# MORSES POND ANNUAL REPORT: 2017

**PREPARED FOR THE TOWN OF WELLESLEY**

**BY WATER RESOURCE SERVICES, INC.**

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This report documents the implementation of the 2005 Comprehensive Morses Pond Management Plan through 2017. Program elements include: 1) phosphorus inactivation, 2) plant harvesting, 3) low impact development demonstration, 4) education, and 5) dredging.

# Phosphorus Inactivation

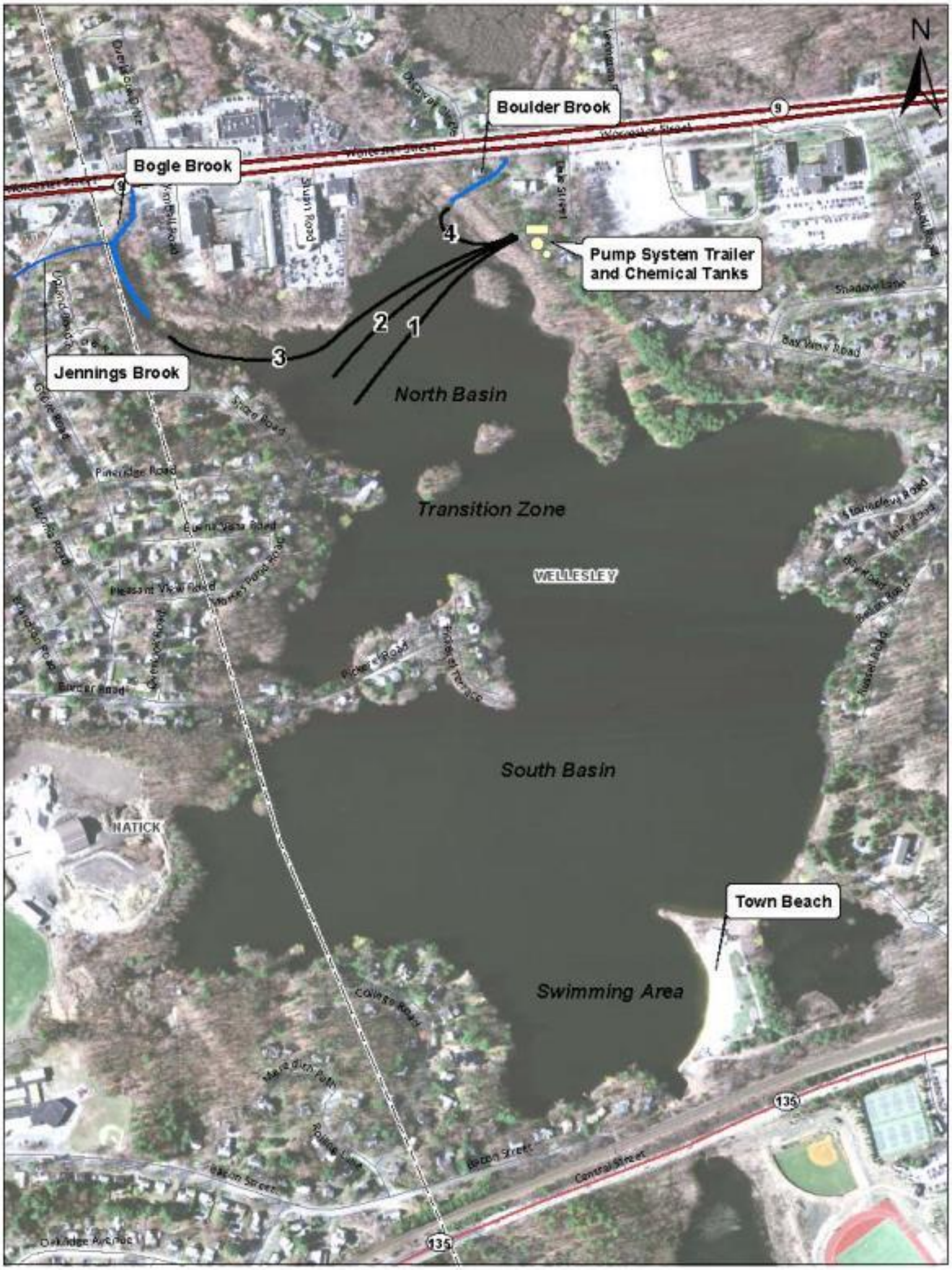
## Operational Background

Phosphorus entering through Bogle Brook and Boulder Brook was determined to be the primary driver of algae blooms in Morses Pond. Dry spring-summer periods fostered fewer blooms than wetter seasons in an analysis of over 20 years of data. Work in the watershed to limit phosphorus inputs is a slow process and has limits related to urbanization that are very difficult to overcome. Reduction in the phosphorus content of lawn fertilizer is believed to be reducing inputs to the pond, but with so much developed land in the watershed, loading is still excessive. Inactivation of incoming phosphorus is possible, however, and has been used extensively and successfully in Florida to limit the impact of development on lakes there. The comprehensive plan called for a similar effort at Morses Pond.

A phosphorus inactivation system was established at Morses Pond in the spring of 2008. After testing and initial adjustment in 2008, the system has been operated in the late spring and part of summer in 2009 through 2017. The chemical pump station was initially portable, stationed for the treatment period at the Town of Wellesley Dale Street Pump Station, but in 2015 this was made a "permanent" station without the trailer. Then in 2016 the system became automated using an application for a smart phone that would allow control and monitoring of the system without people being present at the time of a wet weather event. Four sets of lines initially ran from the pump station into the north basin (Figure 1), each set consisting of an air feed line and two chemical feed lines. The phosphorus inactivation chemicals used for the treatment were aluminum sulfate (alum) and sodium aluminate (aluminate). Both are flocculating agents responsible for the inactivation of phosphorus, with alum creating acidic conditions and aluminate shifting the pH to a more basic level; both were added at a roughly 2:1 ratio (alum to aluminate, by volume) to balance the pH of treatments.

Two lines with single diffusers and sets of chemical ports near the end of each line ran within the north basin to the mouths of Boulder Brook and Bogle Brook. This facilitated inlet treatment, generally considered the most effective means of inactivation, given mixing and settling as the streams proceed into the north basin. The other two lines, each with four diffusers and corresponding chemical ports, were spaced within the north basin itself to allow treatment of water in that basin. This allowed treatment if operation was not possible from the start of a storm, or if additional treatment in the basin appeared necessary. However, as spring progressed, dense vegetation within the north basin limited horizontal mixing and overall system efficiency. Additionally, once a portion of the north basin had been dredged (2012-2013), mixing that would limit particle settling became undesirable, so lines 1 and 2 that had served the north basin were removed in 2013. With the automation of the system, the start of storms is no longer missed, further obviating the need for an in-lake component.

**Figure 1. Original Phosphorus Inactivation System for Morses Pond**



The two sets of lines addressing the Bogle and Boulder Brook inlets were operated in 2013, and it was determined that the mixing function of the compressor was not needed for inlet injection to be effective. Therefore, compressor use was discontinued in 2014, which eliminated the need for fuel as well; the chemical feed pumps run on electricity, potentially supplied by a generator on the trailer at first, but more conveniently provided from the Dale Street pump station by extension cord. Consequently, the system was greatly simplified in 2014 and was much quieter, with a compressor used only at the end of the season to clear the lines, no generator use, and the pumps being housed in a wooden cabinet. Chemical lines were extended further up Bogle Brook in 2014 and an underground electrical line was extended to the pumps in 2015.

Alum and aluminate were added to the north basin in May through at least late June to achieve a target total phosphorus level in the south basin of <20 ppb and preferably close to 10 ppb near the 4th of July. Traditionally, algal blooms started about that time, necessitating copper treatments to regain water clarity and keep the beach open. It was thought that additional treatment during summer might not be necessary if the starting phosphorus level was low enough. No problems were noted in 2009, but algal blooms developed in August of 2010 and 2011. Responsive treatment helped, but was considered too late to prevent some loss of clarity. In 2010 the chemicals were available to respond to declining clarity in late July, but no action was taken. In 2011 the chemicals were not available when a response was deemed appropriate in late July, and it took two weeks to obtain the necessary chemicals. In 2012, sufficient chemical was on hand to respond to reductions in water clarity during summer, but system functionality problems limited the effectiveness of treatment. In 2013, chemicals were ordered and available from mid-July into August, but pump and delivery line issues limited effectiveness.

A further development in 2014 was the switch from alum and aluminate to just one chemical, polyaluminum chloride (PAlCl). Improvement of PAlCl in recent years made it worth testing, as both alum and aluminate are more hazardous to handle and more viscous in the feed lines. PAlCl is not much more viscous that water and does not damage skin rapidly on contact. It is more pH neutral, causing no detectable fluctuation in most waters to which it is applied at typical doses. It is intermediate to alum and aluminate in aluminum content (5.6%, or 0.59 lb/gal) and cost (about $2/gal). Testing in late 2013 and early 2014 with Bogle Brook water indicated phosphorus removal rates in excess of 90% with doses between 3 and 10 mg/L as aluminum. Consequently, the system could be further simplified to have one chemical in each of two chemical tanks, each with a dedicated pump, and each serving one inlet stream. With flows in Bogle Brook being larger than those in Boulder Brook, the larger pump (nominal capacity of 84 gal/hr) and the larger tank (2000 gal) were assigned to Bogle Brook and the smaller pump (nominal capacity 52 gal/hr) and smaller tank (1000 gal) were assigned to Boulder Brook, although swapping of hoses from the tank to the pump or the pump to the delivery lines allows switching if necessary.

In 2014 and 2015 the same approach was applied, with 6000 to 7900 gallons of PAlCl applied, most of it between late May and early July. Precipitation was below average from May through August, and some portion of every storm was treated in May and June. As a result of this program the lowest phosphorus levels were recorded for Morses Pond in over 20 years. Even with a few larger storms in summer, phosphorus remained well below the 20 ug/L threshold into August, and clarity was more than acceptable throughout the summer. With two years of highly desirable operational features and in-lake results after the switch to polyaluminum chloride, an automated and remote controllable system was installed in late 2015 and functional going into the 2016 treatment season.

The automated system runs on a smart phone through LoggerLink, an application produced by Campbell Scientific. It was then customized for our inactivation system by Don Cuomo of Blu-Dot Inc. The system relies on a rain gauge placed on the roof of the town pump station adjacent to the permanent inactivation station to measure precipitation, with a preselected threshold for precipitation (typically 0.1 to 0.25 inches) triggering the chemical pumps to turn on, sending PAlCl to the brooks for a predetermined length of time (typically 4 hr). Measurements are recorded by the cell application and can be observed in real time. Furthermore, settings on the application facilitate changing threshold limits for when the pumps turn on and for how long. All settings can also be overridden and turned on or off remotely as warranted.

Chemical exposure of pump parts with the diaphragm pumps lead to eventual failure of one diaphragm pump in 2015, although the remaining pump was able to handle both inlets for the remaining part of summer that year. Replacement of the aging diaphragm pumps with peristaltic pumps for 2016 reduced maintenance, limiting contact between the chemical and the actual pump system. This system puts the least amount of stress on the pump and the only replacements would be to the hose located on the outside of the pump, which is both an inexpensive and simplified fix.

A total of 5800 gallons of PAlCl were applied to Morses Pond in 2016, less than in 2015 but similar to 2014 (Table 1). Precipitation during the treatment season was the least since the inactivation process commenced, and all operations ran smoothly with only some adjustments being made to the rain gauge. Both the application and pumps functioned well and proved to be very advantageous. With 4.7 inches of rain in May-June and a total of 7.3 inches in May-August (Table 1), the system easily treated the small wet weather events on only 13 days in 2016. This enabled us to keep lake phosphorus at 0.005 mg/L with clarity of 5.5 meters (Figure 3), even better than in 2014 and 2015.

Operations in 2017 were much like in 2016, but there were some clogging issues that limited treatment of Bogle Brook during part of the season. There was also considerably more rain in spring and summer of 2017 than in any year since 2013. Yet the system performed well enough to maintain the desired conditions in Morses Pond; no algae blooms were detected through monitoring or reported by users. No more PAlCl was used than in the previous two years, yet treatment was adequate to meet program goals.

The record of phosphorus inactivation effort over the duration of this project is summarized in Table 1. As the chemicals used have changed, the most relevant measure of application is the pounds of aluminum applied, which has varied between 3422 (2016) to 6720 (2012) lbs per treatment season, except for the lower value for the initial testing year (2008). The amount of aluminum needed is largely a function of precipitation, particularly in May and June under the operational scenario applied. Yet even with a wetter 2017 treatment season, less chemical was used than earlier in the program, owing mainly to automation and efficiency.

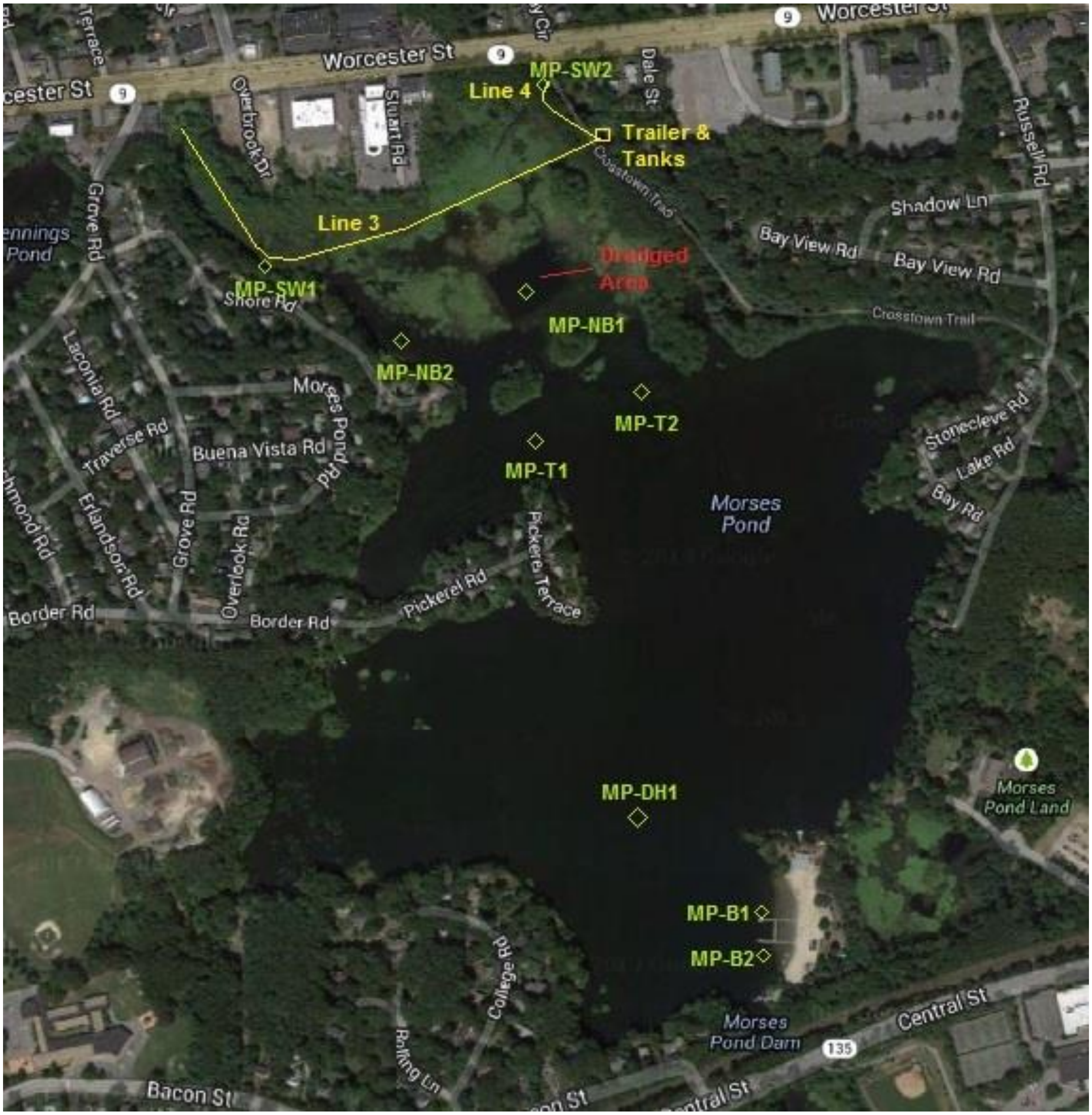
**Table 1. Summary of Phosphorus Inactivation Effort, 2008-2017**

| Year | Applied Alum (gal) | Applied Aluminate (gal) | Aluminum Mass (lbs) | # of Treatment Days | May-June Precipitation (in) | May-August Precipitation (in) | Notes |
|---|---|---|---|---|---|---|---|
| 2008 | 2000 | 1000 | 2240 | 5 | 6.2 | 16.7 | Testing and adjustment phase, most treatment in July |
| 2009 | 6002 | 2900 | 6595 | 16 | 5.9 | 16.1 | Some elevated storm flow untreated |
| 2010 | 4100 | 2080 | 4630 | 13 | 6.1 | 14.5 | Additional chemical applied after early July |
| 2011 | 5000 | 2475 | 5569 | 14 | 8.0 | 17.8 | Some equipment failures. Additional chemical applied in August in response to bloom |
| 2012 | 6000 | 3000 | 6720 | 19 | 6.9 | 14.4 | Equipment problems hampered dosing during treatment |
| 2013 | 6055 | 2785 | 6476 | 20 | 13.7 | 19.1 | Very wet June (26.7 cm), unable to treat all storm flows; continued treatment through July |
| | Polyaluminum chloride | | | | | | |
| 2014 | 5985 | | 3531 | 12 | 5.5 | 11.8 | No treatment after 1st week of July, first year using polyaluminum chloride |
| 2015 | 7900 | | 4661 | 14 | 6.2 | 10.5 | Leftover chemical used in summer, but little treatment after first week of July |
| 2016 | 5800 | | 3422 | 13 | 4.7 | 7.3 | Only a little over half of the chemical was used by early July, remainder by August 15th |
| 2017 | 6000 | | 3540 | 17 | 8.3 | 13.9 | Two deliveries of chemical were made and all was used by early July |

