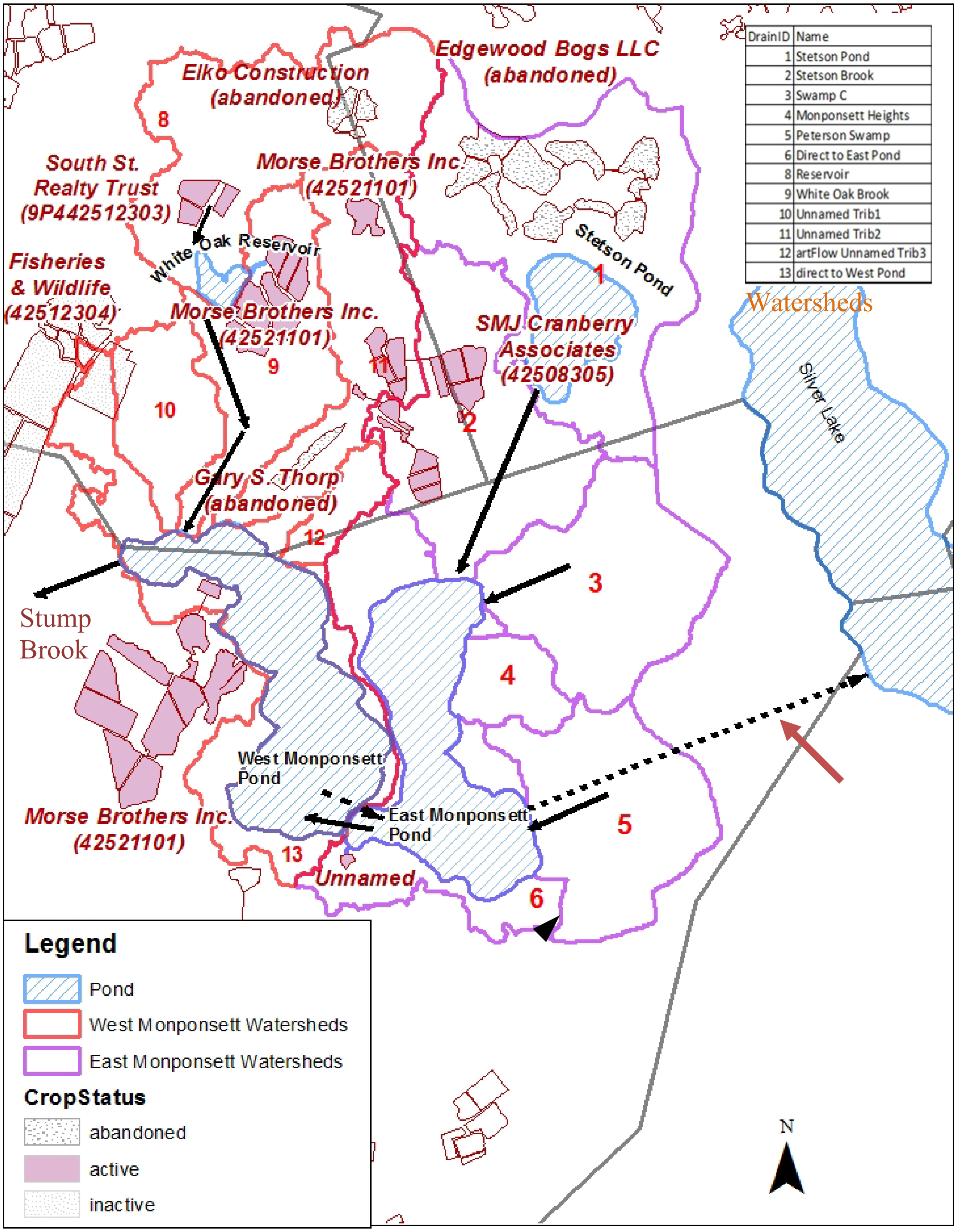

Figure 1: Flow Diagram for TMDL Study Area

Watershed Characterization

The East and West Monponsett Ponds watershed area is 1,555 hectares (including the ponds' surface area) (Figure 2). Using the MassGIS Landuse (MassGIS 2005) data layer, the landuse in the TMDL study area was analyzed. The most common landuse categories are forest, water (including ponds) and low density residential which compromise approximately 26%, 20% and 15% of the overall TMDL study area, respectively. Also of note, are forested wetland, cranberry bog and non-forested wetland which compromise approximately 13%, 8% and 4% of the overall study area, respectively. Landuse categories in the TMDL study area are summarized in Table 2. All the waterbodies covered in this TMDL are part of the Taunton River watershed. Detailed information on the watershed and the lakes are included in Table 3.

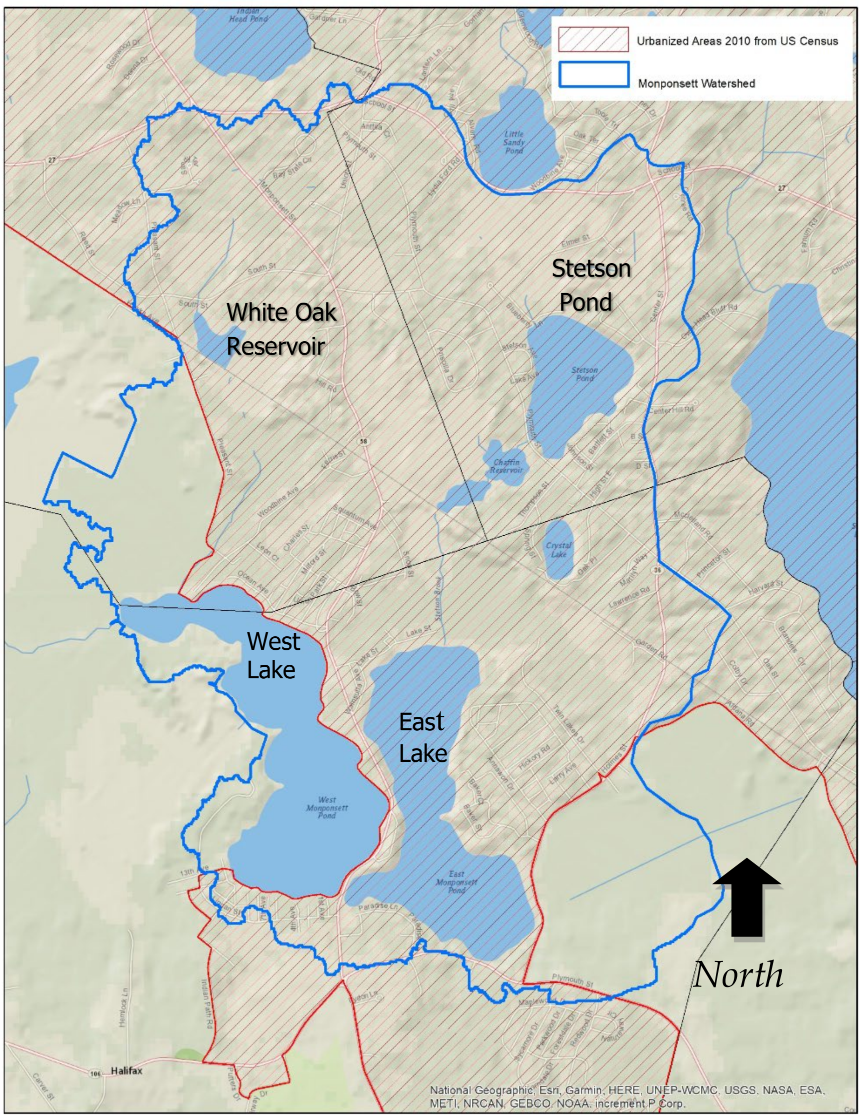

Figure 2. Monponsett Ponds Watershed and TMDL Study Area
Stetson Pond is just east of Plymouth Street and White Oak Reservoir is above West Monponsett just south of South Street. Silver Lake is to the right, outside of the catchment area. Urbanized areas subject to MS4 stormwater permit are shown as hatched. (Map made via ggmap, courtesy Kahle and H. Wickham 2013, base map data© 2016 Google)

Table 2. Summary of the Landuse in the TMDL study area

Landuse Code	Frequency	2005 Landuse Description	Area (hectares)	% Total Study Area
3	82	Forest	400.3	26%
20	19	Water	303.8	20%
13	71	Low Density Residential	239.5	15%
37	99	Forested Wetland	208.4	13%
12	27	Medium Density Residential	131.8	8%
23	18	Cranberry Bog	121.6	8%
4	66	Non-Forested Wetland	58.8	4%
18	2	Transportation	24.7	2%
15	11	Commercial	14.2	1%
10	6	Multi-Family Residential	13.5	1%
38	36	Very Low Density Residential	8.5	1%
11	2	High Density Residential	7.4	<1%
2	4	Pasture	6.8	<1%
6	5	Open Land	5.2	<1%
31	4	Urban Public/Institutional	3.6	<1%
17	5	Transitional	2.1	<1%
16	2	Industrial	2.1	<1%
7	3	Participation Recreation	1.5	<1%
36	1	Nursery	1.0	<1%
		Total	1554.7	

Lake Morphometry

The ponds in this TMDL study are all shallow with maximum depths that range between 2.33 meters in White Oak Reservoir and 9.88 meters in Stetson Pond. Stetson Pond is estimated to have a lake volume of 1.26 x10^6 m^3 (BEC 1993) while East Monponsett Pond has an estimated volume of 2.1x10^6 m^3. White Oak Reservoir with an average depth of only 1.1 meters is estimated to have a volume of approximately 66,000 m^3. The largest pond, West Monponsett Pond, has an estimated volume of 2.61x10^6 m^3 (Princeton Hydro, 2013). Given the shallow depths and inflows to the ponds, all the ponds are well flushed with flushing rates that range from 1.5 lake volumes/year for Stetson to 17.4 lake volumes/year for White Oak Reservoir. It is important to note the modeled flushing rates correspond to an annual time step and do not account for seasonal variations. The diversion was included in the model calibrations but is averaged over the year. The estimated retention time of water measured in days is 247 days for Stetson Pond, 117 days for East Monponsett Pond, 21 days for White Oak Reservoir and 178 days for West Monponsett Pond. A summary of morphometric data, physical characteristics and watershed characteristics for ponds in the study area can be found in Table 3.

Table 3. Select morphometric data, physical characteristics and watershed characteristics for ponds in study area

Parameters			Stetson	East Monponsett	White Oak Reservoir	West Monponsett
Morphometric Data						
	Symbol	units				
Lake Mean Depth	Z	meters	3.3	1.9	1.1	2.1
Maximum Depth	D_M	meters	9.80[1]	3.96[2]	2.33	6.84
Lake Surface Area	SA	hectares	38.1	109.9	6.0	124.6
Lake Volume	V	$meters^3$	1,259,265[1]	2,124,000	65,891	2,610,000
Width at widest point	W_D	meters	657	1143	326	1089
Maximum Length	L_M	meters	889	1957	414	2146
Shoreline Perimeter	S_L	meters	2719	6313	1476	7804
Physical Characteristics						
Retention Time	T	days	247	117	21	178
Flushing Rate	F	flushings/yr	1.5	3.1	17.4	2.1
Watershed Characteristics						
Watershed Area	WA	hectares	242.1	1042.4	166.5	675.4
Watershed: Lake Ratio			6.4	9.5	27.7	5.4
% Watershed Occupied By Lake			16%	11%	4%	18%
Primary Landuse (By%)			Natural	Natural	Low Intensity Development	Natural
Secondary Landuse (By%)			Low Intensity Development	Low Intensity Development	Natural	Low Intensity Development
Tertiary Landuse (By%)			Abandoned Cranberry Bogs	Forested Wetland	Forested Wetland	Forested Wetland

1- BEC (1993), 2 –Princeton Hydro (2013)

<u>Summary of Previous Analysis</u>

Several previous studies have been conducted on the Monponsett Ponds. Over the last few decades while these studies have yielded useful information that contributes to management decisions, some of the information conflicts. Lycott (1987) conducted a comprehensive diagnostic/feasibility study of both East and West Monponsett Ponds. This study included significant sampling of several tributary waterbodies for streamflow, water quality, stormwater outfall sampling, groundwater test well sampling, seepage sampling, macrophyte mapping, and in-lake sampling. In addition, using a mass balance model, an estimate of total phosphorus loading of 793 kg/yr for both East and West Monponsett Ponds was calculated (Lycott 1987, pg. 5-10). This loading included an estimated 378 kg/yr from septic systems or 47.7% of the total load. The next three largest sources of loading included 177 kg/yr from forest land, 168 kg/yr from diffuse residential including stormwater and 53 kg/yr from precipitation. Lycott (1987) estimated outputs from the Monponsett Pond system of 61 kg/yr to Stump Brook and 45 kg/yr to Silver Lake via drinking water diversion.

Princeton Hydro (2013) conducted analysis of water management for the Monponsett Ponds, Furnace Pond and Silver Lake in order to recommend options to improve water quality as well as provide more sustainable flows in Stump Brook. As part of their work they estimated the hydrology of the Monponsett Pond system and modeled both current water quality and water quantity under various management scenarios. Princeton Hydro estimated a current total phosphorus load of 2,431 kg to both ponds and 1,374 kg/yr and 1,057 kg/yr to West and East Monponsett Ponds, respectively. Princeton Hydro also found that for West Monponsett Pond approximately 70% of the entire outflow is routed through the diversion to the east basin (on an annual basis). As a result, approximately 40% of the inflow to East Monponsett Pond consists of the higher nutrient water from West Monponsett Pond.

Horsley Witten (2015) conducted an evaluation of the management of the Stump Brook dam and its effects on the brook's flows and Monponsett Pond levels. As part of their work they modified USGS Modflow groundwater model to predict groundwater flows and model the hydrology of the system. In addition to determining the hydrological effects of different Stump Brook dam management options, they modeled water quality in the ponds based on their possible dam management scenarios using the Lake Loading Response Model (LLRM). Horsley Witten estimated a total phosphorus load of 727 kg/yr to both ponds (185 kg/yr and 542 kg/yr to East and West Monponsett Ponds, respectively). Horsley Witten estimated internal loads during their model calibration process. They estimated internal loading was 381 kg/yr in West Monponsett Pond or approximately 49% of load inputs. Watershed land use loads were 292 kg/yr or approximately 38% of load inputs. Atmospheric deposition and septic loads were estimated to be 50 kg/yr and 53 kg/yr respectively. Export of phosphorus via transfers out of West Monponsett Pond was estimated to be 235 kg/yr.

In addition to estimating current loading to the Monponsett Ponds, Horsley Witten (2015) evaluated several management scenarios. They estimated in the absence of the Brockton water supply diversion, West Monponsett Pond would have a total phosphorus concentration of 57 ppb while East Monponsett Pond would have a total phosphorus concentration of 19 ppb. The impact of diversion is discussed later in this report. The modeled effects of no internal nutrient loading were even more pronounced with estimated total phosphorus concentrations in West and East Monponsett Pond of 37 and 29 ppb. The estimated total phosphorus concentrations in West and East Monponsett Pond respectively were 64 and 4 ppb under the 50% reduction in land loads scenario.

The three previous water quality model attempts for the Monponsett Ponds used a variety of different assumptions and arrived at somewhat different loading estimates as described above and as shown in Table 4. For example, Princeton Hydro (2013) and Lycott (1987) considered Wine Brook Bogs to be part of the West Monponsett Pond watershed while Horsley Witten (2015) did not. There are likely many differences between the different previous water quality modeling efforts. A comprehensive comparison of previous model efforts is beyond the scope of this document but a summary of the three previous water quality modeling efforts, loadings, estimated major loading sources and key model assumptions is provided in Table 4. Previous work has indicated the importance of internal loading and cranberry bogs. Both sources are identified as significant in this TMDL. This TMDL builds on prior work and supports management decisions for nutrient control.

Table 4. Comparison of Previous Water Quality Modeling Efforts for Monponsett Pond.

Previous Work	Model Type	Total Loading (kg/yr)	Top Loading Sources	Septic System Modeling Approach	Key Model Assumptions
Lycott (1987)	Mass Balance	793 (Both Ponds)	Septic Systems, Forest Land, Diffuse Residential (including stormwater), Precipitation	Included houses within twice the average septic system setback (271 houses total)	No internal loading, cranberry bog export coefficient of 0.16 kg/ha/yr, estimated hydraulic discharges for Stump Brook and diversion
Princeton Hydro, LLC (2013)	Various Mass Balance, Unit Area Load for landuse loads	2431 (Both Ponds), 1057 (East), 1374 (West)	Land use, Atmosphere, Septic	Houses within 100 ft included, Estimated per capita loading	Modeled both with current diversion and with no diversion. No internal loading, cranberry bog export coefficient of 9.9 kg/ha/yr
Horsley Witten Group, Inc. (2015)	Mass Balance (Lake Loading Response Model)	727 (Both Ponds), 185 (East), 542 (West)	Internal Loading, Watershed Landuse, Septic, Atmospheric	Houses within 100 ft (151 Houses total)	Includes diversion and net TP transfer out of West Monponsett Pond of 235 kg/yr

Recent aluminum treatments for West Monponsett Pond

To reduce the severity of cyanobacteria blooms in West Monponsett Pond, the pond was treated with light doses of aluminum sulfate and sodium aluminate (alum) solutions in a 2:1 ratio during the summer of 2013, 2015, 2016, 2017, 2018 and 2019. Due to concerns about three state listed aquatic species of concern, additional testing was required as part of the Wetland Protection Act Order of Conditions. The freshwater mussels *Leptodea orchracea* (Tidewater mucket) and *Ligumia nasuta* (Eastern Pondmussel) are rare species that are listed by the Massachusetts Natural Heritage and Endangered Species Program (NHESP) as “Special Concern”. The dragonfly *Neurocordulia obsolete* (Umber Shadowdragon) is also rare species listed as “Special Concern” by the NHESP.

The aluminum dose was applied over a period of days between June 4 and June 7, 2013 using 1,300 gallons of alum plus 6,500 gallons of sodium aluminate (Lycott, 2014). Assuming the treatment spread across the bottom of West Monponsett Pond the effective concentration of aluminum would be about 3.4 mg/l or 7.1 g/m^2. The monitoring study noted some increases and some decreases in mussel density before and after the treatment. A video showed no evidence of obvious stress responses and the authors could not say that the treatment had any effect on the juveniles or adult mussels (Biodrawversity, 2014). Similarly, the same study examined emergence of the dragonflies over several years and found no evidence of any immediate adverse impacts on *N. obloseta* or the dragonfly community, in general (Biodrawversity, 2014). A similar study on mussels in 2015 determined that conclusions were difficult to draw but short-term impacts appeared to be minimal (ACT, 2015).

The pond did not have any aluminum treatments in 2014. A second year of light dose treatments occurred over two months from June 2, 2015 to July 23, 2015 in West Monponsett Pond. This time the dose was 9,000 gallons of aluminum sulfate and 4,500 gallons of sodium aluminate resulting in an effective dose of about 2.3 mg/l (4.9 g/m^2). Thus the total dose of aluminum to the bottom for 2013 and 2015 was 12 g/m^2. An additional alum treatment of 3.2 g/m^2 was conducted in the summer months of 2016. Using EPA 319 grant funding the Town of Halifax received permission to add additional alum to West Monponsett in 2017. For 2017 the total dose of aluminum to the bottom was 17 g/m^2, in 2018 it was 10 g/m^2, and in 2019, 8 g/m^2. The estimated total buffered alum treatment through 2019 for West Monponsett Pond is approximately 50 g/m^2 Al. Water quality data for 2018 and 2019 from West Monponsett Pond shows a continued downward trend in total phosphorus.

Water Quality Trends

As described above the general thresholds that are noted in the CALM document are a target of 1.2 m Secchi disk transparency, dissolved oxygen of 5 mg/l, 16 ppb chlorophyll *a*, 25% or less coverage of duckweed and cyanobacteria densities less than 70,000 cells/mL. The trends in the data will be discussed in downstream order, from Stetson Pond, East Monponsett Pond, White Oak Reservoir and West Monponsett Pond.

Stetson Pond was sampled in 1988 for a diagnostic feasibility study and they reported *Anabaena* blooms lowering the Secchi disk transparency to 0.8 m (BEC, 1993). MassDEP sampled the pond on one visit in late summer of 2003 and sampled the pond again in the summer of 2015 during 4 monthly visits. Total Phosphorus for all three surveys, is shown in Figure 3. Note the high TP concentrations reported in Stetson Pond in 1987 (BEC, 1993). A large decline in TP was observed following the sale of the bogs to the town and later abandonment of cranberry operations at the 85.4 acre Edgewood Bogs to the north of Stetson Pond (McLaughlin, 2016). Despite the reductions in TP, the chlorophyll *a* concentrations show no improvement (Figure 4) with the highest chlorophyll *a* concentrations found during the September 2015 sampling date. Stetson Pond was also monitored for cyanobacteria and records indicate the pond was posted with a warning of a cyanobacteria bloom that lasted 37 days in late summer of 2010 (MassDPH, 2014) The median Secchi disk transparency shows slightly less transparency in 2015, but the range of readings show the recent Secchi disk transparencies are maintaining transparency greater than the 1.2 m threshold (Figure 5). A hypolimnion was noted on August 2015 sampling date and temperature stratification was found during the summer (Appendix C, Figure C11-C12).

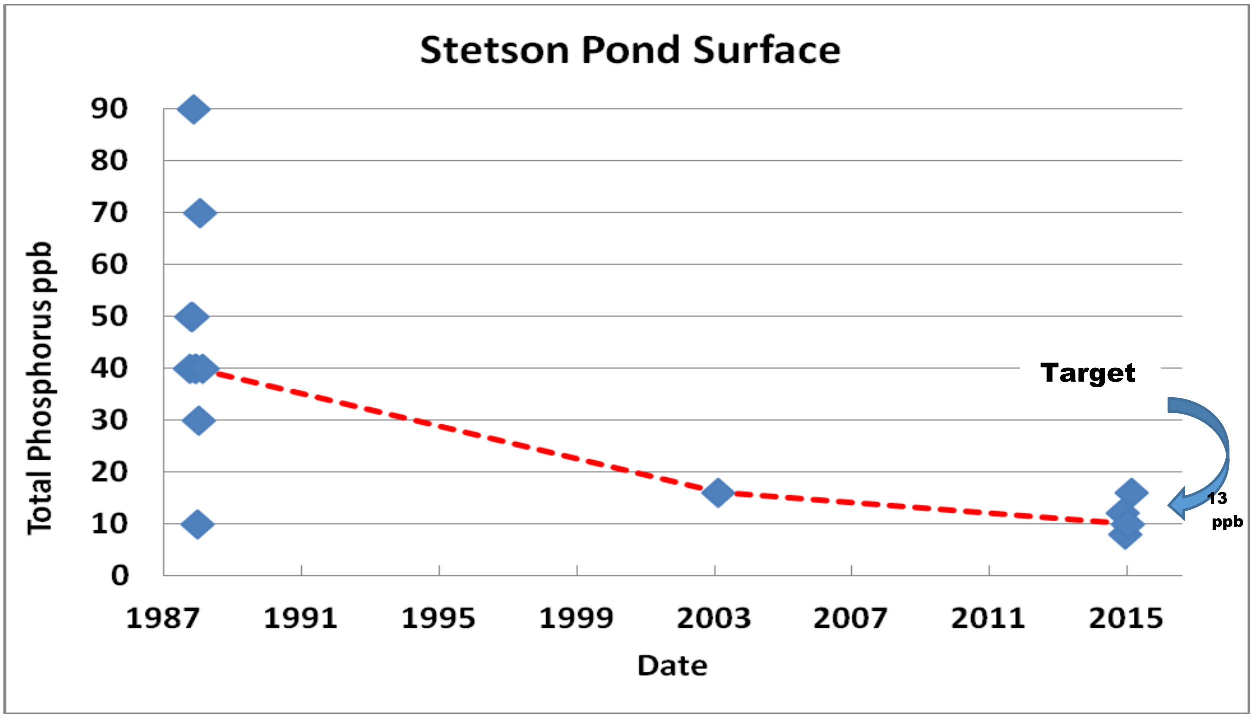

Figure 3. Stetson Pond Surface Total Phosphorus. Summer median values are indicated by the dashed line.

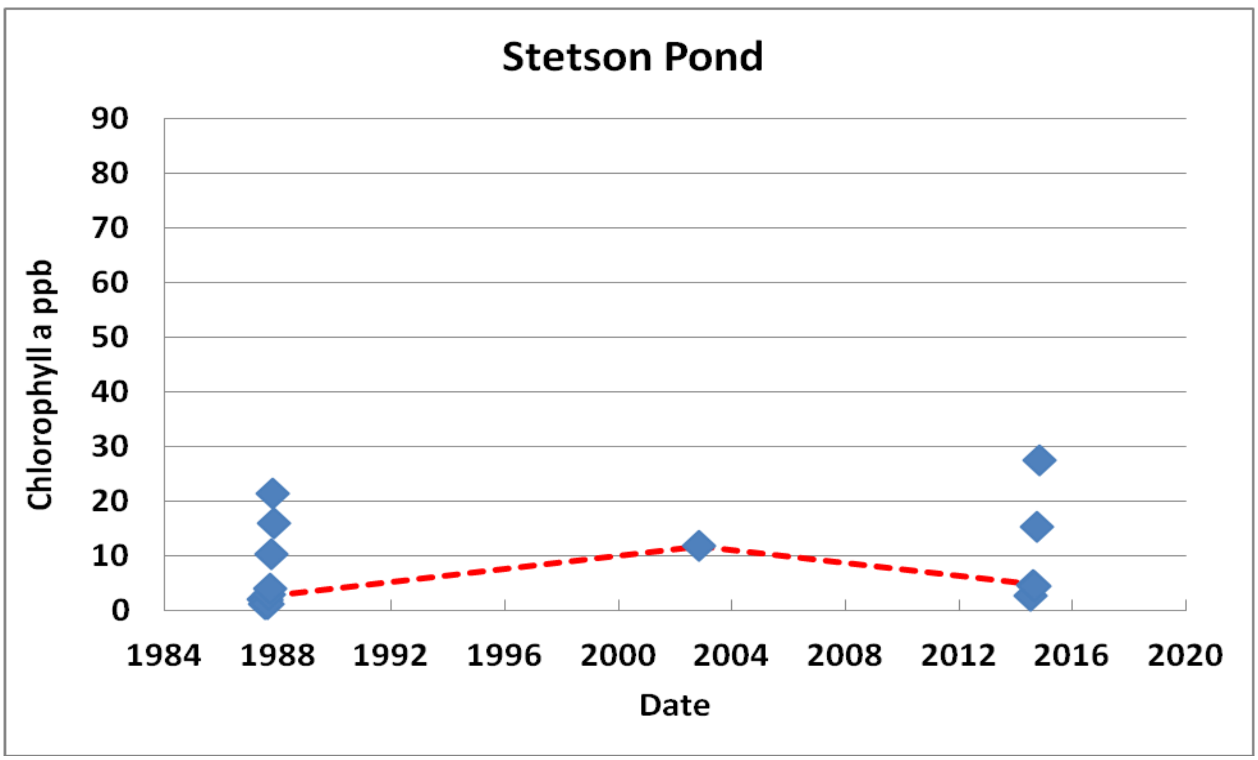

Figure 4. Stetson Pond Chlorophyll *a* . Summer median values are indicated by the dashed line.

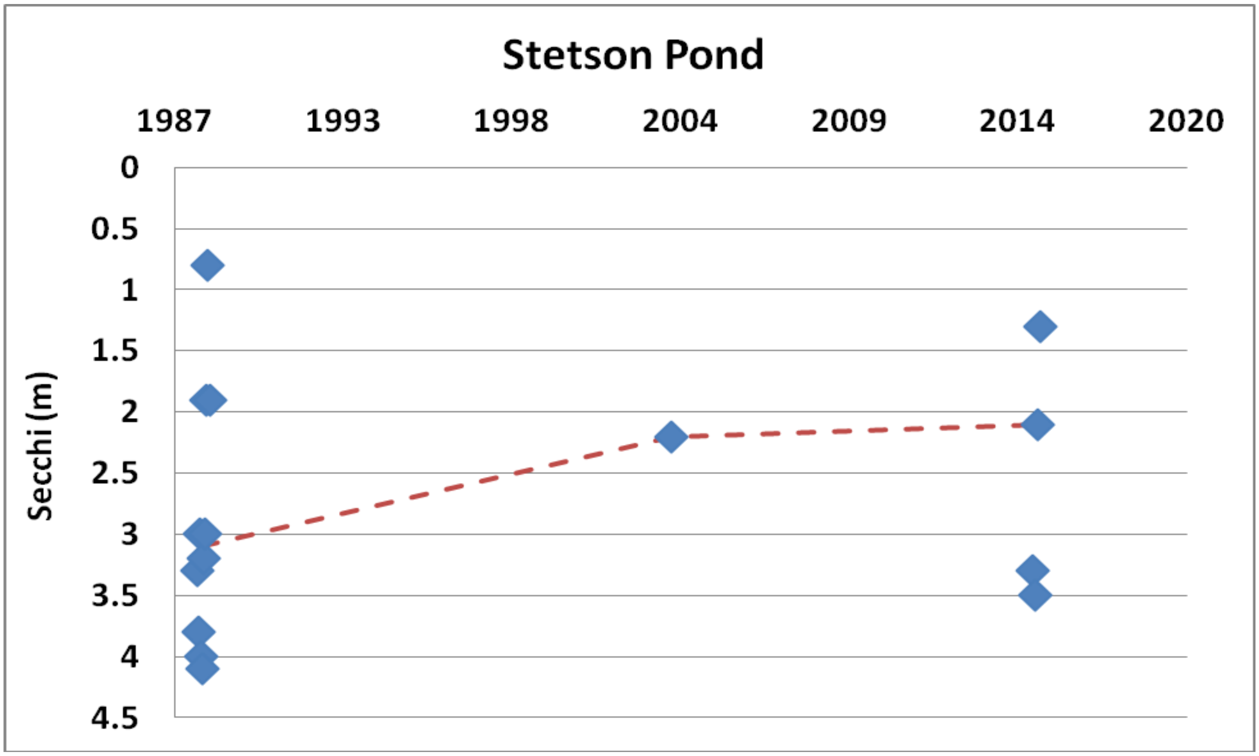

Figure 5. Stetson Pond Secchi disk transparency. (Note y axis reversed). Summer median values are indicated by the dashed line.

East Monponsett Pond was sampled by MassDEP during the summers of 2001 and 2009 through 2015. The TP concentrations have been relatively constant but with a recent decline since 2013 (Figure 6). A slight drop in concentration was also noted in 2010 and is associated with a dry summer. The chlorophyll *a* concentration shows more variability with generally higher concentrations (above the 16 ppb guidance threshold) in 2009-2014 (Figure 7). In 2015, there was a marked improvement. Secchi disk transparency in East Monponsett (Figure 8) follows the trends in chlorophyll *a*, noted above. The mean transparency was near the 1.2 m threshold in 2009-2010 except for 2010 discussed above. Note that the transparency was markedly improved to nearly 3 meters in 2015. East Monponsett Pond was generally not noted to be hypoxic at depth and did not exhibit temperature stratification (Appendix C, Figures C13-C15). The pond also had frequent and/or prolonged algal blooms between 2011 and 2014 and was posted between 28 and 81 days each bathing season (MA DPH, 2014).

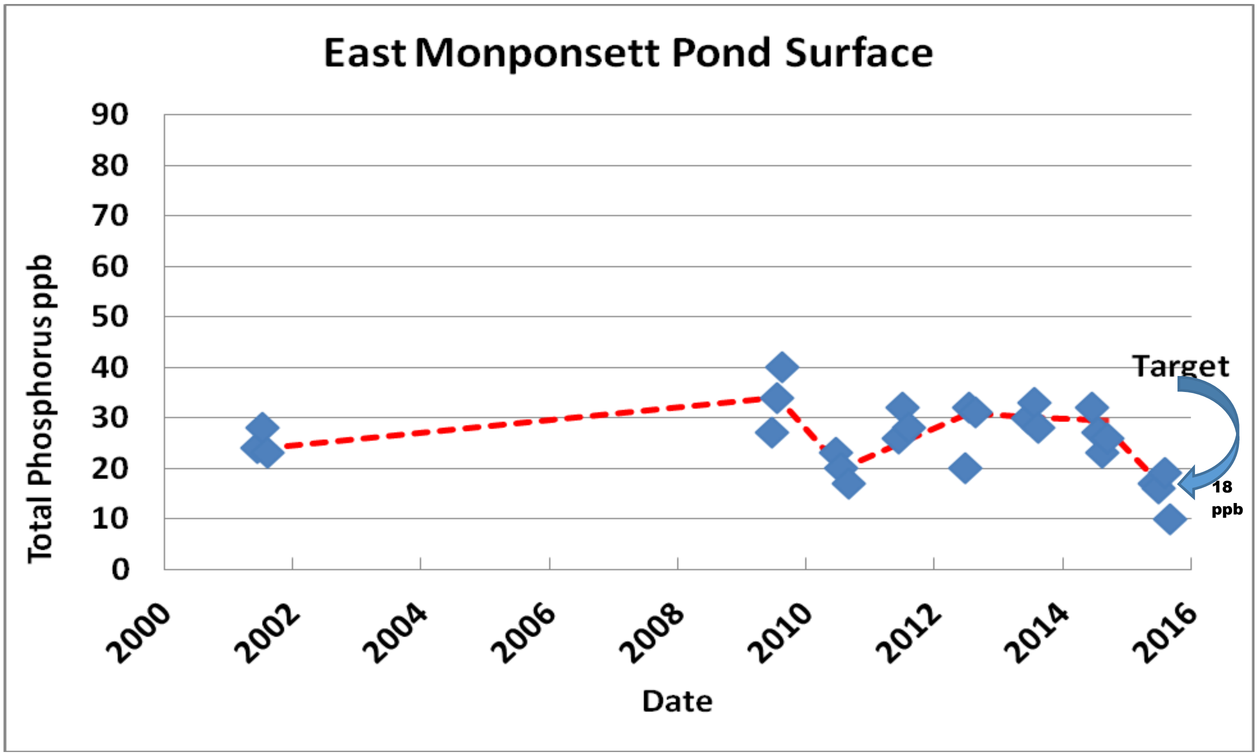

Figure 6. East Monponsett Pond Surface Total Phosphorus. Summer median values are indicated by the dashed line.

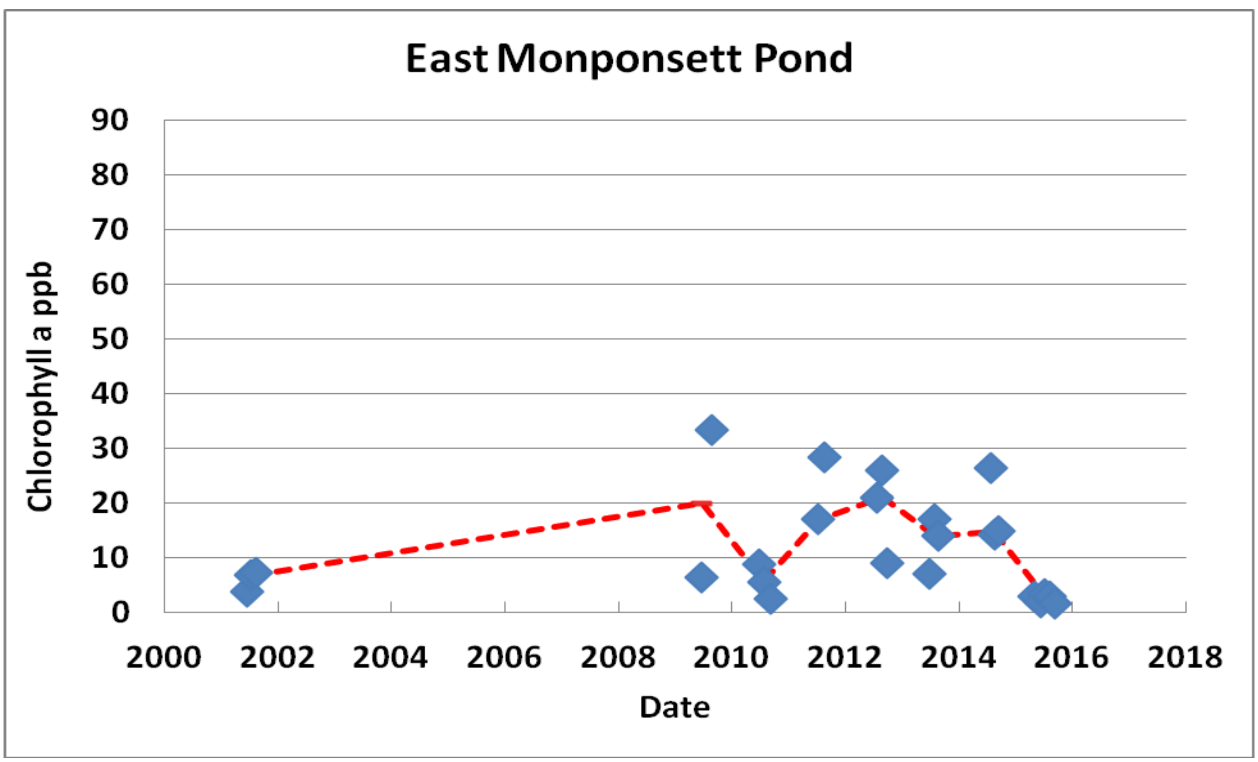

Figure 7. East Monponsett Pond Chlorophyll *a* . Summer median values are indicated by the dashed line.

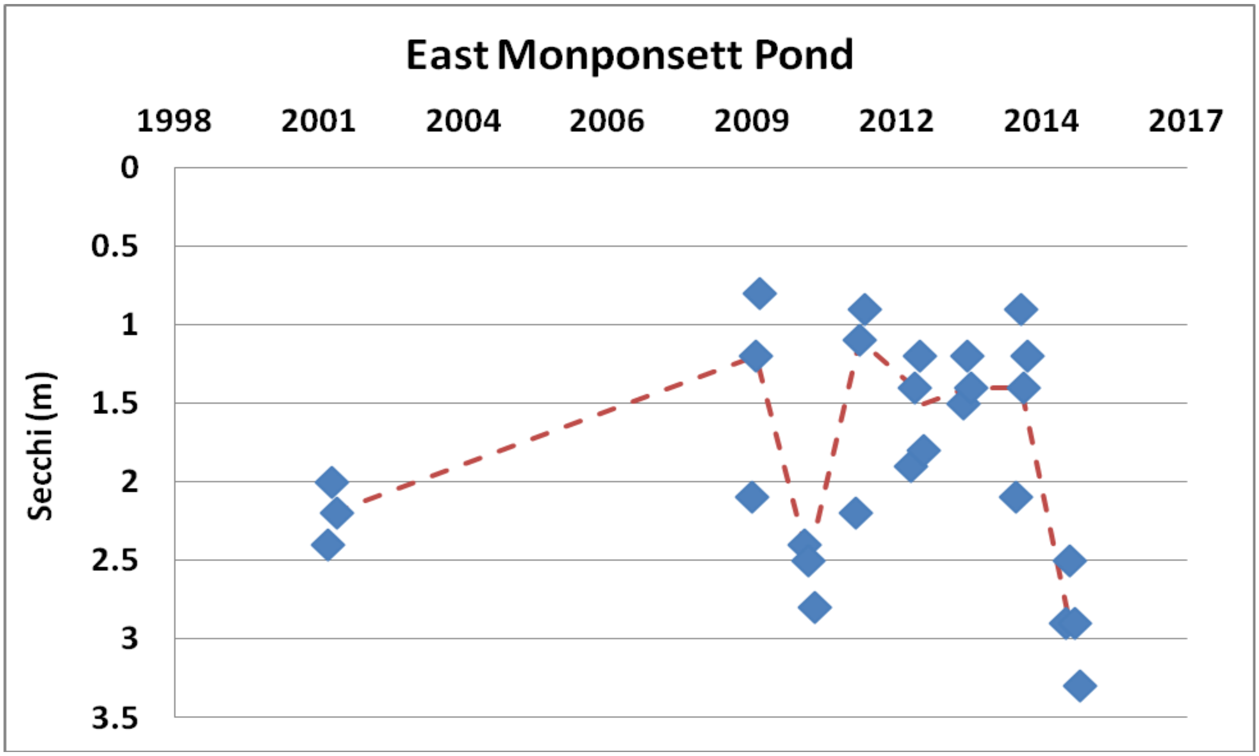

Figure 8. East Monponsett Pond Secchi disk transparency. (Note y axis reversed). Summer median values are indicated by the dashed line.

White Oak Reservoir was sporadically sampled for various parameters in 2009-2015 with no clear trends in TP or chlorophyll *a* (Figure 9, Figure 10). Median Secchi disk transparency did improve to 1.5 m (just above the 1.2 m threshold) in 2015 (Figure 11). The White Oak Reservoir was often noted in 2015 to have a dense whole lake plant coverage which consisted of *Cerotophyllum*, *Cabomba caroliniana*, *Wolffia* and *Lemna minor*. In past years the *Lemna minor* (duckweed) coverage was observed to be an impairment (>25%) to aquatic life support and a candidate for listing on the impaired waters list in need of a TMDL. In 2011 for example the White Oak Reservoir was observed to be 30%, 75% and 40% covered by duckweed on visits in June, July and August, respectively. During the 2015 sampling season duckweed cover began around 1% of the surface area of the White Oak Reservoir in May and by the end of the sampling season in September covered approximately 35% of the reservoir's surface area. Steffenhagen *et al.* (2012) have found that *Lemna minor* and *Ceratophyllum* can incorporate a significant amount of in pond phosphorus in their standing stock. For this reason, even though the median summer TP was only 35 ppb in 2015 (Figure 9), the true concentration may be as high as 50 ppb if the mass of non-rooted macrophytes is included.

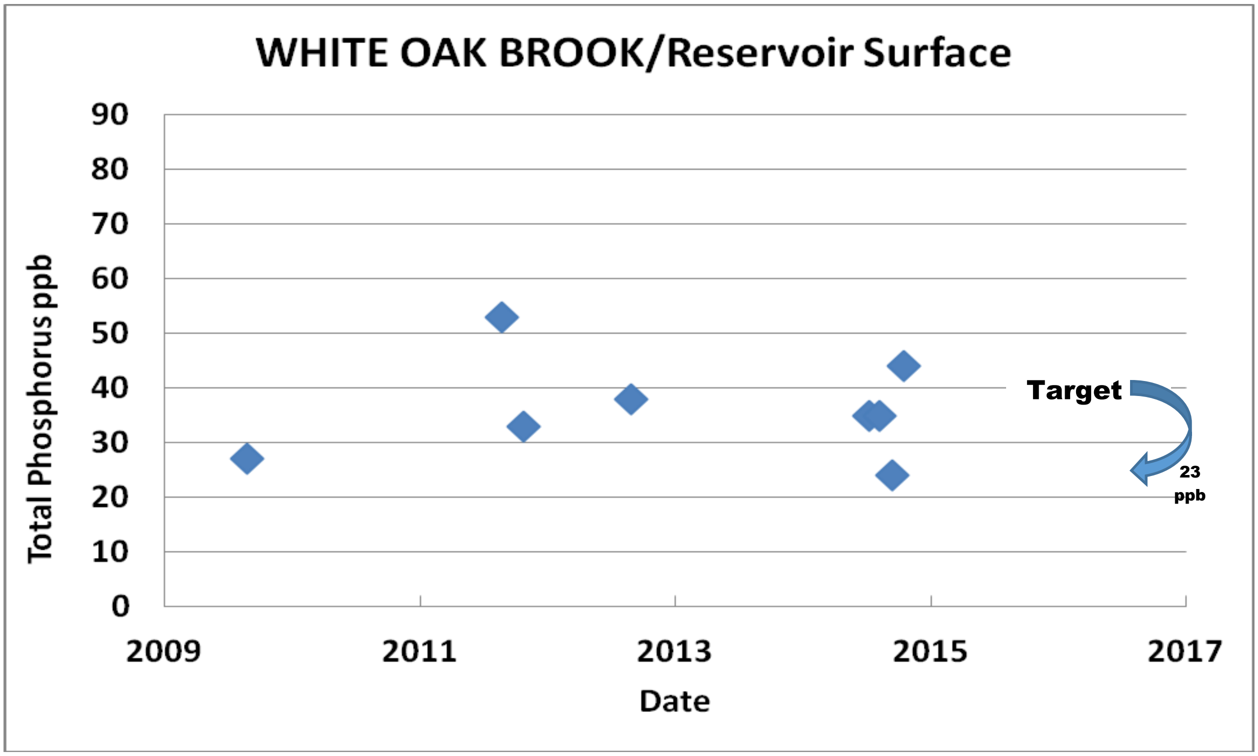

Figure 9. White Oak Reservoir Surface Total Phosphorus. Not enough data to compute summer median data.

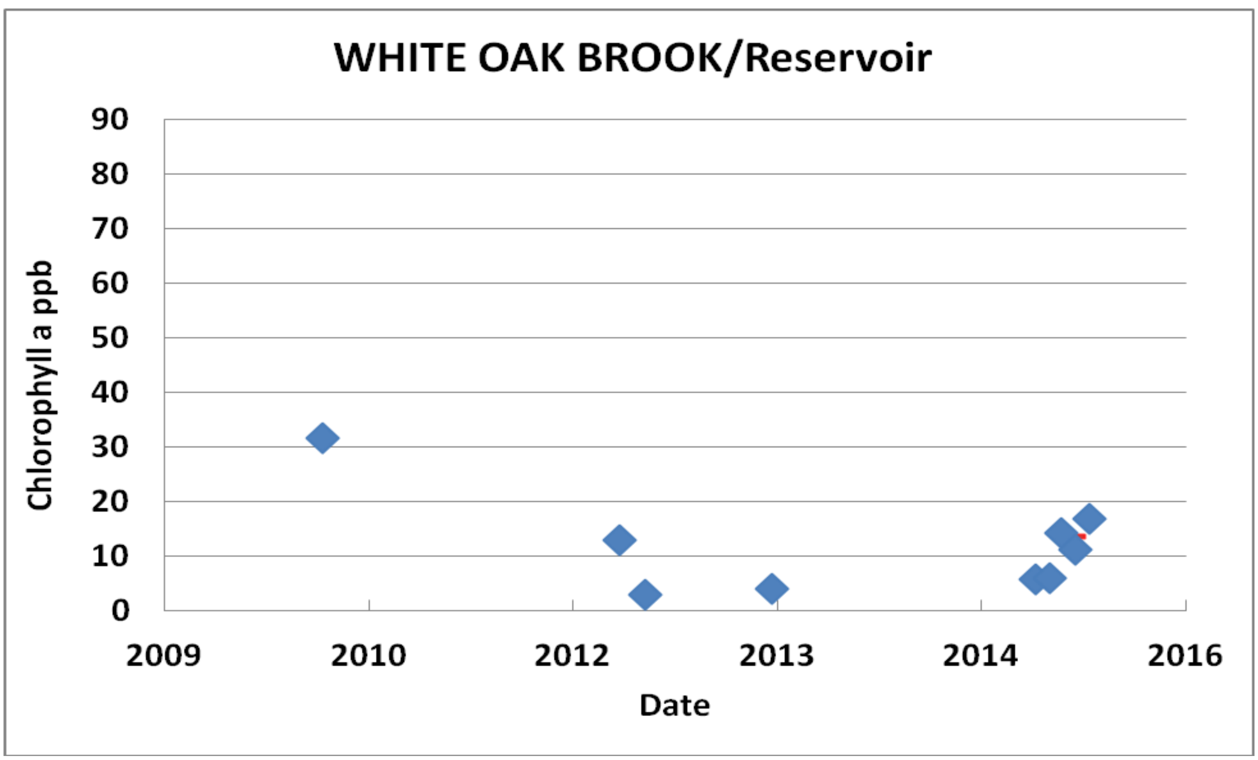

Figure 10. White Oak Reservoir Chlorophyll *a* . Not enough data to compute summer median.

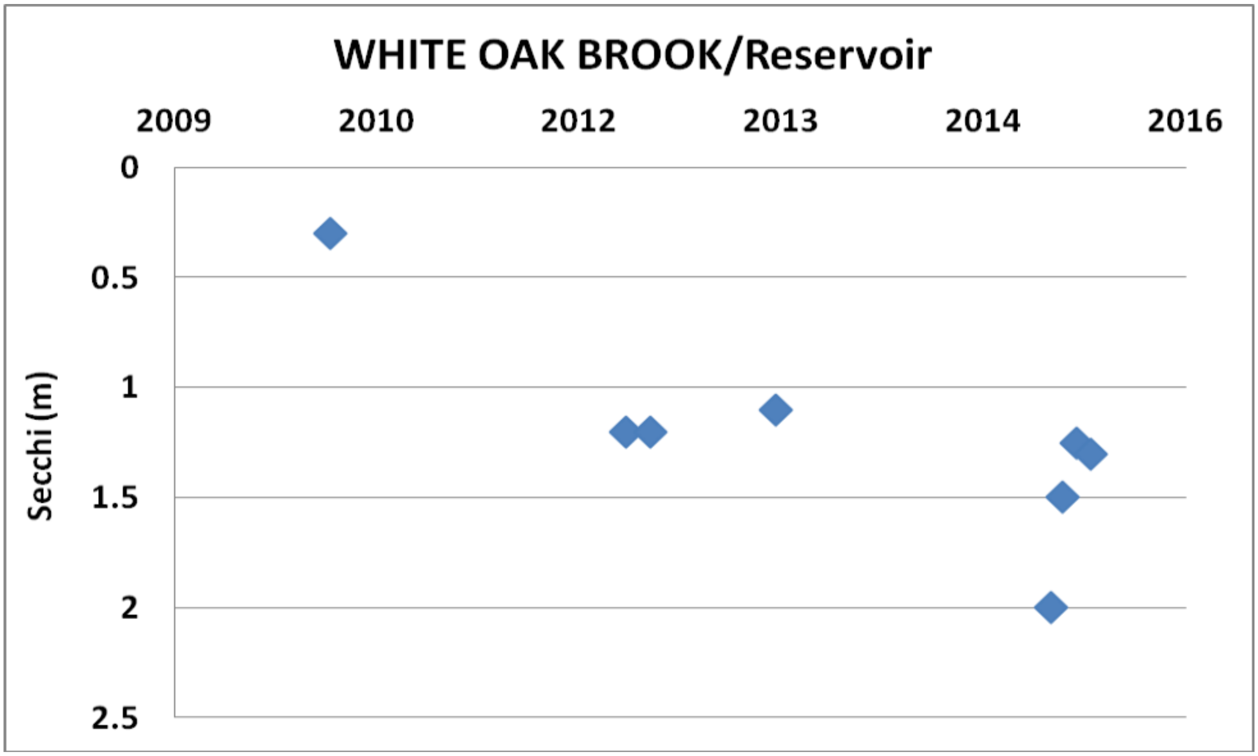

Figure 11. White Oak Reservoir Secchi disk transparency. (Note y axis reversed). Not enough data to compute summer median.

West Monponsett Pond was sampled in the summers of 1985 and again in 2007 by Lycott (1987, 2007) and both sets of data are summarized in Lycott (2007). Unfortunately, Lycott sampled at both the surface and one foot off the bottom (indicated as deep), but the report cites the exact same results in Table A as Surface and in Table B as Deep so it is unclear where the samples came from (Lycott, 2007) but in either case the results were very high TP with one sample exceeding 1,000 ppb.

MassDEP sampled West Monponsett Pond on the same days as East Monponsett Pond in the summers of 2001 and 2009 through 2015. The June-August median TP concentration was 57 ppb in 2001 and was 70 ppb in 2009 (Figure 12). TP concentrations dropped after 2009 and the medians were 54 ppb in both 2011 and 2012. A t-test on the mean summer TP from the combined 2009 and 2010 data compared to the combined 2011 and 2012 data show a significant decline of 12.2 ppb (a=0.026). The 23 percent decline in median lake TP is coincident with a 71 percent reduction in phosphorus fertilizer rates (from 28.6 lb/acre to 8.2 lb/acre) at upstream Morse Brothers cranberry bog #19 and a 61 percent reduction (from 17.3 lb/acre to 6.8 lb/acre) at the small, 2 acre section of their Winebrook Bog next to the lake over the years 2008-2014 (DeMoranville, 2016b). An additional drop in TP concentrations can be seen in 2013 and 2015 that is coincident with the aluminum treatment described above. Some recovery in TP concentrations can be seen in 2014 during a year with no aluminum treatment (Figure 12).

Despite the reductions in West Monponsett TP concentrations between 2009 and 2013, the chlorophyll *a* concentrations appeared to increase during that time period as shown in Figure 13 reaching a median of just over 70 ppb in 2013, greatly exceeding the target of less than 16 ppb. The chlorophyll *a* concentrations tracked the TP concentrations and the June-August 2015 median chlorophyll *a* concentration declined to 11.5 ppb. A large bloom occurred in August-September that exceeded 40 ppb (Figure 13) resulting in the bloom shown on the cover of this report. The Secchi disk transparency also tracks the TP and chlorophyll *a* trends but the median summer values have generally been less than the 1.2 m target (Figure 14). Transparency improved following the aluminum treatment in 2015 and resulted in the June-August median slightly beating the target. Again, the late bloom in August and September resulted in poor transparencies for those months.

West Monponsett Pond was generally not noted to be hypoxic at depth and did not exhibit temperature stratification (Appendix C, Figures C15-C16). This pond has been found to consistently exceed the Massachusetts Department of Health (MA DPH) Advisory level of 70,000 cells/mL. The pond exceeded this level for substantially all the summer and fall seasons during 2013 and 2014 (Appendix C). Cyanobacteria blooms continued to be an issue during the summers of 2015, 2016 and 2017. A reduction in the frequency and severity of cyanobacteria blooms is a key restoration goal for this TMDL. The pond was not posted due to cyanobacteria blooms in 2018 while draft results indicate total phosphorus concentrations remained below the target threshold.

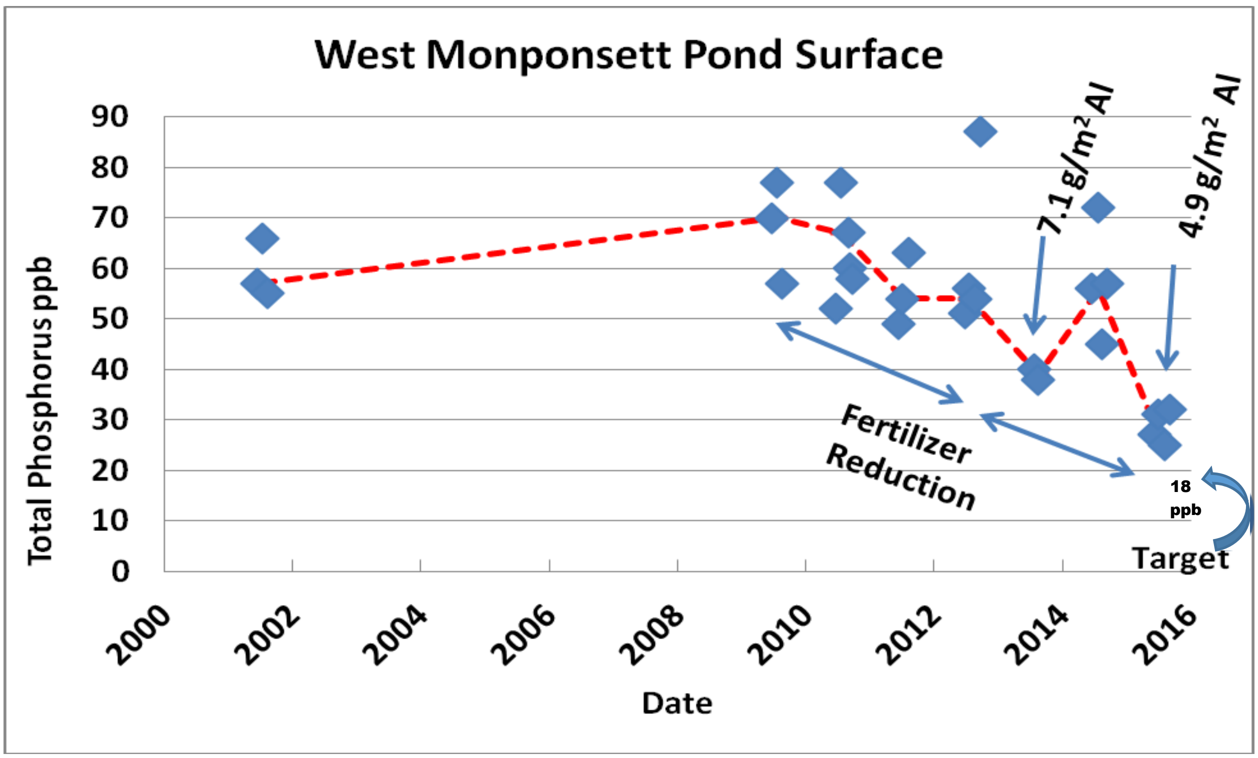

Figure 12. West Monponsett Pond Surface Total Phosphorus. Summer median values are indicated by the dashed line.

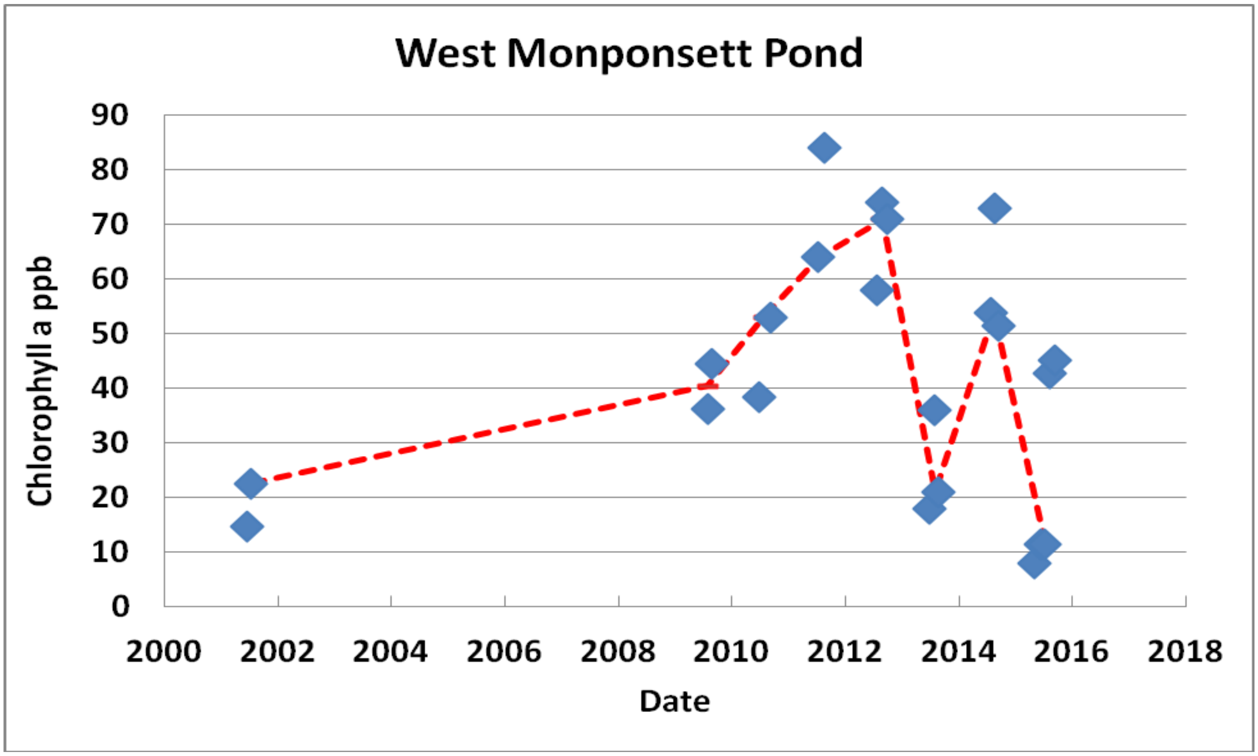

Figure 13. West Monponsett Pond Chlorophyll *a* . Summer median values are indicated by the dashed line.

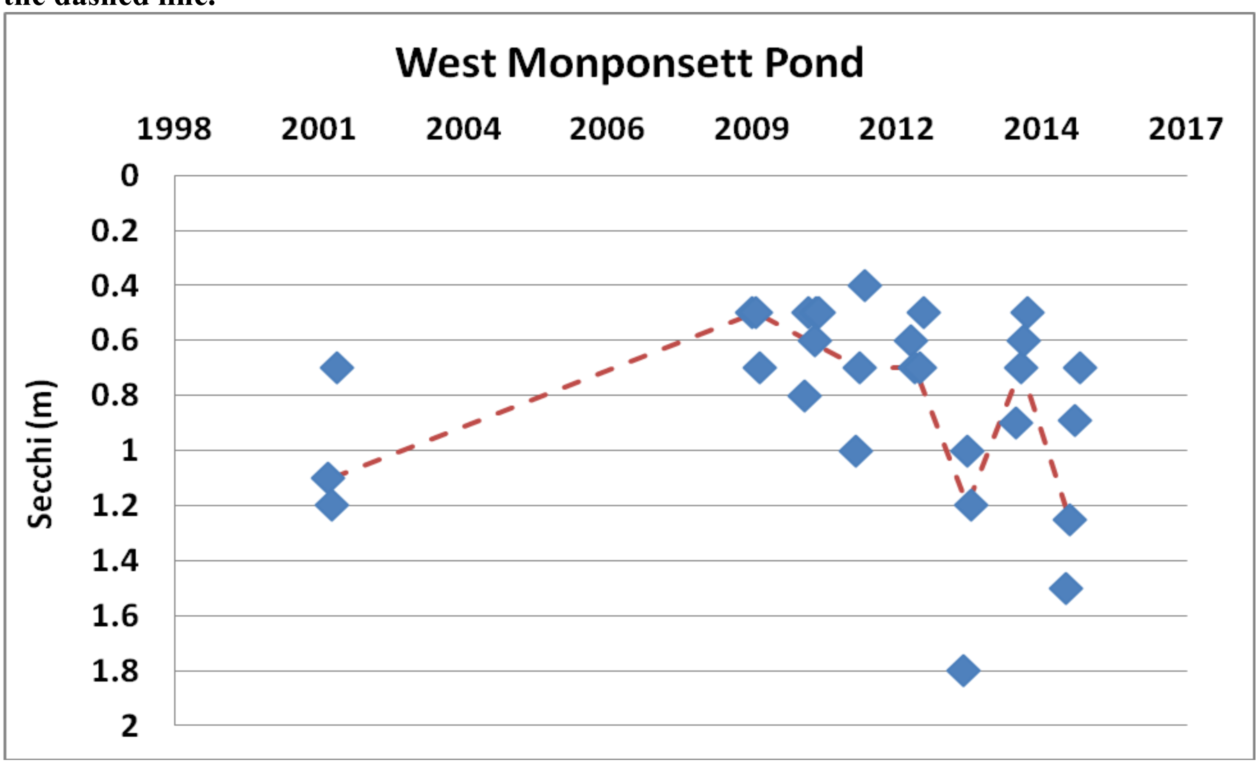

Figure 14. West Monponsett Pond Secchi disk transparency. Summer median values are indicated by the dashed line. (Note y axis reversed).

