Restoring Water Quality in the Lake Memphremagog Basin: Evaluating Project Effectiveness along Three Tributaries in 2017

Prepared for the

Vermont Department of Environmental Conservation

by

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Memphremagog Watershed Association

The Memphremagog Watershed Association (MWA), founded in 2007, is a nonprofit organization dedicated to the preservation of the environment and natural beauty of the Lake Memphremagog Basin. The Memphremagog Watershed Association achieves this mission by 1) promoting the ecological awareness of people who live in, work in, and visit the Lake Memphremagog Basin; 2) promoting efforts to preserve the environment and natural beauty of the basin; 3) working with area lake associations; local, state, and federal governments; and businesses to develop guidelines and policies that protect and improve the quality of life in and around the basin; and 4) participating in efforts to monitor water quality in the lake and its tributaries, clean-up and re-naturalize shorelines, and protect local plants and wildlife.

Orleans County Natural Resources Conservation District

The Orleans County Natural Resources Conservation District (OCNRCD) was established in 1946 as a non-regulatory, grant-funded organization led by local landowners. OCNRCD's mission is to protect and enhance the quality of all of the waters in Orleans County by providing leadership, education, and services for implementing sound land stewardship practices.

Beck Pond LLC

Beck Pond LLC, a limited liability company founded in 2008, partners with public and private organizations to conduct scientific research that not only increases our understanding of the natural environment but also informs and guides on-the-ground conservation and management. Among other projects, Beck Pond LLC has conducted scientific studies and helped develop conservation projects that assessed the impacts of historical land uses on forest plant communities in northern New England; assessed the impacts of invasive plants on California grasslands and New England forests; identified, assessed, and proposed solutions to water quality problems in the Lake Memphremagog, White River, Mad River, and Missisquoi Bay Basins; protected and restored floodplain forests and wetlands along the Connecticut River and in the Lake Memphremagog Basin; and identified and protected critical wildlife habitat across northern New England and eastern Canada.

Cover. *Agricultural improvement projects, such as this filter strip along a small, ditched stream, have the potential to greatly improve water quality in the Lake Memphremagog Basin. Photographed in Irasburg, Vermont on 2 October 2017.*

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Acknowledgments

This project would not have been possible without the support and assistance of many individuals and organizations. Neil Kamman (Vermont Department of Environmental Conservation) spearheaded the development of, obtained funding for, and provided valuable advice throughout this project. Ben Copans (Vermont Department of Environmental Conservation) helped develop and implement all aspects of this project, including obtaining funding and support from the Vermont Agriculture and Environmental Laboratory, designing and implementing the project, collecting water samples, compiling and analyzing the water quality data, creating the flow duration curve template, and administering this project. Sarah Damsell and Lindsay Cotnoir (Orleans County Natural Resources Conservation District) obtained funding for and administered this project, collected water samples, and coordinated efforts to with local farmers to develop and implement conservation projects. David Pasco (Vermont Department of Environmental Conservation) administered the project. Jim Kellogg (Vermont Department of Environmental Conservation) and Dan Needham (Vermont Agriculture and Environmental Laboratory) enabled establishment of the Analytical Services Partnership to analyze the water samples at the Vermont Agriculture and Environmental Laboratory. Alison Farnsworth (Vermont Agriculture and Environmental Laboratory) provided valuable administrative and logistical support for analyzing the water samples at the Vermont Agriculture and Environmental Laboratory. Don Hendrich and Bill Round (Memphremagog Watershed Association) helped collect water samples. Kristen Underwood (South Mountain Research & Consulting) created the template that was used to guide the presentation in this report. Numerous landowners graciously allowed us to sample water quality and discussed restoration and protection opportunities on their properties. The Vermont Agency of Natural Resources supported this project financially through a LaRosa Volunteer Water Quality Monitoring Analytical Services Partnership Organizational Support Grant (2016-WQMON-04), LaRosa Volunteer Water Quality Monitoring Partnership Analytical Support (contract #33072), and Analytical Services Partnership with the Vermont Agriculture and Environmental Laboratory. The assistance and support of all of these individuals and organizations are greatly appreciated.

Executive Summary

1. Over the past decade, there has been increasing concern about water quality conditions in Lake Memphremagog, especially the high phosphorus levels and more frequent and widespread algal and cyanobacterial blooms. Because most of the lake's watershed lies in Vermont, considerable effort has been expended to identify, assess, and remediate nutrient and sediment sources along the Vermont tributaries of Lake Memphremagog. In 2017, we continued these efforts by further pinpointing and assessing possible sources of water quality problems and evaluating the success of projects and practices implemented to correct those problems. In this report, we present the data and analyses conducted to evaluate the success of water quality improvement projects and practices that were implemented along three tributaries of Lake Memphremagog and the Tomifobia River.

2. To evaluate the effectiveness of these water quality improvement projects and practices, we collected and analyzed water samples for total phosphorus and total nitrogen at 45 sites on eight dates during April-October 2017. We then analyzed the resulting water quality data to evaluate whether or not these projects and practices had actually led to improvements in water quality.

3. In general, water quality conditions were somewhat improved at three sites along Brighton Brook and its northern tributary, where farmstead improvement projects and field practices were implemented during 2015-2017. These improvements in water quality conditions, especially phosphorus levels, were most pronounced at the upstream-most site, which was located nearest to the agricultural production area and several large corn fields.

4. In general, phosphorus and sediment levels remained high at several sites along the Junkyard Tributary, where field practices have been improved in several steep, highly-erodible corn fields. At the two upstream sites, which drained the farmstead and these fields, phosphorus levels tended to decrease over time during 2013-2017, but similar decreases in phosphorus levels were not measured further downstream near the mouth of this tributary.

5. In general, water quality conditions were somewhat improved along the Tributary of Stearns Brook, where farmstead improvement projects and field practices were implemented during 2015-2017. The most dramatic decreases in phosphorus levels were measured at the sample site located immediately downstream of the farmstead.

6. Collectively, these data and analyses greatly increased our understanding of water quality conditions and possible sources of water quality problems in the Lake Memphremagog and Tomifobia River Basins. Based on these analyses, water quality conditions did tend to improve somewhat, but additional improvements in water quality are needed along all three tributaries. In 2018, we will continue to refine our knowledge about nutrient and sediment sources along the Vermont tributaries of Lake Memphremagog and the Tomifobia River and to identify and implement on-the-ground protection and restoration projects that most effectively reduce nutrient and sediment inputs.

1.0 Introduction

Lake Memphremagog straddles the United States/Canada border between the Northeast Kingdom of Vermont and the Eastern Townships (Cantons de l'Est) of Quebec. Lake Memphremagog and its tributaries are highly-valued resources that provide important ecological, economic, and aesthetic benefits. Water bodies in the basin are used extensively for boating, swimming, fishing, hunting, nature-viewing, and other recreational activities. Lake Memphremagog and the Clyde River (one of four major tributaries of Lake Memphremagog in Vermont) are important links in the Northern Forest Canoe Trail, which extends 1,191 km (740 mi) from Old Forge, New York through Vermont, Quebec, and New Hampshire to Fort Kent, Maine. Lake Memphremagog and other surface waters in the basin serve as public water supplies, provide hydroelectric power and disposal of treated wastewater, and support agricultural and industrial production. The floodplains and the many wetlands around the lake and its tributaries serve important flood control and water filtration functions and provide important fish and wildlife habitat. In addition, the surface waters and associated habitats support a number of rare plants and animals and significant natural communities, which contribute greatly to regional biodiversity.

Lake Memphremagog and its tributaries currently face a number of threats, including elevated sediment and nutrient levels, excessive algal growth, eutrophication, elevated mercury levels in walleye (*Sander vitreus*), and exotic species invasions (State of Vermont 2016a, 2016b, 2017b, Quebec/Vermont Steering Committee 2008). Over the past decade, there has been increasing interest in protecting and improving water quality in Lake Memphremagog and its tributaries. This interest has been spurred by concerns that water quality in Lake Memphremagog is declining and is threatened by high nutrient and sediment levels, more frequent and widespread algal blooms, and accelerated eutrophication (Figure 1). This concern has been further exacerbated by more frequent and widespread occurrences of cyanobacterial (blue-green algal) blooms, especially during the past several years (Figure 2). Lake Memphremagog has been listed by the State of Vermont as impaired and in need of a Total Maximum Daily Load (TMDL) due to elevated phosphorus levels, nutrient enrichment, and excessive algal growth (Part A, State of Vermont 2016a). In September 2017, the Environmental Protection Agency (EPA) approved a phosphorus TMDL for Lake Memphremagog that requires a 29% reduction in phosphorus loading to Lake Memphremagog (State of Vermont 2017a). In addition to reductions from developed lands, forested lands, and stream channel erosion,. the TMDL requires that large reductions come from agricultural lands, including a 46% reduction from farm fields and a 64% reduction from agricultural production areas.

Figure 1. *Turbid water and algae near the mouth of the Johns River in Derby, Vermont in 2006. Excessive nutrients and sediment increase plant and algal growth and decrease water quality.*

Efforts to identify and assess the various threats and to protect and improve water quality in the Lake Memphremagog Basin are coordinated by the Quebec/Vermont Steering Committee on Lake Memphremagog, an international partnership of governmental and non-governmental stakeholders from Quebec and Vermont. Since 2004, the Steering Committee has coordinated water quality monitoring efforts in both Quebec and Vermont. The overall goal of these efforts has been to identify, prioritize, implement, and evaluate projects and practices that protect and improve water quality throughout the Lake Memphremagog Basin. To that end, monitoring efforts have focused on documenting water quality conditions throughout the basin, assessing compliance with applicable water quality standards, calculating phosphorus loading in order to develop a comprehensive pollution control plan for the Vermont waters, identifying possible sources of water quality problems, identifying and prioritizing watersheds where protection and restoration projects will most effectively reduce nutrient and sediment loads, and developing and implementing on-the-ground projects and practices to protect and improve water quality. Since 71% of the Lake Memphremagog Basin lies in Vermont, many of these efforts have been focused along the Vermont tributaries of Lake Memphremagog.

Figure 2. *Cyanobacterial bloom along the north shore of Derby Bay in Derby, Vermont on 23 September 2008 (photograph courtesy of Karen Lippens). Cyanobacterial blooms are exacerbated by high nutrient and sediment levels and indicate that water quality is declining in Lake Memphremagog.*

2.0 Study Goals

In 2017, the Orleans County Natural Resources Conservation District (OCNRCD), Memphremagog Watershed Association (MWA), Vermont Department of Environmental Conservation (DEC), and Beck Pond LLC again partnered to undertake a multi-part program to protect and improve water quality in the Lake Memphremagog Basin as well as along Stearns Brook, a tributary of the Tomifobia River. As part of these efforts, we undertook targeted water quality sampling focused along three tributaries where phosphorus-reduction projects and practices had been implemented previously. The goal of this sampling was to evaluate the effectiveness of these projects and practices in protecting and improving water quality. As in previous years, we continued to share these data and analyses with key agency and organizational partners, who were able to further evaluate the need for and develop and implement projects and practices to reduce nutrient and sediment exports into Lake Memphremagog and the Tomifobia River.

