

***Implementation of a Bathymetric Survey of Lake Musconetcong,
Sussex and Morris Counties, New Jersey***
NJDEP Identification Number: RP07-056

**Watershed and HUC 11 code:
Lake Musconetcong Watershed
Upper Musconetcong / Musconetcong River Watershed Management Area
(WMA-01)
HUC-11 02040105150**

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Sussex and Morris Counties
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**Project awarded in March 2007
Project completed in June 2011**

Funds for this project were awarded to the Lake Musconetcong Regional Planning (LMRPB) through the New Jersey of Environmental Protection's (NJDEP's) Non-Point Source 319(h) grant program. In-kind matches toward the project were provided by the LMRPB, the Borough of Stanhope, the Borough of Netcong, the Township of Roxbury, the Township of Byram, the County of Morris, the County of Sussex, and the Musconetcong State Park. Technical and consulting services were provided by Princeton Hydro, LLC.

Executive Summary

The Lake Musconetcong Regional Planning Board (LMRPB) is the recognized steward of Lake Musconetcong, a State-owned, publicly accessible 329-acre artificial impoundment of the Musconetcong River (WMA-01; HUC-14 02040105150030). Since their formation, the LMRPB have overseen the completion of the Phase I Diagnostic / Feasibility Clean Lakes study, a Phase II Implementation Project that included the selective removal of unconsolidated material from three near shore sites and the design and implementation of a mechanical weed-harvesting program.

Since Lake Musconetcong is identified by NJDEP as being impaired for phosphorus, a phosphorus TMDL was conducted on the lake in March 2003 by NJDEP and approved later that same year by US EPA. This TMDL was revised with updated land use information and a Restoration Plan was developed for the lake and its immediate watershed. In turn, the TMDL-based Restoration Plan was approved by NJDEP in the spring of 2006.

While the Restoration Plan outlines a series of site-specific, watershed-based stormwater projects to attain the TMDL's targeted total phosphorus load for Lake Musconetcong, the plan also recognizes that in-lake impairments are quite severe due to the shallow water depths and dominance of the aquatic plant community by the exotic, invasive species Eurasian watermilfoil (*Myriophyllum spicatum*) and more recently water chestnut (*Trapa natans*). Given the fact that 67% of the phosphorus load entering Lake Musconetcong originates from the Lake Hopatcong watershed, and a variety of watershed-based measures are currently being implemented in the Lake Hopatcong watershed, it was decided to focus current restoration efforts on in-lake rather than watershed-based efforts for Lake Musconetcong.

One of the main components of this 319(h) project (SFY07) was to conduct a permit-grade, whole lake bathymetric survey of Lake Musconetcong. In addition, navigational hazards and submerged structures of concern were GPS-located and placed into the GIS mapping database. The bathymetric survey quantified both water depth and sediment thickness; the mean water depth of the lake was 3.6 ft. Additionally, some detailed coring was conducted with a Vibracore to assess the extent and thickness of the peat layer that exists below the unconsolidated material. These cores revealed that the amount of total unconsolidated material in the lake averaged 6.1 ft, with 2.0 ft of this being sediment and the remaining 4.1 ft being peat.

Another set of water - sediment cores were collected in tact and incubated in a laboratory under seasonal conditions to quantify the amount of phosphorus that is released from the sediments under oxic and anoxic conditions. One water - sediment chamber was allowed to go anoxic while the other was well oxygenated. Three days after the incubating chambers were established, dissolved oxygen concentrations fell below 1 mg/L in the anoxic chamber; four days later there was substantially more TP in the anoxic chamber relative to the oxic chamber. The difference in TP concentrations between the two chambers increased over the 28 days the experiment was run, with the anoxic chamber TP concentration being seven times higher than the oxic chamber. Combined, these

coring and laboratory measures will be used to empirically quantify the internal phosphorus load for Lake Musconetcong.

The water – sediment chamber experiment demonstrated that the sediments of Lake Musconetcong have the potential to generate a substantial amount of phosphorus once they become anoxic ($DO < 1 \text{ mg/L}$). Such anoxic conditions do occasionally occur in the lake, as demonstrated with the 2009 water quality data, and are dependent largely on prevailing weather conditions and the density of the resident aquatic vegetation. At the end of the 28 day incubation period, the anoxic chamber had seven times more phosphorus relative to the oxic chamber. The results of the experiment were used to calculate phosphorus release rates from the sediments.