Source Assessment

In order to estimate the current phosphorus loadings to the TMDL study ponds, the Lake Loading Response Model (AECOM 2009) was used. The Lake Loading Response Model (LLRM) is a spreadsheet based model which uses an annual steady state suite of models to estimate nutrient loadings. These estimated nutrient loadings along with pond morphometric and physical characteristics are then used to predict in-pond nutrient concentrations using a suite of well accepted lake models for phosphorus predictions (Kirchner-Dillon 1975, Vollenweider 1975, Larsen-Mercier 1976, Jones-Bachmann 1976 and Reckhow 1977). Details of models and notes on calibration of the models for the Monponsett Ponds can be found in the Monponsett Pond TMDL Modeling Documentation (Appendix E).

The LLRM model uses inputs for estimated nutrient loadings from landuse, septic systems, waterfowl, internal loading, areal deposition and point sources. The model was calibrated and used to estimate current loading to the ponds in the TMDL study area. An initial attempt was made to simply use the areas corresponding to landuse categories and multiply them by conventional phosphorus export coefficients to obtain nutrient loadings, but this approach resulted in very high loadings compared to estimates of loading based on lake concentrations and flushing rates. The phosphorus loadings appear to be greatly attenuated in the groundwater transport in this system as noted in discussion of calibration of the LLRM in Horsley Witten (2015). A similar issue was previously noted by another researcher in modeling the Pembroke Ponds which include Stetson Pond (BEC, 1993). Following the approach used by BEC (1993) we focused on direct fluvial inputs such as cranberry bogs discharges, inputs from streams draining forested wetlands and relatively direct inputs of lake sediment phosphorus recycling and stormwater inputs. MassDEP staff collected a series of sediment cores from West Monponsett Pond and aerobically incubated the cores in the lab to measure phosphorus release to the overlying water headspace. From these measurements an aerobic phosphorus release rate was determined and later used in calculations of summer release rates (MassDEP, 2010b; Appendix E).

Numeric Water Quality Target

The waterbodies in the TMDL study area are all classifed as Class A in the Massachusetts Surface Water Quality Standards (Table 1). Class A waterbodies are designated as a source of public water supply as well as "designated as excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and or primary and secondary contact recreation, even if not allowed" (MassDEP, 2022). Massachusetts' narrative criteria for nutrients is "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 …" (MassDEP, 2022).

In order to asssess waterbodies in the Massachusetts uses the CALM (MassDEP, 2016) as part of 305b and 303d listing for Clean Water Act purposes. As referenced above this document has guidance threshold values which allow the characterization of whether a waterbody is supporting its designated uses. Lacking a nutrient criterion, a numeric target total phosphorus concentration must be chosen which should meet certain CALM guidance thresholds for lakes and allow for the meeting of designated uses and therefore meeting SWQS. The target total phosphorus concentration must be chosen to be low enough for all designated uses to be attained. In the case of nutrients the uses include primary and secondary contact recreation, aquatic life and aesthetics. Based on MassDEP's CALM document (MassDEP, 2016) all of these lakes should generally meet the 1.2 meter Secchi disk transparency, 5 mg/l dissolved oxygen concentration, the maximum monthly chlorophyll *a* concentration should not exceed 16 ppb, have less than 25% non-rooted macrophytes and be free from frequent cyanobacteria blooms (>70,000 cells/mL) to be considered free of nutrient impairment (unless the exceedance is a natural condition). There is always uncertainty in the data collected, the modeling assumptions and modeling error in the loads. In addition there is temporal variability that is not included in the steady state models used here. As such there may be sometimes when the biological thresholds are exceeded. The rationale for MassDEP's selection of these target TP concentrations for each waterbody is described in the following sections.

Generally, all uses for typical warm water lake fisheries (including swimming, boating and aesthetics) can be met at the USEPA "Gold Book" recommendation of 0.025 mg/l (USEPA, 1986). A further refinement of total phosphorus targets utilizes concentrations of phosphorus in lakes within uniform ecological regions (the ecoregion approach). The phosphorus ecoregion map of Griffith et al. (1994) indicates the lake is in an ecoregion with concentrations of 15-19 ppb, based on spring/fall concentrations, while the phosphorus ecoregion map of Rohm et al., (1995) suggests that typical lakes in this ecoregion would have concentrations between 30 and 50 ppb, based on summer concentrations. The United Stated Environmental Protection Agency (USEPA) has proposed a lower TP concentration for lakes in Ecoregion XIV of 8 ppb (https://www.epa.gov/sites/production/files/documents/rivers14.pdf). MassDEP reviewed EPA's ecoregion approach and concluded that Massachusetts water quality data was not represented in the EPA analysis which calls into question the validity of directly applied EPA criteria to Massachusetts' waters.

Clear water seepage lakes tend to have lower total phosphorus concentrations than typical lakes with inlet streams. The median summer surface total phosphorus concentration in other relatively unimpacted clear water seepage lakes in southeastern Massachusetts is very low ranging from 6 to 16 ppb (MassDEP, 2003, 2004, 2007a, 2007b, 2009, 2013).

The total phosphorus concentration expected to attain the biological thresholds of the CALM listed above may vary between types of lakes. In this case the lakes in question are quite different and are expected to respond differently to total phosphorus. Previous MassDEP sampling in lakes in Massachusetts suggests a target of 23 ppb total phosphorus for clear (not tea colored) lakes that are dominated by groundwater seepage and 48 ppb total phosphorus for clear impoundments is appropriate (MassDEP, 2003, 2004, 2007a, 2007b, 2009, 2013). However, in colored lakes with high concentrations of dissolved carbon, as indicated by true color measurements exceeding 57 PCU, the natural total phosphorus is expected to be higher than in otherwise similar clear water lakes (MassDEP, 2003, 2004, 2007a, 2007b, 2009, 2013). Using professional knowledge and a weight of evidence the pond's target concentrations were determined.

In the case of Stetson Pond, the data show that the lake has largely recovered from impairment in recent years (see Figure 3). There was a large reduction in TP concentrations from a surface median of 40 ppb down to near 15 ppb between the 1988 study and the recent 2015 data, respectively. This reduction is associated with the sale of the upstream cranberry bogs (Edgewood Bogs) to the town and subsequent abandonment of the cranberry production in 2008. The large reduction in TP is also associated with a general reduction in the nuisance algal blooms which caused impairment in 1988, yet the median chlorophyll *a* and median Secchi disk transparency did not change significantly (see Figure 4 and Figure 5). The lake is now attaining the minimum water quality response thresholds for chlorophyll *a* and duckweed but the lake still has brief oxygen depletion in the bottom waters as shown for the sample collected on 8/13/15 in Figure C-12. Such brief oxygen depletions near the bottom of the lake are expected as natural conditions in mesotrophic lakes.

Stetson Pond is a shallow, clear water lake with the longest residence time of the ponds in the TMDL study area. The TP concentration target is set at 13 ppb, just below the current volume weighted average of 15 ppb. The lake is a clear water lake and is expected to be relatively low in TP. The LLRM is basically a phosphorus model and does not predict hypolimnetic dissolved oxygen. MassDEP believes the target of 13 ppb TP will result in natural levels of dissolved oxygen in the lake and should attain all uses related to nutrient impairment. Even very low phosphorus, oligotrophic, similar sized lakes such as Mirror Lake in New Hampshire do not maintain oxygen in the deep hypolimnion and this is not a reasonable expectation (Winter and Likens, 2009).

White Oak Reservoir is listed as impaired for Nutrient/Eutrophication Biological Indicators in the 2018/2020 Integrated List of waters (MassDEP, 2022). Comparing the data on *Lemna* (duckweed) percent cover on the pond to our CALM assessment threshold of 25%, supports this impairment. MassDEP sampling protocol generally excluded duckweed fragments from the phosphorus sample. MassDEP believes the TP concentrations reported for the water do not include the TP taken out of the water by the floating duckweed and we made adjustments to the loading models previously described. Because so much of the current phosphorus loading is quickly taken up in the duckweed, future reductions in phosphorus loadings may not be reflected in proportional reductions in TP as measured by traditional whole water total phosphorus samples. Instead, we expect the mass and percent cover of duckweed on the pond to diminish until the pond is less than 25% covered by duckweed and meets the biological threshold within the MassDEP CALM. The nominal target is thus set to 23 ppb which represents a reduction in loading of about 54 percent. This target is appropriate based on previous MassDEP lake surveys (MassDEP, 2003, 2004, 2007a, 2007b, 2009, 2013).

White Oak Reservoir is a very shallow, well flushed and colored impoundment and this is expected to influence its response to nutrients. Most lakes nutrient budgets are calculated on an annual basis, as it is generally believed that they respond slowly to changes in nutrient loadings due to the long residence time. White Oak Reservoir, however, has a very short residence time of about 21 days due to the shallow mean depth of 1.1 m. This fast flushing time is expected to limit the growth of the algae and unattached macrophytes which are expected to be flushed downstream before growing to levels otherwise expected from the TP concentrations. Leesville Pond, a shallow pond with fast flushing time in central Massachusetts has an approved TMDL with a target TP concentration of 40 ppb (MassDEP, 2002). Note that according to the Carlson Trophic State analysis (Carlson,1977) a lake should have total phosphorus concentrations of about 40 ppb to meet the 4-foot transparency requirement for swimming beaches in Massachusetts. Furthermore, relatively high color in the impoundment (which averages about 55 PCU of true color) suggests a higher TP concentration may be appropriate. Despite the justification for a higher target total phosphorus concentration a lower target of 23 ppb was chosen. This conservative value was selected as the impoundment is tributary to a public water supply and it will provide some margin of safety for White Oak Reservoir, while also protecting downstream resources in West Monponsett Pond.

East Monponsett Pond is a shallow, moderately flushed and colored pond with complex hydrology. It combines surface water flows with groundwater inputs as well as reverse flows from West Monponsett Pond during periods of diversion to Silver Lake. This waterbody had moderately high median color of 61 PCU in 2009 which is associated with higher TP (MassDEP, 2003, 2004, 2007a, 2007b, 2009, 2013). (Note that true color and TP in the East Monponsett Pond has been declining (i.e. improving), possibly due to implementation of Best Management Practices at the upstream cranberry bogs). However, East Monponsett Pond is also classified as Class A and is tributary to the public water supply, Silver Lake, and thus a lower target TP concentration should be considered as a measure to protect the water supply use of the Monponsett Ponds. A target of 20 ppb TP was initially selected because even at the higher current concentrations, no obvious impact to Silver Lake water quality has been observed and based on the LLRM model estimates that the chlorophyll *a* will meet the target of 16 ppb approximately 96% of the time. In the two years (2010 and 2015) that the East Monponsett Pond averaged 20 ppb TP it met the CALM thresholds for chlorophyll *a* and Secchi disk transparency (see Figure 7 and Figure 8). To add an additional margin of safety and to match the target of West Monponsett Pond the final TMDL target is set to 18 ppb.

West Monponsett Pond is also a shallow and colored pond and is equally complex in hydrology as East Monponsett Pond. This pond has a flushing rate greater than Stetson Pond but less than East Monponsett Pond. In addition to the flows and diversions mentioned above, West Monponsett Pond also has variable elevations and downstream flows due to changes in the dam gates by the City of Brockton. While the nominal target would be 23 ppb as above, the lake is also tea colored with a median color of 57 PCU in 2009 and thus a higher natural TP concentration target would be expected (note as above, color and TP have been declining (i.e. improving) in the pond in recent years). During times of diversion, water from West Monponsett Pond may flow (via East Monponsett Pond) to Silver Lake which is used for the City of Brockton's water supply, and therefore a more restrictive TP concentration target is appropriate. Given the pond's lower flushing rate when compared to East Monponsett Pond a more conservative target is also warranted. The target concentration for West Monponsett was initially set to 20 ppb. However, data collected in the summer of 2016 and 2017 indicated that West Monponsett surface waters continued to bloom with cyanobacteria and exceeded the CALM guidance value of 16 ppb chlorophyll *a* in 2016 and did not meet the Secchi disc CALM threshold of 1.4 meters. Based on this information the final TMDL target is set 10 percent lower to 18 ppb. In 2018 cyanobacteria blooms remained below the 70,000 cells/ml MA DPH advisory level while draft data indicate the total phosphorus threshold was met. It is important to note that West Monponsett Pond may not be in a stable state after recent alum applications.

This target is also supported by the Carlson Trophic State index or TSI (Carlson, 1977) as described in the GEIR (Mattson et al., 2004). The Carlson TSI predicts a trophic state of 57 based on the target Secchi of 1.2 m and a trophic state of 58 based on a maximum chlorophyll a of 16 ppb. The selected total phosphorus target of 18 ppb has a trophic state index of 45.8, which is expected to result in biomass approximately 50% below the biological response targets listed above. In addition, the previously approved TMDL for nearby White Island Pond has similar loading issues (dominated by cranberry bogs and internal loading) and has a target of 19 ppb. After the last alum treatment at that pond the lake is just below 19 ppb and has completely recovered from severe cyanobacteria blooms (MassDEP, 2010a; Mattson, 2015). Thus the targets are conservatively set to meet MassDEP's Water Quality Standards. Historically, records indicate that West Monponsett Pond was consistently more highly colored and was more eutrophic than East Monponsett Pond, but the two TMDL targets have been set the same given the fact both are Class A-ORW waterbodies.

Determination of Loading Capacity

Linking Total Phosphorus to the Numeric Water Quality Target

The LLRM model was used to estimate each pond's target load for total phosphorus based on the target concentrations in the water column described above. The total phosphorus load was adjusted for each pond until its predicted total phosphorus concentration matched the target phosphorus concentration. The predicted concentration used in the LLRM model was an average of all the prediction models excluding the Mass Balance equation (see Appendix B, Table B2, B3).

The estimated allowable total phosphorus load was 48 kg/yr, 182 kg/yr, 35 kg/yr and 186 kg/yr for Stetson Pond, East Monponsett Pond, White Oak Reservoir and West Monponsett Pond, respectively (Tables 5-8, below). The lake models used in this TMDL have a yearly time step. This along with the fact that ponds store phosphorus in the water column and sediments means water quality responds to inputs on a yearly basis. The use of annual loads in TMDLs is a generally accepted method for lake and pond TMDLs and is in accordance with EPA Guidance (EPA 1986 and 1990). Further details on the LLRM modeling are available in Appendix E.

Meeting the threshold loads for each pond will result in reduced algal blooms. All the ponds had a predicted probability of chlorophyll *a* >16 ppb, less than 10% of time. It is important to note White Oak Reservoir is currently dominated by duckweed and aquatic plants. Reduction in duckweed cover is the restoration target for this waterbody. East Monponsett Pond and West Monponsett Pond at their target loads will have predicted peak chlorophyll *a* values of approximately 21 ppb and 23 ppb, respectively, less than 2.5% annually (Appendix E, Table 18). In the future, peak chlorophyll *a* values may occasionally exceed the 16 ppb criterion. The goal of this TMDL is to reduce the extent and severity of current algae blooms and ensure that all surface water quality standards are met.

Pollutant Load Allocations

Waste Load Allocation

Based on estimated current stormwater loads of TP phosphorus to the waterbodies covered in this TMDL generally a 50% to 60% reduction in stormwater loads has been allocated in this TMDL for all affected waterbodies. The total Waste Load Allocations (WLA) for Stetson Pond, East Monponsett Pond, White Oak Reservoir and West Monponsett Pond watersheds are 19.24 kg/yr, 76.58 kg/yr, 21.63 kg/yr and 70.36 kg/yr, respectively. For complete details on the estimation of current stormwater loads and the procedure to allocate a wasteload allocation see Appendix E (pg. 122-128).

In order to reach the target threshold for Stetson Pond a 50% percent reduction in stormwater load will be required from the low intensity development, medium intensity development and natural landuse categories (MassGIS landuse categories: Low Density Residential, Medium Density Residential, Transitional, Forest; Table 5). (Note; reductions in “natural” areas refer to roads and other impervious areas within undeveloped areas.) Similar reductions in stormwater loads will be necessary to meet the target threshold for East Monponsett Pond (Table 6). A 60% reduction in stormwater loads will be necessary from the low intensity development, medium intensity development and high intensity landuse categories while a 50% reduction in the natural category is required (MassGIS landuse categories: Commercial, High Density Residential, Industrial, Low Density Residential, Medium Density Residential, Multi-Family Residential, Participation Recreation, Transportation, Urban Public/Institutional, Very Low Density Residential and Forest). For both ponds the necessary stormwater loading reductions would be associated with impervious areas. Additionally for the two ponds it is recommended to focus on reducing stormwater loads where impervious surfaces exist in any of the landuse categories.

Significant reductions in stormwater loads are also required in White Oak Reservoir and West Monponsett Pond (Table 7, 8 respectively). In order to reach the target threshold for White Oak Reservoir a 60% reduction in stormwater loads from the low intensity development, medium intensity development, high intensity development and natural land use categories is required (MassGIS landuse categories: Commercial, Industrial, Low Density Residential, Medium Density Residential, Multi-Family Residential, Transportation, Urban Public/Institutional, Very Low Density Residential and Forest; Table 7). West Monponsett Pond will also require a 60% reduction in stormwater loads from the high intensity agriculture, medium intensity development, high intensity development and natural land use categories (MassGIS landuse categories: Commercial, Cranberry Bog, Forest, Low Density Residential, Medium Density Residential, Multi-Family Residential, Participation Recreation, Transitional, Transportation, Urban Public/Institutional, Very Low Density Residential; Table 8). For both ponds the necessary stormwater loading reductions would be associated with impervious areas (including within “natural” areas. Additionally, for the two ponds it is recommended to focus on reducing stormwater loads where impervious surfaces exist in any of the landuse categories.

Load Allocation

In order to reach the target threshold for Stetson Pond, a 90% reduction in internal loading will be required (Table 5). In addition watershed load reductions of 25% are necessary from the low intensity development and medium intensity development landuse categories. Reduction could come from reduction in loads from residential fertilizer use.

In order to reach the target thresholds for the East Monponsett Pond in this TMDL, a large reduction in internal loading and current watershed loading is required for East Monponsett Pond (Table 6). The largest source of watershed land use load reductions (88%) will need to come from cranberry bogs (high intensity agriculture). The phosphorus export coefficient target of 0.5 kg/ha/yr successfully used at White Island Pond cranberry bogs (MassDEP, 2010a, Mattson, 2015) can be used to attain the target loads in the bogs located in the greater Monponsett Pond watershed. Additionally 50% reduction in watershed loads from the low intensity development, medium intensity development, and high intensity development land use categories will be necessary.

The White Oak Reservoir will require reductions in total phosphorus loading from cranberry bogs (~88%); the same as described above for East Monponsett Pond (Table 7). In addition a 25% reduction in watershed loads from the low intensity development land use category is necessary.

The West Monponsett Pond will require an approximate 73% reduction in its total phosphorus loading in order to meet the threshold load of 185 kg/yr (Table 8). The reduction in loading will need to come from two of the principal loads, internal sediment recycling and cranberry bogs. Total phosphorus loads from internal loading will require a 90% reduction, principally by aluminum addition. Similarly an 88% reduction in total phosphorus loads from cranberry bogs is also necessary via fertilizer reductions and other BMPs. Finally, watershed loads from the low intensity development, medium intensity development and high intensity land use categories will require a 50% reduction.

In summary, the four waterbodies were modeled with a consistent set of export coefficients and current (2009 or 2015) TP loads were estimated. Target TP concentrations were developed and a new set of TMDL loads were established to meet those targets. The reductions in loads required to reach the targets ranged from 30 to 73% as shown in Table 9.

Margin of Safety

An explicit MOS quantifies an allocation amount separate from other Load and Wasteload Allocations. An explicit MOS can incorporate reserve capacity for future unknowns, such as population growth or effects of climate change on water quality. An implicit MOS is not specifically quantified but consists of statements of the conservative assumptions used in the analysis. The MOS for these TMDLs is implicit. MassDEP used conservative assumptions to develop numeric model applications that account for the MOS. These assumptions are described below, and they account for all sources of uncertainty, including the potential impacts of changes in climate.

Table 5. Current TP Loads and Allocated TP Loads for Stetson Pond

Source	Total Phosphorus Load (kg/yr)			% Reduction
	Current	**Allocated**	Reduction	
Atmospheric	7.62	**7.62**	0.00	0%
Internal	6.87	**0.69**	6.19	90%
Septic System	10.77	**10.77**	0.00	0%
Watershed Load				
Low Intensity Development	6.16	**4.62**	1.54	25%
Medium Intensity Development	3.63	**2.72**	0.91	25%
Forested Wetland	1.09	**1.09**	0.00	0%
Non-Forested Wetland	0.75	**0.75**	0.00	0%
Low Intensity Agriculture	0.22	**0.22**	0.00	0%
Total Watershed Load	11.85	**9.40**	2.45	21%
Total Load	37.11	**28.48**	8.63	23%
Stormwater Load By Landuse				
Low Intensity Development	10.10	**5.05**	5.05	50%
Medium Intensity Development	9.56	**4.78**	4.78	50%
Natural	6.32	**3.16**	3.16	50%
Abandoned Cranberry Bogs	4.45	**4.45**	0.00	0%
Forested Wetland	0.53	**0.53**	0.00	0%
Non-Forested Wetland	0.59	**0.59**	0.00	0%
Low Intensity Agriculture	0.68	**0.68**	0.00	0%
Total Wasteload	32.23	**19.24**	12.99	40%
Totals Maximum Yearly Load[1]	69	**48[1]**	22	31%

1- (Total Maximum Yearly Load = Total Load Allocation plus Total Wasteload Allocation, rounded to nearest kg/year)

Table 6. Current TP Loads and Allocated TP Loads for East Monponsett Pond

Source	Total Phosphorus Load (kg/yr)			% Reduction
	Current	**Allocated**	Reduction	
Atmospheric	21.99	**21.99**	0.00	0%
Internal	30.00	**15.00**	15.00	50%
Septic System	16.24	**16.24**	0.00	0%
Watershed Load				
High Intensity Agriculture	89.79	**11.00**	78.79	88%
Medium Intensity Development	5.24	**2.62**	2.62	50%
Forested Wetland	26.71	**26.71**	0.00	0%
Low Intensity Development	13.53	**6.76**	6.76	50%
High Intensity Development	1.53	**0.77**	0.77	50%
Non-Forested Wetland	3.10	**3.10**	0.00	0%
Low Intensity Agriculture	1.19	**1.19**	0.00	0%
Total Watershed Load	141.09	**52.15**	88.94	63%
Total Load	209.32	**105.38**	103.94	50%
Stormwater Load By Landuse				
High Intensity Agriculture	13.61	**13.61**	0.00	0%
Medium Intensity Development	48.22	**19.29**	28.93	60%
Forested Wetland	13.66	**13.66**	0.00	0%

Source	Total Phosphorus Load (kg/yr)			% Reduction
	Current	**Allocated**	Reduction	
Low Intensity Development	24.01	**9.60**	14.40	60%
Natural	23.31	**11.65**	11.65	50%
High Intensity Development	7.04	**2.82**	4.23	60%
Non-Forested Wetland	2.47	**2.47**	0.00	0%
Abandoned Cranberry Bogs	3.48	**3.48**	0.00	0%
Low Intensity Agriculture	0.00	**0.00**	0.00	0%
Total Wasteload	135.80	**76.58**	59.22	44%
Total Maximum Yearly Load[1]	345	**182**[1]	163	47%

1- (Total Maximum Yearly Load = Total Load Allocation plus Total Wasteload Allocation. Total load is rounded to nearest kg/year)

Table 7. Current TP Loads and Allocated TP Loads for White Oak Reservoir

Source	Total Phosphorus Load (kg/yr)			% Reduction
	Current	**Allocated**	Reduction	
Atmospheric	1.20	**1.20**	0.00	0%
Internal	0.00	**0.00**	0.00	0%
Septic System	0.00	**0.00**	0.00	0%
Watershed Load				
High Intensity Agriculture	26.80	**3.22**	23.58	88%
Low Intensity Development	1.57	**1.17**	0.39	25%
Forested Wetland	5.94	**5.94**	0.00	0%
Non-Forested Wetland	1.59	**1.59**	0.00	0%
Abandoned Cranberry Bogs	0.47	**0.47**	0.00	0%
Total Watershed Load	36.37	**12.39**	23.97	0%
Total Load	37.57	**13.59**	23.97	64%
Stormwater Load By Landuse				
High Intensity Agriculture	5.91	**5.91**	0.00	0%
Low Intensity Development	15.40	**6.16**	9.24	60%
Forested Wetland	2.99	**2.99**	0.00	0%
High Intensity Development	5.16	**2.07**	3.10	60%
Natural	4.79	**1.92**	2.87	60%
Medium Intensity Development	3.07	**1.23**	1.84	60%
Non-Forested Wetland	1.29	**1.29**	0.00	0%
Low Intensity Agriculture	0.06	**0.06**	0.00	0%
Total Wasteload	38.68	**21.63**	17.06	44%
Total Maximum Yearly Load[1]	76	**35**[1]	41	54%

1- (Total Maximum Yearly Load = Total Load Allocation plus Total Wasteload Allocation, rounded to nearest kg/year)

Table 8. Current TP Loads and Allocated TP Loads for West Monponsett Pond

Source	Total Phosphorus Load (kg/yr)			% Reduction
	Current	**Allocated**	Reduction	
Atmospheric	24.92	**24.92**	0.00	0%
Internal	293.54	**14.68**	278.86	95%
Septic System	12.96	**12.96**	0.00	0%
Watershed Load				
High Intensity Agriculture	172.05	**20.65**	151.40	88%
Forested Wetland	28.29	**28.29**	0.00	0%
Non-Forested Wetland	6.51	**6.51**	0.00	0%
High Intensity Development	0.18	**0.09**	0.09	50%
Natural	0.00	**0.00**	0.00	0%
Medium Intensity Development	7.55	**3.77**	3.77	50%
Abandoned Cranberry Bogs	0.68	**0.68**	0.00	0%
Low Intensity Agriculture	0.02	**0.02**	0.00	0%
Low Intensity Development	5.75	**2.88**	2.88	50%
Total Watershed Load	221.03	**62.89**	158.14	72%
Total Load	552.45	**115.45**	437.00	79%
Stormwater Load By Landuse				
High Intensity Agriculture	25.91	**19.43**	6.48	25%
Forested Wetland	14.30	**14.30**	0.00	0%
Non-Forested Wetland	5.27	**5.27**	0.00	0%
High Intensity Development	7.49	**2.99**	4.49	60%
Natural	15.28	**6.11**	9.17	60%
Medium Intensity Development	27.14	**10.86**	16.29	60%
Abandoned Cranberry Bogs	0.10	**0.10**	0.00	0%
Low Intensity Agriculture	0.08	**0.08**	0.00	0%
Low Intensity Development	28.04	**11.21**	16.82	60%
Total Wasteload	123.61	**70.36**	53.24	43%
Total Maximum Yearly Load[1]	676	**186[1]**	490	-73%

1- (Total Maximum Yearly Load = Total Load Allocation plus Total Wasteload Allocation, rounded to nearest kg/year)

Table 9. Summary of Targets, Total Maximum Daily Load and Load Reductions for Ponds

Waterbody	Current TP ppb used in model	Current TP Load kg/yr[1]	Target TP ppb	TMDL Load kg/yr[1]	**TMDL Load kg/day**	Percent TP Load Reduction
Stetson Pond	15	69	13	48	**0.13**	30%
East Monponsett	34	345	18	182	**0.50**	47%
Reservoir	50*	76	23	35	**0.10**	54%
West Monponsett	68	676	18	186	**0.51**	73%

*Measured TP was 35 ppb (see text)
1-all loads rounded to nearest kg/yr

While the general vulnerabilities of coastal areas to climate change can be identified, specific impacts and effects of changing conditions are not well known at this time (https://www.mass.gov/files/documents/2016/08/qz/eea-climate-adaptation-report.pdf). Because the science is not yet available, MassDEP is unable to analyze climate change impacts on streamflow, precipitation, and nutrient loading with any degree of certainty for TMDL development. Considering these uncertainties and informational gaps, MassDEP has opted to address all sources of uncertainty through an implicit MOS. MassDEP does not believe that an explicit MOS approach is appropriate under the circumstances or will provide a more protective or accurate MOS than the implicit MOS approach, as the available data simply does not lend itself to characterizing and estimating loadings to derive numeric allocations within confidence limits. Although the implicit MOS approach does not expressly set aside a specific portion of the load to account for potential impacts of climate change, MassDEP has no basis to conclude that the conservative assumptions that were used to develop the numeric model applications are insufficient to account for the lack of knowledge regarding climate change.

The margin of safety is set by establishing targets for East and West Monponsett Pond that are below a nominal target of 23 ppb TP. Previous lake sampling (MassDEP, 2003, 2004, 2007a, 2007b, 2009, 2013) has shown this target generally meets all CALM thresholds. The TMDL is based on annual loads and it is anticipated that excursions based on certain conditions during short duration events will exceed standards. Although we generally need several years of data after implementation to determine if uses are met, the 20 ppb summer average TP in East Monponsett Pond in 2010 and 2015 met relevant CALM thresholds. This indicates standards will be met and therefore the target appears conservative for these ponds. These two ponds are colored, influenced by both surface water and groundwater, and upstream wetlands. These characteristics make the ponds atypical of lakes fed by clear groundwater seepage. The 18 ppb TP target for these lakes has also been set conservatively given that both East and West Monponsett Ponds are classified as Class A waters (public water supply).

Similarly, the target concentrations for Stetson Pond (13 ppb) and White Oak Reservoir (23 ppb) were also conservatively set. Stetson Pond received a target concentration below its current in-pond concentration to both protect its water quality as well as the water quality of downstream water resources. The lake already meets Secchi disk thresholds and does not suffer from frequent cyanobacteria blooms. The lower TP target should help improve oxygen conditions in the hypolimnion but there is uncertainty in the relationship between TP and hypolimnetic oxygen depletion rates (Borowiak *et al.*, 2011). The White Oak Reservoir target concentration was set well below a nominal target of 48 ppb. Previous sampling of similar clear water impoundments (MassDEP 2003, 2004, 2007a, 2007b, 2009, 2013) has shown this target generally meets CALM thresholds for this waterbody type. This level is expected to reduce duckweed coverage, which is causing the impairment, and should also help restore the principal downstream waterbody, West Monponsett Pond.

Critical Conditions

The effects of yearly total phosphorus loading have their most severe effects in the summer. This effect is captured by the LLRM model which was calibrated to average summer in-pond TP concentrations.

Seasonal Variations

This TMDL captures seasonal variations in water quality with its calibration to summertime in-pond TP concentrations as noted above. Seasonal variations are also accounted for by using the average of several years of rainfall to estimate runoff flows.

Impact of Diversions

As noted in the recent hydrologic evaluations of the diversion of East Monponsett waters to Silver Lake, the hydrology of the system is very complex (Princeton Hydro, 2013; Horsley Witten, 2015). The diversion occurs on a seasonal basis and with complex spatial mixing that can't be completely simulated with any well mixed, steady state model such as LLRM. The steady state models can be used to make estimates of how the system is likely to respond. For example, if the diversion of water and associated nutrients to Silver Lake did not occur then our model estimates that TP concentrations in West Monponsett Pond would decrease by 24%. This is in close agreement with the previous studies that found a 'no diversion' scenario would reduce TP concentrations in the pond by 23% to 32% (Horsley Witten, 2015 and Princeton Hydro, 2013, respectively). The improvement in water quality would be due to increased flushing with relatively clean East Monponsett Pond water. It should be noted that the above reports, as well as this report, conclude that stopping the diversion alone would not solve the cyanobacteria bloom problem. The watershed BMPs and aluminum treatment of West Monponsett are required to meet the TMDL.

There are additional impacts of the diversion on waters outside of the ponds that should be noted here. Both the Princeton Hydro (2013) report and the Horsley Witten (2015) report noted impacts to both Stump Brook and to the Jones River. The Jones River (segment MA94-12) is of concern because it is also listed as impaired on the 2018/2020 Integrated List (see Table 1) and requires a separate TMDL. The excess algae and dissolved oxygen problems noted may be alleviated if more water from relatively clean (less nutrient-rich) Silver Lake were to flush naturally downstream. All reasonable efforts should be made to reduce the reliance on Silver Lake so that impacts to all waters in the region are minimized.

Implementation

Implementation of the TMDL will focus on the largest sources including the sediment recycling of phosphorus during the summer and the cranberry bog BMPs. Additional implementation will include upgrading Title 5 septic systems as required by regulations (310 CMR 15.00) or by sewering areas as development increases. There are no reasonable BMPs available to significantly reduce atmospheric precipitation and dryfall inputs.

In the case of the Monponsett Ponds, Stetson Pond and White Oak Reservoir much of the above implementation has been underway since 2009. As noted previously the major bog owners have already reduced the fertilizer rates by 60-70% (DeMoranville, 2016a) and West Monponsett Pond exhibited a 23% reduction in TP concentrations coincident with those fertilizer reductions as shown in Figure 12. As more bog operators continue to reduce phosphorus fertilizer applications and begin additional bog water BMPs (such as holding floodwater less than ten days and diverting discharges to detention ponds and upland areas as recommended in the UMass Cranberry bog BMPs) additional reductions in lake TP concentrations are expected. Such efforts were successful in restoring White Island Pond (Mattson, 2015). In addition, MassDEP has awarded Section 319 grant monies to the University of Massachusetts Cranberry Experiment Station to test additional BMPs. One of the tests involves the use of an iron enriched sand filterbed to remove phosphorus from water discharged from the Winebrook bogs on West Monponsett Pond. Initial testing resulted in clogging of the filter but additional prefilters and a gravel layer are expected to alleviate the clogging problems and provide additional TP removal (DeMoranville, 2016b).

Internal Loads

For West Monponsett Pond to meet its target TP concentration will require a 90% reduction in TP loads from the sediments. The origin of this large amount of sediment phosphorus was due to historically high anthropogenic phosphorus inputs that have transferred and settled to the sediments over many years. The control of summer sediment phosphorus release in this lake can be treated with a buffered alum and sodium aluminate treatment; iron treatment combined with aeration; or by dredging the sediments after the major surface discharges are controlled. Aluminum treatment generally has been most cost effective (Mattson et al., 2004). There is a concern regarding rare species impacts with any of the treatment methods. Coordination with the Massachusetts NHESP staff is required to develop a treatment plan that will protect the rare freshwater mussel species. West Monponsett Pond was treated with low doses of buffered alum in the summer of 2013 and 2015 (Figure 12) and later in 2016, with no impacts to the rare mussels reported (Biodrawversity, 2014). Additionally, alum treatments were conducted in 2017, 2018 and 2019 with no reported impacts to rare mussels. The estimated total buffered alum treatment through 2019 is approximately 50 g/m^2 Al, the estimated Al needed to treat the internal loading of 293.5 kg/yr for West Monponsett Pond.

East Monponsett Pond may also require an aluminum treatment of sediment phosphorus sources if further implementation of watershed control fails to stop cyanobacterial blooms in the pond. If treatment is required, a lighter dose than that used for West Monponsett Pond is likely to be enough. The same is true for Stetson Pond. Although TP concentrations were low in Stetson Pond surface waters in 2015, a cyanobacterial bloom occurred in late summer (August and September). Blooms also resulted in posting swimming bans by the local Board of Health in 2010 for 37 days. A lighter dose would probably be enough for this lake to meet water quality standards and eliminate the blooms. White Oak Reservoir may not need aluminum treatment to control the duckweed problem. The recommended approach is to implement cranberry bog BMPs upstream first and monitor the reservoir.

Cranberry Bogs

A key to the success of this TMDL is the reduction of TP load from local cranberry bogs whose discharge is tributary to the lake. The cranberry bog discharge must be limited to 0.5 kg/ha/yr (0.45 lb/ac/yr), the same as recommended in Mattson (2009) and used in White Island Pond (Mattson, 2015). This level of phosphorus export can be achieved by limiting water discharge rates to 3.5 acre-feet per acre of bog (see below) with average total phosphorus concentrations of 50 ppb (the acceptable concentration of inputs to lakes from EPA, 1986 “Gold Book”). A recent review of phosphorus export versus phosphorus fertilizer use suggests that exports can be dramatically reduced with reductions in phosphorus fertilizer application while maintaining crop yields (DeMoranville et al., 2009). In fact, some bogs can show zero export or even negative phosphorus export (uptake of phosphorus) while maintaining good yields by reducing phosphorus fertilizers (DeMoranville and Howes, 2005; DeMoranville et al., 2008). The key to maintaining yield is to supply the correct amount of nitrogen (generally the limiting nutrient for cranberries) while reducing the phosphorus in the fertilizer. This is accomplished by switching from low ratios of N:P:K to higher N fertilizers with proportionately less P. Commercial cranberry growers have used high ratios in the past (bags labeled 10-12-24, 10-20-20 or even 5-15-30) where the ratio of N to P_2O_5 on the bag is 1:1.2 or 1:2 or 1:3 (Howes and Teal, 1995). This supplies excess phosphorus for plant growth needs. The recent UMass study recommends products with bag ratios of 18-8-12 or 15-15-15 (DeMoranville and Howes, 2005). For example, in order to deliver enough nitrogen to the crop while reducing phosphorus applications to a target of 10 lb/ac/year phosphorus, a fertilizer with a N:P ratio of 2:1 such as 18-8-12, or even lower P fertilizer would be required. Caution needs to be exercised so that the amount of nitrogen applied does not exceed the crop needs. Excess nitrogen would likely migrate from the site and contribute to nitrogen enrichment in down gradient embayment systems.

Manipulation of water usage is also critical for reducing the phosphorus loading to receiving waters. In order to meet the TMDL loading target of 0.5 kg/ha/yr the yearly discharge of 3.5 feet of water per acre of bog at a concentration of 50 ppb TP or less would satisfy the TMDL requirements. Other combinations of discharge and concentrations are also acceptable if they are demonstrated to meet the TMDL load. Increased public water supply demand requires an increase in water discharged through the spillway, increasing the leaching of phosphorus from the bogs. Irrigation water should be recycled from water stored in the bog ditches or in storage ponds to the greatest extent possible. Harvest water should also be recycled from section to section rather than flooding the entire bog complex at one time. After cranberry harvest the water should be retained in the bog complex for at least 1 to 3 days to allow particulate matter to settle out, but always less than 10 days to avoid excess release from sediments. Water should be discharged slow enough to minimize turbulence and erosion within the bogs. When possible, the discharge should be directed away from sensitive surface waters, particularly in the growing season. It is recommended that the small Winebrook bog currently discharging to West Monponsett Pond be further treated or diverted away from the pond. Winter floods should be withdrawn beneath newly formed ice within 10 days to avoid anoxic injury to plants and anoxic release of phosphorus from the flooded soils. Additional treatment and alternatives to winter flood discharges should be considered to meet the TMDL loading requirements. For a more comprehensive list of efforts to reduce total phosphorus from commercial cranberry bogs see Mattson, 2009.

Because of the large build-up of excess phosphorus in cranberry bog soils, soil tests often show very high TP concentrations that do not relate to crop yields and plant tissue tests may be more appropriate for determining fertilizer needs (DeMoranville and Davenport, 1997). Because of the high phosphorus in the soils, there may be a delayed response to the reductions in phosphorus fertilizer inputs and water discharges from the bogs. It is recommended that after fertilizers have been reduced to 10 lbs/acre/year and the water reuse BMPs have been initiated and the watershed source TMDL are largely met before any further and potentially more expensive in-lake BMPs be initiated. Recent studies on commercial cranberry bogs have shown that reduced phosphorus fertilizer application led to increased yield of cranberries while reducing expensive fertilizers and reducing TP concentrations in discharge water (DeMoranville et al., 2009). Additional studies on plots have shown there was no justification for using high phosphorus fertilizers. Even the zero phosphorus plots showed no signs of deficiency after 6 years of study (Roper, 2009), but tissue tests are recommended to monitor plant health. For further background information and recommendations to reduce total phosphorus loading from cranberry bogs see Appendix D: Guidelines for Total Maximum Daily Loads of Phosphorus from Commercial Cranberry Bog Discharges in Massachusetts.

Flow Management

MassDEP acknowledges the diversions "lessen the pond's nutrient absorptive capacity by reducing new water additions to West Monponsett Pond that otherwise would improve flushing and reduce stagnation" (MassDEP 2017). MassDEP has issued an Administrative Consent Order to the City of Brockton. This administrative consent order requires that the City of Brockton take action to reduce the likelihood of water going from the West to East Monponsett Pond during diversion by altering their diversion transfer rate (MassDEP 2017, Provision 28). The ACO (MassDEP 2017) requires a minimum flow of 900,000 gallons/day to leave West Monponsett Pond both during diversion periods and beginning June 1, 2017 to be released at all times unless as stipulated in the consent order (Provisions 30,32). The ACO also requires the City of Brockton to create a Resource Management Plan that will "based on scientific data and evaluation that will include recommended metrics and procedures for Silver Lake Diversions and Stump Brook Dam operations intended to improve Monponsett Pond's water quality and ecosystem while maintaining Brockton's drinking water supply system reliability" (Provisions 33). In order to study possible dam management regimes it is recommended that the potential for increased flushing based on cyanobacteria counts be investigated.

Control of Septic Loads and Stormwater Loads

The control of septic system inputs is recommended, although not currently required to meet the TMDL. Older homes with cesspools may be contributing disproportionate amounts of phosphorus to the groundwater near the lake. Local Boards of Health, as the Approving Authorities, are required to insure Title 5 compliance under the state regulation.

Another possibility for reducing the loading from septic systems is to sewer the area and thus divert phosphorus loadings to a wastewater treatment plant where it can be removed prior to discharge outside the watershed. Opportunities for sewering may occur if developers are required to reduce nutrient loadings to compensate for additional loadings of new home construction. The densely populated area along the shores of the West and East Monponsett Ponds is a potential area for sewering and this would eliminate the septic system phosphorus loads to the lake from those homes.

Except for Peterson Swamp and the wetlands northwest of West Monponsett Pond, the TMDL study area is considered an urbanized area and are included in the jointly issued EPA- MassDEP NPDES General Permits for Stormwater Discharges from MS4s. The 2016 Massachusetts MS4 General Permit became effective July 1, 2018. The NPDES permits require six minimum control measures including public education, public participation, illicit discharge detection and elimination, construction site runoff control, post construction runoff control, and good housekeeping at municipal operations. The latter 'good housekeeping' control should include BMPs and a schedule of activities to control pollution. The permits also require the development of a stormwater management plan that must include mapping outfalls to receiving waters. Details on Massachusetts stormwater program are available at: https://www.mass.gov/info-details/stormwater.

In addition to these measures, substantial reduction in TP loads (50% - 60%) from stormwater will be required for Stetson Pond, East Monponsett, White Oak Reservoir, and West Monponsett Pond watersheds to meet this TMDL. These reductions will not be easily achieved with any one single technology but are more likely to be achieved with several technologies used in combination.

Necessary stormwater reductions in the TMDL study area which will be targeted by appropriate MS4 stormwater permits. Due to uncertainties in the sources and the lack of precision in watershed models these limits should not be disaggregated into smaller individual outfall limits, but rather applied as a basis for percent reduction targets for the watershed.

Responsibilities for Implementation

MassDEP has authority to enforce existing water laws and regulations that relate to water use and water quality. The Commonwealth has provided a strong framework to encourage watershed management through on-site septic system regulations under Title 5, by legislation requiring low phosphorus detergents, and restrictions on the use of fertilizers on non-agricultural turf and lawns. Agricultural fertilizer rates and BMPs are also enforceable under the Massachusetts Department of Agriculture (MDAR) Plant Nutrient Regulations, https://www.mass.gov/service-details/plant-nutrient-management.

The MassDEP will be responsible for obtaining public comment and support for this TMDL. The proposed tasks and responsibilities for implementing the TMDL are shown in Table 10. The local citizens within the watershed will be encouraged to locate and describe additional sources of erosion and phosphorus within the watershed following methods described in the MassDEP guidebook "Surveying a Lake Watershed and Preparing an Action Plan" (MassDEP 2001) available at: https://www.mass.gov/guides/water-quality-monitoring-for-volunteers .

Responsibility for remediation of each identified source will vary depending on land ownership, local jurisdiction and expertise. For example, the local lake associations or the Towns may organize a septic tank pumping and inspection program for all lakeside homeowners. Usually a discount for the pumping fee can be arranged if many homeowners apply together. Cranberry growers can apply for money to implement BMPs as part of the NRCS programs in soil conservation. Town public works departments will generally be responsible for reduction of erosion from town roadways and urban runoff. The local conservation commissions and building inspectors will generally be responsible for ensuring the BMPs are being followed to minimize erosion from construction sites within their town. BMPs for general nonpoint source pollution control are described in a manual by Boutiette and Duerring (1994), BMPs for erosion and sediment control are presented in MassDEP (1997, reprinted 2003). See the MassDEP web site https://www.mass.gov/doc/erosion-sedimentation-control-guidelines-sec-1/download for Erosion and Sediment Control Guidelines. MassDEP also has an Unpaved Roads BMP Manual and general information on nonpoint source BMPs at https://www.mass.gov/files/documents/2018/01/30/dirtroad.pdf . A description of potential funding sources for these efforts is provided in the Program Background section, above.

The City of Brockton is required to complete several tasks as outlined in the recent Administrative Consent Order (MassDEP 2017). The local towns of Halifax, Pembroke and Hanson will be required to comply with their relevant stormwater permits. The costs of in-lake treatments including aluminum treatment should be equitably shared by the responsible parties with the City of Brockton, the towns of Halifax, Hanson and Pembroke as well as cranberry growers with additional funding provided by matching state and federal grants, as available.

A proactive approach to protecting the waterbodies in the TMDL study area may include implementation of local bylaws limiting development, particularly in areas near the lake, changes in zoning laws and lot sizes, requirements that new developments and new roadways include BMPs for runoff management and more stringent regulation of septic systems. As new housing development expands within the watershed, additional measures are needed to minimize the associated additional inputs of phosphorus. Although over fertilization of lawns was not apparent based on visual examination, homeowners should be aware of the Massachusetts Law limiting the use of phosphorus fertilizers on lawns (MGL Ch. 128 S. 65A). Additional BMPs are presented in the Nonpoint Source Management Manual by Boutiette and Duerring (1994) that was distributed to all municipalities in Massachusetts. Other voluntary measures may include encouraging the establishment of a native plant, vegetative buffer around the lake. Such BMPs provide enhancements that residents should find attractive and, therefore, should facilitate voluntary implementation.

Portions of the towns of Halifax, Hanson and Pembroke are designated urbanized areas and are therefore subject to regulation under Massachusetts Small MS4 General Stormwater Permit (effective date July 1, 2018). The 50-60 percent reductions in TP in stormwater required under this TMDL will be included in the next amendment of the MS4 General Permit (expected issue date 2023). Municipalities discharging stormwater to waters with a TP TMDL are required to prepare a Lake Phosphorus Control Plan (LPCP) as required in Appendix F, A: II (pg. 18-26) of the permit.

The town of Halifax has recently mapped and investigated several stormwater outfalls around East and West Monponsett Pond and investigated possible control measures (GHD 2017). The towns are encouraged to investigate the feasibility of treating as much of the impervious watershed area using smaller capacity low-tech controls (e.g., 0.2 to 0.4 inches of runoff) than treating less impervious area with larger capacity controls (e.g., 1.0 inch) as EPA research in the

Upper Charles River Watershed indicates this can be a more cost effective approach (USEPA 2011).

MassDEP is recommending that the East and West Monponsett Pond be monitored on a regular basis with emphasis on cyanobacteria monitoring to protect public health. If the ponds do not meet water quality standards additional implementation measures including sewering may be required. For example, if phosphorus concentrations remain high after watershed controls are in place, then control of other sources may be considered and efforts to increase flushing may be investigated.

As phosphorus concentrations in the ponds in the TMDL study area are reduced and transparency of the lake increases, increased light reaches the sediments, then an increase in the growth of rooted aquatic plants is expected. Reducing the supply of nutrients will not in itself result in achievement of all the goals of the TMDL and continued macrophyte monitoring and appropriate management is an essential part of the implementation plan.

Table 10. TMDL Tasks and Responsibilities

Tasks	Responsible Group
TMDL development	MassDEP
Develop Cranberry Farm Plan, fertilizer type and rates and water management BMPs that meet TMDL requirements	Cranberry Growers in concert with NRCS, Soil Conservation Service, the Cape Cod Cranberry Growers Association and the UMass Cranberry Station.
Ensure that noncompliant septic systems are upgraded to meet Title 5 requirements and consider inspections for compliance	Local Boards of Health and homeowners
Use lesser amounts of lawn fertilizers, particularly no phosphorus fertilizers	Homeowners and lake association
Monitor chlorophyll, Secchi disk transparency and total phosphorus in lake	MassDEP and lake association
Organize and implement TMDL education, outreach programs, write grant and loan funding proposals	Local lake association and Towns working with consultants
After discharges are controlled implement sediment phosphorus controls	Cranberry growers, lake associations and towns with consultation with MassDEP
50% to 60% reduction in stormwater loads to Stetson Pond, East Monponsett Pond, White Oak Reservoir and West Monponsett Pond	Towns of Halifax, Pembroke and Hanson
Implement Phase II BMPs, twice yearly road sweeping, catchbasin inspection and maintenance, install infiltration or other BMPs	Towns of Halifax, Hanson and Pembroke in urbanized areas

Pass town bylaws to control development, erosion from all lands, driveways and limit fertilizers on non-agricultural land.	Town Selectmen, town meeting
Coordination of municipalities within the Central Plymouth County Water District with regards to relevant water issues	Central Plymouth County Water District
Compliance with Administrative Consent Order, Watershed and water supply management plan that focuses on efforts to improve water quality in Monponsett Ponds	City of Brockton

Reasonable Assurances

Reasonable assurances that the TMDL will be implemented include both enforcement of current laws and regulations, availability of financial incentives, and the various local, state and federal program for pollution control. Active cooperation of the cranberry growers and the Cape Cod Cranberry Growers Association, homeowners, the towns of Halifax, Hanson and Pembroke, City of Brockton, EPA, NRCS and the UMass Cranberry Station is required for this TMDL to be effective in returning the lake to an unimpaired status.

MassDEP is responsible for the implementation and enforcement of the laws related to discharges of pollution, including any nonpoint sources, under authority of Massachusetts General Laws M.G.L. c.21§ 26-53, the Massachusetts Surface Water Quality Standards at 314 CMR 4.00 and the Groundwater Discharge Permit Program at 314 CMR 5.00. MassDEP is also responsible for the implementation and enforcement of M.G.L. c.91 and the Waterways Regulations at 310 CMR 9.00. Enforcement of regulations may include USEPA enforcement of the MS4 Phase II permit conditions under NPDES. The Commonwealth of Massachusetts also oversees the implementation of 310 CMR 15.00 (Title 5) regulations of onsite septic systems by the local boards of health.

Financial incentives include Federal monies available under the 319(b) NPS program and the 604(b) and 104(b) programs, which are provided as part of the Performance Partnership Agreement between MassDEP and the EPA. Additional financial incentives include state income tax credits and low interest loans for Title 5 septic system upgrades, Clean Water Act State Revolving Fund loans, and cost sharing for agricultural BMPs under the Federal NRCS program.

Climate Change

MassDEP recognizes that long-term (25+ years) climate change impacts to southeastern Massachusetts, including the area of this TMDL, are occurring based on known science. Massachusetts Executive Office of Energy and Environmental Affairs 2011 Climate Change Adaptation Report: https://www.mass.gov/service-details/2011-massachusetts-climate-change-adaptation-report predicts that by 2100 the sea level could be from 1 to 6 feet higher than the current position and precipitation rates in the Northeast could increase by as much as 20 percent.

However, the details of how climate change will affect sea level rise, precipitation, streamflow, sediment and nutrient loading in specific locations are generally unknown. The ongoing debate is not about whether climate change will occur, but the rate at and the extent to which it will occur, and the adjustments needed to address its impacts. EPA's 2012 Climate Change Strategy http://water.epa.gov/scitech/climatechange/upload/epa_2012_climate_water_strategy_full_report_final.pdf states: "Despite increasing understanding of climate change, there still remain questions about the scope and timing of climate change impacts, especially at the local scale where most water-related decisions are made." For TMDLs in Massachusetts, MassDEP recognizes that this is particularly true, where water quality management decisions and implementation actions are generally made and conducted at the municipal level on a sub-watershed scale.

EPA's Climate Change Strategy identifies the types of research needed to support the goals and strategic actions to respond to climate change. EPA acknowledges that data are missing or not available for making water resource management decisions under changing climate conditions. In addition, EPA recognizes the limitation of current modeling in predicting the pace and magnitude of localized climate change impacts and recommends further exploration of the use of tools, such as atmospheric, precipitation and climate change models, to help states evaluate pollutant load impacts under a range of projected climatic shifts.

In 2013, EPA released a study entitled, "Watershed modeling to assess the sensitivity of streamflow, nutrient, and sediment loads to potential climate change and urban development in 20 U.S. watersheds." (https://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=256912). The initial "first order" conclusion of this study is that, in many locations, future conditions, including water quality, are likely to be different from experience. However, most significantly, this study did not demonstrate that changes to TMDLs (the water quality restoration targets) would be necessary for the region. EPA's 2012 Climate Change Strategy also acknowledges that the Northeast, including New England, needs to develop standardized regional assumptions regarding future climate change impacts. EPA's 2013 modeling study does not provide the scientific methods and robust datasets needed to predict specific long-term climate change impacts in the southeastern Massachusetts region to inform TMDL development.

MassDEP believes that impacts of climate change should be addressed through TMDL implementation with an adaptive management approach in mind. Adjustments can be made as environmental conditions, pollutant sources, or other factors change over time. Massachusetts Coastal Zone Management (CZM) has developed a StormSmart Coasts Program to help coastal communities address impacts and effects of erosion, storm surge and flooding which are increasing due to climate change. The program, www.mass.gov/czm/stormsmart offers technical information, planning strategies, legal and regulatory tools to communities to adapt to climate change impacts.

As more information and tools become available, there may be opportunities to make adjustments in TMDLs in the future to address predictable climate change impacts. When the science can support assumptions about the effects of climate change on the loadings to the TMDL can be reopened, if warranted.

Water Quality Standards Attainment Statement

The proposed TMDL, if fully implemented, will result in the attainment of all applicable water quality standards, including designated uses and numeric criteria for each pollutant named in the Water Quality Standards violations noted above. In addition to the margin of safety within the context of setting the TP threshold levels as described above, a programmatic margin of safety also derives from continued monitoring of these waterbodies to support adaptive management. This monitoring effort provides the ongoing data to evaluate the improvements that occur over the multi-year implementation of the TMDL. This will allow refinements to ensure that the desired level of restoration is achieved.

Monitoring

The cyanobacteria numbers have been monitored in the past by MassDEP and the Massachusetts Department of Public Health will continue as needed. As resources allow, future lake surveys by MassDEP, should include Secchi disk transparency, nutrient analyses, temperature and dissolved oxygen profiles and aquatic vegetation maps of distribution and density. With additional data, the strategy for restoration of the water resources in this TMDL study area and reducing total phosphorus concentrations can be re-evaluated and the TMDL modified if necessary. Monitoring of total phosphorus concentrations and transparency by local volunteer groups is encouraged when possible.

Provisions for Revising the TMDL

The MassDEP reserves the right to modify this TMDL as needed to account for new information or data made available during the implementation of the TMDL. Modification of the TMDL will only be made following an opportunity for public participation and be subject to the review and approval of the EPA. New information, which will be generated during TMDL implementation includes monitoring data, climate change, new or revised State or Federal regulations adopted pursuant to Section 303(d) of the Clean Water Act, and the publication by EPA of national or regional guidance relevant to the implementation of the TMDL program. MassDEP uses an adaptive management approach to observe implementation results over time and allow for adjustments. If water quality targets are met and yet guidance threshold values and other habitat indicators indicate impaired water quality, total phosphorus water quality targets may be revised and TMDL loadings adjusted accordingly. MassDEP will propose modifications to the TMDL analysis only if a review of the new information or data indicates that such a modification is warranted and is consistent with the anti-degradation provisions in the Massachusetts Water Quality Standards. The subject waterbodies of this TMDL analysis will continue to be included on the State of Massachusetts Integrated List of Waters, in the appropriate category.

If the nutrient load reductions required in this TMDL are not achieved, other methodologies and technologies to improve water quality may be considered. One such methodology, a shore based micro-floc aluminum injection pump, may be necessary to control remaining watershed sources into the future while providing more flexibility in application rates. In theory this type of system can control the dose of alum applied daily each summer to more precisely regulate TP and transparency. It has the potential advantage of being able to influence the amount of sunlight reaching the bottom and opening the possibility for controlling the maximum depth of nuisance plant populations. Further details on such a system can be found in Moore *et al.* (2009).

Public Participation

The draft TMDL was announced in the Massachusetts Environmental Monitor and held December 15, 2016 in the Halifax Town Hall, Halifax, MA. Kimberly Groff provided an overview of TMDLs and the work of the MassDEP Watershed Planning Program. Mark Mattson and Matthew Reardon (MassDEP) summarized the draft TMDL and described its findings. Other MassDEP staff in attendance included David Johnston, Jon Hobill and Barbara Kickham. Comments received at the public meeting and received in writing within a 30-day comment period following the public meeting were considered by MassDEP. This final version of the TMDL report includes both a summary of the public comments together with MassDEP's response to the comments and scanned images of the attendance sheets from the meeting (Appendix F).

As a result of EPA comment and review of the Draft TMDL, changes were made to the Wasteload Allocations in the first Draft, which necessitated providing an additional 30-day public comment period. A notice of the second draft TMDL document was posted in the Massachusetts *Environmental Monitor* and an email was sent to stakeholders in the watershed of this opportunity to comment. Additional comment letters and MassDEP responses to comments received on the second draft TMDL are included in Appendix F.