## Analysis of Program Results

Water quality is assessed prior to the start of treatment, normally in May, again in early summer, and yet again at least once later in the summer in up to three areas: the north basin, the transition zone to the south basin just south of the islands, and near the town beach at the south end of the pond (Figure 2). Visual and water quality checks are made on an as needed basis, as part of normal operations or in response to complaints, major storms, or town needs. The water quality record for 2017 (Table 2) incorporates field and laboratory tests at multiple sites. A summary of phosphorus data for key periods since 2008 is provided (Table 3) to put the treatments and results in perspective. It is intended that total phosphorus will decrease through the treatment, such that values in the south basin, assessed in the swimming area near the outlet of the pond, will be lower than in the north basin, with the transition zone exhibiting intermediate values. Based on data collected since the early 1980s, total phosphorus in the south basin in excess of 20 µg/L tends to lead to algal blooms, while values <20 µg/L minimize blooms and values near 10 µg/L lead to highly desirable conditions (Figure 3).

**Figure 2. Current system layout and water quality sampling sites in Morses Pond.**



# Table 2. Water quality record for Morses Pond in 2017

| Station | Depth meters | Temp °C | Oxygen mg/l | Oxygen % Sat | Sp. Cond µS/cm | pH Units | Turbidity NTU | Alkalinity mg/L | Total P mg/L | Diss. P mg/L | TKN mg/L | NO3-N mg/L | Secchi meters | Chl-a µg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | |
| **Stream Inlets** | | | | | | | | | | | | | | |
| MP-SW-1 Bogle | | | | | | | | | | | | | | |
| 5/15/2017 | | | | | | | | | 0.032 | | 0.549 | 0.466 | | |
| 7/31/2017 | | | | | | | | | 0.032 | | 0.544 | 0.552 | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| MP-SW-2 Boudler | | | | | | | | | | | | | | |
| 5/15/2017 | | | | | | | | | 0.044 | | 0.578 | 0.800 | | |
| 7/31/2017 | | | | | | | | | 0.044 | | 0.333 | 1.600 | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| **5/15/2017** | | | | | | | | | | | | | | |
| **North Basin** | | | | | | | | | | | | | | |
| MP-NB-1 (dredged) | 0.0 | 12.0 | 9.3 | 87.3 | 499 | 7.2 | 4.3 | | 0.030 | | 0.501 | 0.379 | | 4.3 |
| | 1.0 | 12.0 | 9.3 | 87.1 | 501 | 7.2 | 4.4 | | | | | | | 5.3 |
| | 2.0 | 11.9 | 9.2 | 87.0 | 496 | 7.1 | 4.4 | | | | | | | 5.5 |
| | 3.0 | 10.1 | 8.3 | 75.4 | 1669 | 7.1 | 4.1 | | | | | | | 3.9 |
| | 3.5 | 8.1 | 5.6 | 48.1 | 1948 | 6.7 | 4.3 | | | | | | | 5.6 |
| | 4.0 | 7.4 | 2.6 | 22.0 | 1991 | 6.7 | 4.5 | | | | | | | 6.1 |
| MP-NB-2 | 0.0 | 12.4 | 9.9 | 94.6 | 582 | 6.8 | 5.7 | | 0.031 | | 0.487 | 0.300 | | 5.1 |
| | 1.0 | 12.4 | 9.9 | 94.6 | 581 | 6.8 | 5.7 | | | | | | | 6.3 |
| | 1.5 | 12.4 | 9.9 | 94.0 | 580 | 6.8 | 5.9 | | | | | | | 6.1 |
| **Transition Zone** | | | | | | | | | | | | | | |
| MP-T-1 | 0.3 | 12.7 | 9.2 | 88.4 | 575 | 6.9 | 4.1 | | 0.026 | | 0.437 | 0.305 | | 4.6 |
| | 1.0 | 12.7 | 9.2 | 87.6 | 574 | 6.9 | 4.0 | | | | | | | 5.1 |
| | 1.5 | 12.5 | 9.2 | 87.2 | 573 | 6.9 | 4.1 | | | | | | | 6.0 |
| | 2.0 | 12.2 | 8.8 | 83.2 | 572 | 6.9 | 5.8 | | | | | | | 5.7 |
| | | | | | | | | | | | | | | |
| MP-T-2 | 0.4 | 12.2 | 9.4 | 88.9 | 533 | 7.2 | 3.8 | | 0.027 | | 0.681 | 0.338 | | 5.1 |
| | 1.0 | 12.2 | 9.4 | 88.6 | 532 | 7.2 | 4.0 | | | | | | | 5.6 |
| | 1.0 | 12.2 | 9.4 | 88.5 | 533 | 7.2 | 3.9 | | | | | | | 5.3 |
| | 1.5 | 12.0 | 9.1 | 85.5 | 530 | 7.1 | 4.1 | | | | | | | 47.3 |
| **South Basin** | | | | | | | | | | | | | | |
| MP-B-1 | 0.4 | 13.4 | 9.3 | 90.4 | 628 | 7.2 | 2.4 | | 0.012 | | 0.441 | 0.369 | | 2.7 |
| | 1.0 | 13.4 | 9.2 | 90.0 | 628 | 7.1 | 2.4 | | | | | | | 3.3 |
| MP-B-2 | N/A | | | | | | | | 0.018 | | 0.453 | 0.370 | | |
| | | | | | | | | | | | | | | |
| MP-1 (MP -DH1) | 0.4 | 13.3 | 9.0 | 87.8 | 632 | 6.9 | 3.5 | | 0.016 | | 0.502 | 0.373 | | 3.3 |
| | 1.0 | 13.4 | 9.1 | 88.1 | 631 | 7.0 | 2.7 | | | | | | | 3.1 |
| | 2.0 | 13.3 | 9.1 | 88.4 | 631 | 7.0 | 2.5 | | | | | | | 3.2 |
| | 3.0 | 13.3 | 9.0 | 87.6 | 631 | 7.1 | 2.4 | | | | | | | 3.5 |
| | 4.0 | 13.1 | 8.7 | 84.2 | 634 | 7.1 | 2.3 | | | | | | | 2.6 |
| | 5.0 | 10.3 | 5.4 | 48.8 | 722 | 7.1 | 2.3 | | | | | | | 3.3 |
| | 6.0 | 8.1 | 2.2 | 18.7 | 733 | 7.0 | 2.6 | | | | | | | 3.1 |
| | 6.8 | 7.9 | 1.2 | 10.3 | 736 | 6.8 | 4.5 | | 0.018 | | 0.368 | 0.259 | | 3.3 |
| | | | | | | | | | | | | | | |
| **6/26/2017** | | | | | | | | | | | | | | |
| **North Basin** | | | | | | | | | | | | | | |
| MP-NB-1 (dredged) | 0.0 | 23.9 | 6.9 | 83.0 | 477 | 7.2 | 3.5 | | 0.026 | | 0.631 | 0.253 | | 3.2 |
| | 1.1 | 22.1 | 3.6 | 41.8 | 442 | 7.1 | 3.5 | | | | | | | 2.5 |
| | 2.0 | 15.1 | 1.5 | 15.0 | 461 | 7.3 | 3.5 | | | | | | | 4.3 |
| | 3.0 | 10.8 | 3.1 | 28.9 | 1528 | 7.3 | 3.6 | | | | | | | 2.7 |
| | 3.4 | 10.0 | 4.4 | 39.7 | 1619 | 7.5 | 10.0 | | | | | | | 8.0 |
| | | | | | | | | | | | | | | |
| MP-NB-2 | 0.1 | 25.4 | 8.3 | 103.0 | 468 | 6.5 | 3.4 | | 0.035 | | 0.500 | 0.266 | | 3.0 |
| | 1.0 | 25.3 | 8.2 | 100.9 | 468 | 6.4 | 3.4 | | | | | | | 3.7 |
| | 2.0 | 24.2 | 6.4 | 77.7 | 465 | 6.2 | 3.8 | | | | | | | 4.0 |
| | 3.0 | 16.5 | 3.5 | 36.3 | 464 | 6.1 | 3.6 | | | | | | | 3.5 |
| | 3.6 | 14.5 | 2.1 | 20.7 | 509 | 6.1 | 4.5 | | | | | | | 2.8 |
| | | | | | | | | | | | | | | |
| **Transition Zone** | | | | | | | | | | | | | | |
| MP-T-1 | 0.0 | 25.7 | 8.7 | 108.2 | 492 | 7.2 | 4.1 | | 0.039 | | 0.618 | 0.274 | | 5.8 |
| | 0.8 | 24.2 | 7.6 | 92.4 | 487 | 7.3 | 3.8 | | | | | | | 2.6 |
| | 1.2 | 23.6 | 6.8 | 81.2 | 499 | 7.4 | 3.3 | | | | | | | 5.4 |
| | | | | | | | | | | | | | | |
| MP-T-2 | 0.1 | 25.4 | 7.7 | 94.7 | 476 | 7.6 | 4.8 | | 0.029 | | 0.633 | 0.198 | | 3.9 |
| | 0.6 | 24.1 | 7.5 | 90.1 | 471 | 7.6 | 3.3 | | | | | | | 4.7 |
| | 1.0 | 24.0 | 7.6 | 91.0 | 473 | 7.6 | 5.8 | | | | | | | 4.7 |
| | | | | | | | | | | | | | | |
| **South Basin** | | | | | | | | | | | | | | |
| MP-B-1 | | | | | | | | | | | | | | |
| MP-B-2 | 0.1 | 25.4 | 8.3 | 103.0 | 468 | 6.5 | 3.4 | | 0.021 | | 0.466 | 0.191 | 3.2 | 3.0 |
| | 1.0 | 25.3 | 8.2 | 100.9 | 468 | 6.4 | 3.4 | | | | | | | 3.7 |
| | 2.0 | 24.2 | 6.4 | 77.7 | 465 | 6.2 | 3.8 | | | | | | | 4.4 |
| | 3.0 | 16.5 | 3.5 | 36.3 | 464 | 6.1 | 3.6 | | | | | | | 3.5 |
| | 3.6 | 14.5 | 2.1 | 20.7 | 509 | 6.1 | 4.5 | | | | | | | 2.8 |
| | | | | | | | | | | | | | | |
| MP-1 (MP -DH1) | 0.0 | 25.1 | 8.4 | 102.9 | 469 | 7.3 | 5.0 | 41 | 0.015 | | 0.482 | 0.205 | 3.9 | 2.4 |
| | 1.0 | 25.1 | 8.3 | 101.9 | 468 | 7.1 | 5.4 | | | | | | | 3.6 |
| | 2.0 | 23.3 | 5.1 | 60.3 | 456 | 6.9 | 6.4 | | | | | | | 5.1 |
| | 3.0 | 16.6 | 3.9 | 40.2 | 456 | 6.9 | 7.3 | | | | | | | 4.6 |
| | 4.0 | 13.1 | 2.3 | 22.5 | 536 | 6.8 | 10.6 | | | | | | | 3.9 |
| | 5.0 | 10.6 | 0.8 | 7.1 | 600 | 6.8 | 14.4 | | | | | | | 4.3 |
| | 6.0 | 9.6 | 0.6 | 5.0 | 618 | 6.7 | 24.8 | | | | | | | 3.1 |
| | 6.3 | 9.4 | 0.6 | 5.3 | 625 | 6.7 | 16.6 | 46 | 0.046 | | 0.700 | 0.058 | | 2.9 |

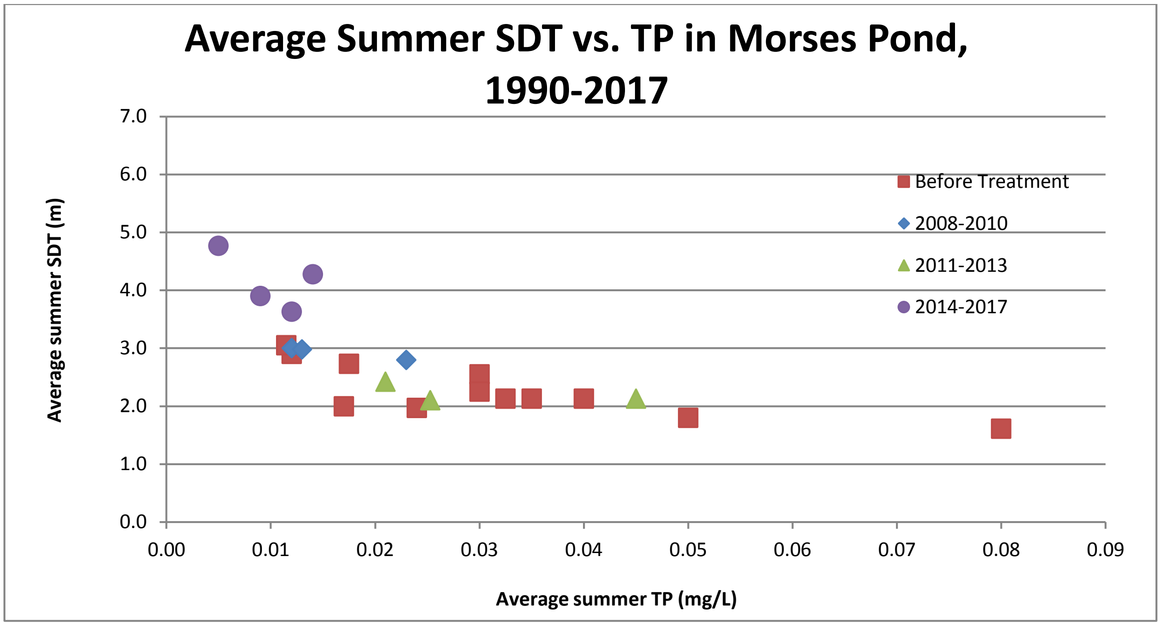
## Table 3. (continued) Water quality record for Morses Pond in 2017

