WHIPPANY RIVER WATERSHED
LAKES STUDY

FINAL REPORT
OCTOBER 31, 2005

PREPARED FOR THE
WHIPPANY RIVER WATERSHED ACTION COMMITTEE
NJDEP WATERSHED MANAGEMENT AREA 6

PREPARED BY
WHIPPANY RIVER TECHNICAL ADVISORY COMMITTEE

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THIS PROJECT WAS FUNDED WITH A GRANT FROM THE VICTORIA FOUNDATION

<u>ACKNOWLEDGEMENTS</u>

THE WHIPPANY RIVER WATERSHED ACTION COMMITTEE GRATEFULLY ACKNOWLEDGES THOSE INDIVIDUALS WHO PARTICIPATED IN THE FIELD WORK, SAMPLING, DATA ANALYSIS AND/OR PREPARATION OF THIS REPORT.

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FINAL REPORT

A. ORGANIZATION INFORMATION, B. CONTACT PERSON & TELEPHONE:

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C. MISSION: The mission of the Whippany River Watershed Action Committee is to protect and improve the waters of the Whippany River through community action.

D. SERVICES OFFERED:

1. Technical Advisory Committee: The Technical Advisory Committee is monitoring water quality trends and identifying sources fecal of contamination using a grant from Victoria Foundation and another from the New Jersey Department of Environmental Protection. The Chair of the TAC is Dr. George Van Orden, Health Officer of the Hanover Township Regional Health Department. TAC members include municipal health officers.

2. Education and Outreach Committee: Because municipalities are responsible for land use in New Jersey, the Action Committee focused on education and training for municipal officials and staff in practices that reduce non-point source pollution of waterways. The Action Committee's Education and Outreach Committee (EOC) has presented successful workshops on department of public works' Best Management Practices, goose damage management, use of GIS in environmental protection applications, water quality monitoring, and creating low cost riparian buffers. In order to encourage networking and adoption of Best Management Practices, these workshops included speakers from watershed municipalities, as well as conservation professionals. The Action Committee also directs education and outreach toward the public at large through river clean ups, planting events, production of educational materials, and media coverage of its activities. In 2001, the Action Committee won US EPA Region 2's Environmental Quality Award. The EOC had the award framed and is circulating it through member municipalities to reinforce the participation of municipal officials and to call public and media attention to the need for water resources protection and improvement.

3. Watershed Restoration Action: On April 20, 2002, the Action Committee will sponsored a volunteer planting and clean-up day, the second phase of a lakeside riparian restoration in a public park in Morristown, NJ. In April, June, and November 2001, the Action Committee constructed lakeside and streamside vegetated water quality buffers in Morristown and Morris Township. The buffers are designed to reduce nonpoint source pollution that enters the river, including fecal coliform from goose feces and sediment from eroding riparian lands. Volunteers planted with members of the Action Committee under the supervision of TRC Omni Environmental Associates.

4. Best Management Practices: Cahill Associates has helped our members update their ordinances and conduct land use planning and development in ways that protect and improve water quality and the quality of life of communities. Work on ordinances was completed in the four municipalities in the Whippany watershed that are not members of the 10 Towns or Rockaway River Cabinet (Florham Park, Morris Plains, Hanover, and Mountain Lakes). In addition, East Hanover is adding a new stream corridor protection zone to its zoning ordinance.

5. Providing a Watershed Forum, Funding, and Support: The Action Committee meets nine times a year and host special events. Its Executive Committee meets monthly. The Action Committee has received funding and support for its work from member municipalities, the County of Morris Board of Chosen Freeholders, the state legislature, NJDEP, and Victoria Foundation. The Action Committee solicited projects from member communities and is seeking funding to implement them. The Action Committee makes its members aware of funding opportunities, e.g., to restore brownfields and to purchase open space.

E. POPULATION SERVED: There are 16 communities in the Whippany River watershed, 13 of which are members of the Action Committee.

F. SUMMARY OF REQUEST: The Whippany River Watershed Action Committee's Technical Advisory Committee will implement a lakes management program that 1. Reinforces local governments' commitment to regional watershed planning and use of Best Management Practices in development and public works to address water quality impairments that threaten public health and rob waterways of habitat, recreational, and aesthetic value; 2. Addresses the Whippany River's TMDL for fecal coliform (58% reduction) and other problems identified in our watershed management plan; 3. Yields a Risk Index and Root Cause Analysis to guide local government action and; 4. Efficiently dovetails with water quality monitoring and studies in the Whippany watershed previously funded by Victoria Foundation and NJDEP. Funding will be used to buy sampling equipment, pay a certified laboratory to test samples collected by municipal health officers and environmental commission members, and prepare a final report.

G. AMOUNT REQUESTED/GRANTED: $10,500/$10,500

H. REPORT DATE: OCTOBER 31, 2005

II. PROJECT SUMMARY

The Whippany River Watershed Action Committee's Technical Advisory Committee will implement a lakes management program based on the scientific evidence found in this study that 1. Reinforces local governments' commitment to regional watershed planning and the use of Best Management Practices in development and public works to address water quality impairments that threaten public health and rob waterways of habitat, recreational, and aesthetic value; 2. Addresses the Whippany River's TMDL for fecal coliform (58% reduction) and other problems identified in our watershed management plan; 3. Yields a Risk Index and Root Cause Analysis to guide local government action and; 4. Efficiently dovetails with completed and ongoing water quality monitoring work in the Whippany watershed that already has been funded by Victoria Foundation and the NJ Department of Environmental Protection (NJDEP). $10,000 in funding from Victoria Foundation was used to buy sampling equipment, pay a certified laboratory to test samples collected by municipal health officers, prepare a final report and provide a seminar for municipalities within the watershed which will include the data, discussion of the data and recommendations from this study.

Work completed by Dr. George Van Orden, Health Officer, Hanover Township Regional Health Department, and the TAC includes: 1. $75,000 sanitary survey funded by NJDEP through a 604(b) grant; 2. Water quality trends project (Final Report dated March 24, 2003) funded by Victoria Foundation. Also, previous monitoring and modeling done for the Whippany River during NJDEP's seven-year, multi-million-dollar pilot Whippany Watershed Project produced baseline data.

Impoundments created by small dams across our local streams have been a traditional flood control measure commonly used by municipalities in New Jersey. In addition to flood control, the impoundments often are incorporated into public parks in order to provide recreational opportunities for local residents. While these amenities have been an attractive feature in our communities, they are being threatened by water quality concerns. The water quality problems that exist within these lakes commonly include: 1. High levels of nutrients; 2. Fecal coliform; 3. Biochemical oxygen demand; 4. Algal growth; 5. Discharge directly into lakes or the streams that feed them of stormwater runoff, sediment, and NPS from roadways and from older developments without stormwater detention or from new construction; 6. Harmful populations of waterfowl that contribute a significant nutrient and fecal coliform load to the system; 7. Mowed turf or bare eroding soil at the shoreline of lakes; 8. Vegetated riparian buffer with native trees, shrubs, and herbaceous plants that is too narrow or lacking altogether; and 9. Thick layer of sediment on the lake bed that binds phosphorus and also traps other pollutants.

Water quality impairments in lakes rob them of their recreational and aesthetic values, e.g., a lake that is a foot or two deep and is filled with several feet of sediment, lots of fecal material, and mats of algae cannot be enjoyed for public swimming or boating. This project will focus the attention of municipalities on the problems and potential of their lakes. This information will come to municipal officials from their own health officers, as well as the Action Committee. Root causes will be identified, as well as water quality problems. The root cause analysis will make clear to local government officials the connection between their municipal codes and practices, and water quality and public health problems.

The watershed management planning methodology developed in the Whippany watershed is being employed throughout the state's twenty Watershed Management Areas. The Whippany River's Total Maximum Daily Load (TMDL) for fecal coliform mandates a 58% reduction in the levels of this pollutant. It was the first TMDL in the state. Vast amounts of time and money have been spent on planning. In the Whippany, problems have been identified. It is time for action supported by implementation funding.

III. ORIGINAL PROJECT BUDGET WITH ACTUAL GRANT AMOUNT & EXPENDITURES

EXPENSE ITEM	COST	$ FROM VICTORIA FOUNDATION	$ FROM OTHER SOURCES
Laboratory fees	Estimated at $7,500.00 **Actual Cost = $7,750.00** **Sampling (8/20/04)- 1,925.00** **Sampling (6/10/04)- 1,925.00** **Sampling (8/30/04)- 1,575.00** **Sampling (7/14/05)- 1,100.00** **Sampling (8/18/05)- 1,225.00**	$7,750.00	$75,000 for the sanitary survey in which the TAC also is participating. That funding will pay for laboratory testing, equipment, and the time of Rutgers' personnel who are working on the survey.
Preparation of final report, copies for distribution to watershed municipalities, technical seminar to discuss findings and recommendations	$1,718.83	$1,718.83	In-kind services from Dr. Van Orden, Garry Annibal, Pete Summers, and other municipal health officers
Dredge sampler	$ 429.00	$ 429.00	$0
Water quality monitoring equipment, GPS unit (already purchased and being used currently for our trends data project for the Whippany River)	$602.17	$602.17	$2,713.72 spent on equipment we also will use during this project. Funds came from our 2001 Victoria Foundation grant.
TOTAL	$10,500, plus in-kind donation of professional services and $75,000 from NJDEP for related work	$10,500	In-kind donations and $75,000 from NJDEP

IV. NARRATIVE

A. PURPOSE OF THE ORGANIZATION: The Whippany River Watershed Action Committee's mission is to protect and improve the waters of the Whippany River through community action. Member municipalities that had been meeting informally for several years incorporated as the Whippany River Watershed Action Committee in 1999. In December 2000, the Action Committee applied for 501(c)(3) status, which it received (Final Determination). At present, thirteen of the sixteen watershed municipalities are members of the Action Committee. Members include Denville, East Hanover, Florham Park, Hanover, Madison, Mendham Borough, Mendham Township, Morris Plains, Morris Township, Morristown, Mountain Lakes, Parsippany- Troy Hills, and Randolph.