Under well-established anoxic conditions, the sediments release between 0.36 and 2.91 mg of TP / m^2 / day, with a mean release rate of 1.58 mg of TP / m^2 / day. In contrast, the oxic sediments generate negligible amounts of TP. While these values were lower than those from the scientific literature, typically used to quantify the internal TP load, they still produced a sizable amount of internal phosphorus for Lake Musconetcong. For example, it is estimated that if the internal TP load was addressed in Lake Musconetcong through a combination of dredging and aggressive plant management, it has the potential to remove approximately 40% of the TP targeted for removal under the lake's TMDL. It should also be mentioned that peat underneath the existing layer of unconsolidated sediments has a substantial amount of extractable (loosely bound) phosphorus that could easily be released under anoxic conditions. Thus, if the lake is dredged, the peat should be removed as well as the unconsolidated sediments.

In addition to phosphorus, a variety of physical and chemical testing of the sediments was conducted to develop a dredging plan for the lake. Seven of the collected sediment samples were analyzed for a variety of chemical constituents which included volatiles, semi-volatiles, polychlorinated byphenols (PCBs), pesticides and metals. All chemical concentrations detected were below the New Jersey Department of Environmental Protection Soil Remediation Standard (SRS), with the exception of one sediment sample, which had an arsenic concentration of 21.5 mg/kg; the NJDEP SRS for arsenic is 19 mg/kg. Since the difference between the measured and SRS value was less than 3 mg/kg, some additional, more detailed sampling for arsenic is recommended for that region of the lake where the 21.5 mg/kg value was measured.

The results of the bathymetric survey and physical / chemical sediment and peat testing were used to develop a dredging plan for Lake Musconetcong. This included the generation of permit-grade CAD drawings, a review of potential access locations and staging areas, and potential means of disposing the removed material. The Plan also provided recommendations for the establishment of shoreline access sites and the actual processing / disposal of the material. A detailed cost assessment for the permitting and implementation (removal and disposal of material) of the proposed dredging project was also provided.

Introduction

The Lake Musconetcong Regional Planning Board (LMRPB) is a regional organization that was formed in the 1980's and serves as the steward of Lake Musconetcong (Sussex and Morris Counties, New Jersey; Figure 1), a State-owned, publicly accessible 329-acre artificial impoundment of the Musconetcong River. The LMRPB's role as steward of Lake Musconetcong and its immediate watershed has been recognized by the three municipalities that immediately surround the lake, both Sussex and Morris County and the State of New Jersey.

As previously mentioned, Lake Musconetcong is a 329-acre shallow waterbody, located between Morris and Sussex Counties approximately 1.3 miles downstream of Lake Hopatcong. These two lakes form the headwaters of the Musconetcong River, a major tributary of the Delaware River, and are located in the Upper Delaware River Watershed (Watershed Management Area (WMA) 1). Lake Musconetcong is located in HUC 14 02040105150030 (Appendix A).

Based on NJDEP's USEPA-approved 2004 *Integrated List of Waterbodies*, Lake Musconetcong appears on Sublist 4 with the water quality impairment designated as phosphorus. A phosphorus Total Maximum Daily Load (TMDL) for Lake Musconetcong was developed and established by NJDEP in March 2003 and approved by USEPA Region 2 in September 2003. Subsequently, this TMDL was refined and a Restoration Plan was developed that addressed both direct (elevated phosphorus loads) and indirect (excessive densities of an invasive species of aquatic plant) TMDL issues of concern. However, it must be emphasized that elevated loads of total phosphorus (TP) and total suspended solids (TSS) are responsible for the in-lake problems (for more details see below).

As previously cited, a Restoration Plan based on the refined phosphorus TMDL was developed for Lake Musconetcong and its immediate watershed. In addition to serving as a "blue-print" of watershed-based stormwater projects that would reduce TP and TSS loads and move toward compliance of the TMDL, the Plan also provides in-lake recommendations on how to restore Lake Musconetcong to a non-impaired state. These recommendations include minimizing the relative magnitude of the lake's internal phosphorus load.