| Station | Depth meters | Temp °C | Oxygen mg/l | Oxygen % Sat | Sp. Cond µS/cm | pH Units | Turbidity NTU | Alkalinity mg/L | Total P mg/L | Diss. P mg/L | TKN mg/L | NO3-N mg/L | Secchi meters | Chl-a µg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **7/12/2017** | | | | | | | | | | | | | | |
| **North Basin** | | | | | | | | | | | | | | |
| MP-NB-1 (dredged) | 0.1 | 25.5 | 7.6 | 94.2 | 624 | 6.7 | 2.7 | | 0.013 | | 0.395 | 0.100 | | 2.5 |
| | 1.0 | 21.9 | 3.5 | 41.1 | 472 | 6.6 | 3.4 | | | | | | | 1.8 |
| | 2.0 | 18.7 | 1.6 | 17.5 | 726 | 6.7 | 2.8 | | | | | | | 5.0 |
| | 3.0 | 12.1 | 3.7 | 34.9 | 1944 | 7.0 | 5.1 | | | | | | | 5.0 |
| | 3.6 | 11.2 | 5.2 | 48.5 | 2022 | 7.0 | 7.8 | | | | | | | 10.4 |
| | 3.7 | 11.3 | 4.6 | 42.5 | 2018 | 6.8 | 8.4 | | | | | | | 10.2 |
| **Transition Zone** | | | | | | | | | | | | | | |
| MP-T | 0.1 | 26.3 | 10.1 | 127.5 | 618 | 7.5 | 2.2 | | 0.014 | | 0.492 | 0.025 | | 5.0 |
| | 0.5 | 25.3 | 10.0 | 123.1 | 624 | 7.5 | 1.8 | | | | | | | 5.1 |
| | 1.0 | 24.4 | 8.6 | 104.1 | 624 | 7.5 | 1.7 | | | | | | | 3.6 |
| | 1.3 | 23.4 | 5.6 | 66.4 | 599 | 7.1 | 4.0 | | | | | | | 7.5 |
| **South Basin** | | | | | | | | | | | | | | |
| MP-B-2 | | | | | | | | | 0.014 | | 0.531 | 0.069 | 3.9 | |
| MP-1 (DH) | 0.1 | 26.4 | 8.5 | 107.6 | 610 | 6.8 | 2.6 | | 0.005 | | 0.416 | 0.060 | 3.9 | 6.4 |
| | 1.0 | 25.7 | 8.3 | 102.8 | 608 | 6.7 | 2.6 | | | | | | 3.9 | 3.1 |
| | 2.0 | 25.0 | 6.3 | 77.3 | 609 | 6.5 | 2.5 | | | | | | | 3.5 |
| | 3.0 | 20.7 | 3.7 | 41.6 | 590 | 6.6 | 2.8 | | | | | | | 6.0 |
| | 4.0 | 13.8 | 1.6 | 15.8 | 677 | 6.5 | 2.5 | | | | | | | 6.3 |
| | 5.0 | 11.2 | 1.2 | 11.4 | 749 | 6.5 | 2.1 | | | | | | | 6.8 |
| | 6.0 | 10.3 | 1.2 | 10.6 | 764 | 6.5 | 8.5 | | | | | | | 5.4 |
| **7/31/2017** | | | | | | | | | | | | | | |
| **North Basin** | | | | | | | | | | | | | | |
| MP-NB-1 (dredged) | 0.1 | 23.3 | 6.2 | 74.2 | 531 | 6.6 | 1.4 | | 0.019 | | 0.422 | 0.128 | | 1.0 |
| | 1.0 | 19.8 | 3.7 | 40.8 | 464 | 6.6 | 1.5 | | | | | | | 1.0 |
| | 2.0 | 18.3 | 1.8 | 18.9 | 497 | 6.7 | 2.2 | | | | | | | 1.0 |
| | 3.1 | 14.7 | 2.6 | 26.2 | 1644 | 6.7 | 3.5 | | | | | | | 3.6 |
| | 3.7 | 12.4 | 6.0 | 57.1 | 1781 | 6.7 | 8.2 | | | | | | | 9.4 |
| MP-NB-2 | 0.1 | 25.5 | 10.4 | 128.6 | 595 | 7.0 | 1.0 | | 0.026 | | 0.448 | 0.071 | | 6.6 |
| | 0.4 | 22.3 | 10.6 | 123.6 | 623 | 7.0 | 1.1 | | | | | | | 5.6 |
| **Transition Zone** | | | | | | | | | | | | | | |
| MP-T1 | 0.1 | 25.1 | 9.9 | 121.9 | 560 | 6.9 | 1.1 | | 0.022 | | 0.506 | 0.025 | | 4.5 |
| | 0.5 | 23.2 | 8.6 | 102.6 | 595 | 6.9 | 1.0 | | | | | | | 3.1 |
| | 1.1 | 21.7 | 8.2 | 94.7 | 585 | 7.1 | 0.8 | | | | | | | 3.0 |
| | 1.6 | 20.8 | 6.8 | 77.5 | 588 | 7.1 | 0.8 | | | | | | | 3.7 |
| | 2.0 | 20.3 | 3.8 | 42.1 | 578 | 7.0 | 0.9 | | | | | | | 4.7 |
| MP-T2 | 0.1 | 26.4 | 10.0 | 125.8 | 558 | 7.1 | 1.0 | | 0.023 | | 0.447 | 0.025 | | 2.9 |
| | 0.9 | 21.2 | 6.9 | 78.4 | 506 | 7.1 | 1.0 | | | | | | | 7.5 |
| | 1.0 | 20.7 | 4.4 | 50.2 | 500 | 6.8 | 17.5 | | | | | | | 11.9 |
| **South Basin** | | | | | | | | | | | | | | |
| MP-B-1 | | | | | | | | | | | | | | |
| MP-B-2 | | | | | | | | | 0.020 | | 0.474 | 0.025 | 3.8 | |
| MP-1 (DH) | 0.1 | 24.6 | 9.6 | 117.2 | 557 | 7.0 | 1.3 | | 0.019 | | 0.443 | 0.025 | 4.8 | 2.1 |
| | 1.0 | 23.3 | 9.6 | 114.7 | 553 | 7.0 | 1.3 | | | | | | | 4.0 |
| | 2.0 | 22.8 | 9.5 | 111.4 | 552 | 7.0 | 1.3 | | | | | | | 4.1 |
| | 3.0 | 22.2 | 8.3 | 96.5 | 551 | 7.0 | 1.3 | | | | | | | 5.6 |
| | 4.0 | 18.2 | 2.3 | 24.4 | 566 | 6.9 | 1.4 | | | | | | | 6.4 |
| | 5.0 | 12.9 | 2.1 | 20.1 | 647 | 6.9 | 1.6 | | | | | | | 10.5 |
| | 6.0 | 10.7 | 1.3 | 11.7 | 675 | 6.7 | 2.5 | | 0.050 | | 0.639 | 0.025 | | 11.4 |
| | 6.2 | 10.5 | 0.8 | 6.9 | 687 | 6.3 | 12.5 | | | | | | | 8.2 |
| **8/31/2017** | | | | | | | | | | | | | | |
| **North Basin** | | | | | | | | | | | | | | |
| MP-NB-1(dredged) | 0.3 | 20.3 | 6.4 | 71.6 | 689 | 6.5 | 0.6 | | 0.013 | | 0.463 | 0.025 | 2.8 | 1.4 |
| | 1.0 | 19.7 | 3.8 | 41.7 | 692 | 6.5 | 0.8 | | | | | | | 2.5 |
| | 2.0 | 19.1 | 3.5 | 38.6 | 701 | 6.4 | 0.9 | | | | | | | 2.1 |
| | 3.0 | 16.8 | 3.7 | 38.7 | 1800 | 6.4 | 1.4 | | | | | | | 4.4 |
| | 3.5 | 14.7 | 3.8 | 37.8 | 2016 | 6.3 | 8.9 | | | | | | | 8.3 |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| **Transition Zone** | | | | | | | | | | | | | | |
| MP-T-2 | 0.9 | 21.3 | 8.1 | 92.8 | 684 | 6.8 | 9.0 | | 0.014 | | 0.439 | 0.025 | | 6.4 |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| **South Basin** | | | | | | | | | | | | | | |
| MP-1-S | 0.4 | 22.6 | 8.4 | 98.0 | 675 | 7.1 | 1.4 | | 0.015 | | 0.452 | 0.025 | 4.5 | 3.2 |
| | 1.1 | 22.5 | 8.3 | 97.7 | 676 | 7.1 | 1.4 | | | | | | | 3.1 |
| | 2.0 | 22.5 | 8.2 | 96.1 | 675 | 7.1 | 1.3 | | | | | | | 2.6 |
| | 3.0 | 22.2 | 8.2 | 95.2 | 675 | 7.1 | 1.4 | | | | | | | 2.6 |
| | 4.0 | 21.5 | 5.3 | 61.5 | 677 | 7.1 | 1.6 | | | | | | | 2.9 |
| | 5.0 | 16.1 | 2.8 | 28.7 | 743 | 7.1 | 1.8 | | | | | | | 3.2 |
| MP-1-B | 6.1 | 12.2 | 1.2 | 11.3 | 805 | 6.8 | 6.6 | | 0.027 | | 0.487 | 0.025 | | 8.4 |

## Table 4. Water quality testing results relative to the phosphorus inactivation system

| Year | Location | Pre-Application TP (ug/L) | Early Summer TP (ug/L) | Late Summer TP (ug/L) | Algae Observations |
|---|---|---|---|---|---|
| **2008** | North Basin | 28 | 18 | 13 | Mats observed, some cloudiness |
| | Transition Zone | 31 | 22 | 14 | Some cloudiness, brownish color |
| | Swimming Area | 21 | 12 | 12 | No blooms reported, first year without copper treatment in some time |
| **2009** | North Basin | 35 | 40 | 63 | Cloudy, some green algae mats |
| | Transition Zone | 35 | 39 | 45 | Cloudy |
| | Swimming Area | 15 | 10 | 27 | Generally clear, no blooms reported |
| **2010** | North Basin | 26 | 46 | 53 | Cloudy, green algae mats evident |
| | Transition Zone | 28 | 21 | 32 | Brownish color, minimally cloudy |
| | Swimming Area | 19 | 15 | 43 | Generally clear, no blooms until late August (Dolichospermum) |
| **2011** | North Basin | 53 | 33 | 130 | Cloudy, green algae mats evident |
| | Transition Zone | 48 | 29 | 95 | Slightly brownish |
| | Swimming Area | 30 | 29 | 60 | Cyanobloom in early August (Dolichospermum), dissipated after just a few days without treatment |
| **2012** | North Basin | 32 | 24 | 48 | Very dense plant growth, associated green algae mats |
| | Transition Zone | 28 | 37 | 28 | Brownish most of summer |
| | Swimming Area | 20 | 27 | 24 | Had bloom in mid-July (Dolichospermum), treated with copper |
| **2013** | North Basin | 36 | 47 | 30 | Water brownish, but little visible algae; first year with newly dredged area within north basin |
| | Transition Zone | No Data | 78 | 32 | Generally elevated turbidity, but much of it is not living algae |
| | Swimming Area | 24 | 33 | 28 | Continued treatment kept TP down, but not to target level; June flushing minimized algae biomass |
| **2014** | North Basin | 30 | 22 | 20 | Dense plant growths outside dredged area, some green algae mats, but water fairly clear |
| | Transition Zone | 21 | 20 | 18 | Dense plant growths, some mats, water fairly clear |
| | Swimming Area | 12 | 13 | 17 | Water clear; Secchi to bottom in swimming area, no blooms reported |
| **2015** | North Basin | 12 | 17 | 23 | Dense plant growths outside dredged area, abundant green algae mats, but water fairly clear |
| | Transition Zone | 8 | 15 | 14 | Dense plant growths, but water fairly clear |
| | Swimming Area | 5 | 5 | 14 | Water clear; Secchi to bottom in swimming area, no blooms reported |
| **2016** | North Basin | 12 | 9 | 5 | A few mats but much less than in recent years |
| | Transition Zone | 19 | 16 | 5 | Dense plant growths but few mats, high water clarity |
| | Swimming Area | 14 | 5 | 5 | Water clear all summer |
| **2017** | North Basin | 30.5 | 30.5 | 13 | Dense rooted plants, some algae mats |
| | Transition Zone | 26.5 | 34 | 14 | Dense rooted plants, few algae mats |
| | Swimming Area | 17 | 18 | 15 | Some cloudiness, but no visible algae blooms |

**Figure 3. Relationship between water clarity and total phosphorus in Morses Pond, 1990-2017**




Dissolved phosphorus is a subset of total phosphorus, and tends to be near the limit of detection in many samples, as algae readily take up this available P form. The focus of management is on total phosphorus as the primary indicator of algal bloom potential. All but one value from the southern basin of Morses Pond in 2017 were below 20 µg/L, but there were higher values in the northern section as a consequence of more precipitation than in recent years. Concentrations declined as water moved south through the pond, as intended by treatment and detention. Despite more inputs due to wetter weather and some equipment issues during part of the treatment period, the P goal for the southern basin was met.

Nitrogen values tend to be low to moderate, with total Kjeldahl nitrogen (TKN) <1 mg/L and nitrate <0.5 mg/L. Values normally decline over the summer. Loss of nitrate can be a concern, as low ratios of available N to available P favor cyanobacteria, but the low phosphorus levels helped with algae control overall.

There are periodic oxygen deficiencies in the deep hole area (MP-1), but not consistently. Low oxygen was observed in June through August in the deepest water, but was always adequate at water depths shallower than 5 m (16.5 ft). There was also an odd oxygen depression at about 2 m (7 ft) in the dredged area in the north basin. This area has high conductivity that may limit mixing and allow oxygen depletion where decay is substantial, but the deepest water in the dredged area showed less oxygen depression, which is unusual and unexplained at this time.

Conductivity is high in surface waters of Morses Pond and very high in deeper water, indicating large amounts of dissolved solids in the water, although conductivity does not reveal the nature of those solids. Salts from road management are a likely source, as are lawn fertilizers. The pH is slightly elevated near the surface and declines with depth, as decomposition adds acids at deeper locations. The pH also tends to increase as water moves through the pond, with photosynthesis by algae and rooted plants removing carbon dioxide and raising the pH. Turbidity is moderate in most of the water column, decreasing with distance from inlets but increasing right at the bottom in the deep hole location; accumulation of very light solids is suggested at the deep hole station, and explains most other water quality variation. Alkalinity was moderate at the deep hole location.

Average summer water clarity was lower in 2017 than in the record-breaking 2016, but slightly higher than in 2014 and 2015 despite slightly higher P concentrations in 2017 (Figure 4).

Bogle and Boulder Brooks were sampled only twice in 2017 (Table 2), but values were again below typical runoff concentrations for urban areas. While still elevated in terms of what is desirable for Morses Pond, these lower values make treatement easier and may reflect the reduction of phosphorus in commercial lawn fertilizers that is ongoing. Historically, inlet concentrations have averaged 130 µg/L for both Bogle and Boulder Brooks.

The 9 year phosphorus inactivation history can be functionally divided into 3 periods: 2008-2010, 2011-2013, and 2014-2017, both in terms of system function and average summer water clarity data (Figure 4). While treatment in 2008 started late and was largely experimental, results for total phosphorus for 2008 were <20 µg/L. Similar results were achieved in 2009 and 2010; throughout these three years average summer phosphorus was 10-25 µg/L and average summer water clarity was about 3 m (10 ft). Equipment worked well and the operations team was effective in responding to storms.

Total phosphorus remained somewhat elevated in 2011-2012, with summer averages of 22-45 µg/L. 2011 and 2013 were the rainiest treatment periods on record and equipment problems became more frequent. Timely repairs kept the treatments going, but they were not as efficient and apparently not as effective as in the previous three years. Detention capacity of the north basin was limited by shallow depth resulting from years of sediment deposition; dredging was planned for fall 2012 but not completed until 2013, and June of 2013 set records for precipitation and flows. Water clarity averaged slightly more than 2 m (about 7 ft), not appreciably better than pre-treatment years, although it should be kept in mind that clarity would have been lower in the pre-treatment period if not for copper treatments.