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Appendix A: Landuse Analysis

Table A1: Landuse in Stetson Pond

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
1	**Stetson Pond**	Natural	63.21	31%
1		Low Intensity Development	54.18	27%
1		Abandoned Cranberry Bogs	44.47	22%
1		Medium Intensity Development	26.39	13%
1		Non-Forested Wetland	4.44	2%
1		Forested Wetland	4.07	2%
1		Water	3.14	2%
1		Open	2.72	1%
1		Low Intensity Agriculture	1.41	1%
1		High Intensity Development	0.00	0%
	Stetson Pond Total		204.0	100%

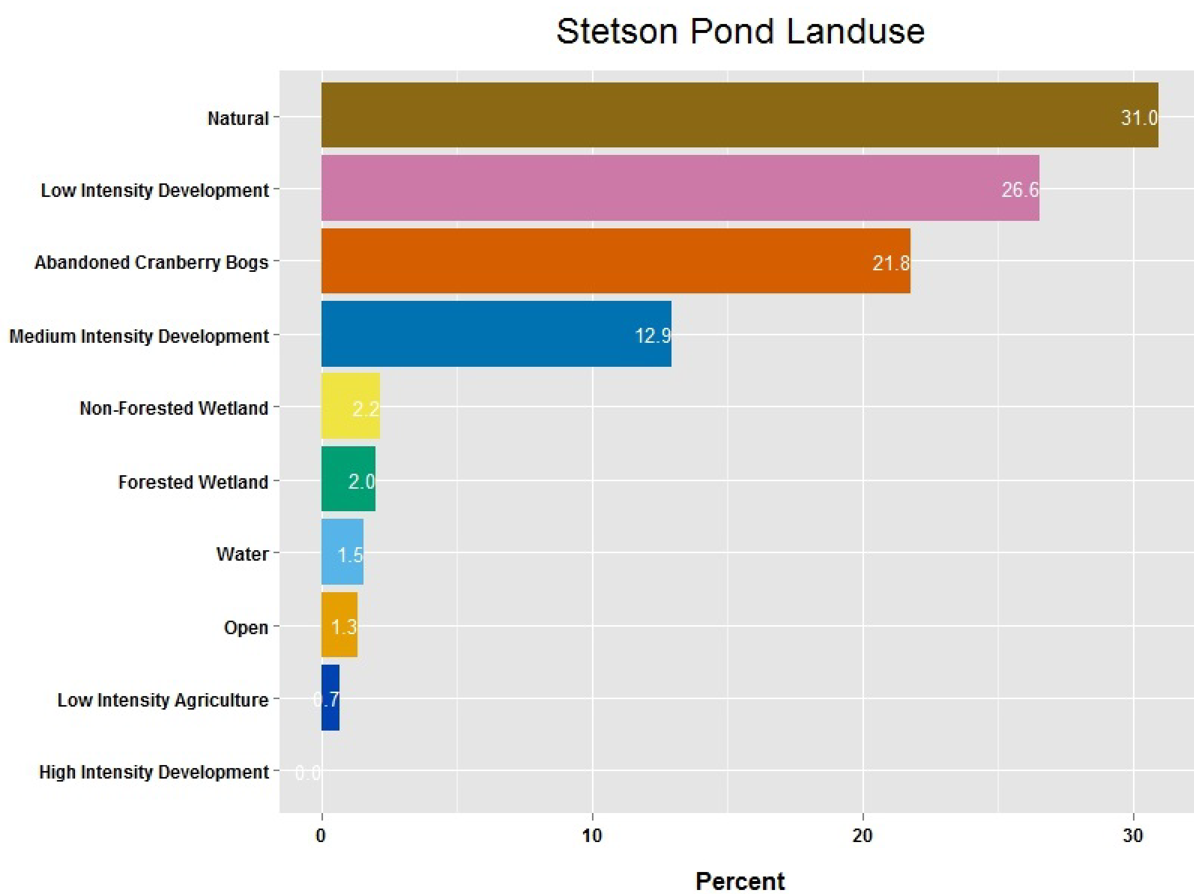


Figure A 1: Landuse in the Stetson Pond Watershed by %

Table A2: Landuse in Stetson Brook

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
2	**Stetson Brook**	Natural	50.01	32%
2		High Intensity Ag. (bog)	22.74	15%
2		Low Intensity Development	22.67	15%
2		Water	19.91	13%
2		Forested Wetland	17.09	11%
2		Medium Intensity Development	16.66	11%
2		Non-Forested Wetland	2.68	2%
2		Open	2.23	1%
2		High Intensity Development	0.09	0%
	Stetson Brook Total		154.09	100%

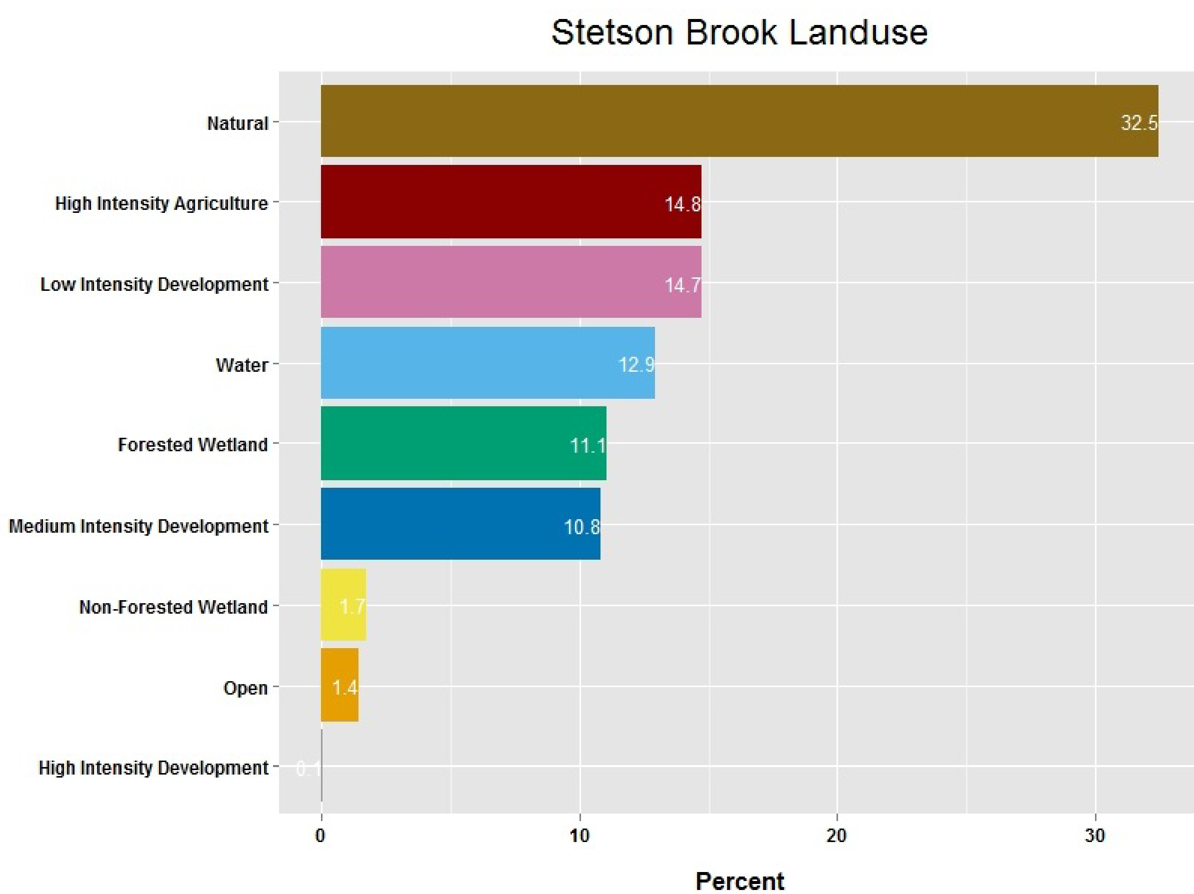


Figure A 2: Landuse in the Stetson Brook Watershed by %

Table A3: Swamp C Landuse

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
3	**Swamp C**	Natural	55.60	43%
3		Low Intensity Development	24.89	19%
3		Forested Wetland	19.76	15%
3		Medium Intensity Development	17.80	14%
3		Non-Forested Wetland	10.66	8%
3		High Intensity Development	0.40	0.3%
3		Open	0.25	0.2%
3		Water	0.07	0.1%
	Swamp C Total		129.43	100%

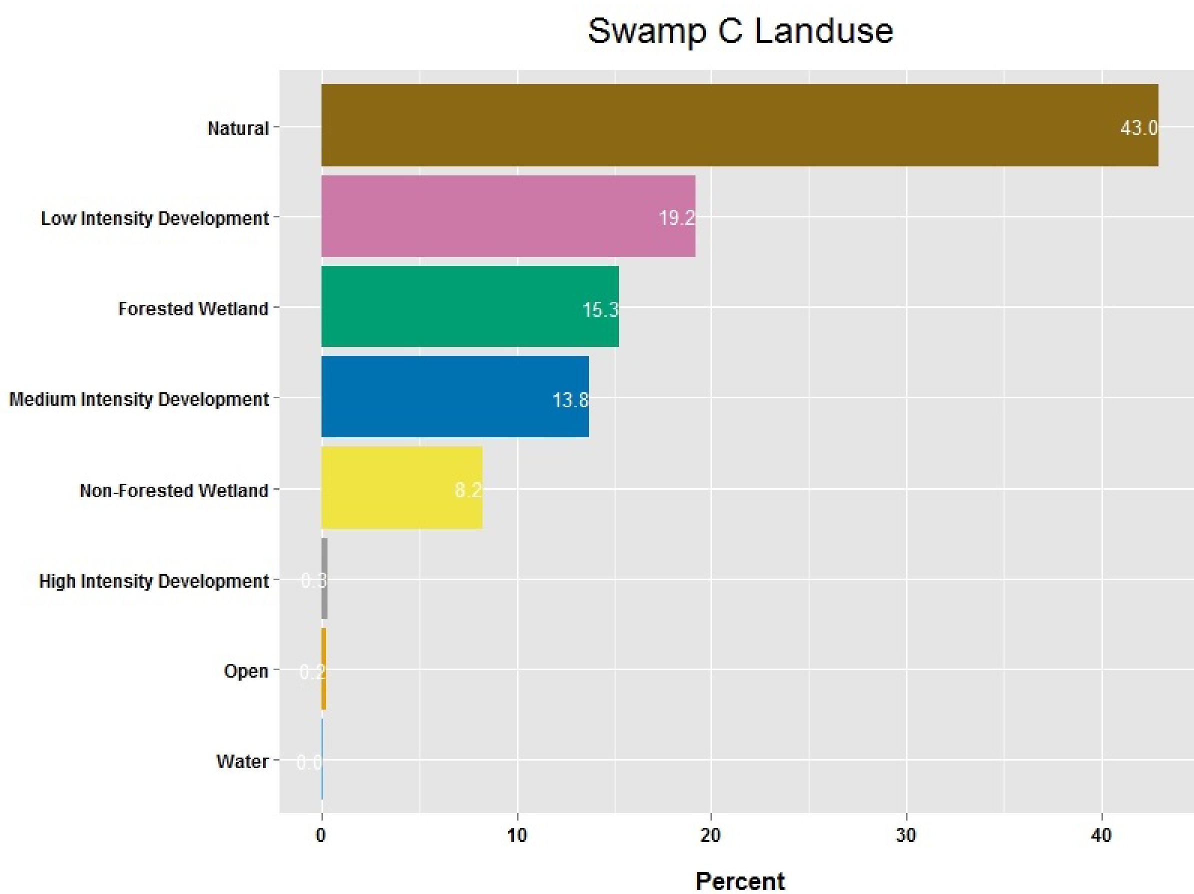


Figure A 3: Landuse in the Swamp C Watershed by %

Table A4: Monponsett Heights Landuse

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
4	**Monponsett Heights**	Medium Intensity Development	17.11	54%
4		Natural	6.53	21%
4		Low Intensity Development	5.00	16%
4		Forested Wetland	2.58	8%
4		Non-Forested Wetland	0.34	1%
4		Water	0.01	0%
	Monponsett Heights Total		31.57	100%

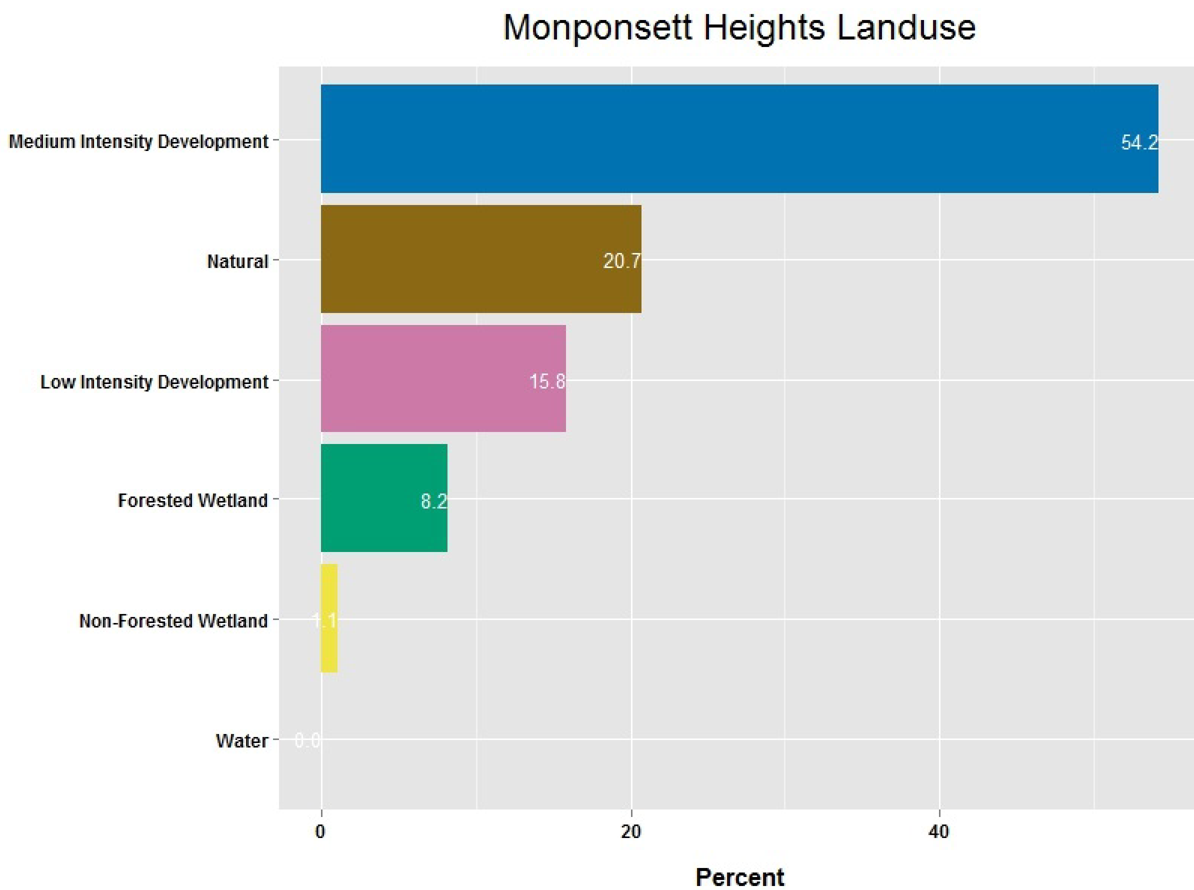


Figure A 4: Landuse in the Monponsett Heights Watershed by %

Table A5: Peterson Swamp Landuse

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
5	**Peterson Swamp**	Natural	46.16	38%
5		Forested Wetland	44.25	36%
5		Medium Intensity Development	14.56	12%
5		Low Intensity Development	11.42	9%
5		Low Intensity Agriculture	5.11	4%
5		Water	0.37	0.3%
5		Non-Forested Wetland	0.20	0.2%
5	**Peterson Swamp Total**		122.07	100%

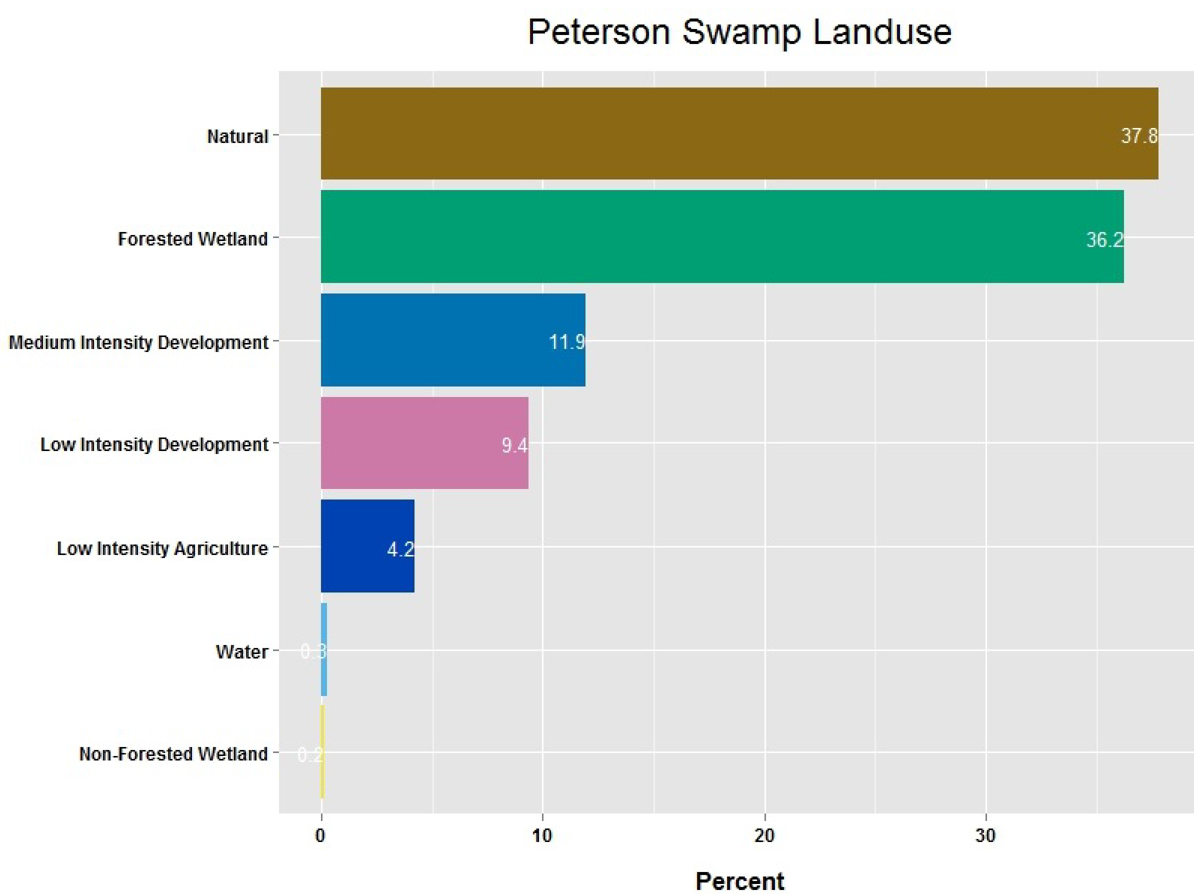


Figure A 5: Landuse in the Peterson Swamp Watershed by %

Table A6: Direct to East Pond Landuse

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
6	**Direct to East Pond**	Natural	25.82	28%
6		Medium Intensity Development	20.36	22%
6		Low Intensity Development	19.16	21%
6		Forested Wetland	14.07	16%
6		High Intensity Development	8.09	9%
6		Non-Forested Wetland	1.23	1.4%
6		Low Intensity Agriculture	1.10	1.2%
6		High Intensity Ag. (bog)	0.51	0.6%
6		Water	0.40	0.4%
	Direct to East Pond Total		**90.73**	100%

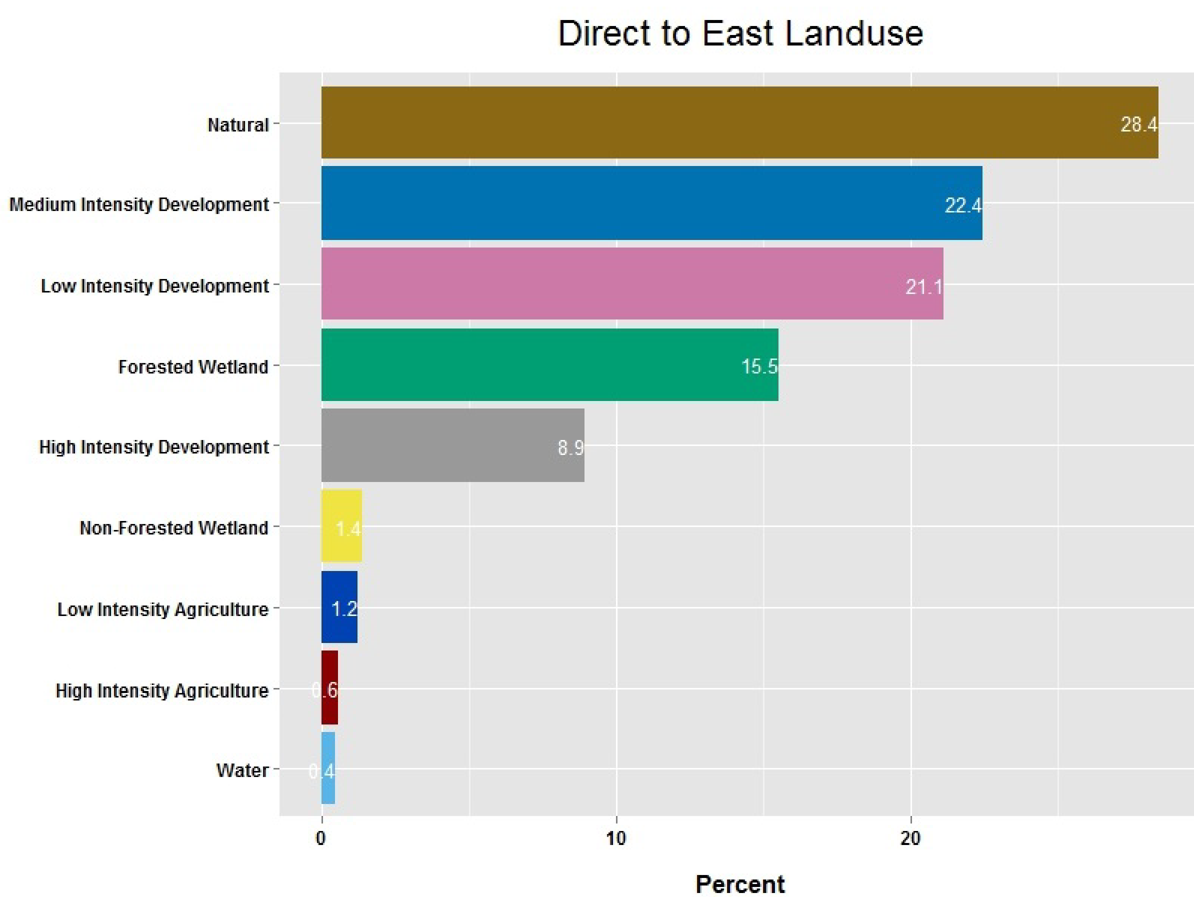


Figure A 6: Landuse in the Direct to East Pond Watershed by %

Table A7: Summary of All Landuse in East Monponsett Pond

Group	Area (Hectares)	% of Total Watershed Area
Natural	247.33	32.1%
Low Intensity Development	137.32	17.8%
Medium Intensity Development	112.88	14.7%
Forested Wetland	101.83	13.2%
High Intensity Ag. (bog)	67.71	8.8%
Water**	61.96	8.0%
Non-Forested Wetland	19.55	2.5%
High Intensity Development	8.58	1.1%
Low Intensity Agriculture	7.62	1.0%
Open	5.20	0.7%
All Landuse East Pond Total	**769.98**	100.0%

** does not include surface area of Stetson Pond and East Monponsett Pond

Table A8: White Oak Reservoir Landuse

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
8	White Oak Reservoir	Low Intensity Development	56.56	34%
8		Natural	47.91	29%
8		Forested Wetland	22.34	13%
8		Non-Forested Wetland	9.58	6%
8		High Intensity Ag. (bog)	7.61	5%
8		Water	6.38	4%
8		Medium Intensity Development	6.14	4%
8		High Intensity Development	5.16	3%
8		Abandoned Cranberry Bogs	4.71	3%
8		Low Intensity Agriculture	0.13	0.1%
	White Oak Reservoir Total		**166.53**	100%

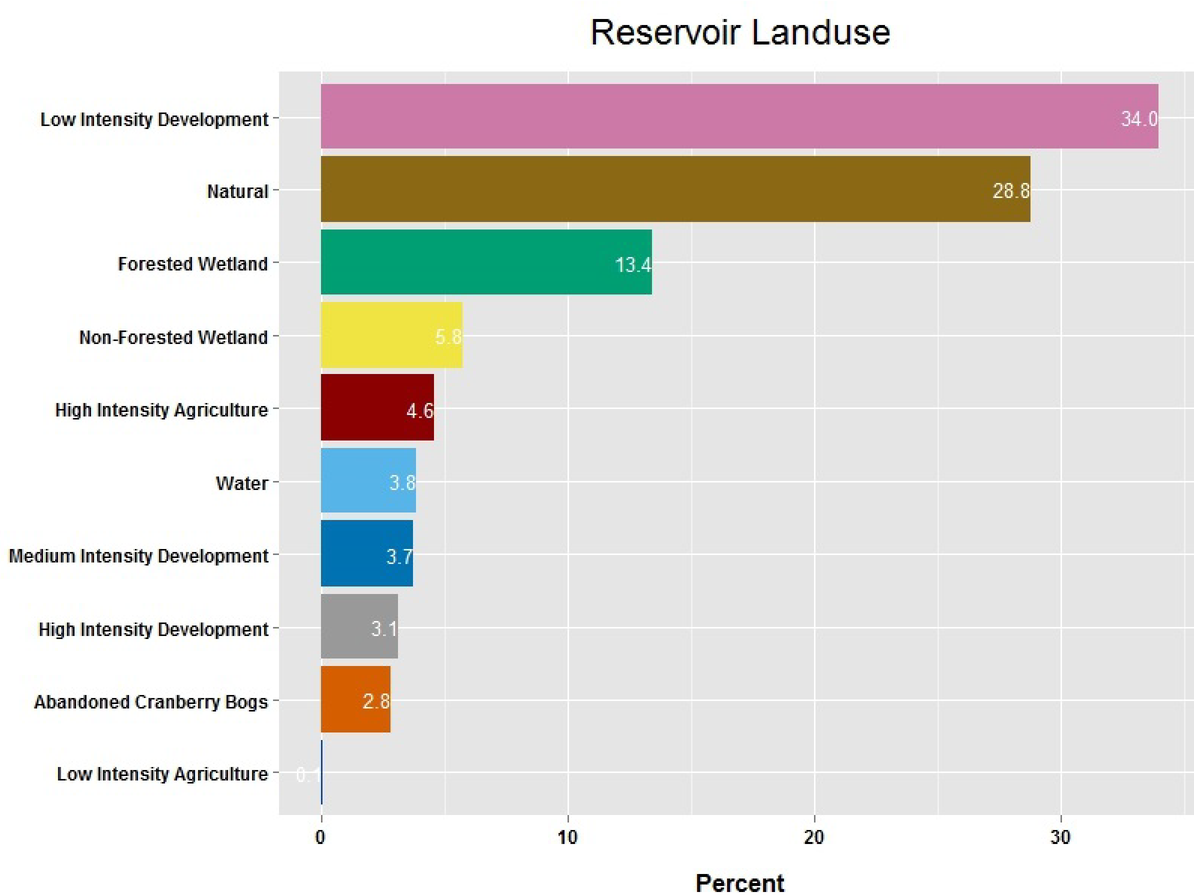


Figure A 7: Landuse in the White Oak Reservoir Watershed by %

Table A9: White Oak Brook Landuse

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
9	White Oak Brook	Natural	32.12	30%
9		High Intensity Ag. (bog)	23.59	22%
9		Low Intensity Development	21.24	20%
9		Forested Wetland	16.97	16%
9		Non-Forested Wetland	7.34	7%
9		Medium Intensity Development	5.47	5%
9		Water	0.34	0%
9		Low Intensity Agriculture	0.03	0%
	White Oak Brook Total		107.09	100%

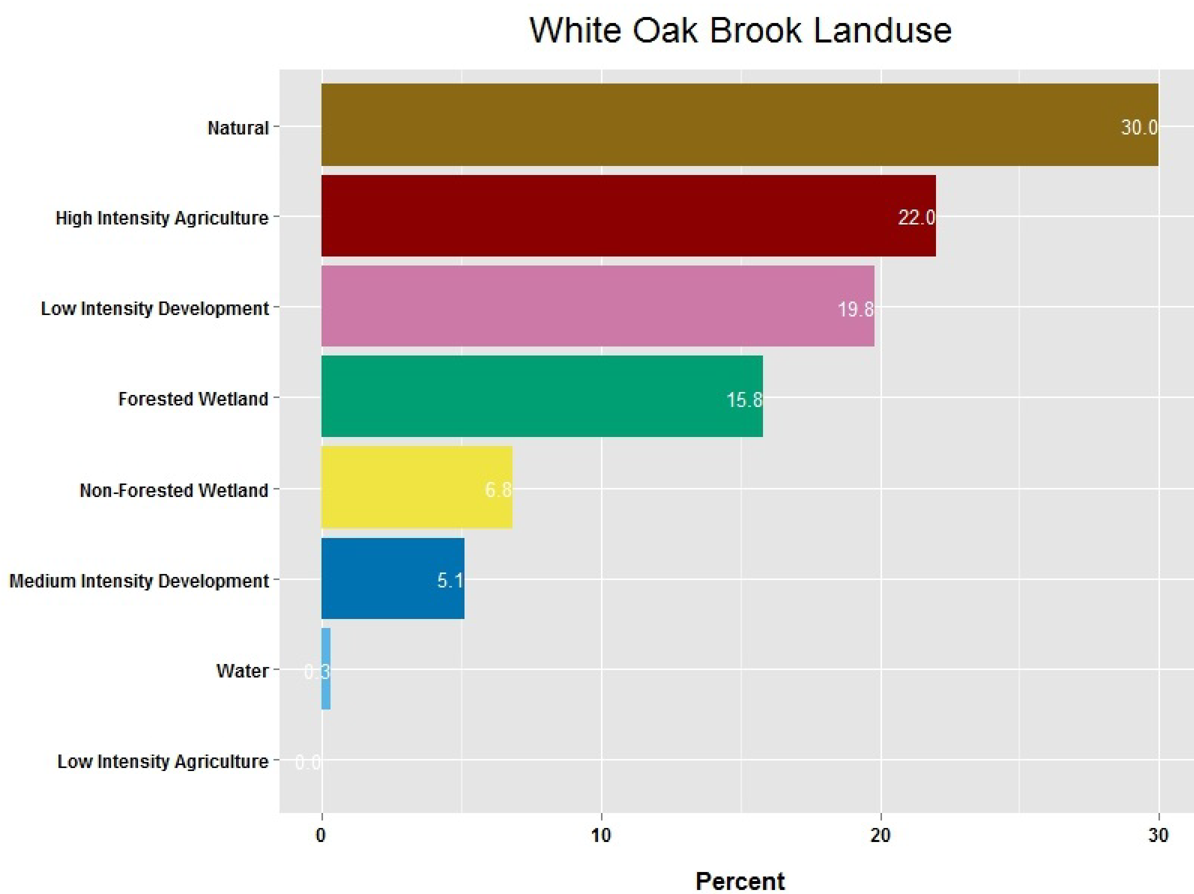


Figure A 8: Landuse in the White Oak Brook Watershed by %

Table A10: Unnamed Tributary 1 Landuse

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
10	Unnamed Tributary1	Forested Wetland	32.96	62%
10		Natural	12.96	25%
10		Low Intensity Development	3.80	7%
10		Non-Forested Wetland	1.85	3%
10		High Intensity Ag. (bog)	0.74	1%
10		Medium Intensity Development	0.54	1%
10		Water	0.01	0%
	Unnamed Tributary1 Total		52.86	100%

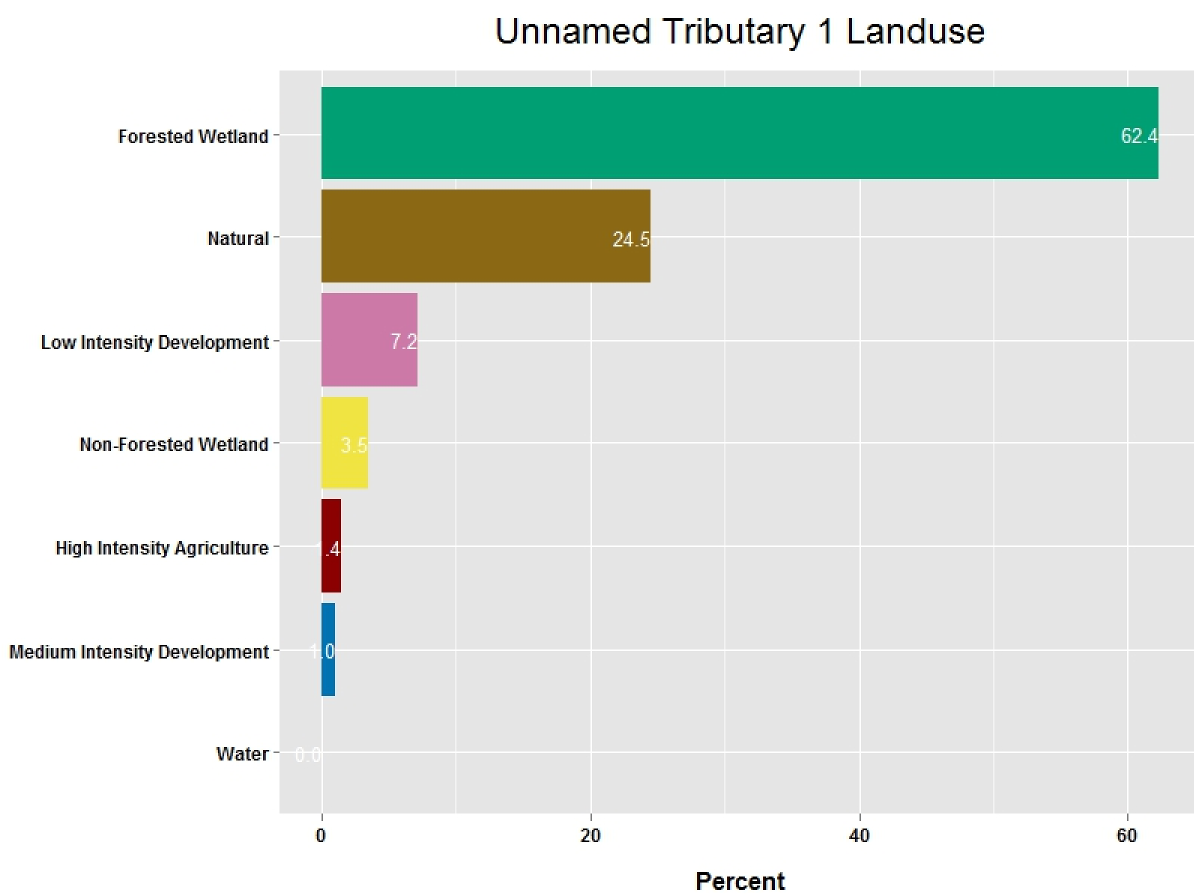


Figure A 9: Landuse in the Unnamed Tributary 1 Watershed by %

Table A11: Unnamed Tributary 2 Landuse

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
11	Unnamed Tributary2	Natural	29.74	27%
11		Low Intensity Development	23.99	22%
11		Medium Intensity Development	20.75	19%
11		High Intensity Ag. (bog)	11.73	11%
11		Non-Forested Wetland	9.96	9%
11		Forested Wetland	8.01	7%
11		Abandoned Cranberry Bogs	3.12	3%
11		Water	0.69	1%
11		High Intensity Development	0.67	1%
	Unnamed Tributary2 Total		**108.65**	100%

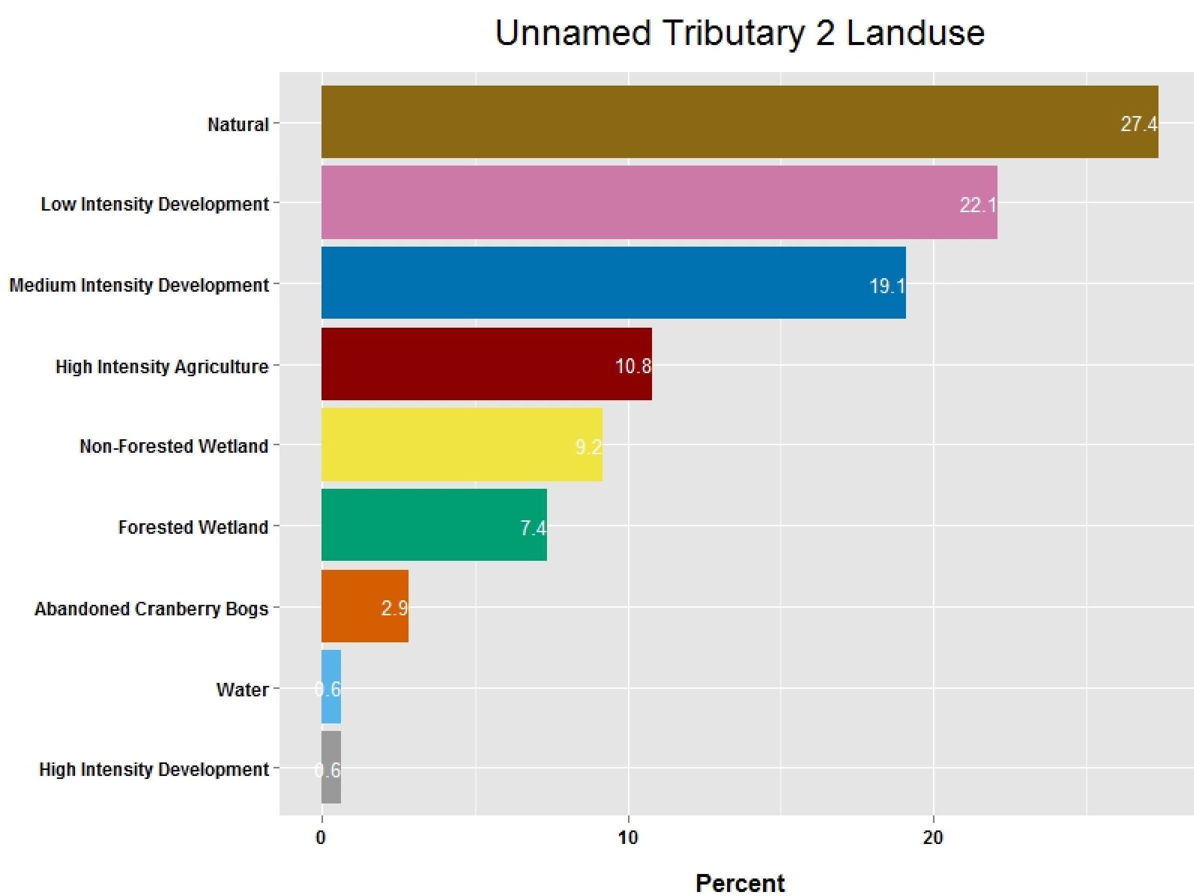


Figure A 10: Landuse in the Unnamed Tributary 2 Watershed by %

Table A12: Artificial Flow Path/Unnamed Tributary Landuse

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
12	ArtFlow Unnamed Tributary3	Medium Intensity Development	17.96	84%
12		Natural	2.68	12%
12		Non-Forested Wetland	0.46	2%
12		Forested Wetland	0.20	1%
12		Water	0.08	0.4%
12		High Intensity Development	0.06	0.3%
	Artificial Flow Unnamed Tributary3 Total		**21.44**	**100%**

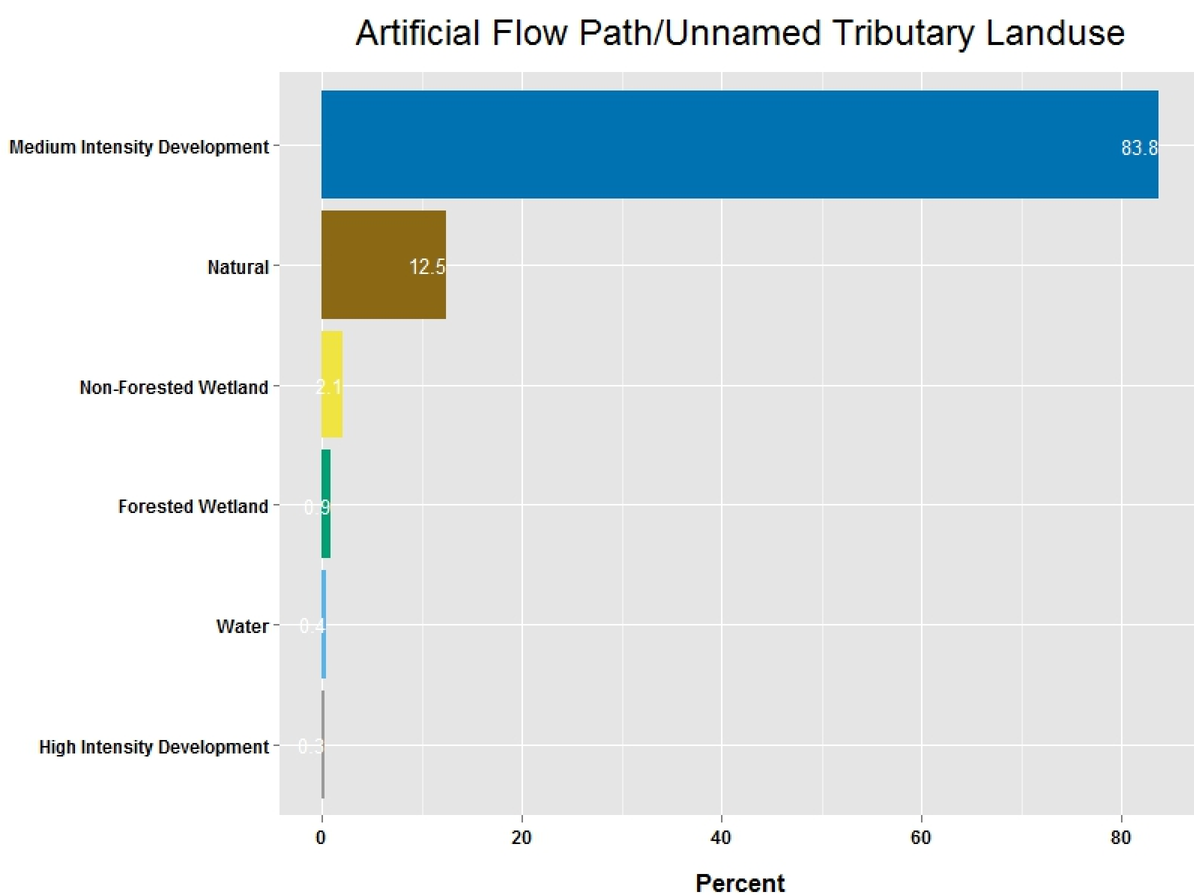


Figure A 11: Landuse in the Artificial Flow Path/Tributary Watershed by %

Table A13: Direct to West Pond Landuse

Shed #	Shed	Group	Area (Hectares)	% of Total Watershed Area
13	Direct to West Pond	Natural	27.38	29.1%
13		Forested Wetland	26.00	28%
13		Medium Intensity Development	18.53	19.7%
13		Non-Forested Wetland	10.08	11%
13		Low Intensity Development	7.05	7%
13		High Intensity Ag. (bog)	2.37	3%
13		High Intensity Development	1.77	2%
13		Water	1.04	1%
	Direct to West Pond Total		**94.21**	1

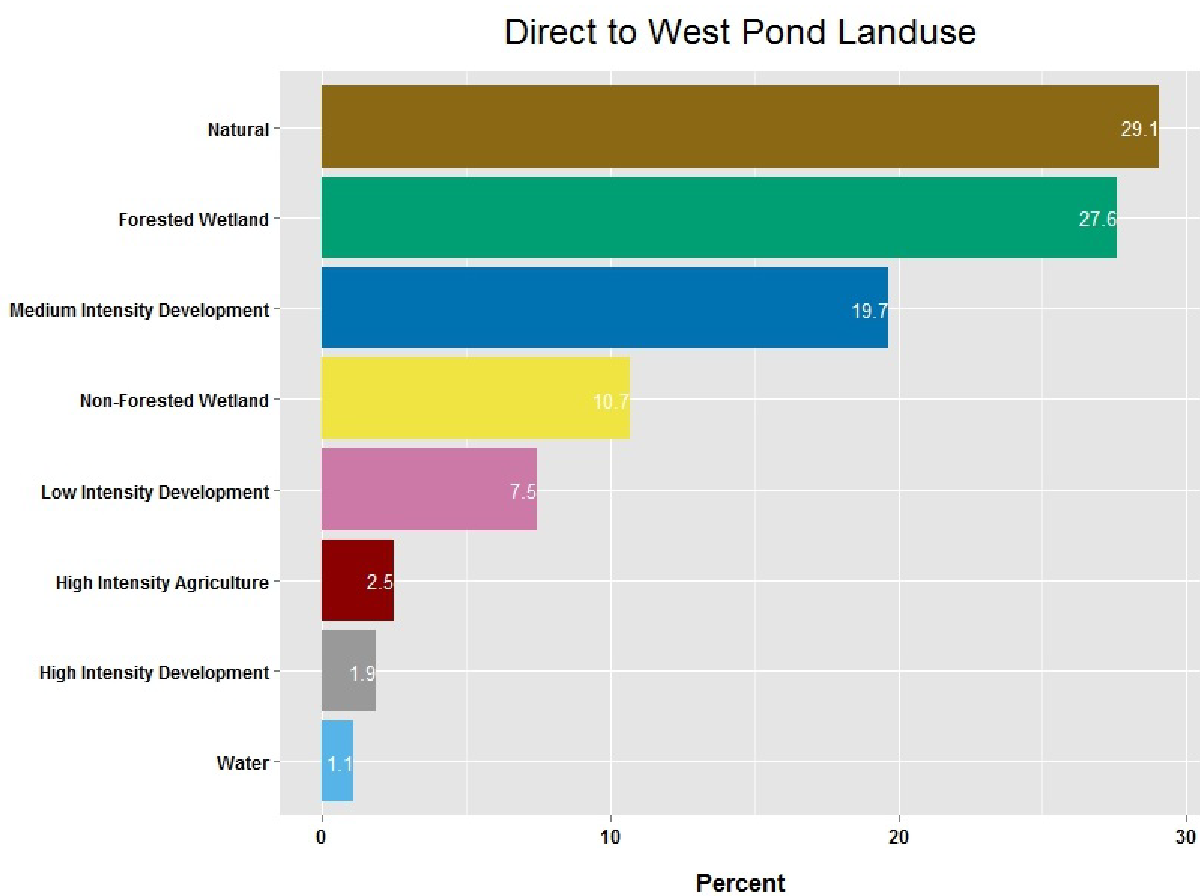


Figure A 12: Landuse in the Direct to West Pond Watershed by %

Appendix B: Select LLRM Information

Table B1: Water and TP Landuse Export Coefficient used for current condition LLRM model calibration

Landuse Grouping	TP (kg/ha/yr)	Flow Coeff (%)
Natural	0.10	0.50
Low Intensity Agriculture	0.64	0.50
Medium Intensity Agriculture	1.50	0.50
High Intensity Ag. (bog)	4.30	0.50
Forested Wetland	0.40	0.50
Non-Forested Wetland	0.30	0.50
Low Intensity Development	0.30	0.50
Medium Intensity Development	0.50	0.50
High Intensity Development	1.00	0.50
Open	0.00	0.50
Water	0.00	0.50
Abandoned Cranberry Bog	0.10	0.50

Table B2: LLRM TP Prediction Equations

Name	Formula
Mass Balance (Maximum Conc.)	TP=L/(Z(F))*1000
Kirchner-Dillon 1975 (K-D)	TP=L(1-Rp)/(Z(F))*1000
Vollenweider 1975 (V)	TP=L/(Z(S+F))*1000
Larsen-Mercier 1976 (L-M)	TP=L(1-Rlm)/(Z(F))*1000
Jones-Bachmann 1976 (J-B)	TP=0.84(L)/(Z(0.65+F))*1000
Reckhow General (1977) (Rg)	TP=L/(11.6+1.2(Z(F)))*1000

(see table B3 for symbol definitions and value derivations, see references above for citations)

Table B3: Symbols Used In LLRM Model

Symbol	Parameter	Units	Derivation
TP	Lake Total Phosphorus Conc.	ppb	From in-lake models
KG	Phosphorus Load to Lake	kg/yr	From export model
L	Phosphorus Load to Lake	g P/m2/yr	KG*1000/A
TPin	Influent (Inflow) Total Phosphorus	ppb	From export model
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data, if available
I	Inflow	m3/yr	From export model
A	Lake Area	m2	From data
V	Lake Volume	m3	From data
Z	Mean Depth	m	Volume/area
F	Flushing Rate	flushings/yr	Inflow/volume
S	Suspended Fraction	no units	Effluent TP/Influent TP
Qs	Areal Water Load	m/yr	Z(F)
Vs	Settling Velocity	m	Z(S)
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)

Appendix C: Select MassDEP Sampling Data

Algal Sampling

Given human health impacts MassDEP has monitored West Monponsett Pond since 2013 for total cyanobacteria counts and speciation. Massachusetts Department of Health (MA DPH) Advisory Level (AL) state that cyanobacteria cell counts greater than 70,000 per mL indicate a moderate risk level for adverse human health effects from potentially toxic cyanobacteria. At 70,000 cells/mL and above MA DPH will advise communities to post signage at waterbodies warning people to avoid contact with the water. Children and pets are most susceptible to the cyanotoxins because of the amount of time they are in the water and the amount of water they typically ingest in play. Dermal, liver or neurological effects may result from contact or ingestion of these waters.

In 2013 MassDEP conducted algal sampling at two locations on West Monponsett Pond, 4th Avenue Beach and Ocean Avenue Beach. Total cyanobacteria count at the 4th Avenue Beach sampling location were greater than 70,000 cells/mL, the MA DPH Advisory Level for contact recreation, for a substantial portion of the summer and high counts lasted into December of 2013 (Figure C1). During the period where total cyanobacteria counts exceeded the MA DPH Advisory Level, counts were on average 3.4 times the Advisory Level. The highest cyanobacteria count at the 4th Avenue Beach were found on October 15, 2013. On this date, the total cyanobacteria count was approximately 1.2 million cells/mL with the sample dominated by *Microcystis* and *Aphanizomenon* (Figure C3).

MassDEP sampling at the Ocean Avenue Beach found prolonged exceedance of the MA DPH advisory level for cyanobacteria cells counts (Figure C2). High total cyanobacteria counts were found beginning in July of 2013 and with exception of a slight dip in August continued into December of 2013. In general total cyanobacteria counts at this location were generally higher than the 4th Avenue sampling site in 2013 and the bloom timing pattern was slightly different. During the period, counts were on average 5.2 times the Advisory Level. The two highest cyanobacteria count at this location in 2013 occurred on September 16 and November 18th with counts of 1,045,517 and 2,002,234 (cells/mL). The September bloom was largely composed of *Microcystis* while the November bloom was principally composed of *Aphanizomenon* (Figure C4).

In 2014 MassDEP sampled at three locations on West Monponsett Pond, the 4th Avenue Beach, the boat launch and the Ocean Avenue Beach. The 4th Avenue Beach was found to have elevated total cyanobacteria counts beginning in July and lasting into December of 2014 (Figure C5). During the period where total cyanobacteria counts exceeded the MA DPH Advisory Level, counts were on average 1.8 times the Advisory Level. On September 29th the highest total cyanobacteria count (271,302 cells/mL) was found at this location and the dominant taxa on this date was *Anabaena*. MassDEP sampling at the boat launch in 2014 documented elevated total cyanobacteria counts on dates between July 1 and December 1st (Figure C6). Samples during this period were always greater than the

MA DPH Advisory Level. The samples during this period were on average approximately 4 times the Advisory Level. The highest total cyanobacteria count at the boat launch sampling station was 1,974,152 and occurred on September 29th. During this bloom the *Anabaena (large celled)* made up the majority of the total cell count (Figure C9).

In 2014 MassDEP sampling at the Ocean Avenue Beach documented elevated total cyanobacteria counts which exceed the MA DPH Advisory Level on dates between July 8 and November 24 (Figure C7). During the period, counts were on average 2.2 times the Advisory Level. The highest total cyanobacteria count of 555,544 (cells/mL) was found on September 29th and was dominated by *Anabaena (large celled)* (Figure C10).

MassDEP sampling has documented a severe impairment of the recreational use of West Monponsett Pond due to harmful algal blooms, namely cyanobacteria. In order to restore this resource a significant reduction in nutrient loading in this system will be required.

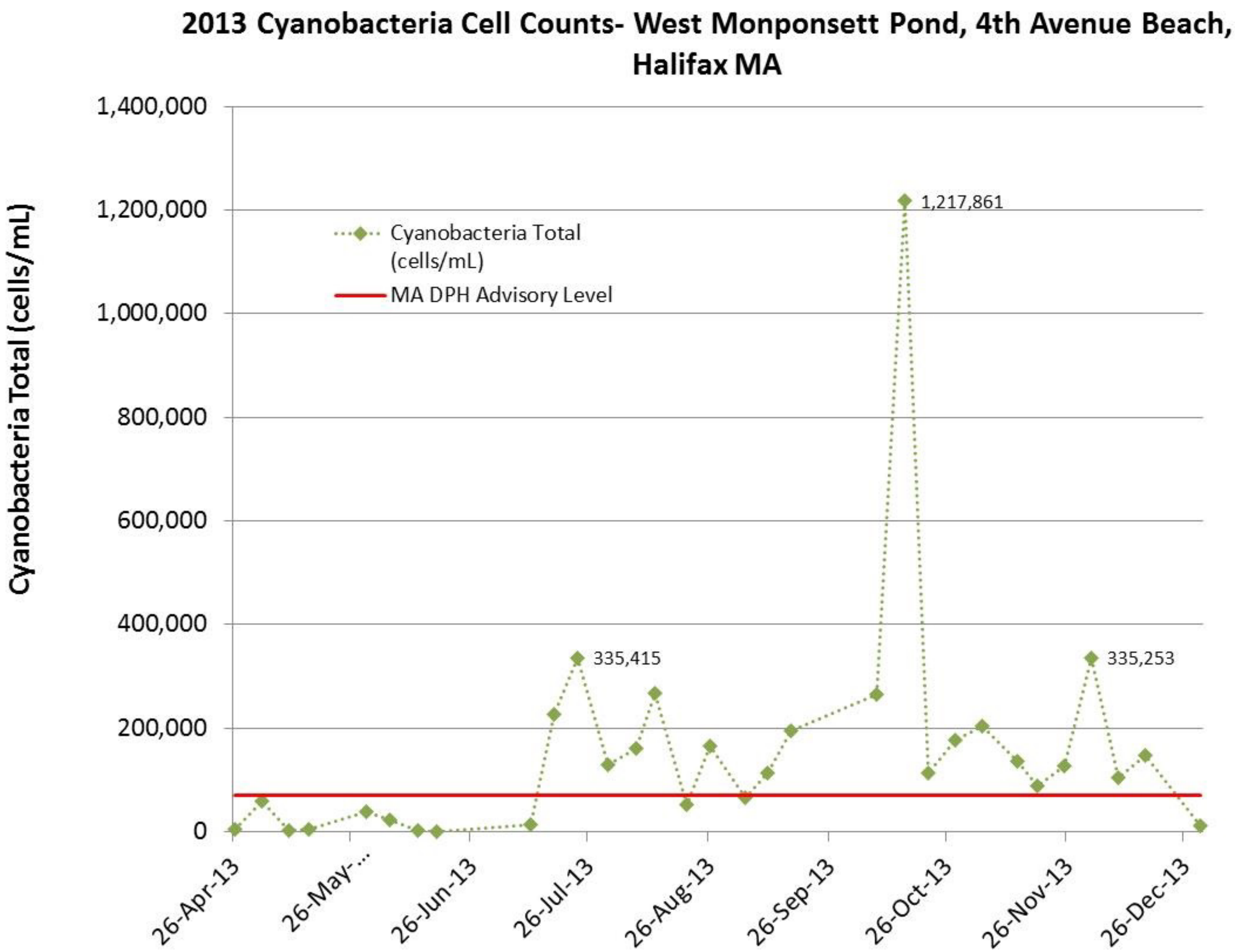


Figure C 1: West Monponsett Pond, 4th Avenue Beach, 2013 Cyanobacteria Cell Counts

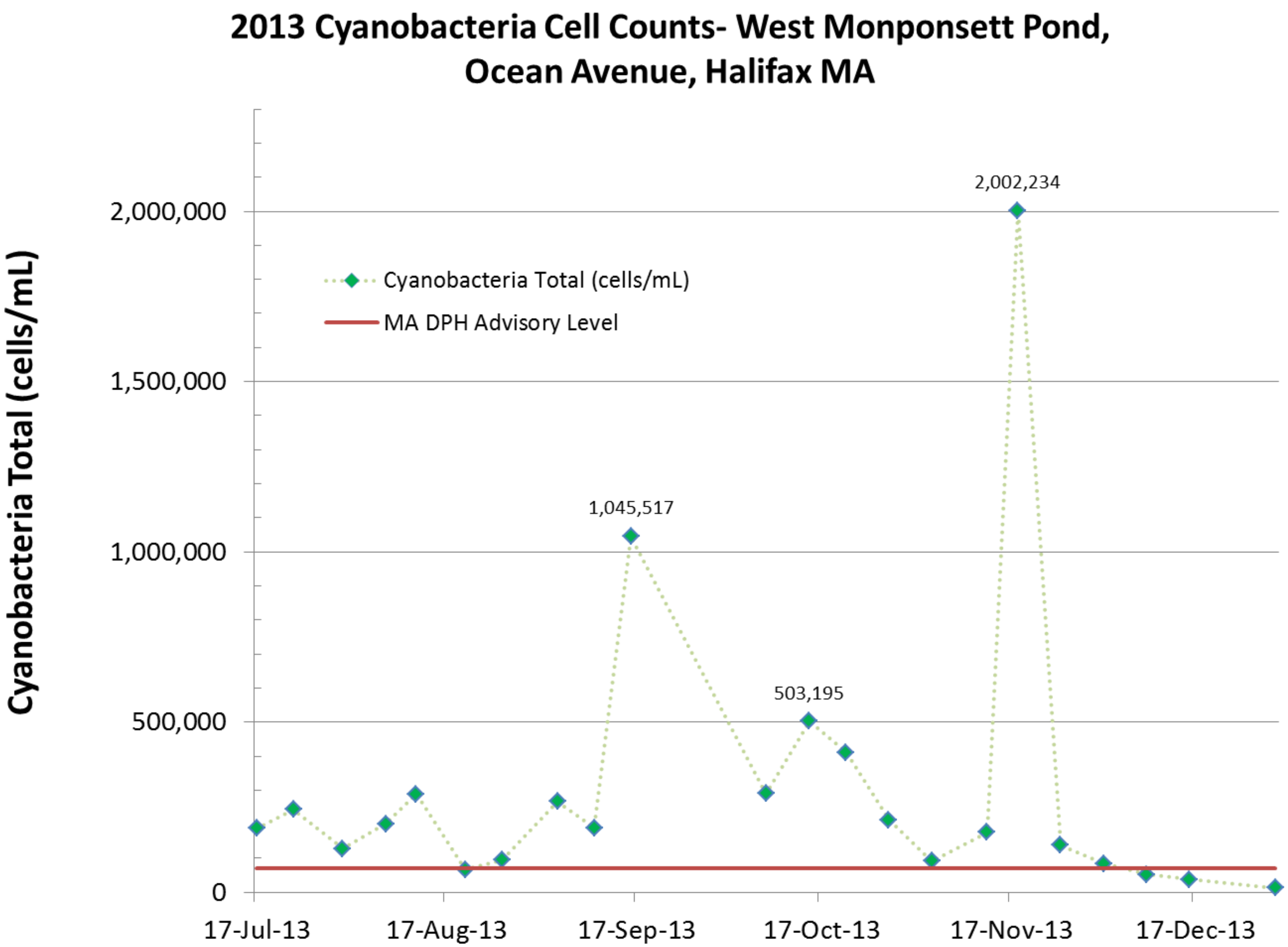


Figure C 2: West Monponsett Pond, Ocean Avenue Beach, 2013 Cyanobacteria Cell Counts

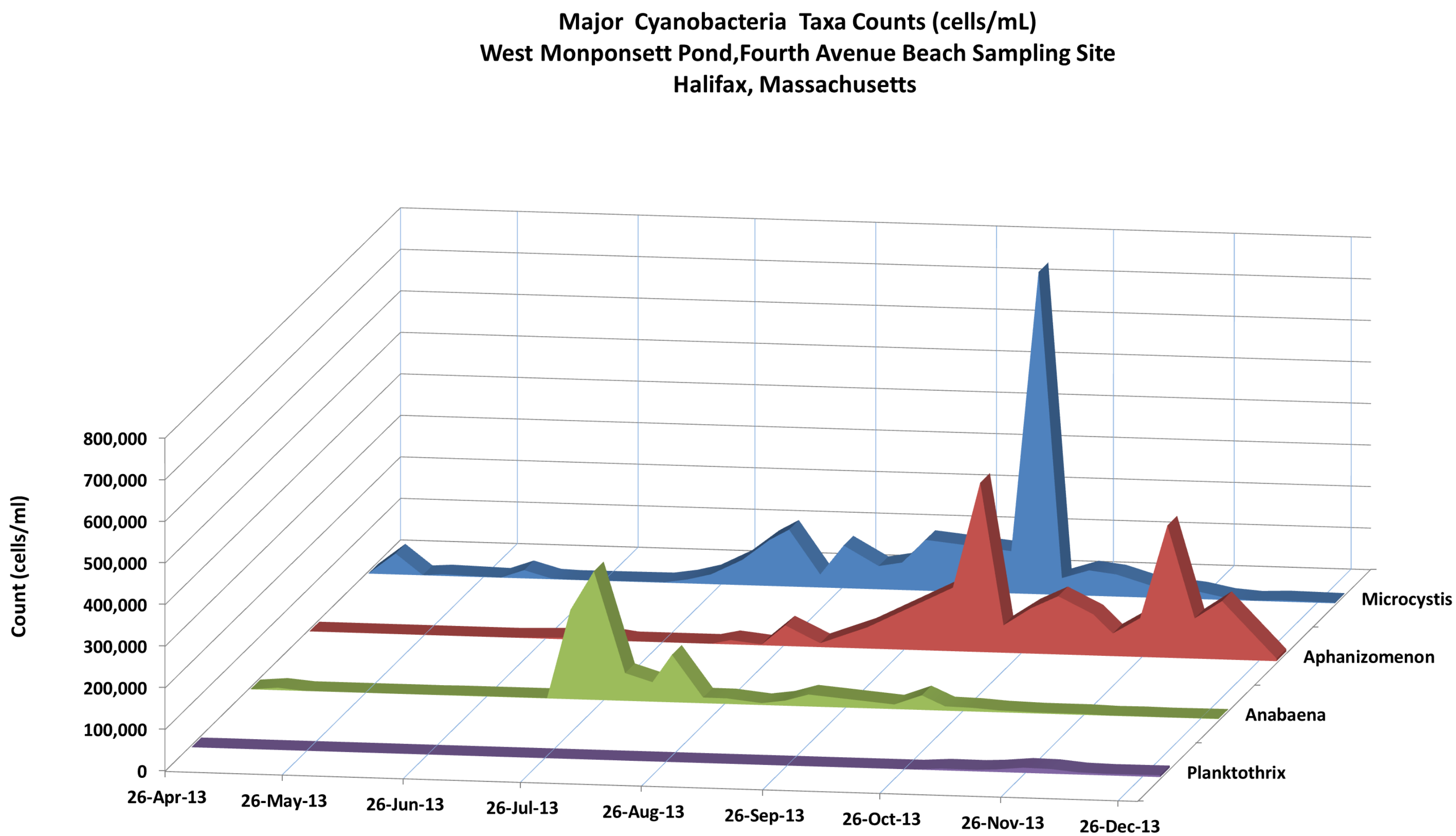


Figure C 3: West Monponsett Pond, 4th Avenue Beach, 2013 Major Cyanobacteria Taxa Counts (cells/mL)