3.0 Description of Watershed

The Lake Memphremagog Basin is located in the Northeast Kingdom of Vermont and the Eastern Townships (Cantons de l'Est) of Quebec and is a tributary watershed of the Saint-François River, which ultimately flows into the St. Lawrence River. This study focused on the Vermont portion of the Lake Memphremagog Basin, which includes approximately 1,266 km^2 (489 mi^2) in Orleans, Essex, Caledonia, and Lamoille Counties in northeastern Vermont (Figure 3). The Southern Basin of Lake Memphremagog is fed by three major tributaries that lie entirely within Vermont (Barton, Black, and Clyde Rivers) and one medium-sized tributary that straddles the Quebec/Vermont border (Johns River). In addition, numerous small tributaries flow from the eastern and western shores directly into Lake Memphremagog. Lake Memphremagog is listed as an impaired surface water in need of a TMDL due to nutrient enrichment, elevated phosphorus levels, and excessive algal growth (Part A, State of Vermont 2016a), and Lake Memphremagog and South Bay are listed as stressed due to elevated levels of mercury in walleye (State of Vermont 2016b). As noted earlier, a phosphorus TMDL was completed and approved for Lake Memphremagog in 2017 (State of Vermont 2017a).

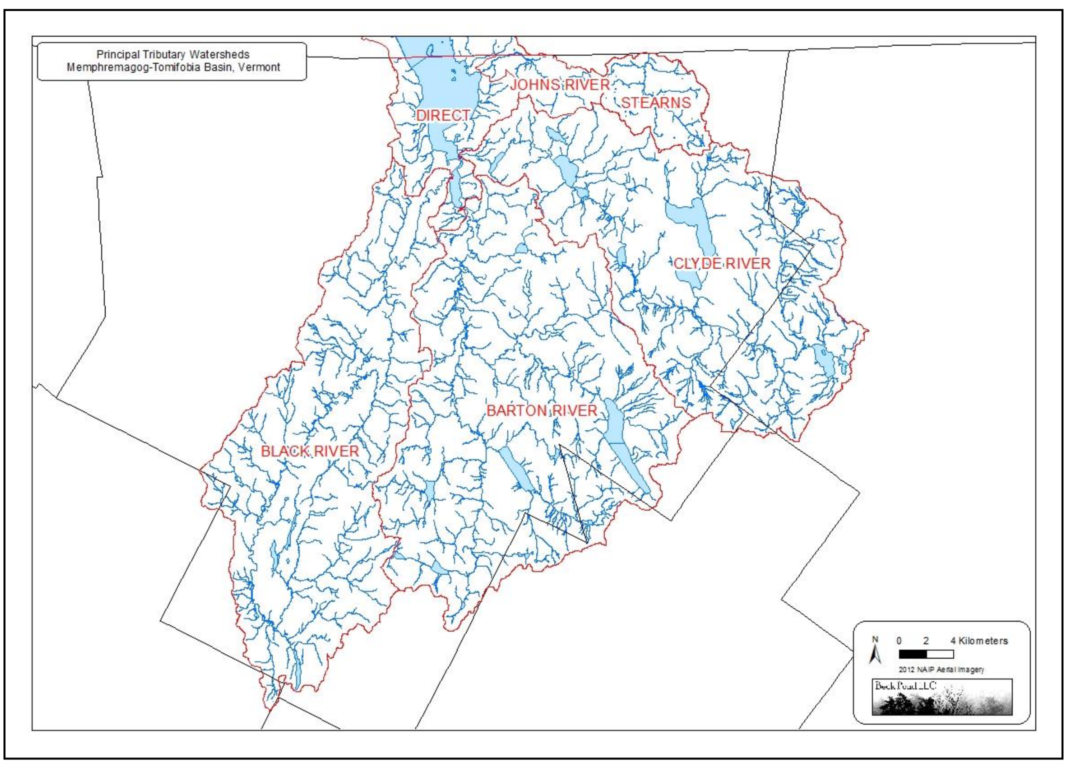

Figure 3. *Vermont portion of the Lake Memphremagog Basin, including the watersheds of the four major tributaries (Barton, Black, Clyde, and Johns Rivers), and the watershed of Stearns Brook, a tributary of the Tomifobia River.*

The Black River (Waterbody ID VT17-09/10) drains an area of 349 km^2 (135 mi^2) extending from its headwaters in the towns of Craftsbury and Greensboro downstream to the western shore of South Bay in Newport City. The watershed includes one major tributary (Lords Creek) and several small lakes and ponds. Lake Elligo has been altered by aquatic invasive species due to locally abundant Eurasian watermilfoil (*Myriophyllum spicatum*)(Part E, State of Vermont 2016a).

The Barton River (Waterbody ID VT17-07/08) drains an area of 445 km^2 (172 mi^2) extending from its headwaters in the towns of Barton, Glover, and Westmore downstream to the south end of South Bay in the town of Coventry. This watershed includes one major tributary (Willoughby River) and several large lakes, including Lake Willoughby [657 ha (1,623 acres)] and Crystal Lake [274 ha (677 acres)]. The Barton River in Orleans is listed as stressed due to the presence of toxins (State of Vermont 2016b). Roaring Brook, a tributary of the Barton River, is listed as impaired and in need of a TMDL due to elevated nutrients and impacted macroinvertebrates possibly due to agricultural runoff (Part A, State of Vermont 2016a). Brownington Pond has been altered by invasive aquatic species due to locally abundant Eurasian watermilfoil (Part E, State of Vermont 2016a). Finally, Shadow Lake has been altered by seasonal water level fluctuations that may be harming aquatic habitats and aesthetics (Part F, State of Vermont 2016a).

The Clyde River (Waterbody ID VT17-04) drains an area of 373 km^2 (144 mi^2) extending from its headwaters in the towns of Brighton and Morgan downstream to its mouth in Newport City. The watershed includes two major tributaries (Pherrins River and the outlet of Seymour and Echo Lakes) and numerous large lakes, including Seymour Lake [667 ha (1,648 acres)], Lake Salem [232 ha (573 acres)], and Island Pond [221 ha (546 acres)]. Lake Salem is already part of an approved TMDL addressing elevated mercury levels in walleye (Part D, State of Vermont 2016a). Lake Derby has been altered by aquatic invasive species due to locally abundant Eurasian watermilfoil (Part E, State of Vermont 2016a). An unnamed tributary in Brighton has been altered by flow regulation due to the possible lack of minimum flows below a water supply intake (Part F, State of Vermont 2016a). Finally, Clyde Pond has been listed as stressed due to elevated mercury levels in walleye (State of Vermont 2016b).

The Johns River (Waterbody ID VT17-01) drains an area of approximately 29 km^2 (11 mi^2) in the towns of Derby, Vermont and Stanstead, Quebec. The Johns River is fed by Crystal Brook and several smaller tributaries and flows into Lake Memphremagog at Derby Bay, just south of the Quebec/Vermont border. The Johns River has been listed as stressed due to elevated nitrogen and turbidity levels (State of Vermont 2016b). However, Crystal Brook was recently removed from the list of impaired surface waters in need of a TMDL thanks to projects that reduced sediment and nutrient inputs from agricultural runoff.

In addition, the Southern Basin of Lake Memphremagog is fed by numerous small tributary streams that flow directly into the eastern and western shores of the lake. Although small, any nutrients or sediments carried by these tributaries are delivered directly into and impact the health of the lake. None of these tributaries are listed as impaired or stressed (State of Vermont 2016a, 2016b), although high nutrient and sediment levels have been measured in several of these tributaries (Gerhardt 2009, 2010).

In 2014, we expanded this project to assess water quality conditions, to pinpoint and assess possible nutrient and sediment sources, and to work with landowners to implement phosphorus-reduction projects and practices in several small tributaries of Stearns Brook, which is a tributary of the Tomifobia River and ultimately of Lac Massawippi in Quebec. Stearns Brook (Waterbody ID VT17-02) drains an area of approximately 33 km^2 (13 mi^2) in the towns of Derby and Holland, Vermont and Stanstead-Est, Quebec. One of its tributaries is listed as impaired and in need of a TMDL due to elevated nutrients from agricultural runoff (Part A, State of Vermont 2016a). Stearns Brook itself is listed as stressed due to sediment eroding from streambanks, poor logging practices, and poor road maintenance (State of Vermont 2016b).

4.0 Methods

In 2017, we sampled and analyzed water quality at 45 sites along the Vermont tributaries of Lake Memphremagog and the Tomifobia River (Figure 4). These 45 sites included six sites along two tributaries of the Black River, 13 sites along two tributaries of the Barton River, eight sites along four tributaries of the Clyde River, and 18 sites along four tributaries of Stearns Brook. Of these 45 sites, 15 sites were sampled to assess the success of phosphorus-reduction projects and practices that had been or were being implemented along three tributaries of the Black River (Brighton Brook, 3 sites), Barton River (Junkyard Tributary, 6 sites), and Stearns Brook (Tributary of Stearns Brook, 6 sites).

To accomplish the goals of this study, we collected water samples on eight dates during 10 April-26 October 2017. These eight dates included six regularly-scheduled sampling dates, one snowmelt date, and one rain event. On each sample date, we collected water samples from each site to be analyzed for total phosphorus and total nitrogen. Samples were collected in pre-labeled, sterilized bottles according to protocols established in conjunction with the Vermont DEC and the Vermont Agriculture and Environmental Laboratory (State of Vermont 2006, 2009). At all sites, we collected grab samples with or without a dip sampler. Before collecting samples, we rinsed the total nitrogen bottles and dip sampler with sample water three times. All samples were collected on a single day, stored in coolers, and delivered to the Vermont Agriculture and Environmental Laboratory the next day or the following morning. This schedule ensured that the laboratory was able to process the samples in a timely manner.

Prior to sampling, we prepared a Quality Assurance Project Plan (QAPP) in conjunction with the Vermont DEC. To implement the Quality Assurance Project Plan, we collected five sets of field blanks and five sets of field duplicates on each sample date. Blank sample containers were rinsed and filled with de-ionized water and, if done properly, should result in values below the detection limits for each parameter (5 µg/l for total phosphorus and 0.1 mg/l for total nitrogen). Field duplicates required collecting a second set of samples at the same time and place as the original set of samples. When done properly, the mean Relative Percent Difference (RPD) among all pairs of duplicate samples should be less than 30% for total phosphorus and less than 20% for total nitrogen. For total phosphorus, we also collected matrix spikes at five sites on each sample date, so that the Vermont Agriculture and Environmental Laboratory could perform in-house quality assurance analyses.