B. CURRENT NEEDS TO BE ADDRESSED BY GRANT FUNDS: Impoundments created by small dams across our local streams have been a traditional flood control measure commonly used by municipalities in New Jersey. In addition to flood control, the impoundments often are incorporated into public parks in order to provide recreational opportunities for local residents. While these amenities have been an attractive feature in our communities, they are being threatened by water quality concerns. The water quality problems that exist within ponds, lakes and impounded areas commonly include: 1. High levels of nutrients; 2. Fecal coliform; 3. Biochemical oxygen demand; 4. Algal growth; 5. Discharge directly into lakes or the streams that feed them of stormwater runoff, sediment, and NPS from roadways and from older developments without stormwater detention or from new construction; 6. Harmful populations of waterfowl that contribute a significant nutrient and fecal coliform load to the system; 7. Mowed turf or bare eroding soil at the shoreline of lakes; 8. Vegetated riparian buffer with native trees, shrubs, and herbaceous plants that is too narrow or lacking altogether; and 9. Thick layer of sediment on the lake bed that binds to phosphorus and also traps other pollutants.

Water quality impairments in lakes rob them of their recreational, aesthetic, and habitat value. A lake that is a foot or two deep, filled with several feet of sediment, lots of fecal material, and mats of algae cannot be enjoyed for public swimming or boating. One of the worst case scenarios for a local lake is a fish kill. This occurs when dissolved oxygen levels fall below what is needed to sustain aquatic life, as a result of the problems listed above. There have been several fish kills in the Whippany River watershed over the past few years, most recently at Bee Meadow Pond in Hanover Township in 2001.

This project will focus the attention of municipalities on the problems and potential of their lakes. The understanding of the role of municipalities in water quality protection and improvement is uneven among local government officials. During this project, root causes will be identified, as well as water quality problems. The root cause analysis will make clear to local government officials the connection between water quality problems and their municipal codes and practices. For example, the root cause analysis will make the connection between the lost recreational and aesthetic value of lakes, and communities' stormwater management, development ordinances, and development practices. The root cause analysis also will make clear the association between public health threats posed by drinking water pollution and, for example, park landscaping and maintenance practices, and the value of goose damage management (e.g., nest management) by departments of public works and volunteers. Because this is a community-based project, the outreach, education, advocacy, and information will come to municipal officials from their own health officers, not from a consultant or a higher level of government. The work of intermunicipal watershed organizations in this region has demonstrated the effectiveness of municipalities' setting water quality protection and improvement goals, devising objectives to fulfill them, and working on them together with peers.

With the budget constraints that presently exist in government, funding was obtained from Victoria Foundation to purchase materials and laboratory services needed for this project.

There is a need for public officials to take actions that aid watershed management and water quality protection and improvement. The Whippany River's Total Maximum Daily Load (TMDL) for fecal coliform, which was approved by US EPA in the winter of 2000, mandates a 58% reduction in the levels of this pollutant. Vast amounts of time and money have been spent on planning. In the Whippany, problems have been identified and it is time for action supported by implementation funding.

With the modest amount of funding obtained for this project, the Action Committee and its members will continue their community-based process of education, change, implementation, and NPS pollution reduction that already is well under way.

C. PROGRAM OBJECTIVES FOR THE FUNDING PERIOD THAT WERE ACHEIVED:

1. Involve Morris County and municipalities in the Whippany River watershed in the development and implementation of a regional, watershed-based lake monitoring program that efficiently builds on past and present water quality monitoring efforts and yields guidance for local government officials;
2. Provide hands-on, community-based educational opportunities for public officials that reveal the assets, problems, and needs of the Whippany River, and the responsibilities of local government for water resources and public health;
3. Manage the watershed for the public health and welfare;
4. Involve local governments and citizens in water resources management;
5. Maintain, preserve, and improve the quantity and quality of water resources;
6. Improve the livability and habitat for the watershed's living resources;
7. Reduce nonpoint source fecal coliform levels by 58%, as agreed to in the winter of 2000 by the New Jersey Department of Environmental Protection and US EPA in the Total Maximum Daily Load (TMDL) for the Whippany River;
8. Increase human enjoyment and appreciation of the Whippany River;
9. Ensure continuation of this project after the grant period ends;
10. Publicize the project, its purposes, and participants through media and the resources of the project's partners.

D. PROGRAM IMPLEMENTATION: Dr. George Van Orden was responsible for implementing the program, with the assistance of Ralph Rhodes, Mendham Township Environmental Commission Chair, Garry Annibal, Harding Township's Health Officer, and Louise Jensen, Facilitator for the Action Committee. This grant covered programs from July 1, 2002 through October 31, 2005. The following was accomplished:

- The Action Committee's Technical Advisory Committee (TAC) used the same sampling protocols and QA/QC that were developed for the trends project funded in 2001 by Victoria Foundation;
- The TAC created a database in which to store past and future sampling data;
- The TAC selected and sample five lakes in the watershed. The lakes include Lake Parsippany, Sunrise Lake, Mountain Lake, Bee Meadow Pond, and Speedwell Lake. The sampling team will use the Trimble GPS unit to locate the sampling sites;
- Sampling was conducted during dry weather conditions in the summers of 2003, 2004 and 2005;
- Sampling was conducted by Dr. Van Orden at times determined by him. Dr. Van Orden led a team of volunteers from municipal health departments and environmental commissions. During sampling in the field, all team members learned how to use monitoring and GPS equipment.
- After samples were collected they were immediately delivered to a certified laboratory (Garden State Laboratories, Inc.) for testing. Because fecal coliform is the major pollutant of concern in the Whippany River at this time, samples were handed off to the lab within six hours after they are drawn from the river.
- Measures – for which some equivalent historical data exists for some lakes -- included: Dissolved Oxygen, pH, Salinity, Conductivity, Secchi Depth, Nitrate Nitrogen, Nitrite Nitrogen, Ammonia Nitrogen, Total Kjeldahl Nitrogen, Ortho Phosphorus, Total Phosphorus, Productivity of Phytoplankton (plant growth) using

Chlorophyll A, Nutrients (in both the sediments and water column), Total Dissolved Solids, Total Suspended Solids, Physical Characterization of the lake (stratification and depth), Water Temperature, Fecal Streptococcus (organisms/100 ml), Fecal Coliform (organisms/100 ml). Water quality was determined for lake inlets, outlets, epilimnion, and hypolimnion where they existed.

- The TAC stored the data in a database (using both Excel and GIS formats), compared the data to existing water quality criteria (where they exist), analyzed results, and attempted to identify problems (including potential problems) and possible causes.
- The TAC discussed sampling results and provided reports on its findings and recommendations to the Action Committee.
- The Action Committee will include the results of the TAC's work in reports to member municipalities.
- The information developed through this grant did build on Dr. Van Orden's ongoing sanitary survey and trend analysis of the Whippany River Watershed. New Jersey, in 1998, listed fecal coliform as a Section 303(d) Known Water Quality Impairment for the Whippany River. The potential sources of the fecal coliform impairment have been identified as malfunctioning and older improperly sized septic systems, Canada Geese, pest waterfowl and other wildlife, pet waste, and storm water basins. Total Maximum Daily Loads (TMDLs) are required, under Section 303(d) of the Federal Clean Water Act, to be developed for water bodies that cannot meet water quality standards after the implementation of technology-based effluent limitations. The State of New Jersey has agreed on a TMDL for fecal coliform in the Whippany River with US EPA: a 58% reduction. As part of the Whippany River Watershed Project, Killam Associates conducted Storm Event Water Quality sampling on November 8-9, 1996, April 12, 1997, July 9, 1997 and June 12, 1998. Reports generated indicate elevated levels of both fecal coliform and enterococcus in runoff during storm events. The Township of Hanover Health Department completed a sanitary survey of the Whippany River Watershed (report dated June 30, 2004) which identified known and potential sources of fecal contamination within the watershed.
- Should members of the sampling team wish to conduct additional sampling in their communities, they may borrow the GPS unit and sampling equipment from Dr. Van Orden, who will store and maintain sampling and GPS equipment at his offices in the Hanover Township municipal building.

E. Accomplishments of the Whippany River Watershed Action Committee:

1. Outreach & Education:

- Conducted goose damage management workshops for local government officials and the private sector in 2000, 2001, and 2002 (scheduled for February 15, 2002) in partnership with the Morris County Freeholders to directly address the TMDL for the Whippany River and fecal pollution of waterways;
- Involved hundreds of citizens in watershed education and river stewardship action during river clean ups and riparian restoration projects in 2000, 2001, and 2002 (scheduled for April 19 –26, 2002);
- Received and publicized a 2001 US EPA Region 2 Environmental Quality award. To reach the widest possible audience with its message of watershed protection and improvement, the Action Committee framed the award and is presenting it to members' governing bodies at their meetings. These presentations have been broadcast on cable TV and pictured in weekly newspapers. The award is rotating through our members' town halls.

2. Good Watershed Management Practices:

- Five member municipalities participated in restoring more than 1,000 linear feet of stream and river corridor and lakeside (approximately 36,500 square feet) and a wetland in 2000 and 2001. Two other restoration projects are scheduled for 2002, and, if funding is forthcoming, two or three others will be completed in 2003. Six municipal members of the Action Committee scoped out and committed to completing restoration projects that we estimate will cost $700K.

- With Trout Unlimited, the Whippany River Watershed Association, and other volunteers, plan and conduct annual river clean ups.
- Municipal members are using "A Cleaner Whippany River Watershed," and updating their ordinances and planning and development practices to include Best Management Practices. Examples include East Hanover, which is implementing a zoning ordinance to protect its river and stream corridors, and Morris Plains, which mandates infiltration of storm water for new development.

3. Community Partnerships - Planning & Acting for a Sustainable Future:

- Organized, incorporated, and attained 501(c)(3) nonprofit status for the Action Committee, which succeeded in attracting and retaining 13 of the 16 watershed municipalities as members. In 2002, the Action Committee will apply for Watershed Management Group status for the Whippany River.
- Under the leadership of Dr. George Van Orden of the Hanover Township Regional Health Department, organized health officers from 15 of the 16 Whippany municipalities into a Technical Advisory Committee for the Action Committee.

VI. EVALUATION STATEMENT

The success of the project will be measured by the degree of completion of each of the programs in Section V. D. Evaluation measures will include:

- **COMPLETED:** Dr. Van Orden purchases equipment;
- **COMPLETED:** TAC select lakes for sampling (Mountain Lake, Lake Parsippany, Bee Meadow Pond, Speedwell lake and Sunrise Lake);
- **COMPLETED**: Number of samples taken (25 SAMPLES WERE COLLECTED);
- **COMPLETED:** Success of sampling as measured against QA/QC standards;
- **COMPLETED**: Number of public officials participating in sampling (nine people assisted in conducting the field GIS work and sampling);
- **COMPLETED**: Creation and maintenance of the database, which will include some baseline, as well as new, data;
- **COMPLETED**: Risk factors and causes (incorporated into the final report under data discussion, conclusions and recommendations);
- **NOT COMPLETED AT THIS TIME BUT WILL BE COMPLETED**: Preparation and dissemination of reports re. findings and recommendations to Action Committee and member municipalities (reports will be disseminated to the Action Committee along with a presentation to discuss the findings in the final report, a seminar will be offered to Action Committee members and professions to discuss the findings in the report and recommendations with respect to lake management);
- **COMPLETED AND ON-GOING**: Media coverage concerning the work of the TAC and the Action Committee.