Only one algae bloom occurred during the swimming season since P inactivation commenced. The combination of treatment and detention was insufficient to prevent a cyanobacteria bloom from forming in mid-July 2012. The only copper treatment since phosphorus inactivation started was conducted in the swimming area to reduce algae and increase clarity in mid-July, but a major storm within a few days resulted in a major flushing of the lake. The storm inputs were treated with aluminum, and no further algal blooms occurred.

Conditions in 2014-2017 were a product of dry weather, effective treatment, and improved detention in the north basin. Phosphorus was low and water clarity was the highest it has been since implementation of the comprehensive plan (and indeed going back almost 30 years). No serious problems were encountered in application, chemical costs were not elevated, and labor

**Figure 4. Average summer water clarity and total phosphorus in Morses Pond, 1994-2017.**

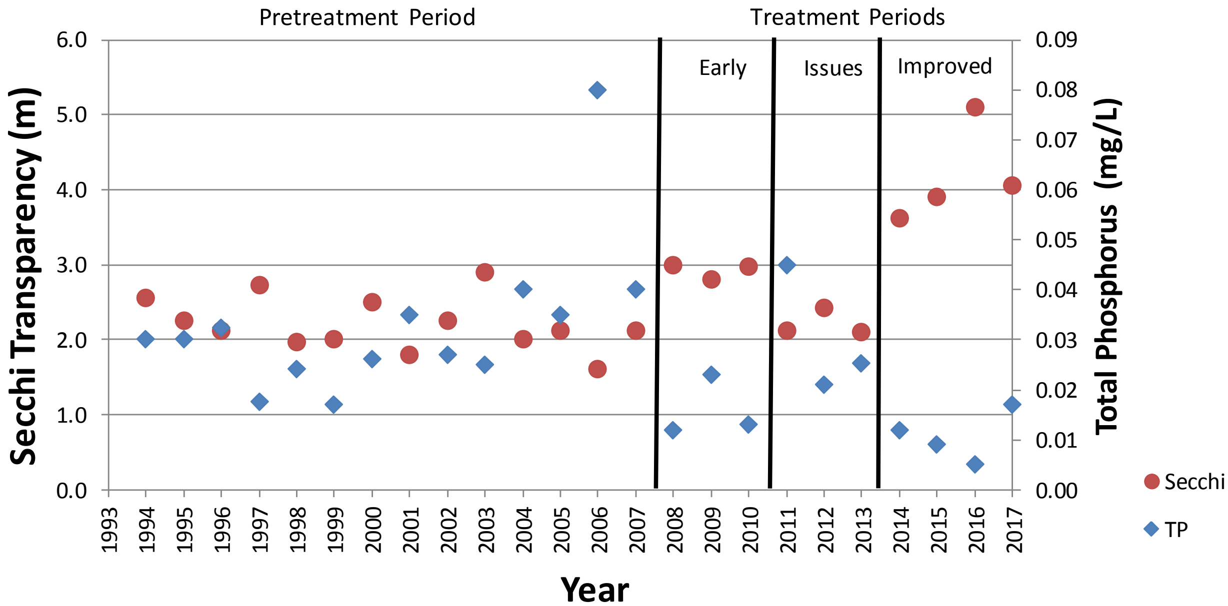
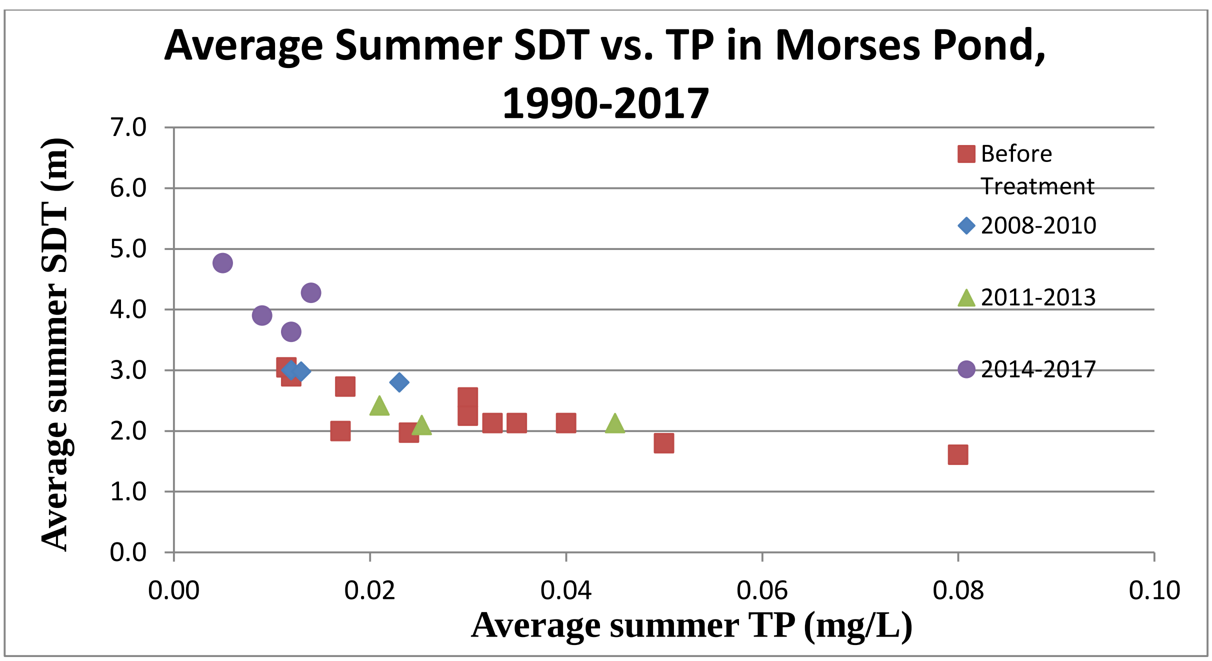



**Figure 5. Relationship between summer water clarity and total phosphorus in Morses Pond.**



costs were reduced by the automated application system in 2016. The current system is expected to run for the foreseeable future with limited adjustment or maintenance needs.

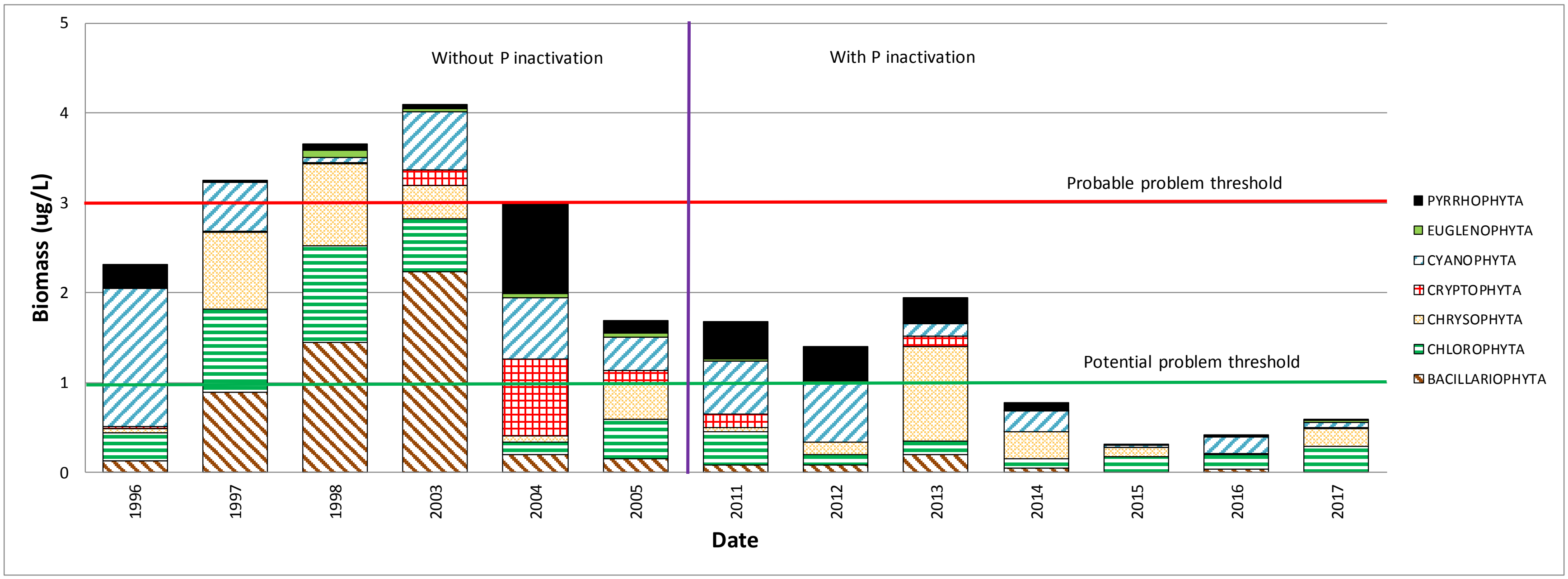
The higher clarity is related to lower algae abundance, which is in turn related to lower phosphorus levels. The relationship between clarity as Secchi transparency and total phosphorus (Figure 5) is fairly tight for Morses Pond. The early program (2008-2010) results were among the best observed to that time, while the middle program (2011-2013) results were not obviously better than the pre-treatment record. The last three years (2014-2016) have been the best on record.

Algal data for 1996-2017 illustrate processes in Morses Pond over the summer (Figure 6). Algae biomass and composition can be very variable, depending on combinations of nutrient levels, light, temperature and flushing. Morses Pond phytoplankton was frequently elevated prior to spring phosphorus inactivation, but since then biomass values have not exceeded the general threshold of 3 mg/L that signals low clarity (note that there is no official threshold for algae, but the red line in Figure 6 is a useful limit). Phytoplankton biomass has been below the 1 mg/L threshold indicative of low biomass since the system adjustments of 2014.

Cyanobacteria were moderately abundant in late summer 2011 and at times in 2012, when the P inactivation system was not operating as well as desired, but have not been common since then. The cyanobacteria that were detected since 2012 did not reach bloom proportions. Bloom forming cyanobacteria were observed in small clumps along the shoreline in late September of 2015, but were absent from plankton samples. In 2016 cyanobacteria were present in the August sample, but were not measured in bloom amounts and all phytoplankton biomasses were still well under the potential problem threshold. Cyanobacteria were minimal in 2017.

Morses Pond had been plagued by a variety of algae blooms in summer over the years of monitoring, necessitating copper treatments to keep the beach open. The P inactivation program has been very successful in limiting algae biomass and is reflected in beach and lake use. Only one copper treatment was conducted since the treatment system was installed, and no treatments have been conducted since the system was improved in 2014. This portion of the Morses Pond comprehensive plan, including watershed loading reductions (reduced P in fertilizer), dredging for increased detention in the north basin, and P inactivation at inlets during storms in late spring and early summer, has achieved its goals.

Figure 6. Summer average algae biomass divided into major algae groups for 1996-2017

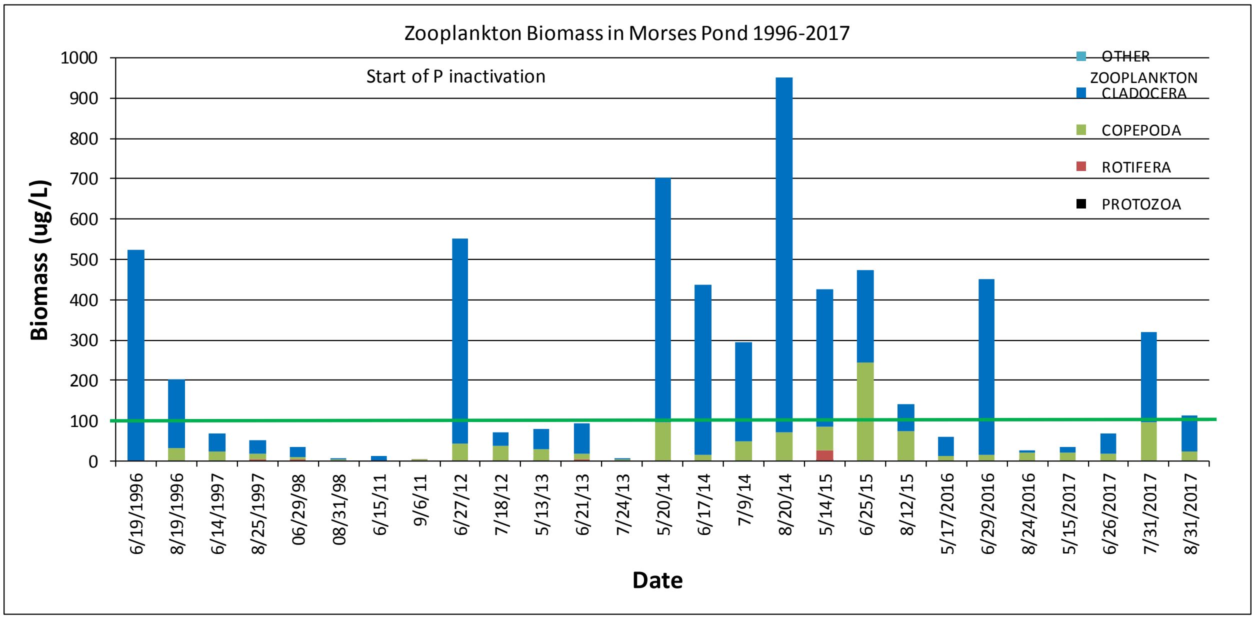


Zooplankton have also been sampled, and while not as tightly linked to nutrients, provide important information on the link between algae and fish (Figures 7 and 8). Zooplankton biomass varies strongly between and within years. Values <25 ug/L are low and values higher than 100 ug/L are high as rough thresholds; Morses Pond values span that range and more. Values in later summer are expected to be lower than in late spring or early summer, as fish predation by young-of-the-year fish (those hatching that year) reduces populations of zooplankters. Spring levels will depend on water quality, predation by adult fish, and available algae, which are food for zooplankton. The dominant zooplankton tends to be cladocerans and copepods, both groups of micro-crustaceans. *Daphnia*, among the larger cladocerans, filters the water to accumulate algae as food, and can increase water clarity markedly.

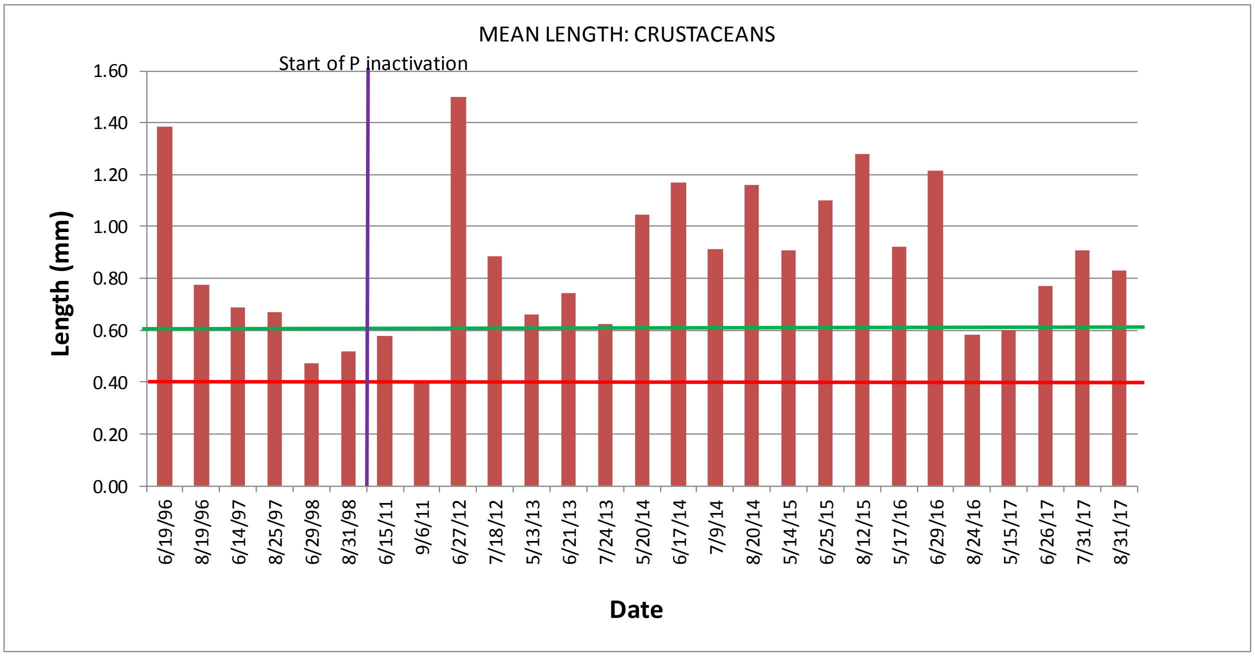
*Daphnia* were present in Morses Pond in all monitored years, a good sign, and abundance was elevated in most of spring and summer of 2014 and 2015. The late summer zooplankton population was very low in 2011 and 2013, but was substantial in 2012 and hit an all-time record in 2014. Late summer biomass was also high in 2015, although much lower than in 2014. 2016 June samples exhibited biomass above the desirable 100 ug/L threshold, but declined markedly in August, as expected based on fish predation. Biomass was lower than usual in spring and early summer in 2017, but increased to substantial levels in later summer. The harvesting program tends to reduce refuges for small fish, allowing more predation by larger fish and potentially allowing large and more zooplankton to survive into late summer. Weedier conditions in 2016 and 2017 protect small fish from their predators and lead to greater predation on zooplankton, so variation is explainable but not very predictable. There is no indication of any aluminum toxicity to zooplankton; the treatment protocols minimize this probability.