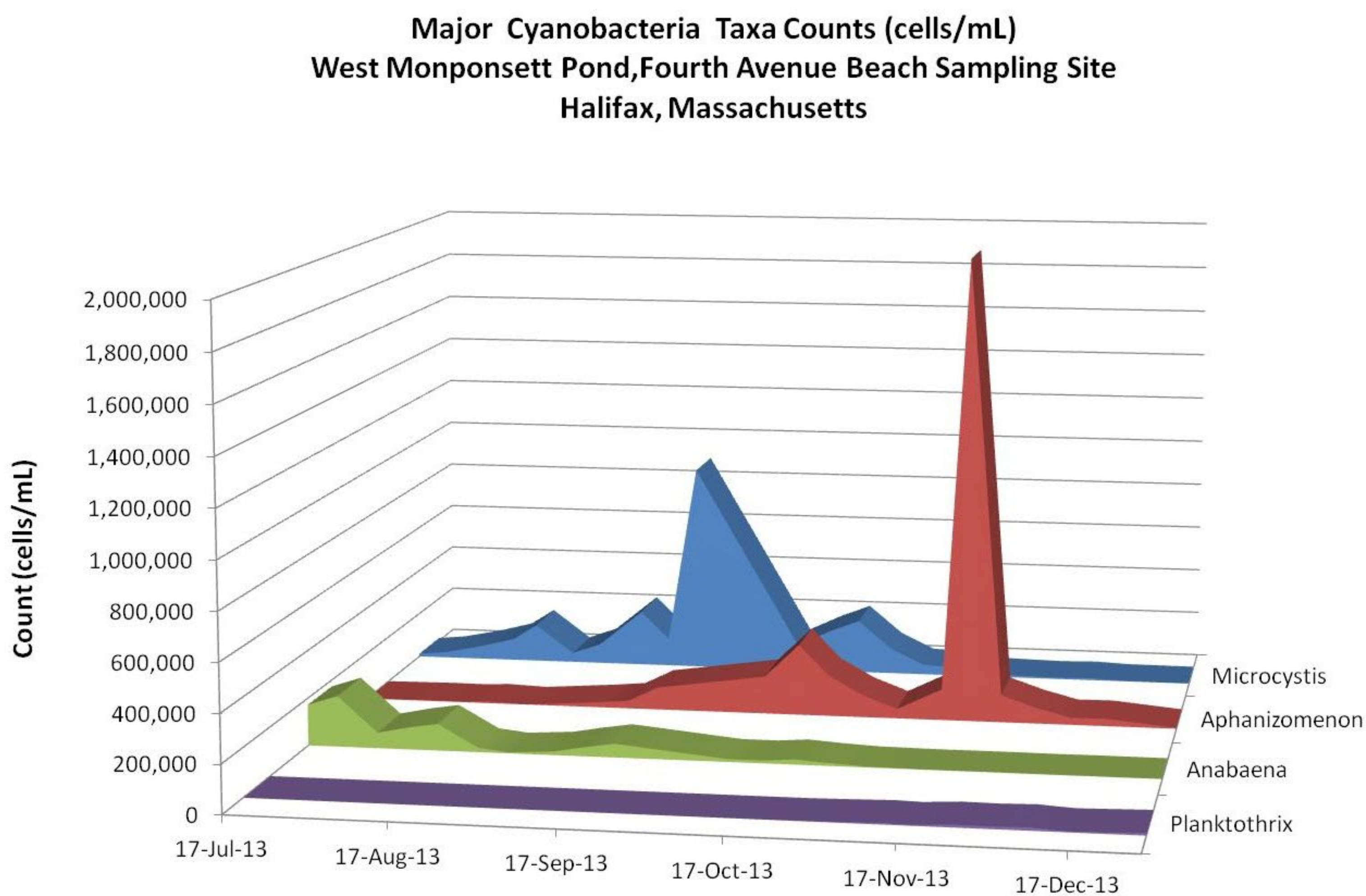


Figure C 4: West Monponsett Pond, Ocean Avenue Beach, 2013 Major Cyanobacteria Taxa Counts (cells/mL)

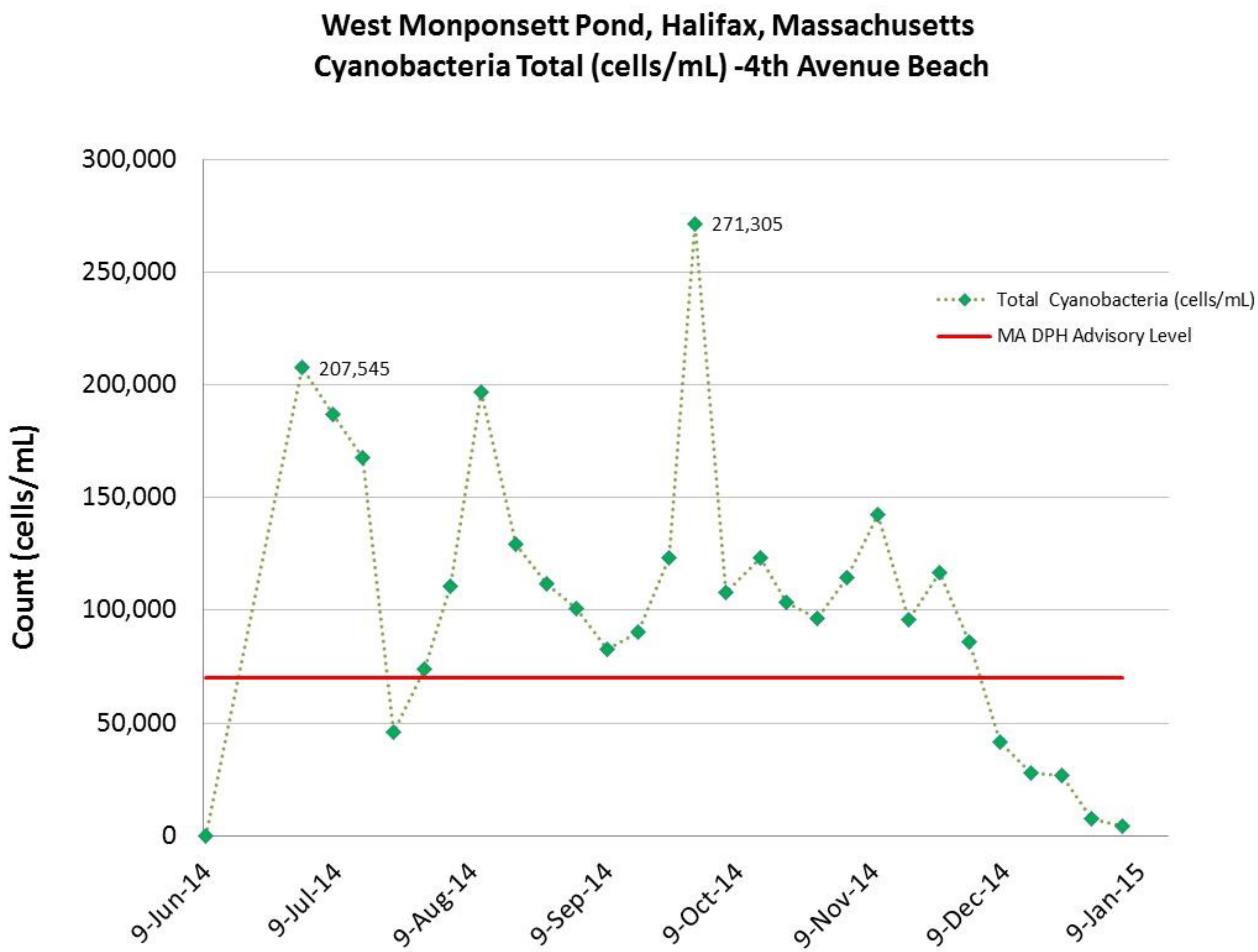


Figure C 5: West Monponsett Pond, 4th Avenue Beach, 2014 Cyanobacteria Cell Counts

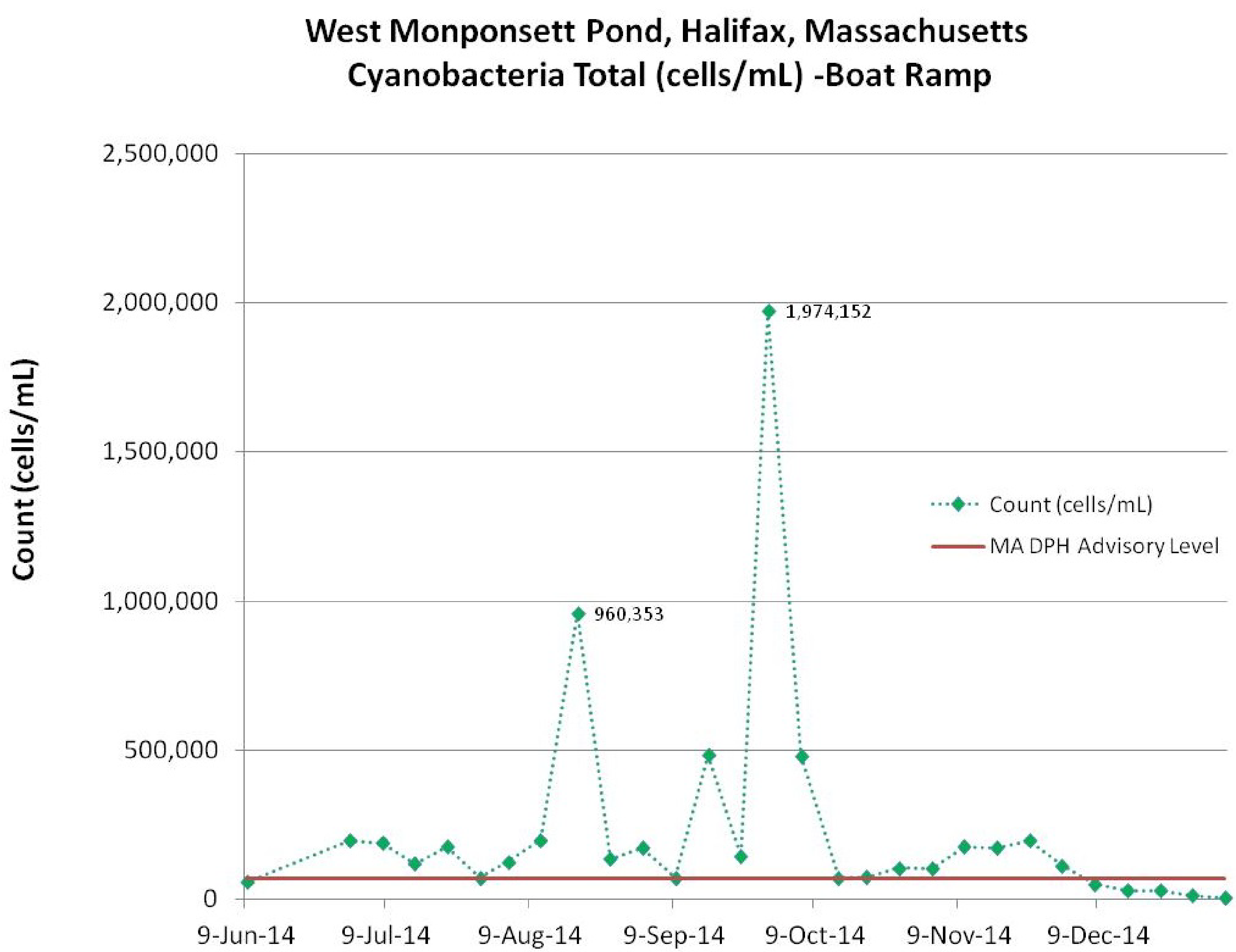


Figure C 6: West Monponsett Pond, Boat Ramp 2014 Cyanobacteria Cell Counts

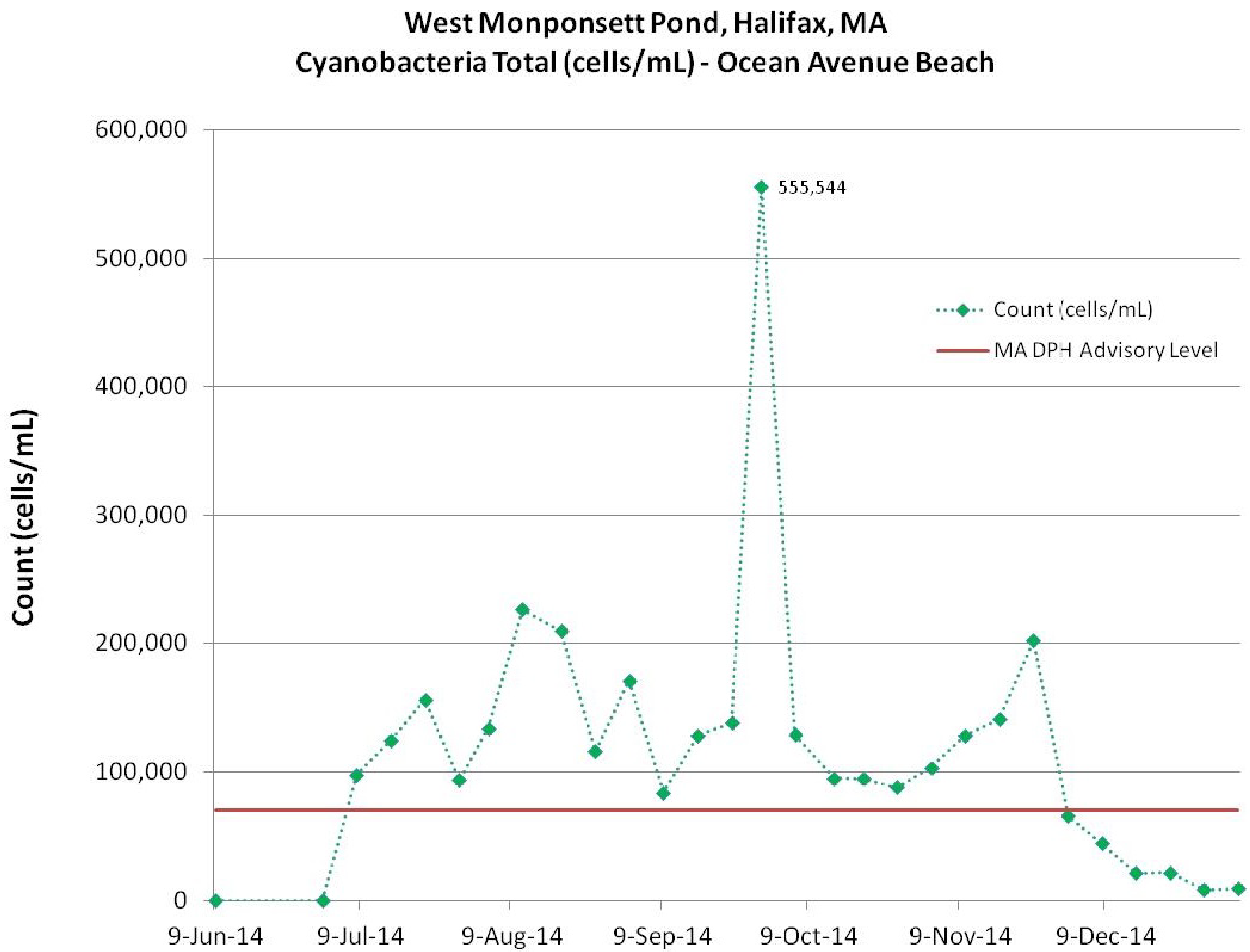


Figure C 7: West Monponsett Pond, Ocean Avenue Beach 2014 Cyanobacteria Cell Counts

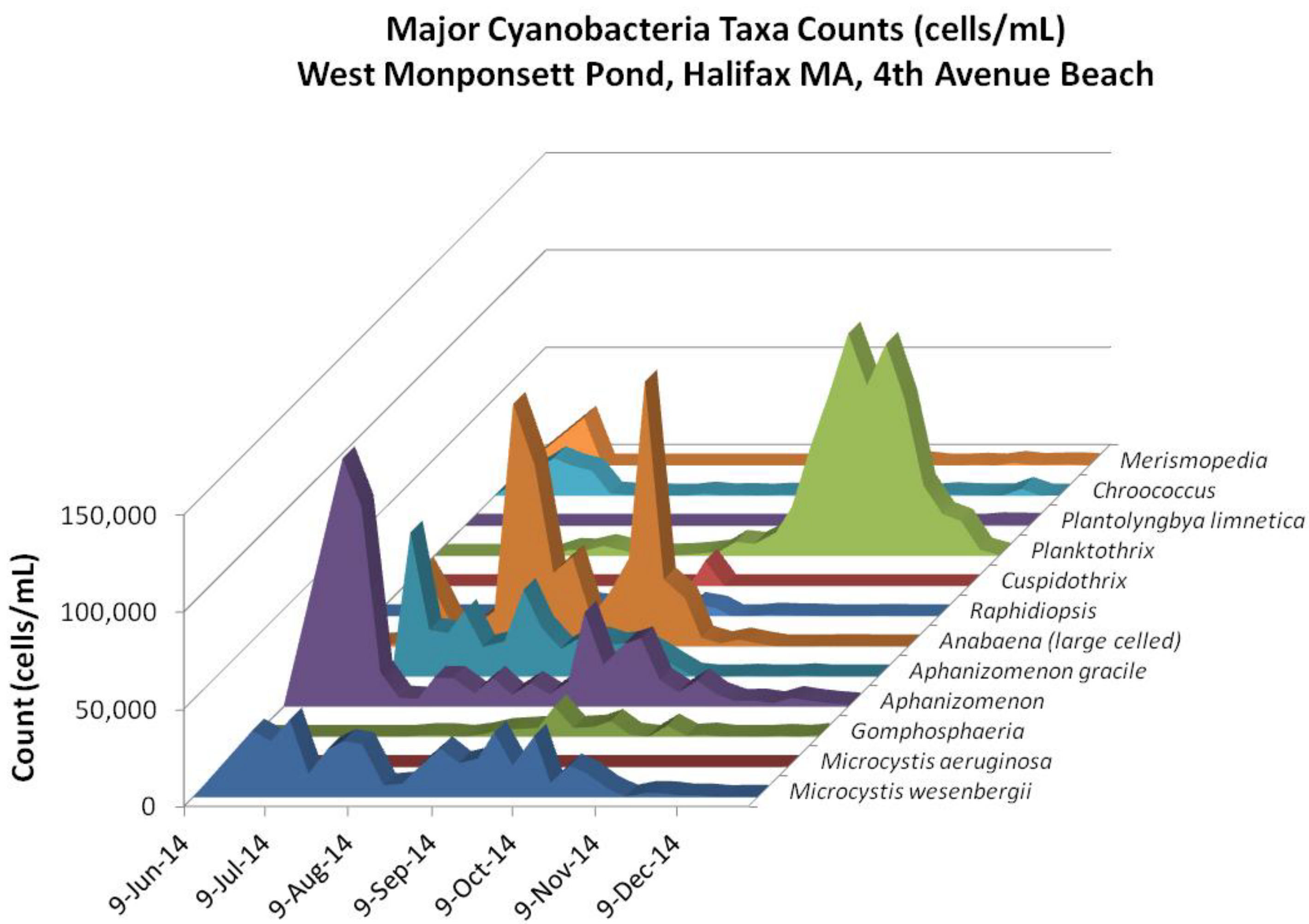


Figure C 8: West Monponsett Pond, 4th Avenue Beach, 2014 Major Cyanobacteria Taxa Counts (cells/mL)

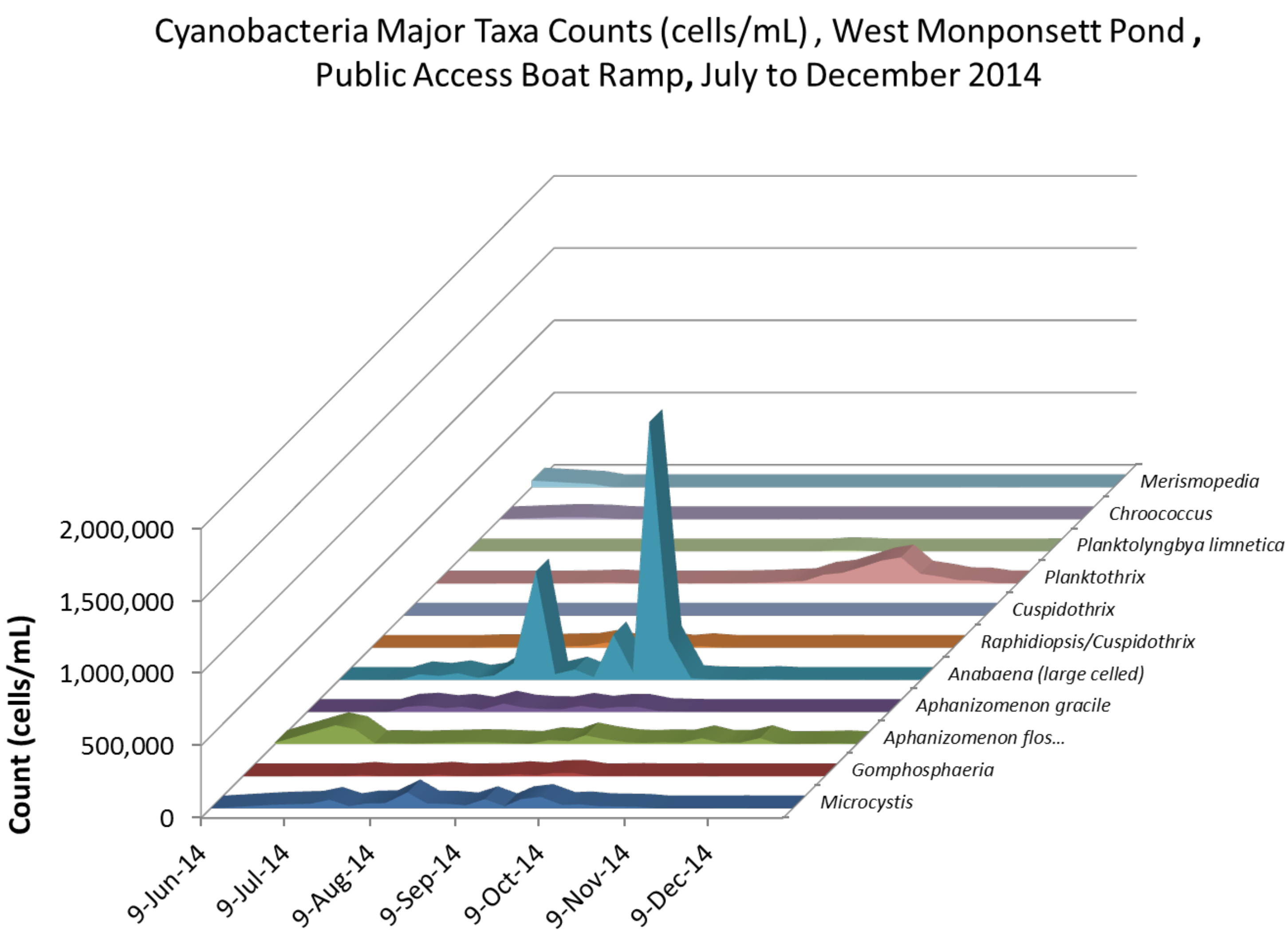


Figure C 9: West Monponsett Pond, Boat Ramp, 2014 Major Cyanobacteria Taxa Counts (cells/mL)

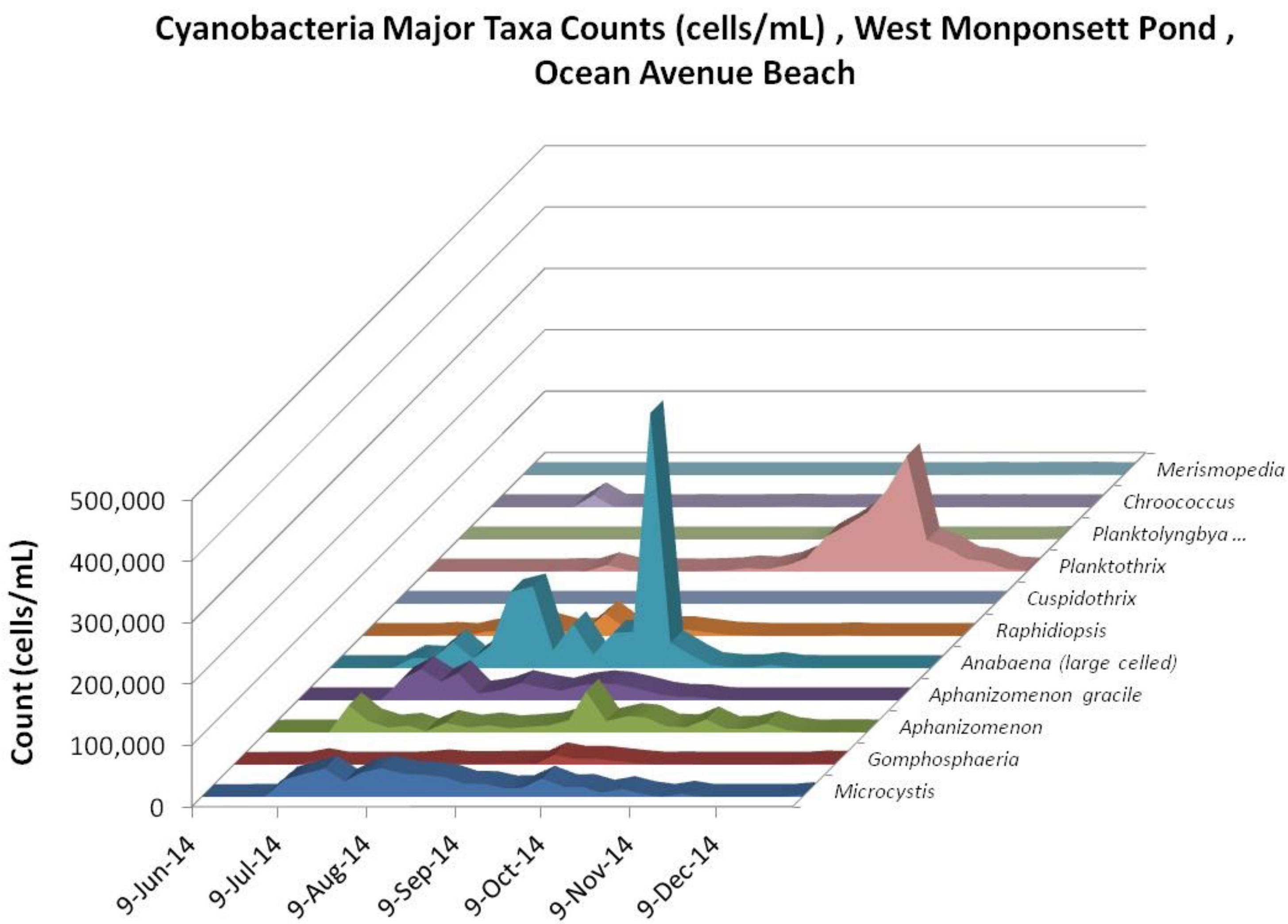
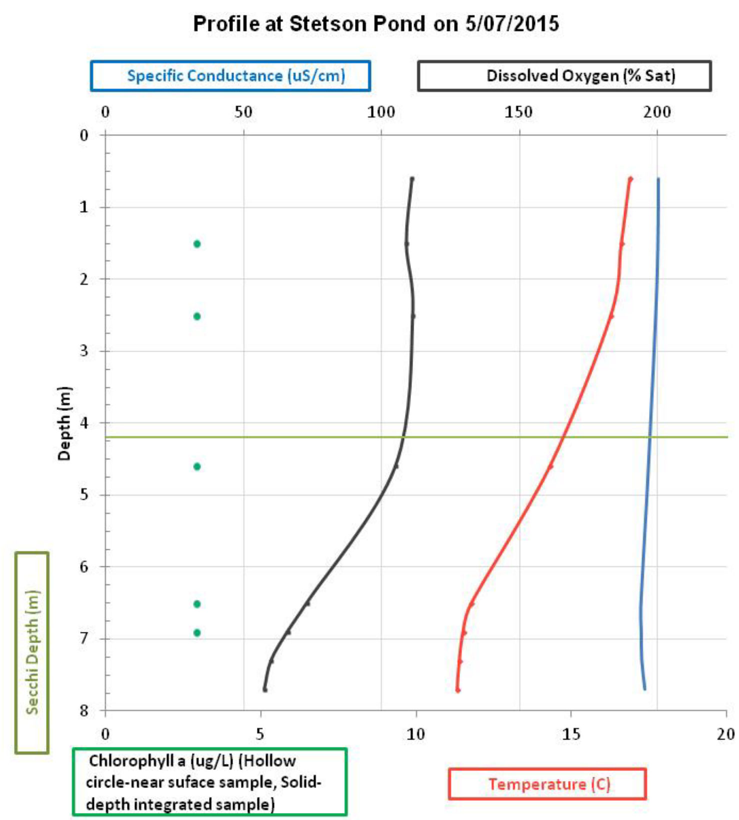


Figure C 10: West Monponsett Pond, Ocean Ave. Beach, 2014 Major Cyanobacteria Taxa Counts (cells/mL)

Dissolved Oxygen Profiles



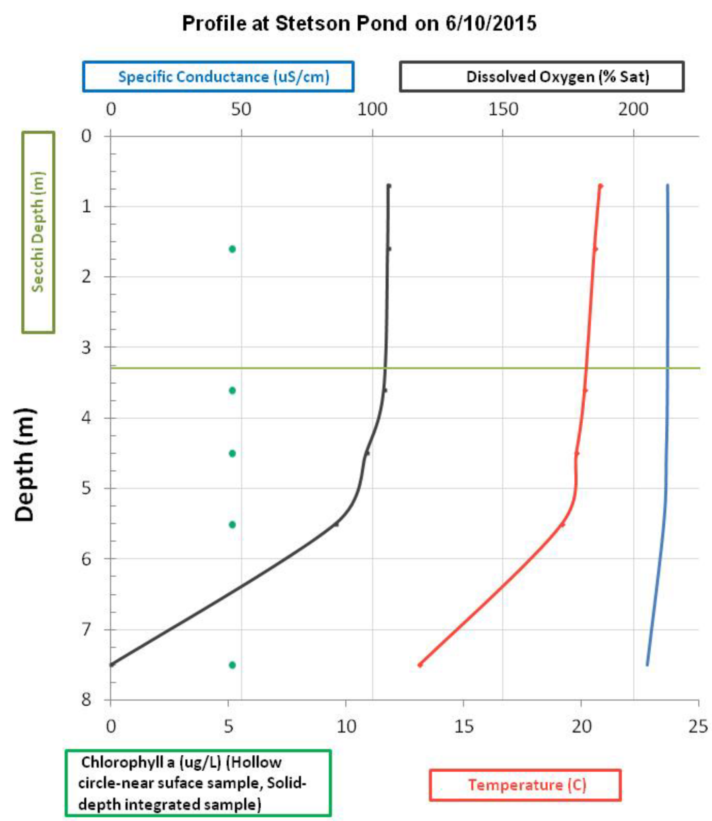
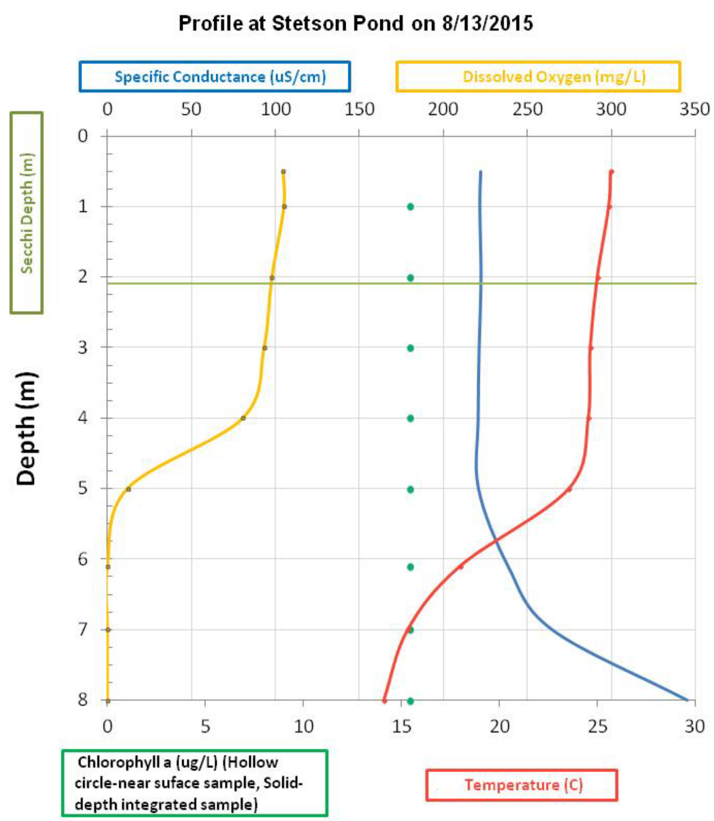


Figure C 11: Stetson Pond DO Profile May 2015 (left) and Stetson Pond DO Profile June 2015 (right)



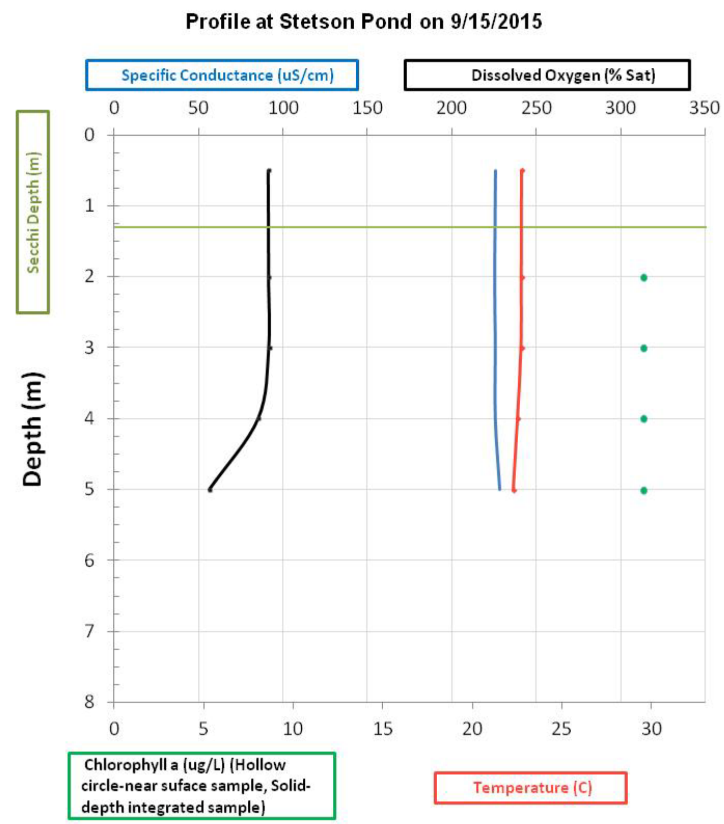
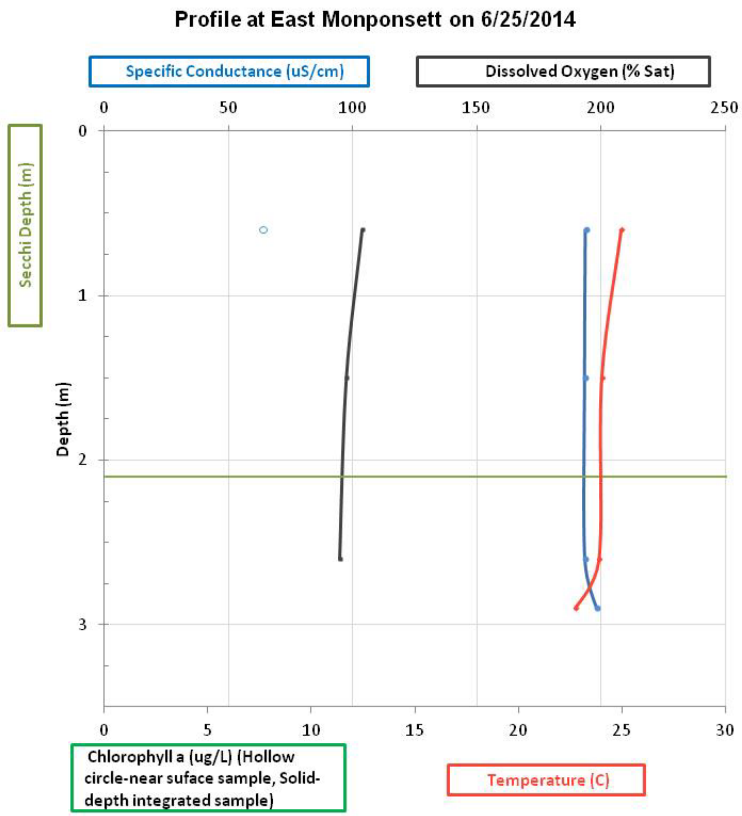


Figure C 12: Stetson Pond DO Profile August 2015 (left) and Stetson Pond DO Profile Sept. 2015 (right)



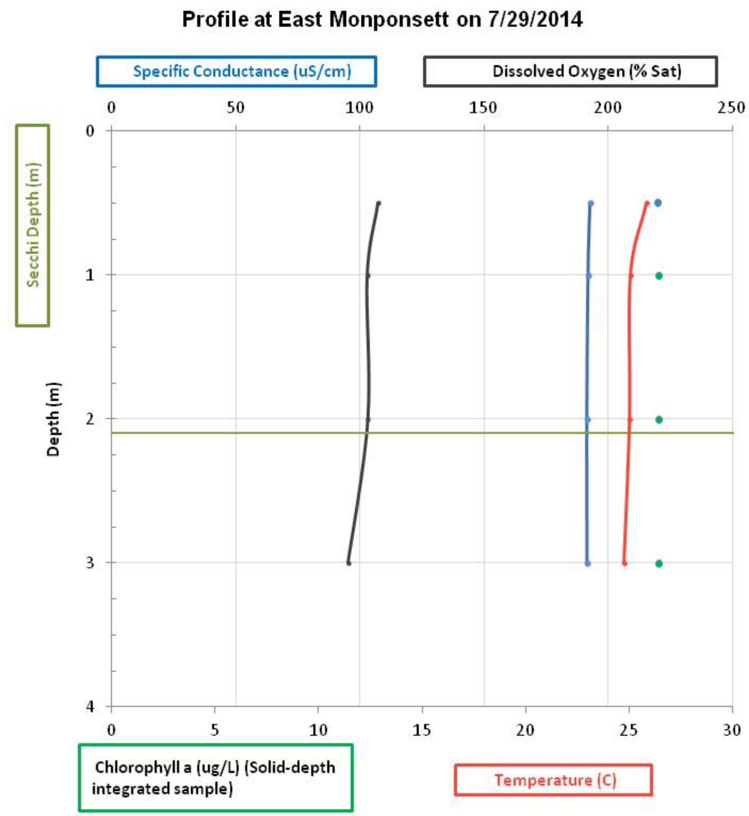
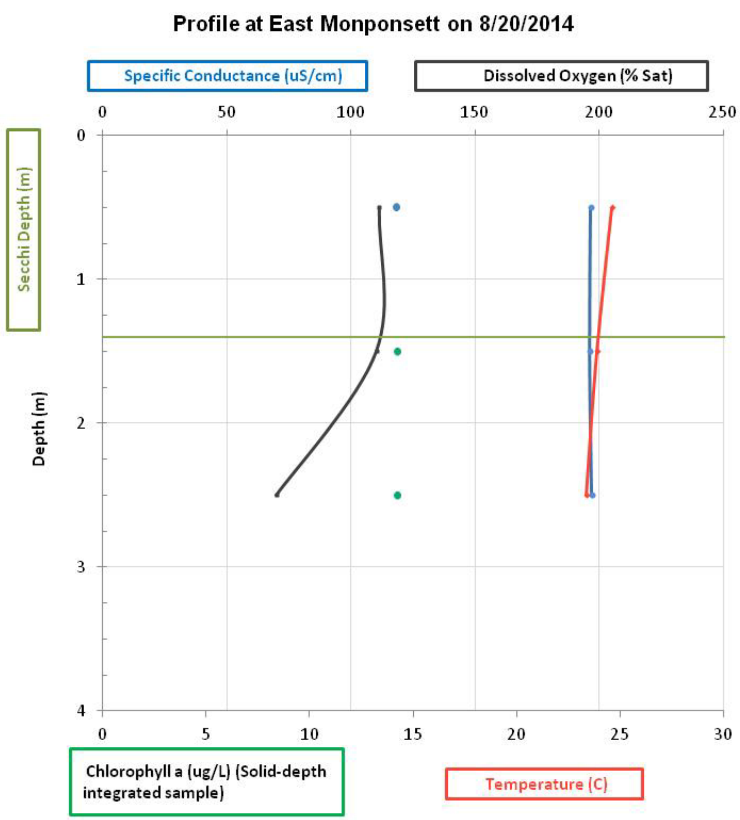


Figure C 13: East Monponsett Pond DO Profile June 2014 (left) and East Monponsett Pond DO Profile July 2015 (right)



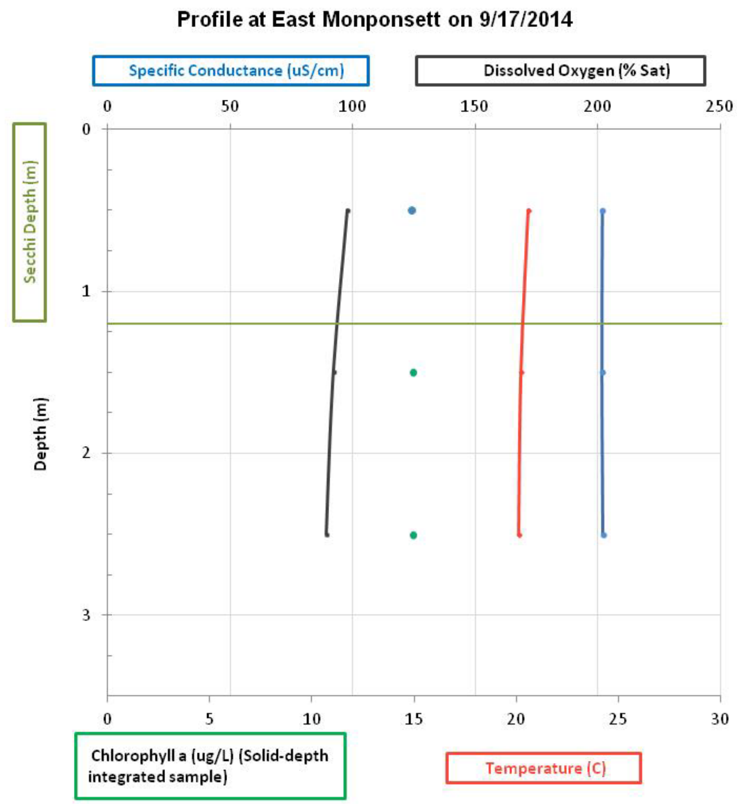
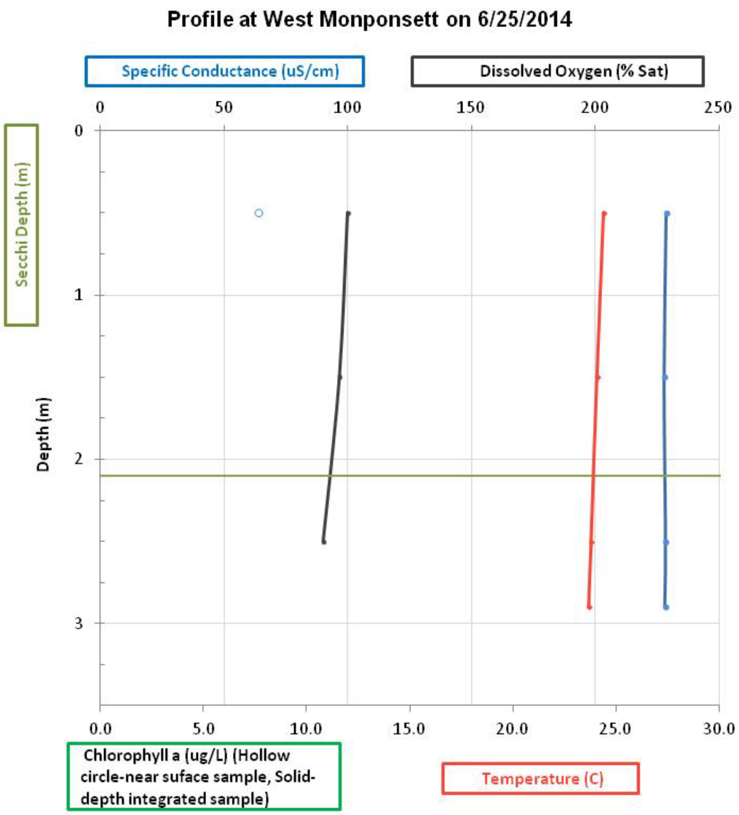


Figure C 14: East Monponsett Pond DO Profile August 2014(left) and East Monponsett DO Profile Sept. 2014 (right)



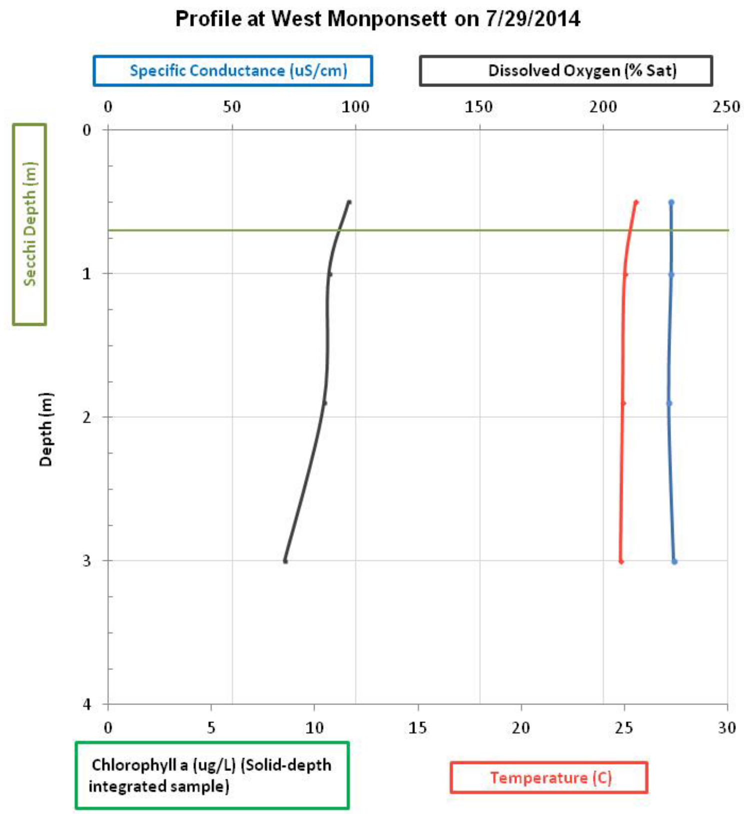
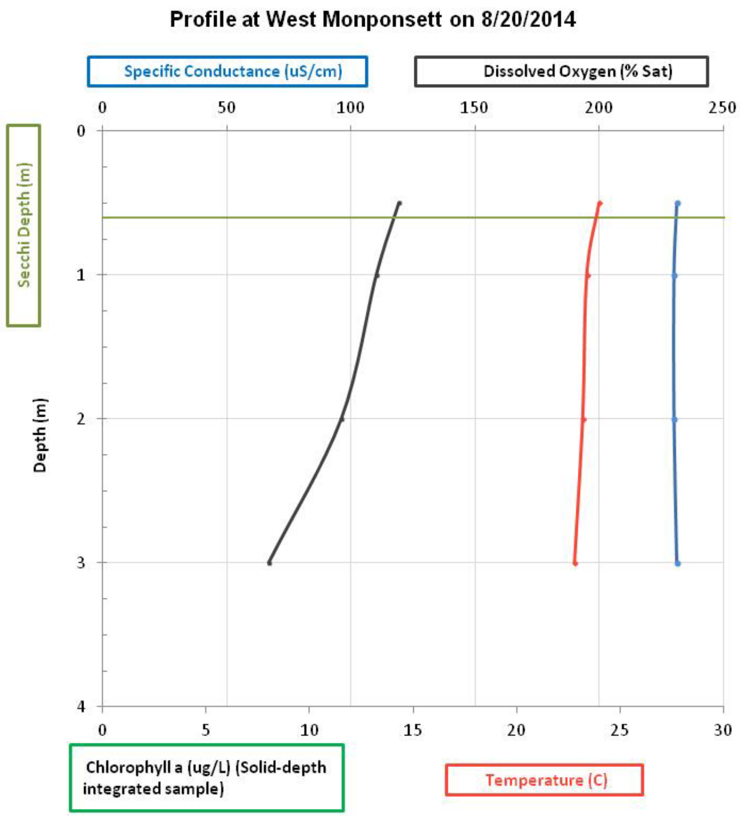


Figure C 15: West Monponsett Pond DO Profile June 2014 (left) and West Monponsett Pond DO Profile July 2014 (right)



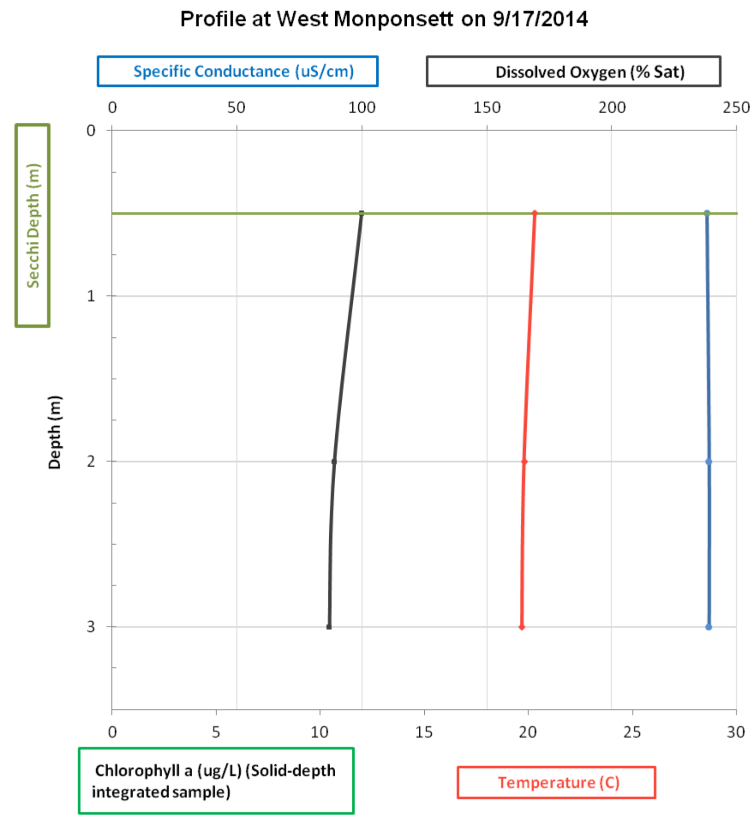
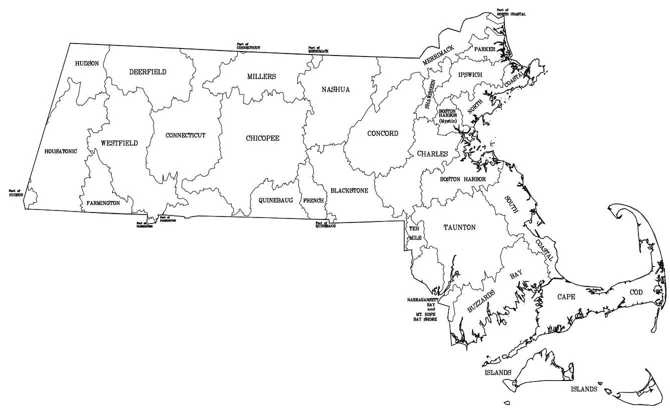


Figure C 16: West Monponsett Pond DO Profile August 2014 (left) and West Monponsett Pond DO Profile Sept. 2014 (right)

Appendix D. Guidelines for Total Maximum Daily Loads of Phosphorus from Commercial Cranberry Bog Discharges in Massachusetts.

Mark D. Mattson
MassDEP TM-T-1, CN307.0, DWM February 9, 2009



NOTICE OF AVAILABILITY

Limited copies of this Guideline are available at no cost by written request to:
Massachusetts Department of Environmental Protection
Division of Watershed Management
627 Main Street
Worcester, MA 01608

DISCLAIMER

References to trade names, commercial products, manufacturers, or distributors in this report constitute neither endorsement nor recommendations by the Division of Watershed Management.

Introduction

The purpose of this document is to evaluate available information on the operation of commercial cranberry bogs in relation to discharges of nutrients, particularly phosphorus, into sensitive receiving waters such as freshwater lakes. The current operation of water use and fertilizer use is summarized to estimate the annual discharge of phosphorus from commercial bogs. In addition, the available information from the literature is summarized to establish new Best Management Practices for both water use, reuse and discharge as well as phosphorus fertilizer rates that are expected to result in receiving waters attaining all relevant Water Quality Standards.

Commercial cranberry production is a major crop in southeastern Massachusetts. The cranberry is a native wetland plant (*Vaccinium macrocarpon*) that is planted into bogs and fertilized like other crops. But unlike other crops, cranberries require frequent irrigation and seasonal flooding. The discharge of waters from the bogs, from excessive rain or groundwater inputs, return flows from irrigation during the growing season or due to discharge of the flood waters allows nutrients such as phosphorus and nitrogen, to be discharged from the bogs to nearby or downstream surface waters. It is this large discharge of nutrient rich water that is a concern to local water quality because the nutrient can stimulate the growth of nuisance aquatic plants and algae.

Currently, many of the large recreational lakes in southeastern Massachusetts are impaired by various combinations of nutrients, noxious aquatic plants (includes algae), turbidity (due to algae blooms) and impairments of low dissolved oxygen and organic enrichment. Many of these lakes receive large discharges of water from nearby commercial bogs and these lakes are listed in the Massachusetts 2006 Integrated list (MassDEP, CN 262.1, 2007; http://www.mass.gov/dep/water/resources/2006il4.pdf) as impaired (Category 5) under Section 303d of the Federal Clean Water Act: New Bedford Reservoir in Acushnet, Noquochoke Lake in Dartmouth, Parker Mills Pond and Tihonet Pond in Wareham, White Island Pond and Billington Sea in Plymouth and Wareham, Furnace Pond and Stetson Pond in Pembroke, Wampatuck Pond in Hanson, Lower Mill Pond, Upper Mill Pond and Walkers Pond in Brewster, Santuit Pond in Mashpee, West Monponsett Pond in Halifax/Hanson.

According to the Federal Clean Water Act, the state must develop allowable nutrient budgets or Total Maximum Daily Loads (TMDLs) for these waters such that they fully support all designated uses. In addition to these there are numerous streams and coastal embayments downstream of the bogs that are also listed as impaired by nutrients. Many of the smaller lakes and streams in the region have not been assessed but may be threatened by excess nutrients because they are also located near the discharge areas of the commercial bog operations. Similar problems with lake eutrophication have been seen in Wisconsin (the leading producer of cranberries) where cranberry production was implicated as the major source of nutrients (Garrison and Fitzgerald, 2005). This report reviews the operation of the bogs and reviews the literature on fertilizer use and nutrient export from commercial bogs and natural wetlands and provides guidance for the development of total phosphorus Total Maximum Daily Loads for freshwater lakes.

Background on Commercial Bog Operations

Historically, commercial cranberry bogs were created over natural wetlands, but natural wetlands have been protected since the development and revisions of the Wetlands Protection Act in Massachusetts between 1963-1972. Any new commercial bogs created in Massachusetts since that time are required to be constructed in upland areas by grading the land level and adding sand as the plant bed. A series of dikes, ditches, pumps and flumes allows for periodic flooding and sand is added to the beds as a rooting medium. Water enters as rainfall and is pumped in for frequent irrigation. In some cases surface water runoff, a natural stream or groundwater seepage may add additional water to the bogs and is also discharged as needed (i.e., a flow-through bog; see Figure 1). The fall harvest occurs by flooding the bogs to allow the berries to be knocked loose and float into collection areas. After harvest the water is discharged to nearby surface waters. Flooding also occurs temporarily during winter to allow ice formation to protect vines from freezing. Flooding may also occur at other times for insect control. Typically, commercial cranberry bogs require about 10 acre-feet of water, including rainfall, each year for combined irrigation and flooding purposes (DeMoranville and Howes, 2005).

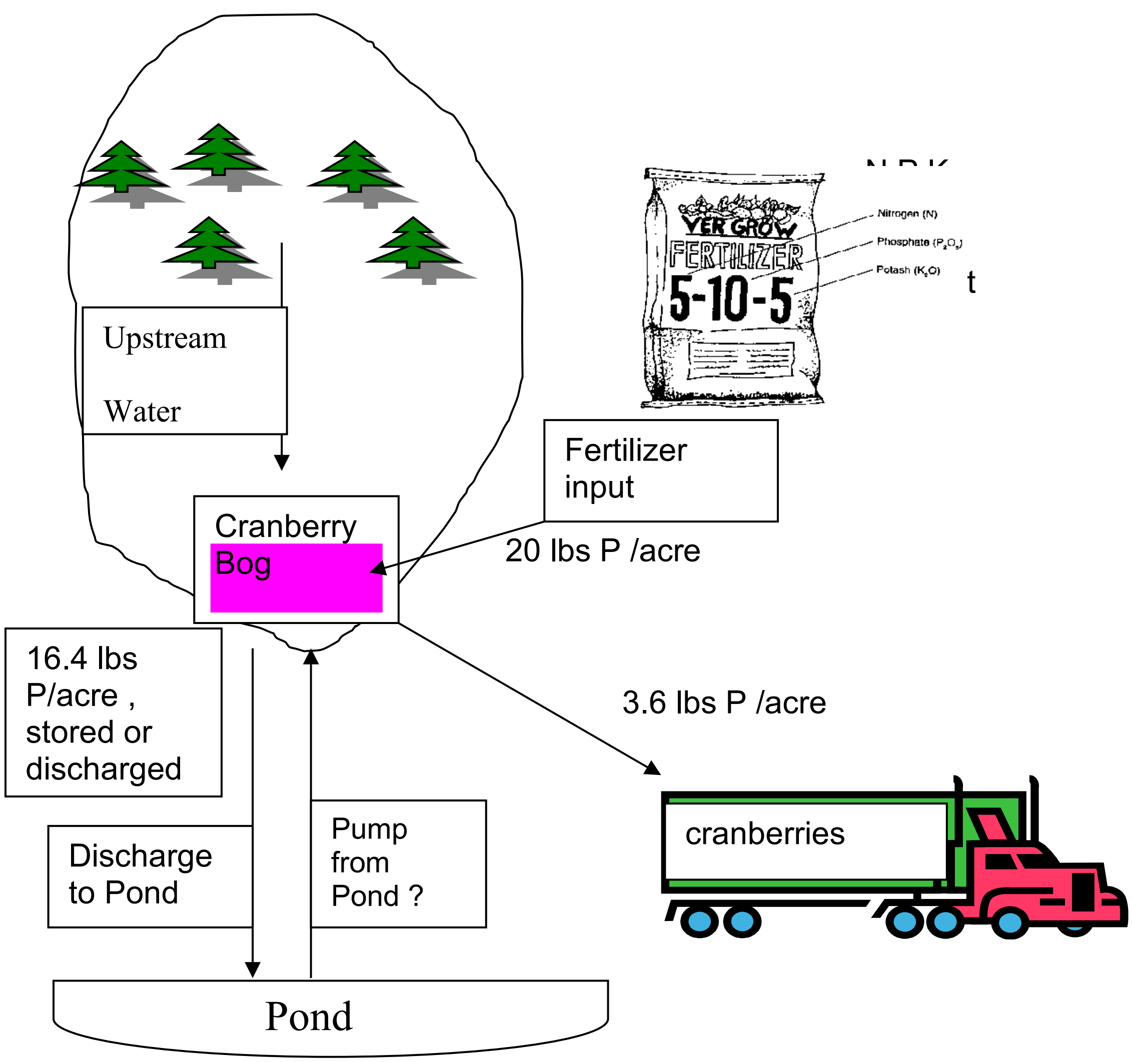


Figure 1. Schematic Diagram of a Phosphorus Budget for a Cranberry Bog.

Up until recently, the recommended phosphorus fertilizer inputs for traditional cranberry bogs has been 20 pounds per acre per year, according to the University of Massachusetts Cranberry Station publications http://www.umass.edu/cranberry/services/bmp/phosphorus.shtml although higher rates are recommended in some cases. The Best Management Practices are under review by the University and by MassDEP. Typical commercial bogs often use higher rates than the recommended 20 lbs/ac/yr (22.4 kg/ha/yr) as shown in Table 16 in DeMoranville and Howes, (2005). In that study, half of the bogs were applying phosphorus fertilizer at rates of 31 to 45 lbs P/ac/yr (27.9-39.8 kg/ha/yr) in the first year of the study. These rates are similar to a study of a nearby bog where the rates of phosphorus fertilizer application were 29.2 lb P/ac/yr (Howe and Teal, 1995). The harvest of berries and associated leaves and twigs removes about 3.6 pounds of phosphorus per acre each year (DeMoranville and Howes, 2005). If a bog were fertilized at the recommended rate (20 lbs/ac/yr) it implies that 16.4 pounds per acre (18.3 kg/ha/yr) are potentially available for buildup in the soil or for downstream export (see Figure 1). Over many years of excess phosphorus application soils are expected to become saturated with excess phosphorus and may start to export more phosphorus over time.

Review of Fertilizer Application and Crop Yield

Several lines of evidence are available on the phosphorus fertilizer requirements of cranberries. As noted in Roper et al., 2004, a number of early studies had identified that 22 kg/ha/yr (20 lbs/acre/yr) was sufficient for commercial cranberry operations, but the studies did not examine if lower fertilizer rates would also be sufficient. More recent studies in Massachusetts have found that yields of cranberry are not very responsive to phosphorus in fertilizer at any rate, presumably because of over fertilization in past years has built up a supply of phosphorus in the cranberry soils. These studies include the recent whole bog studies as well as smaller, but more detailed plot studies in Massachusetts (DeMoranville and Howes, 2005; DeMoranville, 2006) which found no reduction in cranberry yield as phosphorus was lowered to less than 20 lbs/acre/year and in some cases yields increased with lower or even no phosphorus applied at all. In the Eagle Holt bog fertilizer rates were reduced to 16.1 kg/ha and 6.3 kg/ha (14.3 lb/ac and 5.6 lb/ac) in 2003 and 2004, respectively, and yields actually increased by 31 percent over the previous two years (DeMoranville and Howes, 2005). The average yield for all six bogs in the first two years was 135 bbl/acre/yr, but the yield actually increased to 155 bbl./acre/yr during the next 2 years as fertilizer was reduced on the six bogs studied by DeMoranville and Howes (2005). The final recommendations of the DeMoranville and Howes (2005) study was that 20 lbs/acre/year of phosphorus fertilizer are sufficient and that typical native cranberries on organic soils may have lower targets of 10-15 lbs/acre/year unless tissue tests show deficiency (<0.1% in August).