TECHNICAL REPORT

Introduction

The goal of this work was to study the water quality of five lakes within the Whippany River Watershed. This work included sampling lake inlets and outlets, lake water columns and sediments and to determine and map lake depths. Samples were collected under dry weather conditions. Where lake stratification occurred, samples were collected from both the lake's epilimnion and hypolimnion. One sample was collected from each lake inlet and outlet where flow existed. One sample location was established in each lake where a lake water column sample (one from each the epilimnion and hypolimnion where stratification occurred) and lake sediment sample was obtained. The one exception to this was Lake Parsippany. At Lake Parsippany, during the time of sampling, there was no flow into or out of the Lake. Therefore, at Lake Parsippany there were no inlet or outlet samples collected. Two sampling locations were established for Lake Parsippany where both water column (there was no stratification) and sediment samples were collected. It is important to note that the limited number of samples collected did not provide good insight into both the temporal and spatial variability of each lake.

Water quality data was collected at selected locations for each of the lakes studied. Sampling locations have been mapped for each lake (see **Appendix A**). Sampling and depth locations were determined in the field and recorded using a Trimble GeoExplorer 3 global positioning system. This information was converted into shape files which were used in GIS mapping. Depth measurements were collected on June 3, 2003 (Sunrise Lake), June 12, 2003 (Mountain Lake), August 12, 2003 (Bee Meadow Pond), October 18, 2004 (Lake Parsippany), and July 12, 2005 (Speedwell Lake). Water quality samples were collected on August 20, 2003 (Sunrise Lake), June 10, 2004 (Mountain Lake), August 30, 2004 (Bee Meadow Pond), July 14, 2005 (Lake Parsippany), and August 18, 2005 (Speedwell Lake). Samples and depth measurements were collected under dry weather conditions. Water quality parameters determined included temperature, dissolved oxygen (DO), pH, conductivity, specific conductivity, salinity and secchi depth which were analyzed in the field and total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH3-N), nitrite nitrogen(NO2-N), nitrate nitrogen(NO3-N), orthophosphorus (ortho-P), total phosphorus (Total-P), total suspended solids (TSS), total dissolved solids (TDS), total alkalinity, chlorophyll A, fecal coliform and fecal streptococcus. Sediment samples were also collected at each lake and analyzed for total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH3-N), nitrate nitrogen (NO3-N), orthophosphorus (ortho-P), total phosphorus as phosphorus (Total-P), fecal coliform and fecal streptococcus.

GIS maps were developed for the Whippany Watershed and for each lake studied (**Appendix A**). The maps developed include depths, sampling locations, aerial photographs (April 24, 1999), groundwater recharge and land use. This report includes first an evaluation of the data for each lake followed by a comparison of all lakes.

Description of Study Area

For a complete description of the study area (Whippany River Watershed) please refer to the "Whippany River Watershed Characterization Report" prepared by the Whippany Watershed Partnership in September of 1995 and "A Cleaner Whippany River Watershed, May 2000," prepared by the New Jersey Department of Environmental Protection and the Whippany Nonpoint Source Work Group, both of which are kept on file with the New Jersey Department of Environmental Protection, Division of Watershed Management, and the Whippany River Watershed Action Committee. A summarized description of the Whippany River Watershed may be found in **Appendix D** of this report titled "The Whippany River Watershed Action Now Strategy of the Whippany River Watershed Management Plan, January 2000."

Mountain Lake: Mountain Lake is a 75.4 acre fresh water lake located in Mountain Lakes Borough, Morris County, New Jersey. It is part of the group of interconnected lakes (Birchwood Lake, Crystal Lake, Sunset Lake, Wildwood Lake and Mountain Lake) located in the northern portion of the Whippany River Watershed. Mountain Lake receives drainage from all of the lakes mentioned in this group. Please refer to **Appendix A** for GIS maps which show the surrounding inputs, elevation contour lines, roads, streams, land use and ground water recharge for this lake. 27 Depth measurements were taken during this study (see Mountain Lake Depth and Sampling Location map found in **Appendix A**). From the 27 depth measurements taken the mean lake depth was 6.8 feet with a standard deviation of 2.3 feet and range of 3 to 11 feet. Stratification was observed with the top of the thermocline occurring at approximately 3.75 feet below the water surface. There are two surface water inputs to the lake. The surface water inputs directly connect Mountain Lake to Sunset Lake and Wildwood Lake. However, during this study (dry weather conditions) there was no flow at the Sunset Lake input (located in the south-western portion of the Lake) and very little flow from the Wildwood Lake Input (Lake Drive inlet) located in the north-eastern portion of the Lake. During this study residents from Mountain lakes reported that the Lake Drive inlet has been know to flow in both directions (from Wildwood Lake to Mountain Lake and from Mountain Lake to Wildwood Lake – allowing for equalization between both lakes). During this investigation flow was observed from Wildwood Lake to Mountain Lake. There is one lake outlet, which did have a small amount of flow during this study, located in the southern portion of the lake (at the dam spillway) near Lake Drive. The outlet eventually discharges to Troy Brook.

The soils surrounding Mountain Lake provide a moderate amount of groundwater recharge (ranging from 5.6 to 15.3 inches from precipitation per year). This area receives an average annual precipitation of 44 inches per year. Land use surrounding the lake consists mostly of medium to low density residential (urban) with some forested and wetland areas. Mowed, residential lawns surround much of the lake.

Compared to other lakes within the Whippany Watershed, the attached algal density appeared to be low. Attached macrophyton was observed along some shore (shallow) areas. This lake was periodically treated with a herbicide. On June 4, 2004, (one week prior to sampling) this lake was treated with a herbicide "Aquathol K."

All of the dwellings in Mountain Lakes Borough are served by public drinking water provided primarily by the Mountain Lakes Water Department (well water supply). The entire Borough is serviced by a public sanitary sewerage system (which discharges to the Parsippany-Troy Hills Sewerage Authority). Historical reports indicate that this lake has had a dense population of Canada Geese. However, during this study very few geese were observed. There are no wastewater treatment plant discharges (point source discharges) upstream or directly into this lake.

Lake Parsippany: Lake Parsippany is a 155.4 acre fresh water lake located in the Township of Parsippany-Troy Hills, Morris County, New Jersey. It is located in the north-central portion of the Whippany River watershed. Please refer to **Appendix A** for GIS maps which show the surrounding inputs, elevation contour lines, roads, streams, land use and ground water recharge for this lake. 33 Depth measurements were taken during this study (see Lake Parsippany Depth and Sampling Location map found in **Appendix A**). From the depth measurements taken the mean lake depth was 5.0 feet with a standard deviation of 1.9 feet and range of 2 to 8 feet. Stratification was not observed during the time of this study. There is one surface water inlet to the lake (located in the northern portion of the lake). There is one outlet located in the south-eastern portion of the lake which discharges to Eastmans Brook and eventually into Troy Brook. However, it is important to note that during this study there was no inlet or outlet flow observed. Lake residents reported that flow through the lake (inlet and outlet) only occurs during wet weather conditions (during and shortly after a storm event).

The soils surrounding Lake Parsippany provide mostly a moderate amount (ranging from 5.6 to 15.3 inches from precipitation per year) of groundwater recharge with a smaller area (located in the northern portion of the lake) providing a lower rate of recharge (ranging from 0.0 to 5.6 inches from precipitation per year). This area receives an average annual precipitation of 44 inches per year. Land use surrounding the lake consists mostly of medium density residential (urban) with some forested and wetland areas. Mowed, residential lawns surround much of the lake.

Compared to other lakes within the Whippany Watershed, the attached algal density appeared to be low. Attached macrophyton was observed along some shore (shallow) areas. This lake is periodically treated with "Aqua Blue," a water coloring agent (gives the lake water a blue color) which inhibits sunlight penetration and algal productivity. Aqua Blue was applied one week prior to sampling. Secchi depths observed during sampling were 2 feet. Aqua Blue most likely had an effect on secchi depth.

Most of the residents of Parsippany-Troy Hills are served by public drinking water. Less than 1% of the residents of the township are served by individual, on site wells. Most of the residents of the Township are served by public sewerage facilities (which discharge to the Parsippany-Troy Hills Sewerage Authority). Historical reports indicate that this lake has had a dense population of Canada Geese. During this study a large number of geese were observed. A large amount of goose droppings were observed on the ground in areas surrounding the lake. There are no wastewater treatment plant discharges (point source discharges) upstream or directly into this lake.

Bee Meadow Pond: Bee Meadow Pond (Pond 1) is an 11.9 acre fresh water pond located in the Township of Hanover, Morris County, New Jersey. It is one of a series of three interconnected ponds which discharges directly into West Brook which eventually discharges into Troy Brook. It is located in the east-central portion of the Whippany River watershed. Please refer to **Appendix A** for GIS maps which show the surrounding inputs, elevation contour lines, roads, streams, land use and ground water recharge for this pond. 21 depth measurements were taken during this study (see Bee Meadow Pond Depth and Sampling Location map found in **Appendix A**). From the depth measurements taken the mean pond depth was 9.6 feet with a standard deviation of 4.7 feet and range of 2 to 17 feet. Stratification was observed during the time of this study. The top of the thermocline was estimated at 6.3 feet below the pond surface. It is important to note that of the five lakes included in this study, the hypolimnion layer of Bee Meadow Pond was the thickest (estimated at approximately 7 feet thick). There is one surface water inlet to the pond (located in the western portion of the pond) which originates from Bee Meadow Pond 2. There is one outlet located in the eastern portion of the pond which discharges to West Brook and eventually into Troy Brook.