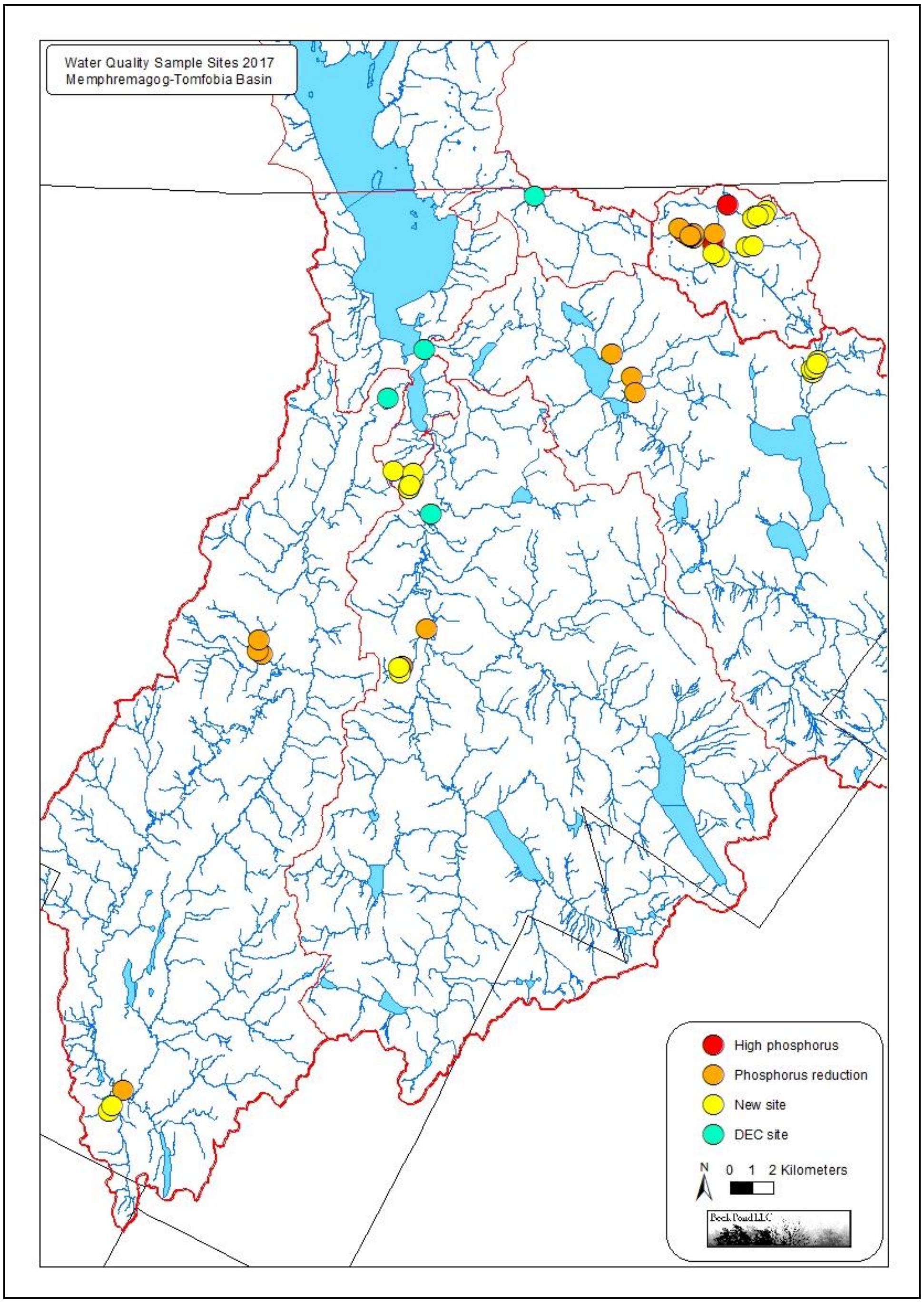

Figure 4. *Locations of 45 sample sites (plus four Vermont DEC sites) where water quality was sampled along the Vermont tributaries of Lake Memphremagog and the Tomifobia River during April-October 2017.*

To relate the water quality data to stream flows, we relied on a single source of stream flow data. The U.S. Geologic Survey (USGS) maintains gage stations that measure water depths and stream flows on the Barton, Black, and Clyde Rivers. For this study, we used the daily stream flows measured at the Black River as a proxy for stream flows at all sites, although all of our sites were located 4-30 km (2.5-18 mi) away on streams that were smaller and generally steeper than the Black River.

Both field and laboratory data were entered into Microsoft Excel spreadsheets (Microsoft Home and Office 2010, Microsoft, Redmond, Washington). All data sheets and analyses were archived by the author, and the electronic data were uploaded to the Vermont DEC for inclusion in their online databases.

4.1 Statistical Analyses

To evaluate the effectiveness of the water quality improvement projects, we used parametric *t*-tests and linear regressions to analyze differences in water quality conditions prior to and after the projects were implemented. A linear regression models the relationship between two numerical variables (in this study, the sample dates and total phosphorus or total nitrogen concentrations) to determine whether or not there is a statistically-significant relationship. A *t*-test compares the means of two groups of measurements (in this study, the total phosphorus or total nitrogen concentrations measured before and after treatment) to determine whether or not they are statistically different. For the *t*-tests presented in this report, we compared two years of pre-treatment data (2014-2015) and two years of post-treatment data (2016-2017). For all statistical tests, a *P*-value less than the established level of significance (0.05) indicates that the linear relationships were statistically significant or that the mean values before and after treatment were statistically different. A *P*-value greater than 0.05 indicates that the linear relationships or not statistically significant, that the two means are not statistically different, or that the available data are insufficient to detect a significant difference. The latter is particularly relevant for this study, because phosphorus levels can be extremely variable, and this variability and the strong relationship between phosphorus levels and stream flows combined with small sample sizes often make it difficult to detect significant differences, even when there are relatively large changes in mean or median values. For these parametric tests, total phosphorus and total nitrogen concentrations were $\log_{10}$-transformed to approximate a normal distribution.

5.0 Results and Discussion

5.1 Quality Assurance

This project was conducted in accordance with a Quality Assurance Project Plan developed in conjunction with the Vermont DEC. In general, our 2017 sampling met the quality assurance standards for both total phosphorus and total nitrogen (quality assurance data are presented in Appendix A). None of the 76 field blanks, which indicate possible contamination during sampling, exceeded the detection limits for either total nitrogen or total phosphorus. The mean Relative Percent Differences between duplicate samples were also well below the prescribed differences for both total phosphorus [10% (prescribed difference <30%)] and total nitrogen [4% (prescribed difference <20%)]. In addition, none of the 38 pairs of total nitrogen samples and only three of the 38 pairs of total phosphorus samples exceeded the prescribed differences. Thus, the quality assurance samples, including both field blanks and field duplicates, indicated that the water samples were being collected in a repeatable manner and were not being contaminated during collection or processing.

5.2 Stream Flow

Stream flow measures the volume of water passing a specific location per unit of time (usually measured as cubic feet or cubic meters per second) and is calculated by multiplying the cross-sectional area of the stream by water velocity. Stream flow affects both water quality and the quality and characteristics of aquatic and riparian habitats. For example, fast-moving streams are more turbulent and better aerated than slow-moving streams. High flows also dilute dissolved and suspended pollutants but, at the same time, typically carry more surface runoff and stormwater and the associated sediment and nutrients. Stream flow is extremely dynamic and changes frequently in response to changes in temperature, precipitation, and season.

To approximate stream flows at the sites sampled in this study, we used the daily stream flows measured for the Black River at Coventry, Vermont (USGS station 04296000). The 2017 sampling season was characterized by high peak spring flows during early March and again in the first half of April (Figure 5). Subsequently, flows decreased steadily throughout the first half of summer and then remained relatively low into late autumn before peaking again in late October following heavy rains.

Our sample dates largely reflected the variation in stream flows during 2017 (Figure 5). The sample dates included two high-flow events (10 April and 15 May), four moderate-flow events (12 June, 10 July, 5 September, and 26 October), and two low-flow events (7 August and 2 October). The first sample date (10 April) occurred during peak spring snowmelt, when copious amounts of melt water were flowing overland and into the rivers and streams, and the last sample date (26 October) occurred during and following moderate rains. Collecting water samples across this range of stream flows enhanced our ability to identify and assess water quality problems, especially those affected by stream flow. Low flows were most informative for identifying and assessing nutrient and sediment inputs originating from point and groundwater sources. In contrast, high flows were more informative for identifying and assessing nutrient and sediment inputs originating from surface runoff and other nonpoint sources, which typically generate the majority of the nutrient and sediment loads exported from these watersheds.

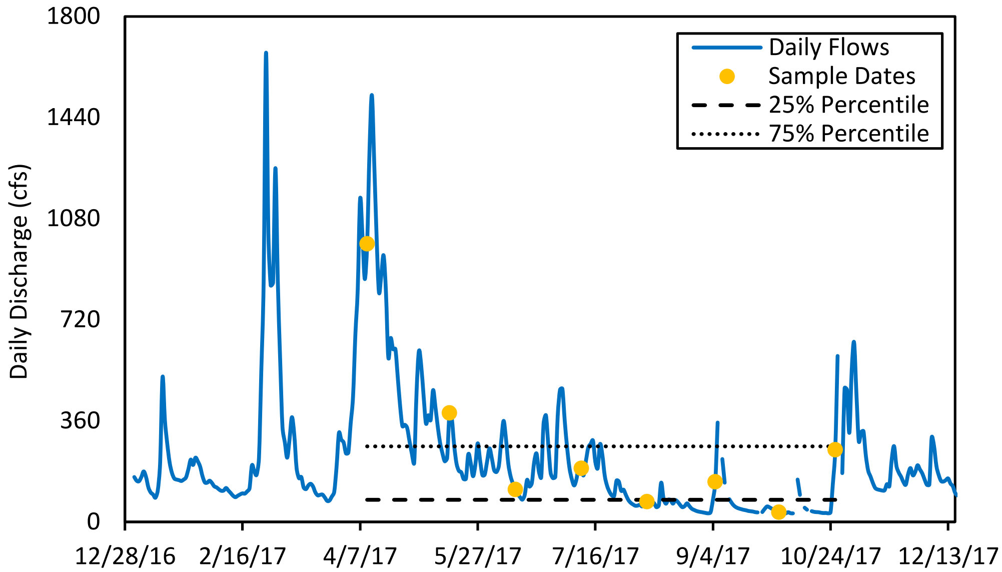

Figure 5. *Stream flows along the Black River at Coventry, Vermont during January-December 2017. Stream flows were measured by the U.S. Geological Survey (USGS station 04296000). The eight dates on which water samples were collected are indicated by orange circles.*

5.3 Project Effectiveness

In the sections that follow, we discuss the water quality data and analyses for three tributaries of Lake Memphremagog and the Tomifobia River where water quality improvement projects and practices have been implemented. More specifically, we describe possible sources of water quality problems, the water quality protection and improvement projects implemented to date, the water quality data, and recommendations for future efforts to protect and improve water quality in these watersheds.

5.3.1 Brighton Brook

Brighton Brook, a tributary of the Black River, drains approximately 1,403 ha (3,466 acres) in the towns of Irasburg and Newport Town. Water quality in Brighton Brook was first sampled in 2010 and exhibited high levels of phosphorus, nitrogen, and turbidity. In subsequent years, we sampled water quality at additional sites along this stream and its tributaries to better pinpoint and assess possible nutrient and sediment sources. During 2011-2017, total phosphorus and total nitrogen concentrations have been consistently high along the northern branch of Brighton Brook and extremely high in a small tributary of this northern branch. This small tributary drains an area encompassing a large agricultural production area, including barns, manure pits, silage storage bunkers, and a mortality compost pile, as well as large fields of corn and hay. Identifying the source(s) of the high nutrient levels in this tributary was complicated by 1) the presence of a series of small ponds and wetlands that likely store nutrients during high flows and release them during low flows in late summer, 2) the draining and filling of a large wetland formerly located in the upper watershed, and 3) installing drain pipes and grassed waterways in many of the corn fields and wetlands in the upper watershed. Nevertheless, following heavy rains in 2014, we were able to identify leachate from a large mortality compost pile as a likely source of nutrients flowing into the northern branch of Brighton Brook (Figure 6). Despite repeated requests to relocate and/or collect the leachate from this mortality compost pile, no actions were undertaken, and so the State of Vermont pursued an environmental enforcement action that resulted in an agreement in 2015 to correct this problem. Based on conversations with agency staff and field observations, it is our understanding that the mortality compost pile was removed slowly during 2016 and 2017.