An extended multiyear study of four of the experimental bogs also showed that the three lowest phosphorus fertilizer rates below 10 kg/ha/yr (averaging about 6 lb/ac/yr) produced cranberry yields greater than the median of all the treatments (Figure 2). These results are supported by recent work of Parent and Marchand (2006) who found there were year-to-year differences and site-to-site differences in cranberry production but found there was no benefit to adding phosphorus on the yield of cranberries in a Quebec study. Additional studies on plots have shown there was no justification for using high phosphorus fertilizers to increase yields . Even the zero phosphorus plots showed no signs of deficiency after 6 years of study (Roper, 2009).

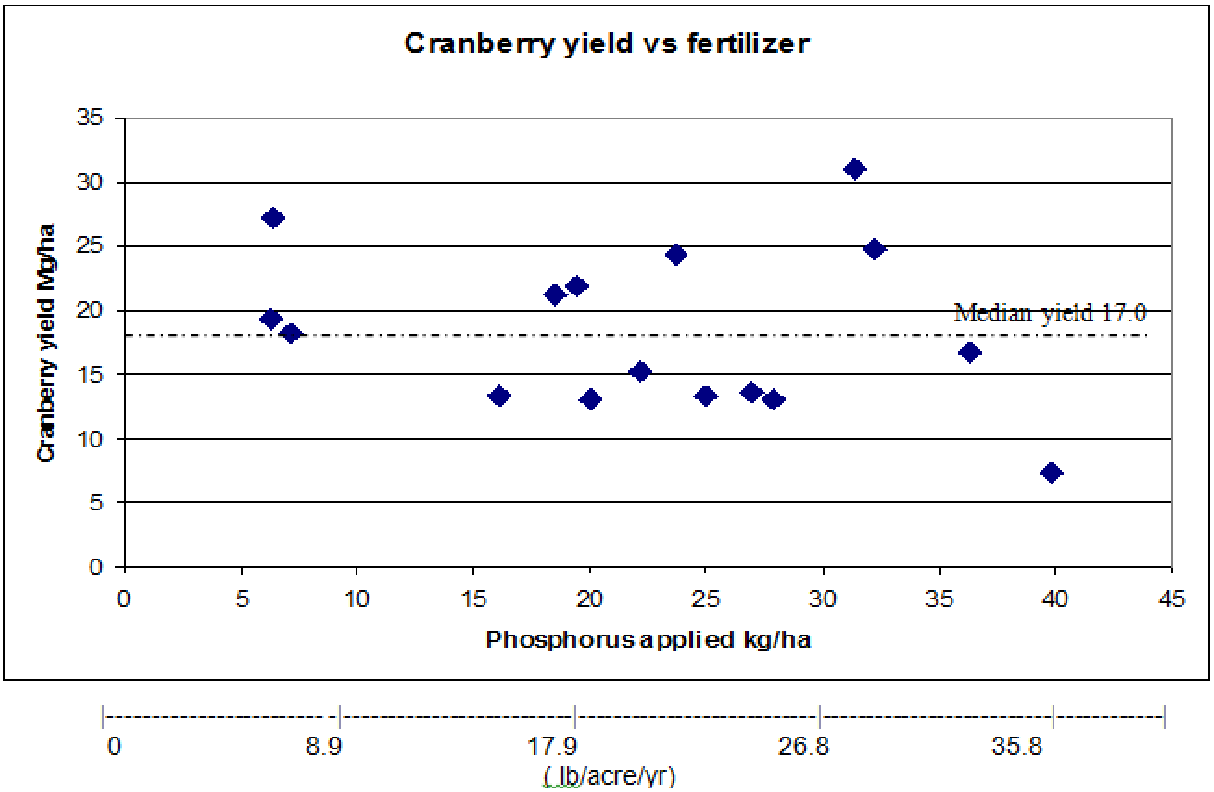


Figure 2. Cranberry yield vs. Fertilizer Rates (Data from DeMoranville et al., 2009).

Export of Phosphorus from Commercial Cranberry Bogs

There have been two recent studies on nutrient export from commercial cranberry bogs in Massachusetts. The first study (Howes and Teal, 1995), focused on a flow-thru bog while the second study (DeMoranville and Howes, 2005), was more extensive and included varying fertilizer rates, and measuring cranberry yields along with both net and gross export of nutrients from six commercial bogs over several years. Much of the following discussion will focus on the more recent study (DeMoranville and Howes, 2005).

The bogs studied by DeMoranville and Howes (2005) showed variation in export related to soil type and fertilizer rates. The two upland bogs on mineral soils (Mineral 5 and 6 in Figure 3) with essentially no discharges other than harvest discharges had total phosphorus concentrations equal to or less than 100 ppb in discharge water, with resulting low export rates of about 0.5 kg/ha/yr. The four organic bogs studied by DeMoranville and Howes (2005), were established bogs on organic (wetland) soils with periodic discharges during the growing season as well as during harvest or winter floods. These bogs tend to have concentrations of phosphorus between 15 and 50 ppb in the discharge water and tend to discharge about 3 kg/ha/yr (see Figure 3, Organic 1-4). The median of the organic bog net discharge in the first year (prior to major reductions in fertilizer application was 3.4 kg/ha/yr and is the best estimate of typical organic cranberry bog export in Massachusetts. Because the total discharge of water (per unit area) was similar from the series of six bogs there is a linear relationship between the net discharge of phosphorus from the bogs and the concentration of phosphorus in the discharge water (Figure 3). Lacking other information the net export from bogs can be estimated from the average total phosphorus concentration as shown in Figure 3 as: net export (kg/ha/yr) = -0.59+8.83*Conc. (mg/l), N=18, r^2=0.47, α=0.001. The flow-thru bog was reported to export large amounts of phosphorus (9.9 kg/ha/yr) with the major discharge events having phosphorus concentrations averaging 530 ppb (0.53 mg/l) during winter floods (Howes and Teal, 1995). Recent studies on commercial cranberry bogs have shown that reduced phosphorus fertilizer application did not suppress the yield of cranberries, rather yields increased while reducing TP concentrations in discharge water (DeMoranville et al., 2009).

Much of the phosphorus exported from the bogs is associated with flood discharges. In particular, flood waters held for more than about 10 days leads to anoxia and the release of phosphorus (DeMoranville and Howes, 2005).

Export of total phosphorus from natural wetlands and forested watersheds was also reviewed by DeMoranville and Howes (2005). The literature suggests that freshwater wetlands such as beaver ponds, peat soil wetlands, and wetlands bordering streams export between 0.41 kg/ha/year and 0.68 kg/ha/year (median of 0.47 kg/ha/yr), while cypress swamps and tidal saltwater marshes export higher amounts. The forested wetland system in Westport Massachusetts had a gross export of 0.14 to 0.15 kg/ha/yr of phosphorus. This is in general agreement with a review of phosphorus export from various land uses that indicates forests export an average of 0.236 kg/ha/yr, while row crops export an average of 4.46 kg/ha/yr (Reckhow et al., 1980). Thus, the overall mean fluvial export of 1.65 and 3.02 kg/ha/yr (net and gross, respectively) reported for commercial cranberry bogs by DeMoranville and Howes (2005) indicates cranberries export much larger amounts of phosphorus than forests or typical freshwater wetlands, but generally export less than agricultural row crops. Note that net fluvial phosphorus exports are lower than gross fluvial exports if the bogs are using source water with high concentrations of phosphorus. Flow-through bogs may export higher amounts of phosphorus than most row crops (Howes and Teal, 1995).

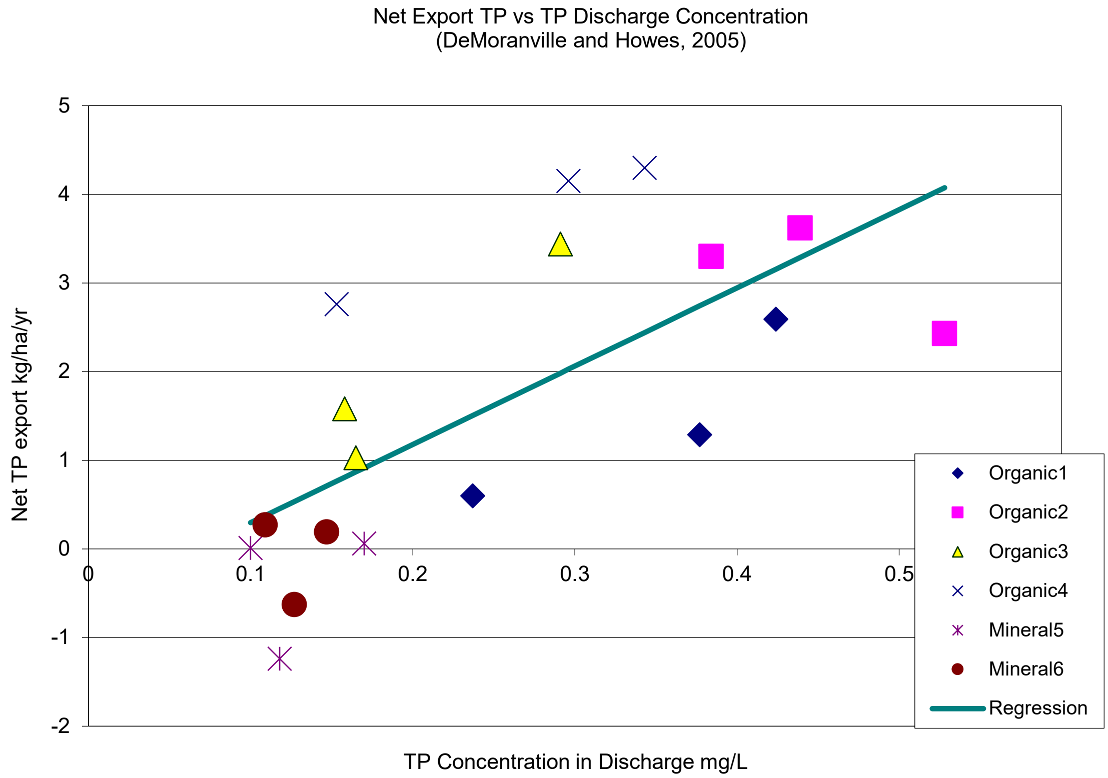


Figure 3. Net TP Export vs. TP Concentration.

Lake Nutrient Budgets

Nutrient budgets for impaired lakes require knowledge of nutrient export from local sources including point sources (discharges from pipes or other discrete sources as well as various land uses that discharge nonpoint source pollution. This report examines nutrient budgets from commercial cranberry operations within Massachusetts as diagramed in Figure 1. Nutrient budgets are typically presented both as net budgets and as gross discharge budgets and as 'fluvial budgets'. The nutrient budgets measure (or estimate) all nutrients entering the bog and all nutrients leaving the bog as shown in the schematic diagram below. Generally, the two major nutrient inputs to a bog are nutrients in the irrigation water and nutrient in the fertilizers. The two major nutrient losses from a bog are nutrients discharged in released water, and nutrients in plant materials harvested from the bog (berries as well as leaves and twigs). From a water quality standpoint we are most interested in the 'fluvial budget', that is, the amount of nutrients delivered to a lake via natural water inputs compared to the additional nutrients in discharge water that enter the bog due to commercial bog operations. Other imports to the bogs (such as fertilizers) and exports from the bog, such as phosphorus in the crop of cranberries, are accounted for outside of the fluvial budget in the total budget.

From a lake water quality point of view there are two general types of bogs and associated nutrient budgets to consider: autochthonous nutrient sources and allochthonous nutrient sources. First, where the source of bog irrigation and floodwater is a tributary to the receiving pond or is the receiving pond itself (autochthonous), the most appropriate nutrient flux is the net fluvial nutrient budget. In such bogs the original nutrients in the irrigation and flood waters was either in the lake or would have entered the lake in the absence of bog operations. In that case, the nutrients in the input source water are subtracted from the fluvial outputs to calculate the net difference. In other words the extra amount of nutrients entering the pond due to the cranberry bog operation is the net fluvial export from the bog. Corrections may be required if the source water is polluted from previous discharges from the same bog. The second case would be a bog that gets irrigation and flood water from an outside water source (allochthonous), that is, from a source that normally would not enter the receiving pond. Typically this is a groundwater well or stream or source pond that is not tributary to the receiving pond. In this case the gross fluvial export is calculated as the input to the receiving pond, because the input to the pond includes both the nutrients from the bog as well as nutrients in the original source water. The nutrients from both the water as well as nutrients derived from fertilizers are new inputs to the bog as a result of management operations.

Target loads and nutrients to maintain water quality standards.

The Massachusetts Water Quality Standards 314CMR4.05 http://www.mass.gov/dep/service/regulations/314cmr04.pdf) state conditions for best available technology (BAT) for point and nonpoint sources including publicly owned treatment works (POTWs) and other sources:

> 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.

In addition, water withdrawals are regulated under the Water Management Act regulations http://www.mass.gov/dep/service/regulations/310cmr36.doc. These regulations allow for registration and/or permitting of water withdrawals for cranberry operations including regulations regarding water conservation, water quality, farming practices and reporting requirements to protect other water uses. Water withdrawals may be established under nonconsumptive use which means any use of water which results in its being discharged back into the same water source at or near the withdrawal point in substantially unimpaired quality and quantity.

As a general guideline, concentrations should not exceed 50 ppb in any stream entering a lake or pond (USEPA, 1986). The USEPA has issued guidance for water quality nutrient concentrations of total phosphorus of 31 ppb l for rivers in southeastern Massachusetts (USEPA, 2000; http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_14.pdf.)

The lakes in southeastern Massachusetts may be considered as belonging to two general types: lakes with tributaries and seepage lakes with no tributaries. The seepage lakes are fed mainly by groundwater and direct precipitation and tend to be more oligotrophic, clear water lakes. Some seepage lakes are set in organic soils that may contribute dissolved organic compounds that color the water, and this may result in higher phosphorus levels. The clear water seepage lakes are thus more sensitive to nutrient inputs and generally should have lower total phosphorus concentrations. Clearwater seepage lakes in southeastern Massachusetts may reasonably be expected to have concentrations of total phosphorus of less than 20 ppb and possibly as low as 8 ppb (MassDEP, 2003, 2004, 2007a, 2007b, 2009, 2013; USEPA, 2001; http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/lakes/lakes_14.pdf).

Thus, inputs from external sources must be limited to meet the state's Water Quality Standards and to protect designated uses. The nutrient management requirements to meet Water Quality Standards may vary depending on the receiving water but at a minimum, discharges should not exceed the EPA guideline of 100 pb for streams and the 50 ppb for tributaries to lakes. By way of comparison, current National Pollutant Discharge Elimination System (NPDES) permits for typical wastewater treatment plant discharges in Massachusetts are set at 100 ppb in the discharges to sensitive receiving waters. Extensive Best Management Practices may be required in order to ensure receiving waters meet the state's Water Quality Standards.

Best Management Practices Protective of Water Quality

The data from the six commercial cranberry bogs studies in the DeMoranville and Howes (2005) study was further analyzed to examine the relationship of fertilizer rates on cranberry yields, concentrations of phosphorus in discharge waters and downstream export of nutrients. The data indicate that if most protective BMPs recommended by DeMoranville and Howes (2005) are followed, export of phosphorus from commercial bogs can be reduced with little or no impact on crop yields.

For bogs that discharge to sensitive surface waters some combination of the following BMPs may be required. Specifically, no more phosphorus than the lower range of fertilizer rates of 10-15 lbs/acre/year recommended by DeMoranville and Howes (2005) may be required. In addition, the recommended best management of water use (using tailwater or retention ponds to remove phosphorus prior to discharge, holding floodwater 1-3 days, but less than 10 days, with slow discharge and winter flood control to minimize flood holding times to avoid anoxia) may be required. Fertilizers with ratios of $N:P_2O_5$ of greater than 1:1 and preferably 2:1 such as commercial 18-8-12 or 12-6-8 may be required. If discharges are to a sensitive clear water seepage bog the additional BMPs recommended by DeMoranville and Howes (2005) of installing tailwater recovery or other physical barriers or filtration may be required to meet water quality standards.

If the recommended phosphorus fertilizer rates of 10-15 lb/acre/year are followed the data suggest commercial cranberry bogs will achieve net fluvial discharges of less than 1 kg/ha/year.

This can typically be achieved if total phosphorus concentrations in discharge waters are at or below 0.1 mg/l (Figure 3) and/or, if increase in phosphorus concentration between source water to discharge water is held to an increase of no more than 0.032mg/l (assuming 10 acre feet of water use and no reuse of source water). If the discharge is to sensitive waters then lower export rates may be required. A discharge of 0.5 kg/ha/yr (higher than forests but lower than row crops) may be required and this could be achieved if discharge concentrations follow than the EPA 'Gold Book' (EPA, 1986) guidelines of 0.050mg/l for discharges to lakes and discharge volumes are limited to 3.3 acre-feet per acre bog per year or less. Bogs discharging to less sensitive waters may be able to discharge 5 acre-feet or more as long as net nutrient loading rates are kept low by reuse of water or other BMPs.

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Appendix E: Monponsett Pond TMDL Modeling Documentation

COMMONWEALTH OF MASSACHUSETTS

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October 2017

Stormwater Section Revised August 2019

CN 455.5.1

Monponsett Pond TMDL Modeling Documentation

Introduction and Background

The Monponsett Pond system which includes Stetson Pond, White Oak Reservoir, East Monponsett Pond and West Monponsett Pond is located in Southeast Massachusetts. A TMDL has been written for the four ponds in this system. A number of impairments have been identified in this system principally related to nutrient enrichment and specifically phosphorus loads. The TMDL was written to reduce phosphorus loading in this system and to restore all uses associated for the pertinent waterbodies. A principal restoration goal was West Monponsett Pond which has experienced harmful algal blooms in recent years.

The City of Brockton was allowed to use Silver Lake as it's water supply as far back as1899. In 1964 the Massachusetts Legislature approved Act 371 to further allow a diversion from East Monponsett Pond to Silver Lake to supplement the water supply with some restrictions. Diversions occur generally only in the fall, winter and spring between October and June. During times of diversion the natural flow direction under the culvert between the ponds may be reversed. There are local concerns that the potentially toxic cyanobacterial blooms and excess nutrients in West and East Monponsett will flow into Silver Lake and the altered hydrology may impact both West and East Monponsett Pond as well as their downstream outlet, Stump Brook (Princeton Hydro, 2013; Horsley Witten, 2015). In addition, the diversion from Silver Lake results in only brief outflows to the Jones River (Princeton Hydro, 2013). As a result of hydrologic diversions the Jones River itself is listed as impaired on the 303d list of impaired waters.

East Monponsett Pond is diverted to Silver Lake, which is used by the City of Brockton for use as a public water supply (Figure 1). West Monponsett Pond is connected to East Monponsett Pond by a culvert under Route 58. When water is pumped from East Monponsett Pond to Silver Lake, water flows into East Monponsett Pond from West Monponsett Pond. Both ponds are highly influenced by both their surrounding landuse and the pond's use as a source of public water supply. The ponds use as a public water supply affects both their hydrology and consequently water quality. The high levels of total phosphorus (TP) result in excessive algal growth and impair designated uses of the waters. The federal Clean Water Act requires that such waters be listed on the 303d list in Category 5 (impaired) and that a Total Maximum Daily Load report be developed and submitted to the EPA. The modeling approach and implementation in this report follow the previously approved TMDL for White Island Pond (MassDEP 2010a).

Water Quality Model

The purpose of the MassDEP modeling effort was to quantify the principal sources of phosphorus loading in this system and to determine the maximum allowable total phosphorus loads to the ponds in this system. The Lake Loading Response Model (LLRM) is a spreadsheet based model which allows the estimation of hydrologic input and nutrient inputs as well as allowing estimation of atmospheric deposition, septic loads, point source loads, internal loading and loading from waterfowl (AECOM 2009). This model was chosen as it provides a reasonable estimation of nutrient loads and requires less time, effort and expertise than more complex models (SWAT, BASINS, HSPF).

The watershed is described in “Watershed and Lake Characterization” of the TMDL. USGS StreamStats (USGS 2015) was used to delineate individual subbasins for streams and artificial flow paths. The StreamStats derived watersheds were then adjusted so that they did not overlap each other. In addition the StreamStats derived watersheds were adjusted so they did not extend beyond the GeoSyntec (2015) pond watersheds. The delineated watersheds are presented in Figure 2. Using the MassGIS Landuse (2005) data layer and a GIS system the landuse in the TMDL study area was analyzed. For land use analysis by subwatershed see Appendix A.

Scope and Approach for Model

Annual precipitation from the Plymouth weather station for 2001, 2003 and 2008-2014 (years in which MassDEP sampled in the TMDL study area) were analyzed. The average annual precipitation for the period examined was 55.74 inches. This is slightly higher than the average annual rainfall in Plymouth of 52.36 inches. This annual average is similar to the 52.8 inches used in Horsley Witten (2015). Precipitation coefficients for each landuse were set at 50% in order to obtain a water yield of 26.2 inches per year. Only total flow was estimated in the LLRM model. Flows were not split between runoff flows and base flows.

The year 2009 was chosen as the target year for the LLRM model calibration for the entire Monponsett Pond system as this was before recent alum treatments in West Monponsett Pond. The year 2009 appears to have been typical for both yearly and summer precipitation (Figure 1) and therefore a good choice for modeling the system in terms of average water and phosphorus loading. The model was calibrated based on 2009 in-pond total phosphorus concentration for East and West Monponsett Pond as well as White Oak Reservoir.

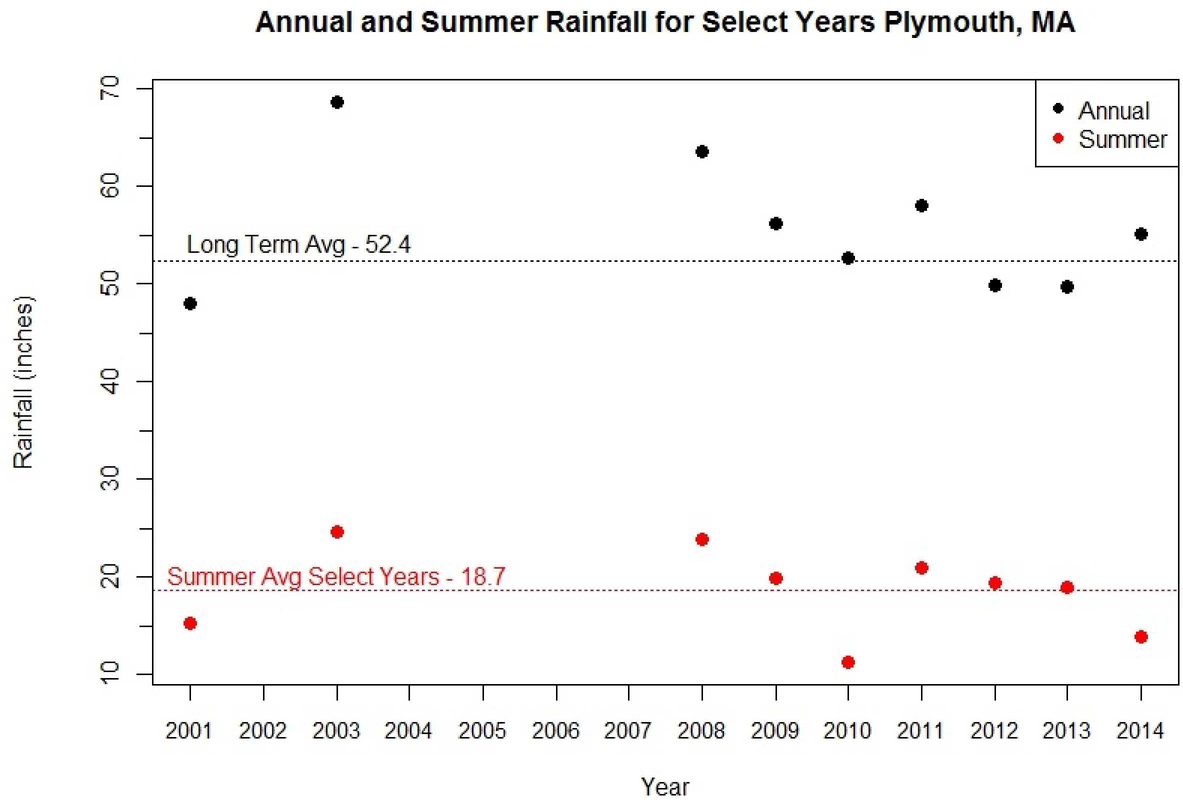

Figure 1: Annual and Summer Rainfall for Select Years Plymouth, MA (National Climatic Data Center 2016)

Quality of Acquired Data

MassDEP has conducted water quality sampling in the TMDL study area for several years. A summary of the principal in-pond sampling data by years and the quality control status of the data see Table 1. For an overview of MassDEP data validation see MassDEP 2012. Recently acquired data that is considered "draft" in the quality control process was reviewed and checked before use in this TMDL and any modeling activity. No data were excluded from analysis due to quality control or quality assurance issues. Sampling of tributary streams by MassDEP and Lycott Environmental Inc. was conducted for validation of the LLRM model (2007).

Water Body	Sampling Site	Sampling Years	QC Status
Stetson Pond	W1086	2003, 2015	QC5, draft
East Monponsett Pond	W0930	2001, 2009, 2010, 2011, 2012, 2013, 2014, 2015	2001 and 2009 to 2012 - QC4, 2013 Lab and Attended Data - QC4, 2014 Attended Data QC4 (rest draft), 2015 draft
West Monponsett Pond	W0926	2001, 2009, 2010, 2011, 2012, 2013, 2014, 2015	2001 and 2009 to 2012 - QC4, 2013 Lab and Attended Data - QC4, 2014 Attended Data QC4 (rest draft), 2015 draft
White Oak Reservoir	W2173	2010, 2012, 2013, 2015	2010 & 2012 - QC4, 2013 Lab and Attended Data - QC4, 2015 draft

Table 1: MassDEP sampling by year and QC status for principal sampling stations

Description of Model

The LLRM model is a mass balance type model. Required inputs are estimates of rainfall, nutrient loading, internal loading, point source loading, atmospheric deposition and other nutrient inputs. This model has been used in several TMDL studies in New England (AECOM 2009b, AECOM 2011, FB Environmental Associates, 2014). The model is documented in AECOM (2009a). The LLRM model is a spreadsheet model using Microsoft Excel software.

Model Configuration

The LLRM model was applied to a delineated watershed for the TMDL study area. The principal model inputs are estimated hydrologic inputs for the water budget, nutrient inputs by subwatershed and other nutrient loading estimates. The general pattern of flow in this system is described in Figure 1. The equations that predict in-pond phosphorus concentrations rely on a steady state condition. The goal of the TMDL is to model the overall nutrient budget for this system so a steady state model and assumptions are satisfactory. Another key assumption of the calibration or base scenario model run as part of the TMDL process was that only water contributions from East and West Monponsett Ponds watersheds would go to each pond, respectively. No flow was modeled from East to West. Previous modeling efforts (Princeton Hydro, LLC, 2013) indicated that the volume of water withdrawn for water supply was equal to the total annual water yield to East Monponsett Pond as well as a portion of the annual hydrologic loading of water to West Monponsett Pond. Flows were not split between runoff flows and base flows.

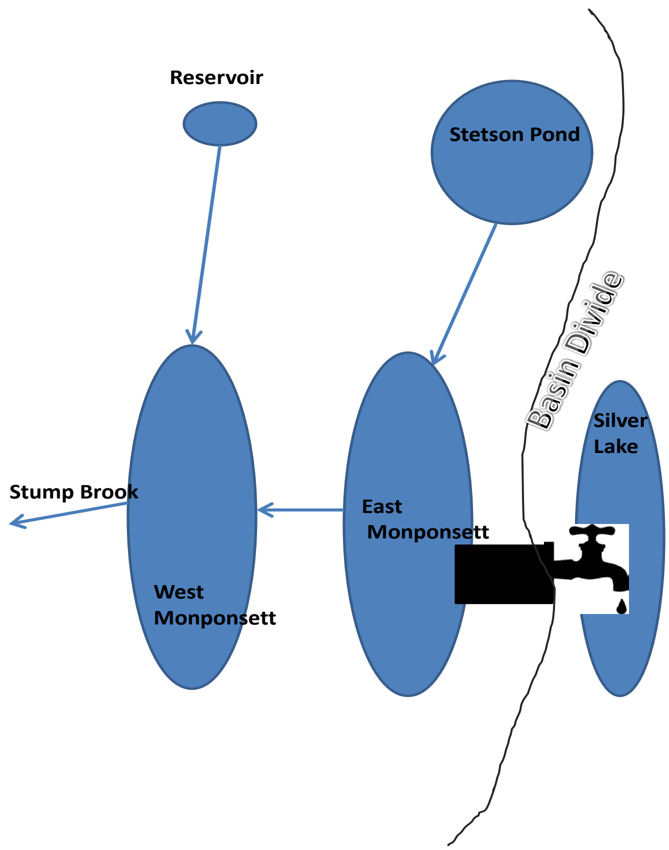

Figure 1: Model Schematic Showing Flow Patterns in TMDL study Area

Watershed Delineations

In consultation with the GIS department at MassDEP, watersheds for each pond in the TMDL study area were obtained based on the work of Geosyntec (2015). Using a GIS system these watersheds were then adjusted to match the Taunton River watershed basin as appropriate. USGS StreamStats (USGS 2015) was used to delineate individual subbasins for streams and artificial flow paths. The StreamStats derived watersheds were then adjusted so that they did not overlap each other. In addition the StreamStats derived watersheds where adjusted so they did not extend beyond the Geosyntec (2015) pond watersheds. The delineated watersheds are presented in Figure 2. It is important to note that these watersheds are based on surface topology and may not reflect complex groundwater flow patterns that may exist in the study area.

Model Load Inputs

Landuse Analysis

Landuse in the delineated watersheds was analyzed based on the MassGIS Landuse (2005) datalayer. The landuses were then aggregated into logical categories for modeling purposes (Table 2). As part of landuse analysis, an investigation into current cranberry bog activities was conducted. An inventory of cranberry bog land use was created and in consultation with the MassDEP Southeast Regional Office (McLaughlin 2016) the current status of the cranberry bogs (active, inactive etc.) was determined (Figure 3). The Edgewood Bogs LLC located in the Stetson Pond watershed were abandoned in 2008 while the Gary S. Thorp Bogs in the unnamed tributary 2 watershed to the West Monponsett Pond were abandoned in 2006. The Elko Construction Bogs located in the White Oak Reservoir watershed were abandoned in 1994. For the purposes of nutrient loading modeling the abandoned bogs were given their own landuse category, "abandoned cranberry bog". Based on MassDEP sampling which found elevated total phosphorus in samples from tributaries in the Swamp C and Peterson Swamp watersheds, the MassGIS landuse categories "Forested Wetland" and "Non-forested Wetland" were retained for modeling purposes. For a more detailed analysis of land use see MassDEP 2016, Appendix A.

Parameterization (calibration) Input

The major parameterization (calibration) dealt with assigning land use export coefficients for phosphorus (see Table 3). Using the measured in-pond total phosphorus concentrations, these coefficients values were iteratively optimized to provide the best fit between predicted in-pond total phosphorus concentrations and measured in-pond concentrations in all four ponds simultaneously. The White Island Pond TMDL (MassDEP 2010) and the work of Mattson (2015) helped provide estimates of total phosphorus loading from cranberry bog areas which made up almost the entirety of the High Intensity Agriculture land use category. Based on MassDEP sampling in Stetson Brook, Swamp C tributary and the Peterson Swamp tributary where total phosphorus concentrations ranged from 0.032 mg/l to 0.098 mg/l, phosphorus export coefficients for the two major wetland landuse types, forested wetland and non-forested wetland were assigned. The forested wetland landuse category was assigned a phosphorus export coefficient of 0.40 kg/ha/yr while the non-forested wetland category was assigned a value of 0.30 kg/ha/yr. Although in-stream phosphorus values were elevated in some of the tributaries, especially the Peterson Swamp tributary, there is some uncertainty as to the water load from these areas. During sampling some of the tributaries were noted to be stagnant. The atmospheric deposition was estimated to be 0.2 kg TP/ha/yr based on the median value from the reference variables worksheet associated with the LLRM model.

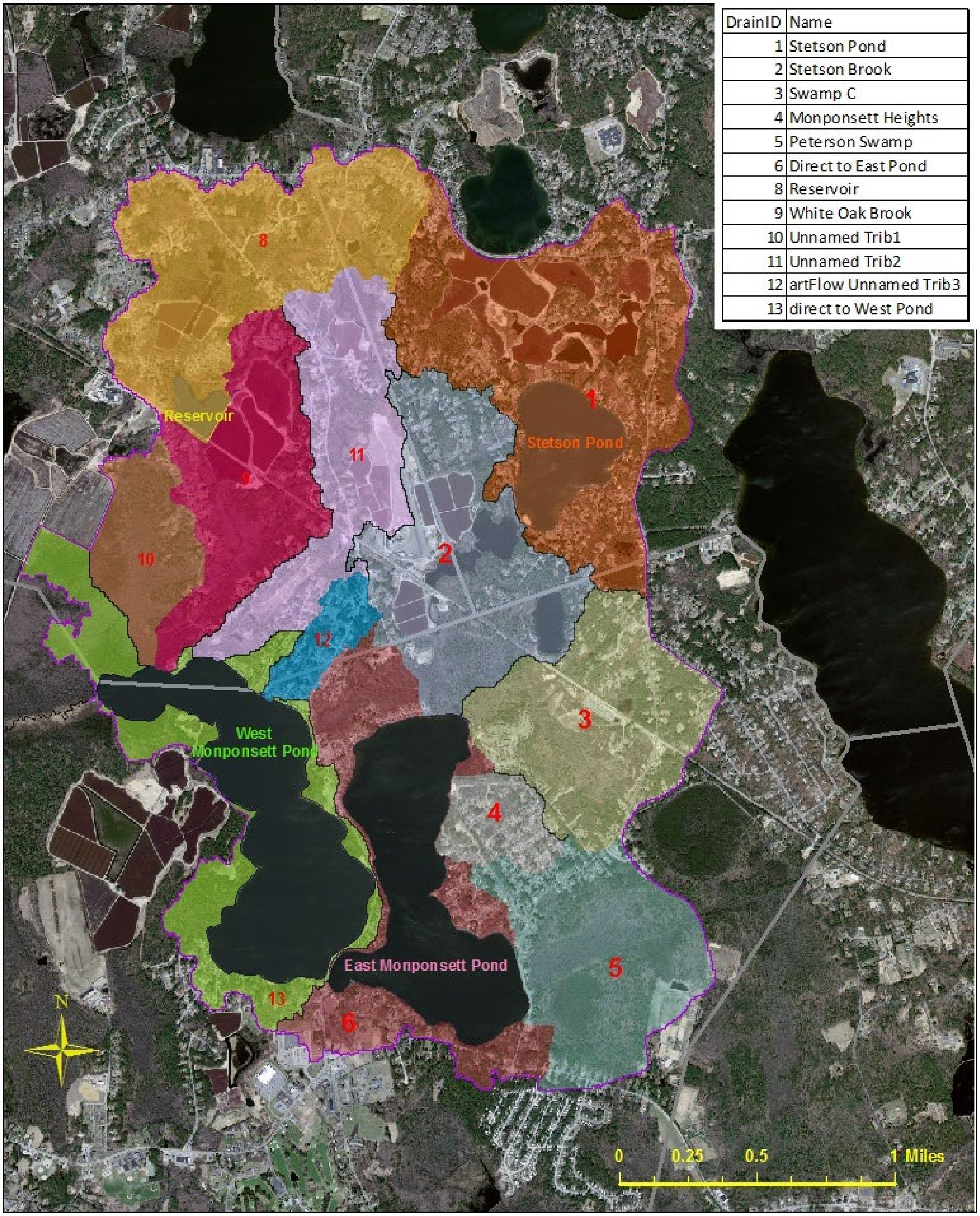

Figure 2. Watersheds in the TMDL study area.

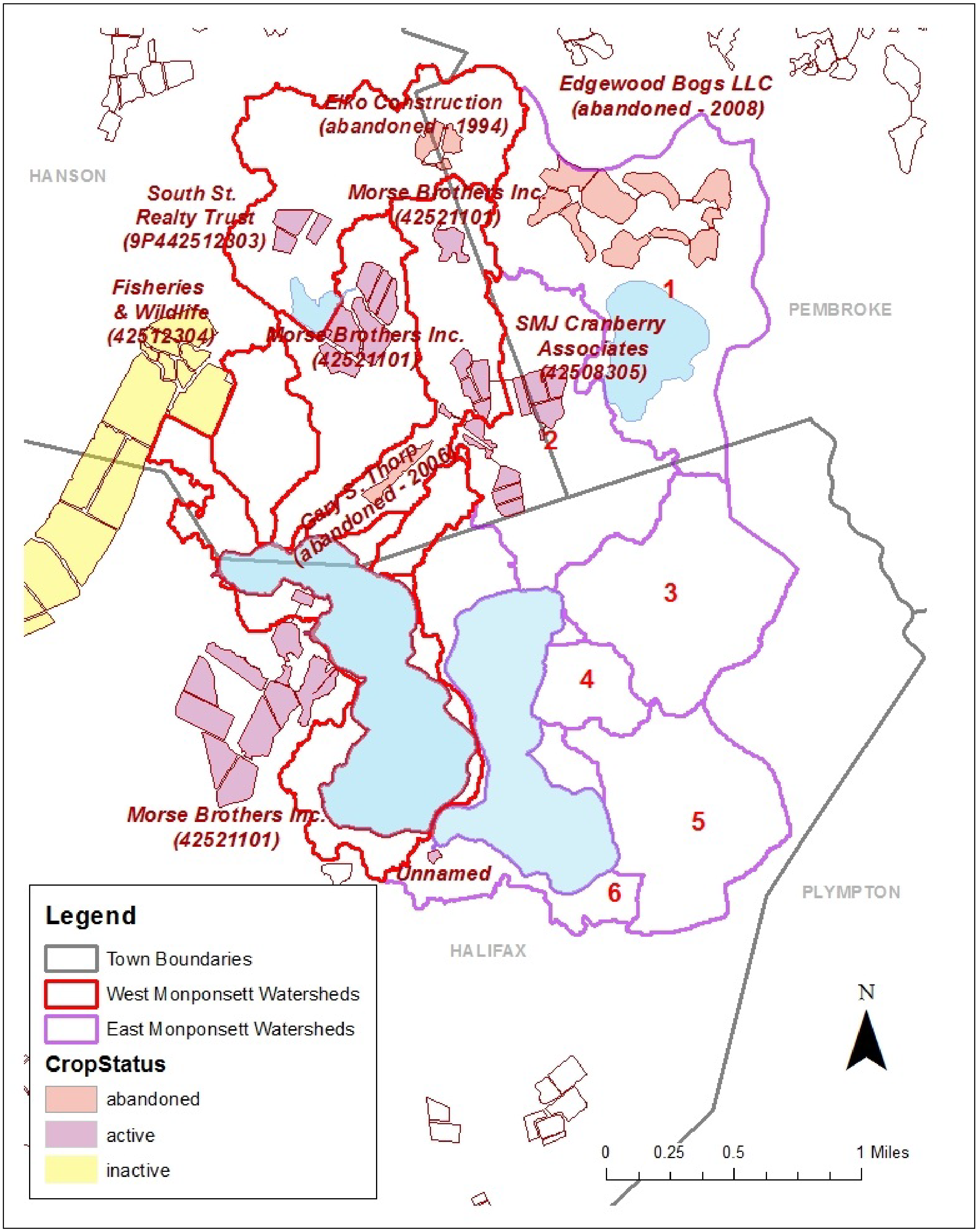

Figure 3. Cranberry Bogs and their Status in TMDL study area (if active water withdrawal Water Management Act (WMA) # in parenthesis)

Table 2: Mapping of MassGIS 2005 Landuse Categories to Aggregated Groups for Modeling

MassGIS 2005 Description Land Use	TMDL Grouping	EPA Designation Stormwater P Load Calculations
Brushland / Successional	Natural	Forest
Commercial	High Intensity Development	Commercial
Cranberry Bog	High Intensity Ag. (bog)	Agriculture
Cranberry Bog	Abandoned Cranberry Bog	Agriculture
Cropland	Medium Intensity Agriculture	Agriculture
Forest	Natural	Forest
Forested Wetland	Forested Wetland	Forest
High Density Residential	Medium Intensity Development	High Density Residential
Industrial	High Intensity Development	Industrial
Low Density Residential	Low Intensity Development	Low Density Residential
Medium Density Residential	Medium Intensity Development	Medium Density Residential
Multi-Family Residential	Medium Intensity Development	High Density Residential
Non-Forested Wetland	Non-Forested Wetland	Forest
Nursery	Low Intensity Agriculture	Agriculture
Open Land	Open	Open Land
Participation Recreation	Medium Intensity Development	Open Land
Pasture	Low Intensity Agriculture	Agriculture
Transitional	Low Intensity Development	Commercial
Transportation	Medium Intensity Development	Highway
Urban Public/Institutional	Medium Intensity Development	Open Land
Very Low Density Residential	Low Intensity Development	Low Density Residential
Water	Water	Water

The landuse export coefficients used in this study are within reasonable ranges and generally within ranges detailed in the LLRM model and Reckhow (1980). The ranges for some development landuse categories are slightly lower than the median values found in the LLRM. Lower export coefficients are believed to be warranted given the importance of groundwater in the TMDL study and attenuation. It is expected that given the sandy glacial soils in the study, high infiltration and low soil nutrient content should act to reduce pollutant loading. BEC (1993) found using their export coefficients overestimated loading to Stetson Pond and used a groundwater and surface water export model. In order to more reasonably approach both tributary and in-pond total phosphorus concentrations, landuse export coefficients slightly lower than median values found in the LLRM reference variables were used.

Grouping	TP (kg/ha/yr)	LLRM ranges*(kg/ha/yr)	Reckhow (1980) (kg/ha/yr) ranges**
Natural	0.10	0.02 - 0.83	0.019 – 0.830
Low Intensity Agriculture	0.64	0.1 - 2.9	0.1 – 2.90
Medium Intensity Agriculture	1.50	0.14 - 4.9	0.14 – 4.90
High Intensity Agriculture	4.30	0.29 - 18.6	0.29 - 18.6
Forested Wetland	0.40	0.02 - 0.83	--
Non-Forested Wetland	0.30	0.02 - 0.83	--
Low Intensity Development	0.30	0.19 - 6.3	0.19 – 2.7
Medium Intensity Development	0.50	0.19 - 6.3	0.88 – 1.7
High Intensity Development	1.00	0.19 - 6.3	0.56 – 1.1
Open	0.00	0.02 - 0.83	--
Water	0.00	0.02 - 0.83	--
Abandoned Cranberry Bog	0.10	--	--

Table 3: Landuse Categories and Assigned Total Phosphorus Export Coefficients

*comparison based on most relevant LLRM landuse categories (note some LLRM ranges are based on Reckhow 1980)
** comparison based on most relevant landuse in Reckhow (1980) export coefficients compilation

Stormwater

Stormwater loadings was estimated using an analysis which included MassGIS landuse classifications (MassGIS 2005), analysis of directly connected impervious areas and hydrologic soil group classifications as well as individual TP export loading rates by landuse for directly connected impervious area and for pervious areas as provided by Table 1-2 in Appendix F of the 2016 Massachusetts MS4 permit.

For each watershed the impervious area (MassGIS 2007) was intersected with the MassGIS landuse classification and directly connected impervious area percentages and loadings were calculated using EPA methodology (EPA 2010). Soil survey information for the TMDL study area was downloaded from Natural Resources Conservation Service web soil survey (Survey Staff, National Resources Conservation Service, 2018). The downloaded soils data was accessed with the use of NRCS Soil Data Viewer Software ArcMap add-in and the HSG classification was rated using the dominant condition aggregation method. MassGIS landuse classifications were summarized according to the MA Stormwater Permit, Appendix F, Attachment 1, Table 1-3. The landuse in areas without impervious surface was then intersected with hydrologic soil group information from the NRCS web soil survey. In areas without a soil classification, the dominant soil classification for that landuse and watershed was assigned. Soil classifications that were split were assigned the first soil rating classification. The stormwater load from pervious areas was then calculated using the total phosphorus loading factors in Table 4 below for each landuse and hydrological soil group classification. Specifically the area for each landuse and hydrological soil group in Table 4 for each subwatershed was multiplied by the appropriate pervious landuse TP export rate (Table 4).

Land Use & Cover[1]	**TP (lb/acre/year)**	**TP (kg/hectare/yr)**
AGRICULTURE, HSG A	0.45	0.50
AGRICULTURE, HSG B	0.45	0.50
AGRICULTURE, HSG C	0.45	0.50
AGRICULTURE, HSG D	0.45	0.50
AGRICULTURE, IMPERVIOUS	1.52	1.70
COMMERCIAL, HSG A	0.03	0.03
COMMERCIAL, HSG B	0.12	0.13
COMMERCIAL, HSG C	0.21	0.24
COMMERCIAL, HSG D	0.37	0.41
COMMERCIAL, IMPERVIOUS	1.78	2.00
FOREST, HSG A	0.12	0.13
FOREST, HSG B	0.12	0.13
FOREST, HSG C	0.12	0.13
FOREST, HSG D	0.12	0.13
FOREST, HSG IMPERVIOUS	1.52	1.70
HIGH DENSITY RESIDENTIAL, HSG A	0.03	0.03
HIGH DENSITY RESIDENTIAL, HSG B	0.12	0.13
HIGH DENSITY RESIDENTIAL, HSG C	0.21	0.24
HIGH DENSITY RESIDENTIAL, HSG D	0.37	0.41
HIGH DENSITY RESIDENTIAL, IMPERVIOUS	2.32	2.60
HIGHWAY, HSG A	0.03	0.03
HIGHWAY, HSG B	0.12	0.13
HIGHWAY, HSG C	0.21	0.24
HIGHWAY, HSG D	0.37	0.41
HIGHWAY, IMPERVIOUS	1.34	1.50
INDUSTRIAL, HSG A	0.03	0.03
INDUSTRIAL, HSG B	0.12	0.13
INDUSTRIAL, HSG C	0.21	0.24
INDUSTRIAL, HSG D	0.37	0.41
INDUSTRIAL, IMPERVIOUS	1.78	2.00

Land Use & Cover[1]	TP (lb/acre/year)	TP (kg/hectare/yr)
LOW DENSITY RESIDENTIAL, HSG A	0.03	0.03
LOW DENSITY RESIDENTIAL, HSG B	0.12	0.13
LOW DENSITY RESIDENTIAL, HSG C	0.21	0.24
LOW DENSITY RESIDENTIAL, HSG D	0.37	0.41
LOW DENSITY RESIDENTIAL, IMPERVIOUS	1.52	1.70
MEDIUM DENSITY RESIDENTIAL, HSG A	0.03	0.03
MEDIUM DENSITY RESIDENTIAL, HSG B	0.12	0.13
MEDIUM DENSITY RESIDENTIAL, HSG C	0.21	0.24
MEDIUM DENSITY RESIDENTIAL, HSG D	0.37	0.41
MEDIUM DENSITY RESIDENTIAL, IMPERVIOUS	1.96	2.20
OPEN LAND, HSG A	0.03	0.03
OPEN LAND, HSG B	0.12	0.13
OPEN LAND, HSG C	0.21	0.24
OPEN LAND, HSG D	0.37	0.41
OPEN LAND, IMPERVIOUS	1.52	1.70
WATER, HSG	0	0.00
[1]MassGIS landuse category assigned per Appendix F, Attachment 1, Table 1-3 2016 MA MS4 Permit,; HSG = Hydrologic Soil Group		

Table 4: Landuse Categories and Assigned Total Phosphorus Export Coefficients for DCIA and pervious areas (per 2016 MA MS4 permit, Appendix F, Attachment 1, Table 1-2).

The total DCIA load and pervious stormwater load by watershed was calculated (Table 5). Except for Stetson Pond all stormwater loads were less than the calculated TMDL watershed load. For Stetson Pond this discrepancy is likely explained by the fact that the agricultural areas in this watershed are largely abandoned cranberry bogs and not active operations. The pervious agriculture TP export coefficient of 0.50 kg/hectare/yr (Table 4) is likely an overestimate in this watershed and 0.1 kg/hectare/yr TP was used as a more appropriate estimate. A crosswalk between the modeled watershed loading landuse groupings (Table 3) and EPA MA MS4 landuse groupings (EPA 2016, Appendix F, Attachment 1, Table 1-3) for each MassGIS landuse code was then constructed to allow the determination of stormwater loads for each modeled watershed loading landuse grouping.

As described above the total modeled watershed loading was calculated for each watershed. On occasion the calculated total stormwater load was greater than the modeled watershed load for a given modeled watershed landuse grouping, therefore for the purposes of the stormwater wasteload allocation (WLA) in the TMDL, the entirety of the modeled watershed load was assigned to the wasteload allocation for stormwater.

The calculated stormwater loads and the assigned stormwater wasteload allocation for Stetson Pond, East Monponsett Pond, White Oak Brook Reservoir and West Monponsett Pond can be found in Tables 6, 7, 8 and 9 respectively.

Watershed	DCIA TP Load (kg/yr)	Pervious TP Load (kg/year)	Total Stormwater TP Load[1] (kg/year)	Modeled TP Watershed Load (kg/yr)
Stetson Pond	18.0	33.1	51.0	44.1
East Monponsett	73.3[1]	83.7[1]	157.0[2]	276.9
White Oak Reservoir	19.9	21.5	41.4	75.1
West Monponsett	54.8[2]	74.8[2]	129.6[3]	344.6
Grand Total				740.7

1- Total Stormwater Load is the sum of the DCIA TP Load (column 1) and Pervious TP Load (column 2)
2- Includes unattenuated loads from Stetson Pond
3- Includes unattenuated loads from White Oak Reservoir

Table 5: Total Stormwater Load as the sum of DCIA TP Load and Pervious TP Load

(report continued next page)

TMDL Grouping	DCIA TP Load (kg/year)	Pervious TP Load (kg/year)	Total Stormwater Load[1] (kg/year)	Modeled Watershed Load (kg/yr)	Current Stormwater Waste Load (kg/yr)[2]
Forested Wetland	0.0	0.5	0.5	1.6	0.5
High Intensity Ag. (bog)	0.0	20.9	20.9[3]	4.4	4.4
High Intensity Development	0.0	0.0	0.0	0.0	0.0
Low Intensity Agriculture	0.1	0.6	0.7	0.9	0.7
Low Intensity Development	8.5	1.6	10.1	16.3	10.1
Medium Intensity Development	8.9	0.6	9.6	13.2	9.6
Natural	0.2	8.1	8.3	6.3	6.3
Non-Forested Wetland	0.0	0.6	0.6	1.3	0.6
Open	0.3	0.1	0.4	0.0	0.0
Water	0.0	0.0	0.0	0.0	0.0
Grand Total					**32.2**

1- Total Stormwater Load is the sum of the DCIA TP Load (column 1) and Pervious TP Load (column 2)
2- The TMDL Stormwater WLA is the Total Stormwater Load or the Modeled Watershed Load, whichever is less.
3- Stormwater Load from pervious agriculture areas likely overestimate as majority of agricultural area is abandoned cranberry bogs

Table 6: Stormwater Loads for Stetson Pond

TMDL Grouping	DCIA TP Load (kg/year)	Pervious TP Load (kg/year))	Total Stormwater Load[1] (kg/year)	Stetson Attenuated Total Stormwater Load (kg/year)	Total Stormwater Load Included Attenuated Stetson Pond Stormwater Load (kg/yr)	Modeled Watershed Load (kg/yr)	Current Stormwater Waste Load (kg/yr)[2]
Forested Wetland	0.0	13.1	13.1	0.5	13.7	40.4	13.7
High Intensity Ag. (bog)	0.0	10.2	10.2	3.4	13.6	103.4[3]	13.6
High Intensity Development	6.8	0.2	7.0	0.0	7.0	8.6	7.0
Low Intensity Agriculture	0.1	2.9	3.0	0.5	3.5	4.7	3.5
Low Intensity Development	13.2	3.0	16.2	7.8	24.0	37.5	24.0
Medium Intensity Development	38.3	2.5	40.8	7.4	48.2	53.5	48.2
Natural	0.5	23.9	24.4	4.9	29.3	23.3	23.3
Non-Forested Wetland	0.0	2.0	2.0	0.5	2.5	5.6	2.5
Open	0.6	0.2	0.8	0.0	0.8	0.0	0.0
Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total							**135.8**

1- Total Stormwater Load is the sum of the DCIA TP Load (column 1) and Pervious TP Load (column 2)
2- The TMDL Stormwater WLA is the Total Stormwater Load or the Modeled Watershed Load, whichever is less.
3- Includes the attenuated load from abandoned cranberry bogs in Stetson Pond
(note all values rounded to the nearest tenth of a kilogram/yr)

Table 7: Stormwater Loads for East Monponsett Pond

TMDL Grouping	DCIA TP Load (kg/year)	Pervious TP Load (kg/year))	Total Stormwater Load[1] (kg/year)	Modeled Watershed Load (kg/yr)	Current Stormwater Waste Load (kg/yr)[2]
Forested Wetland	0.0	3.0	3.0	8.9	3.0
High Intensity Ag. (bog)	0.0	5.9	5.9	32.7	5.9
High Intensity Development	6.1	0.2	6.3	5.2	5.2
Low Intensity Agriculture	0.0	0.1	0.1	0.1	0.1
Low Intensity Development	11.1	4.4	15.4	17.0	15.4
Medium Intensity Development	2.7	0.4	3.1	3.1	3.1
Natural	0.1	6.3	6.3	4.8	4.8
Non-Forested Wetland	0.0	1.3	1.3	2.9	1.3
Water	0.0	0.0	0.0	0.0	0.0
Grand Total					**38.7**

1- Total Stormwater Load is the sum of the DCIA TP Load (column 1) and Pervious TP Load (column 2)

2- The TMDL Stormwater WLA is the Total Stormwater Load or the Modeled Watershed Load, whichever is less. (note all values rounded to the nearest tenth of a kilogram/yr)

Table 8: Stormwater Loads for White Oak Reservoir

TMDL Grouping	DCIA TP Load (kg/yr)	Pervious TP Load (kg/yr))	Total Stormwater Load[1] (kg/yr)	White Oak Reservoir WLA	Total Stormwater Load Including White Oak Reservoir WLA (kg/yr)	Modeled Watershed Load (kg/yr)	Current Stormwater Waste Load (kg/yr)[2]
Forested Wetland	0.0	11.3	11.3	3.0	14.3	42.6	14.3
High Intensity Ag. (bog)	0.0	20.0	20.0	5.9	25.9	198.7[3]	25.9
High Intensity Development	2.2	0.2	2.3	5.2	7.5	7.7	7.5
Low Intensity Agriculture	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Low Intensity Development	10.2	2.4	12.6	15.4	28.0	33.8	28.0
Medium Intensity Development	22.2	1.9	24.1	3.1	27.1	34.7	27.1
Natural	0.3	13.6	13.9	4.8	18.7	15.3	15.3
Non-Forested Wetland	0.0	4.0	4.0	1.3	5.3	11.8	5.3
Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total							**123.5**

1- Total Stormwater Load is the sum of the DCIA TP Load (column 1) and Pervious TP Load (column 2)
2- The TMDL Stormwater WLA is the Total Stormwater Load or the Modeled Watershed Load, whichever is less.
3- Includes the load from abandoned cranberry bogs
(note all values rounded to the nearest tenth of a kilogram/year)

Table 9: Stormwater Loads for West Monponsett

Internal Loading

MassDEP sampling in 2015 found hypoxia in Stetson Pond below a depth of 6 meters. Based on an estimated area below 6 meters of approximately 3.8 hectares and a sediment release rate of 2 $mg/m^2/day$ for a period of 90 days, an estimated internal load of approximately 6.9 kg/yr was calculated for Stetson Pond. MassDEP sampling in White Oak Reservoir did not indicate internal loading was a source for total phosphorus therefore no internal load was estimated.

The internal load in West Monponsett Pond was estimated based on MassDEP sediment core sampling and laboratory incubation of the cores with oxic headspace lake water in September 2010 (MassDEP 2010c) following the methods of Nowlin et al., (2005). The average phosphorus loading from the set of four cores was found to be approximately 1.57 $mg/m^2/day$ (median 1.67). Using this areal phosphorus release rate over a period of 150 days for the entire surface of the pond, yielded an internal load of 293 kg/year. This may be an underestimate because West Monponsett Pond does become anoxic during rare periods of calm conditions and phosphorus release may be much higher at those times. Between 2009 and 2015 MassDEP conducted 24 dissolved oxygen profiles at the deep hole in West Monponsett Pond (Site ID W0926) between the months of May and September. On five occasions the dissolved oxygen was below 1 mg/l at the near bottom sampling depth, indicative of anoxia. Low dissolved oxygen at depth often occurred in the months of August and September, likely due to high phytoplankton biomass and warmer water temperatures often seen during these months.

For the East Monponsett Pond no sediment cores were taken with which to estimate internal loading directly. MassDEP estimated the internal loading to be 30 kg/yr using an estimated phosphorus release of 1 $mg/m^2/day$ affecting approximately 25 hectares of the lake for 120 days. A lower phosphorus release rate was chosen for East Monponsett Pond given the fact it has historically had a lower in pond total phosphorus concentrations.

Septic Systems

In order to estimate septic system loading to each pond the number of houses within 100 feet of each water body and between 100 and 300 feet was estimated using a GIS system with orthophotos and parcel data (Table 10). For septic system loads, an average of 2.5 people per dwelling, a water use of 0.25 cubic meters per day per person and an effluent concentration of 8 mg/l and a phosphorus attenuation factor of 0.1 was used. An example of septic system loading calculations for East Monponsett Pond is provided in Table 11.

# Houses	Stetson Pond	East Pond	White Oak Reservoir	West Pond
within 100 feet	59	89	0	71
between 100 and 300 feet	44	73	6	80

Table 10: Estimate of Septic Systems near ponds in TMDL study area

DIRECT SEPTIC SYSTEM LOAD

Septic System Grouping (by occupancy or location)	Days of Occupancy/Yr	Distance from Lake (ft)	Number of Dwellings	Number of People per Dwelling	Water per Person per Day (cu.m)	P Conc. (ppm)	P Attenuation Factor	Water Load (cu.m/yr)	P Load (kg/yr)
Group 1 Septic Systems	365	<100	89	2.5	0.25	8	0.1	20303	16.2
Group 2 Septic Systems	365	100 - 300	73	2.5	0.25	8	0	16653	0.0
Totals								36956	16.2

Table 11: Estimated Septic Load for East Monponsett Pond

Load Routing

As part of the model, loads must be routing through different subbasins for each pond as appropriate. In the model each basin on the left of the spreadsheet passes into another basin in a column to the right is labeled with a 1. A zero value is otherwise the default. Each basin passes through itself so the first row in the Table 9 below is 1. So for example Stetson Pond (Basin 1) passes into Stetson Brook which then passes into East Monponsett Pond (Table 12). Routing was conducted similarly for all the ponds in this TMDL.

ROUTING PATTERN

1=YES 0=NO
XXX=BLANK

(Basin in left hand column passes through basin in column below if indicated by a 1)

	BASIN 1 Stetson Pond (CU.M/YR)	BASIN 2 Stetson Brook (CU.M/YR)	BASIN 3 Swamp C (CU.M/YR)	BASIN 4 Monponsett Heights (CU.M/YR)	BASIN 5 Peterson Swamp (CU.M/YR)	BASIN 6 Direct To East Pond (CU.M/YR)
INDIVIDUAL BASIN	1	1	1	1	1	1
BASIN 1 OUTPUT	XXX	1	0	0	0	0
BASIN 2 OUTPUT	0	XXX	0	0	0	0
BASIN 3 OUTPUT	0	0	XXX	0	0	0
BASIN 4 OUTPUT	0	0	0	XXX	0	0
BASIN 5 OUTPUT	0	0	0	0	XXX	0
BASIN 6 OUTPUT	0	0	0	0	0	XXX
BASIN 7 OUTPUT	0	0	0	0	0	0
BASIN 8 OUTPUT	0	0	0	0	0	0
BASIN 9 OUTPUT	0	0	0	0	0	0
BASIN 10 OUTPUT	0	0	0	0	0	0

Table 12 Water Routing for East Monponsett Pond subwatersheds

Load Routing and Attenuation

Water load attenuation and phosphorus attenuation largely did not play a significant factor in this modeling effort. A small amount of attenuation was estimated for Stetson Pond. Based on a predicted in-pond total phosphorus concentration 19.4 ppb and a measured concentration of 15 ppb, a 22.5% attenuation was estimated. Similarly 35% water load attenuation was estimated for Peterson Swamp given the large portion of wetlands in its watershed and to more closely match measured in-stream concentrations. In general this modeling effort relied on parameterizing land use export coefficients throughout the study area and not on subwatershed specific attenuation factors to bring loading into balance with measured conditions.

Estimated Watershed Loads

The landuse export coefficients for phosphorus were based on ranges presented in Reckhow et al., 1980 and default values used in the LLRM model with some exceptions as noted below. Using the phosphrorus export coefficients determined as part of the calibration of the LLRM model (Table 3), the watershed loads for each of the ponds in the TMDL study area were estimated. The high intensity agriculture (cranberry bogs) export coefficient of 4.3 kg/ha/yr was estimated. The forested wetland was broken out as a separate landuse due to the extensive area of this unusual forest type and the large observed concentrations in waters flowing out of the wetland areas. The estimated watershed loads for the Stetson Pond watershed and all watersheds that contribute to East Monponsett Pond can be found in Table 13. The estimated watershed loads for the White Oak Reservoir watershed and all watersheds that contribute to West Monponsett Pond can be found in Table 14.