The soils surrounding the Bee Meadow Pond series (Ponds 1, 2 and 3) provide mostly low rates (0.0 to 5.6 inches from precipitation per year) of groundwater recharge with some areas of high rates (15.3 to 17.6 inches from precipitation per year) of groundwater recharge. Approximately 50 % of the soils surrounding Pond 1 have low recharge potential (0.0 to 5.6 inches from precipitation per year) with the remaining soils providing good recharge (15.3 to 17.6 inches from precipitation per year). Ponds 2 and 3 are surrounded mostly by soils which provide poor groundwater recharge. This area receives an average annual precipitation of 44 inches per year. Land use surrounding the pond consists of a mix of medium density residential (urban) with forested and wetland areas. Mowed pubic and residential lawns surround much of the ponds.

Compared to other lakes within the Whippany Watershed, the attached algal density appeared to be moderate along the shoreline. Attached macrophyton was observed along most shore (shallow) areas. This lake is not treated with an algaecide or water coloring agent. The geomorphology of this pond (deep with a small area of shallow water) is not supportive of rooted or attached macrophytes because these plants would become light limited in the deep water and there is only a relatively small area of shallow water. This pond becomes very deep within a relatively short distance from the shoreline. This type of water body would tend to enrich for phytoplankton which would dominate over attached plant growth.

Almost all of the residents of the Township of Hanover are served by public drinking water. Most of the residents of the Township are served by public sewerage facilities (which discharge to the Hanover Sewerage Authority). There are no septic systems in the areas surrounding the ponds. Historical reports indicate that this pond has had a dense population of Canada Geese and ducks. This was confirmed during this study. A large amount of goose droppings were observed on the ground in areas surrounding the pond. There are no wastewater treatment plant discharges (point source discharges) upstream or directly into this pond. There is a rooster farm located immediately north (within 50 feet) of Bee Meadow Pond 1.

Speedwell Lake: Speedwell Lake is a 19.5 acre fresh water lake located in the Town of Morristown, Morris County, New Jersey. Speedwell lake is actually an impoundment of the Whippany River which forms upstream of the Speedwell Lake Dam. It is located in the southern portion of the Whippany River watershed. Please refer to **Appendix A** for GIS maps which show the surrounding inputs, elevation contour lines, roads, streams, land use and ground water recharge for this lake. 22 Depth measurements were taken during this study (see Speedwell Lake Depth and Sampling Location map found in **Appendix A**). From the depth measurements taken the mean lake depth was 2.3 feet with a standard deviation of 1.9 feet and range of 0.5 to 7.5 feet. Stratification was not observed during the time of this study. There is one surface water inlet (Whippany River at Lake Road) which is located in the western portion of the lake. There is one outlet at Speedwell Lake Dam (Whippany River at Speedwell Avenue) located in the eastern portion of the lake. It is important to note that during this study the Speedwell Lake outlet was sampled below Speedwell Dam (after dam reaeration).

The soils along the south shore of Speedwell Lake provide mostly a large amount (ranging from 15.3 to 21.0 inches from precipitation per year) of groundwater recharge. The soils along the north shore of Speedwell Lake provide a much lower rate (ranging from 0.0 to 5.5 inches from precipitation per year) of groundwater recharge. This area receives an average annual precipitation of 44 inches per year. Land use surrounding the lake consists mostly of medium density residential (urban) with some forested and wetland areas. Forested land surrounds much of the lake's immediate shore line.

Compared to the other lakes studied within the Whippany Watershed, the attached algal growth is extremely dense consisting mostly of filamentous algae. Thick beds of macrophyton were observed throughout the lake which is very shallow. This lake is not treated with an algaecide or a water coloring agent.

Almost all of the residents of the Town of Morristown are served by public drinking water. All of the residents of the Town are served by public sewerage facilities (which discharge to the Morristown Sewage Treatment Plant). Historical reports indicate that this lake has had a dense population of Canada Geese. During this study a large number of geese were observed. There are two wastewater treatment plant discharges (point source discharges) upstream this lake (Morris Township's Butterworth Sewage Treatment Plant with it's effluent discharge located approximately 0.5 miles upstream of the Lake and the Greystone State Hospital Wastewater Treatment Plant effluent which discharges to Watnong Brook which eventually discharges to the Whippany River below the Butterworth STP effluent discharge).

Sunrise Lake: Sunrise Lake is a 4.4 acre fresh water lake located in Mendham Township, Morris County, New Jersey. It is located in the western portion of the Whippany River Watershed (within the headwater area of the Whippany River). Please refer to **Appendix A** for GIS maps which show the surrounding inputs, elevation contour lines, roads, streams, land use and ground water recharge for this lake. 16 Depth measurements were taken during this study (see Sunrise Lake Depth and Sampling Location map found in **Appendix A**). From the depth measurements taken the mean lake depth was 5.4 feet with a standard deviation of 2.0 feet and range of 2 to 9 feet. Stratification was observed with the top of the thermocline occurring at approximately 6.25 feet below the water surface. There are two surface water inlets located in the southern portion of the lake. Both surface water inlets drain mostly forested land up-gradient of the lake. There is one lake outlet located in the northern portion of the lake (at the spillway) near Mendham Road. The outlet discharges directly to the Whippany River.

The soils surrounding Sunrise Lake provide a large amount (ranging from 15.3 to 17.6 inches from precipitation per year) of groundwater recharge. This area receives an average annual precipitation of 44 inches per year. Land use surrounding the lake consists mostly of forested land with some areas of low density residential (urban). Mowed public lawn and forested area surround much of the lake's shoreline.

Compared to other lakes within the Whippany Watershed, the attached algal density appeared to be low. Attached macrophytes were observed along some shore (shallow) areas.

The majority of the dwellings within the Township rely on individual on-site wells. Approximately 40 % of the homes are services by public drinking water supplies. Almost all of Mendham Township is not sewered (rely on on-site wastewater disposal systems). Historical reports indicate that this lake has had a dense population of Canada Geese. This was confirmed during this study. Large accumulations of goose droppings were observed on the ground surrounding the lake. There are no wastewater treatment plant discharges (point source discharges) upstream or directly into this lake.

Methods

Maps and GIS shape files were obtained from the New Jersey Department of Environmental Protection and New Jersey Geological Survey. Field surveys and depth measurements were made prior to developing a sampling plan and conducting sampling. Field surveys were made by walking around the lake (where access was possible) and by boat. Major surface water inputs and potential sources of contaminations were identified. Depth measurements were made using a Fish-Ray Handheld Sonar Gun (Model FR-100 by Manta Sonar). Approximately 50 % of the sonar depth measurements were verified using a metal tape measure. Depth locations, sampling locations and depth measurements were recorded using a Trimble GeoExplorer 3. The information collected was transferred to a shape file (using GPS Pathfinder Office data processing software) which was then used in developing the GIS maps. GIS maps were created using ArcGIS 9 (ArcView) software by ESRI.

Samples were collected under dry weather conditions. Where lake stratification occurred, samples were collected from both the lake's epilimnion and hypolimnion. One sample was collected from each lake inlet and outlet where flow existed. One sample location was established in each lake where a lake water column sample (one from each the epilimnion and hypolimnion where stratification occurred) and lake sediment sample was obtained. The one exception to this was Lake Parsippany. At Lake Parsippany, during the time of sampling, there was no flow into or out of the Lake. Therefore, at Lake Parsippany there were no inlet or outlet samples collected. Two lake sampling locations were established for Lake Parsippany where water column (there was no stratification) and sediment samples were collected. It is important to note that the limited number of samples collected did not provide good insight into both the temporal and spatial variability of the lakes.

Maps of the sampling locations can be found in **Appendix A.** Samples were collected manually from the inlets and outlets by using clean and rinsed plastic buckets to collected water samples from the water column. Lake water column samples were collected by using clean, rinsed plastic buckets for epilimnion samples and by using clean, rinsed Van Dorn-Style Bottles (trigger release mechanism seals the sample chamber at the desired depth) for hypolimnion samples. Sediment samples were collected using an Ekman Bottom Grab sampling kit. Secchi measurements were made using a Wildco Fieldmaster Secchi Disk. Samples were collected in accordance with the "NJDEP Field Sampling Procedures Manual, May 1992." Samples were collected, preserved, refrigerated and delivered to Garden State Laboratory (within 6 hours of collection) by the sampling staff (Dr. Van Orden). Sample bottles and preservative was provided by Garden State Laboratory. Quality Control/Quality Assurance (QA/QC) requirements were met as recommended in the NJDEP Field Sampling Procedures Manual and as pre-established by the Whippany River Watershed Action Committee's Technical Advisory Committee (TAC).

Field measurements for Dissolved oxygen, temperature, pH, conductivity and salinity were made by sampling staff (Dr. Van Orden) during the time of sampling using an YSI Model 85 handheld oxygen, conductivity, salinity and temperature meter and an Orion model 265A pH meter. Both meters were calibrated immediately prior to each sample run (in accordance with the manufacturer's instructions) and checked for calibration at the completion of the sample run for drift. In-situ dissolved oxygen and temperature measurements (to determine stratification and depth to thermocline) were made using an YSI model 5739 DO/Temperature probe (with mechanical stirrer) at known depths and YSI Model 51 B Dissolved Oxygen/Temperature meter.

Data

The raw data and field notes used in this study may be found in **Appendix C** of this report. Summarized data (which includes data tables) may be found in **Appendix B**.

Discussion

Samples were collected at each of the above mentioned lakes during warm, dry weather conditions. Nineteen (19) parameters were measured for each lake water sample collected. Seven (7) parameters were measured for each lake sediment sample collected. See **Appendix B** for a listing of the parameters measured. . While performing the calculations all values received from the laboratory were included (K descriptor values refer to an actual concentration which is less than the reported concentration, J descriptor values refer to an estimated concentration). However, if a K value or J value was used in the calculation the final mean value calculated was labeled with the appropriate symbol (i.e. if a "K" value was used in the calculation, the final mean value was given a " < " less than label indicating that the actual mean value is less than the calculated and reported mean value). While graphing the data all values received from the laboratory were used. However, if a K value or J value was reported by the laboratory then the value used in graphing was the actual numerical value received (i.e. if the value was <.01 mg/l then the value plotted was 0.01 mg/l

Thermal stratification was observed in Mountain Lake, Bee Meadow Pond and Sunrise Lake. It is important to note the following from Cooke, et al (1986) regarding thermal stratification:

"One of the most significant determinants of the physical, chemical and biological interactions of a lake or reservoir is its annual temperature cycle. In temperate climates, deep basins ($\geq$ 7-10 meters deep) stratify thermally during the summer months into a deep, dark, stagnant, cold layer (termed hypolimnion) and an upper, lighted, circulating, warm layer (termed epilimnion). These zones are separated by a band of water in which temperature declines rapidly with depth, the metalimnion (or as used in this report, thermocline). They remain stratified through the summer.