The size distribution of zooplankton (Figure 8) is important, as larger individuals are more effective grazers and represent better food for small fish. Mean lengths for at least crustacean zooplankton exceed the minimum desirable threshold (0.4 mm) in all samples, and exceed the preferred threshold (0.6 mm) in all but a few samples. Yet average length tends to be higher and more desirable in samples since phosphorus inactivation commenced when compared to the limited pre-treatment data base. Grazing capacity in 2014 through 2017 was high and undoubtedly contributed to low algae abundance and high clarity. Lower 2016 and 2017 biomasses and mean lengths are probably a consequence of weedier conditions than usual that protected small fish (see the harvesting review below for more explanation). The high mean length data are indicative of high game fish abundance and suggest good fishing. This is consistent with angler observations. As it is now, the biological structure of Morses Pond is almost ideal from a human use perspective, featuring lots of game fish for anglers and relatively clear water for swimmers.

## Figure 7. Zooplankton abundance for 1996-2017.




## Figure 8. Crustacean zooplankton mean length, 1996-2017.



# Plant Harvesting

## Harvesting Strategy

The Town of Wellesley initiated the enhanced Morses Pond vegetation harvesting program in 2007. The zoned vegetation harvesting strategy originates from the 2005 pilot program and comprehensive management plan written that year. For the pilot program, Morses Pond was divided into seven zones in order to better track the harvesting process. Figure 9 shows these zones and Morses Pond bathymetry. Harvesting protocols have been adjusted through experience to maximize effectiveness and minimize undesirable impacts, such as free fragments that accumulate along shore. The goal is to complete one harvest all targeted areas by the end of June, sometimes using two harvesters, with a cutting order and pattern that limits fragment accumulation, especially at the town swimming beach. This usually involved cutting in area 6 first, with any work around the edge of area 7 second, followed by work in areas 2, 3 and 4 in whatever order appears warranted by conditions. Area 5 is in Natick and is usually not cut, and area 1 is the north basin and is also not cut, except when the dredging was planned and avoidance of pipeline clogging was desired. A second cutting occurred from August into October until 2015, when the second cutting was initiated in July and completed by early September. The intent for 2016 and 2017 was to repeat the 2015 pattern, although equipment issues limited activity.

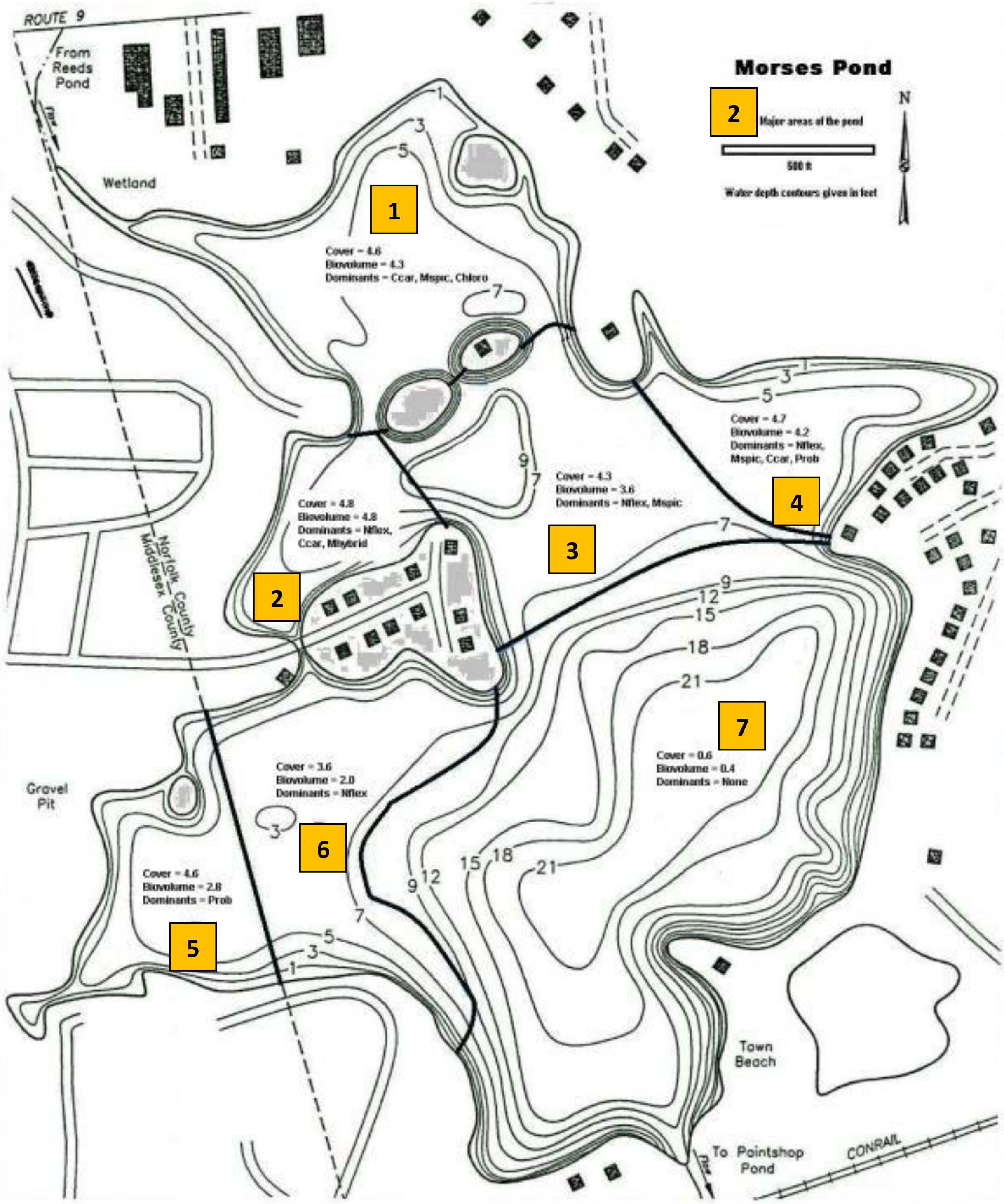
The keys to successful harvesting include:

- Initiating harvesting by the Memorial Day weekend, sooner if plant growths start early in any year.
- Cutting with or against the wind, but not perpendicular to the wind, to aid fragment collection.
- Limiting harvesting on very windy days (a safety concern as well as fragment control measure).
- Using a second, smaller harvester to pick up fragments if many are generated.
- Cutting far enough below the surface to prevent rapid regrowth to the surface, but not so far as to cut desirable low growing species such as Robbins' pondweed.
- Minimizing travel time on the water with a cutting pattern that does not end a run any farther from the offloading point near the outlet than necessary.
- Preventive maintenance in the off season to minimize down time during the harvest season.
- Using trained personnel who know what to cut, where to cut, and how to avoid damage that would necessitate maintenance of the harvester.

The second, older harvester has been used mainly to collect fragments released by the larger, newer harvester, or to accelerate harvesting at key times and in key places, and this approach has worked well. However, in 2016 the larger harvester was inoperable for 3 weeks in June and the smaller harvester was used to work in areas 6 and 7. This ensured acceptable conditions in the most used area of the pond, but allowed excessive growths in other areas. Even with extra effort once the larger harvester was back in service, it was not possible to catch up and achieve desirable conditions in areas 2, 3 and 4. In 2017 the smaller harvester was declared unserviceable and there were further equipment problems with the larger harvester, resulting in inefficient harvesting for over a month and no harvesting for another month; conditions were unacceptable in the normal harvesting areas of Morses Pond.

A fundamental problem is a decrease in efficiency when plant growth is dense. Aquatic plant harvesting is very much like mowing a lawn; if grass is allowed to get too high, cutting becomes difficult in one pass, clogging is an issue, and more frequent unloading of the grass catcher is needed. In the aquatic environment this problem can be magnified, as travel time to dump each load can be substantial. It is

**Figure 9. Plant Management Zones for Morses Pond.**



therefore important to stay ahead of plant growth when harvesting, maintaining maximum cutting rate and minimizing travel time. Equipment issues that reduce cutting time and allow plants to grow high and dense can prevent achievement of goals.

## Harvesting Record

Records provided by the Town of Wellesley document the harvesting effort expended on Morses Pond (Table 4). Although the record is not always complete, records have been kept since 2007. Between late May and late October, from 2007 through 2017, harvesting was conducted on a range of 43 to 76 days. This represents a range of 303 to 520 total hours devoted to some aspect of the harvesting program, and 184 to 335 hours of actual harvesting time. Total loads of aquatic plants harvested have ranged from 54 to 125 per harvesting season. Total weight of plants harvested, as measured upon entry to the composting facility (so some draining of water, but not a dry weight) has ranged from 224,000 to 808,000 lbs. Between 6.4 and 10.6 hours are spent on a day when harvesting occurs, including transport to and from the pond, actual cutting, transport on the water, loading and unloading, and harvester maintenance. A range of 3.5 to 5.4 hours per day are spent on actual cutting. Some variation may be a function of record keeping, but the wide range bears further scrutiny for indications of how to maximize results.

Data for 2012 and part of 2013 differ from other years due to cutting in area 1 in preparation for dredging; plant density is very high in this section of the pond, which is not normally harvested, and resulted in faster load generation but more travel time, reducing hours spent actually cutting each day but raising the biomass removed. Equipment problems in 2016 and 2017 caused variation in those years. Use of only the smaller harvester for part of 2016 and more time spent cutting in the second half of the season caused measured harvesting attributes to fall within the range for all program years, but conditions were not acceptable outside areas 6 and 7 for most of the late spring and summer. Additionally, the very mild winter of 2015-2016 allowed early plant growth and exacerbated the equipment limitations, allowing early achievement of dense plant growths that could not be overcome. Problems with the hydraulic system in 2017 caused inefficient harvesting in May and part of June, then failure of the hydraulic oil tank and lack of a second harvester caused low values for cutting hours, loads collected, and plant weight removed. More hours were worked per day, but less plant material was removed.

An increasing number of non-cutting hours was observed from 2009 until 2015 (Figure 10), and appeared related to increases in time for maintenance and travel. Beginning in 2014, records were kept for non-cutting hours in categories including transport time on the water, transport time on land, and maintenance (Figure 11). With a renewed emphasis on efficiency, the 2015 record indicates that non-cutting time was roughly cut in half. Non-cutting time increased very slightly in 2016 but was still far less than in 2014. Non-cutting time increased markedly in 2017, as the large harvester was not working properly, resulting in low efficiency and an eventual breakdown.

Considering total time spent on harvesting program activities and dividing that total into cutting and non-cutting hours (Figure 12), it is apparent that actual hours of time spent cutting plants has declined

**Table 5. Harvesting record summary for Morses Pond**

| Year | Days of Harvesting per Year | Total Hours per Year | Cutting Hours per Year | Total Hr/Day | Cutting Hr/Day | Total Loads | Total Weight | Weight/ Day | Weight/ Load | Weight/ Total Hr | Weight/ Cutting Hr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (Days) | (Hr) | (Hr) | (Hr) | (Hr) | (Load) | (Pounds) | (Pounds) | (Pounds) | (Pounds) | (Pounds) |
| 2007 | 49 | 359 | 255 | 7.3 | 5.2 | 109 | NA | NA | NA | NA | NA |
| 2008 | 43 | NA | NA | NA | NA | NA | 270320 | 6287 | NA | NA | NA |
| 2009 | 57 | 390 | 304 | 6.8 | 5.3 | 78 | 224060 | 3931 | 2891 | 575 | 738 |
| 2010 | 44 | 303 | 223 | 6.9 | 5.1 | 78 | 226960 | 5278 | 2900 | 749 | 1017 |
| 2011 | 54 | 414 | 291 | 7.7 | 5.4 | 102 | 292000 | 5407 | 2863 | 706 | 1003 |
| 2012 | 70 | 460 | 296 | 6.6 | 4.2 | 124.5 | 807760 | 11539 | 6488 | 1756 | 2729 |
| 2013 | 76 | 519.5 | 335 | 6.8 | 4.4 | 119.5 | 595277 | 7833 | 4981 | 1146 | 1777 |
| 2014 | 75 | 476.5 | 265.5 | 6.4 | 3.5 | 110 | 455220 | 6070 | 4138 | 955 | 1715 |
| 2015 | 57 | 363 | 268 | 6.4 | 4.7 | 90 | 607710 | 10662 | 6752 | 1674 | 2268 |
| 2016 | 48 | 350 | 252 | 7.3 | 5.3 | 85 | 521000 | 10854 | 6129 | 1489 | 2067 |
| 2017 | 43 | 454.5 | 183.5 | 10.6 | 4.3 | 54 | 348200 | 8098 | 6448 | 766 | 1898 |
| For 2009 total hours, assumes 1.5 hr/harvesting day of non-cutting time, based on values for those days with total and cutting hours. | | | | | | | | | | | |
| For 2010 total weight, assumes 202,000 pounds resulting from hydroraking, based on values for days when hydroraking occurred. | | | | | | | | | | | |
| For 2012 and 2013, harvesting includes Area 1, which had very dense plant growths and accounts for additional weight removed. | | | | | | | | | | | |