	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Basin 6	Total
	Stetson Pond	Stetson Brook	Swamp C	Monponsett Heights	Peterson Swamp	Direct To East Pond	
LAND USE	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)
High Intensity Ag. (bog)	0.0	97.8	0.0	0.0	0.0	2.2	100.0
Medium Intensity Development	10.2	8.3	8.9	8.6	7.3	10.2	53.5
Forested Wetland	1.3	6.8	7.9	1.0	17.7	5.6	40.4
Low Intensity Development	12.6	6.8	7.5	1.5	3.4	5.7	37.5
Natural	4.9	5.0	5.6	0.7	4.6	2.6	23.3
High Intensity Development	0.0	0.1	0.4	0.0	0.0	8.1	8.6
Non-Forested Wetland	1.0	0.8	3.2	0.1	0.1	0.4	5.6
Low Intensity Agriculture	0.7	0.0	0.0	0.0	3.3	0.7	4.7
Abandoned Cranberry Bogs	3.4	0.0	0.0	0.0	0.0	0.0	3.4
Medium Intensity Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	34.1	125.6	33.4	11.8	36.4	35.5	276.9

Table 13: Watershed Loads by Landuse for East Monponsett Pond Watersheds

	Basin 8	Basin 9	Basin 10	Basin 11	Basin 12	Basin 13	Total
	White Oak Reservoir	White Oak Brook	Unnamed Tributary 1	Unnamed Tributary 2	Artificial Flow/ Unnamed Tributary 3	Direct to West Pond	
LAND USE	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)
High Intensity Ag. (bog)	32.7	101.4	3.2	50.4	0.0	10.2	198.0
Forested Wetland	8.9	6.8	13.2	3.2	0.1	10.4	42.6
Medium Intensity Development	3.1	2.7	0.3	10.4	9.0	9.3	34.7
Low Intensity Development	17.0	6.4	1.1	7.2	0.0	2.1	33.8
Natural	4.8	3.2	1.3	3.0	0.3	2.7	15.3
Non-Forested Wetland	2.9	2.2	0.6	3.0	0.1	3.0	11.8
High Intensity Development	5.2	0.0	0.0	0.7	0.1	1.8	7.7
Abandoned Cranberry Bogs	0.5	0.0	0.0	0.3	0.0	0.0	0.8
Low Intensity Agriculture	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Medium Intensity Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	75.1	122.7	19.6	78.1	9.5	39.5	344.6

Table 14: Watershed Loads by Landuse for West Monponsett Pond Watersheds

Water Quality Predictions

Using spreadsheet values provided or generated as part of the nutrient load predictions the LLRM model can predict in-pond total phosphorus concentrations, mean and peak chlorophyll *a*, and Secchi disk depth. The model can also estimate bloom frequency (as % of time) above certain chlorophyll *a* concentrations. Each prediction is based on an empirical equation from literature obtained across a range of pond and lake sizes and types with a large proportion located in North America. It should be noted that the model results included were often developed in large, deep waterbodies with greater retention times. They are considered standard model equations however and the average of the results is considered reasonable. An example of the predicted total phosphorus for West Monponsett Pond is given in Table 15 below. For the purposes of this modeling effort the results of the Mass Balance equation were excluded from the average of the model values used to predict in-lake total phosphorus concentrations.

NAME	FORMULA	PRED. CONC. (ppb)
Mass Balance (Maximum Conc.)	TP=L/(Z(F))*1000	126
Kirchner-Dillon 1975 (K-D)	TP=L(1-Rp)/(Z(F))*1000	47
Vollenweider 1975 (V)	TP=L/(Z(S+F))*1000	100
Larsen-Mercier 1976 (L-M)	TP=L(1-Rlm)/(Z(F))*1000	74
Jones-Bachmann 1976 (J-B)	TP=0.84(L)/(Z(0.65+F))*1000	81
Reckhow General (1977) (Rg)	TP=L/(11.6+1.2(Z(F)))*1000	32
Average of Model Values		67

Table 15: West Monponsett - Prediction of in-lake total phosphorus based on model prediction equations

Calibration Results

The LLRM Model was calibrated based on average 2009 in-pond total phosphorus concentrations (as measured during MassDEP sampling) for White Oak Reservoir, West Monponsett Pond and East Monponsett Pond. Stetson Pond was not sampled until 2015 and therefore for Stetson Pond the model was calibrated to 2015 in-pond total phosphorus concentrations.

In general the calibrated LLRM model matched observed conditions in each of the ponds. Rather than calibrating each pond seperately with different landuse coefficients and/or attenuations, we calibrated all the lakes with the same coefficients simultaneously, with minor adjustments to internal loading to obtain a more robust model for all ponds. Due to a discrepency in the loading model predicted in lake TP concentration and the observed in lake concentration in White Oak Reservoir, the modeled calibration target was adjusted as follows. The median observed TP concentration in the White Oak Reservoir was observed to be 35 ppb (See MassDEP 2016, Figure 9). The calibration target was adjusted from 35 to 50 ppb to account for the phosphorus in the biomass of the *Lemna* (duckweed) on the surface. Once this adjustment was made the models calibrated fairly well. The % error between the predicted concentrations and the observed concentrations in all the ponds ranged from 1.6% in West Monponsett to 29% in Stetson (Table 16). The absolute error in Stetson is only 4.4 ppb and given the ponds disparate size, morphology and landuse, this fit is acceptable.

Name	Lake Predicted Concentration (ppb)	Observed (ppb)	Abs (error)	% Error
Stetson Pond	19	15	4.4	29.1
East Monponsett	33	34	0.8	2.4
White Oak Reservoir	51	50	1.2	2.5
West Monponsett	67	68	1.1	1.6

*Actual observed TP in White Oak Reservoir was 35 ppb (see text MassDEP 2016).

Table 16: Comparison LLRM Predicted TP Concentration and Observed TP Concentration

Sensitivity Analysis

It is likely the most sensitive landuse export coefficient for TP is for cranberry bog areas or high intensity agriculture. A comparison of landuse export coefficient for high intensity agriculture and predicted in-pond phosphorus concentrations is detailed in Table 17 below. Stetson Pond which no longer has active cranberry bog operations is insensitive to changing high intensity agriculture landuse TP export coefficient. East Monponsett, White Oak Reservoir and West Monponsett Pond are all sensitive to changing high intensity agriculture landuse export coefficient. It can easily be seen that White Oak Reservoir is the most sensitive to the high intensity agriculture landuse TP export coefficient likely due to its relatively small watershed size and small pond volume.

Model Prediction Runs

MassDEP determined target TP concentrations for each pond in the TMDL study area (MassDEP 2016). The TP load was adjusted for each pond until its predicted TP concentration matched the target TP concentration. The predicted concentration used in the LLRM model was an average of all the prediction models excluding the Mass Balance equation.

The estimated allowable TP load for was 48 kg/yr, 183 kg/yr, 35 kg/yr and 186 kg/yr for Stetson Pond, East Monponsett Pond, White Oak Reservoir and West Monponsett Pond, respectively (Table 18). The lake models used in this TMDL have a yearly time step. This along with the fact that ponds store phosphorus in the water column and sediments means water quality responds to inputs on a yearly basis.

	Predicted Total Phosphorus Concentration (ppb)			
High Intensity Agriculture TP (kg/ha/yr)	Stetson Pond	East Monponsett	Reservoir	West Monponsett
2.2	19	28	40	57
3	19	30	45	61
3.5	19	31	47	63
4	19	32	50	65
4.5	19	34	52	68
5	19	35	55	70
5.5	19	36	57	73
6	19	37	60	75
6.5	19	38	63	78
7	19	39	65	80
7.5	19	41	68	83
9.9	19	46	80	94
Measured Values	15	34	50	68

Table 17: Comparison of Predicted Total Phosphorus Concentration for TMDL study ponds and high intensity agriculture TP export coefficient

Meeting the threshold loads for each pond will result in reduced algal blooms. All the ponds had a predicted probability of Chlorophyll *a* >16 ppb (typically considered a cause of impairment) less than 10% of the time (Table 18). It is important to note White Oak Reservoir is currently dominated by duckweed and aquatic plants. Reduction in duckweed cover is the restoration target for this waterbody. East Monponsett Pond and West Monponsett Pond at their threshold loads will have predicted peak Chlorophyll *a* values of approximately 21 ppb and 23 ppb, respectively. In the future peak Chlorophyll *a* values may exceed the 16 ppb criterion. The goal of this TMDL is to reduce the extent and severity of current algae blooms such that the Chlorophyll *a* criterion is predicted to be met over 90% of the time.

Model Summary

The LLRM model although lacking the sophistication of more complex flow related models was adequate to identify the major sources of loading in the TMDL study area. It also provides a method to predict the results of management actions to reduce total phosphorus loading in this system. There is some uncertainty in the estimates of internal loading but this is the only modeling effort with measured nutrient flux measurements. Some uncertainty is unavoidable, however, given the Margin of Safety within the TMDL it is believed modeling efforts are sufficient to guide future management actions in this system.

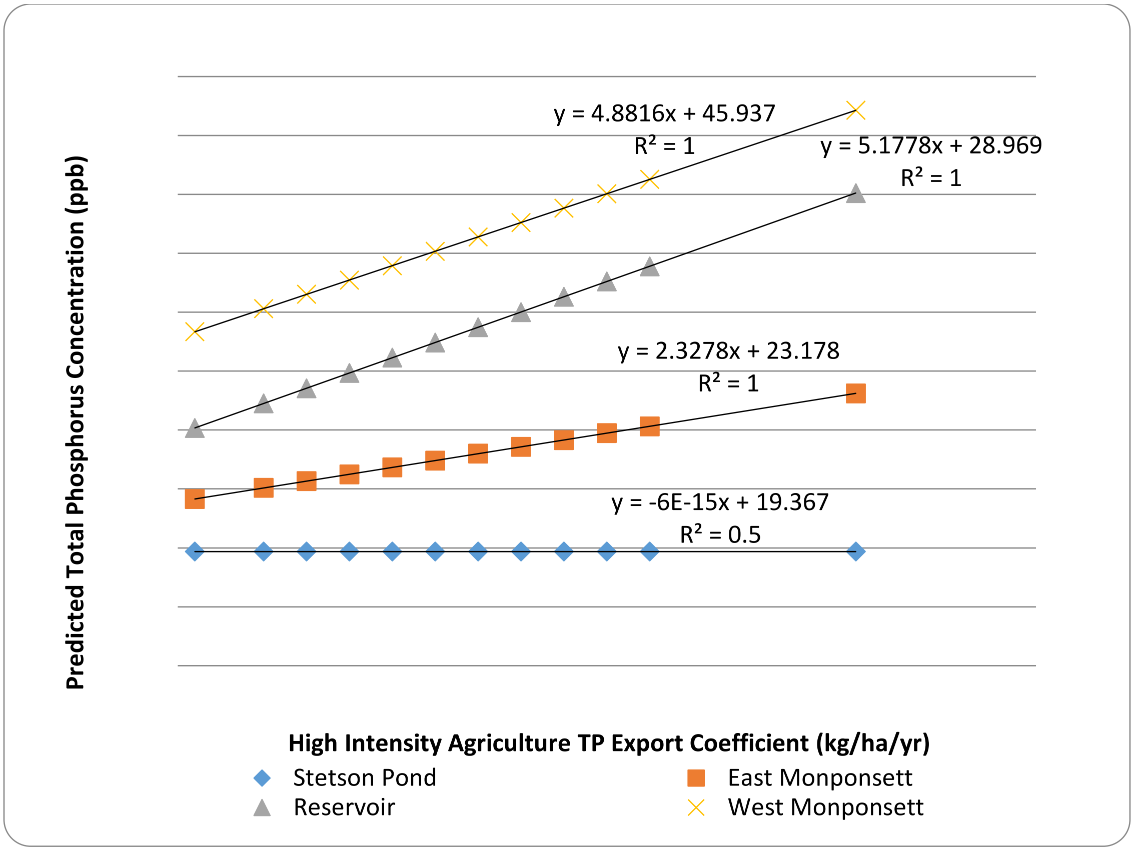

Figure 4: Comparison Predicted TP Concentration and High Intensity Agriculture TP Export Coefficient

Waterbody	Target TP Concentration (ppb)	Target Load TP (kg/yr)	Predicted Mean Chlorophyll *a* (ppb)	Predicted Peak Chlorophyll *a* (ppb)	Probability of Chl >16 ppb (% of time)
Stetson Pond	13	48	4	16	0.2%
East Monponsett	18	182	6	21	1.3%
White Oak Reservoir	23	35	9	31	8.4%
West Monponsett	18	186	7	23	2.3%

Table 18: Threshold Loads for Study Area Waterbodies
(note all values rounded to the kilogram/yr)

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Appendix F: Response to Comments For DRAFT West and East Monponsett Pond System Total Maximum Daily Loads For Total Phosphorus

Comments Received During Draft TMDL meeting
Monponsett Pond System Total Phosphorous TMDL Public Meeting
December 15, 2016
Halifax Town Hall, Halifax, MA
DEP Staff in attendance: Dave Johnston, John Hobill, Kim Groff, Mark Mattson, Matthew Reardon, and Barbara Kickham

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Main Points of Concern:

- Diversion should be included in the modeling and the implementation plan in the TMDL.
- Diversion and the dam at the outlet of Monponsett Pond are cause of the extremely poor water quality. Diversion should be stopped, dam should be removed.
- Act of 1964 refers to diversion of water from Monponsett Pond, not just East basin. This was important to those in attendance. Several attendees were under the impression that East Monponsett Pond is more protected due to its status as a PWS.
- The Act of 1964 also required that the existing uses of the pond be maintained, including swimming, fishing, and boating.
- Brockton needs an alternate water supply to replace Silver Lake to stop the diversion.

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1. **Question:** After all the work and expense of alum treatments, do outboard motors have an impact on the bottom sediments and the alum treatments?

MassDEP Response: Although boat motors can cause turbulence and resuspension of bottom sediments the effect is limited by depth and the size of the motor. Even if the alum is resuspended the phosphorus bound to the aluminum would not be released. It is possible that resuspension of the aluminum floc and subsequent transfer to deeper sections of the lake (sediment focusing) may reduce the effectiveness of aluminum treatment of the shallow areas but this has not been reported to be a problem with aluminum treatments.

2. **Question:** I noticed you refer to East Monponsett as a water supply to Silver Lake. Do you think this is true or is this a mistake? The original regulations say that the withdrawal is from Monponsett Pond, not East or West, but both. It is wrong to say that East Monponsett is a water supply because it is cleaner than West. The reason we are here is because the waters of the ponds are mixing. This is a theory presented by the Brockton Water Department that they are only taking water from East Monponsett Pond for the water supply. DEP is tilting towards the theory that Brockton is only taking water from East which is cleaner?
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MassDEP Response: Please refer to the response to comment 43 below.

3. **Question:** What do you mean by Class A water body?

MassDEP Response: Class A waterbodies "include waters designated as a source of public water supply and their tributaries They are designated as excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation, even if not allowed. These waters shall have excellent aesthetic value. These waters are protected as Outstanding Resource Waters." (CMR 314 5.05(3a)).Both Silver Lake and Monponsett Pond (East and West) are considered public water supplies. This means all of their tributaries are considered Class A as well. An unofficial version of the Massachusetts State Water Quality Standards is available for convenience online at: http://www.mass.gov/eea/docs/dep/service/regulations/314cmr04.pdf. Please note that OFFICIAL versions of all state statutes and regulations (and many of the MassDEP policies) are only available through the State Bookstore or from the Secretary of State's Code of Massachusetts Regulations (CMR) Subscription Service. In general Class A waterbodies have the strictest water quality standards which are outlined in the Massachusetts State Water Quality standards.

4. **Question:** Are you recommending that Stetson Pond receive alum treatments?

MassDEP Response: The town of Pembroke or other interested entities are encouraged to apply for grant funding for the purpose of treating Stetson Pond with alum.

5. **Question:** What is the Remediation plan for White Oak Pond?

MassDEP Response: The results of our modeling indicate that BMP implementation at the cranberry bogs will reduce TP loads and ultimately reach target TP concentrations.

6. **Question:** How do you measure or monitor reduction in fertilizer use at cranberry bogs?

MassDEP Response: The cranberry bog operators are required by MassDAR to keep fertilizer application rate records and through that we can document the reductions in fertilizer use.

7. **Question:** Did White Island Pond have cyanobacteria blooms, on the same scale as West Monponsett Pond (>2 million cells)?

MassDEP Response: Yes, White Island Pond was even worse. A thick scum was often observed to float near shore.

8. **Question:** I want to echo the previous comment regarding the Acts, CH 371. The Act refers to Monponsett Ponds, the withdrawal is not just from East Monponsett Pond. The Act does not differentiate between East and West Monponsett Ponds for the diversion.

MassDEP Response: Please refer to the response to comment 43 below.

9. **Question:** You don't mention the diversion in your modeling, so it appears that you ignored it? Is that true?

MassDEP Response: The model was run for current conditions in which the Monponsett Pond system is subject to diversion. We also modeled the effect of stopping the diversion. The TMDL estimated that West Monponsett Pond might be 24% higher due to the diversion, but once the lake starts to clean up due to the cranberry BMPs and the limited aluminum treatments to date, the impact of diversion will be less than 24% and maybe as low as 6%. Stopping the diversion alone will not stop the blooms. Please refer to response 45 below.

10. **Question:** Do you agree that if the diversions were stopped that the cyanobacteria blooms would cease?

MassDEP Response: MassDEP does not believe that the nutrient reduction targets set in the draft TMDL can be relaxed regardless of future flow management regimes. The treatment of the sources of nutrients is necessary. Stopping the diversion alone will not provide a long term solution to cyanobacteria blooms. The short time scale (days to weeks) effect of increased amounts of water leaving West Monponsett Pond should act to reduce the standing stock of cyanobacteria in West Monponsett Pond and along with reducing nutrients can act as a control on cyanobacteria populations. In the Final TMDL we have rewritten the implementation section to note that a combined approach of better management of the diversion, along with the required reductions in TP loading, will result in meeting the goals, adding a margin of safety to the implementation and providing additional benefits to downstream waters. Please see response 45 below.

11. **Question:** Who instructed you to NOT consider the diversion as part of the solution? A portion of the Act is key – even with the withdrawal, the pond must be suitable for all uses.

MassDEP Response: Many different staff at MassDEP contributed to writing the TMDL report. The Watershed Planning Program conducted the sampling, modeling and analysis while the Southeast Regional staff were working with Brockton to address management issues.

MassDEP noted in the report that the diversion does impact West Monponsett Pond and we have also taken steps within our authority to mitigate those impacts. The actual management and regulation of the diversion flows and water quantities is not under the authority granted to MassDEP under the Federal Clean Water Act for Total Maximum Daily Load. The TMDL program is limited to pollutants. The TMDL is a phosphorus pollution budget and when the TMDL is implemented we anticipate that the pond will in fact be suitable for all uses. On advice of our legal team, MassDEP is using the authority under our state laws MassDEP negotiated an

ACO to manage water quantities in a manner that complies with all applicable laws. Brockton has a WMA Registration in addition to the Act allowing the diversion for water supply. Please also refer to response to comment 9 above and response to comments 45 and 47 below.

The goal of the TMDL is to restore all uses for the pond through a combined approach of better management of the diversion, along with the required reductions in TP loading, will result in meeting the goals of the Clean Water Act.

12. Q (Rep Calter): If diversions alone don't get us there, why not at least use the diversion in negotiating the Consent Order? We don't have $400-500K to fix the cyanobacteria blooms. Brockton can't just use Silver Lake for water supply, must be a combination of answers.

MassDEP Response: In the Final TMDL we have rewritten the implementation section to note that a combined approach of better management of the diversion, along with the required reductions in TP loading, will result in meeting the goals, adding a margin of safety to the implementation and providing additional benefits to downstream waters. As now required by an Administrative Consent Order between the City of Brockton and MassDEP, a minimum of 900,000 gpd must flow over the Stump Brook Dam at all times except when the fish ladder is fully open and no flow is available due to the pool elevation (see response to comments 44 and 47 below). This will return some natural flow to the Monponsett system. MassDEP is directing available resources to complete more alum treatments to reduce the phosphorus concentrations to a point where cyanobacteria blooms are (unlikely/will not) occur.

13. Question: Why didn't you consider removing the dam in West Monponsett Pond and see how that helps?

MassDEP Response: Lowering the lake level was considered in the modeling and it is not expected to improve the condition of the lakes. The dam removal might make some conditions worse, such as there will be less water available for flushing, water temperatures might increase, and as a result there could potentially be more blooms. This would also reduce the pool elevation for agricultural and recreational uses. The TMDL report analyzes options that can be done without changes in law and/or the removal of any rights granted by law. The removal of the dam could only happen with the agreement of the City of Brockton to forfeit its right to the dam or a change to Act 371 of the Acts of 1964.

14. Question: Why not dredge the lake above the dam?

MassDEP Response: Brockton has the legal right to maintain the dam. This is the third dam at that location in the last 100 years. Dredging is very expensive and has many negative impacts on *lake biota. Dredging of the pond would be an effective way to remove the sediment that contains phosphorous. A dredging program that continued to allow for agricultural uses, meet endangered species protections and restore any damaged habitat would likely have a cost of in the tens of millions of dollars. This does not consider the disruption to the lives of nearby residents.*

15. **Question:** (Brockton Water Commissioner) I have heard nothing but complaints about the diversion. Why should Brockton pay for the mistakes of other towns?

MassDEP Response: MassDEP believes that all interested parties can be a part of the remediation of the ponds in the TMDL. Brockton is encouraged to work with the towns of Halifax, Hanson and Pembroke to improve the water quality of the Brockton public water supply.

16. **Question:** We have sat in many meetings with you and now you have not considered the diversion in the solutions. We don't want a quick fix. We want you to look at the stagnation in the ponds. If the diversion continues the problem will not go away.

MassDEP Response: It is the goal of MassDEP to reduce the effects of decreased flushing and flow reversals to the extent possible under relevant laws and statutes to provide for better management of the diversion. Please refer to the response to comment 45 and 50.

17. **Question:** Is there a reason that the water quality concentrations are already close to the target concentrations and yet there were millions of cyanobacteria in West Monponsett and not in East Monponsett?

MassDEP Response: The commenter is correct that summer 2016 conditions in West Monponsett Pond do not reflect healthy conditions. Although concentrations are reduced approaching 20 ppb, large blooms may still occur at TP concentrations above 20 ppb. It is important to note that 2016 was a drought year and the model used in the TMDL is based on average rainfall conditions and as such it is difficult to predict year to year variations. Given the unacceptably large cyanobacteria blooms for much of the summer we have remodeled the ponds and rewritten the final TMDL with a lower target of 18 ppb for both West and East Monponsett Pond.

18. **Question:** Will the concentration of cyanobacteria go to zero in West Monponsett Pond if we get to the target?

MassDEP Response: The goal of the TMDL for West Monponsett Pond is to restore all water quality uses including primary and secondary contact uses (swimming and fishing/boating respectively). The concentration of cyanobacteria is unlikely to go to zero but the goal is to reduce concentrations so that the pond is free from frequent cyanobacteria blooms and that concentrations of cyanobacteria remain below70,000 cells/ml or less. Cyanobacteria are natural part of the algae community in many ponds in the state and are principally a cause of concern during bloom conditions.

19. **Question:** We don't care about the phosphorous. It is the cyanobacteria that we are concerned about. How will this help the cyanobacteria? We think you should leave the sluice gates open to cleanse the lake. We have historical evidence that when the gates are left open, and the natural flow is allowed, the water is clear.

MassDEP Response: The excessive growth of cyanobacteria is mainly caused by excessive amounts of phosphorus. Experience in other similar lakes has shown that frequent blooms of cyanobacteria can be controlled by reducing phosphorus to less than 20 ppb. Brockton is required under the recently issued Administrative Consent Order (ACO) "to continue implementation of its current practice of manually opening the Monponsett-to—Silver Lake diversion structure/apparatus to provide a lower water transfer rate (approximately 12 to 14 million gallons per day, which is approximately 50% of the maximum diversion rate) with the intended goal of pulling less water from West Monponsett to East Monponsett during diversions" (#28).

The cyanobacteria blooms in West Monponsett Pond have been due to elevated nutrients in the pond principally total phosphorus. The effects of the diversion in reducing flushing have exacerbated the nutrient enriched conditions. In the Final TMDL we have rewritten the implementation section to note that a combined approach of better management of the diversion, along with the required reductions in TP loading, will result in meeting the goals, adding a margin of safety to the implementation and providing additional benefits to downstream waters. Please refer to response 45 below.

20. **Question:** Brockton is supposed to release water down to stump Brook. It is the natural outlet and it is not being used. The law, the Clean Water Act, says you must do a release to maintain water quality. You have not modeled the release in Stump Brook.

MassDEP Response: Please refer to the response to comment 19 above and comment 50 below.

21. Question: Are you going to require Brockton to use Aquaria?

MassDEP Response: The purpose of the original Administrative Consent Order(ACO) with Brockton in 1995 was to have Brockton comply with its Water Management Act (WMA) authorizations. One of the parts of that compliance strategy was to arrange for a supplemental water supply source which culminated with an agreement to purchase water from Aquaria. It was assumed that Brockton could not reliably reduce its water demand to comply with its WMA authorizations and would be required to use Aquaria, Brockton now maintains its demand within its WMA authorizations and cannot be compelled to use the Aquaria source. As now required by the ACO between the City of Brockton and MassDEP, Brockton must revisit the Comprehensive Water Management Plan (CWMP) which includes a Resource Management Plan for Monponsett. Brockton is also considering the purchase of the Aquaria plant. It is believed with recent events, findings and the future potential purchase of Aquaria, a revised CWMP can be drafted which defines thresholds when water will be taken from Aquaria.

22. Question: I have not seen one mention of natural flow in the TMDL report. Did you consider that in the modeling, yes or no?

MassDEP Response: Please refer to the response to comment 50 below.

23. Question: Not everyone has time to write letters, we want answers now. What is the effect of stagnation on the problem? It is not mentioned in the report. The EPA website says there are three ingredients to cause cyanobacteria, slow moving water, sunlight, and nutrients. We have all three. The Act says that Brockton can't divert if the elevation of the water is < 52 feet and it has been below that elevation this summer. Need to put the effects of stagnant water in the report. We need a broader look at the problem than just the model.

MassDEP Response: Please refer to the response to comment 19 above and 50 below.

24. Question: You said sediments in both ponds is the same?

MassDEP Response: No, the sediments in West Monponsett are likely a much larger source of recycled phosphorus.

25. Question: How much turnover occurs in West Monponsett due to the diversion?

MassDEP Response: West Monponsett Pond has a flushing rate of approximately 2 times per year based on the current diversion amounts. If the diversion did not occur the flushing rate for West Monponsett Pond would be approximately 4.5 times per year.

26. **Question:** Is there a difference in the sediment cores in East and West Monponsett Ponds?

MassDEP Response: Sediment cores were collected only for West Monponsett Pond so a direct comparison between the two is not possible.

27. **Question:** Is the fact that the dam is there, does that make the sediment load worse in West?

MassDEP Response: It is not possible to speculate on the long term effects of the dam on the internal load in West Monponsett Pond.

28. **Question:** Does the presence of the dam decrease the flushing of the West Monponsett Pond? Did the model consider removal of the dam? Isn't there a build up of sediments because of the dam?

MassDEP Response: The effects of the use of the Monponsett Ponds as a public water supply and more specifically the diversion results in less flushing for West Monponsett Pond. A complete removal of the dam was not modeled. The dam is owned by the City of Brockton. It is not possible to speculate on the long term effects of the dam on the internal load and settling dynamics in West Monponsett Pond.

29. **Question:** When will we get a chance to look at the next draft TMDL report?

MassDEP Response: Based on EPA review, MassDEP revised the stormwater in the Draft TMDL. This portion of the Draft TMDL will be made available for additional public comment. The response to comments is prepared and the draft TMDL is finalized and will be submitted to EPA for review. The public is free to provide comments to EPA but no further formal response is planned. If EPA approves the TMDL it will be posted on the MassDEP website.

30. **Question:** Has anyone looked at the Silver Lake mussel grave yard?

MassDEP Response: Yes, both staff from the Watershed Planning Program and the Southeast Regional Office have observed dead mussels in Silver Lake recently. The commenter's concern for the ecological effects of the management of Silver Lake as a public water supply by the city of Brockton is noted.

31. **Question:** Why didn't Brockton have water ban this past summer (2016)? At least not until the end of August.

MassDEP Response: The City of Brockton is not specifically required to implement water use restrictions under it's existing Water Management Permit (last revised in June 2005). The permit requires that an Enhanced Water Conservation Plan be developed should Brockton exceed a summer/winter ratio of 1.2 and identifies that a plan may include "more stringent restrictions on nonessential outside water use." Brockton's summer/winter ratios between 2013 and 2019 did not exceed 1.2 so an Enhanced Water Conservation Plan was not required.

Brockton's Water Management Permit issued in the Taunton River Basin is scheduled to undergo a 20-Year Review and Renewal in 2021, as is the registration statement issued in the South Coastal River Basin. The permit renewal process will revisit the operating conditions of Brockton's permit and will include conditions requiring restrictions be implemented based on a several factors, which may include streamflow triggers, calendar triggers, system-capacity triggers. The Comprehensive Management Plan will also require that Brockton develop a plan that includes these triggers.

32. **Question:** You have not talked about the population increases since the Act of 1964. Silver Lake only safely produces (recharges) about 4 MGD. If Brockton take 3 MDG from Aquaria and installs some groundwater wells, we can get to the 11 MGD that the City needs.

MassDEP Response: The TMDL recommends that the City of Brockton conduct a watershed and water supply management plan that focuses on management efforts to improve water quality in Monponsett Ponds. This planning process could also allow for factoring in the effects of population changes as well as alternative sources of water supply. The ACO requires that the city of Brockton develop a comprehensive Water Management Plan.

33. **Question:** DEP you have not approved the Water Management Plan as Brockton was required to do, when will we see it? Brockton has unaccounted for water of 30%, how will they address that?

MassDEP Response: As now required by a new Administrative Consent Order between the City of Brockton and MassDEP, Brockton must revisit the Comprehensive Water Management Plan (CWMP) which considers a Resource Management Plan for Monponsett. Brockton has received State Revolving Loan Fund money to conduct leak detection on the transmission main from Silver Lake to Brockton with the intent to repair any leaks. The next Water Management Act permit renewal will evaluate Brockton's efforts to control their unaccounted for water (UAW). Brockton's UAW as reviewed and approved by MassDEP fell to 20% in 2018, and continued to improve to 14% in 2019.

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Comments on Model Documentation Appendix Received via email 1/8/2017 from Frank Schellenger (see also comments 75-79)

34. **Comment Pg. 107 paragraph 3:** Interesting that Horsley-Witten 2015 did not use a uniform 50%.

MassDEP Response: Your comment is noted.

35. **Comment Pg. 108 Figure 1:** Highlight of improper citation.

MassDEP Response: The citation has been properly updated.

36. **Comment Pg. 109 paragraph 2:** The model does not appear to be in the public domain. An internet search did not find it.

MassDEP Response: See email dated January 9, 2017 sent to commenter by Matthew Reardon (matthew.reardon@state.ma.us). The model was obtained from Dr. Ken Wagner. The model is also available online here: https://github.com/MattAtMassDEP/LLRM_model

37. **Comment Pg 115 paragraph 2:** The importance of groundwater is not very well described. What evidence is available that the groundwater flow to the lakes does not have a significant load of phosphorous? in particular, sand does not "attenuate" phosphorous very well - not enough fines - especially over a long time.

MassDEP Response: It is not clear which lake is being referred to. Some of the lakes in the TMDL study receive significant landuse sources of phosphorous, including contributions from septic systems. Phosphorous load from septic systems will reach the water table, then travel in the groundwater. We agree that sand is generally less adsorptive of phosphorous than other soils with higher iron content.

38. **Comment Pg. 115 paragraph 3:** This analysis makes no sense at all. Was it by hectares/acres within each watershed? Or by percentage of each watershed area? And why is a 1987 estimate OK, when the watersheds have continued to develop?

MassDEP Response: The stormwater allocation has been updated in the final TMDL. The new methodology followed can be found in Appendix E.

39. **Comment Pg 116 paragraph 2:** See page 93 (of the draft TMDL) for 2014 O2 results. The location and depth of W0926 is not given in this report. The areal loading applied over the entire lake surface area is an over-estimate. Location and lake depth of the cores is not given in the report.

MassDEP Response: Site W0926 (the deep hole) is about 13 feet (~4 m) depending on lake level. Because the water at the site is usually oxic and fully mixed it was appropriate to extend
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the estimate of internal recycling to the entire lake area. The cores were taken at W0926 and the cores included about 25 cm of sediment in the 51 cm Plexiglas tube.

40. **Comment Pg 116 paragraph 2:** You need to make more justification than is given for the highlighted paragraph above re: West Lake Pg. 117 Septic Systems: 2.5 people/household is OK. 0.25 m3/d water use is ~66 GPD, OK.Ceff = 8 mg/L is OK. Attenuation = 0.1 is 90% immobilization -not OK. Most septic systems at MP have been in use for many years - it is more likely that "attenuation" is ~0.9. The idea that only households within 300 feet(~100 m) of the lake contribute is also not OK - after much time has passed, many more of the SS in the watershed contribute.

MassDEP Response: The septic system loads are difficult to estimate directly and in most studies are based on literature estimates. Previous work in the lakes of southeastern Massachusetts indicates septic system inputs are lower than literature estimates. In the White Island Pond TMDL the export coefficient used was 0.25 kg/house/year for homes within 100 m of the lake (MassDEP 2010). A later analysis of inputs on White Island Pond (after cranberry bog inputs were halted and sediment recycling of TP was treated by alum) revealed the lake was lower in TP concentrations than expected because cranberry inputs were underestimated. The results of Mattson (2015) suggested septic system inputs were probably overestimated and thus lower export coefficients were used here in the Monponsett Pond TMDL. This is supported by the results in other ponds such as Ezekiel Pond which has even more homes per meter of shoreline yet exhibits a remarkably low TP of 6 ppb. If higher export coefficients were used it would result in drasatic overestimates of predicted lake TP in the Monponsett Pond TMDL. With the LLRM maximum recommended septic attenuation for both the closer Group 1 septic systems (within 100ft) and Group 2 septic systems (100 – 300ft) of 0.5 the predicted load for Stetson Pond is overestimated. Reckhow (1980, pg. 24)) recommends site specific attenuation factor based on soil related factors "phosphorus adsorption capacity, natural drainage, permeability and slope" and estimates of phosphate removal mechanisms. Using the LLRM high estimate for attenuation (0.5) results in Stetson Pond having a predicted in-pond concentration of 45 ppm compared to measured 15 ppm (Table 3). For Stetson this a yearly load of 153 kg/ha/yr. The load that would be predicted by using 15 ppb concentration as the in-pond condition and running the models in reverse would be 51 kg/ha/yr. So for Stetson Pond at a minimum, this higher septic estimation is a large overestimate. Given the larger size of East and West Monponsett Ponds the predicted TP concentration would also result in an overestimate although it is less extreme due to the higher overall loads. It should also be noted that East Monponsett Pond actually has a higher septic system load than West Monponsett, yet West Monponsett has about 3 fold higher TP concentration than the East. Thus, it is unlikely that a higher septic systems loading coefficient can explain the much higher TP in West Monponsett. Given the above, and the fact that we are using a four lake simultaneous calibration procedure to improve overall accuracy, we believe the septic system export coefficients are appropriate to this system.

41. **Comment Pg 117 Table 5:** Attenuation factor is not explained. The math for P load is clear, but the attenuation factor is much too low, and zero is ridiculous. The previous model, NPSLAKE, would have estimated the load to East Lake as

162 x 0.5 = 81 kg/yr, and West Lake as 75.5 kg/yr. Even these estimates are far too low, given the ages of the septic systems and the sand soil.

MassDEP Response: Please refer to the response to comment 40 above.

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Comments received via email on 1/13/2017 from Paul Collis, Monponsett Watershed Association

The Monponsett Watershed Association hereby submits its comments on the Department of Environmental Protection (DEP) draft TMDL for the Monponsett Watershed. While the TMDL presents a wealth of scientific data about the contamination of water bodies in the Watershed, the document ignores some obvious solutions to the contamination, and repeatedly mischaracterizes the facts. Here are our comments.

42. **Comment P. 5:** - the report claims that the cranberry growers in the Monponsett Watershed have introduced so called Best Management Practices (BMPs) and that West Monponsett Pond has shown a significant reduction in total phosphorus. This assertion does not correspond with reality. In 2016 West Monponsett Pond had the highest cyanobacteria cell counts (over 2 million cells per ML) since regular testing began in 2009. As for the cranberry growers use of BMPs, who is verifying this claim ? Relying on industry affiliated groups like the Cape Cod Cranberry Growers Association and the UMASS Cranberry Station is not independent verification. Moreover, trusting cranberry growers to self regulate is not realistic especially if it increases their work and expenses.

MassDEP Response: The cranberry growers have implemented BMPs as part of our 319 grant to the UMass Cranberry Experiment Station. One of the BMPs, (a concrete sand filter tank) is visible on the shore of West Monponsett Pond and is visible on Google earth images. Our results in Figure 12 show a downward trend. If you would like to review the laboratory results directly, you may to make a public information request for the data from MassDEP's certified laboratory. The writer is correct that summer 2016 conditions in West Monponsett Pond do not reflect healthy conditions. Although concentrations are reduced approaching 20 ppb, large blooms may still occur at TP concentrations above 20 ppb. In the past, verification of BMPs was difficult; however, in 2012 the Massachusetts Legislature passed An Act Relative to the Regulation of Plant Nutrients which requires farmers to follow the nutrient BMPs recommended by the University. This new law is enforceable by the Massachusetts Department of Agricultural Resources (MDAR) and you are encouraged to contact MDAR to report violations. The BMPs recommend maximum application rates of phosphorus per acre. Since phosphorus is a cost to the growers, following BMPs can actually cost less money not following the BMPs

43. **Comment P. 21**: - the report claims that East Monponsett Pond is the public water supply that flows to Silver Lake. This is simply wrong. St. 1964, c. 371 authorizes the City of Brockton to divert water from Monponsett Pond, not
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individual East or West basins. Additionally water in the two basins are commingled via tunnel under Rte. 58. DEP is, of course, aware of these facts so it is puzzling that it is written into the TMDL (this misrepresentation is repeated on p. 45 of the report). It may be that the DEP is “tilting" toward the City of Brockton. In the past Brockton has tried to claim that the Monponsett water is clean because it comes from the East basin; again an obvious misrepresentation. Ironically, the DEP has contradicted itself in this report because on p. 26 it states that 40% of the inflow to the East basin consists of poorer quality water from the West basin.

MassDEP Response: The final TMDL has been clarified to reflect the content of cited 1964 law and more precisely describe the system. The author infers a “tilting towards the City of Brockton” from the draft TMDL text. The original intent was to state that the proximate source of water for diversion to Silver Lake is East Monponsett Pond. In the TMDL, we list the West and East sides of the pond separately, because they are listed separately in the Federal Clean Water Act list of impaired waters. Furthermore, the hydrology of the ponds is different and for modeling purposes we divided the pond into West and East (as other researchers have done in the Horsley Witten report and the Princeton Hydro report). There is no intent in any of these reports to deceive the public. The water diverted proximately from the East Monponsett Pond diversion structure can indeed come from throughout the entire Monponsett Pond system. In the Massachusetts Surface Water Quality Standards (SWQS) Monponsett Pond is described as “Source to outlet in Halifax and those tributaries thereto” is classified as Class A and has a qualifier of Public Water Supply. An unofficial version of the Massachusetts State Water Quality Standards is available for convenience online at: https://www.mass.gov/regulations/314-CMR-4-the-massachusetts-surface-water-quality-standards. Please note that OFFICIAL versions of all state statutes and regulations (and many of the MassDEP policies) are only available through the State Bookstore or from the Secretary of State’s Code of Massachusetts Regulations (CMR) Subscription Service. The mapping of the SWQS to the waterbody segments as defined for use in reporting the status of water bodies as part of Section 303d of the Clean Water Act is provided in Table 1. The authors apologize for any confusion the original draft TMDL may have caused and we will try to clarify the text in the final report.

44. **Comment P. 25—26** :- on these pages the DEP discusses Monponsett Watershed water flows, but this is essentially a review of past studies. Throughout this draft TMDL report the DEP studiously avoids discussing the City of Brockton’s role in the water quality in the Watershed, particularly Monponsett Pond. The DEP has known for years that the Brockton Water Department has been manipulating the water levels in Monponsett Pond so that they can divert as much water as possible to Silver Lake. This manipulation involves closing the gates in the dam in the West basin outflow stream, Stump Brook. Such action causes Monponsett Pond to rise to an elevation (52 feet USGS base) at which point the law (St. 1964, c. 371) allows Brockton to divert water to Silver Lake. This water “management" practice by Brockton has resulted in a stagnant pool of water in Monponsett Pond because Brockton has to wait until the level rises to the allowable limit for diversion. This practice has been going on for decades. It is a well known fact that stagnant water

is a major contributor to harmful algal blooms (HABs). The US EPA website on HABs states: " Harmful algal blooms need: Sunlight, Slow -moving water, Nutrients (nitrogen and phosphorus)".

Incredibly the impact of stagnant water on algal growth in Monponsett Pond is barely mentioned in this draft TMDL report. The only conclusion that can be drawn from this omission is that it is deliberate. Unfortunately this may be another example of the City of Brockton being shielded from responsibility for the poor water quality in Monponsett Pond.

MassDEP Response: We disagree with the statements that we avoided analyzing or discussing the effects of the diversion. In fact, we reviewed the past studies on the diversion and discussed the reports. We modeled the effects of the diversion and concluded that the diversion has an adverse impact on West Monponsett Pond. Using a simple steady state model based on yearly hydrology (as the previous studies did) we concluded TP would improve by 24% if the diversion were halted on a yearly basis due to the longer retention time or 'slow moving water'. It was not feasible for us or the previous reports by Lycott or Princeton Hydro or Horsley Witten to study 'stagnation' i.e., lack of flow, on a daily basis because steady state models are not designed for this level of detail.

As now required by an Administrative Consent Order between the City of Brockton and MassDEP, a minimum of 900,000 gpd must flow over the Stump Brook Dam at all times except when the fish ladder is fully open and no flow is available due to the pool elevation.

45. **Comment P. 45:-** the report states that if there were no diversion of water from Monponsett Pond the TP concentration would be reduced by 24 %. Yet the authors of the TMDL report do not recommend ceasing diversions despite the obvious benefit. This omission is puzzling because five pages earlier in the report the authors state that reducing algal blooms is the goal of the TMDL report. If the DEP is serious about reducing algal blooms and the public health and environmental health threats that they pose, they would recommend stopping diversions immediately.

MassDEP Response: The Federal Clean Water Act requires us to identify the pollutant (total phosphorus) and to allocate acceptable sources of the pollutant to achieve our water quality standards goals. Stopping the diversion alone will not achieve the goals. In the Final TMDL we have rewritten the implementation section to recommend a combined approach of better management of the diversion, along with the required reductions in TP loading. This combined approach will further reduce the TP concentrations in West Monponsett Pond thereby adding a margin of safety to the TMDL and simultaneously provide additional benefits to downstream waters. The City of Brockton signed an Administrative Consent Order (ACO) which was issued by MassDEP March 22, 2017. See also comment 47 below which itemizes some of the ACO conditions.

46. **Comment P. 47-48:-** this portion of the report makes detailed recommendations about reducing the impact of the cranberry growing operations on Monponsett Pond. There is mention of the small Winebrook bog currently discharging into West Monponsett Pond. The DEP recommends diverting water from the bog away from the Pond. A better solution is to stop using the bog entirely. This is a two acre bog out of 100 acres at the Winebrook site yet it discharges directly into the Pond. If the DEP is serious about reducing the external loading of phosphorus, this is the place to start.

MassDEP Response: MassDEP's powers are legally limited regarding return flows from agriculture. The regulations in effect and the 1964 law do in fact allow continued use of the pond by the public and by the cranberry growers. Working within the confines of the law, we do recommend that even the two acre Winebrook bog discharges be diverted from the pond or further treated in the future.

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Comments received via email on 1/13/2017 from Suzanne Lillie, Monponsett Watershed Association

Please find below additional comments from the Monponsett Watershed Association on the Department of Environmental Protection (DEP) draft TMDL for the Monponsett Watershed.
Thank you,
Suzanne Lillie, Treasurer
Monponsett Watershed Association

47. **Comment on page 21:** List all actions taken by City of Brockton to reduce environmental impacts and results of such actions.

MassDEP Response: An Administrative Consent Order was finalized between the City of Brockton and MassDEP on March 22, 2017. The following includes the requirements and the paragraph containing the requirement.

1) Requirement Paragraph 27: No Monponsett-to-Silver Lake diversions can occur if there is a blue-green algae bloom that exceeds the MDPH standard of 70,000 colonies.
Intended Outcome Goal: Avoid having a Monponsett-to-Silver Lake diversion create a public health impact by spreading blue-green algae over the MDPH standard.

2) Requirement Paragraph 28: When diverting from Monponsett to Silver Lake, continue to divert at a reduced rate of approximately 50% of maximum, which equates to 12-14 MGD.
Intended Outcome Goal: Reduce potential of having diversion pull water from West Monponsett Pond to East Monponsett Pond because West Monponsett Pond is lower water quality compared to East Monponsett Pond.
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3) Requirement Paragraph 29: Install stop logs on top of the dam-like structure that separates the Monponsett Pond water, holding chamber, from the Silver Lake diversion pipe, in the diversion building on the shore of East Monponsett Pond.
Intended Outcome Goal: Installation of stop logs will reduce the possibility of Monponsett Pond water entering the Silver Lake diversion pipe when there is no active diversion particularly if there is a failure of the valve at the diversion station.

4) Requirement Paragraph 30: Operate Stump Brook dam to ensure that 900,000 gpd is passing at all times, during diversions, and that water flows over the fish ladder during herring migration season.
Intended Outcome Goal: Operate Stump Brook dam to meet the explicit language for flow and fish passage contained in Brockton's MassDEP issued Chapter 91 License.

5) Requirement Paragraph 31: Contact area Cranberry Growers to coordinate opening Stump Brook dam fish ladder and sluiceway when cranberry cultivation return flows are being released to Monponsett Pond.
Intended Outcome Goal: Allow the cranberry cultivation return flows to exit the Monponsett Pond system as quickly as possible.

6) Requirement Paragraph 32: Operate Stump Brook dam and fish ladder to ensure that 900,000 gpd is passing at all times (constant flow) as long as Monponsett Pond elevation is up to the fish ladder's lowest setting.
Intended Outcome Goal: Require continuous flow out of Stump Brook dam and fish ladder (so long as pond elevation is adequate) to reduce stagnation in West Monponsett Pond.

7) Requirement Paragraph 33: Submit Scope of Work for Resource Management Plan.
Intended Outcome Goal: Require Brockton to develop a plan to operate the Stump Brook dam based on parameters (e.g., pond elevations, historic pond elevations, precipitation, time of year, etc.) developed based on scientific research, actual flow data and public input in hopes that more informed dam operation decision-making will improve Monponsett Pond water quality while providing adequate drinking water.

8) Requirement Paragraph 34: Require a DRAFT Scope of Work for the Resource Management Plan be developed for public comment and hold a public meeting.
Intended Outcome Goal: Provide opportunity for Public Comment and Input into Resource Management Plan development.

9) Requirement Paragraph 35: Submit a Final Scope of Work and Implementation Schedule for the Resource Management Plan.
Intended Outcome Goal: Provide twenty-four months to submit the Final Resource Management Plan and Implementation Schedule for MassDEP approval.

10) Requirement Paragraph 36: Require the Draft/Final Scope of Work for the Resource Management Plan be opened for public comment and hold a public meeting before submittal to MassDEP for approval.

Intended Outcome Goal: Provide opportunity for Public Comment and Input into Resource Management Plan before submittal to MassDEP for approval.

11) Requirement Paragraph 37: Within 6 months begin to implement the Final Resource Management Plan as approved by MassDEP.
Intended Outcome Goal: Require Brockton to implement a plan to operate the Stump Brook dam based on parameters (e.g., pond elevations, historic pond elevations, precipitation, time of year, etc.) developed based on scientific research, actual flow data and public input in hopes that more informed dam operation decision-making will improve Monponsett Pond water quality while providing adequate drinking water.

12) Requirement Paragraph 38: Brockton must receive MassDEP approval before changes can be made to Resource Management Plan based operation of Stump Brook dam.
Intended Outcome Goal: Provide a process to modify the Resource Management Plan if necessary, subject to MassDEP approval.

13) Requirement Paragraph 39: Within 6 months submit a Scope of Work to MassDEP to update Brockton's Comprehensive Water Management Plan (CWMP) consistent with the requirements of Brockton's Water Management Act Permit and the Resource Management Plan to be developed.
Intended Outcome Goal: Require Brockton to provide a plan to update the CWMP so it can be approved by MassDEP.

14) Requirement Paragraph 40: Within 24 months submit an updated CWMP that meets the requirements of Brockton's Water Management Act Permit and is consistent with the Resource Management Plan approved by MassDEP.
Intended Outcome Goal: Require Brockton to submit an updated CWMP that can be timely approved by MassDEP because it meets their Water Management Act Permit (specifically Condition #4) and is informed by the Resource Management Plan.

15) Requirement Paragraph 41: Brockton must continue to limit total drinking water entering their system to 11.3 mgd or 110% of safe yield, whichever is larger, and submit monthly record keeping or MassDEP will determine Brockton has submitted a petition for a declaration of water emergency.
Intended Outcome Goal: Continue to require Brockton to meet water use limits set in the 1995/1997 ACO or MassDEP can accept a declaration of water emergency and require water use restrictions unless Aquaria or some other source of water can be used to augment Brockton Reservoir and Silver Lake (which includes Monponsett Pond and Furnace Pond).
Furthermore, the City of Brockton has committed to automate the control of the Stump Brook dam so that the flow can be better controlled to allow for more flushing of the Monponsett system. The money spent on the automation will be used to match a CWA Section 319 grant to treat the ponds with alum.

48. **Comment on page 35:** The year 2016 should be included with 2013, 2014, 2015 as cyanobacteria blooms continued to be an issue in 2016.

MassDEP Response: The final TMDL has been updated to note all recent years where cyanobacteria blooms have been an issue.

49. **Comment on page 36:** *Please include data chart in ppb to accurately compare to TMDL targets*

MassDEP Response: Figure 12 of West Monponsett Pond Surface Total Phosphorus is already shown in ppb as indicated on y axis.

50. **Comment on page 45 para 5:** *Reduced diversions by volume or month should be modeled and included in TMDL requirement. Ignoring the potential for reduced TP concentrations in the pond should not be ignored.*

MassDEP Response: This TMDL as well as the previous studies, have modeled the pond with a simple steady state model that assumes the annual water withdrawal volume is evenly distributed throughout the year. Such simple models do not model short time scale events. Running a dynamic model as the commenter suggests would entail collecting flow data for all the inputs and outputs of all the ponds which is expensive. Calibrating a dynamic model is also much more complicated and MassDEP did not have the staffing or funding required for such an effort. We do believe the steady state models used are adequate to identify the major sources of nutrients to the ponds and to establish the target concentrations to restore the pond.

51. **Comment:** *There is no mention of the stagnant water body created by the City of Brockton by closing both sluice gate and fish ladder at the dam. This very real scenario should be modeled and reported. Reviewing the work documented by Horsley Witten, 2015 it appears that flow is a given. In other words the modeling includes the assumption that there is outflow through the sluice gate or the fish ladder of the Stump Brook Dam. However, there are many, many days in which both are completely closed.*

MassDEP Response: See response to comment 50 above. The modeling of short time scale events was outside the scope of this project. It is the goal of MassDEP to reduce the effects of decreased flushing and flow reversals to the extent possible under relevant laws and statutes to provide for better management of the diversion. Please refer to the response to comment 45 above.

p 46
Initial testing resulted in clogging of the filter…(Demoranville, 2016b)

52. Comment on p. 46 (clogging of filter): This reference is to an email sent to Charlie Seelig on January 13, 2016. There should be a reference to the results of the addition of prefilters and a gravel layer during the season and harvest of 2016 before this report is finalized.

MassDEP Response: The 319 grant that was summarized by Demoranville, (2016b) ended and the recommendation to add the prefilter was not completed under that grant. We will encourage future research on iron sand filters to include prefilters and gravel as needed.

53. **Comment p. 47***:* What is current yearly discharge of water per acre bog? It is essential to know this figure to understand how much progress is needed to meet this requirement.

MassDEP Response: We do not know the exact discharge from each bog. According to the UMass Cranberry Experiment Station reports, cranberry growers require a nominal 10 acre-feet of water per year (some of which evaporates or seeps into the ground).

54. **Comment p. 48*:*** It is recommended that the small Winebrook bog currently discharging to West Monponsett Pond be further treated or diverted away from the pond. Agree strongly with this recommendation. What is the plan put forward by Morse Brothers*?*

MassDEP Response: Please refer to the response to comment 46 above.

Comments received via email on 1/16/2017 from Pine DuBois and Alex Mansfield

RE: Comments on DEP report number CN 446.0: Draft West and East Monponsett Pond System Total Maximum Daily Loads for Total Phosphorus

Dear Mr. Reardon:

The Jones River Watershed Association (JRWA) in Kingston, MA offers the included comments to the Draft West and East Monponsett Pond System Total Maximum Daily Loads for Total Phosphorus. For thirty years the Jones River Watershed Association has been working on the ground to reduce residential, municipal, and agricultural nutrient sources. We have conducted successful stormwater improvements, dam removals, and land protections. We conduct water quality monitoring from our headwater at Silver Lake to Kingston Bay. We have lived our whole lives swimming in Monponsett Pond, Silver Lake, and all the waters of Southeastern Massachusetts. We have personally and physically experienced the degradation (and occasional improvement) of our local waters. Suffice to say that we are highly invested and aligned with DEP's goals to improve local water quality. We absolutely concur that reduction of external nutrient loading is the most important way to ensure long-term water quality in these ponds, and we have been impressed that the towns and cranberry growers in the region have expended concerted time, effort and money on addressing the issues under their control. However, there are other actions that can and must be taken. Our comments offer those recommendations.

55. Comment: General Notes

The Draft TMDL mixes and matches units of measurement making it particularly hard to follow. Most notably ppb and mg/L are switched back and forth for several parameters. It would be much more reader-friendly and understandable if consistent units were used. At a minimum, use units that represent the same order of magnitude (i.e. ppm and mg/L or ppb and µg/L), although we recommend that the whole report use one standard unit of measure.

MassDEP Response: Where appropriate in the main TMDL document the units for total phosphorus have been standardized to parts per billion (ppb). In some cases we are presenting results from other studies which may use different units.

56. Comment Page 20: The culvert between the Monponsett Basins is under Route "58" not "56"

MassDEP Response: This typo has been corrected in the Final TMDL.

Primary comments

The Draft TMDL report (the report) has several mischaracterizations that are detrimental to the analysis. These include:

57. Comment:

1) The description of all four target waterbodies as "tributary" to Silver Lake. They are NOT tributary to Silver Lake. They are physically, unnaturally diverted via a man-made pipe and Legislative action. The language of the report creates a misperception and misunderstanding that is pervasive throughout the document. The correct descriptions of these natural waterbodies as well as the man-made structures and policies are required in order to properly define both the problems and the solutions.

MassDEP Response: Additional explanation of the four target waterbodies description in the Massachusetts State Water Quality Standards has been added to the Final TMDL. The words "are tributary" in draft TMDL (pg.4) have been replaced with "flow". Please also refer to the MassDEP response to Comment 43 above, from Paul Collis, Monponsett Watershed Association. It is worth noting that the Massachusetts State Water Quality Standards (CMR 314 4.06(6) define Tributaries as "Tributaries to a Class A public water supply include, but are not limited to, waterbodies from which water is manually diverted to the Class A public water supply."

58. Comment: The repeated characterization of only "East Monponsett Pond" being the water supply authorized under Act 371 (1964). Act 371 does not call out East Monponsett Pond specifically, instead it only refers to "Monponsett Pond". In fact, Act 371 describes "Monponsett pond situated in the towns of Halifax and Hanson..." which can only be a definition for the combined basins (or of the West basin exclusively) since East Monponsett Basin is not in Hanson. For many reasons, this is not a trivial distinction in the context of the TMDL report:

a. Naturally, Monponsett Pond is one waterbody. This can clearly be seen on historic maps of Plymouth County. As described in the Massachusetts Historic Commission (MHC) Reconnaissance Survey Town Report for Halifax, first a first the bridge (~1848) then road and rail (1859) were constructed from Whites Island across the pond (MHC 1981). This filling and construction of this causeway sets the stage for limited exchange between the basins. This manipulation of the natural flow should be acknowledged the TMDL report. The report should also consider options of improving the exchange, flow, and flushing between the Monponsett Pond Basins.

MassDEP Response: Please also refer to the MassDEP response to Comment 43 above, from Paul Collis, Monponsett Watershed Association.

b. Conversely, there have previously been absurd and detrimental recommendations (by DEP) that one approach to water quality improvements is to manually cut off flow between the East and West basins. Such an approach would be disastrous to the health of both Monponsett basins. Yet, the description of East Monponsett as the focus of Act 371 appears designed to set the stage for this approach.

MassDEP Response: The TMDL document does not recommend any specific implementation efforts to "manually cut off flow between the East and West basins". In previous discussions it was suggested to place stop logs at Route 58 during times of diversion. It is important to the health of the ponds that the backflow be minimized. The Administrative Consent Order recently signed with Brockton and MassDEP requires Brockton to divert at a reduced rate of approximately 50% of maximum to reduce the potential of having a diversion pull water from West Monponsett Pond to East Monponsett Pond. Please also refer to the MassDEP response to Comment 43 above, from Paul Collis, Monponsett Watershed Association.

c. Suggesting that only East Monponsett Pond was included in Act 371, also suggests that West Monponsett Pond is not covered by the protections explicit in that Act. The protections stated in the act include: *"nothing in this act shall be construed as preventing the normal use of the aforesaid Furnace Pond and Monponsett Pond for bathing, boating, fishing, and other purposes…"* These protections are extremely important since the nutrient loading that is exacerbated by the diversions has resulted in 303(d) listing for both primary and secondary contact (i.e. bathing, boating, and fishing). If, as the TMDL report describes, the diversions are exacerbating the impairments in Monponsett Pond, then those diversions are in violation of Act 371 (as well as the Clean Water Act). In fact, the Act 371 requires discharge to Stump Brook of a minimum of 900,000 gallons per day. In the recent past, Brockton practiced a contrivance of this requirement by only releasing water when the diversion was turned "on". This practice over many decades has contributed to the condition of both Monponsett Pond and Silver Lake.

MassDEP Response: There was no intention to suggest "that only East Monponsett Pond was included in Act 371". Please refer to the MassDEP response to Comment 43 above, from Paul Collis, Monponsett Watershed Association.

A close reading of Act 371 of the Acts of 1964 only requires a flow of 900,000 gpd over the Stump Brook Dam when water is diverted to Silver Lake. As now required by an Administrative Consent Order between the City of Brockton and MassDEP, a minimum of 900,000 gpd must flow over the Stump Brook Dam at all times except when the fish ladder is fully open and no flow is available due to the pool elevation.

59. Comment: The Draft TMDL report accurately cites the 2013 Princeton Hydro report and its conclusion (on page 26) that *"for West Monponsett Pond approximately 70% of the entire outflow is routed through the diversion to the east basin (on an annual basis). As a result, approximately 40% of the inflow to East Monponsett Pond consists of the poorer quality water from West Monponsett Pond."* However, the TMDL report does not include an assessment of the obvious nutrient loading to East Monponsett that comes with that 40% inflow from West Monponsett Pond. Instead, DEP chose not to include flows between East and West ponds (in either direction) for their model, despite recognizing several times in the report that these flows exist and are significant. As a result, the DEP model explicitly and intentionally fails to characterize a significant nutrient loading route to East Monponsett Pond. This becomes even more apparent in light of the 2015 Horsley Witten findings that the TMDL report also cites. This study estimated that *"in the absence of the Brockton water supply diversion, West Monponsett Pond would have a total phosphorus concentration of 0.057 mg/l while East Monponsett Pond would have a total phosphorus concentration of 0.019 mg/l."* (Conversion: 0.019 mg/l = 19ppb, we hope DEP will standardize units in the final report). DEP's stated goal for East Monponsett Pond is a TP concentration of 20 ppb. Therefore, based on Horsley Witten's calculations, <u>DEP's ENTIRE goal for East Monponsett Pond could be achieved by stopping the diversions.</u>

MassDEP Response: See response to comment 50 above and more specifically the response to comment 47(#2) .Ultimately the goal of the TMDL is to meet the target concentrations such that both ponds are restored. Also please note the new target is 18 ppb for both West and East Monponsett Ponds in the Final TMDL.

60. Comment: Silver Lake

Page 39 of the Draft TMDL includes several mischaracterizations and incorrect information about Silver Lake. These include:
"…East Monponsett Pond is also classified as Class A and is tributary to the public water supply, Silver Lake…" East Monponsett Pond is not a tributary to Silver Lake. It is physically, unnaturally diverted via a man-made pipe and a legislated unpermitted interbasin transfer, only allowed to continue by default. Also, East Monponsett is not *"tributary to the public water supply"* it is PART OF the public (Brockton) water supply as defined in Act 371.

MassDEP Response: See response to Comment 57 above.

61. **Comment:** *"A compromise target of 20 ppb TP was selected because even at the higher current concentrations, no obvious impact to Silver Lake water quality has been observed…"* **What**? This statement by DEP is absolutely untrue, unsubstantiated, and irresponsible. There HAVE been obvious impacts to Silver Lake from the water diversions from Monponsett. JRWA and all residents around Silver Lake have observed a degradation of water clarity and an increase in macrophytes throughout the lake. See several examples of photo documentation below, and video at https://www.youtube.com/watch?v=XCJP60NIi78 which shows extremely impaired water being dumped in to Silver Lake. The manager of the filtration plant on Silver Lake has publicly commented that when the diversion is on Brockton/Veolia has to increase their treatment of the water due to higher particulate loads. The state Division of Marine Fisheries did conduct a two year study of Silver Lake: "Massachusetts Division of Marine Fisheries Technical Report TR-54: River Herring Spawning and Nursery Habitat Assessment Silver Lake 2008-2009" (http://www.mass.gov/eea/docs/dfg/dmf/publications/tr-54.pdfl). That report showed elevated nutrients and other water quality issues. One finding was that *"Measured nutrient concentrations during the Silver Lake habitat assessment resulted in an impaired classification for eutrophication."* Some of the report figures are included below. We recommend that DEP read this state published document. If DEP has monitoring data showing that Silver Lake water quality has not been impacted they should provide it. If they do not have this data they are being extremely unscientific and irresponsible in suggesting that Silver Lake has not been impacted.