The significance of the thermal stratification to the eutrophic process and to lake or reservoir restoration lies in the separation of the upper and lower lake zones during the summer through differences in water density (cold water being heavier). In eutrophic lakes and reservoirs the high content of organic matter in the lake sediments, originating from the production of algae and macrophytes as well as from income via streams, provide an excellent source of energy for bacteria, fungi, Protozoa and some invertebrate animals. The respiration of such organisms consumes the oxygen that was stored in the hypolimnion at the time of thermal stratification in the spring and releases some of the elements bound in the organic matter. There may also be extensive chemical oxygen demand. As oxygen is reduces, at a rate called the lake's oxygen deficit rate, the ability of the sediments to retain elements such as phosphorus in iron-hydroxy complexes is altered and these elements are released to the hypolimnetic water. At a low dissolved oxygen concentration, phosphorus, usually the most limiting nutrient is readily released from its association with iron (III) into the water column."

The data collected during this study does confirm the above. In general, where stratification did occur, dissolved oxygen was reduced and nitrogen and phosphorus concentrations were higher in the hypolimnion when compared to the epilimnion.

Mountain Lake:

Samples collected on June 10, 2004, included lake epilimnion, hypolimnion and sediment sample samples, two inlet samples (Boulevard Road and Lake Drive) and one outlet sample (Lake Drive). The secchi depth for the lake during sampling was 6 feet. Temperature of the lake epilimnion was 4 degrees C higher than the hypolimnion (25 degrees C and 21 C degrees respectively).

Dissolved oxygen **(Figure 1** below) and pH (**Figure 2** below) was lower in the hypolimnion (6.0 mg/l and 7.75 respectively) than the epilimnion (8.9 mg/l and 8.18 respectively). During the time of sampling, all lake water and outlet samples collected met the NJDEP dissolved oxygen criteria for FW2 Trout Maintenance (not less than 5.0 mg/l at any time) and FW2 Non Trout (not less than 4.0 mg/l at any time) classifications. For all future discussions please note that the NJDEP classifications of FW refer to fresh water and classifications TM and NT refer to trout maintenance and non-trout respectively. The dissolved oxygen (DO) concentration for the Boulevard Road inlet (4.6 mg/l) met the FW2 NT classification (not less than 4.0 mg/l at any time) but did not meet the FW2 TM classification. The DO concentration for the Lake Drive inlet did not meet the NJDEP criteria for any of the above mentioned classifications. All surface water samples collected met the pH (6.5 to 8.5 standard units) criteria for FW2 TM and FW2 NT classifications.

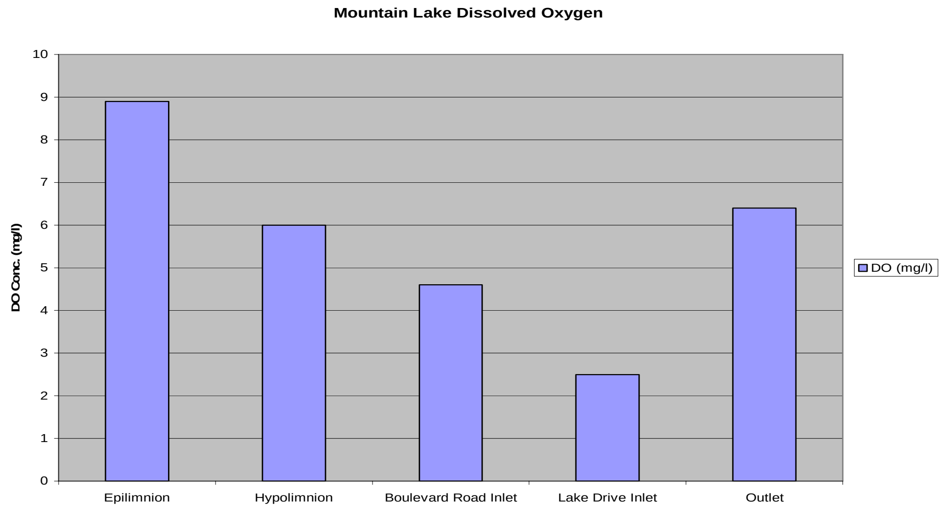


FIGURE 1 : Mountain Lake Dissolved Oxygen

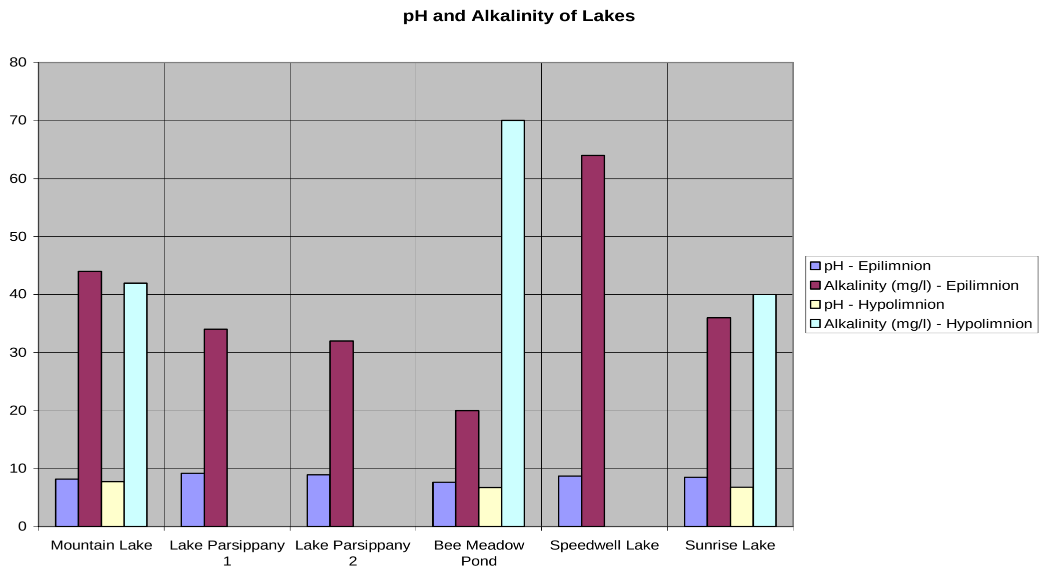
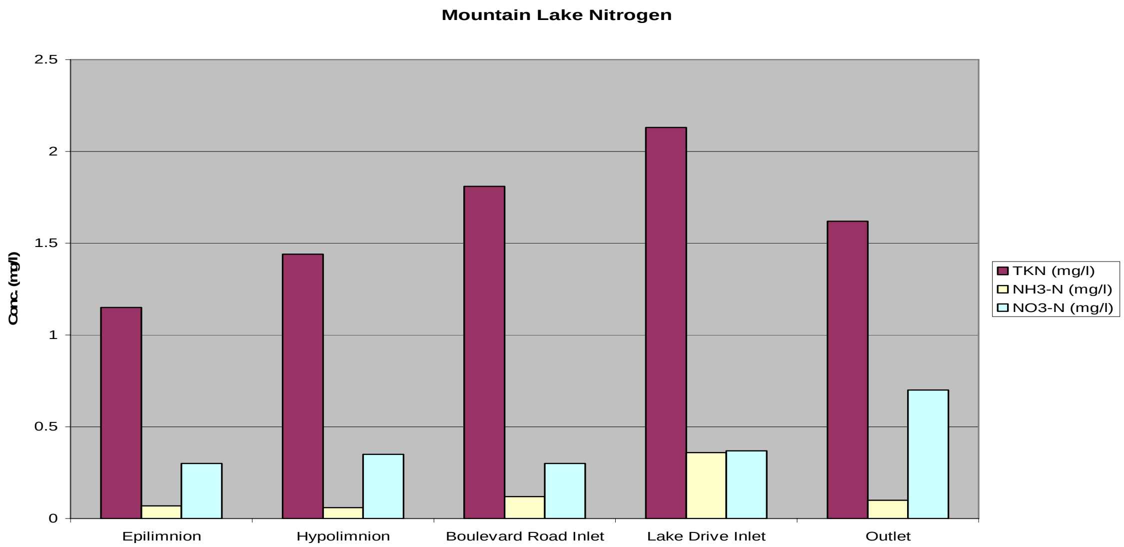


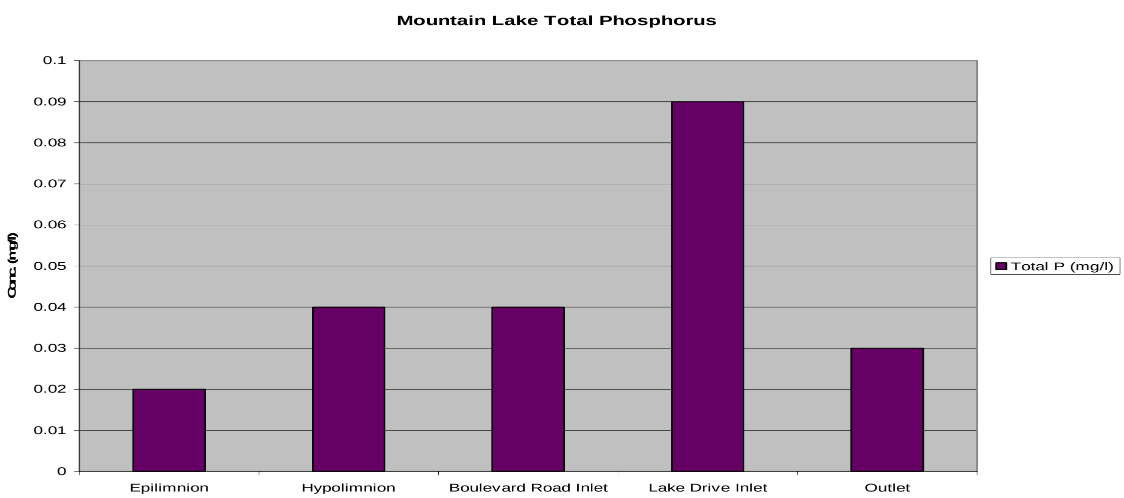
FIGURE 2 : pH and Alkalinity of Lakes Studied

Total lake nitrogen (organic nitrogen, ammonia nitrogen, nitrite nitrogen and nitrate nitrogen) in the hypolimnion (<1.8 mg/l) was slightly higher than in the epilimnion (<1.5 mg/l). Please refer to **Figure 3** below. In both the epilimnion and hypolimnion , the organic nitrogen (1.08 mg/l and 1.38 mg/l respectively) was the predominant form of nitrogen. Organic nitrogen was calculated as the difference between Total Kjeldahl Nitrogen (TKN) and Ammonia Nitrogen (NH3-N). The lake sediments (**Figure 5** below) appear to be a significant source of Nitrogen. The total nitrogen concentration (organic nitrogen, ammonia nitrogen and nitrate nitrogen) in the sediment sample was 2,333 mg/kg dry weight with organic nitrogen (2,029.7 mg/kg dry weight) being the predominant nitrogen species followed by NO3-N (<253 mg/kg dry weight). Of the inputs sampled, the Lake Drive total nitrogen concentration was the largest at 2.5 mg/l (organic nitrogen being the predominant species at 1.77 mg/l). The Boulevard Road inlet total nitrogen concentration was <2.1 mg/l (organic nitrogen being the predominant species at 1.69 mg/l). All lake samples including inlets and outlet met the NJDEP NO3-N criteria of 10 mg/l for all FW2 waters.