**Figure 10. Non-cutting hours associate with the harvesting program.**

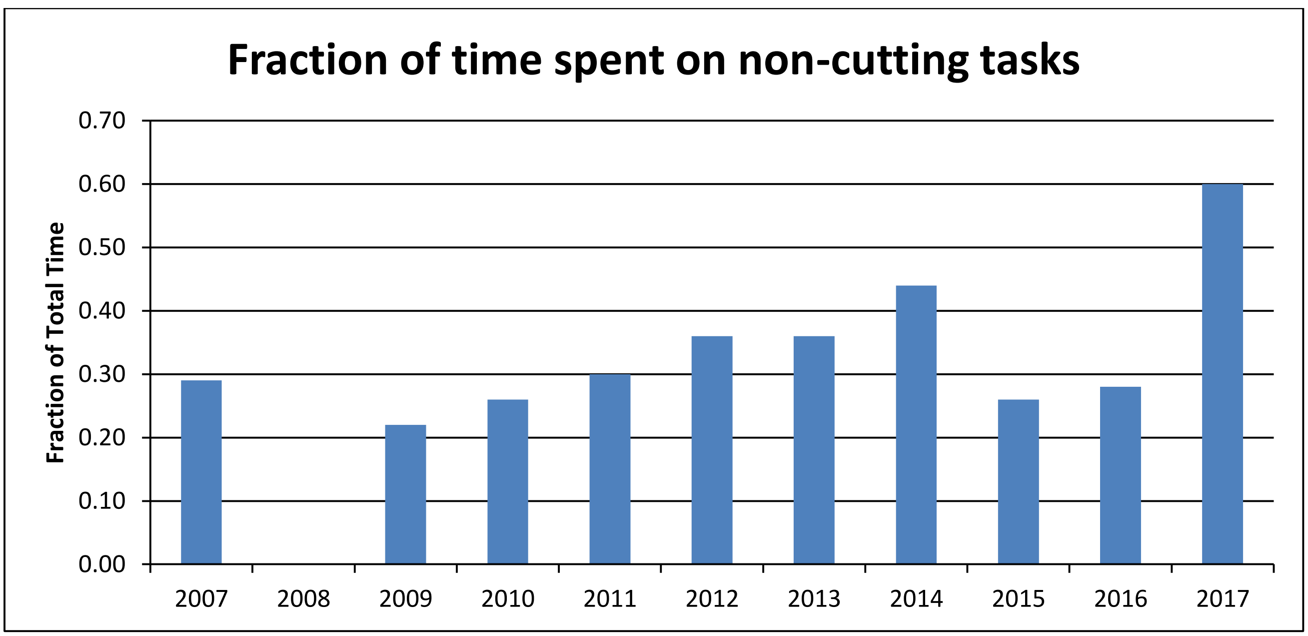


**Figure 11. Fraction of logged hours spent on all tasks for harvesting program**

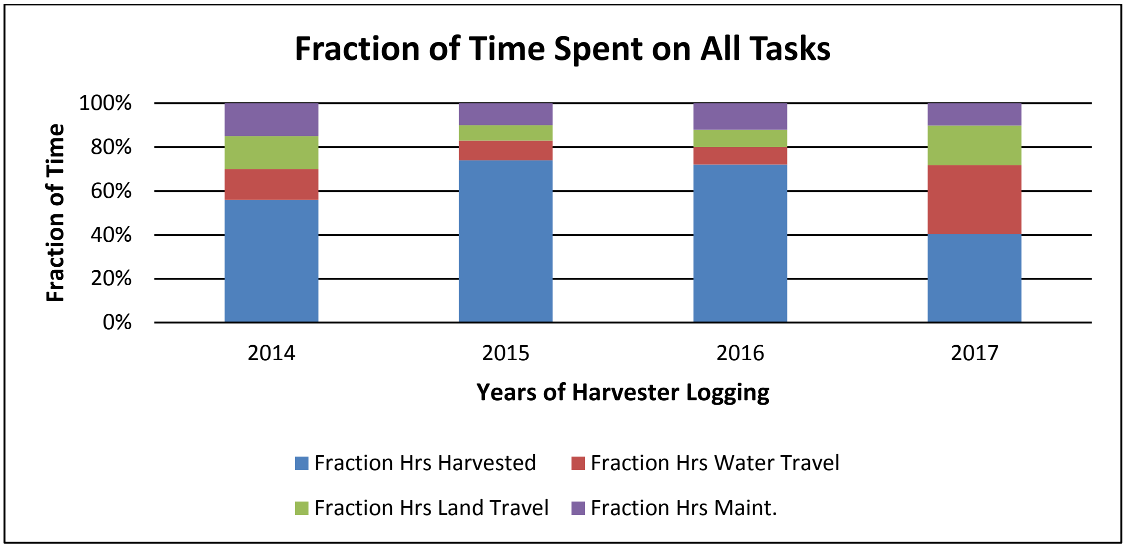
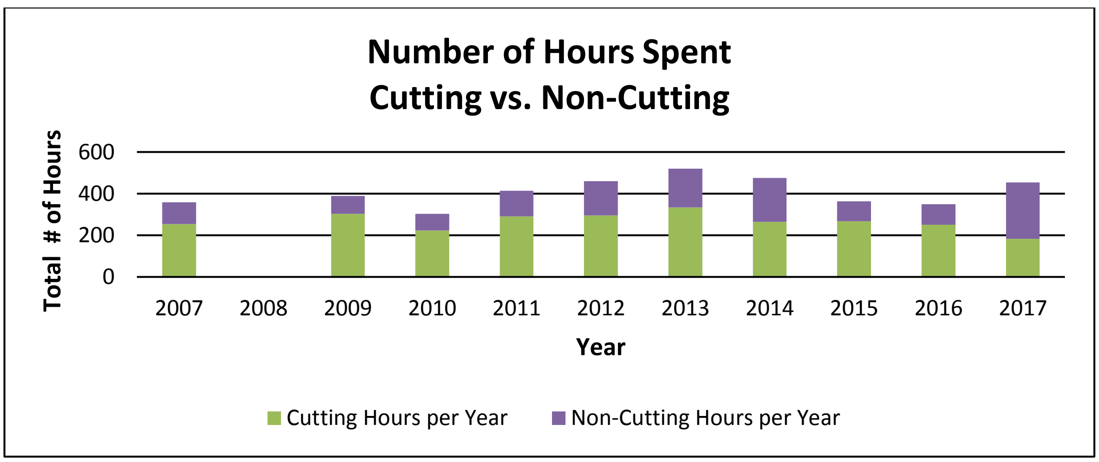



**Figure 12. Number of hours spent on cutting and non-cutting tasks for harvesting program**




since 2013, independent of efficiency factors. The decrease is partly a function of downtime, as only some much time can be made up later, and loss of efficiency will compound the problem of insufficient cutting hours if plant growths get too dense. Less cutting hours can produce acceptable results if plant growth is slower (wet, cloudy springs and summers) or efficiency is maximized, and more cutting time may not be adequate if efficiency is low (dense plants, operational issues that limit harvester speed).

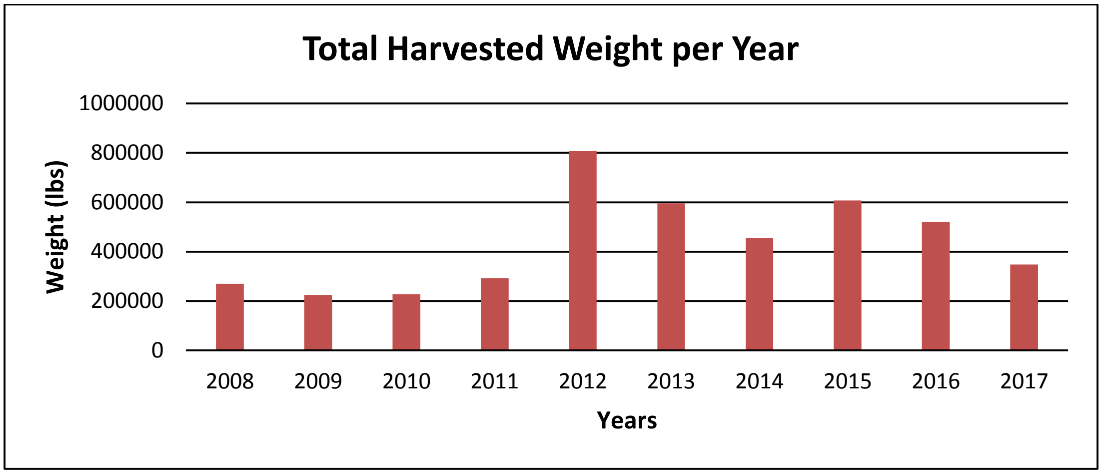
The results from 2015 are considered to best represent desirable operation, with no more than an average rate of plant growth after a late ice out, initiation of harvesting in mid-May, no prolonged periods of harvester inoperation, and relatively high efficiency of cutting. A total of 268 hours of actual cutting time were recorded, representing 74% of total program staff time, but the numbers by themselves can be misleading. In 2016, a year where program goals were not met, 252 hours were spent cutting, 72% of total program staff time, which is only slightly less than in 2015. But ice out was very early, plants grew fast, and 3 weeks of downtime in June made it very hard to catch up. Considering known conditions over the last decade of operation, it seems likely that about 250 hours of cutting time are needed with no prolonged periods of inoperation to meet the goals as currently laid out.

Total weight of plants harvested increased dramatically in 2012 from previous years (Figure 13), a result of harvesting area 1 where plants grow dense and harvesting rarely occurs. This was done in preparation for dredging in that area. Additional early harvesting in 2013 to support the conclusion of the dredging program increased the total harvested biomass in that year as well. Achieved conditions in 2008-2011 were considered acceptable with less harvested biomass recorded, but this may be a function of plant growth pattern and possibly some record keeping issues. Harvested plant biomass in 2014 and 2015 appears to bracket the necessary range for achieving desired conditions over the entire target area of the pond, but that harvest has to occur without significant interruption. Harvested biomass in 2016 was within that range but did not result in acceptable conditions, a result of too much downtime and resulting excessive growths by late spring that could not be effectively addressed in all areas once the large harvester was fully functional.

Weight per day, per load, per total hour and per cutting hour vary considerably among years, and will vary substantially among days within years. Some periods are more productive than others, owing to areas of variable plant density and distance to the offloading area between the beach and outlet. With a weight per load that is typically between 3000 and 5000 lbs, the operator is ideally cutting for between 2 and 3 hours, coming in to unload and get a break, then getting a second cutting session in the same day. This should result in slightly more than 5 hr of cutting per day; this target was met in the first 4 years with records but not been met in the next 4 years. The staffing adjustment of 2015 improved this metric, with 4.7 hours of cutting time achieved per day, and the 5 cutting hr/day threshold was achieved in 2016. Cutting time declined to 4.3 hr/day in 2017 due to equipment issues that limited efficiency.

The harvester has met its goal of at least one complete cut of the roughly 45 acres of dense vegetation outside area 1 before the 4$^{th}$ of July weekend in each year until 2015, when a short period of downtime for maintenance put the program just slightly behind schedule. Necessary repairs and delays in parts acquisition limited harvesting before the 4$^{th}$ of July in 2016 and 2917. Harvesting in 2015 continued through July, making it a more continuous process and plant growths were not excessive as a result of late ice out. Conditions suitable for harvesting were encountered by late April in 2016, yet the operator was not available until mid-May and the large harvester was not operational until the second week of June. The smaller harvester cannot accomplish what the larger one can, so plant growths were very dense by the time the harvesting program was running as planned with two harvesters available. Despite putting in extra hours through July and August that brought the hourly cutting total and the weight of plants removed into the range for recent years, the program never caught up and plant growths in areas 2-4 were excessive for much of the summer. Plant growths did not start as early in 2017, but the smaller harvester was no longer available and the larger harvester did not work well until late July, so plant density was similar in 2016 and 2017 and unacceptable to many users.

**Figure 13. Total weight of harvest material per year for harvesting program**




Improved efficiency is the primary goal for moving forward and the key step is to limit the amount of harvester downtime during the harvesting season. Better maintenance and rehabilitation in the off season is a key component of this strategy, facilitated by a detailed assessment of needs at the end of the harvesting season, conducting mechanical maintenance in the fall rather than spring, and having parts that are likely to be needed on hand going into the harvesting season. But this is might easier written than accomplished. A full assessment was done in December 2016, including inspection by a manufacturer's representative, all parts expected to be necessary were ordered, and all known maintenance needs were covered by late April of 2017. The hydraulic system malfunctioned and then failed, something no one envisioned, and it took month to get all needed parts as custom fabrication was involved.

The larger harvester is now in its 12th year, and maintenance needs for harvesters in their second decade increase substantially. There is minor downtime in almost any year, as this is a complex machine with multiple mechanical systems that all have to work; breaking a cutting blade on a submerged log, overheating during a hot summer with long runtime, and other minimally avoidable hazards exist. But the downtime has increased noticeably since 2014 and according to multiple manufacturers and owners contacted, increased maintenance and unplanned downtime is to be expected after the first decade of use. More detailed memos about conditions and options were prepared over the last year, most recently in October, but the short summary is as follows:

1. Routine maintenance needs are known and can be conducted in early spring without causing operational delays, as long as staff time is allocated and any needed parts are in stock.
2. Specific but less predictable maintenance needs are sometimes known when the harvesters come off the water at the end of the cutting season, and should be acted upon before spring when the risk of operational delays increases.
3. Careful inspection at the end of the season may reveal more maintenance issues and allow pro-active management that will both extend harvester life and avoid spring delays to cutting.

4. Uncovered outdoor storage is resulting in increased rust and potential metal failure. If storage in a building is not possible, use of a tarp over a frame or even just draped over the harvesting equipment (harvesters and shore conveyors) would at least limit winter weather impacts.
5. The next expected problem with the large harvester will likely be leakage in the barge itself. According to the manufacturer, there are ports that will allow inspection and such inspection should be conducted over the coming winter, with repairs as warranted.
6. The small harvester used for 33 years has been deemed inoperable and unrepairable. Funds have been allocated for the purchase of a new smaller harvester, for use on other Wellesley ponds as well as in Morses Pond, and specifications are almost final. Getting this new harvester operational by summer 2018 is highly desirable.
7. The only viable alternative to meet current goals for plant management in Morses Pond if harvesters are unavailable when needed is contract harvesting. It will be difficult to get an arrangement whereby a contractor responds to an intermittent need when one of the Wellesley harvesters breaks down, but early season support is possible with winter contracting if there is an expectation of a delayed start due to needed harvester maintenance. The cost for about 20 days of effort is expected to be about $30,000. If we contracted for the normal full season of harvesting, it would cost about $125,000. Funds are not currently allocated for contract harvesting.

Note that the town contracted with SOLitude Lake Management in 2017 on an emergency basis for just over a week of harvesting when it became apparent that the large harvester would be out of service for several weeks. When an effort to contract for harvesting was initiated in June, there were scheduling issues that prevented prompt action by any contractor. SOLitude eventually provided a harvester and operator in an effort to help the town and Morses Pond, and channels were cut to facilitate access and scheduled events in the pond. Getting the best equipment and the most experienced operator will be challenging on a contract basis unless set up as a guaranteed project well in advance.

If town-owned harvesters are not available and funding or an effective contract arrangement for a vendor to provide such services cannot be provided, the targeted harvest area could be reduced to area 6 and area 3, with channels cut into areas 1, 2, 4 and 5 for access to open water, and channels through area 3 as needed. The premise here is that it is better to do an adequate job with a smaller area than an inadequate job with a larger area in the event that mechanical harvester problems continue. This would not meet the current goal of the harvesting program, but would provide the maximum benefit possible with the available resources.

With an understanding developed from experience and extensive discussions with harvester manufacturers and users, the following draft specifications for the new, smaller harvester have been developed:

1. Size should facilitate transport and maneuverability. Prefer <10,000 lbs, 5 to 6 ft cutting width. For most applications, large carrying capacity for weeds is not a critical issue, but it should be able to hold the equivalent of about 20-30 minutes of cutting in dense weeds (estimated at 100 to 200 cubic feet capacity).

2. Re-enforced hull with chambers. Prefer added layer or thickness at all corners and edges that might strike rocks or hard bottom. Multiple chambers would limit accumulated water if leaks occur. Foam fill could be considered for buoyancy and size/weight reduction of the hull. Use of stainless steel should be offered as an option.
3. Water cooled diesel engine, Kubota being an acceptable example brand. The engine should provide 125% of expected power need, so it can run at lower rpm and still accomplish goals.
4. Horizontal cutting blade on base of forward end of harvester, but no vertical blades or other side devices that create fragments or cause a forward wave under harvester movement.
5. No flared wings at the cutting end, as they slow the harvester down and reduce maneuverability.
6. Standard pressure compensated pump system; minimize solenoids and other system components that tend to increase maintenance needs or cause reduced performance. Use cables to control hydraulics, minimizing electronics that tend to fail more readily.
7. Hydraulic oil tank with 125% of the minimum necessary volume and two filters in the hydraulic line from tank to rest of system. Tank should be stainless steel with a clean out port on the top and a drain at the lowest point of the tank.
8. Hydraulic oil cooling system, such as a radiator, to control fluid temperature.
9. A removable stainless steel fuel tank.
10. Stainless steel conveyor system, minimizing maintenance needs and adherence of algae mats and vegetation during harvesting, should be offered as an option.
11. Channel mounted track guards made of polyethylene or similar material mounted on the framework over which any conveyor moves, to minimize friction and wear on conveyors.
12. Rear conveyor (links to shore conveyor) must be raised enough to clear the shore conveyor entry area; movable rear conveyor (vertically adjustable) preferred.
13. Retractable paddlewheels or placement such that removal is not necessary for transport.
14. Sun and rain protection for operator (canopy or similar structure).
15. GPS and depth gauge for navigation of harvester.
16. Trailer to haul harvester to work sites; minimize friction on trailer bed to aid offloading and onloading operations. The trailer will be hauled by Wellesley DPW trucks with a range of hitch types possible and adequate power to haul heavy loads, but note that a harvester with a weight <10,000 lbs is preferred.
17. Electric winch on trailer, allowing hook up to truck battery to winch harvester onto trailer.