    We encourage DEP to initiate a monitoring program for Silver Lake, or require that Brockton conduct sampling. This data will help inform DEP of the ongoing conditions of Silver Lake, especially as it relates to the diversions. On November 11, 2016 the DEP Deputy Regional Director for the Bureau of Water Resources – Southeast Region visited Silver Lake. He found that even with the diversion turned "off" Brockton's pipe into Silver Lake was discharging 115,000 and 150,000 gallons per day of highly anoxic water. This discharge has been ongoing for over four months. A monitoring program would be useful in evaluating the water quality impact of discharges from Brockton's pipes.

Photo documentation of Silver Lake impairments as a result of the water diversions:

Figure 15. Obvious degraded water entering Silver Lake through Monponsett Diversion pipe.

Figure 16. Algae bloom Silver Lake 2009

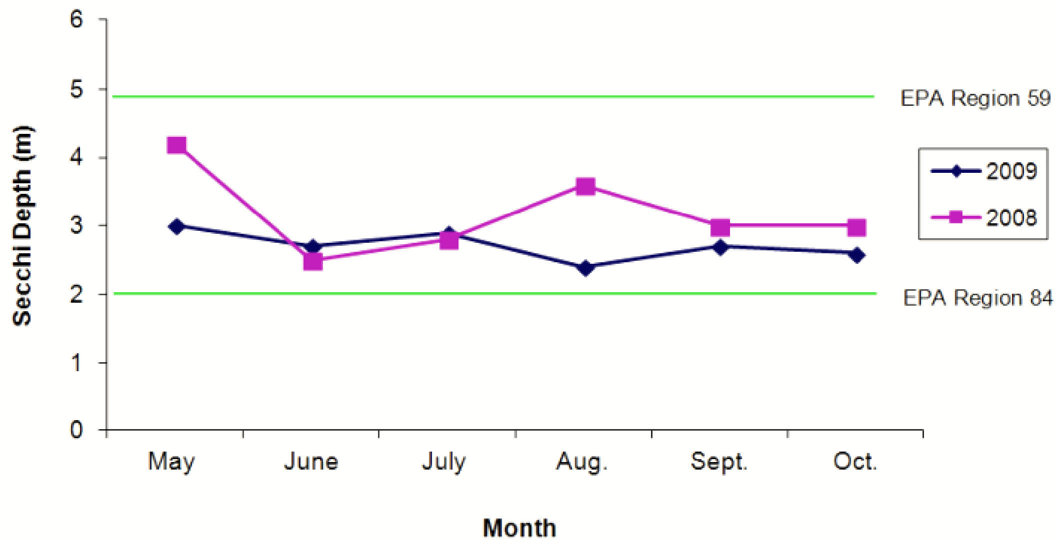

Figure 7. Secchi disc measurements taken at Upper Silver Lake, 2008-2009. The lines plot average Secchi disc depth measured each month at the three transect stations: SL2, SL3, and SL4 (N = 3).

Figure 17. Secchi disc data from Marine Fisheries TR-54 relative to EPA recommendations

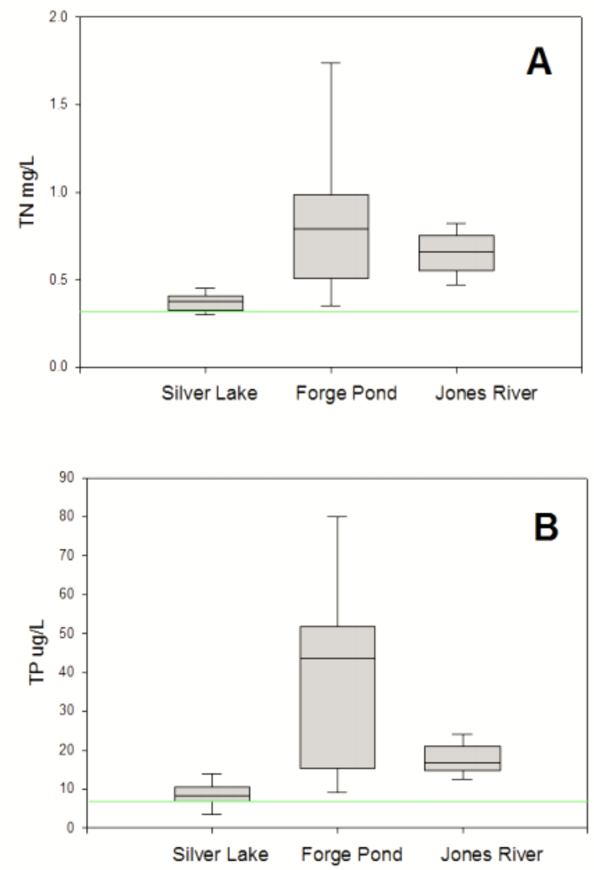

Figure 6. Box plots of total nitrogen (A) and total phosphorus (B) measurements in Silver Lake during 2008-2009. Green lines represent the US EPA nutrient criteria.

Figure 18. Nutrient data from Marine Fisheries TR-54 showing elevated nutrients in Silver Lake

MassDEP Response: Silver Lake is not covered in this current TMDL. Silver Lake (MA94143) is not on the 303(d) list in the Massachusetts 2016 Integrated Report and as such does not require a TMDL. The data the commenter has submitted will be considered when MassDEP updates the water quality assessment for Silver Lake. All data submitted will be analyzed based on the Massachusetts Consolidated Assessment and Listing Methodology (MassDEP 2016a). The Federal Clean Water Act requires the waters to meet the state criteria, not the EPA recommended criteria. The state criteria have been approved by the EPA. The target concentration for the Final West and East Monponsett Pond System Total Maximum Daily Loads For Total Phosphorus has been reduced to 18 ppb. Please see page 36 to 40 (Numeric Water Quality Target section). Please also refer to the MassDEP response to Comment 69 below for a discussion of the new target concentrations for West and East Monponsett Ponds. Brockton is encouraged to conduct standard limnological water quality sampling of the pond to ascertain its health and to protect its use as a public water supply.

62. **Comment:** *"In the two years (2010 and 2015) that the **pond** averaged 20 ppb TP the **lake** met the CALM thresholds for chlorophyll a and Secchi disk transparency (see Figure 7 and Figure 8)."* This sentence needs correction or clarification. Please define which "pond" and "lake" are being described. In the context of this report, the sentence implies that the "lake" is Silver Lake. However, this must be incorrect because there is no data provided for Silver Lake and the two referenced figures are of East Monponsett Pond not Silver Lake. Please correct this sentence, or if there is actual data for Silver Lake, please provide it.

    MassDEP Response: The text cited has been revised in the Final TMDL for clarification as well as to include updated target concentrations for East and West Monponsett Pond.

63. **Comment:** Act 371 of 1964 allowed the diversion of water from Monponsett Pond into Silver Lake. According to the Draft TMDL report not only Monponsett Ponds, but also Stetson Pond and White Oak Reservoir are part of that diversion. As described in the Draft TMDL report, all four of these water bodies are impaired by excessive nutrients (and other impairments). The Draft TMDL report states that these diversions potentially discharge cyanobacteria and nutrients into Silver Lake (pg. 4).

    We are aware that the report is a targeted TMDL study of Stetson Pond, White Oak Reservoir, and the Monponsett Ponds and that Silver Lake is not a focus of the study. However, the study makes some very clear findings that are relevant to Silver Lake and it would be highly irresponsible of DEP not to include those conclusions in the report. Most specifically, it is obvious from the report that the nutrient loadings and impairments of the four waterbodies are being transferred to Silver Lake via the diversion pipe. DEP <u>must conclude</u> that it is unacceptable to further degrade and impair Silver Lake with these water transfers. And, DEP <u>must conclude that it is a violation of the Clean Water Act</u> to continue these diversions when DEP knows and acknowledges the impairments they bring. The objective of the Clean Water Act is *"the restoration and maintenance of the chemical, physical and biological integrity of the country's water."* DEP's own finding in the Monponsett TMDL report clearly show that transferring water from Monponsett Ponds to Silver Lake violate the objective of the Clean Water Act as well as the specific regulations of the Massachusetts Surface Water Quality Standards Antidegradation Provision.

    MassDEP Response: Silver Lake is not covered in this current TMDL. Silver Lake exhibits good water clarity and is not currently on the 303(d) list as impaired and as such does not require a TMDL. Any updates to the water quality assessment of Silver Lake will occur when MassDEP updates the water quality assessment for Silver Lake. If at any future date Silver Lake is deemed to require a TMDL a complete investigation of all the sources of nutrient loadings will be conducted. MassDEP anticipates that the implementation of the recommendations in the TMDL for the Monponsett Pond system will meet the TMDL target concentrations and reduce TP loading to Silver Lake.

64. Comment: Conclusions

The Draft TMDL report acknowledges that, *"if the diversion of water and associated nutrients to Silver Lake did not occur then our model estimates that TP concentrations in West Monponsett Pond would decrease by 24%. This is in close agreement with the previous studies that found a 'no diversion' scenario would reduce TP concentrations in the pond by 23% to 32% (Horsley Witten, 2015 and Princeton Hydro, 2013, respectively). The improvement in water quality would be due to increased flushing with relatively clean East Monponsett Pond water."* The Horsley Witten (2015) report concluded that "*a **combination** of land load reductions, internal load reduction in West Pond, reduced diversions from the ponds, and increased flow through the Stump Brook Dam could potentially bring both ponds at least close to, relevant EPA water quality criteria, although West Pond might still require some additional measures or slightly more stringent load reductions."* We completely agree, and cannot understand why DEP only recommends a subset of these remedies. DEP fails to include reduced diversions or increased flow through Stump Brook Dam in their implementation recommendations. Given all of the clearly defined impacts that the diversions have on the impairment of West Monponsett, East Monponsett, Silver Lake, and the Jones River how are the diversions not even mentioned as part of the remedy in the implementation section? Since the report's science appears sound, we can only assume that political dysfunction is the primary driver for DEP's decision to ignore their own findings in their recommendations.

MassDEP Response: We have revised our implementation to include the combined approach referred to above. Please refer to the MassDEP response to Comment 45 above. Also note that the City of Brockton signed an Administrative Consent Order (ACO) which was issued by MassDEP March 22, 2017 after the draft TMDL was released. Elements of the ACO are included in response to comment 47.

65. **Comment:** DEP, Princeton Hydro, Horsley Witten, and others have all shown that the transfer of water from Monponsett Ponds to Silver Lake is detrimental to Silver Lake and the Jones River. These water bodies are also listed as impaired and the primary source of those impairments is listed as "Flow Alterations from Water Diversions". How can DEP list the specific source of the impairments, identify the solutions, and then choose not to recommend implementation of those solutions? **This TMDL report cannot be considered complete, accurate, or effective until it recommends implementation of ALL the identified remedies.**

MassDEP Response: Silver Lake and the Jones River are not covered in this current TMDL. TMDLs are required for impairments caused by pollutants, not for impairments caused by changes in flow due to use as a water supply. Jones River is listed as impaired by nutrients and will require a TMDL. MassDEP makes recommendations to meet the TMDL, but recommendations regarding flow alterations are outside the scope and authority of the Monponsett Pond System TP TMDL. The TMDL provides recommendations on implementation strategies on ways to reduce the TP loadings to within the TMDL. The communities have flexibility in implementing alternative strategies to meet the TMDL, however, it must be demonstrated that the alternative strategies will be protective of the entire system. The Final

TMDL will be submitted to the United States Environmental Protection Agency (EPA) for approval.

66. **Comment:** We agree that this is a regional problem and we agree with DEP's assertion that, *"The successful implementation of this TMDL will require cooperative support from the public including lake and watershed associations, local officials and municipal governments in the form of education, funding and local enforcement."* We also expect that successful implementation will require DEP's commitment to enforce violations of the Federal CWA and the State WQS, many of which are identified in this report.

MassDEP Response: The commenter is correct to note that MassDEP hopes to restore all the impaired waterbodies included in this TMDL. The principal aim of the TMDL is to provide a management plan to restore Stetson Pond, East Monponsett Pond, White Oak Reservoir and West Monponsett Pond. The TMDL alone is not an enforceable document. MassDEP can only offer recommendations to meet the Federal CWA and State WQS but we also have to observe the Massachusetts General Laws which allow the diversion.

67. **Comment:** A significant omission in the Draft TMDL report is no mention of the Central Plymouth County Water District Commission (CPCWDC). This District and the Commission were created by Act 371 in part to focus on the exact things the TMDL report focuses on. Specifically the Act states that, "*The commission shall also investigate all pertinent matters relating to the quantity of water required, the quality of water to be obtained from available sources, its quality, the best methods of protecting the purity of the water…."* It seems clear that the CPCWDC has direct authority (and the obligation) to implement most of the recommendations of the TMDL report, yet that authority and opportunity are not acknowledged in the DEP report.

MassDEP Response: The Central Plymouth County Water District Commission has been added to Table 10. It is the hope of the TMDL authors that all interested parties can find common ground to advance solutions that result in the restoration of the affected waterbodies.

68. Comments received via email on 1/16/2017 from Brian Wick, Cape Cod Cranberry Growers' Association

Dear Mr. Reardon:

On behalf of the Cape Cod Cranberry Growers' Association (CCCGA), I offer comments on the Draft West and East Monponsett Ponds System Total Maximum Daily Load (TMDL) For Total Phosphorus (CN-446.0). CCCGA represents more than 325 cranberry growers in Southeastern Massachusetts, Cape Cod and Nantucket. These growers farm 13,250 acres of cranberry bog and maintain more than 60,000 acres of additional wetland and upland support property. Cranberries are the largest agricultural food commodity produced in the state with an annual crop value of $99.8 million dollars. According to a recent Farm Credit East Knowledge Exchange Report, the Massachusetts cranberry industry provides over 6,900 jobs and a total economic benefit of over $1.4 billion to the Massachusetts economy.

The cranberry industry remains committed to supporting environmental stewardship and specifically, ongoing efforts to increase water quality, for the benefit of all. We recognize that water is a shared resource, particularly at Monponsett Pond and remain firm in our commitment to continue to work with shareholders and state officials to do whatever is possible to assist in making the water of Monponsett Pond and the related watershed as clean as possible. Through ongoing horticultural and environmental research, most notably efforts led by the University of Massachusetts Cranberry Station and the USDA Agricultural Research Service, the industry has been making notable advancements in nutrient and water management over the past 10 plus years. This research and resultant management changes will continue into the future.

After reading the draft TMDL prepared for the Monponsett Pond system, we received a third-party analysis in the form of a technical memorandum, conducted by TMDL Solutions. The technical memo is attached to this comment letter, providing much more detail to the comments contained herein. We have attempted to summarize the most salient points of the analysis in the hopes of having a final TMDL with the potential for the highest level of success.

Overall, the most important aspect of the draft TMDL is the need to obtain more data in relevant areas. Much of the report relies on modeling, making broad assumptions, particularly with cranberry bog data. The draft TMDL correctly states that cranberry bogs are highly variable and as such, relying on modeled data or previous studies of other bogs, may not accurately describe what the impact is from the bogs associated with this system, including abandoned bogs. It is suggested that additional sampling of these bogs in/outflows be measured and used to verify the assumptions in the TMDL. Without an accurate understanding of the true impact of these bogs, especially since they are identified in the draft TMDL as being one of the largest contributors of phosphorous, potential costly management or treatment options may not have the desired effect should the loads not be accurately identified.

There are also inconsistencies in data comparing the most current studies of the pond system as compared to the work of Lycott in the 1980s. These discrepancies should be more closely examined, particularly since White Oak Reservoir has been assigned a TMDL target with no accompanying data. The target TMDL phosphorous levels for all of the ponds may be too high, given the inconsistencies with current versus historical data.

As noted in the draft TMDL, phosphorus recycling from sediments, particularly in West Monponsett Pond, are significant but resultant data quantifying this source is missing. The sediment levels should be measured as results from the alum applications indicate that it is likely the major source of phosphorous for summer production. Having a better understanding of the makeup and depth of the sediments will help direct potential future treatment options. Given the complexities of the hydrology of the system, conducting a sediment survey and target core collection will determine the mode of phosphorous release.

More data is required to understand the complexity of in/outflows, water diversions, etc. of the management of the water in the pond and surrounding watershed system. However, there is virtually no data in the draft TMDL that studies how all of these factors may be interconnected and their resultant impacts. Flows in/out and between the Monponsett Ponds are needed, as well as flows out of Stetson Pond and White Oak Reservoir. An updated bathymetric map of the ponds should also be considered as the data used in the draft TMDL is old. In some cases, the bathymetry of ponds does not change but in others cases it can have a significant impact, changing the path of management options. Having a thorough understanding of how water moves through this pond system is necessary.

Finally, it is suggested that stormwater inputs be measured, including flow and phosphorous levels. If these levels are not measured accurately, particularly if too high of a number has been assigned, then attaining water quality goals may be compromised.

In closing, the health of the Monponsett Pond Watershed system is of the utmost importance to the cranberry industry. We support the work of those involved in attempting to improve the water quality, including the associated cranberry growers. The industry will continue to move forward with management strategies as the research results unfold over time. The draft TMDL as presented is lacking data in some critical areas. Relying on modeling for a system that is complicated and unique could prove costly. Most management options to increase water quality are costly and take time to complete. I think everyone can agree that any future treatments should be well thought out to produce a high degree of success. There are some instances where the lack of data could pose challenges for the goals of the draft TMDL to be attained. Resources should be assigned to fill in the data gaps, allowing for a TMDL that will be more accurate and will have a higher likelihood of success. Thank you again for the opportunity to comment on this critically important work.

Sincerely,
Brian Wick, Executive Director
Attachment: TMDL Solutions Technical Memorandum

MassDEP Response: MassDEP agrees that lack of data could pose challenges to the goals of the TMDL MassDEP has been denied access on occasion to the bogs of some farmers who are members of the Cape Cod Cranberry Growers Association (CCCGA). Any assistance from the CCCGA in obtaining access to sample outflows would be greatly appreciated. Monitoring post

TMDL implementation will be necessary to evaluate effectiveness of the target TP concentrations. Collecting data at key locations will be essential to this evaluation. It may be necessary to adjust target TP concentrations through adaptive management as part of the TMDL implementation process.

The attached comments of Eduard Eichner, TMDL Solutions and Brian Howes, Coastal Systems Program/SMAST, UMass Dartmouth that Mr. Wick refers to are included and addressed below.

69. Attachment to Comments of Brian Wick:

To: Brian Wick, Cape Cod Cranberry Growers Association, Executive Director
From: Eduard Eichner, TMDL Solutions
Brian Howes, Coastal Systems Program/SMAST, UMass Dartmouth
RE: Review of Draft Total Phosphorus TMDL for West and East Monponsett Pond System
Date: January 13, 2016

As requested, we have completed a review of the draft West and East Monponsett Pond System, Total Maximum Daily Loads For Total Phosphorus (CN 446.0) prepared by the Massachusetts Department of Environmental Protection (MassDEP). Total Maximum Daily Loads (TMDLs) are required under the federal Clean Water Act for any water bodies that are designated as impaired. Waters are classified as impaired if they do not meet state surface water regulations. A TMDL document is required to address the contaminant or contaminants causing impairment and typically contains two parts: 1) determination and basis for a target concentration/load that will allow the water body to attain the regulatory standards and 2) a management outline of the contaminant sources contributing to the impairment and a prospective strategy lowering contaminant levels to attain the target concentration/load.

Our review of available information related to the ponds addressed in the TMDL indicates that there is key data that has not been developed for these pond systems and that adequately addressing the data gaps may suggest an alternative approach to water quality management of the four ponds included in the draft TMDL. This finding is discussed in more detail below.

I. Description of the West and East Monponsett Pond System, Stetson Pond, and White Oak Reservoir: The Monponsett Pond System is a complex ecosystem because of its structure, but also because of significant current and past management activities. West and East Monponsett Ponds are two relatively shallow basins (max depth of each ~ 4 m) connected by a culvert under Route 58. West Monponsett Pond has a surface area of 282.8 acres, while East Monponsett Pond has an area of 244.6 acres. Stetson Pond and White Oak Reservoir are located within the watershed to the two Monponsett Ponds. Stetson Pond has a maximum depth of 9.8 m with an area of 88.2 acres. White Oak Reservoir has a maximum depth of 2.3 m with an area of 14.8 acres.

Water flow in this system is highly managed. The City of Brockton has been authorized since 1899[1] to transfer drinking water from Silver Lake, which is located ~ 1.4 miles east of East Monponsett Pond. In 1964, the Massachusetts Legislature approved transfer of water from Monponsett Pond into Silver Lake to address Brockton water supply needs. Diversions tend to be highest between January and April. [2] Princeton Hydro (2013) review of the Monponsett Pond water budget based on data from 2009 to 2012 showed that an average of 85% of the watershed input to the Monponsett Ponds was diverted to Silver Lake through a pipe located in the southeastern portion of East Monponsett Pond.

At the northwestern edge of West Monponsett Pond, Stump Brook flows out toward the Taunton River. Stump Brook has a dam with a sluice gate and fish ladder. Horsley Witten Group (2015) began the process of completing a comprehensive groundwater model for the Monponsett Pond watershed based on a USGS transient model, but found modeled pond water levels were more responsive than actual measurements. HWG concluded that further model calibration would have required activities beyond available funding and collection of complementary data, such as reliable streamflow measurements in Stump Brook.

Stetson Pond and White Oak Reservoir are likely to have stream discharges to the Monponsett Ponds intermittently. According to the draft TMDL, a natural brook flows from Stetson Pond to East Monponsett Pond, while an intermittent brook flows from White Oak Reservoir to West Monponsett Pond. No flow information is presented for these brooks in the draft TMDL. Lycott (1987) observed no flows reaching West Monponsett Pond from White Oak Reservoir Brook during the 1985/86 water year.[3] Flow measurements in Baystate (1993) averaged 1.99 cfs out of Stetson Pond during the 1987/88 water year with no outflow late in the summer.[4]

Other ecosystem management has also factored into the current water quality of the two Monponsett Pond basins. Alum treatments have been completed in West Monponsett Pond in both 2013 and 2015[5] using relatively low doses in each application to attempt to reduce the severity of cyanobacteria/blue green algae blooms. East Monponsett Pond was treated with three pond-wide doses of an herbicide (Sonar) in 2015 to address non-native rooted plants. [6] MassDFW stocked the ponds with 13 species prior to 1946 and killed and removed over 50,000 pounds of fish in 1959.[7]

II. TMDL Basis and Target Concentrations

The initial phase of assessing whether a water body needs a TMDL is determining whether it is impaired according to state regulations. In Massachusetts, the primary regulations for determining impairment of surface waters are the MassDEP surface water regulations (314 CMR 4). These regulations include both numeric and narrative water quality standards. Numeric standards exist for only four parameters: pH, dissolved oxygen (DO), temperature, and bacteria. Because of this, TMDL assessments tend to rely on the narrative standards unless low DO or bacterial contamination is measured. Narrative criteria describe acceptable habitat and aesthetic conditions and differentiate between cold and warm water fisheries, as well as whether the water body is used as a drinking water supply.

MassDEP has begun to translate some of the narrative criteria into numeric thresholds in the Consolidated Assessment and Listing Methodology (CALM) Guidance Manual.[8] This Manual describes the data analysis and numeric thresholds that MassDEP used in developing the Massachusetts Integrated List, which includes all water bodies that have been categorized as impaired and requiring TMDLs.[9] The draft TMDL for East and West Monponsett Ponds, Stetson Pond and White Oak Reservoir uses the following CALM guidance levels for the review of impairments:

1.2 meter Secchi disk transparency,
16 ppb chlorophyll a concentration,
5 mg/l dissolved oxygen concentration,
less than 25% non-rooted macrophytes and
free from frequent cyanobacteria blooms (>70,000 cells/ml).

Dissolved oxygen data is not substantially reviewed in the draft TMDL. Monitoring of East and West Monponsett Ponds presented in the draft TMDL (Appendix C) show DO concentrations during the summers of 2014 and 2015 above the MassDEP minimum. It is notable that 1985 measurements[10] in both basins were regularly below the state minimum, but this is not cited within the draft TMDL. Stetson Pond had two of the four 2015 water column profiles included in the draft TMDL with DO measurements below the state regulatory minimum. The more extensive sampling of Stetson Pond during 1987/88 showed DO measurements less than state regulatory minimum in 16 of 18 profiles.[11] White Oak Reservoir, which is included in the draft TMDL, does not have DO profile data presented.

The CALM manual lists 1.2 m Secchi transparency as a guidance level based on "best professional judgement" as unsafe for recreational use. This depth is based on a 4 ft minimum developed in 1968 by the federal government to ensure that the bottom could be seen in "learn to swim" areas.[12] It is unclear from the draft TMDL how much the included ponds are used for swimming, but this is not an ecological standard. USEPA review of 211 lakes/ponds in the Monponsett Ponds ecoregion suggested that 4.9 m be used as an ecological guidance level[13];essentially meaning that the bottom should be visible in both Monponsett ponds and White Oak Reservoir. Application of this ecological guidance level to Stetson Pond would set a goal of light penetration through approximately half of its water column.

We have generally advocated the understanding the fluctuations of natural conditions within individual ponds and significant loss of clarity as a more appropriate basis for using Secchi measurements to assess ecological conditions. Comparison of the 1985 Secchi dataset for the Monponsett Ponds to the more recent data presented in the draft TMDL generally showed a loss of clarity in 2009 to 2012 in West Monponsett Pond, but a similar range in East Monponsett Pond during both time periods. Clarity in 2014 to 2015 in East Monponsett Pond was the highest measured in the available data suggesting recent reductions in the factors influencing clarity (perhaps spillover from the alum treatments in West Monponsett). In West Monponsett Pond, the 2014 to 2015 Secchi readings were lower than the 2009 to 2012 peak, but still higher than the 1985 range. These results seem to suggest nutrient levels in West Monponsett Pond have decreased recently, but still remain higher than in 1985 (supported by recent TP data presented in the TMDL). Recent Secchi measurements in Stetson Pond do not seem significantly different from those measured in 1987/88. Similar comparisons are not available for White Oak Reservoir.

The MassDEP CALM manual lists 16 µg/L chlorophyll a as a guidance level for impairment; this appears to be very high, especially since historic data shows impairments at much lower concentrations. According to Lycott (1987), chlorophyll a concentrations ranged from <0.3 to 8.0 µg/L in East Monponsett Pond and from <0.3 to 15.14 µg/L in West Monponsett Pond in 1985/86. Even though these concentrations were below the CALM guidance concentration, Lycott (1987) assessed the pond as impaired by nutrients (P) and recommended a series of substantial management steps including sewering of targeted areas around the pond. USEPA review of 211 lakes/ponds in the Monponsett Ponds ecoregion suggested that 4.2 µg/L be used as a guidance level[14], which would be more consistent with the 1987 data and assessment of impairment.

The presented chlorophyll data in the draft TMDL does show exceptionally high concentrations in Stetson Pond (late summer increase to 29 µg/L, similar to what was seen in 1987/88), one reading in West Monponsett, readings between 14 and 27 µg/L in East Monponsett, and no data in White Oak Reservoir. This data does show impaired concentrations, but questions remain about what an ecologically appropriate target concentration should be.

The regular occurrences of cyanobacteria/blue green algae blooms in West Monponsett Pond are a clear indication of impairment. These blooms are documented in the draft TMDL with cell counts exceeding the Massachusetts Department of Health (MA DPH) advisory level state of 70,000 per mL in 2013 and 2014. Blue green algal blooms typically occur when there are excessive persistent phosphorus loads and/or rapid releases of phosphorus. Similar testing or concerns are not included in the draft TMDL for East Monponsett Pond, Stetson Pond, or White Oak Reservoir. The 2013 and 2015 alum treatments in West Monponsett Pond were conducted ostensibly to reduce phosphorus levels and the severity of cyanobacteria/blue green algae blooms.

Macrophytes are not discussed in the draft TMDL as an impairment except for White Oak Reservoir: high surface area coverage of duckweed (30 to 70% coverage during three 2011 visits[15]). The CALM manual lists greater than 25% coverage as a guidance level. Selection of a guideline for this factor is difficult because it does not account for the features of individual ponds: shallow ponds, where light can penetrate all the way to the bottom, are much more likely to have significant macrophyte growth than deep ponds where suitable macrophyte habitat is only located along the margins. Selection of whether a system is impaired based on this guideline necessarily should account for the features of the pond and the ecoregion (i.e., whether extensive fringing macrophytes is common or whether phytoplankton is the predominant plant community). Similar issues were not listed as concerns for East Monponsett Pond, West Monponsett or Stetson Pond.

In summary, the draft TMDL lists the ponds as impaired for the following reasons:

West Monponsett Pond: cyanobacteria blooms, elevated chlorophyll a concentrations
East Monponsett Pond: elevated chlorophyll a concentrations
Stetson Pond: elevated chlorophyll a concentrations
White Oak Reservoir: excessive macrophytes

Fluctuations in total phosphorus (TP) concentrations are discussed in the draft TMDL, but selection of guidance level for each pond is based on modeling (i.e., use of the LLRM[16]) and comparison of TP concentrations in other ponds and consideration of other factors, such as duckweed coverage and chlorophyll a concentrations. The CALM manual uses 25 µg/L TP as a guidance limit, while EPA's review of pond data within the ecoregion resulted in a guidance limit of 8 µg/L TP.[17] It is not clear if the models included all sources and sinks and how they were verified to be accurate. Usually and independently derived metric is used, but does not seem to be the case here.

The recent TP concentrations cited in the draft TMDL for the Monponsett Ponds are significantly higher than 1985/86. The year-long Lycott (1987) study had average shallow and deep concentrations of 19 µg/L TP and 34 µg/L TP (no significant statistical difference at $\rho<0.05$ level) in West Monponsett Pond.[18] According to the draft TMDL, West Monponsett Pond had a summer median surface TP concentration of 57 µg/L in 2001, 70 µg/L in 2009, 54 µg/L in 2011, and 54 µg/L in 2012.[19] These higher concentrations beginning in 2001 raise questions about differences in laboratory methods and sampling frequencies and/or whether some conditions significantly changed between 1986 and 2001. Low DO concentrations measured in 1985-1986 would seem to favor higher TP concentrations than later years through greater transfer to TP from the sediments to the water column in hypoxic conditions. The draft TMDL does not show or discuss shallow and deep TP water column concentrations. The June 2015 ACT pre-alum water column testing showed surface concentrations ranging from 38 to 58 µg/L in different portions of the pond with concentrations of ~25 µg/L in July following the third application.[20]

Given that West Monponsett Pond had impaired conditions in 1985/86 with an average measured surface TP concentration of 19 µg/L, this data suggests that a target TMDL TP concentration for West should be less than 19 µg/L. As listed in the draft TMDL, the target TP concentration for West Monponsett Pond is proposed as 20 µg/L. Reconciliation of this difference should occur before a final TMDL is approved.

East Monponsett had an average shallow TP concentration in 1985/86 of 15 µg/L and an average deep concentration of 32 µg/L TP (significant statistical difference at $\rho<0.08$ level). The pond had a shallow average TP concentration of approximately 30 µg/L TP between 2009 and 2014.[21] Given that East Monponsett had impaired DO concentrations (i.e., less than the MassDEP minimum) in all 6 of the summer DO profiles in 1985/86, this suggests that an appropriate TP TMDL target for East Monponsett Pond should be lower than the shallow average of 15 µg/L. As listed in the draft TMDL, the target TP concentration for East Monponsett Pond is proposed as 20 µg/L. Reconciliation of this difference should occur before a final TMDL is approved.

Stetson Pond had an average summer surface TP concentration of 46 µg/L in 1988 with a significant difference ($\rho<0.08$) between shallow and deep averages. Based on the data in the draft TMDL report, average surface TP in 2015 appears to be approximately 15 µg/L, but the pond has persistent deep DO concentration below the MassDEP minimum and accompanying high summer chlorophyll concentrations. It is not definitively clear from the graphs in the draft TMDL, but the continuing impaired conditions at the measured lower TP concentration suggest that the appropriate TP TMDL target for Stetson Pond should be lower than the 13 µg/L proposed in the draft TMDL.

White Oak Reservoir does not have as extensive water quality data as the other three ponds included in the draft TMDL report. Measured surface TP concentration range from approximately 23 to 53 µg/L.[22] The discussion in the draft TMDL suggests that a true measurement of TP concentrations in the water column has not been accomplished; it is suggested that significant TP is bound in the extensive duckweed in the reservoir. Given that

White Oak Reservoir does not have the benefit of a historic diagnostic/feasibility study and most of the available data was collected in only one year (2015), selection of a draft TMDL TP concentration using the approach used by MassDEP seems to be a bit premature given the uncertainties associated with the reservoir ecosystem. The target draft TMDL TP concentration for White Oak Reservoir is 28 µg/L.

III. TMDL Recommended Management Activities

Once MassDEP selected the recommended target TP concentrations, they used the LLRM loading model to evaluate various sources of watershed and internal phosphorus loads. This model was also used to reduce various sources to develop recommended water quality management strategies in the draft TMDL. From this analysis, it was determined that cranberry bog inputs and runoff associated with residential development were the largest controllable phosphorus sources and that internal regeneration of sediment phosphorus was major source in West Monponsett Pond.[23]

This analysis presupposes that the factors in the LLRM are accurate for the individual ponds, including sufficient characterization of factors such as bathymetry, water budget, sediment contributions, and the watershed loads and that the model is properly calibrated and verified. Based on the review of available data, the characterization of the ponds seem to be inaccurate in important ways and suggest that addressing internal loads first may be a more appropriate management approach than targeting watershed loads first as suggested in the draft TMDL.

Selected issues are listed and discussed below:

A. Cranberry Bog Characterization: Individual Bog Contributions

Individual cranberry bog growers utilize water in different ways depending on a number of factors, including bog elevations, accessibility to water (e.g., gravity feed vs. pumping), and harvest techniques (e.g., dry vs. wet). Attention to downstream phosphorus impacts and crop yields[24] has changed bog phosphorus fertilizer applications significantly in the last 10 years. It is mentioned in the draft TMDL that some of the bogs within the watershed have been abandoned and some have significantly reduced their phosphorus applications.[25] However, no details are mentioned on how these bogs around the draft TMDL ponds discharge or withdraw water from the ponds. It is suggested that more refined sampling be completed to quantify the actual phosphorus contributions to ponds, especially since the draft TMDL states that reductions of these loads should be accomplished prior to addressing internal sediment regeneration.

For example, the watershed phosphorus load reductions calculated in the LLRM model began with a base bog phosphorus loading rate of 4.3 kg/ha/yr. The draft TMDL also recommended reductions in phosphorus loads to a rate of 0.5 kg/ha/yr, based on monitoring conducted for White Island Pond. CSP/SMAST monitoring of the all the 2010 discharges from the two bogs adjacent to White Island Pond found that the net phosphorus contributions from the bogs were 0.48 and 0.45 kg/ha/yr and that almost all of the individual discharges occurred outside of the primary water quality management period (June to September).[26] Derivation of these rates included measurement of the volume of each individual discharge from the bogs to the pond, the associated discharge TP concentrations, and the TP concentrations of flood waters added to the bogs from the pond.

Given that lack of similar measurements for the bogs adjacent to the draft TMDL ponds and the variability in measurements seen between bogs in previous studies, the cranberry bog loads assumed for the bogs addressed in the draft TMDL does not seem sufficiently accurate or robust for use in implementing a TMDL. This is particularly crucial since the draft TMDL identifies cranberry agriculture as a large fraction of the ponds phosphorus budget. Therefore, it is recommended, so as to prevent management practices that are costly and fail to attain desired water quality goals, that actual flow and concentration (load) measures be made for the bogs impacted by the draft TMDL prior to implementation of further bog fertilizer reductions or removal of bogs from production in order to have a definitive baseline of the phosphorus contributions of the bogs.

B. Internal P loading Characterization: Pond Sediment Loading

From the water quality response to the alum treatments in West Monponsett Pond, it is clear that its sediments are a major contributor (possibly the largest source of P) to the nutrient-related water quality in the pond. What is less clear is the mode of phosphorus release and the characteristics of the sediments within this pond and all the other ponds addressed under the draft TMDL. CSP/SMAST collection and incubation of pond sediment cores have found significantly varying phosphorus releases depending on the depth in the pond, the location in the pond, the characteristics of the sediments (e.g., sandy vs. muddy), and redox conditions in the near sediment bottom waters. Given the complexities of the hydrology within the Monponsett Ponds, in particular, it is recommended that a sediment survey and targeted core collection be completed. The past history of both these ponds show hypoxia regularly occurred, so incubation of the cores should include oxic decompositional release and chemical release under anoxia to help understand whether intermittent hypoxic events could account for the phosphorus concentrations measured in the ponds. It is also recommended that continuous dissolved oxygen temperature, and chlorophyll dataloggers be installed to evaluate triggers for algal blooms and sediment phosphorus releases in all of the ponds included in the draft TMDL.

C. Hydrology: Pond Flows, Withdrawals, and Bathymetry

The hydrology in the Monponsett Ponds is complex with transfers between the Monponsett Ponds, transfer of water to Silver Lake, and outflow through Stump Brook. Review of the available data shows that there are seasonal variations (e.g., greater transfers to Silver Lake early in any given year) and year-to-year variations (e.g., water years with drought conditions). Water is likely transferred between the two ponds depending on timing and magnitude of outflows and it likely that this is impacting the residence time of water and nutrients, especially during the critical summer water quality management period. It is highly likely that these variations play a role in determining the water quality conditions within the ponds, but the analysis and data gathering to understand this is incomplete.

It is recommended that a continuous water level datalogger be installed in each pond and that this data collection be coordinated with continuous measurement of outflows through Stump Brook and transfers to Silver Lake. Combining this information with the logging of continuous water quality data will provide insights into the way water moves within the system and how that helps to determine the measured water quality. Similar measurement of flows into and out of

Stetson Pond and White Oak Reservoir will also provide similar insights for the management of water quality within those systems.

At the same time, it is recommended that an updated bathymetric map of the ponds be completed. Bathymetry is important for accurate determination of the volume of water in the pond, the residence time, and the relationship between phosphorus loads and measured water quality. From the information presented in the draft TMDL report, it appears that the known sources of bathymetry that is being used are relatively old and likely based on a coarse grid similar to other surveys at that time. Bathymetry appears to be as follows: East Monponsett Pond, 1985/86; Stetson Pond, 1987/88. It is unclear what the sources of bathymetry data are for West Monponsett Pond and White Oak Reservoir. CSP/SMAST has completed updated bathymetry on approximately 10 ponds in the last 5 years and has found that some volumes from the 1970s and 1980s are generally acceptable (2 - 4% difference). However, some measurements have found more significant volume differences (>30% in Sassaquin Pond, for example[27]) and more refined bottom characteristics have provided additional insights important for management.

D. Stormwater P inputs: Identification and Measurement

CSP/SMAST preparation of lake management plans for communities in southeastern Massachusetts have typically included identification and measurement of stormwater runoff directly to the ponds (significantly easier with recent MS4 inventories).[28] Our experiences have generally found that runoff sources can be identified, flows measured, and phosphorus loads quantified. All of these monitoring studies have found that measured phosphorus loads are significantly smaller than modeled or estimated loads.

If the stormwater loads are less than modeled in the LLRM, then other sources must be greater in order to maintain the model balance of phosphorus loads. Said another way, if the LLRM loads are inaccurate, expenditures to address less significant loads will not result in the attainment of water quality goals. Addressing the primary phosphorus sources is the key to attaining water quality goals in a cost effective manner.

IV. Conclusions/Recommendations

The following recommendations were made based on the review discussed above:

a. Target TP TMDL concentrations for West and East Monponsett Ponds and Stetson Pond should be lower than recommended in the draft TMDL.

b. Selection of a target TP TMDL for White Oak Reservoir should wait until a more refined characterization of the ecosystem is completed.

c. Phosphorus loads from the cranberry bogs within the Monponsett Ponds watershed should be measured from flow and concentration data, rather than simulated.

d. Phosphorus recycling from sediments should be measured as results from the alum applications indicate that it is likely the major source of P for summer production.

e. Better characterization of the all the ponds should be completed to assess the following:

- Flows into, out of, and between the Monponsett Ponds
- Flow out of White Oak Reservoir and Stetson Pond
- Continuous measurement of water levels and water quality characteristics in the Monponsett Ponds to better understand seasonal residence times and cyanobacteria bloom triggers
- Measure rather than model stormwater runoff inputs to each of the ponds

Please contact us if we can clarify these any further.

1 Princeton Hydro. 2013. Monponsett Pond and Silver Lake Water Use Operations and Improvement. SWMI Project No. BRP 2012-06. Ringoes, NJ. 75 pp.
2 Ibid, Figure 10 C and Figure 5 in Horsley Witten Group. 2015. Stump Brook / Monponsett Pond Hydrologic and Water Quality Assessment. Sandwich, MA. 41 pp.
3 Lycott Environmental Research, Inc. 1987. East and West Monponsett Ponds, Diagnostic/Feasibility Study. Southbridge, MA. 318 pp.
4 Baystate Environmental Consultants, 1993. Diagnostic/Feasibility Study for the management of the Pembroke Ponds: Oldham, Furnace, Little Sandy Bottom and Stetson, Pembroke, MA. East Longmeadow, MA. 126 pp.
5 Aquatic Control Technology. 2015. Western Basin of Monponsett Pond, 2015 Year-End Alum Treatment Report. Shrewsbury, MA. 26 pp.
6 Aquatic Control Technology. 2015. 2015 Annual Summary Report, Aquatic Management Program, East Monponsett Pond. Sutton, MA. 6 pp.
7 Division of Fisheries and Wildlife. Monponsett Ponds Pond Map. Last updated December 22, 2005. 2 pp.
8 Massachusetts Department of Environmental Protection. July 2016. Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2016 Reporting Cycle. CN 445.0. MassDEP, Division of Watershed Management, Watershed Planning Program. Worcester, MA. 108 pp.
9 Massachusetts Department of Environmental Protection. December 2015. Massachusetts Year 2014 Integrated List of Waters, Final Listing of the Condition of Massachusetts' Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act. CN 450.1. MassDEP, Division of Watershed Management, Watershed Planning Program. Worcester, MA. 311 pp.
10 Lycott Environmental Research, Inc. 1987. East and West Monponsett Ponds, Diagnostic/Feasibility Study.
11 Baystate Environmental Consultants, 1993. Diagnostic/Feasibility Study for the management of the Pembroke Ponds.
12 Draft TMDL, p. 47.
13 U.S. Environmental Protection Agency. 2001. Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for Lakes and Reservoirs in Nutrient Ecoregion XIV. EPA 822-B-01-011. US Environmental Protection Agency, Office of Water, Office of Science and Technology, Health and Ecological Criteria Division. Washington, DC.
14 Ibid.
15 Draft TMDL, p. 33.
16 Lake Loading Response Model. A spreadsheet based model used for evaluating watershed and internal phosphorus loads.
17 U.S. Environmental Protection Agency. 2001.
18 Each pond had a total of 29 water quality samples collected between 1985 and 1986.
19 Draft TMDL, p. 35.
20 All concentrations read off Figure 1 in ACT (2015).
21 Concentrations read off Figure 6 in draft TMDL.
22 Concentrations read off Figure 9 in draft TMDL.
23 Draft TMDL, p. 5.
24 DeMoranville, C., B. Howes, D. Schlezinger and D. White. 2009. Cranberry Phosphorus Management: How changes in practice can reduce output in drainage water. Acta Hort. 810: 633-640.
25 Draft TMDL, p. 35.
26 CSP/SMAST. 2012. White Island Pond: Water Quality and Management Options Assessment and Phosphorus Mitigation Program for Cranberry Bogs. University of Massachusetts Dartmouth. New Bedford, MA.
27 CSP/SMAST. 2012. White Island Pond: Water Quality and Management Options Assessment and Phosphorus Mitigation Program for Cranberry Bogs. University of Massachusetts Dartmouth. New Bedford, MA.
28 MS4 = municipal separate storm sewer systems; MS4 is a provision under the NPDES portion of the Clean Water Act that requires communities to develop stormwater management plans. Identifying all stormwater collection systems is one of the first steps in formulating a plan.

MassDEP Response: The comments of Eduard Eichner, TMDL Solutions and Brian Howes, Coastal Systems Program/SMAST, UMass Dartmouth as summarized in their conclusions and recommendations a-e above are addressed below:

a) MassDEP agrees that the targets for East and West Monponsett Pond should be lower. The draft was written before the summer 2016 data was collected. That data clearly shows that the lake is at or near the 20 ppb draft target yet West Monponsett exhibited unacceptably large cyanobacteria blooms for much of the summer. We have remodeled the ponds and rewritten the final TMDL with a lower target of 18 ppb for both West and East Monponsett Pond. Stetson Pond has already recovered from the impacts of previous cranberry bog operations upstream of *the pond. All of those bogs were retired and the lake has shown a dramatic improvement in TP and the lake transparency is now consistently above the 1.2 m guidance value. A value lower than the 2015 data was selected as a margin of safety. Future alum treatment is expected to further lower the TP concentration to meet that target and MassDEP believes the target for Stetson Pond is adequate to meet our water quality standards. If a further review of water quality data shows the pond is not meeting the targets the TMDL can be revised.*

b) On the selection of a TP target for White Oak Reservoir we agree more data would be helpful but the available data from 2009 to present are enough to show the Reservoir is impaired and has high TP concentrations. Because White Oak Reservoir is upstream of the impaired West Monponsett Pond, the implementation for West Monponsett Pond necessarily includes White Oak Reservoir and its watershed. As such, all of the implementation recommendations on cranberry bogs tributary to the Reservoir, for example, would be required even if we delayed establishing a TMDL on the Reservoir itself. It makes sense therefore to write a TMDL for the Reservoir since all the data and modeling have been completed. If the target for White Oak Reservoir needs to be modified up or down, that can be done at a later time when additional data is collected.

c) We agree with the commenters that it would be better to collect exact daily flow and concentration data from the bogs. As noted in response #35 above the growers that are part of the Cape Cod Cranberry Growers Association have denied MassDEP access to their properties so direct sampling is not available in all cases. We have responded to Brian Wick of the Cape Cod Cranberry Growers Association (#35 above) that we would greatly appreciate assistance to allow access to the properties.

d) Phosphorus recycling from the sediments of West Monponsett Pond was estimated largely based on actual cores taken from the pond as detailed in the TMDL. We agree the limited aluminum treatments do indicate that the sediments are the major source of phosphorus, at least in West Monponsett Pond. In the other ponds sediment sources are smaller than cranberry bog inputs with the exception of Stetson Pond where the pond has largely recovered after all commercial cranberry bogs were put out of production. Even in West Monponsett Pond where the internal sources are larger than the cranberry bog inputs today it should be noted that the internal pool of phosphorus accumulated over many years of external inputs. Those external inputs in the years before the TMDL was being developed were largely dominated by the commercial cranberry industry. Subtracting the internal sediment load for West Monponsett we calculate the cranberry bogs were the major external source and accounts for more than half of all external inputs to the system and likely account for more than half of all the phosphorus in the sediments.

e) We agree that better characterization of the system including flows into, out of and between the Monponsett Ponds, flows out of both White Oak Reservoir and Stetson Pond, continuous measurement of water levels and water quality characteristics in the Monponsett Ponds to better understand seasonal residence times and cyanobacteria bloom triggers and measurement of stormwater inputs to all ponds would be great and would improve the accuracy of the TMDL. While we did not do continuous monitoring we did have accurate measurements of flows associated with the diversion and good estimates of other flows in the hydrology study by

Princeton Hydro. In addition we did collect many monthly samples of TP during the summer months from a wide variety of tributaries to the pond and used this data to refine our modeling coefficients. Conducting continuous monitoring of all tributaries and stormwater and measurements of TP concentrations associated with those flows would be very expensive and time consuming for a lake TMDL. None of the studies done to date by Lycott, Horsley Witten, or Princeton Hydro were able to conduct such a detailed study. Even the multi- million dollar studies in the Massachusetts Estuary Project TMDL do not collect such detailed continuous flow and concentration data. While more data is better, the more appropriate question should be: Are the available data sufficient to identify the major sources of nutrients to the pond and to outline steps needed for recovery? MassDEP believes for these ponds the data are sufficient. Similar work done at White Island Pond demonstrates the success of such an approach and that pond now meets our water quality standards (Mattson, 2015).

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70. Comment received via email on 1/16/2017 from Frank Basler

Dear Mr. Reardon;

I am writing to you per the direction of the Plymouth County Commissioners as voted at their January 3, 2017 meeting. The Commissioners appreciate the attention and efforts that have been put forth focusing on the ponds and waterways of Plymouth County. The Commissioners understand that the ponds, lakes and waterways are critical resources that need to be preserved for all Plymouth County inhabitants. The Commissioners would like to officially comment as part of the public response request concerning the West and East Monponsett Ponds System Total Maximum Daily Load (TMDL) for Total Phosphorus, Report CN 446.0. As seeing that the West and East Monponsett Ponds have been identified as impaired waters, it is critical to move forward on remediation as quickly as possible with an alignment of all regional groups. The Commissioners are supportive of the DEP working with the Central Plymouth County Water District Commissioners as a critical resource and sounding board to improve this important pond system.

The TMDL Report clearly proves that stagnation caused by current management practices, have contributed to the deterioration of West Monponsett Pond. The Commissioners request that the DEP factor this important data into the Administration Consent Order which is about to be published. Please count on the support of the Plymouth County Commissioners to assist in the process of remediation in any and all ways possible, including if help is needed from our new fresh water dredge excavator.

Please contact me if you have any questions for the Commissioners,

Frank Basler
Administrator, County of Plymouth
fbasiey@ PlymouthCountyMA.gov
p: 508.830.9104 m: 7817183967 f: 508.830.9106
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MassDEP Response: As required by an Administrative Consent Order, signed on January 30, 2017 by the City of Brockton and issued by MassDEP on March 22, 2017, a minimum of 900,000 gpd must flow over the Stump Brook Dam at all times except when the fish ladder is fully open and no flow is available due to the pool elevation. This will serve to reduce stagnation in the pond system. Please also refer to the response to comments 45, 47 and 49 above.

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71. **Comment received via email on 1/16/2017 from Carol Traverse, Taunton River Watershed Alliance**

Dear Mr. Reardon:

The Taunton River Watershed Alliance, Inc. (TRWA) submits the following comments on the Draft Total Maximum Daily Loads (TMDLs) for Total Phosphorus for the West and East Monponsett Pond System developed by the Bureau of Water Resources of the Massachusetts Department of Environmental Protection (DEP). TRWA is committed to the protection and restoration of natural resources of the Taunton River, its tributaries and the special and irreplaceable ecosystems of its watershed. The West and East Monponsett Ponds as well as Stetson Pond and White Oak Reservoir (also addressed in this Draft) lie within the Taunton River Watershed.

The purpose of the TMDL is to establish concentration limits for Total Phosphorus (TP) to eliminate current impairment of water quality, especially excessive growth of algae. TMDLs are developed to improve the water quality of rivers, lakes and ponds. As stated in the Draft, West Monponsett Pond and Stetson Pond have been identified as "impaired waters" under Section 303(d) of the federal Clean Water Act. Stetson Pond is listed for TP, dissolved oxygen and non-native aquatic plants. West Monponsett Pond is listed for TP, excessive algae growth and non-native aquatic plants. Elevated levels of *chlorophyll a* and potentially toxic cyanobacteria blooms have also been observed in this pond. The Draft also states that East Monponsett Pond and White Oak Reservoir were recently determined by DEP to be "impaired" as well by excessive algae growth and nuisance aquatic plants.

We commend DEP for developing the Draft TMDLs. We strongly support the identification of target concentration limits for TP in these water bodies and the establishment of TMDLs that will achieve these limits. We also support the implementation measures proposed in this Draft, including reduction of fertilizer use for cranberry bogs and residential areas, improved stormwater management and upgrade of substandard septic systems.

The recommended implementation measures, however do not address one of the major causes of high nutrient loading and excessive algae growth. **The Monponsett Pond System has suffered severe water quality deterioration for many years as a result of the manipulation of natural water flow in the East and West Monponsett Ponds.** This manipulation occurs during the period from October to May for the purpose of diverting water from the Ponds to Silver Lake which lies in the Jones River Watershed, for use by the City of Brockton as water supply. This
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diversion includes reversal of natural flow direction between the two ponds: water would naturally flow from the East to the West Pond, discharging to Stump Brook, then downstream to the Satucket River and eventually the Taunton River mainstem. However, an impoundment on Stump Brook, controlled by the City of Brockton is used during the diversion period to reverse the flow of water from the West pond to the East pond, from which water is conveyed to Silver Lake by a pipe.

The Draft indicated (p. 26) that Princeton Hydro conducted analysis of water management for the Ponds in 2013 to identify options to improve water quality and provide more sustainable flows in Stump Brook. The studies found that approximately 70% of the entire outflow of West Monponsett Pond is routed to East Monponsett Pond on an annual basis as a result of the impoundment, and that “40% of the inflow to East Monponsett Pond consists of the poorer quality water from West Monponsett Pond.” Such a large diversion frequently results in low-flow or no-flow conditions in Stump Brook and serious degradation of habitat for fish and other aquatic organisms. Unnatural alterations in lake levels exacerbate leaching of nutrients from septic systems surrounding the ponds and disrupt the life cycle of fresh water mussels and benthic aquatic life which are important natural nutrient removers.

In the chart found on p. 6, the Draft identifies the current TP concentration in West Monponsett Pond as 68 ppb and in East Monponsett Pond as 34 ppb. Horsley Witten Group studied the management of the Stump Brook dam and its effects on the brook’s flows and Monponsett Pond levels in 2015. Among other conclusions, they estimated (p. 26 of Draft): “in the absence of the Brockton water supply diversion, West Monponsett Pond would have a total phosphorus concentration of 0.057 mg/l while East Monponsett Pond would have a total phosphorus concentration of 0.019 mg/l.” The section of the Draft titled “Impact of Diversions” (p. 45) indicates that DEP used a model to evaluate TP concentrations in West Monponsett Pond in the absence of water diversions. The Draft states:

> “…our model estimates that TP concentrations in West Monponsett Pond would decrease by 24%. This is in close agreement with the previous studies that found a ‘no diversion’ scenario would reduce TP concentrations in the pond by 23% to 32% (Horsley Witten, 2015 and Princeton Hydro 2013, respectively). The improvement in water quality would be due to increased flushing with relatively clean East Monponsett Pond water…”

DEP, Princeton Hydro and Horsley Witten Group have all linked Brockton’s water diversions to elevated TP levels. These elevated levels cause or contribute to impairment of designated uses of the water bodies, and as a result, the diversions constitute violations of both the Massachusetts Water Quality Standards and the federal Clean Water Act. TRWA is aware that the use of the Monponsett Ponds as a water supply source for Brockton was authorized by the General Court of Massachusetts through Act 371 of 1964. However we note that a viable alternative water supply is now available to the City as a result of the construction and operation of the Aquaria Desalination Plant in Dighton. This plant was specifically intended to provide an alternate water supply for Brockton. In addition, establishment of a connection and use of MWRA is a viable alternative. As a result, the interbasin diversions could be significantly reduced or eliminated entirely.

For these reasons, we urge DEP to add "elimination or significant reduction of flow reversals and diversions of water from the Monponsett Pond System" as a high priority implementation measure to achieve the TP concentration targets.

Thank you for considering these comments. In closing, we note that the Draft stated that owners of local cranberry bogs have reduced fertilizer use, TP concentrations in West Monponsett Pond dropped by 23% between 2010 and 2016, and this period was coincident with reductions in fertilizer use of 60-70% by major bog owners. We commend these actions.

Sincerely,

Joseph Callahan, President
Taunton River Watershed Alliance, Inc.

cc: Pine DuBois, Jones River Watershed Association
Charlie Seelig, Town of Halifax
Larry Rowley, City of Brockton

MassDEP Response: MassDEP appreciates the support indicated for the TMDL and the efforts of the Taunton River Watershed Alliance in the Taunton River watershed. It is the goal of MassDEP to reduce the effects of decreased flushing and flow reversals to the extent possible under relevant laws and statutes to provide for better management of the diversion. Please refer to the response to comments 45, 47 and 49 above. As now required by an Administrative Consent Order (ACO) between the City of Brockton and MassDEP, a minimum of 900,000 gpd must flow over the Stump Brook Dam at all times except when the fish ladder is fully open and no flow is available due to the pool elevation. The ACO also requires Brockton to divert water from Monponsett to Silver Lake at approximately half the maximum rate in order to reduce the reverse flow from West Monponsett to East.

72. Comment received via email on 1/16/2017 from Sarah Burns

Re: Draft West and East Monponsett Pond System TMDL for Total Phosphorus (CN 446.0)

Dear Mr. Reardon:

Thank you for the opportunity to provide comments on the Draft West and East Monponsett Pond System TMDL for Total Phosphorus released by Massachusetts Department of Environmental Protection on October 24, 2016.

The Nature Conservancy is an international, nonprofit conservation organization. Our mission is to conserve the lands and waters on which all life depends. Our work is carried out in all 50 states and over 30 countries, and is supported by over 36,000 members in Massachusetts and Rhode Island and over one million members worldwide. The Conservancy works globally on freshwater management to help government agencies, water management agencies, industry, scientists, and other non-governmental organizations around the world to improve ecosystem health and implement sustainable solutions.

The Nature Conservancy supports the draft TMDL for total phosphorus. The Conservancy agrees with MassDEP that total phosphorus loading limits are necessary to achieve water quality standards in the East and West Monponsett Pond system and that the limits set by MassDEP are justified by the best available science. Requiring targeted phosphorus reductions from surrounding properties based on best available technologies tailored to land use impacts will help to protect and improve water quality in the Monponsett Ponds system with subsequent protective effects on public water supply in Silver Lake. We view this TMDL as an important piece of a comprehensive and watershed wide approach to restoring the environmental conditions of the Taunton River Watershed.

The Taunton River is the longest free flowing coastal river in New England. The river supports populations of environmentally-sensitive species such as river otters and freshwater mussels; three globally rare species of plants and two globally rare fish, bridle shiner and Atlantic sturgeon, inhabit the watershed. The Taunton River provides important habitat for one of the largest spawning populations of river herring in New England and populations of other fish that play a critical role in supporting marine food webs. The River was designated Wild and Scenic in

2009, to protect six outstanding resource values: agriculture, ecology and biodiversity, estuary, fisheries, history and archaeology, and recreation.

Restoring connectivity and fish passage in the tributaries of the Taunton River is an important goal of The Nature Conservancy. Dam removal projects are restoring anadromous fish access to historic spawning areas, including the Monponsett Ponds system. However, monitoring and research have shown that to be truly effective at scale, restoration success requires improved water quality to support a diversity and abundance of native species and habitats. Limiting phosphorus loading to ponds and lakes that historically served as spawning ground for anadromous fish is a goal of The Nature Conservancy as dam removal continues to reconnect these artificially isolated habitats to the larger diadromous fish habitat.

Nutrient pollution from agriculture and residential development is widely recognized as a major source of impairment for aquatic ecosystems throughout the region. The Conservancy is committed to efforts to reduce bioavailable phosphorus in the freshwater systems of this region because of persistent problems related to excessive phosphorus including widespread algal blooms, with the potential for toxic cyanobacterial blooms, low dissolved oxygen levels, and loss of native species due to invasion of pond ecosystems.

The Conservancy strongly supports the scientifically-derived total phosphorus target loads to support East and West Monponsett Pond system water quality, and agrees with the methods for apportioning load reduction among cranberry bogs and stormwater sources described in the draft TMDL. The Nature Conservancy also strongly supports the draft TMDL suggestion that Title V septic systems be maintained, evaluated, and upgraded as necessary to ensure that total phosphorus interception by septic systems continues at optimal levels. Additionally, The Conservancy agrees with MassDEP that historic anthropogenic phosphorus loading led to elevated internal total phosphorus levels that recycle in the ponds, and that as much as 90% reduction of internal loads is needed in West Monponsett and Stetson Ponds. However, The Conservancy suggests that Ponds system flushing be considered as a viable alternative to further aluminum treatment, and requests that the recommendation for sediment phosphorus control be changed so the responsible parties have the option to work with NHESP to consider the feasibility of both flushing and aluminum treatments and their impacts on the rare species present in the system. Although no adverse impacts of initial aluminum treatment were observed on the rare species, aluminum treatment can have detrimental impacts on mussel and fish populations. Furthermore, the draft TMDL points out that modeling has shown that as much as 32% of the total phosphorus load in West Monponsett could be addressed by adjusting the hydrological management of the Ponds systems.

In coalition with associations representing municipalities and water suppliers, The Nature Conservancy has supported public policy and funding for municipal infrastructure related to water quality including leading the legislative advocacy efforts to create a $20 million loan fund for dam removal and repair and advocating for capital funding legislation to implement the recommendations of the Water Infrastructure Financing Commission. The Conservancy will continue to help ensure public funding and incentives are available to help communities protect clean water to benefit people and the environment.

Thank you for this opportunity to comment. If you have questions, please contact Sara Burns at sara.burns@tnc.org/617-532-8342.

Sincerely,

Wayne Klockner, Vice President and Massachusetts State Director

MassDEP Response: MassDEP appreciates the support indicated for the TMDL and the efforts of the Nature Conservancy in both the Taunton River watershed and throughout Massachusetts. MassDEP does not believe that the nutrient reduction targets set in the draft TMDL can be relaxed regardless of future flow management regimes. The TMDL estimated that West Monponsett Pond might be 24% higher due to the diversion, but once the lake starts to clean up due to the cranberry BMPs and the limited aluminum treatments to date, the impact of diversion will be less than 24% and maybe as low as 6%. Thus, the aluminum treatment of the sediments and/or lake water will still be the most reasonable way to meet the TMDL target. Historic aluminum treatments in low alkalinity lakes did find that if the aluminum is added with poor buffering control, pH changes have the potential to impact fish and possibly mussels. However, with improvements in the balanced use of alum and sodium aluminate during treatment of low alkalinity waters in Massachusetts, no significant impacts have been observed. MassDEP works closely with NHESP to manage the aluminum treatments to protect rare species and monitor the system. In regards to the hydrological management of the waterbodies in this TMDL, it is the goal of MassDEP to reduce the effects of the diversion and associated flow reversals to the extent possible under relevant laws and statutes to provide for better management of the diversion. Please refer to the response to comments 45, 47 and 49 above.