Figure 6. *Mortality compost pile (to front and left of barns) and agricultural production area on a large farm operation along the northern branch of Brighton Brook in Irasburg, Vermont on 8 October 2013. Note the darkened ground where leachate from the mortality compost pile flowed along and puddled at the bottom of the farm road.*

During 2010-2014, we sampled seven sites along the main stem and northern branch of Brighton Brook (Table 1, Figure 7). During 2015-2017, we resampled the three downstream-most sites in order to assess whether water quality conditions had improved as a result of the corrective actions undertaken in this watershed.

Table 1. Seven sites where water quality was sampled along the main stem and northern branch of Brighton Brook during 2010-2017. Sites are ordered from downstream to upstream.

Location ID	Site Name	# Dates Sampled	Years Sampled
502663	Brighton Brook	63	2010-2017
505538	Brighton Brook North	55	2011-2017
507928	Upper Brighton Brook North	31	2012-2017
508495	Lower Farm	14	2013-2014
508485	NW Pipe	15	2013-2014
508485	Northwest	1	2013
508484	Upper Northwest	3	2013

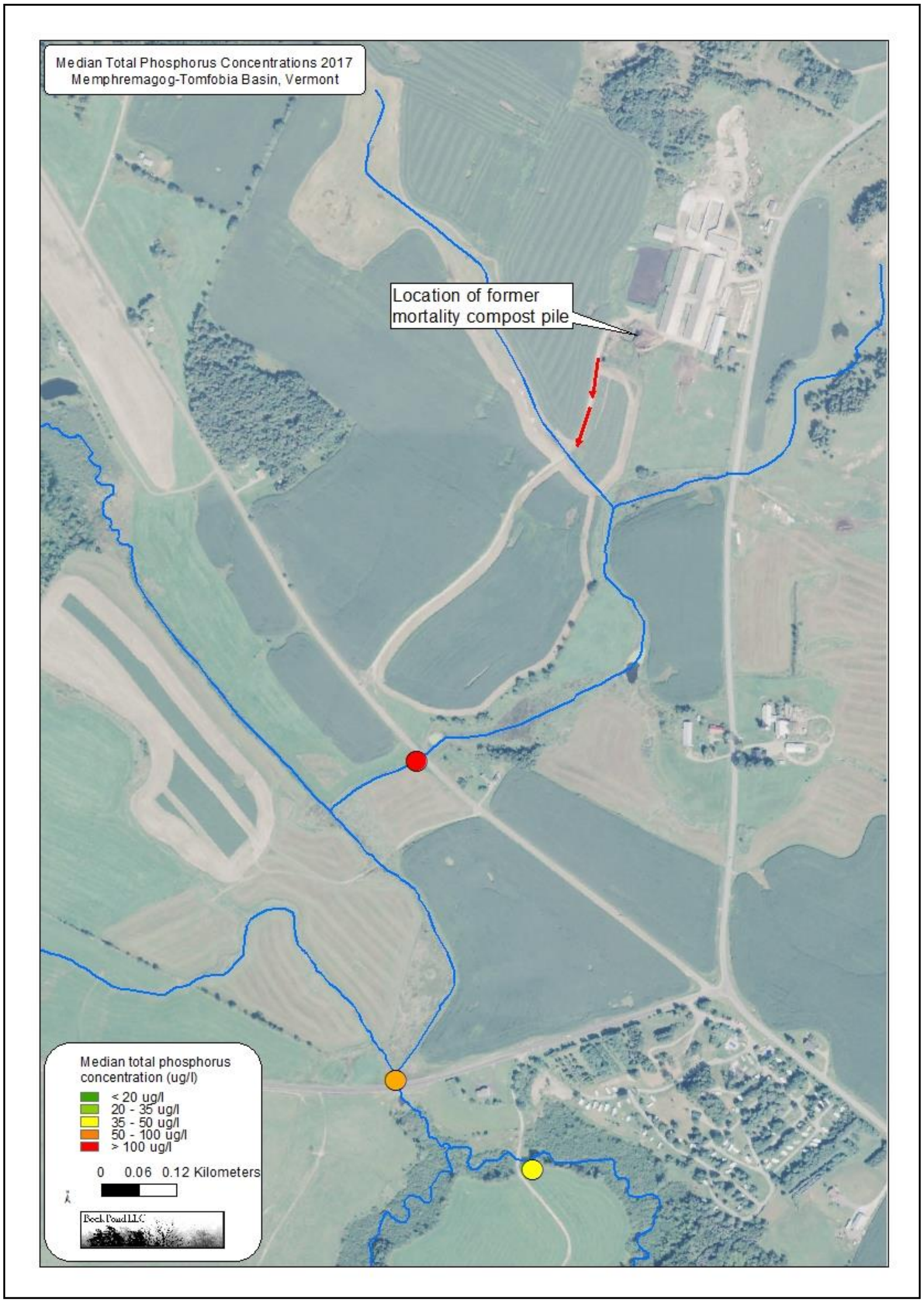

Figure 7. *Locations of three sites sampled along Brighton Brook during 2015-2017. The sample sites are color-coded according to the median total phosphorus concentrations measured at each site. Note former location of mortality compost pile and pathway of leachate draining from the mortality compost pile during rain events (red arrows).*

As in previous years, total phosphorus concentrations were moderately high at the downstream-most site (Brighton Brook, median = 36.4 µg/l, range = 21.3-147 µg/l), markedly higher at the downstream site on the northern branch (Brighton Brook North, median = 66.1 µg/l, range = 30.8-564 µg/l), and extremely high at the upstream-most site (Upper Brighton Brook North, median = 585 µg/l, range = 487-880 µg/l). During the past eight years (2010-2017), mean total phosphorus concentrations have generally decreased at all three sites; however, these decreases have not been consistent across sites or years (Figure 8). Consequently, total phosphorus concentrations at three sites have not shown statistically significant changes over time during 2010-2017 (Brighton Brook, F=1.266, df=1,61, P=0.265; Brighton Brook North, F=1.903, df=1,53, P=0.173; Upper Brighton Brook North, F=3.485, df=1,29, P=0.072). Nevertheless, at the Upper Brighton Brook North site, mean and median total phosphorus concentrations have decreased 50-60% during 2012-2017, and no values exceeded 1,000 µg/l during 2016-2017 while they often exceeded that value in prior years (Figure 9).

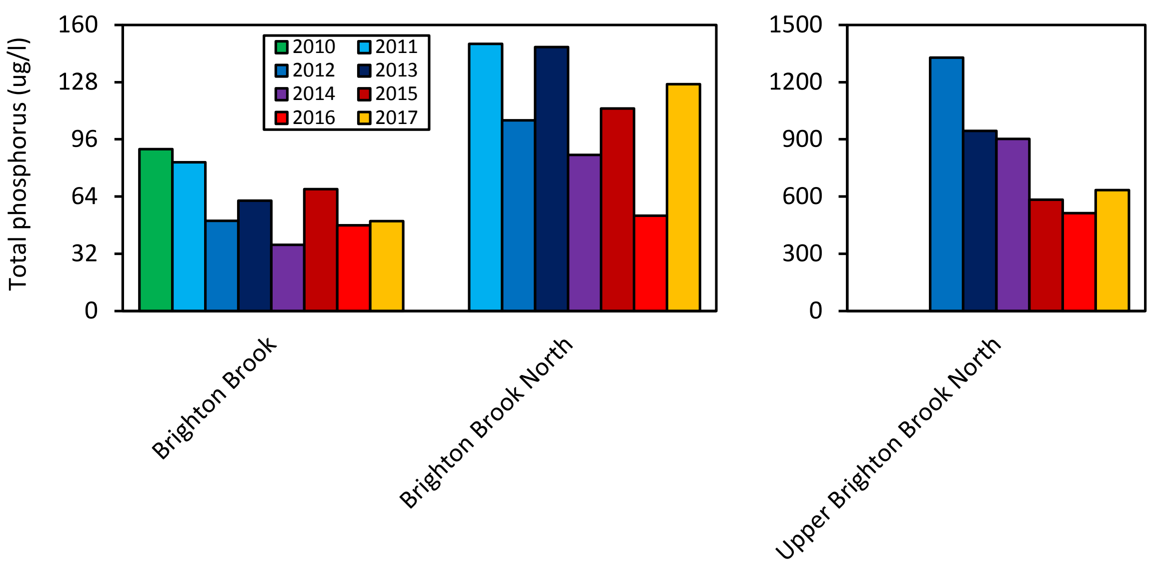

Figure 8. *Mean total phosphorus concentrations at three sites along Brighton Brook and its northern branch from Upper Brighton Brook North downstream to Brighton Brook during 2010-2017.*

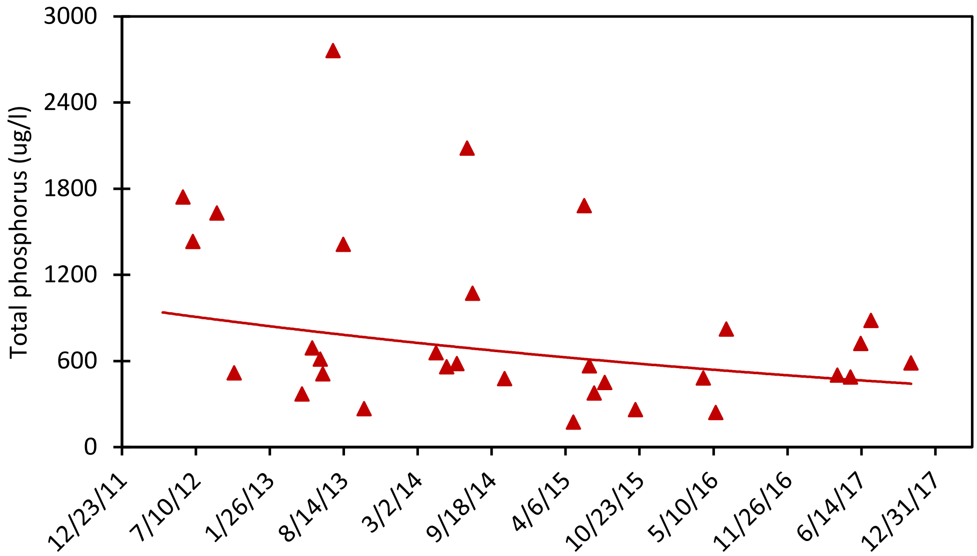

Figure 9. *Total phosphorus concentrations in relation to sample date at the Upper Brighton Brook North site during 2012-2017.*

Similarly, total nitrogen concentrations were consistently high at only the upstream-most site (Upper Brighton Brook North, median = 2.19 mg/l, range = 1.67-8.64 mg/l). At that site, both median and mean total nitrogen concentrations decreased roughly 55% between 2010 and 2011 but have remained fairly consistent since then (Figure 10).