Many of these specifications would apply to a new, larger harvester, a purchase that needs to be considered. Current planning suggests that purchase in 2021 is the earliest likely date.

There have been some plant controls additional to mechanical harvesting. Hydroraking has occurred annually if needed in the beach area, prior to setting up the ropes and docks, but in 2017 WRS assisted the Recreation Department with the regrading of the swim area for safety and the purchase and installation of benthic barriers to restrict plant growths in key areas. This process went very well, eliminated the need for hydroraking in the swim area, and it is expected that benthic barriers will be used again in 2018. Hydroraking was still conducted along the shoreline by arrangement with private property owners in 2017, as it has in some past years. Benthic barriers may be an attractive option for shoreline property owners as well. Past efforts have seemed too labor intensive, but a new type of barrier, used in the swim area, proved effective and fairly easy to use as single panels.

Hand harvesting of water chestnut is practiced each spring by a group of volunteers supported by the town. This effort has kept water chestnut in check, with only scattered plants found and removed each year. Preventing this invasive species from getting established in Morses Pond is an important function that a group within the Friends of Morses Pond has fulfilled well.

## Plant Surveys

Plant surveys were conducted in early to mid-May of 2008, 2009, and 2010 prior to plant harvesting to determine the assemblage features and facilitate recommendation of any program adjustments. These surveys have helped to identify areas supporting very dense aquatic plant growths and helps set priorities for harvesting. Shoreline surveys were also performed to guide localized plant control by shoreline residents, including proposed hydroraking. In 2011, with the harvesting program protocols generally well known to the DPW staff involved in the project, we opted to survey the plants at selected stations during the harvesting, allowing some comparison among harvested areas as a consequence of harvesting. This process was repeated in 2012 and 2013 for continued comparison of harvested vs unharvested areas. In 2014 and 2015 we returned to a pre-harvesting survey to determine if there had been any cumulative impact of harvesting, as it is possible that repeated harvesting could shift the plant community to lower growing, more desirable forms. In 2016 we expected to survey when harvesting was well underway, but with harvester downtime, only areas 6 and 7 had been harvested when we performed the survey. The survey in 2017 was performed prior to any harvesting.

### *Methods*

Surveys applied the point-intercept method, resulting in 306 survey points on Morses Pond the same as utilized during the 2005 vegetation survey that set the stage for the comprehensive plan as relates to plant control in Morses Pond. The point-intercept methodology is intended to document the spatial distribution and percent cover and biovolume of aquatic plants at specific re-locatable sites. At each point the following information is recorded:

- The GPS waypoint.
- Water depth using a metal graduated rod or a mechanical depth finder.
- Plant cover and biovolume ratings using a standardized system.
- Relative abundance of plant species.

For each plant species, staff recorded whether the species was present at trace (one or two sprigs), sparse (a handful of the plant), moderate (a few handfuls of the plant), or dense (many handfuls of the plant) levels at each site. Plant cover represents the total surface area covered in plants (2 dimensions). For cover, areas with no plants were assigned a “0,” areas with approximately 1-25% cover were assigned a “1,” a “2” for 26-50%, a “3” for 51-75%, a “4” for 76-99%, and a “5” for 100% cover. Like plant cover, a quartile scale was used to express plant biovolume, defined as the estimated volume of living plant material filling the water column (3 dimensions). For biovolume, 0= no plants, 1= 1-25%, 2=26-50%, 3=51-75%, 4=76-100%, and 5= 100% of plants filling the water column.

Shoreline surveys to support hydroraking were described in the 2010 annual report. No such surveys were conducted after 2010. The number of points surveyed has been reduced since 2011, based on statistical analysis of how many points are necessary to get an accurate appraisal of plant conditions, but the choice of points is randomized within each established zone each year, so the 306-point configuration remains valid and useful.

### *2017 Results*

For the point-intercept surveys, 37 species are known from Morses Pond, with 23 plant species detected in 2005, 20 plant species encountered in the 2008 and 2009 surveys, 24 in 2010 and 2011, 25 species in 2012, 20 species in 2013, 18 species in 2014, 25 species in 2015, 22 species in 2016, and 15 species in 2017 (Table 5). Oscillations in species richness are largely a function of a few rare species being found or not found in any given year and date of the survey. The 2017 survey was the earliest conducted to date and some species had not yet germinated from seeds. The dominant suite of species remains the same, with the four invasive submerged aquatic plant species encountered including:

- *Cabomba caroliniana* (Fanwort)
- *Myriophyllum spicatum* (Eurasian watermilfoil)
- *Myriophyllum heterophyllum* (Variable watermilfoil)
- *Potamogeton crispus* (Curlyleaf pondweed)

Note that *Trapa natans*, water chestnut, is also known from Morses Pond, but owing to the efforts of volunteer water chestnut pullers, it has never been found in the standard survey. Also note that *Lythrum salicaria* (purple loosestrife) is a peripheral species that is abundant but rarely picked up by our aquatic surveys.

Overall, Morses Pond exhibited moderate vegetation biovolume in the spring 2017 survey (Figure 14). Biovolume is a function of ice out date, the rate of plant growth, and the date of the survey. In 2017 the survey was moved up to assess harvesting needs after a difficult 2016 harvesting season, and yielded results similar to those in later in 2015, when the ice out date was late (Figure 15). Biovolume in 2015 and 2017 was lower than in 2016, when ice out was very early and the rate of plant growth was accelerated by warmer temperatures.

### *Harvesting Program Impact Assessment*

An overall review of the Morses Pond harvesting program was conducted to evaluate impact on the plant community to date. Key questions included:

1. Can harvesting provide desirable conditions with regard to plants on a regular basis in a lake?
2. Does repeated harvesting alter the plant community in any lasting way?
3. Does harvesting remove a significant fraction of the annual P load?
4. Are there undesirable impacts from harvesting?

## Table 6. Aquatic plants in Morses Pond

| | | Plant Rating for Year (note that dates of surveys vary widely and affect results) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scientific Name** | **Common Name** | **2005** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** |
| *Brasenia schreberi* | Watershield | | | | | | | P | P | | P | |
| *Callitriche sp.* | Water starwort | P | | P | | | | | | | | |
| *Cabomba caroliniana* | Fanwort | A | A | A | A | A | A | A | A | A | A | A |
| *Ceratophyllum demersum* | Coontail | C | C | C | A | C | C | C | C | C | A | C |
| *Chlorophyta* | Green algae | C | C | C | A | | P | C | P | P | A | A |
| *Cyanobacteria* | Blue green algae | | P | | C | P | P | | P | P | P | |
| *Decodon verticillatus* | Swamp loosestrife | C | P | | P | P | | | | | | |
| *Elodea canadensis* | Waterweed | C | C | C | C | C | C | C | C | A | A | A |
| *Lemna Minor* | Duckweed | P | P | P | P | P | P | P | | P | | P |
| *Lythrum salicaria* | Purple loosestrife | P | P | P | P | P | P | | | P | | |
| *Myriophyllum heterophyllum* | Variable watermilfoil | P | C | C | A | A | A | C | C | C | A | A |
| *Myriophyllum spicatum* | Eurasian watermilfoil | A | A | A | A | C | C | A | A | C | A | A |
| *Najas flexilis* | Common naiad | C | C | C | C | P | P | P | P | P | A | |
| *Nymphaea odorata* | White water lily | C | C | C | C | C | C | C | P | P | A | P |
| *Nuphar variegatum* | Yellow water lily | C | P | P | P | P | P | P | P | P | P | A |
| *Polygonum amphibium* | Smartweed | P | P | P | P | P | P | P | P | P | P | P |
| *Pontederia cordata* | Pickerelweed | P | | P | P | | | P | | P | | |
| *Potamogeton amplifolius* | Broadleaf pondweed | C | C | C | C | C | C | | C | C | A | C |
| *Potamogeton crispus* | Crispy pondweed | | C | C | C | P | P | P | C | C | A | A |
| *Potamogeton epihydrus* | Ribbonleaf pondweed | | P | P | P | P | P | P | C | P | | P |
| *Potamogeton perfoliatus* | Claspingleaf pondweed | | | | | P | P | | P | P | A | |
| *Potamogeton pulcher* | Spotted pondweed | P | | | P | P | P | P | P | P | P | |
| *Potamogeton robbinsii* | Fern-leaf pondweed | C | C | C | C | P | P | P | C | A | P | A |
| *Potamogeton spirillus* | Spiral seed pondweed | | | | | P | P | P | P | P | P | |
| *Potamogeton zosteriformis* | Flatstem pondweed | | | | | | P | P | | | | |
| *Ranunculus sp.* | Water crowfoot | | | | | | | | | | A | |
| *Salix sp.* | Willow | | | | P | | | | | | C | |
| *Sagittaria gramineus* | Submerged arrowhead | P | P | P | | P | P | | | P | | |
| *Sparganium sp.* | Burreed | | | | | | | | | | P | |
| *Spirodela polyrhiza* | Big duckweed | P | | | | P | | P | | | | |
| *Typha latifolia* | Cattail | | | P | | | | | | | | |
| *Trapa natans* | Water chestnut | | | | | | | | | | P | |
| *Utricularia geminiscapa* | Bladderwort | P | P | | P | | P | P | | P | | |
| *Utricularia gibba* | Bladderwort | C | | | | P | | | | P | C | |
| *Valisneria americana* | Water celery | | | | P | P | P | | | P | | P |
| *Wolffia columbiana* | Watermeal | P | | | P | | P | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | # of Species | 23 | 20 | 20 | 24 | 24 | 25 | 20 | 18 | 25 | 22 | 15 |
| | **P=Present, C=Common, A=Abundant** | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | P<10% freq | C 19-25% freq | | | A >25% freq | | | | | | | |

## Figure 14. Biovolume of plants in areas of Morses pond in 2017

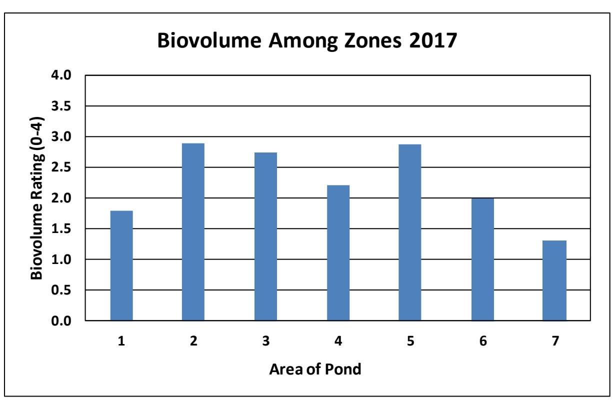


Figure 15. Biovolume comparison, 2015-2017

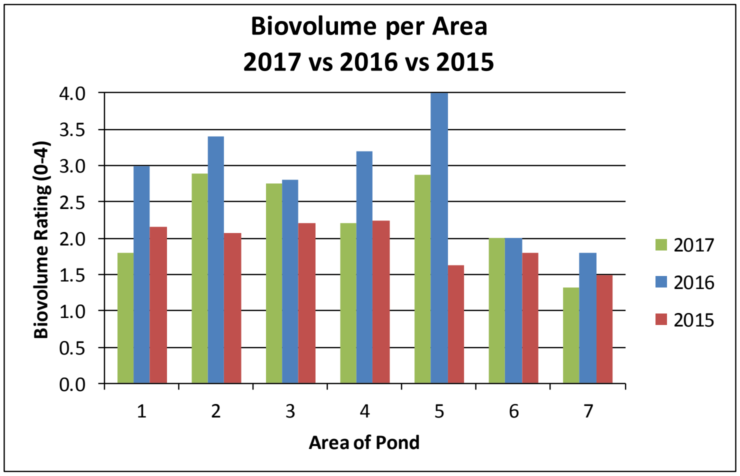
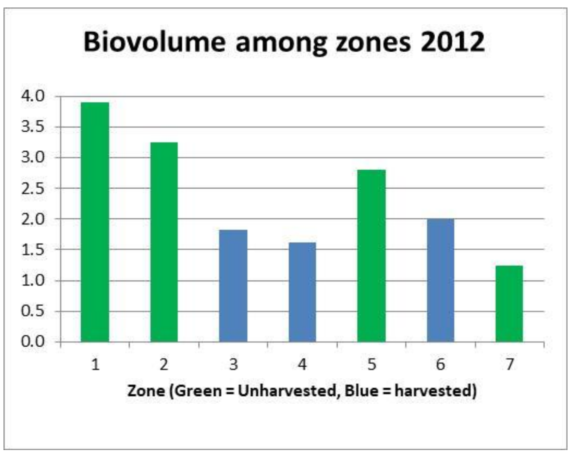
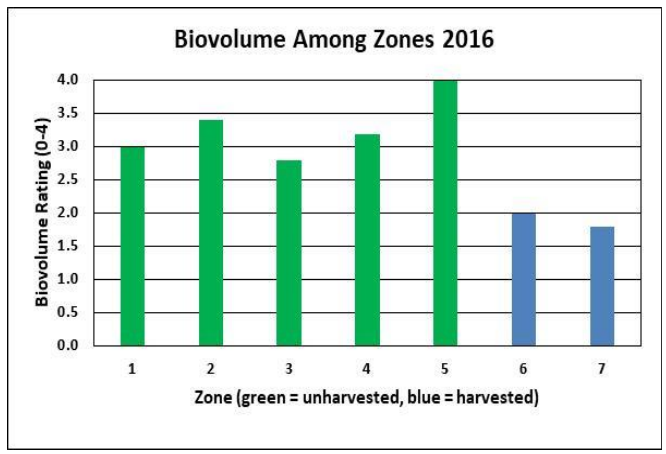



Figure 16. Biovolume comparison in areas with and without harvesting, 2012 and 2016




***Can harvesting maintain desirable plant conditions?***

The best way to see the difference harvesting makes is to compare plant biovolume from areas with and without harvesting. Simple examples from past reports include spring survey data from 2012 and 2016 (Figure 16). The scale of 0-4 is in quartiles of water column volume filled, and anything over a 2 rating is fairly thick growth. Values under 2 would suggest that up to half the water column is filled. If the portion of the water column filled with plants is near the bottom, that is ideal, as it keeps plants off the surface and provides upper volume for swimming and boating while maintaining submerged habitat and covering soft sediment that might otherwise get resuspended by wind. Consequently, the goal of harvesting is to achieve an average value of no greater than 2, but preferably no less than 1. There will be variation over the area of the pond, and some species will create surface coverage that is desirable for habitat if not too dense (e.g., water lilies), but in general the target biovolume for this program is an average value of 2 over the many stations assessed.

For 2012, with a normal pattern of spring growth and a survey in June, unharvested areas 1, 2 and 5 had dense plant growths, while harvested areas 3, 4 and 6 had the upper half or more of the water column cleared of vegetation. Area 2 was about to be harvested when the survey was conducted. Area 7 gets light harvesting around its edge, but includes the deepest part of the lake and does not have severe plant problems. With area 2 harvested to match areas 3, 4 and 6, the goal for plant density in 2012 was met.

For 2016, a year with a very mild winter, early ice out, rapid plant growth before the survey in late May, and use of only the small harvester to that point in time, the plant biovolume was much higher everywhere except in area 6, which was harvested by the time of the survey, and area 7, which usually only needs some peripheral attention, but needed more work in 2016. Harvesting areas with biovolume values of 3 or 4 can be much slower and inefficient, and harvesting was unable to gain control over the rooted plant community in 2016.