73. Comment received via email on 1/17/2017 from E. Heidi Ricci, Mass Audubon

Dear Mr. Reardon:

On behalf of Mass Audubon, I submit the following comments on the draft Total Maximum Daily Load (TMDL) for West and East Monponsett Pond, Stetson Pond and White Oak Reservoir. The focus of these comments is on West and East Monponsett Pond. The Monponsett Ponds are located at the headwaters of the Taunton River watershed. The natural point of discharge flow from these ponds is in a westerly direction via Stump Brook. Approximately 70% of the flow, on average, is diverted via a pipe operated by the Brockton water system, transferring water to Silver Lake in the Jones River watershed. Water is then withdrawn from Silver Lake and treated for consumption in the Brockton water supply system.

Mass Audubon has a longstanding interest in the condition and management of the Monponsett Pond and associated water resources. Mass Audubon's 250-acre Stump Brook Wildlife Sanctuary borders Stump Brook and contains extensive wetlands including Atlantic White Cedar swamp, a rare habitat type. Flow to the brook is regulated by a dam on Monponsett Pond owned by Brockton. Water quality in the pond and the flow or lack thereof across the dam affects the ecological health of Stump Brook and associated fisheries and wetlands.

West Monponsett Pond is listed impaired (Category 5), on the "Massachusetts 2014 Integrated List of Waters" due to excessive nutrients. The pond has experienced repeated, severe blooms of cyanobacteria which has resulted in closure to contact recreation as well as other public health and property value concerns. The diversion of water from West Monponsett into East Monponsett and Silver Lake introduces highly impaired water into cleaner water bodies and the Brockton water supply system. The manipulation of water levels in the ponds by Brockton also has contributed to flooding in surrounding properties and the diversion of water into East Monponsett and Silver Lake at times when Silver Lake was already full. This practice increases the likelihood of additional nutrient inputs from septic systems and lawns around Monponsett, increases diversion of polluted water into Class A and Outstanding Resource Waters (ORWs) that provide public water supply, and exacerbates flooding in the Jones River watershed. It also deprives West Monponsett Pond of flushing via the Stump Brook outlet.

Studies referenced in the TMDL indicate that reductions in diversions could have significant positive effects on water quality in both West and East Monponsett Pond. What is not mentioned in the TMDL is that many diversions have occurred when Silver Lake was already full, and therefore did not contribute to provision of water supply. On the other extreme, with the current drought, severe drawdown of Silver Lake is impacting resources there including mortality of state-listed freshwater mussels and degradation of fish habitat. Monponsett Ponds also support state-listed mussels and a state-listed dragonfly. The Atlantic White Cedar swamp on Mass Audubon's property downstream of Monponsett is also negatively impacted by lack of flow.

The draft TMDL, while mentioning the legislative and administrative history of Brockton's water supply, places virtually all of the burden of implementation on the towns and private landowners. It does not mention the availability of an alternative water supply source, the Aquaria desalinization plant. It also fails to place responsibility on the City of Brockton for developing and implementing a watershed and water supply management plan that would protect natural resources and ensure the ongoing viability of the water supply system. The cranberry bogs and Towns of Halifax and Hanson have already invested significant resources and effort, and have worked collaboratively to secure additional funds and external partnerships in studying and reducing nutrient loadings to Monponsett Ponds. Halifax has also expended considerable funds on in-lake treatments and associated studies and monitoring. The final TMDL should explicitly include Brockton as a responsible party in implementation, and should include a requirement for development of a water management plan that optimizes management of flows and water levels.

The draft TMDL also does not address the role of the Central Plymouth County Water District Commission (CPCWDC), created by Chapter 371 of the Acts of 1964, and its role in overseeing the operation and maintenance of the regional water supply system that includes Monponsett Ponds.

Thank you for considering these comments.

Sincerely,

E. Heidi Ricci

Senior Policy Analyst

MassDEP Response: The commenter's concern for the ecological effects of the management of the Monponsett Ponds as a public water supply by the City of Brockton is noted. The TMDL has added the City of Brockton as a responsible party to Table 10 and recommends that they conduct a watershed and water supply management plan that focuses on management efforts to improve *water quality in Monponsett Ponds. Additionally the Central Plymouth County Water District Commission has also been added to Table 10. It is the hope of MassDEP that all interested parties can find common ground to advance solutions that result in the restoration of the affected waterbodies.*

As now required by an Administrative Consent Order (ACO) between the City of Brockton and MassDEP, a minimum of 900,000 gpd must flow over the Stump Brook Dam at all times except when the fish ladder is fully open and no flow is available due to the pool elevation. This increased flow and the implementation of the recommendations if the TMDL report will increase the water quality and quantity downstream of Stump Brook Dam.

The ACO also requires Brockton to develop a Resource Management Plan for Monponsett, particularly the operation of the dam and the diversion structure which will balance the needs of all stakeholders. One of the considerations to be included in this plan to use time-of year and pond elevation information to target releases through the Stump Brook dam to minimize potential flooding. See response to comment 47.

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74. Comment Received From Cathy Drinan, Halifax Health Agent, Received 1/30/2017

The Draft TMDL identifies that internal loading of Phosphorus (P) is the largest source for West Monponsett Pond (WMP) at a rate of 293.5 kg\yr, far greater than the other three ponds within the study area with East Monponsett at 30 kg/yr, Stetson Pond at 6.9 kg/yr and White Oak Reservoir, 0.0 kg/yr (Tables 5 – 8 in the draft TMDL).

Additionally, given the hydraulics of the study area, as presented in Figure 1 of the Draft TMDL, West Monponsett Pond (WMP) is the furthest downstream pond with only one outlet, Stump Brook. There are several inputs to WMP that are sources of Phosphorus, including the cranberry bogs, septic, and natural sources from numerous streams and culverts that convey water to WMP. We can all agree that these sources have overloaded the pond with P and other nutrients, hence the abundant amount of internal phosphorus as the primary source.

However, the TMDL makes no correlation to the fact that Stump Brook was dammed in 1964 and doing this idled the waters of WMP, not allowing the flushing of the pond for 50+ years leading to this source of elevated internal phosphorus loading. The executive summary of the TMDL states that one purpose of the TMDL is to identify sources of pollution and developing a plan to "bring them back in compliance with the Massachusetts Surface Water Quality Standards".

Hydraulic flushing is vital to the health of any water body, fresh or salt. MassDEP, and other State Agencies have supported this in numerous studies throughout the Commonwealth to assist the restoration the health of eutrophic water bodies. The TMDL should include language to
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recognize the importance that the Stump Brook plays in the ecosystem of the study area, and the detrimental effects that damming it has created.

We were told at the 12/15/16 public hearing that the "model" was run with removing the dam and lowering the water level by 2-feet would result in a negative impact, as this would allow less water in WMP and increase pollution concentrations. If the creation of the dam, and mismanagement of flows for over 50 years, has created (or played a part of creating) a situation where removing the dam will only decrease the water quality of WMP, this should be identified. Just as Halifax is responsible for reducing pollutants from storm-water and septic tanks, the City of Brockton, as owners and operators of the Stump Brook Dam should be responsible to remedy the symptoms they have caused in WMP and the surrounding ecosystems by constructing a man-made feature contributing to the highest source of P in WMP.

In closing, we would comment that the TMDL is lacking the following information that is essential and imperative, to the health of WMP, and surrounding habitats (and consistent with the goals of issuing a TMDL). We would ask that the TMDL be revised to include discussion on the following:

- General statement on the importance of natural outlets to ponds and how these impact the health of the pond.

- A specific discussion on how the damming of Stump Brook Dam (the only natural outlet to the study area) has affected the water quality of WMP.

- Discussion on if the damming of Stump Brook has contributed to the excessive internal P loads of WMP.

- Discussion on how maintaining and restoring adequate flow to Stump Brook may improve water quality in WMP.

- What steps the Owners of the Stump Brook Dam need to do to remedy the negative impacts they have caused WMP by damming Stump Brook and restricting flow for 50+ years.

MassDEP Response: The TMDL provides a list of potential management options to reduce nutrient loading to the Monponsett Pond system. It is not possible to quantify the historic effects of the damming of Stump Brook with any precision. In general increased flushing will result in lower total phosphorus concentrations in a pond. The Monponsett Pond system is quite complex, the diversion, which in addition to removing water from the system, also removes nutrients. As a result there is not a direct correlation to reduction of nutrients due to increased flushing. See page 47 and 48 of the Final TMDL (Impact of Diversions) and response to comment 11 above. In the Final TMDL we have rewritten the implementation section to recommend a combined approach of better management of the diversion, along with the required reductions in TP *loading. This combined approach will further reduce the TP concentrations in West Monponsett Pond thereby adding a margin of safety to the TMDL and simultaneously provide additional benefits to downstream waters. Please refer to the response to comments 45, 47 and 73.*

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Comments on Model Documentation Appendix Received via email 1/8/2017 from Frank Schellenger (continued)

75. **Pg. 118 Table 6:** Does not appear to be complete.

MassDEP Response: This table is presented for illustrative purposes only.

76. **Pg. 120 paragraph 1 and Pg. Table 9:** Why? It isn't clear why one would take an average (leaving out the top one). Why not justify doing so, or use the one that most closely fits the conditions of the subject lake based on the published literature?

MassDEP Response: The simple Mass Balance Model does not capture losses due to settling. Although the Mass Balance Model can be helpful for establishing the general range of loading to a lake, it was excluded from the calibration process since it lacks an estimation for settling losses. The five models chosen Vollenweider (1975), Kirchner and Dillon (1975), Reckhow General (1977), Larsen and Mercier (1975) and Jones and Bachmann (1976) were used to calibrate the LLRM model. These models included different estimates of settling losses. Using the suite of five lake water quality models allows a calibration of the LLRM absent more advanced knowledge on settling dynamics in a given lake. The five lake models used were developed and validated on north temperate lakes with relatively long retention times and a variety of sizes.

77. **Pg. 122 Table 10:** The "observed" (2009) average for West Lake appears to be a little well-chosen. Horsley-Witten 2015 used 84 ppb. The latter would require the estimated loads to be adjusted upward. And would favor a greater input from septic systems.

MassDEP Response: The author is correct that total phosphorus concentrations have been variable over the years in the Monponsett Ponds before the applications of alum. MassDEP sampling in 2001 measured total phosphorus concentrations ranging from 55 ppb to 66. The 2009 average total phosphorus concentration as measured during MassDEP sampling is used to represent conditions before the substantive reductions in cranberry bog fertilizer use and the application of alum.
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78. Pg. 124 Paragraph 4: Incomplete

MassDEP Response: This paragraph has been updated.

79. Pg. 124: I suggest that the reliance on alum treatment to lower the P concentration in West Lake will not last. The loading via groundwater of septic system effluent P will continue, and the lake P concentration will recover. Suggest you put it on your calendar to return every year to West Lake to sample and test for TP.

MassDEP Response: Your comment is noted.

List of Attendees Draft TMDL meeting Monponsett Pond System Total Phosphorus TMDL Public Meeting, December 15, 2016

SIGN IN SHEET 12/15/2016
WEST AND EAST MONPONSETT POND SYSTEM TMDL PUBLIC HEARING

	Signature	Print Name	Affiliation
1.	DONALD H. HOWARD		SELECTMAN & WATER COMM. HANSON
2.	JIM BRAGG		PLYMOUTH County Adv (WATER) BOARD BROCKTON
3.	Frank Schellenger		Hanson
4.	Bill HINKLEY		HALIFAX
5.	MARK Sofir		Pembroke (Silver Lake)
6.	Carolyn DeMoranville		UMass Cranberry Station
7.	[signature]	Eileen Diedrichsen	Halifax
8.	[signature]	Tom Young	Hanson
9.	[signature]	Brian Doucette	Halifax
10.	[signature]	Paul Doucette	Halifax
11.	Russ Kleekamp		GHD

	Signature	Print Name	Affiliation
12.	[illegible]	JESSICA JANNEY	GHD
13.	[illegible]	Bobby McCarty	
14.	Sharon Tavares	Sharon Tavares	
15.	alan Dias	alan Dias	
16.	[illegible]	DAVID O'CONNELL	J.R.
17.	[illegible]	Alex Mansfield	Jones River WA.
18.	[illegible]	Chuck Rogers	MWA
19.	[illegible]	Laura Corkery	
20.	[illegible]	Donald Barrows	MWA
21.	[illegible]	Julie Mack	MWA
22.	Suzanne Lillie	Suzanne Lillie	MWA.
23.	[illegible]	James McLarnon	PWA
24.	Michael Celona	Michael Celona	MADPH

Signature	Print Name	Affiliation
25. Chip Morse		Morse Bros Inc
26. Patricia "Check" McCabe		Pembroke Watershed Assoc VP + Treasurer
27. Pine duBois		Jones River Watershed Association
28. Paul Collins		MWA
29. Jim Roy		Board of Selectmen - Halifax
30. Troy Garron		Board of Selectmen - Halifax
31.		
32.		
33.		
34.		
35.		

Appendix F Continued: Public Comments received on Draft Final TMDL dated January 2021

Comments received via email letter from Charlie Seelig, Town of Halifax Administrator, received February 16, 2021

To: Barbara Kickham, TMDL Section Chief, DEP
From: Charlie Seelig, Town Administrator
Date: February 6, 2021
Re: Comments on Final Draft, West and East Monponsett Pond System, TMDLs for TP

It's been a long haul on this project and the City of Brockton continues to work on its management plan for Monponsett Pond and associated water bodies. This information will be very helpful as Halifax continues to participate in the projects necessary to maintain Monponsett Pond as a water body that can be enjoyed by all.

1. **Comment Pages 3-4**

All four waterbodies covered in this TMDL are classified as Class A waterbodies as well as having been designated Public Water Supply and Outstanding Resource Waters (ORWs) (MassDEP 2022). The four waterbodies flow, via an underground pipe, from East Monponsett to Silver Lake (Pembroke, MA) which is the surface water supply for the City of Brockton. During diversions (mainly in October through May) water flows regularly in the reverse direction and flows backward from West Monponsett to East Monponsett, potentially drawing the cyanobacteria and nutrients into Silver Lake. Action is being taken to address the cyanobacterial blooms observed in West and East Monponsett Ponds and the upstream waterbodies that are tributary to those ponds.

> *Confusing – please provide information in this part of the narrative as to what the normal flow is.*

MassDEP Response: The final report was edited on pages 3-4 to add clarity to the flow description under natural conditions.

2. **Comment Page 20**

The natural surface water flow pattern is from Stetson Pond south via Stetson Brook to East Monponsett Pond and then west through a culvert under Route 56 to West Monponsett Pond (Figure 1). In the northwest part of the watershed, White Oak Brook flows into White Oak Reservoir, then continues south to West Monponsett Pond. Stump Brook is the outlet on the west side of West Monponsett Pond (Figure 1).

> *That should be "Route 58", not "Route 56".*

MassDEP Response: The correction was made on page 19 of the final report.

3. **Comment Page 20-21**

In 1995 MassDEP and the City of Brockton signed an Administrative Consent Order (ACO) which required the City to develop a Comprehensive Water Management Plan and a strategy to reduce environmental impacts.

What was the result of the 1995 Consent Order? Is there a copy of the Management Plan available? What actions were taken as a result of the Management Plan?

MassDEP Response: The conditions of the 1995 Administrative Consent Order signed by the City of Brockton were completed, with the exception of the Brockton Comprehensive Water Management Plan (BCWMP). Consensus between the City and other stakeholders was never resolved and the plan was not finalized.

A requirement of the 2017 Administrative Consent Order (ACO), amended in 2018, and signed by the City of Brockton, is to develop a Monponsett Resource Management Plan (RMP) and a new BCWMP. The RMP will guide a revised BCWMP. The current proposed schedule for the RMP is the following:

1. *July 2022 – Submit final RMP and Response to Comments to MassDEP*
2. *July 2022 – MassDEP to review*
3. *August 2022 – MassDEP approval*

These dates were extended from the amended ACO due to public concerns and hydrological conditions. The final date of the BCWMP will likely be delayed due to the revised dates for the RMP.

4. **Comment Page 51**

The control of septic system inputs is recommended, although not currently required to meet the TMDL. Older homes with cesspools may be contributing disproportionate amounts of phosphorus to the groundwater near the lake. A septic system inspection program and bylaw to insure Title 5 compliance could be instituted in the local towns as part of general lake nutrient management activities.

What did a review of town by-laws, Board of Health regulations, and the current status of septic systems for properties in the study area determine? If this was not done, what information is needed?

MassDEP Response: A review of the town by-laws, Board of Health regulations and current status of septic systems is outside the scope of the TMDL. Local Boards of Health are the Approving Authorities and are required to insure Title 5 compliance under state regulations. This paragraph has been revised to clarify that additional by-laws or regulations are not required.

As part of a Comprehensive Wastewater Management Plan (CWMP), the town would inventory the homes that are currently on septic systems in the watershed, determine when the last inspections were completed, and define sewer needs areas. Where sewering is not under consideration, compliance with Title 5 and installation of Innovative Alternative (I/A) septic systems should be prioritized.

5. **Comment Page 53**

The City of Brockton is required to complete several tasks as outlined in the recent Administrative Consent Order (MassDEP 2017). The local towns of Halifax, Pembroke and Hanson will be required to comply with their relevant stormwater permits. The costs of in-lake treatments including aluminum treatment should be equitably shared by the responsible parties with the City of Brockton, the towns of Halifax, Hanson and Pembroke as well as cranberry growers with additional funding provided by matching state and federal grants, as available

> *Given that the State, and through its "grant" by the State, the City of Brockton, are responsible for Monponsett Pond, as it is a "Great Pond", under what statutes are the Towns of Hanson and Halifax responsible for costs for in-lake treatment of West Monponsett and East Monponsett?*

MassDEP: The Towns of Hanson and Halifax are not required to continue paying for in-lake treatment of the ponds. Between 2013 and 2019, 50 g/m^2 of alum treatment have been applied to West Monponsett Pond, consistent with the recommendation of the TMDL.

6. Comment page 53

A proactive approach to protecting the waterbodies in the TMDL study area may include implementation of local bylaws limiting development, particularly in areas near the lake, changes in zoning laws and lot sizes, requirements that new developments and new roadways include BMPs for runoff management and more stringent regulation of septic systems. As new housing development expands within the watershed, additional measures are needed to minimize the associated additional inputs of phosphorus. Although over fertilization of lawns was not apparent based on visual examination, homeowners should be aware of the Massachusetts Law limiting the use of phosphorus fertilizers on lawns (MGL Ch. 128 S. 65A). Additional BMPs are presented in the Nonpoint Source Management Manual by Boutiette and Duerring (1994) that was distributed to all municipalities in Massachusetts. Other voluntary measures may include encouraging the establishment of a native plant, vegetative buffer around the lake. Such BMPs provide enhancements that residents should find attractive and, therefore, should facilitate voluntary implementation.

> *Has anyone at the Department of Environmental Protection reviewed the local by-laws and made recommendations for changes? Are the new stormwater by-laws sufficient?*

MassDEP Response: The Department has not reviewed nor made specific recommendations on changes to local by-laws. In this paragraph of the TMDL, the Department is recommending that towns in the watershed consider non-structural options to reduce phosphorus load and prevent further degradation of the Monponsett Pond system associated with current and future development within the watershed. Revised stormwater bylaws to align with requirements of the 2016 General Permit for Stormwater Discharges to MS4 are anticipated to be effective for nutrient reduction.

Comment Letter from the Jones River Watershed, Executive Director, Pine duBois, dated March 12, 2021

Dear Secretary Theoharides:

The Jones River Watershed Association (JRWA) supports the approval of the Total Phosphorus TMDL for West Monponsett Pond (Segment ID #MA62182), and East Monponsett Pond (MA62218), Stetson Pond (MA62182) and White Oak Reservoir (MA62157) in Halifax, Hanson, and Pembroke MA. The implementation of this TMDL will be important to improving water quality in not only the waters of the Monponsett Ponds system but in downstream waters Stump Brook in the Taunton River watershed, and as importantly, in Silver Lake and the Jones River in the South Coastal Jones River sub-basin. As noted in the referenced document, Monponsett Pond has been and continues to be seasonally diverted out of its native basin to Silver Lake to supplement the City of Brockton's water supply.

For thirty-five years the Jones River Watershed Association has been working on the ground to reduce residential, municipal, and agricultural nutrient sources. We have conducted successful stormwater improvements, dam removals, and land protections, and continue to work with regional and state partners to improve water quality and ecological connectivity. We have conducted water quality monitoring from our headwater at Silver Lake to Kingston Bay. We have personally and physically experienced the degradation (and finally, some improvement) of our local waters. Our current focus is to restore the diversity and populations of sea run and native aquatic species, which have been drastically thinned as a result of impairments over time, and impacts at sea. Our overarching mission is to protect, restore and steward the natural and historic resources of the Jones River and Cape Cod Bay for present and future generations.

The Jones River is the largest river draining to Cape Cod Bay, and is vital to sustaining the Gulf of Maine fishery. As a result of improvements to water quality and removal of dams, the MA DFG recently re-classified the Jones as a "cold water fishery" from Kingston Bay to Silver Lake.

We absolutely concur with DEP that reduction of external nutrient loading is currently the most important way to ensure long-term water quality in Monponsett Ponds and Silver Lake. We are grateful for the state and local investments of time, effort and funding to begin to address the pollutant discharges into the waterways of the region. However, there are other management actions that can and must be taken. Our comments below lead to some suggestions, and we endorse the recommendations of our sister watershed TRWA for greater use of the Aquaria desalinization plant, examine ground water wells development, and bring MWRA to Brockton.

Primary Comments:

7. **Comment Pages 3-4**

   We note that on page 3, paragraph 5, the executive summary fails to mention the root cause of the diversions made by the City of Brockton to Silver Lake which is an interbasin transfer that was allowed by the emergency legislative action in 1964.

Diversions to Silver Lake are through a pipe laid by Brockton and permitted under Ch. 91 by DEP. While the diversion is a gravity flow, moving tens of thousands of seriously impaired water into the primarily spring fed deep water glacial lake, when instead, the water could be delivered to the Brockton Treatment Plant is a serious flaw in regulatory oversight.

Following implementation of the Water Management Act in 1985, Brockton was somehow allowed to register a commingled 11.11 million gallons of water daily, from its treatment plant although less than 5 MGD originated from Silver Lake during the 1981-1985. If Brockton were to withdraw the daily sustainable amount of water from Silver Lake, there would be no diversions, and no Interbasin Transfer of pollutants from the Taunton River watershed via Monponsett Pond into Brockton's primary drinking water supply, and the headwater of the Jones River.

MassDEP Response: The following language has been added to page 4. "The City of Brockton is authorized through an emergency legislative action in 1964 to withdraw water from Silver Lake."

The TMDL recommends that the City of Brockton conduct a watershed and water supply management plan that focuses on management efforts to improve water quality in Monponsett Ponds. This planning process could also allow for factoring in the effects of population changes as well as alternative sources of water supply. The 2017 ACO requires that the City of Brockton develop a Comprehensive Water Management Plan.

8. **Comment Page 20**

On page 20, "Flow Issues" DEP details the natural watershed flow to East and West Monponsett Pond—which is divided by Route 58 (not 56). Naturally, Monponsett Pond outlets down Stump Brook, and prior to construction of that dam by the City in1964, the high-water level in the ponds was a foot lower than the elevation held today. Nowhere does DEP mention this as the cause of pollutant infiltration from the surrounding landscape.

In 1964 the homes surrounding Monponsett Pond were mostly summer cabins on small lots that were expanded to permanent residences overtime. Even though cesspools were upgraded to septic systems, because the water table was raised by the dam, and managed by Brockton to keep the high level because of the limiting conditions of the Act of 1964, pollution routinely is discharged to the ponds from the surrounding landscape. DEP should address this fact, remembering that the Act of 1964 was an "Emergency Law" to address a particularly extreme drought with the City literally ablaze. It was not intended as a permanent solution to Brockton's long-standing water supply deficit. The Central Plymouth County Water District was established by the same Act 371 because the Legislature was made aware by the bus loads of people attending the hearings, that this could not be a permanent solution. It still is not a solution, and the current state of pollution in these ponds is plain evidence of that FACT.

MassDEP Response: Section "Pollutant Load Allocations" and Appendix A include detailed explanation of the how landuse and the associated phosphorus loading in the watershed was accounted for in the TMDL. The change in water level elevation would increase travel time but not increase the loading. The land use loading calculations are steady state, not time dependent.

When Brockton was given the right in 1899 to use Silver Lake for water supply, it was on the condition that it serve the Town of Whitman as well. The City built a 30-inch high dam on Jones River raising the level of the lake by a foot. By the 1920s the Brockton Water Commission was concerned about running out of water because it was using an excess of 2MGD. This was the amount of water stored in that extra foot of impounded lake level. By the 1950's Brockton was using 4MGD and was unsuccessful in finding new supply. The 1964 drought brought strange relief to the City but led to devastation of the Jones River and gross water impairment in Monponsett Ponds too.

In the same paragraph noted above, it is mentioned that 'there are concerns that the potentially toxic cyanobacterial blooms and excess nutrients in West and East Monponsett Ponds will flow into Silver Lake…'. Silver Lake is already an impaired water body due to lack of flow as a direct result of excessive withdrawals by Brockton. Further diversions should not be occurring according to MA DEP: "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" (MassDEP, 2007)."

9. **Comment Page 20**

   Flow directed from Monponsett Pond to Silver Lake is not naturally occurring, and therefore water flowing from Monponsett Pond into Silver Lake should be subject to higher standards than are currently in place.

MassDEP Response: Silver Lake is listed as a Class A surface water and therefore protected at the highest level by regulation in the Massachusetts Surface Water Quality Standards. See response to Comment on page 137.

Further, the same paragraph states that the use of Silver Lake as a PWS results in only brief outflows to the Jones River (Princeton Hydro, 2013). These 'only brief outflows' from Silver Lake result in diadromous fish populations being blocked from migration to and from Silver Lake and should be included in the discussion. Silver Lake is one of the twelve largest lakes in the Commonwealth. It is deep and cold and now recognized as part of the CFR of the Jones River. DEP acknowledges the studies that show that a third of the total Phosphorus in Silver Lake is from the diversion of Monponsett Pond. This nutrient from the diversion is causing excessive weed growth in the Lake and the chronic near yearly drawdowns kill off the mussels—

many of them of special concern—that would otherwise clean the waters and contribute to the health of the Lake and ecosystem.

10. Comment Page 20

> This paragraph further states "In 1995 MassDEP and the City of Brockton signed an Administrative Consent Order (ACO) which required the City to develop a Comprehensive Water Management Plan and a strategy to reduce environmental impacts." The City of Brockton has not yet produced an approvable "Comprehensive Water Management Plan" after more than 26 years—and its so-called "Drought Management Plan" allows for the Lake to be drawn below the City's intake structure, which leads to concentration of pollutants, huge mussel die-off and often fish-kills as well. See https://jonesriver.org/ecology/silver-lake/ for pictures and videos from 2016 and 2017.

MassDEP Response: See Response to Comment #3, page 194. A requirement of the 2017 Administrative Consent Order signed by the City of Brockton requires them to develop a Monponsett Resource Management Plan (RMP) and a new Brockton Comprehensive Wastewater Management Plan (BCWMP). The current proposed schedule for completing the RMP requires submittal of the final RMP in July 2022. The RMP will become part of Brockton's Comprehensive Water Management Plan (BCWMP).

11. Comment Page 20

> In that paragraph DEP should consider adding to the sentence "The diversion of water from East Monponsett Pond affects the hydrology of both West and East Monponsett Ponds and increases the risk of introducing cyanobacteria to the public water supply source, Silver Lake." That the diversion of water not only increases the risk of introducing cyanobacteria, but also introduces excess nutrients from the Monponsett Pond complex (the cause of cyanobacteria blooms) into Silver Lake, an Outstanding Resource Water, which is a violation of the Clean Water Act and Mass Water Quality Standards.

MassDEP Response: On Page 20 MassDEP states: "There are concerns that the potentially toxic cyanobacterial blooms and <u>excess nutrients</u> (underline added) in West and East Monponsett Ponds will flow into Silver Lake and the altered hydrology may impact both West and East Monponsett Ponds as well as their downstream outlet, Stump Brook which suffers from low flows (Princeton Hydro, 2013; Horsley Witten, 2015)."

12. Comment 12 Page 27

> On page 27, first paragraph under "Recent Aluminum Treatments for West Monponsett Pond" we would like to note that the impacts of alum treatments in West Monponsett pond could have downstream consequences in Silver Lake and should be evaluated.

MassDEP Response: The diversion from East Monponsett to Silver Lake is only allowed from October 1 to May 31. Alum treatments are typically completed in June when there are no diversions to Silver Lake. One exception to the diversion calendar is in the event of downstream flooding, a diversion may be allowed. However, no diversions are allowed for a minimum of 5 days after alum treatments specifically to avoid loss of alum downstream. At this time, there are no scheduled alum treatments for East or West Monponsett Pond.

13. Comment Page 40

> On page 40, second paragraph, it is stated that "East Monponsett Pond is also classified as Class A and (insert: by way of diversions) is tributary to the public water supply, Silver Lake, and thus a lower target TP concentration should be considered as a measure to protect the water supply use of the Monponsett Ponds. A target of 20 ppb TP was initially selected because even at the higher current concentrations, no obvious impact to Silver Lake water quality has been observed and based on the LLRM model estimates that the chlorophyll a will meet the target of 16 ppb approximately 96% of the time."
>
> We agree that the lower target of 20 ppb (or lower) should be applied, and we would like to push for regular TP and chlorophyll-a monitoring in Silver Lake, as relying on a model developed more than 10 years ago might not accurately describe the reality of the situation in Silver Lake now, or even in the past, as this picture taken in Kingston suggests.

MassDEP Response: The target concentration for total phosphorus was lowered to 18 ppb in the TMDL. The baseline water quality data used in the spreadsheet modeling of the TMDL was collected in 2009. This data year was selected because it represents conditions prior to alum treatment. The final TMDL includes a target concentration and total phosphorus reductions intended to meet the SWQS. In addition, see page 56, "Provisions for Revising the TMDL." The following is an excerpt from this section: "MassDEP uses an adaptive management approach to observe implementation results over time and allow for adjustments. If water quality targets are met and yet guidance threshold values and other habitat indicators indicate impaired water quality, total phosphorus water quality targets may be revised and TMDL loadings adjusted accordingly."

14. Comment Page 48

On page 48, first paragraph under "Impact of Diversions" it is stated "For example, if the diversion of water and associated nutrients to Silver Lake did not occur then our model estimates that TP concentrations in West Monponsett Pond would decrease by 24%." The DEP notes that this would likely be due to increased flushing as East Pond naturally flows to West Pond. DEP neglects to say this would require management of the Stump Brook dam that would allow water to continuously flow downstream through Stump Brook to the Winnetuxet and beyond. We would like to note that this is evidence that stopping diversions and limiting the City of Brockton to a sustainable withdrawal from Silver Lake (<4.5 mgd) would benefit multiple watersheds, and the whole of Massachusetts Bay including Narragansett, Cape Cod bays.

*MassDEP Response: This administrative consent order requires that the City of Brockton take action to reduce the likelihood of water going from the West Monponsett Pond to East Monponsett Pond (reverse of the natural flow) during diversion by altering their diversion transfer rate (MassDEP 2017, Provision 28). The ACO (MassDEP 2017) requires a minimum flow of 900,000 gallons/day to leave West Monponsett Pond both during diversion periods and beginning June 1, 2017 to be released at all times unless as stipulated in the consent order (Provisions 30,32). Refer to Section titled, **Flow Management**, page 50.*

15. Comment Page 53

On page 53, second paragraph it is stated "The costs of in-lake treatments including aluminum treatment should be equitably shared by the responsible parties with the City of Brockton, the towns of Halifax, Hanson and Pembroke as well as cranberry growers with additional funding provided by matching state and federal grants, as available." We would like to have an environmental impact report done on the impact the alum treatments being used in these ponds has on freshwater mussel assemblages – as damage to any of these ecosystems is a shared burden.

Eastern shore of Silver Lake, October 1999

MassDEP Response: Refer to page 26 of the TMDL. Due to concerns about three state listed aquatic species of concern, additional testing was required as part of the Wetland Protection Act Order of Conditions.
A 'REVISED Habitat Management Plan for Phosphorus Inactivation in the Western Basin of Monponsett Pond' was submitted to the Massachusetts Division of Fisheries and Wildlife (DF&W) Natural Heritage and Endangered Species Review Program (NHESP) on March 31, 2015. The NHESP provided approval correspondence on May 14, 2015. The additional testing was completed by the NHESP-approved biologist and reported in the following: westmonponsettpondreport2015.pdf (halifax-ma.org) and https://www.halifax-ma.org/sites/g/files/vyhlif4496/f/uploads/westmonponsettreport2017.pdf.

16. Comment

In addition, an alternatives analysis should be done to evaluate the expense of plumbing the Monponsett diversion directly to the Brockton Treatment Plant, or better, installing wells for ground water plumbed to the Brockton plan to improve the health of the overall system. Dams in Stump Brook, Furnace Pond and Jones River could then be removed, while diadromous fish and ecosystem health could be restored. Upgrading this vital water supply system would be well worth the cost now to ensure sustainable water supplies as well as improve the health of ecosystems in the three watersheds now suffering significant impairments due to the current short-sighted management practices.

MassDEP Response: The TMDL recommends that the City of Brockton conduct a watershed and water supply management plan that focuses on management efforts to improve water quality in Monponsett Ponds. This planning process could also allow for factoring in the effects of population changes as well as alternative sources of water supply. The 2017 ACO requires that the City of Brockton develop a Comprehensive Water Management Plan (BCWMP). The current schedule for completion of the Monponsett Resource Management Plan (RMP) is July 2022.

17. Comment Page 55

On Page 55, Table 10, final column and row, we would like to know what the incentive for performance or penalty for non-compliance with the mentioned Administrative Consent Order by the City of Brockton.

MassDEP Response: The 2017 Administrative Consent Order (and amended in 2018) signed by the City of Brockton (ACO) does not include stipulated penalties for non-compliance. The City is currently in compliance with the requirements of the ACO and amendment except those that were beyond the control of the City of Brockton.

18. Comment Page 106

On page 106, paragraph 2, it is stated "The clear water seepage lakes are thus more sensitive to nutrient inputs and generally should have lower total phosphorus concentrations. Clearwater seepage lakes in southeastern Massachusetts may reasonably be expected to have concentrations of total phosphorus of less than 20 ppb and possibly as low as 8 ppb (MassDEP, 2003, 2004, 2007a, 2007b, 2009, 2013; USEPA, 2001; http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/lakes/lakes_14.pdf)." We would like to note that Silver Lake falls under the category of "seepage lake". We recommend that this classification, along with Silver Lake's flow impaired status, its "class A" designation, and now, recognition as a Cold Water Fishery, that Silver Lake should be managed to the highest possible standard and an expectation of having less than 8 ppb total phosphorus, with sustained flows to Jones River, and should be monitored as such according to DEP's guidelines (MassDEP, 2003, 2004, 2007a, 2007b, 2009, 2013; 2017; USEPA, 2001; Horsley Witten, 2015; Princeton Hydro, 2013; http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/lakes/lakes_14.pdf).

MassDEP Response: It is listed as a Class A surface water and therefore protected at the highest level by regulation in the Massachusetts Surface Water Quality Standards as well as protections under the Massachusetts Drinking Water Program regulations.

Thank you for considering these comments.

Pine duBois
Executive Director

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Comment Letter via email from Joseph Callahan, President Taunton River Watershed Alliance dated March 9, 2021.

Dear Ms. Theoharides:

The Taunton River Watershed Alliance (TRWA) supports the approval of the Total Phosphorus TMDL for West Monponsett Pond (Segment ID #MA62182), and East Monponsett Pond (MA62218), Stetson Pond (MA62182) and White Oak Reservoir (MA62157) in Halifax, Hanson, and Pembroke MA. The implementation of this TMDL will be important to improving water quality in not only the waters of the Monponsett Ponds system but downstream waters in Stump Brook in the Taunton River watershed and Silver Lake and the Jones River in the Jones River watershed.

For 32 years, TRWA has been a voice for the 562 square mile Taunton River watershed, an advocate for environmental protection, sustainable development, and responsible stewardship of
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our precious water resources. We are an Alliance of concerned residents, businesses, and organizations united to restore and properly manage water and related natural resources within the Taunton River Watershed.

We note that the TMDL targets in table ES-1 of the Executive Summary on page 5 of 142 particularly the 13 to 23 ppb concentration targets are well supported in the text of the TMDL. The discussion concerning the Impact of Diversions on page 48 of 142 is very important to TRWA because these diversions adversely affect the water quality of East Monponsett Pond, West Monponsett Pond, and Stump Brook in the Taunton watershed by reducing flushing of TP from this system as well as the quality of Silver Lake and the Jones River in the neighboring Jones River watershed.

We support the MassDEP Administrative Consent Order to the City of Brockton. This administrative consent order requires that the City of Brockton take action to reduce the likelihood of water going from the West Monponsett Pond to East Monponsett Pond (reverse of the natural flow) during diversion by altering their diversion transfer rate (MassDEP 2017, Provision 28). The ACO (MassDEP 2017) requires a minimum flow of 900,000 gallons/day to leave West Monponsett Pond both during diversion periods and beginning June 1, 2017 to be released at all times unless as stipulated in the consent order (Provisions 30,32). The ACO also requires the City of Brockton to create a Resource Management Plan that will "based on scientific data and evaluation that will include recommended metrics and procedures for Silver Lake Diversions and Stump Brook Dam operations intended to improve Monponsett Pond's water quality and ecosystem while maintaining Brockton's drinking water supply system reliability" (Provisions33). In order to study possible dam management regimes, it is recommended that the potential for increased flushing based on cyanobacteria counts be investigated.

TRWA believes this TMDL documents why every effort should be made to eliminate or reduce reliance on East Monponsett Pond and Silver Lake for water supply diversion because of the harm caused to waterbodies in both the Taunton and Jones River watersheds. We believe other alternatives including water conservation, tie-in to MWRA for summer demand augmentation or increased use of water from the Aquaria desalinization plant would be better alternatives.
We support the measures included on Pages 49 through 51to reduce TP loadings from cranberry bogs. As stated in the TMDL "A key to the success of this TMDL is the reduction of TP load from local cranberry bogs whose discharge is tributary to the lake." By "lake" we assume MassDEP means any of the ponds or waterbodies in this area of the watershed.

Pages 51 and 52 of the TMDL describe measures for control of septic loads and stormwater loads. TRWA notes that many of the homes around these waterbodies are converted former summer cottages on small lots close to the impaired waterbodies. These areas should be given priority for sewer extension including state assistance due to the likelihood of surface water pollution from continued use of septic system wastewater disposal. The average life span of a septic system is 20 to 30 years. Until sewers are available, systems older than 20 years should be dye tested to make sure they do not have a direct hydraulic connection to any of the waterbodies covered by the TMDL. Any property with a direct hydraulic connection to a waterbody or storm drain should be required to remove the connection.

On page 52 the TMDL states, “The 2016 Massachusetts MS4 General Permit will become effective July 1, 2018. Until that time, the 2003 General Permit is in effect.” This statement is no longer accurate (the reference to the 2003 GP should be deleted). The MS4 General Permit became effective July 1, 2018. This means that important elements required 3 years after the permit effective date such as the requirement on page 45 for MS4 communities to adopt improved bylaws to regulate new development and redevelopment are required by June 30, 2021 less than four months from now.

Thank you for considering these comments.
Truly yours,

Joseph Callahan
President

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MassDEP Response: Thank you for your comments and your support of the Total Phosphorus targeted reductions specified in the TMDL. The reference on page 52 to the effective date of the 2016 MS4 General Permit for Stormwater Discharges has been revised.

Comment Letter via email from the Central Plymouth County Water District Commission dated March 12, 2021.

Dear Ms. Theoharides:

Central Plymouth County Water District Commission (CPCWDC) supports the approval of the Final Draft, West and East Monponsett Pond System, Total Maximum Daily Loads for Total Phosphorus (CN 446.1) (the TMDL). This project was initiated many years ago to address ongoing water quality issues with recreation and public water supply uses. While many of the interventions required by the TMDL either have been or are being implemented, there is still a significant effort required to restore this water system. The swift approval of this Final Draft will be a rallying point for stakeholders to focus and redouble their efforts toward implementing solutions.

CPCWDC was established by the Massachusetts Legislature in 1964. It is composed of three Commissioners appointed by an Advisory Board representing the eight municipalities of the Central Plymouth County Water District. We take a partnership-based approach to developing innovative, holistic solutions to the intertwined issues of water and quantity, ecosystem health, and community resiliency in our District.

We welcome the changes made to this TMDL in response to previous comments from the EPA and the public. In particular, we welcome the required 50-70% reductions in TP loading from developed land uses and stormwater sources. Although this is a significant reduction that will be challenging to meet, it is what is required to begin restoring this water system to a sustainable, resilient state. For decades the system has been degrading – a steady effort over several years will be required to turn the system around. It can be done.

Getting there will require a coordinated, collaborative effort to reduce septic and agricultural loads as well as implement stormwater best management practices, lawn fertilizer management, management of sediment, and adaptive management. This will be a significant effort that should not be shied away from. The health of this water system is critical to meeting the recreational and public water supply needs of several communities, contributing to quality of life and economic development.

CPCWDC welcomes the opportunity to collaborate with stakeholders in our District, including watershed associations, elected officials, municipal governments, and interested residents. For several years, we have been building relationships and bringing stakeholders together to discuss and address water quality and quantity issues in the District. We are currently developing a water quality monitoring program for Silver Lake and are discussing another project to investigate public water supply needs in and solutions for the District. We welcome collaboration on these projects and will be reaching out to stakeholders.

Thank you for your efforts on this TMDL project, and for considering these comments.
Best regards,

Joanne Zygmunt, Chair jzygmunt@plymouthcountyma.gov

MassDEP Response: We thank you for your enthusiastic support of the Monponsett Pond system TMDL for Total Phosphorous and your willingness to conduct outreach and collaboration with stakeholders to reach the target reduction goals.

Appendix G: Monponsett Pond Water Quality Sampling Data

Data associated with the TMDL study area can be found online at https://www.mass.gov/guides/water-quality-monitoring-program-data .

Select figures are provided below.

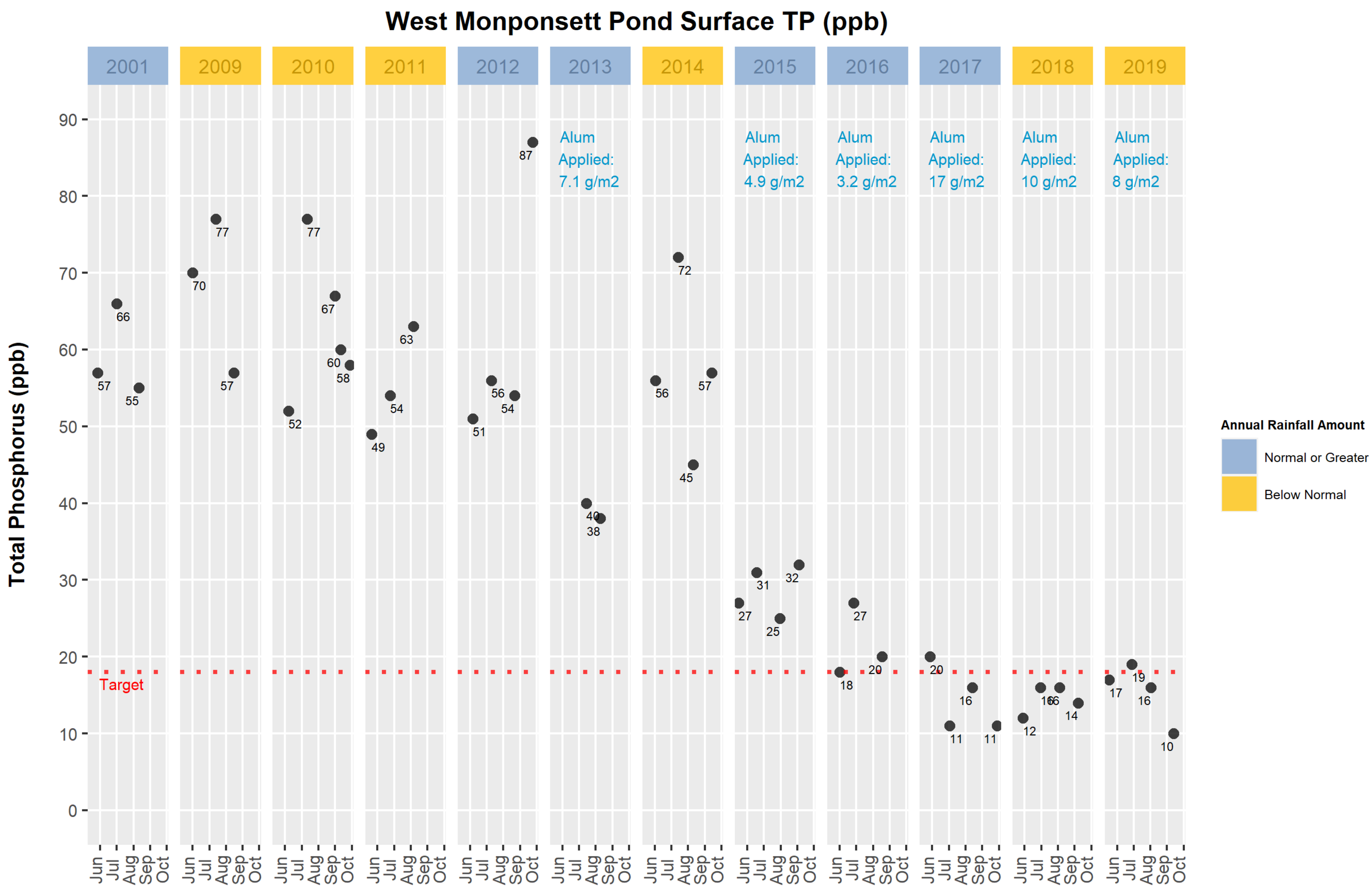

Figure G1. West Monponsett Pond Surface Total Phosphorus

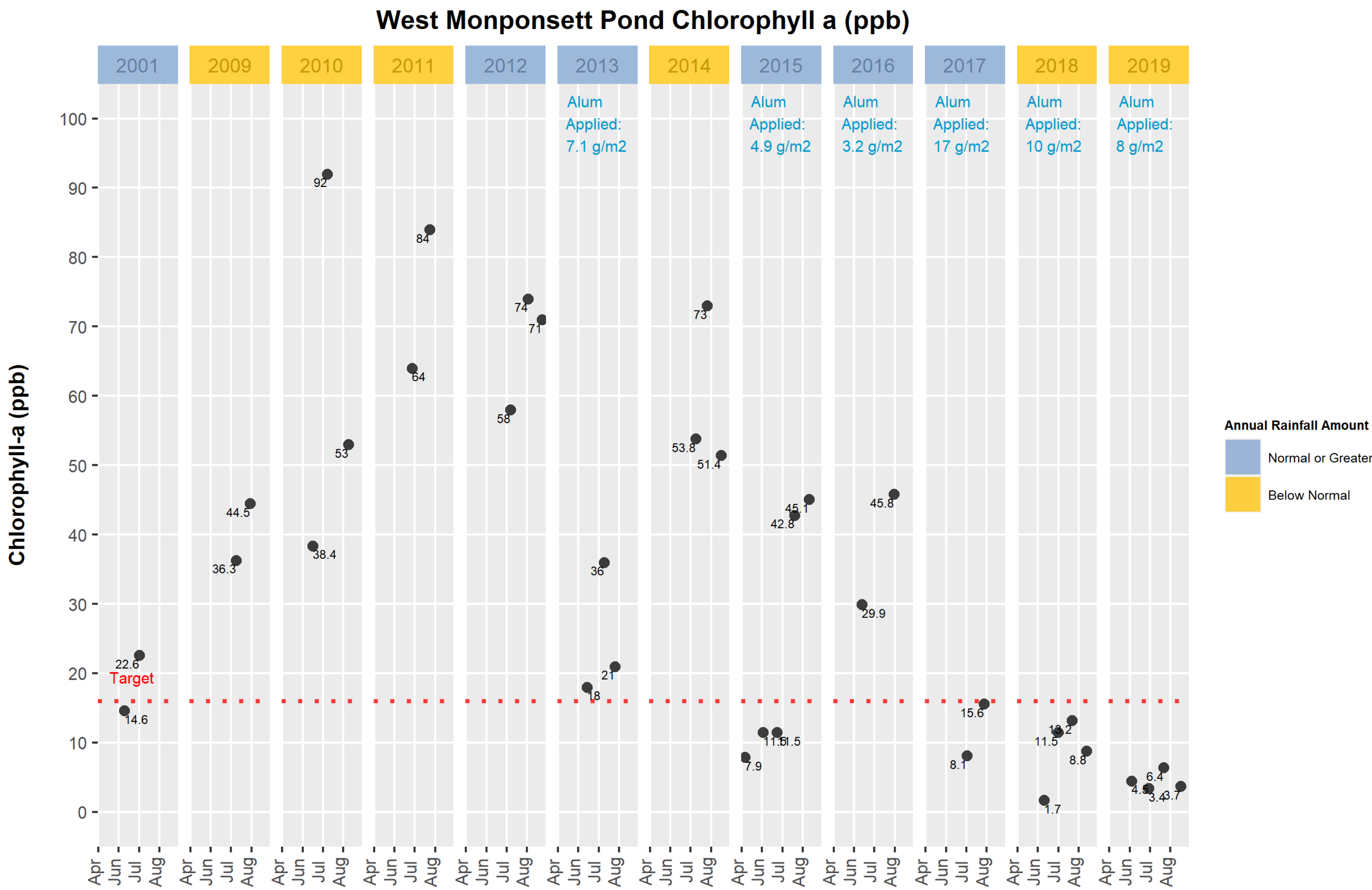

Figure G2. West Monponsett Pond Chlorophyll a Depth Integrated Samples and Surface Samples (note, one value of 200 ppb from August 2001 is excluded, Surface Samples 2017 only)

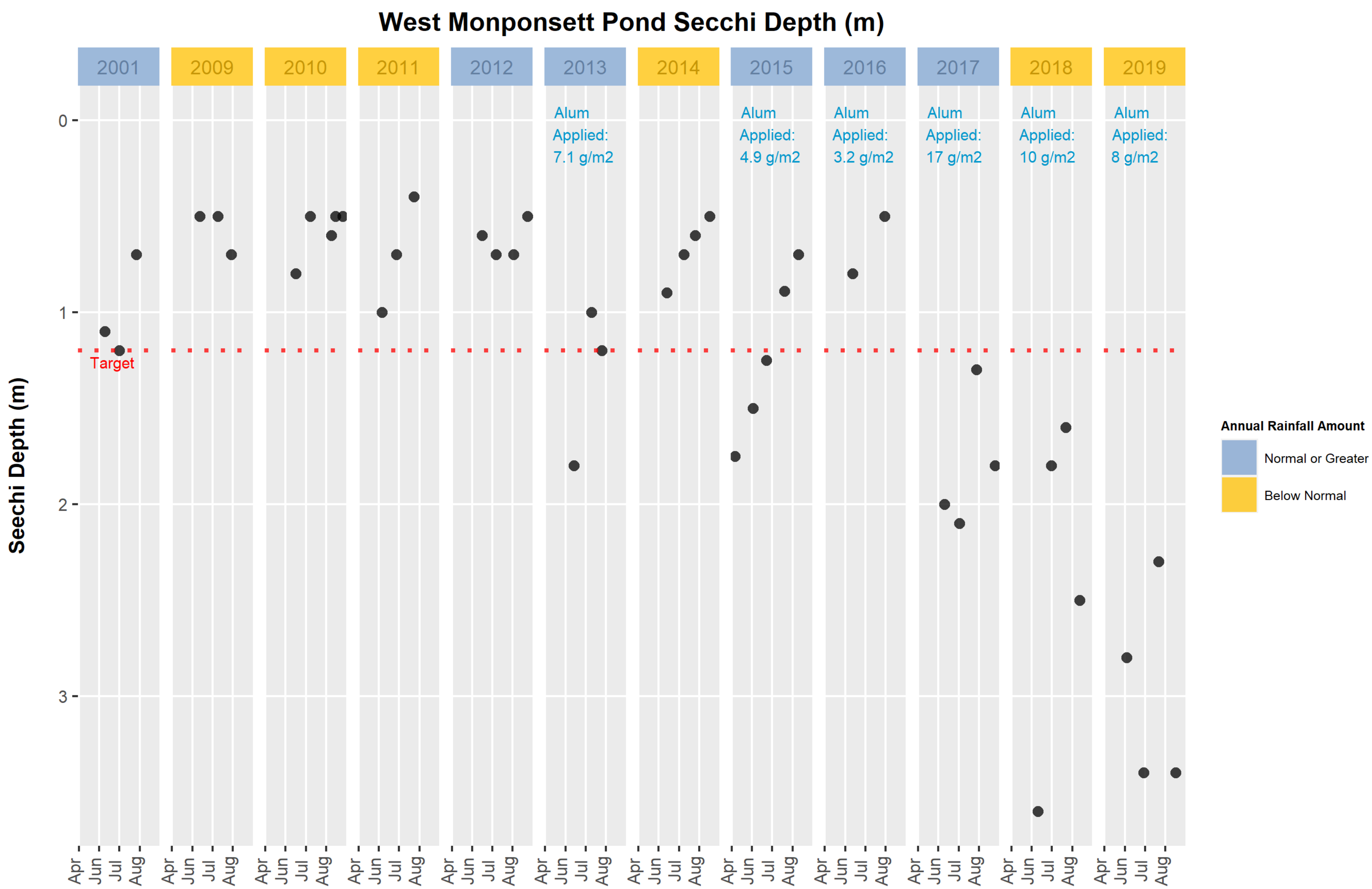

Figure G3. West Monponsett Pond Secchi Depth

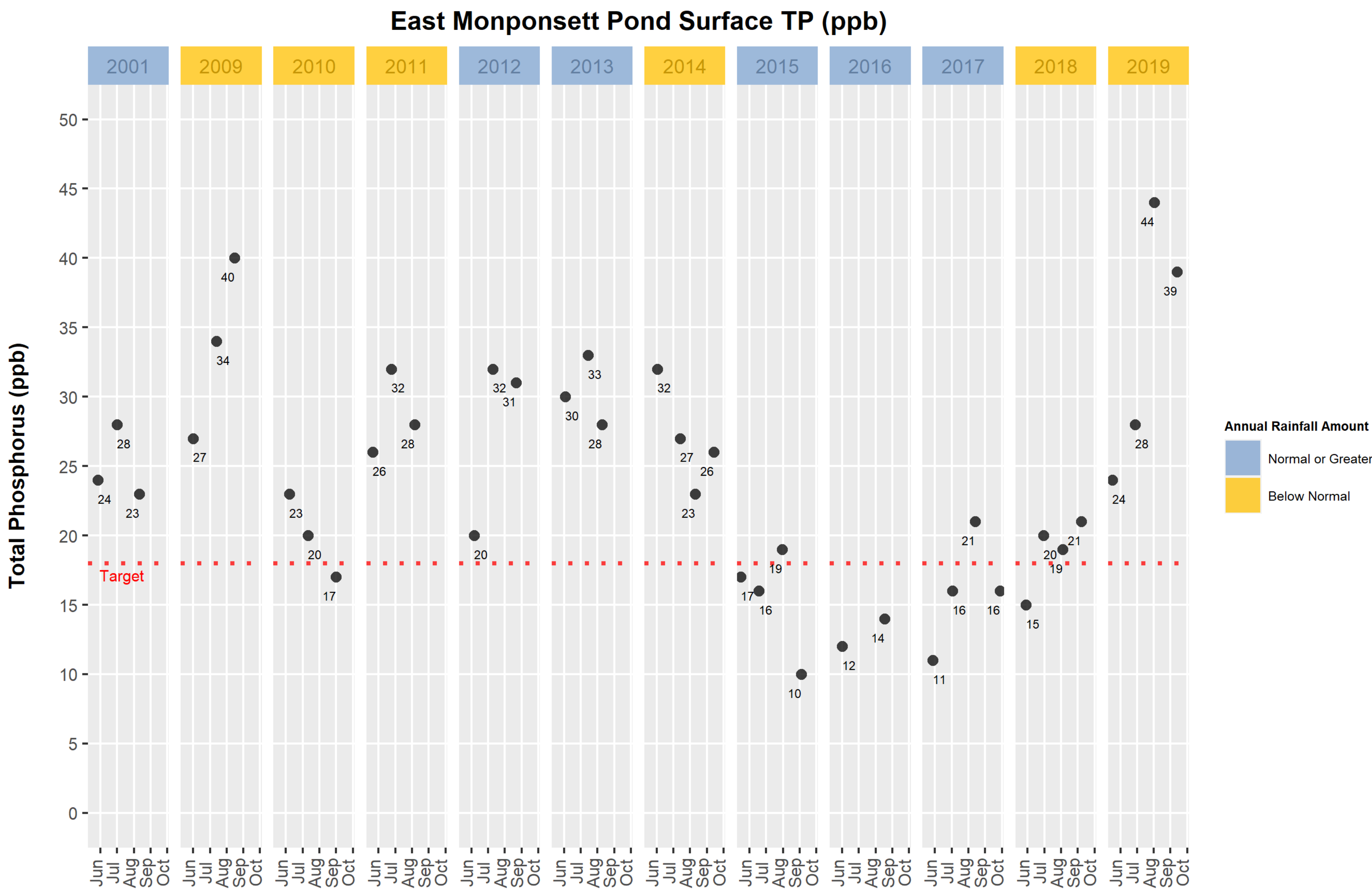

Figure G4. East Monponsett Pond Surface Total Phosphorus

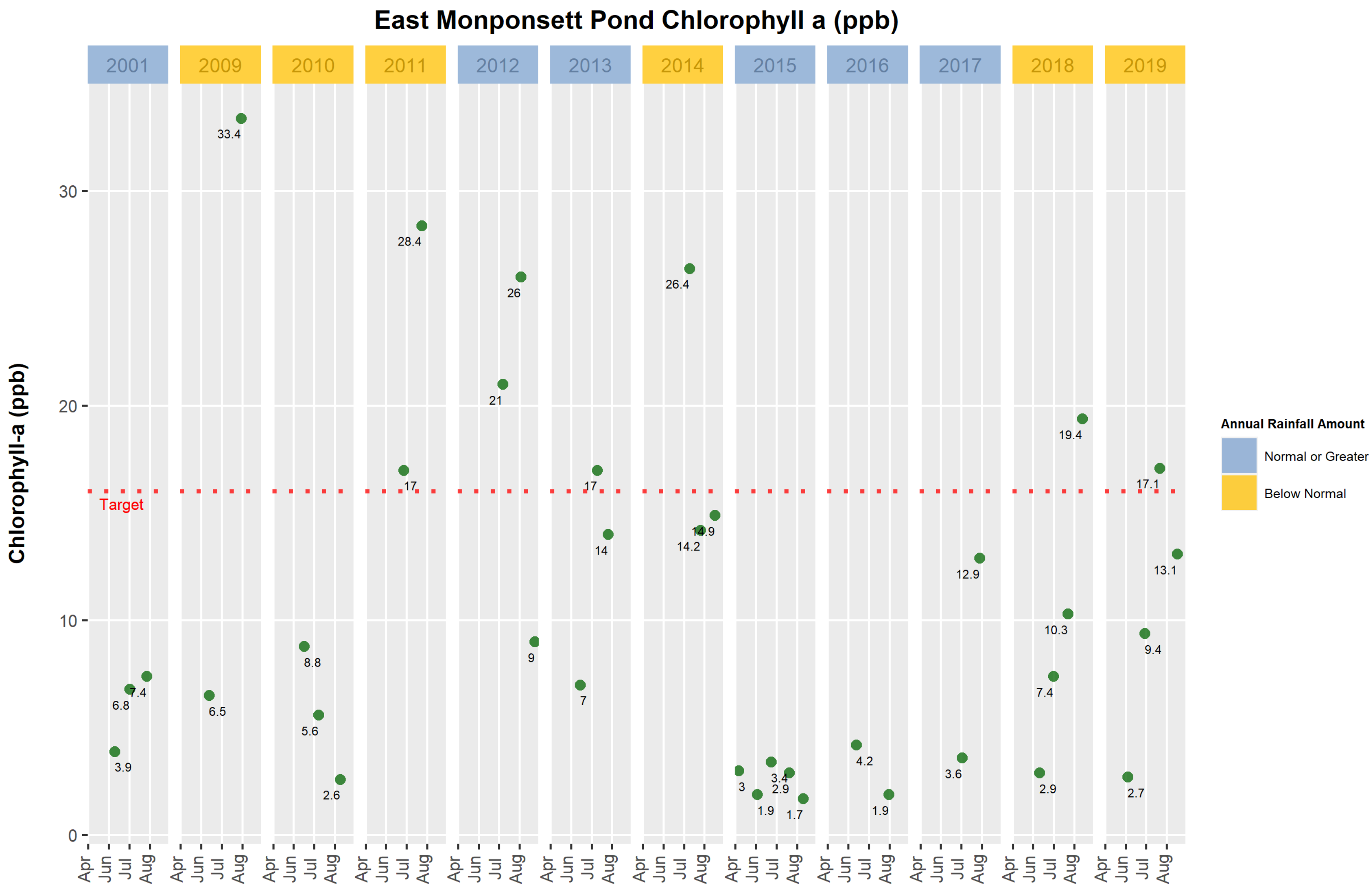

Figure G5. West Monponsett Pond Chlorophyll a Depth Integrated Samples and Surface Samples (Surface Samples 2017 only)