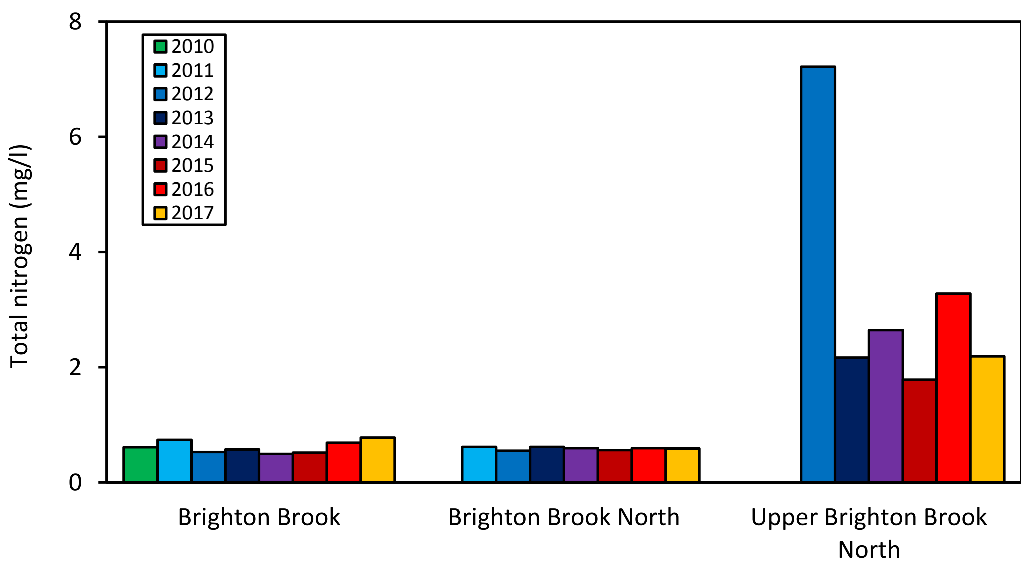

Figure 10. *Mean total nitrogen concentrations at three sites along Brighton Brook and its northern branch from Upper Brighton Brook North downstream to Brighton Brook during 2010-2017.*

Although there is reason to be optimistic that water quality conditions are improving in this tributary of the Black River, especially at the upstream-most site, these improvements have not consistently or significantly reduced phosphorus or nitrogen loading into the Black River. However, this lack of consistent and steady improvement may partly reflect the slow removal of the mortality compost pile over the past two years, and the ongoing heavy use of the agricultural production area and the many large corn fields in this watershed. Thus, we recommend collecting additional data to further evaluate the success of these corrective actions for improving water quality in Brighton Brook.

5.3.2 Junkyard Tributary

The Junkyard Tributary, a small tributary of the Barton River, drains approximately 348 ha (860 acres) in the towns of Irasburg and Barton. This small tributary drains large areas of agricultural lands, almost 2 km (1.2 mi) of Interstate 91, small blocks of forest, and a residential area in the village of Orleans. Water quality in this tributary was first sampled in 2012, and elevated phosphorus levels were identified as an issue of concern. In 2013, we added a second site further upstream, and, in 2014, we added two additional sites where this tributary forks in order to better pinpoint and assess possible nutrient and sediment sources. Based on our data and observations, staff from Vermont Agency of Agriculture, Food & Markets (VAAFM) and Vermont DEC visited a medium farm operation in this watershed to discuss water quality concerns. Subsequently, the owners developed a nutrient management plan, undertook no-till and cover-cropping on several steep corn fields, created a filter strip to capture runoff and sediment at the downhill edge of the steepest corn field (see cover photograph), converted another corn field to hay, and widened the riparian buffer in one area. In the future, the owner hopes to relocate the mortality compost pile and to build additional storage capacity and infrastructure to capture any overflow from the manure pit and leachate from the silage storage bunker.

During 2012-2017, we sampled seven sites along the main stem and tributaries of the Junkyard Tributary (Table 2, Figure 11). In 2017, we resampled three sites that had been sampled in previous years and sampled three new sites further upstream in order to evaluate whether water quality conditions had improved as a result of the improved field practices.

Table 2. Seven sites where water quality was sampled along the main stem and tributaries of the Junkyard Tributary during 2012-2017. Sites are ordered from downstream to upstream.

Location ID	Site Name	# Dates Sampled	Years Sampled
507929	Rock Junkyard	48	2012-2017
508527	Upper Junkyard	8	2013
510229	Route 58 Farm	32	2014-2017
510230	Route 58 Tributary	31	2014-2017
515578	Route 58 Ditch Lower	7	2017
515579	Route 58 Ditch Upper	5	2017
515582	Upper Route 58 Farm	8	2017

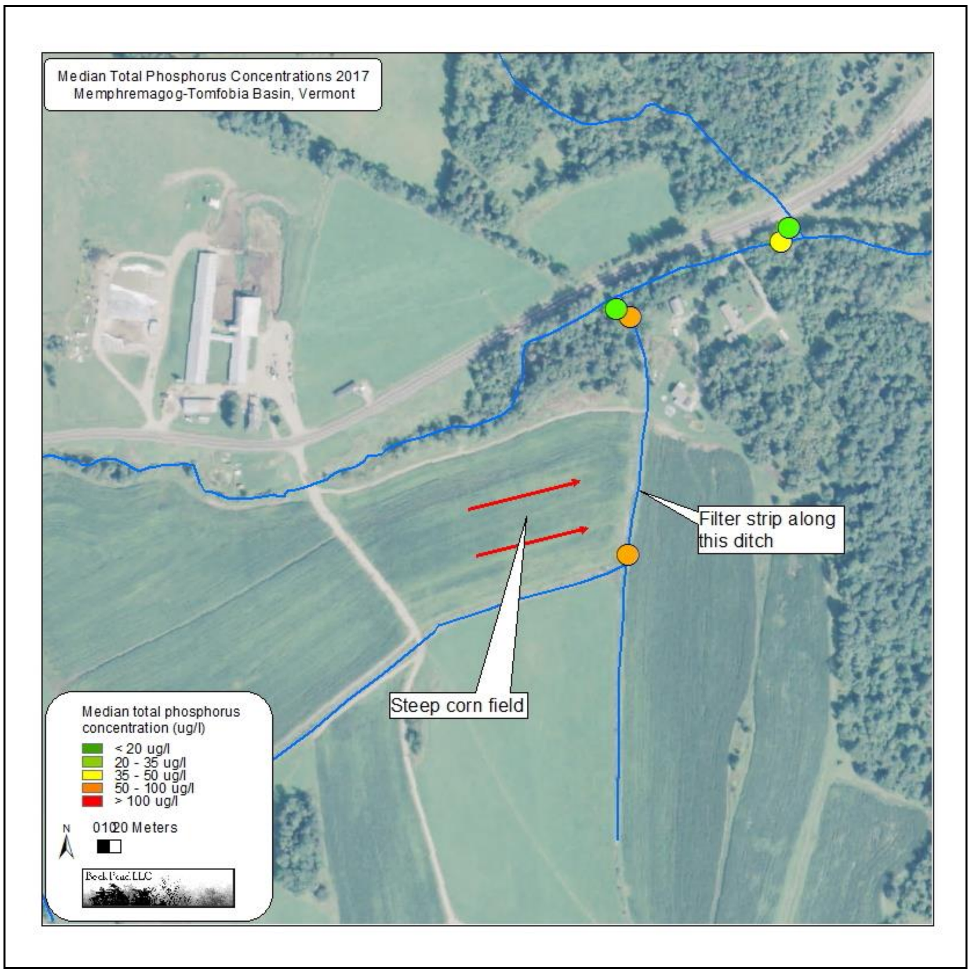

Figure 11. *Locations of seven sites sampled along the Junkyard Tributary during 2012-2017. The two downstream-most sites are located off the map to the right. The sample sites are color-coded according to the median total phosphorus concentrations measured at each site. Note direction of flow off of steep corn field and location of filter strip installed at the start of the 2015 growing season.*

As in previous years, total phosphorus concentrations were slightly elevated at the downstream-most site (Rock Junkyard, median = 24.1 µg/l, range = 12.7-111 µg/l) and moderately high along the two branches of this tributary (Route 58 Farm, median = 40.9 µg/l, range = 29.8-127 µg/l; Route 58 Tributary, median = 34.5 µg/l, range = 16.9-328 µg/l). None of the three sites showed significant changes in total phosphorus concentrations over time during 2014-2017 (Figure 12; Rock Junkyard, F=0.032, df=1,46, P=0.858; Route 58 Farm, F=0.519, df=1,18, P=0.480; Route 58 Tributary, F=1.331, df=1,29, P=0.258). Although not statistically significant, mean total phosphorus concentrations did decrease 96% at the Route 58 Farm site and 50% at the Route 58 Tributary site during 2014-2017 (Figure 13-14). In contrast, median total phosphorus concentrations barely changed at these two sites (Route 58 Farm decreased 17% but Route 58 Tributary increased 9%), and neither mean nor median total phosphorus concentrations changed appreciably at the downstream-most site (Rock Junkyard).

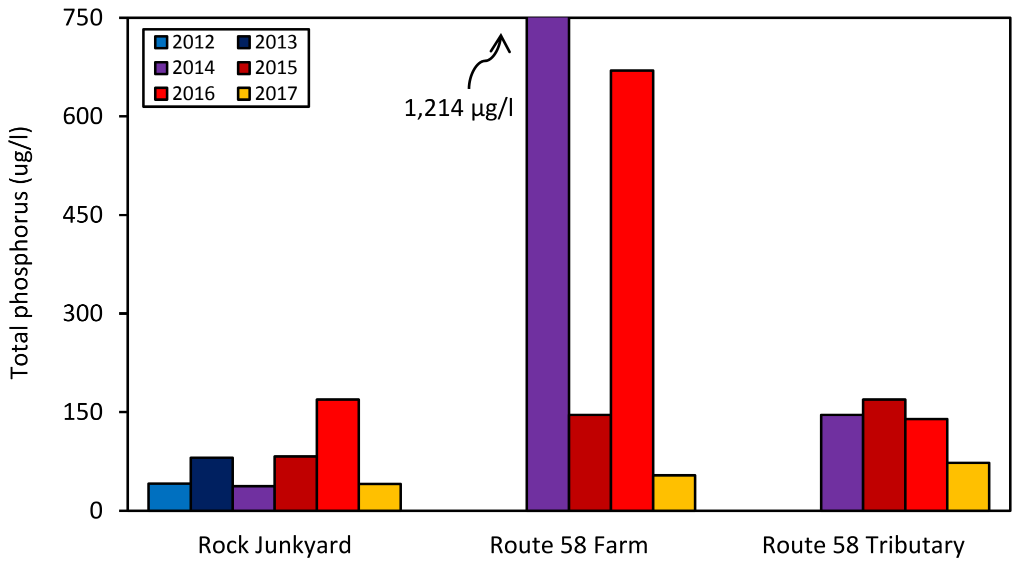

Figure 12. *Mean total phosphorus concentrations at three sites along the Junkyard Tributary from Route 58 Farm and Route 58 Tributary downstream to Rock Junkyard during 2012-2017.*

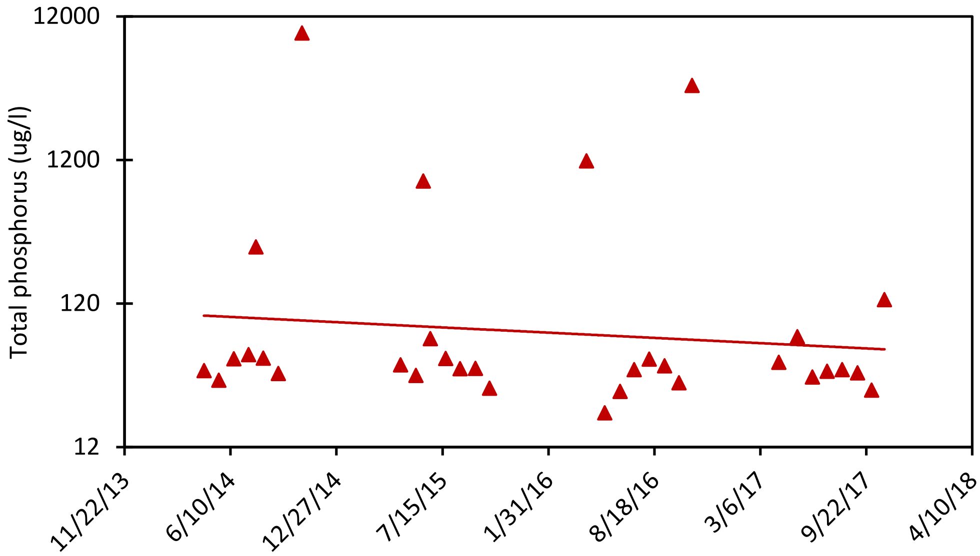

Figure 13. *Total phosphorus concentrations in relation to sample date at the Route 58 Farm site during 2014-2017.*