Harvesting at low biovolume can be inefficient, as more time is spent per load of plants collected, and cutting when an area has reached a biovolume value of 2 is preferred, but not before it has achieved a value exceeding 3. The pattern at the start of May in 2017 (Figure 14) suggests that the key target areas (2, 3, 4 and 6) had all achieved a biovolume of 2, but none exhibited a value of 3, suggesting that the time was right to start harvesting. Unfortunately, the larger harvester had equipment problems that limited efficiency and was eventually out of service for a month, while the smaller harvester was no longer serviceable, leading to the excessive plant biovolumes of summer 2017.

If harvesting commences when plant biovolume exceeds a rating of 2 and proceeds as planned based on normal operation of the equipment with limited downtime, harvesting can and has maintained desirable conditions in Morses Pond. However, if harvesting begins after biovolume exceeds a rating of 3 or there is more than a week of downtime during the harvesting season, harvesting may not be able to establish and maintain the desired conditions.

***Does harvesting alter the plant community in any lasting way?***

Dominant plants include fanwort (*Cabomba caroliniana*), variable watermilfoil (*Myriophyllum heterophyllum*) and Eurasian watermilfoil (*M. spicatum*), all invasive species. Other species are locally abundant, but these three invasive species represent most of the submergent plant biomass and are the targets of harvesting. The primary goal of harvesting is to keep these species at low enough biovolume (portion of the water column filled) to minimize interference with recreation and to maximize habitat for the range of aquatic species and water dependent wildlife using the pond. It has been hypothesized that repeated harvesting will favor species that grow close to the bottom and would be better for a multi-use waterbody, and there have been portions of other lakes where this seemed to be the case. For Morses Pond, however, we see little evidence of such a desirable shift.

Biovolume of the three main invasive species (Figure 17) has oscillated between 2008 and 2017, but shows no directional trend and those species are still dominant. As they reproduce mainly vegetatively, cutting before seeds can be produced does not greatly reduce their abundance or potential for spread, and they are superior competitors for space in most area lakes. One ecological limitation on the harvesting approach is that fanwort tends to initiate growth later than the milfoil species, such that spring harvesting does not greatly retard its growth. Spring cutting largely misses low growing fanwort, which then grows to the surface in July or early August, when harvesting has been suspended in many past years. Figure 17 suggests that there may be some depression of the two milfoil species by harvesting, in which case fanwort becomes dominant. When the harvesting program was weakest (2106 and 2017), the milfoils were more dominant and fanwort abundance decreased. The move to a second cut shortly after the completion of the first cut in 2015 was partly intended to counter that ecological issue, but harvester downtime has limited effectiveness of this approach.

The abundance of lower growing native species also shows no strong trend (Figure 18). Favorable but seemingly temporary shifts in the abundance of some more desirable plants have been observed, and control of the invasive species does not appear strong enough to give those desirable plants a longer term advantage. The second cutting period may also remove some native plants before they can set seed, often the dominant means of reproduction for those plants, and shifting the second cutting to earlier in the summer will exacerbate that problem. Native species also exhibited fluctuations that do not appear clearly related to harvesting. The plant community is not especially stable, but there is no strong indication of any lasting decrease in nuisance species or increase in desirable species as a result of harvesting.

**Figure 17. Frequency of submergent invasive plants at survey sites over time in Morses Pond**

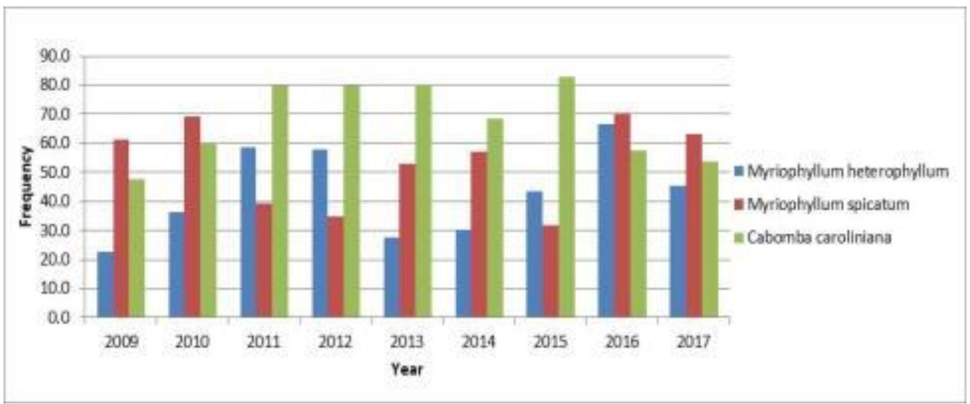
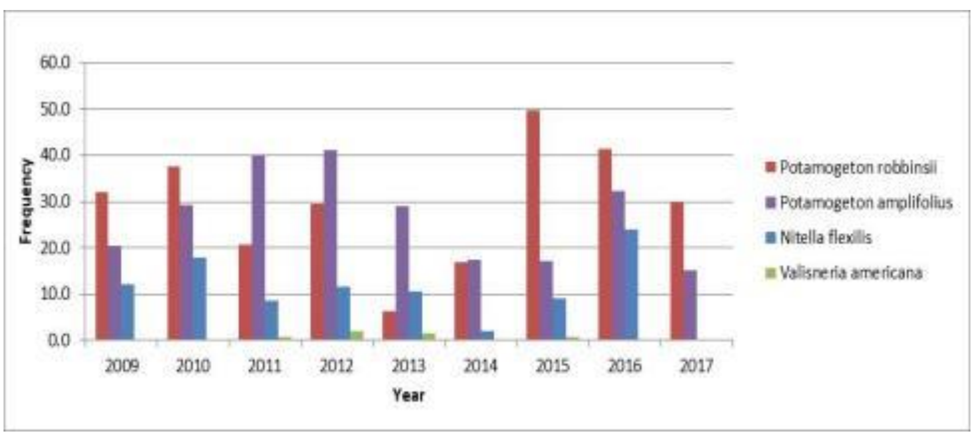



**Figure 18. Frequency of selected native plants at survey sites over time in Morses Pond**




***Does harvesting remove a significant fraction of the annual P load?***

It has been hypothesized that removal of plant biomass takes with it a significant amount of nutrients, especially phosphorus, and that this can be an important component of control over algae blooms.

Historically, peer reviewed literature has not found harvesting to be able to counter external loading or improve water quality, but it doesn't hurt to remove nutrients by harvesting.

Working with the detailed records for plant biomass removal from Morses Pond and a range of possible phosphorus content values for those plants, the average phosphorus removal from Morses Pond each year by plant harvesting is about 70 kg out of an annual load that averages about 484 kg. This suggests a 14% reduction, although not all of the phosphorus in rooted plants would become available to algae. Even considering apparent improvements in runoff inputs to Morses Pond in recent years, the annual load of phosphorus is still at least 363 kg, making the reduction by plant removal no more than 19%.

It should also be noted that most of the phosphorus in plants was extracted from sediment through roots, not from water column, so direct comparisons to external loading may not be appropriate. Harvesting removes some nutrients, but not nearly enough to replace other portions of the management plan intended to minimize algae blooms.

***Are there undesirable impacts from harvesting?***

Harvesting creates turbidity during the actual cutting process, especially in shallow water, and then due to resuspension of sediment by the action of the paddlewheels. This is a temporary condition, however, and much less of an impact than a windstorm, which impacts a much larger portion of the pond at once.

The primary concern is impact to fish and fish habitat, as the intended change in plant community features does indeed reduce habitat for some species while increasing it for others. Overall, there is a general rule in fish management that at least 20% of the portion of a lake capable of supporting plants should have plants, and that greater benefits can be expected with coverage of up to 40% of the possible plant growing area. Some studies have found no negative impact on certain fish at even higher plant coverage, but there are many details to consider, including the type and density of plants and fish species and overall food web structure that make impact assessment at least regional if not lake-specific. Extremely dense plant assemblages, especially those involving invasive species, have been known to result in overabundant panfish populations that grow slowly and scarce gamefish that struggle to get at their panfish prey and whose young compete with abundant panfish for food.

For Morses Pond, about 45 out of 105 acres (43%) supports significant plant growth. In areas <8 feet deep, plants can grow to the surface and completely fill the water column. The potential for stunted panfish and limitation of gamefish foraging is very high. Harvesting has maintained enough plant cover to maintain fishery balance, but opened areas and created edge effect that enhances gamefish populations. No fishery survey of Morses Pond has been conducted, but observations and discussion with fishermen indicates excellent conditions for fish in Morses Pond. Zooplankton abundance and size distribution data (Figures 7 and 8), which reflect fishery balance, support this contention. Maintenance of a biovolume rating between 1 and 2 is entirely consistent with fishery preferences in the literature.

Direct loss of fish from harvesting is minor, but small fish are captured by the harvester during cutting operations. Most literature does not suggest this to be a significant impact on the fish community overall, but a few papers have quantified capture of fish from harvested dense plant plots as substantial. In Morses

Pond, when the harvesting program is running smoothly, the vegetation in the harvested area is not so dense as to harbor so many small fish, and maintenance of plants at a lower density facilitates gamefish predation on those smaller fish, limiting their density and possible harvest impact. Larger fish and occasional turtles that come up the conveyor belt during harvesting operations are returned to the pond, so direct impact is very limited.

### *Conclusions Relating to Plants and Mechanical Harvesting*

Without adequate harvesting, the plant community of Morses Pond would be too dense in most areas and would be dominated by invasive species, impacting both human uses and habitat for many aquatic organisms and water-dependent wildlife. Harvesting with a larger harvester and support from a smaller harvester can control plant biomass and maintain open water in at least the upper half of the water column, produces very few negative impacts, and supports all designated uses of Morses Pond. Longer term shifts in species dominance have not been observed, so harvesting remains necessary each spring and summer. With more than about a week of harvester downtime in late spring and summer, the density of invasive species can become too dense. Once plant growths become excessive, the efficiency of harvesting decreases and available resources may be inadequate to restore desirable conditions in that growing season. It is therefore essential that harvesters be maintained in the best operational condition, but this is challenging once a harvester is more than a decade old. The cost of being prepared for harvester maintenance and downtime (e.g., extensive parts inventory, contract harvest option) can be high and is not necessarily supported by the current program budget.

## Low Impact Development Demonstration

Watershed management through localized application of low impact development (LID) techniques has been viewed as an important element of water quality management for Morses Pond and for Wellesley's water resources in general. Efforts in the early implementation phase of the 2005 Comprehensive Management Plan were limited due to resistance to changes on selected public properties, but a demonstration rain garden was installed near the beach complex at Morses Pond.

The Morses Pond LID demonstration project was viewed as a high visibility site during the beach season, and could be used to educate residents about the need for and potential of simple landscaping techniques in managing urban water quality. Two rain gardens were established and a roof drip line erosion control system was installed. This was meant as both a functioning system for the beach complex and as an educational tool. It was one of the sites used for the 2017 summer Conservation Camp as an educational tool.

Educational efforts to promote LID have been ongoing, but results have not been quantified. Such quantification could be part of a survey of residents to assess awareness, attitudes and willingness to use such techniques.

## Education

WRS participated in the Conservation Camp held in Wellesley in August. Education programs are ongoing in Wellesley, but no new initiatives were implemented by WRS in 2017.

Everyone interacting with the Natural Resources Commission is provided an educational packet which contains brochures and other materials under the theme of the Green Wellesley Campaign. The packet focuses on protecting the environment and living a more sustainable lifestyle as a resident of Wellesley, although the contents are applicable to almost any town in the area. Included is information on:

- Understanding storm water and its impact on our streams and ponds.
- The impact of phosphorus on ponds.
- The importance of buffer strips and how to establish and maintain them.
- Managing residential storm water through rain gardens, infiltration trenches, rain barrels and other Low Impact Development (LID) techniques.
- Organic lawn and landscape management.
- Tree maintenance and related town bylaws.
- Recycling needs and options.
- Energy efficiency in the home.

There is a Morses Pond website with useful information, and the Town has bylaws relating to lawn watering and other residential activities that affect water quality in streams and lakes. The extent to which residents understand these regulations is uncertain, but the educational packet helps in this regard. The right messages are being sent, but reception and reaction have not been gauged recently.

## Dredging

The dredging project recommended in the 2005 Comprehensive Plan was carried out in 2012-2013 and is complete. Less sediment was removed than was desired, due to contamination and related disposal cost, but detention was appropriately increased in the north basin and has helped with management of watershed inputs from the Bogle and Boulder Brooks drainage areas. This project has been detailed in past annual reports, most recently in 2016. No further dredging is planned at this time.

## Financial Summary

At the end of the FY2017 fiscal year on June 30, 2017, a total of $51,985.78 had been expended by WRS for the management of Morses Pond in FY2017, minimally under the $52,000 budget for the year. This budget encompassed funds in the Pond Manager and Monitoring accounts. No funds from the Phosphorus Inactivation account were used by WRS for additional labor for spring treatment of incoming storm water. Rather, funds from that account were used for chemical supplies and system repairs by the DPW.

It is our understanding that the allocations for FY18 are the same as for 2017, $45,000 for the Pond Manager account and $7000 for the Monitoring account, a total of $52,000. Only one invoice has been submitted so far in FY18, that for $14,945.92 at the start of September, covering some P inactivation support over the summer, water quality and biological monitoring, and summer educational programs. With work done since September in relation to analysis of the phosphorus inactivation system and harvesting program under the implementation of the comprehensive plan and preparation of this annual report, some direct expenses for P inactivation wireless service and lab testing, and attendance at an NRC meeting to report on Morses Pond activities, an invoice for about $7500 will be submitted by the end of the calendar year. This will bring the total FY18 expense to slightly less than $22,500 and leave about $29,500 for the remainder of FY18. This is expected to cover winter program support as needed, spring vegetation and water quality monitoring, and phosphorus inactivation operational support through June 2018. WRS is also supporting the Recreation Department's efforts to improve the swimming area under separate contract, but the efforts do overlap in the area of monitoring.

## Important Steps for the Remainder of FY2018

Based on the above information and analysis, the following key steps are outlined for the remaining 6 months of FY2018:

1. Finalize specifications for a smaller harvester for use on Morses Pond and other Wellesley ponds, receive bids, and award a contract. Funds were approved for FY18 and it is hoped that a new smaller harvester can be available by the end of FY18.
2. Maintain the larger harvester as far in advance of the harvesting season as possible. Despite late fall review of needs in 2016, acquisition of all parts known to be needed over the winter, and early maintenance and deployment of the harvester in spring 2017, breakdown of the hydraulic system caused inefficient harvesting for over a month and complete shutdown for another month in 2017. All involved parties have already met and discussed both needs for 2018 and likely replacement of the larger harvester in a few years. Anticipated 2018 needs will be addressed over the winter, but it is not possible to anticipate all possible problems.
3. Discuss with the Town and the Friends of Morses Pond the potential for contract harvesting to cover areas that might not be included in the 2018 harvesting program if the larger harvester has additional performance issues. This would need to be an advance arrangement with specific goals for specific areas, and might not be covered under the harvesting budget.
4. Prepare the phosphorus inactivation system for use in 2018. Some maintenance has been conducted in fall of 2017, and no major needs are anticipated for 2018. Order polyaluminum chloride and have it delivered by early May. Run compressed air through the lines to ensure no blockages. Check the rain gauge for blockages and functionality after winter. Test the automated system to be sure it will come on as needed and fill the lines with chemical to be ready for treatment prior to Memorial Day.
5. Coordinate through NRC and DPW for harvesting on other Wellesley Ponds and use of the new, smaller harvester on Morses Pond as available. Also coordinate application of aluminum to several smaller Wellesley Ponds with a portable dosing system currently on order. Aluminum from the Morses Pond tanks is likely to be used, so an additional delivery may be needed.

6. Consider preferred educational activities in Wellesley for 2018 and coordinate with NRC and Recreation for any needed support by WRS.
7. Perform more intensive storm sampling on Boulder and Bogle Brooks to better assess phosphorus inputs. There is a sense from sampling in 2016 and 2017 that concentrations are declining, a desirable situation expected as a result of phosphorus being reduced in lawn fertilizers. Documentation would be helpful to planning for future management.
8. Conduct a survey of awareness, attitudes and practices on residential properties to assess application potential for LID techniques and further educational needs.