<u>FIGURE 3</u> : Mountain Lake Nitrogen

Total phosphorus (**<u>Figure 4</u>** below) in the hypolimnium (0.04 mg/l) was greater than the epilimnion concentration (0.02 mg/l). The lake sediments (**<u>Figure 5</u>** below) appear to be a significant source of total phosphorus. The total phosphorus concentration in the sediment sample was 1960 mg/kg dry weight. The Ortho Phosphate concentration in the sediment was 104 mg/kg dry weight. Of all the water samples collected only the Lake Drive sample (total phosphorus concentration of 0.09 mg/l) exceeded the NJDEP FW 2 total phosphorus criteria of 0.05 mg/l for lakes (and input to lakes). The Mountain Lake outlet was discharging a total phosphorus concentration of 0.03 mg/l to Troy Brook.



<u>FIGURE 4</u>: Mountain Lake Total Phosphorus

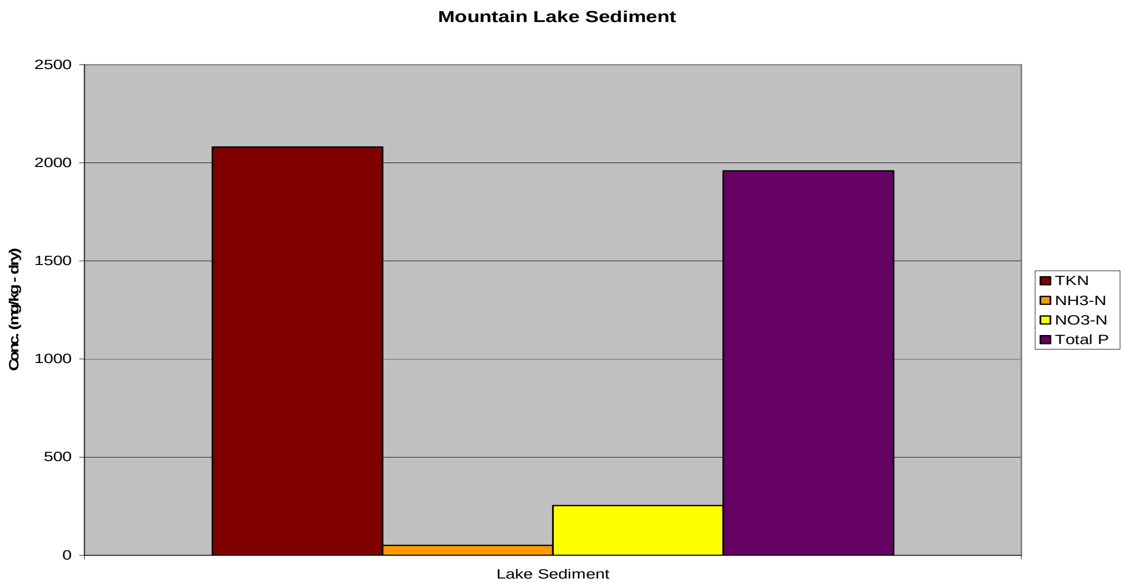


FIGURE 5: Mountain Lake Sediments (Nutrients)

Total suspended solids concentration (**Figure 6** below) in the hypolimnion was higher than the epilimnion (12 mg/l and 6 mg/l respectively). Regarding the total dissolved solids, however, the reverse was true. The total dissolved solids concentration in the epilimnion was higher than the hypolimnion (202 mg/l and 163 mg/l respectively). All water samples collected (lake samples, inlet samples and outlet sample) met the total suspended solids criteria (25 mg/l for FW2 TM) and total dissolved solids criteria (500 mg/l for all FW2 waters).

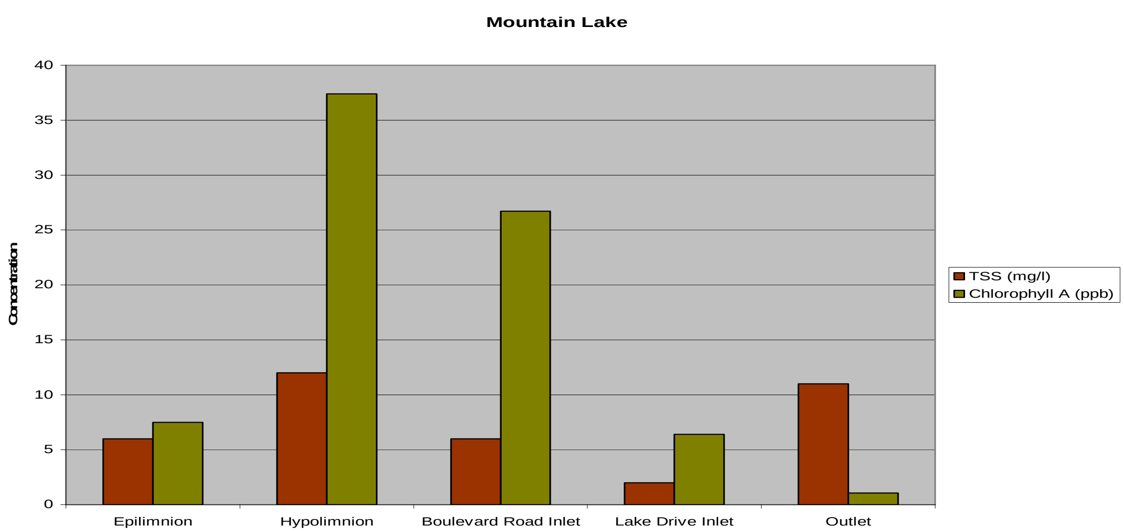


FIGURE 6 : Mountain Lake Total Suspended Solids and Chlorophyll A

See **Figure 2** and **Figure 6** above for Alkalinity and Chlorophyll A data. See **Figure 7** (below) for fecal coliform data. Please note that the fecal coliform standard for FW 2 waters (which include all of the surface waters sampled during this study) is as follows:

"Fecal coliform levels shall not exceed a geometric average of 200/100 ml nor should more than 10 percent of the total samples taken during any 30-day period exceed 400/100 ml."

Please note that only the Lake Drive Inlet sample did not meet the NJDEP FW2 fecal coliform criteria.

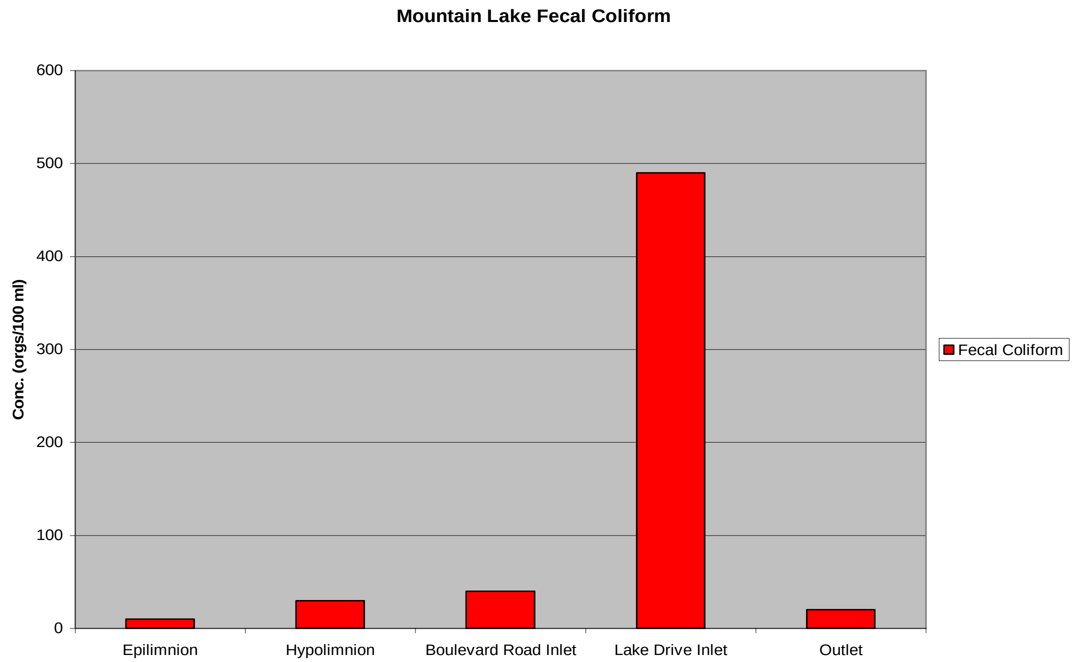


FIGURE 7 : Mountain Lake Fecal Coliform

LAKE PARSIPPANY:

Samples collected on July 14, 2005, included water column and sediment samples collected from two locations in the lake (see **Appendix A** for sampling location map). During sampling, lake stratification was not observed and there was no flow in either the lake inlet or lake outlet. The secchi depth for the lake during sampling was 2 feet. Temperatures of the lake water at the two sampling locations were 26 and 27 degrees C. It is important to note that a compound called "Aqua Blue" was applied to the lake one week prior to sampling. "Aqua Blue" is a water coloring agent which turns the lake water a blue color. The Lake Parsippany Property Owners Association has this material applied to the lake in an effort to control algal growth. This material inhibits sunlight penetration (absorbs the frequencies of sunlight required during photosynthesis) through the water column (most likely responsible for the shallow secchi depth mentioned above).