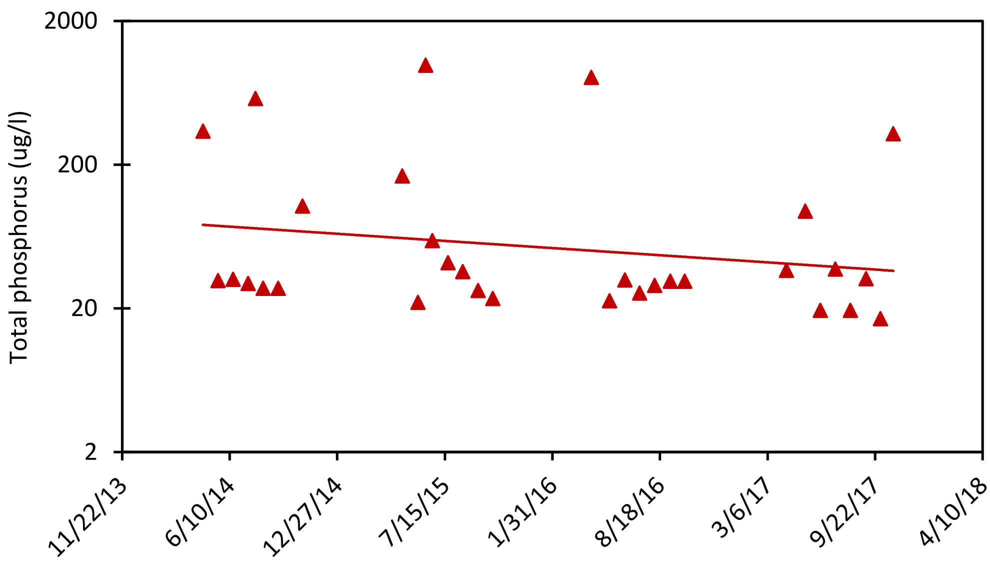

Figure 14. *Total phosphorus concentrations in relation to sample date at the Route 58 Tributary site during 2014-2017.*

In contrast to total phosphorus, total nitrogen concentrations were consistently high at only one of the three sites (Route 58 Tributary, median = 2.10 mg/l, range = 1.09-2.37 mg/l), which drained much of the agricultural production area. Although there were no consistent changes in total nitrogen concentrations at any of the three sites over time, mean total nitrogen concentrations did decrease 88% at the Route 58 Farm site during 2014-2017 (Figure 15).

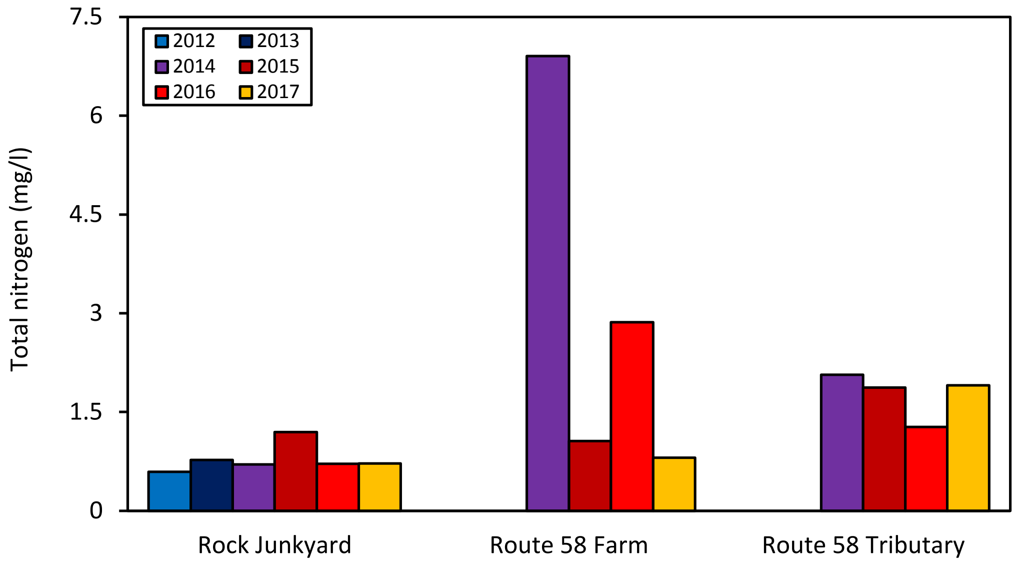

Figure 15. *Mean total nitrogen concentrations at three sites along the Junkyard Tributary from Route 58 Farm and Route 58 Tributary downstream to Rock Junkyard during 2014-2017.*

5.3.3 Tributary of Stearns Brook

This western tributary of Stearns Brook drains approximately 275 ha (679 acres) in the towns of Holland and Derby. Based on an assessment of aquatic life, the Biomonitoring and Aquatic Studies Section of the Vermont DEC designated this tributary as impaired and in need of a TMDL due to nutrients and sediment from agricultural runoff (Part A, State of Vermont 2016a). Beginning in 2014, we analyzed water quality conditions along the main stem (four sites) and two smaller tributaries (two sites) in order to pinpoint and assess possible nutrient and sediment sources. In addition, whenever flows were sufficient, we sampled the outflows from two culverts and two ditches that drained the production area of a large farm operation. Based on the sampling in 2014-2015, we determined that phosphorus levels increased dramatically downstream of the two upstream sites (Upper Stearns Tributary and Stearns Tributary Falls) and upstream of the next site downstream (Middle Stearns Tributary). In addition, total phosphorus concentrations were consistently high in one of the two small tributaries (Valley Road South) and extremely high during rainfall events in the other small tributary (Twin Bridges Road). Like total phosphorus, total nitrogen concentrations increased steadily from the upstream sites down to the Middle Stearns Tributary site, but they were also extremely high in one of the two small tributaries (Twin Bridges Road). We also measured extremely high phosphorus and nitrogen levels flowing from the two culverts and two ditches that drained much of the agricultural production area. Collectively, these data suggested that much of the nutrients and sediment in this stream was originating from the production area and adjacent agricultural fields. In partnership with VAAFM and Vermont DEC, the owners of this farm developed and implemented a number of water quality improvement projects and practices during 2015-2017 to divert runoff from driveways into hay fields, to divert clean water away from the barnyards and laneways, to collect contaminated runoff from the barnyards and laneways into the manure pits, and to add filter strips and cover-cropping to many of the corn fields (Figure 16).

During 2014-2017, we sampled eleven sites along the main stem and tributaries of the Tributary of Stearns Brook (Table 3, Figure 17). In 2017, we resampled water quality at six sites along the main stem and two small tributaries in order to evaluate the success of the farmstead projects and field practice improvements undertaken by the large farm operation.

Table 3. Eleven sites where water quality was sampled along the main stem and tributaries of the Tributary of Stearns Brook during 2014-2017. Sites are ordered from downstream to upstream.

Location ID	Site Name	# Dates Sampled	Years Sampled
501642	Lower Stearns Tributary	31	2014-2017
510234	Twin Bridges Road	29	2014-2017
510251	Valley Road South	29	2014-2017
510222	Middle Stearns Tributary	32	2014-2017
515583	Valley Road Ditch	10	2015-2016
515583	Valley Road Pipe	3	2016
515584	Valley Road Garage	4	2015-2016
515577	Lower Barnyard Culvert	19	2014-2017
515581	Upper Barnyard Culvert	19	2014-2017
510233	Stearns Tributary Falls	32	2014-2017
510235	Upper Stearns Tributary	32	2014-2017

Figure 16. *The large farm along the Tributary of Stearns Brook undertook numerous clean water diversion and runoff control projects during 2015-2017 to improve water quality conditions in the Tributary of Stearns Brook. The top photograph shows a barnyard area prior to construction on 3 July 2015, and the bottom photograph shows the same area during construction of a barrier to separate clean and contaminated water on 28 September 2015 (bottom photograph courtesy of Ben Copans).*

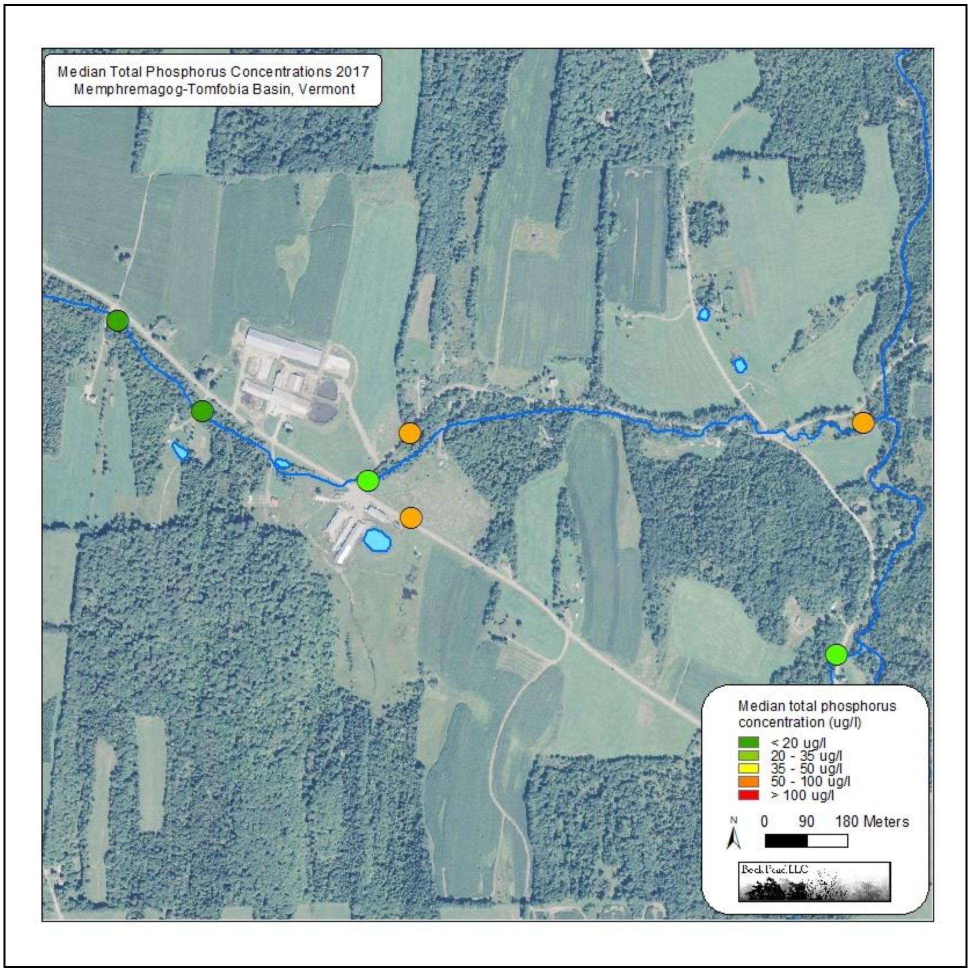

Figure 17. *Locations of eleven sites sampled along the Tributary of Stearns Brook during 2014-2017. The sample sites are color-coded according to the median total phosphorus concentrations measured at each site.*