Specifically, the proposed in-lake rehabilitation recommendations include the expansion of the lake's open water habitat through dredging, which would contribute toward the eradication of the invasive species Eurasian watermilfoil and the establishment of native aquatic vegetation such as tapegrass (*Vallisneria americana*). However, it should be cited that while field work was conducted in 2009, another exotic, invasive species appeared in Lake Musconetcong (for details see below).

A shallow lake inundated with high densities of the submerged, rooted vegetation that reach the surface, such as Eurasian watermilfoil, tends to have a larger internal phosphorus load relative to the a moderately deep lake with lower plant densities. High densities of aquatic vegetation prevent the lake from completely mixing and create pockets of anoxia (dissolved oxygen concentrations less than 1 mg/L) over the sediments,

which allow large amounts of phosphorus to leach into the overlaying waters. This phosphorus contributes to the lake's annual phosphorus load. Thus, reducing the internal phosphorus load through dredging and ecosystem rehabilitation will contribute toward reducing the existing phosphorus load and reaching the targeted load as identified in the lake's TMDL.

Finally, based on the revised Restoration Plan, on-site wastewater treatment systems (i.e. septic systems) account for approximately 4% of the annual total phosphorus load entering Lake Musconetcong from its immediate watershed (Princeton Hydro, 2006). The few septic systems within the immediate watershed of Lake Musconetcong are located within the Borough of Hopatcong. The LMRPB has reached out to the Borough to work with them in addressing this source of phosphorus. These septic systems may be eventually placed off line and sewerered or a Septic Management Plan may be developed to minimize their water quality impacts.

Evaluation Approach and Methodology

The methodology used for this 319-grant project focused heavily on obtaining additional information on the in-lake processes and focused on better quantifying these processes and their associated impacts, in light of the TMDL. Specifically, the methodology included:

1. Conduct a permit-grade bathymetric survey of the lake (**Task 3**), which includes the identification of in-lake and shoreline structures (**Task 1**),
2. Collect a series of sediment samples, 13 samples (1 sample per 25 acres) for physical analyses (**Task 4**),
3. Collect a series of sediment samples, 7 samples (1 sample per 50 acres) for chemical analyses (**Task 5**),
4. Develop a Quality Assurance Protection Plan (QAPP) for all in-lake and in-stream water quality monitoring (**Task 2**),
5. Conduct three in-lake monitoring events over the 2009 growing season; a variety of physical, chemical and biological data were collected (**Task 5**),
6. Conduct six sampling events immediately upstream and downstream of Lake Musconetcong, which will include general site assessments, *in-situ* and flow measurements (**Tasks 8 and 9**) and the collection of discrete samples for chemical analysis (**Task 10**),
7. Quantify the internal phosphorus load in the Lake under oxic and anoxic conditions (**Task 6**), and
8. Identify the existing peat layer under the unconsolidated sediments (**Task 7**).

The resulting database will be used to develop and prepare permit-grade maps for the possible removal of the unconsolidated material (**Task 11**) and the development of Plan to implement such a project (**Task 12**). These project related deliverables requires a certain degree of both project management (**Task 13**) and public outreach (**Task 14**), much of which was conducted by the Lake Musconetcong Regional Planning Board as part of their in-kind contribution.

Results of Project and Evaluation

Project results and associated evaluations are provided in a set of two reports. The first report focuses on the feasibility of dredging Lake Musconetcong. Almost all of the data collected as part of this 319(h) project are provided in the appendices of this report and included:

- Site location, bathymetric and sediment sampling maps (Appendix A)
- Core logs documenting the extent of the sediment and peat layers (Appendix B)
- Chemical analysis of sediments (7 samples; Appendix C) and peat layers (5 samples; Appendix C)
- Physical analysis of sediments (13 samples; Appendix D)
- All in-lake and upstream / downstream water quality data, including the result of the water – sediment chamber, internal phosphorus loading experiment (Appendix C)
- Design plans and cross-section (Appendix G)

The second report focuses on the analysis of the water quality data that were collected both in-lake as well as immediately upstream and downstream of the lake. The data were used to assess current conditions in Lake Musconetcong relative to overall ecological health, as well as to the established phosphorus TMDL. An addendum to this water quality report was some observations and data collected on the lake's macrophyte (aquatic plants and mat algae) community during the in-lake sampling events.