Lake Dissolved oxygen at the two sampling locations was 8.6 and 8.8 mg/l. Lake pHs (Figure 2 above) at the sampling locations was 9.2 and 8.9. Both lake samples collected met the NJDEP dissolved oxygen criteria for FW2 Trout Maintenance (not less than 5.0 mg/l at any time) and FW2 Non Trout (not less than 4.0 mg/l at any time) classifications. Both surface water samples collected did not meet the pH (6.5 to 8.5 standard units) criteria for FW2 TM and FW2 NT classifications. Both samples were slightly more basic than the criteria.

Total lake nitrogen (organic nitrogen, ammonia nitrogen, nitrite nitrogen and nitrate nitrogen) at the two above mentioned lake sampling locations were 1.25 mg/l and <1.14 mg/l. Please refer to **Figure 8** below. In both samples the organic nitrogen (0.93 mg/l and 0.79 mg/l respectively) was the predominant form of nitrogen. Organic nitrogen was calculated as the difference between Total Kjeldahl Nitrogen (TKN) and Ammonia Nitrogen (NH3-N). The lake sediments (**Figure 9** below) appear to be a significant source of Nitrogen. The total nitrogen concentration (organic nitrogen, ammonia nitrogen and nitrate nitrogen) in the sediment samples at sampling locations one and two were <8,889 mg/kg dry weight and 2,052.9 mg/kg dry weight, respectively. The data shows a significant difference in total nitrogen between the two samples. Please note that the area of sample location two (area between and lake inlet and outlet) was recently dredged (around 1999). The area around sample location one was not dredged. The organic nitrogen (8,701.5 and 1,823 mg/kg dry weight, respectively) was the predominant nitrogen species followed by NO3-N (<139 and <42.9 mg/kg dry weight, respectively). All lake samples met the NJDEP NO3-N criteria of 10 mg/l for all FW2 waters.

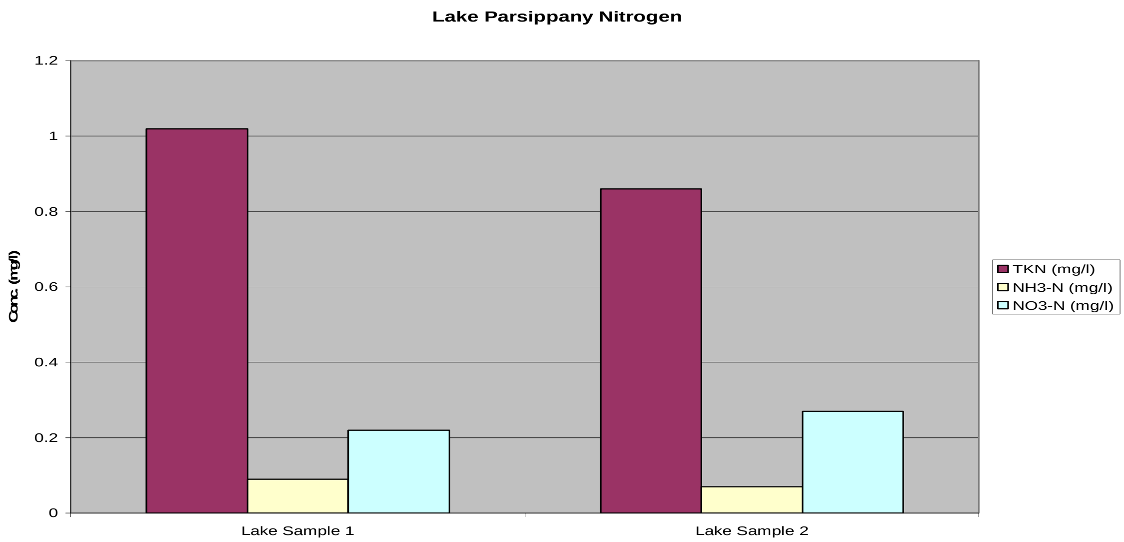


FIGURE 8 : Lake Parsippany Nitrogen

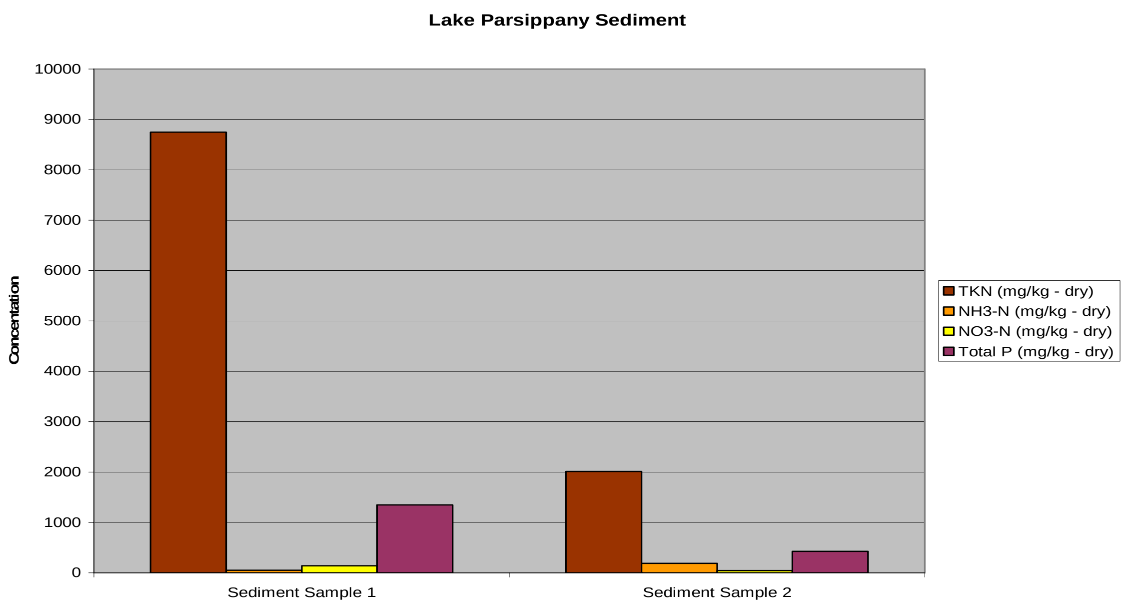


FIGURE 9 : Lake Parsippany Sediments

Total phosphorus (**Figure 10** below) in the two water column samples were 0.08 mg/l and 0.07 mg/l. The lake sediments (**Figure 9** above) appear to be a significant source of total phosphorus. The total phosphorus concentration in the sediment samples (locations one and two) were 1350 mg/kg dry weight and 429 mg/kg dry weight. Again, as with nitrogen mentioned above, there is a significant difference between the two locations with respect to total phosphorus. Both of the lake water column samples collected exceeded the NJDEP FW 2 total phosphorus criteria of 0.05 mg/l for lakes.

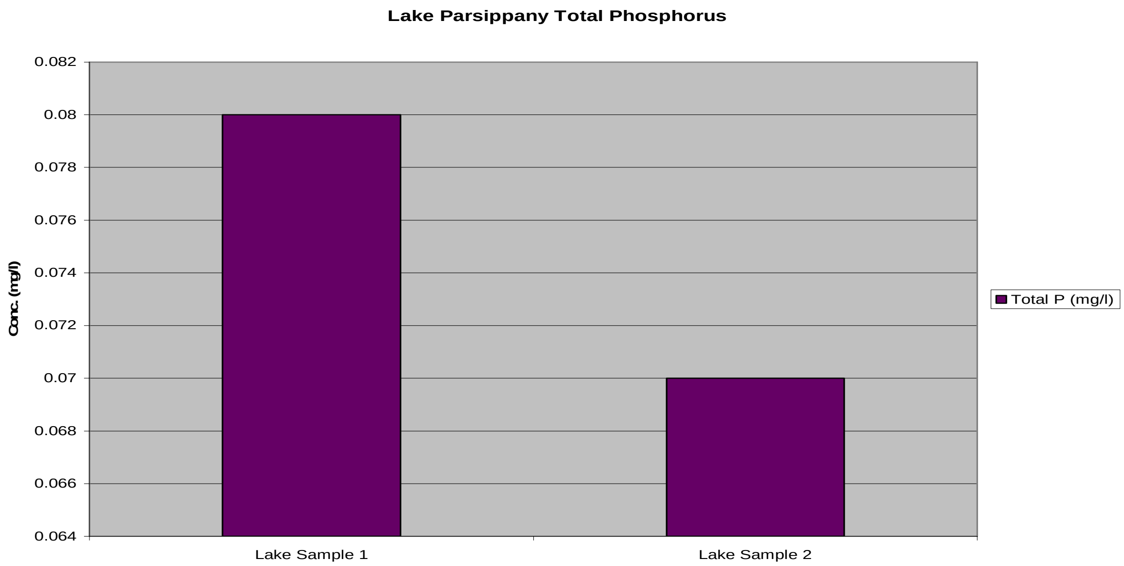


FIGURE 10: Lake Parsippany Phosphorus

Total suspended solids (**Figure 11** below) in the lake water column at sample locations one and two were 11 mg/l and 20 mg/l. The total dissolved solids at both locations were 210 mg/l and 325 mg/l. Both water samples collected met the total suspended solids criteria (25 mg/l for FW2 TM) and total dissolved solids criteria (500 mg/l for all FW2 waters).