The six sites differed in patterns of total phosphorus concentrations over time during 2014-2017 (Figure 18). At the two upstream sites, total phosphorus concentrations remained low and fairly stable across all four years. In contrast, total phosphorus concentrations were high but tended to decrease at the mid-stream site (Middle Stearns Tributary) but not at the downstream site (Lower Stearns Tributary). Although not statistically significant (F=3.404, df=1,30, P=0.075), total phosphorus concentrations did decrease 62% (median) to 92% (mean) at the Middle Stearns Tributary site during 2014-2017 (Figure 19). Interestingly, the decreases at the Middle Stearns Tributary site were most pronounced during high flows, when mean total phosphorus concentrations tended to be lower in 2016-2017 than in 2014-2015 (Figure 20, t=1.994, df=6, P=0.093). In contrast, mean total phosphorus concentrations at low and moderate flows were not different during 2016-2017 than during 2014-2015 (t=1.291, df=14, P=0.218). At the downstream site (Lower Stearns Tributary), mean total phosphorus concentrations before and after project implementation were not significantly different either at low and moderate flows (t=–0.271, df=18, P=0.790) or at high flows (t=-0.600, df=6, P=0.568). Interestingly, median total phosphorus concentrations did decrease 22% but mean total phosphorus concentrations increased 38% at the Lower Stearns Tributary site during 2014-2017. In part, these differences between the Middle Stearns Tributary and Lower Stearns Tributary sites may reflect the fact that total phosphorus concentrations remained unchanged or even increased in the two smaller tributaries (Twin Bridges Road and Valley Road South) that flow into the Tributary of Stearns Brook between the Middle and Lower Stearns Tributary sites.

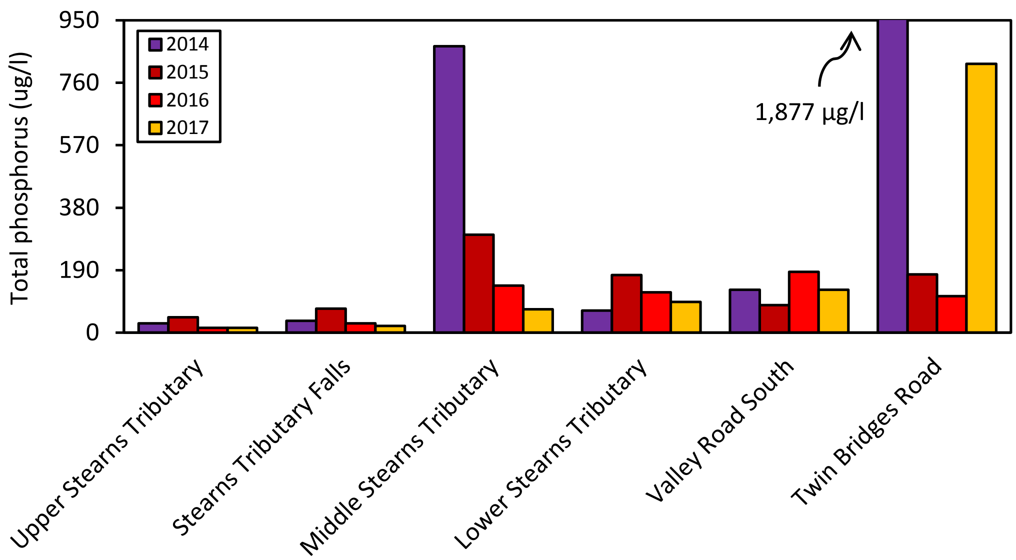

Figure 18. *Mean total phosphorus concentrations at six sites along the Tributary of Stearns Brook from Upper Stearns Tributary downstream to Lower Stearns Tributary during 2014-2017.*

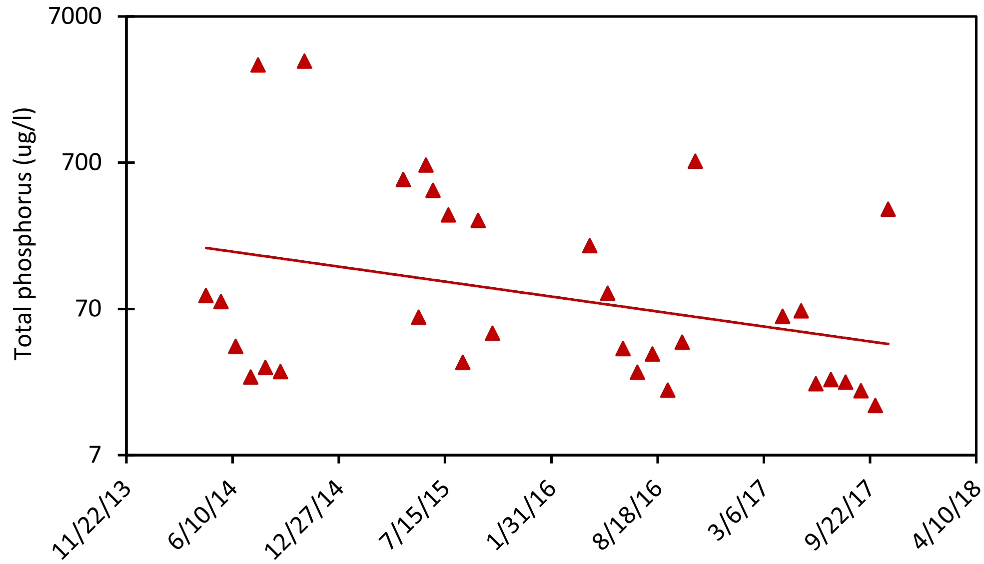

Figure 19. *Total phosphorus concentrations in relation to sample date at the Middle Stearns Tributary site during 2014-2017.*

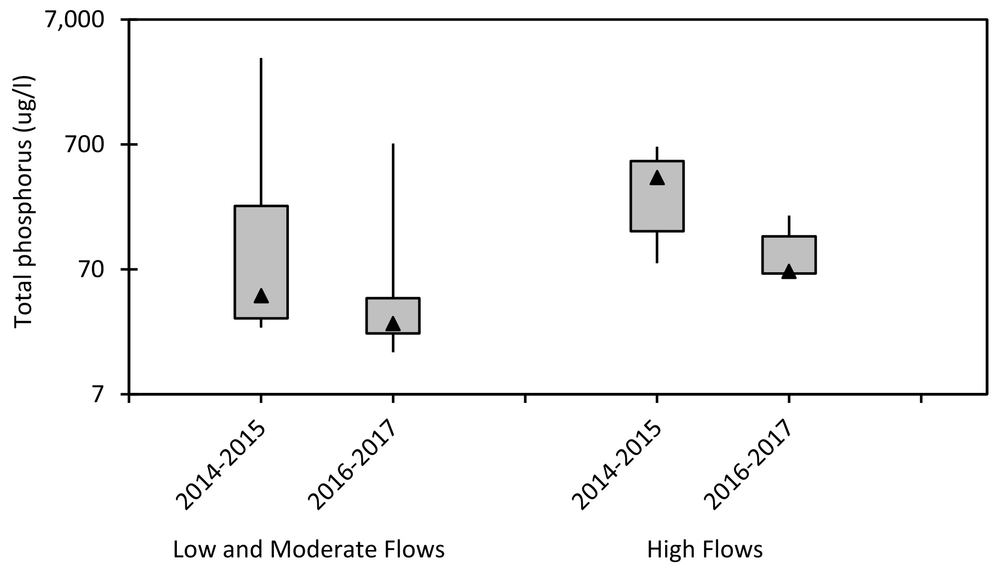

Figure 20. *Total phosphorus concentrations before and after treatment at low to moderate flows and at high flows at the Middle Stearns Tributary site along the Tributary of Stearns Brook during 2014-2017. Values are the median (triangle), 1st and 3rd quartiles (rectangle), and minimum and maximum (line).*

In contrast to total phosphorus, total nitrogen concentrations remained high and relatively stable at all sites, except Valley Road South (Figure 21). Mean total nitrogen concentrations did decrease 53% at the Twin Bridges Road site during 2014-2017, mostly due to a precipitous drop between 2014 and 2015.

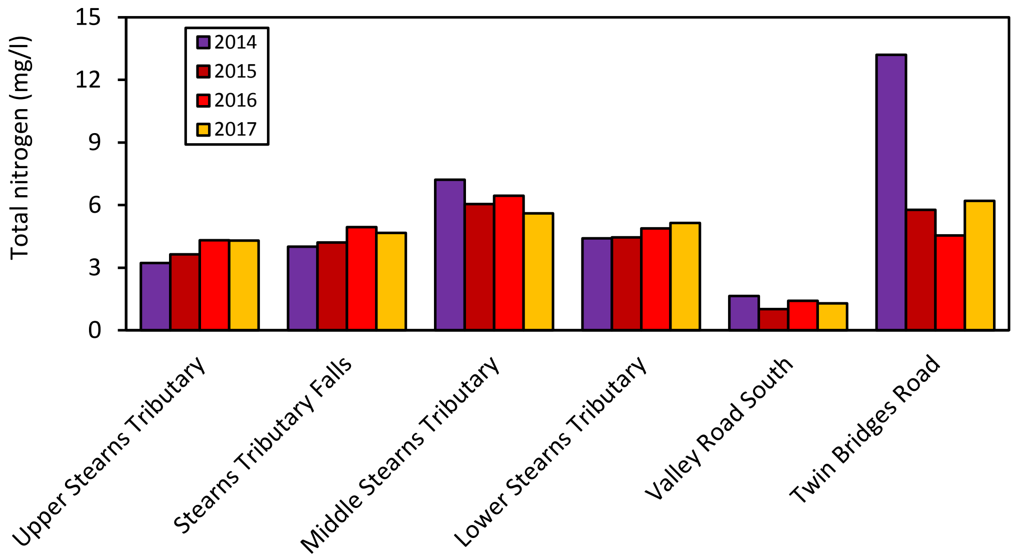

Figure 21. *Mean total nitrogen concentrations at six sites along the Tributary of Stearns Brook from Upper Stearns Tributary downstream to Lower Stearns Tributary during 2014-2017.*

Based on these results, the projects and practices undertaken by the large farm operation appear to have improved water quality somewhat in the Tributary of Stearns Brook. Improvements in water quality were most evident at the Middle Stearns Tributary site, which is located just downstream of the majority of the agricultural production area. In contrast, water quality remains poor, and improvements are still needed along the two small tributaries that drain into the Tributary of Stearns Brook further downstream. Thus, we recommend sampling all of these sites again in 2018 to further evaluate the success of the ongoing water quality improvement projects and practices, especially those implemented in 2017 and 2018.

6.0 Conclusions

Our water quality sampling in 2017 succeeded in collecting the data needed to assess the success of the water quality improvement projects and practices implemented along three tributaries of Lake Memphremagog and the Tomifobia River. However, our analyses also indicated that additional sampling is needed to be able to conclusively confirm the success of these projects and practices and that additional projects and practices are still needed to protect and improve water quality along these three tributaries. These additional data are particularly important in allowing us to evaluate the success of ongoing and future projects and practices. In addition, these data will increase the robustness of our statistical analyses, especially given the inherently high variability in total phosphorus concentrations and the strong relationship between total phosphorus concentrations and stream flow.