Additional components of project and its associated deliverables are provided in Appendices at the back of this 319(h) project report and include:

- Appendix A – Final version of the Quality Assurance Protection Plan
- Appendix B – Navigational Hazards; map and Geographic Coordinate data
- Appendix C – CAD Drawings and associated material for Dredging Plan

Implications and Recommendations

Based on the results of these project activities the following implications can be made:

1. A detailed bathymetric survey of Lake Musconetcong revealed that approximately 3.1 million cubic yards of unconsolidated material is in the lake with an average thickness of 6.1 feet.
2. Approximately 33% of the material is sediment while the remaining 67% is peat.
3. Underneath the mean 2 ft layer of unconsolidated sediment, a layer of peat is present that has a mean thickness of 4.1 ft. The peat layer accounted for between 16 and 100% of the total amount of unconsolidated material, depending on where the core sample was collected, with a mean of 52.8%.
4. A set of water-sediment samples were collected in-tact and incubated under oxic and anoxic conditions.
5. The peat has “extractable” amounts of phosphorus varying between 7.8 and 30.6 mg/kg (equal to mg/L). Such phosphorus is loosely bound to the peat and under anoxic conditions could be easily released into the overlying waters, stimulating additional plant and algae growth.
6. In spite of Lake Musconetcong being a relative shallow waterbody with a mean depth of 3.6 ft and a maximum depth of 8.0 ft, the internal phosphorus load has the potential to account for a significant portion of the lake’s annual TP load, particularly during a dry and hot summer. This load is exacerbated by high densities of submerged (Eurasian watermilfoil) and/or floating-leaved (water chestnut) macrophytes.

Based on the revealed implications, the following recommendations are being made:

1. The removal of the unconsolidated sediments, and possibly the underlying peat, to increase the mean depth of the lake should be seriously considered. In turn, this will reduce the amount of light that can reach the sediments and reduce, but not eliminate, the growth of aquatic vegetation. In addition, deeper waters will make it more difficult for exotic, invasive species, like Eurasian watermilfoil and water chestnut, to grow and favor the growth of desirable aquatic plants such as native pondweeds and tapegrass.
2. In addition to reducing the growth of aquatic vegetation and favor the development of native species, such ecosystem-based changes will minimize the magnitude of the internal phosphorus load. Based on the calculations conducted in the Water Quality Report, reducing the internal phosphorus load, would result in addressing approximately 40% of the TP load targeted for the TMDL reduction under the lake’s immediate drainage basin. Thus, the removal of the unconsolidated material in Lake Musconetcong is strongly recommended.

3. As cited in the Engineering Report, the SED-8 sediment sample had a slightly elevated arsenic value, above the NJDEP-SRS. Thus, some additional, localized sediment samples should be collected and analyzed specifically for arsenic to determine if such elevated values are of concern. If additional sampling shows arsenic concentrations to be above the SRS, the contaminated site must be identified, segregated and disposed of at an NJDEP regulated facility. All remaining sediment that is below the NJDEP Residential Direct Contact Clean-up Criteria and Impact to Groundwater Criteria can be handled and disposed of as clean material at an approved off-site, upland location.
4. The lake should be dewatered as low as possible and the exposed material should be allowed to dewater and consolidate. Equipment such as track excavators, long-reach track-excavators and crane-mounted drag lines or clam shells would be used to remove the existing material. Timber mats and/or haul roads constructed of imported soil or rock would provide the access throughout the lake to dredge the entire lake bottom.
5. Temporary stockpiles should be used to accelerate and dewater the dredged material. Water-sealed trucks would be used to transport the material to a designed, upland disposal site.
6. Monitoring and project oversight during the operation of the dredging and disposal of the material is absolutely necessary to minimize / avoid potential problems, ensure that the volumes excavated match the engineering plans and enforce the provisions identified in both the permits and the Dredging Plan