Brighton Brook - During 2010-2015, our sampling indicated that nutrient and sediment levels were extremely high in this tributary of the Black River. Furthermore, the sampling in 2014 allowed us to confirm that leachate flowing from a mortality compost pile at a large farm operation was a major sources of these high phosphorus, nitrogen, and turbidity levels. In 2017, we continued to sample water quality at three sites along this tributary to assess whether the corrective actions had been successful in improving water quality in this tributary. Perhaps because the mortality compost pile was relocated slowly during 2016-2017, total phosphorus concentrations did not show statistically significant decreases at any of the three sites, although there was a strong trend towards reduced phosphorus at the upstream-most site. Thus, we recommend resampling these three sites in 2018 to further gauge the success of these corrective actions.

Junkyard Tributary - Our sampling during 2012-2017 allowed us to further pinpoint and assess the sources of the high nutrient and sediment levels in the two upstream branches of this tributary of the Barton River. Despite numerous improvements in field practices, the 2016-2017 data did not show any clear and consistent improvements in water quality along this tributary. In order to further assess the effectiveness of the improvements in field practices and to aid implementation of other projects and practices, we recommend resampling all three sites in 2018 and, if possible, continuing to sample the new sites added in 2017 further upstream of and along the ditch that drains the steep corn field on the south side of Vermont Route 58.

Tributary of Stearns Brook - Our sampling in 2014-2017 indicated that nutrient and sediment levels were very high in this tributary of Stearns Brook, especially along the main stem and two small tributaries draining a large farm operation. During 2015-2017, the owners of the large farm operation undertook numerous farmstead improvement and clean water diversion projects. Following these improvements, water quality conditions seemed to have improved somewhat at the site located immediately downstream of the majority of the agricultural production area but remained unimproved further downstream below the confluences of two smaller tributaries. Thus, we recommend resampling these sites in 2018 in order to further evaluate the success of these projects as well as the additional projects and practices that were or will be implemented during 2017-2018.

In 2018, we propose to continue using the water quality data and other analyses to identify, prioritize, and develop projects and practices that will best improve water quality conditions and to evaluate the success of previously-implemented projects and practices along the Vermont tributaries of Lake Memphremagog and the Tomifobia River. As part of these efforts, we will continue to coordinate our efforts with those of other key partners to pinpoint and assess possible sources of water quality problems and to develop and implement projects or practices to correct those problems. In addition, another year of water quality data will increase the robustness of our statistical analyses and will allow us to better evaluate the success of previously-implemented projects and practices along these and other tributaries of Lake Memphremagog and the Tomifobia River.

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Appendix A. Quality assurance data, including field blanks and field duplicates, collected at 45 sample sites along the Vermont tributaries of Lake Memphremagog and the Tomifobia River during April-October 2017. Bold values indicate field blanks that exceeded detection limits (5 µg/l for total phosphorus and 0.1 mg/l for total nitrogen) or field duplicates that differed by >30% for total phosphorus and >20% for total nitrogen.

Field Blanks

Site	Date	Total Nitrogen (mg/l)	Total Phosphorus (µg/l)
Orcutt Brook BLANK	4/10/2017	<0.1	<5
East Stearns Tributary BLANK	4/10/2017	<0.1	<5
Cass Brook BLANK	4/11/2017	<0.1	<5
Route 58 Farm BLANK	4/11/2017	<0.1	<5
Cass Brook BLANK	5/15/2017	<0.1	<5
Route 58 Farm BLANK	5/15/2017	<0.1	<5
Orcutt Brook BLANK	5/15/2017	<0.1	<5
East Stearns Tributary BLANK	5/15/2017	<0.1	<5
Stearns Tributary Falls BLANK	6/12/2017	<0.1	<5
East Stearns Upper BLANK	6/12/2017	<0.1	<5
Tice Mill BLANK	6/12/2017	<0.1	<5
LBartonT Lower BLANK	6/12/2017	<0.1	<5
Route 58 Ditch Lower BLANK	6/12/2017	<0.1	<5
Stearns Tributary Falls BLANK	7/10/2017	<0.1	<5
East Stearns Upper BLANK	7/10/2017	<0.1	<5
Tice Mill BLANK	7/10/2017	<0.1	<5
LBartonT Lower BLANK	7/10/2017	<0.1	<5
Route 58 Ditch Lower BLANK	7/10/2017	<0.1	<5
Valley Road South BLANK	8/7/2017	<0.1	<5
East Stearns Tributary BLANK	8/7/2017	<0.1	<5
Sucker North Driveway BLANK	8/7/2017	<0.1	<5
LBartonT Ditch BLANK	8/7/2017	<0.1	<5
Upper Route 58 Farm BLANK	8/7/2017	<0.1	<5
Middle Stearns Tributary BLANK	9/5/2017	<0.1	<5
6129 Valley Road BLANK	9/5/2017	<0.1	<5
LBartonT Field Lower BLANK	9/5/2017	<0.1	<5
Brighton Brook North BLANK	9/5/2017	<0.1	<5
Upper School Road BLANK	9/5/2017	<0.1	<5

Site	Date	Total Nitrogen (mg/l)	Total Phosphorus (µg/l)
East Stearns Middle BLANK	10/2/2017	<0.1	<5
Sucker North Pasture BLANK	10/2/2017	<0.1	<5
Rock Junkyard BLANK	10/2/2017	<0.1	<5
Brighton Brook BLANK	10/2/2017	<0.1	<5
Coche Brook BLANK	10/2/2017	<0.1	<5
Lower Stearns Tributary BLANK	10/26/2017	<0.1	<5
East Stearns Gully BLANK	10/26/2017	<0.1	<5
Route 58 Farm BLANK	10/26/2017	<0.1	<5
Cass Trib Upper BLANK	10/26/2017	<0.1	<5
Coche Brook BLANK	10/26/2017	<0.1	<5

Field Duplicates

Total Nitrogen

Site	Date	1st Total Nitrogen (mg/l)	2nd Total Nitrogen (mg/l)	Relative % Difference
Orcutt Brook	4/10/2017	1.34	1.16	14
East Stearns Tributary	4/10/2017	3.45	3.19	8
Cass Brook	4/11/2017	0.41	0.35	16
Route 58 Farm	4/11/2017	0.69	0.63	9
Cass Brook	5/15/2017	0.43	0.45	5
Route 58 Farm	5/15/2017	0.53	0.53	0
Orcutt Brook	5/15/2017	0.73	0.73	0
East Stearns Tributary	5/15/2017	2.27	2.27	0
Stearns Tributary Falls	6/12/2017	5.31	5.47	3
East Stearns Upper	6/12/2017	0.34	0.34	0
Tice Mill	6/12/2017	2.02	1.98	2
LBartonT Lower	6/12/2017	0.44	0.48	9
Route 58 Ditch Lower	6/12/2017	0.65	0.72	10
Stearns Tributary Falls	7/10/2017	5.64	5.56	1
East Stearns Upper	7/10/2017	0.35	0.35	0
Tice Mill	7/10/2017	2.01	2.03	1
LBartonT Lower	7/10/2017	0.81	0.78	4
Route 58 Ditch Lower	7/10/2017	0.49	0.51	4

Site	Date	1st Total Nitrogen (mg/l)	2nd Total Nitrogen (mg/l)	Relative % Difference
Valley Road South	8/7/2017	0.89	0.85	5
East Stearns Tributary	8/7/2017	3.37	3.29	2
Sucker North Driveway	8/7/2017	0.29	0.27	7
LBartonT Ditch	8/7/2017	0.97	0.89	9
Upper Route 58 Farm	8/7/2017	0.56	0.54	4
Middle Stearns Tributary	9/5/2017	5.55	5.5	1
Upper School Road	9/5/2017	0.43	0.4	7
6129 Valley Road	9/5/2017	0.18	0.18	0
LBartonT Field Lower	9/5/2017	0.45	0.46	2
Brighton Brook North	9/5/2017	0.55	0.55	0
East Stearns Middle	10/2/2017	4.33	4.41	2
Sucker North Pasture	10/2/2017	0.2	0.19	5
Coche Brook	10/2/2017	0.91	0.91	0
Rock Junkyard	10/2/2017	0.39	0.4	3
Brighton Brook	10/2/2017	0.82	0.83	1
Lower Stearns Tributary	10/26/2017	2.34	2.57	9
East Stearns Gully	10/26/2017	1.15	1.31	13
Coche Brook	10/26/2017	0.77	0.81	5
Route 58 Farm	10/26/2017	2.09	2.09	0
Cass Trib Upper	10/26/2017	0.37	0.35	6
Mean				**4**

Total Phosphorus

Site	Date	1st Total Phosphorus (µg/l)	2nd Total Phosphorus (µg/l)	Relative % Difference
Orcutt Brook	4/10/2017	112	133	17
East Stearns Tributary	4/10/2017	60.2	57.6	4
Cass Brook	4/11/2017	53.6	57.7	7
Route 58 Farm	4/11/2017	46.6	45.2	3
Cass Brook	5/15/2017	38.1	37.6	1
Route 58 Farm	5/15/2017	70.1	53.5	27
Orcutt Brook	5/15/2017	25.5	25.1	2
East Stearns Tributary	5/15/2017	45.9	45.1	2

Site	Date	1st Total Phosphorus (µg/l)	2nd Total Phosphorus (µg/l)	Relative % Difference
Stearns Tributary Falls	6/12/2017	10.4	10.3	1
East Stearns Upper	6/12/2017	21.8	21.9	0
Tice Mill	6/12/2017	14.9	15.2	2
LBartonT Lower	6/12/2017	114	110	4
Route 58 Ditch Lower	6/12/2017	57.4	81.2	**34**
Stearns Tributary Falls	7/10/2017	12.4	19.2	**43**
East Stearns Upper	7/10/2017	21.1	21.9	4
Tice Mill	7/10/2017	21.5	21.8	1
LBartonT Lower	7/10/2017	146	148	1
Route 58 Ditch Lower	7/10/2017	57.6	55.3	4
Valley Road South	8/7/2017	86.4	90.1	4
East Stearns Tributary	8/7/2017	16.5	17.5	6
Sucker North Driveway	8/7/2017	11.9	9.57	22
LBartonT Ditch	8/7/2017	99.5	107	7
Upper Route 58 Farm	8/7/2017	33.2	33.7	1
Middle Stearns Tributary	9/5/2017	19.2	21.3	10
Upper School Road	9/5/2017	8.07	7.28	10
6129 Valley Road	9/5/2017	11.5	12	4
LBartonT Field Lower	9/5/2017	59	107	**58**
Brighton Brook North	9/5/2017	69.9	63.2	10
East Stearns Middle	10/2/2017	9.44	10.2	8
Sucker North Pasture	10/2/2017	9.65	7.88	20
Coche Brook	10/2/2017	7.35	5.9	22
Rock Junkyard	10/2/2017	12.7	12.7	0
Brighton Brook	10/2/2017	21.3	21.9	3
Lower Stearns Tributary	10/26/2017	249.3	244.5	2
East Stearns Gully	10/26/2017	144	150	4
Coche Brook	10/26/2017	75.2	87.8	15
Route 58 Farm	10/26/2017	127	124	2
Cass Trib Upper	10/26/2017	46.8	47.2	1
Mean				**10**

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