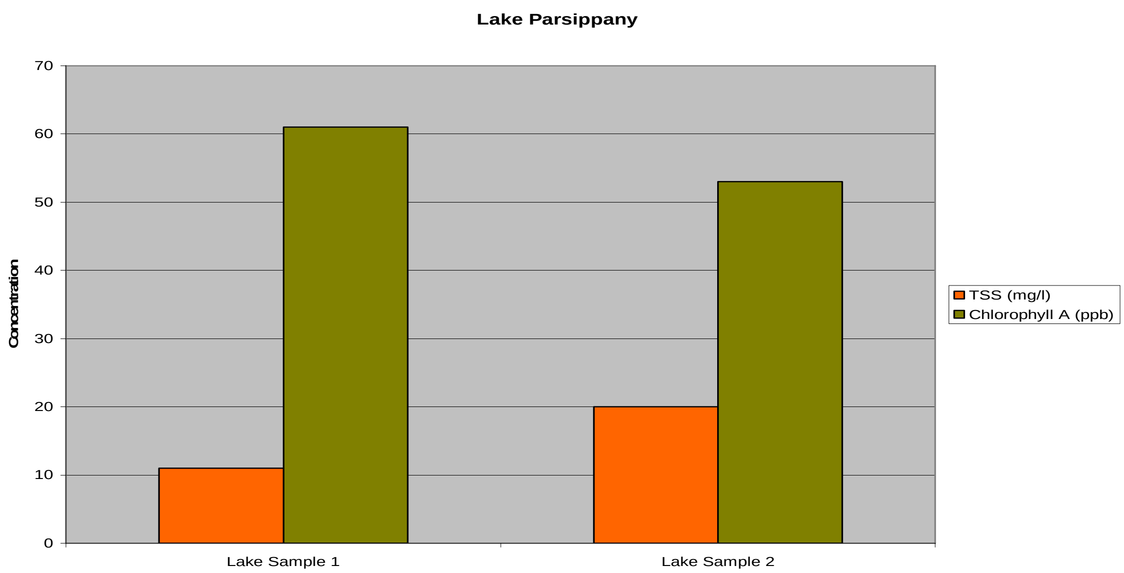


FIGURE 11: Lake Parsippany Total Suspended Solids and Chlorophyll A

See **Figure 2** and **Figure 11** above for Alkalinity and Chlorophyll A data. See **Figure 12** (below) for fecal coliform data. Please note that both lake samples collected met the NJDEP FW2 fecal coliform criteria (criteria stated earlier in the report).

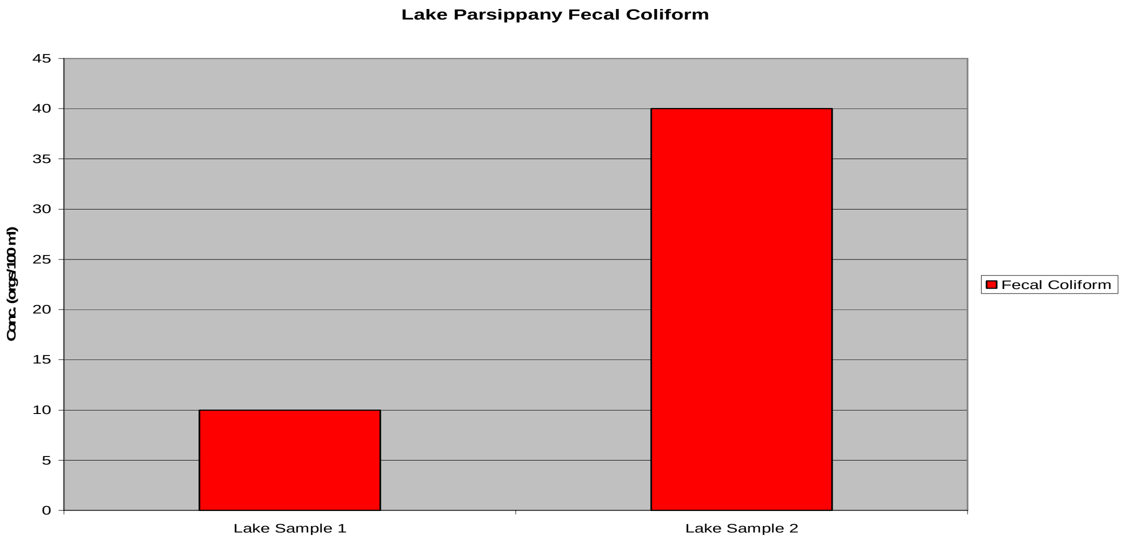


FIGURE 12: Lake Parsippany Fecal Coliform

Bee Meadow Pond (Pond 1) :

Samples collected on August 30, 2004, included lake epilimnion, hypolimnion and sediment samples, one inlet sample (discharge from Bee Meadow Pond 2) and one outlet sample (at Reynolds Avenue which discharges to West Brook). The secchi depth for the lake during sampling was 7 feet. Temperature of the lake epilimnion was 7.3 degrees C higher than the hypolimnion (27 degrees C and 19.7 C degrees respectively).

Dissolved oxygen **(Figure 13** below) and pH (**Figure 2** above) was lower in the hypolimnion (1.7 mg/l and 6.7 respectively) than the epilimnion (8.0 mg/l and 7.7 respectively). During the time of sampling, the lake epilimnion, inlet and outlet samples met the NJDEP dissolved oxygen criteria for FW2 Trout Maintenance (not less than 5.0 mg/l at any time) and FW2 Non Trout (not less than 4.0 mg/l at any time) classifications. The Lake hypolimnion sample did not meet FW2 dissolved oxygen criteria. The dissolved oxygen concentration in the hypolimion (1.7 mg/l) may pose a significant adverse risk to the lake's ecosystem. Bee Meadow Pond's hypolimnion (approximately 7 feet thick) is a relatively thick layer of anoxic water. The mean pond depth was 9.6 feet with a standard deviation of 4.7 feet and range of 2 to 17. The anoxic layer of water (hypolimnion) represents a significant quantity of water. As stated in Manahan "During the autumn, when the epilimnion cools, a point is reached at which the temperature of the epilimnion and hypolimnion are equal. This disappearance of thermal stratification causes the entire body of water to behave as a hydrological unit, and the resultant mixture is known as overturn. An overturn also generally occurs in the spring. During the overturn, the chemical and physical characteristics of the body of water become much more uniform, and a number of chemical, physical and biological changes may result. Biological activity may increase from the mixing of nutrients." During overturn, the anoxic hypolimnion of Bee Meadow Pond will mix with the epilimnion. If overturn occurs over a short period of time the dissolved oxygen level in the pond could drop quickly (below a critical level needed by the aquatic organisms) and possibly cause a fish kill. Bee Meadow Pond (Pond One) does have a history of both fish kills and planktonic algal blooms. Algal blooms were reported and investigated (by the Township of Hanover Health Department) on September 20, 1983, September 19, 1988, September 19, 1989 and September 19, 1990. A fish kill was more recently reported and investigated by the Township of Hanover Health Department on October 2, 2001. Copies of the above mentioned incident reports can be found in **Appendix C**. It is interesting to note that all these events occurred in the fall at a time which would coincide with the fall overturn. During the October 3, 2001 fish kill, water quality measurements were taken for temperature, DO, pH, conductivity and salinity. Approximately 100 fish (less than 7 inches long) were found dead along the bank of the first pond. Water quality measurements recorded (along the north-east shore of Pond One) on October 3, 2001, were as follows:

Time	Temperature (degree C)	DO (mg/l)	pH	Conductivity	Salinity (ppt)
9:50 AM	18.1	4.0	7.1	142.3	0.1
10:00 AM	18.4	3.7			
10:36 AM	15.6	2.7			

On October 4, 2001, a follow-up investigation was conducted. Live fish were observed from the shoreline (bluegills). Water quality measured on October 4th was as follows (same locations as first two measurements mentioned above):

Time	Temperature (degree C)	DO (mg/l)
9:35 AM	19.5	7.5
9:40 AM	19.1	5.2
9:45 AM	19.3	6.0

The occurrence of phytoplankton blooms in the fall may be due to an increase in nutrients from the hypolimnion (nitrogen and phosphorus) into the upper waters (limnetic zone) after turnover.

All surface water samples collected met the pH (6.5 to 8.5 standard units) criteria for FW2 classifications.

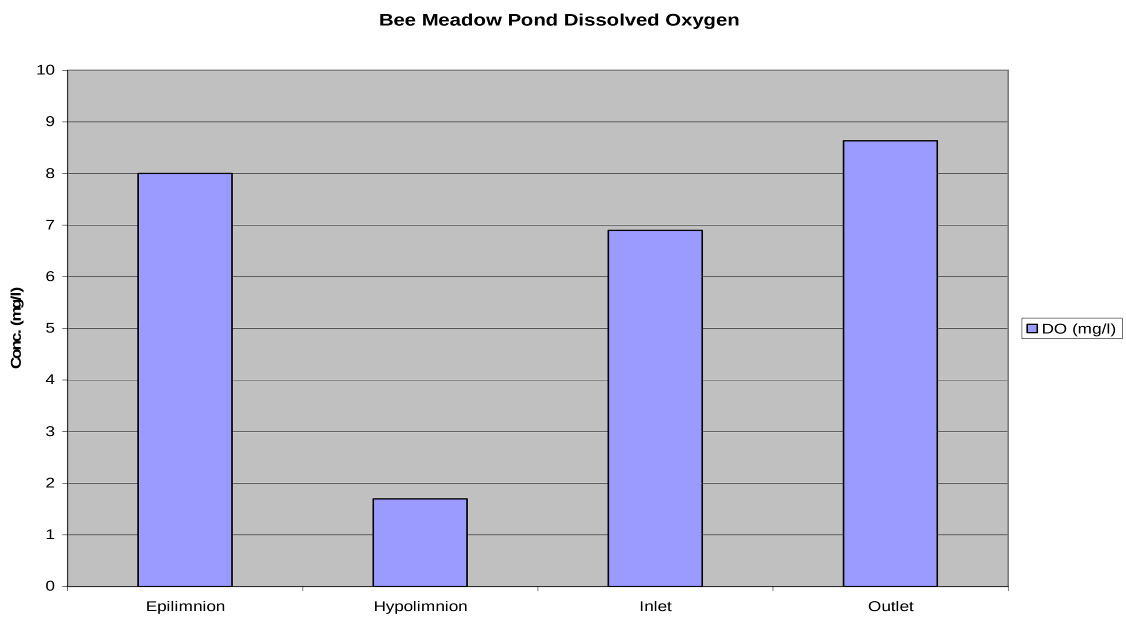


FIGURE 13 : Bee Meadow Pond Dissolved Oxygen

Total lake nitrogen (organic nitrogen, ammonia nitrogen, nitrite nitrogen and nitrate nitrogen) in the hypolimnion (<7.9 mg/l) was higher than in the epilimnion (<2.6 mg/l). Please refer to **Figure 14** below. In the epilimnion the organic nitrogen (2.14 mg/l) was the predominant form of nitrogen. In the hypolimnion the ammonia nitrogen (5.17 mg/l) was the predominant form of nitrogen. The lake sediments (**Figure 15** below) appear to be a significant source of Nitrogen. The total nitrogen concentration (organic nitrogen, ammonia nitrogen and nitrate nitrogen) in the sediment sample was 2,680.4 mg/kg dry weight with organic nitrogen (<2,414 mg/kg dry weight) being the predominant nitrogen species followed by NH3-N (186 mg/kg dry weight). All lake samples including inlet and outlet met the NJDEP NO3-N criteria of 10 mg/l for all FW2 waters.

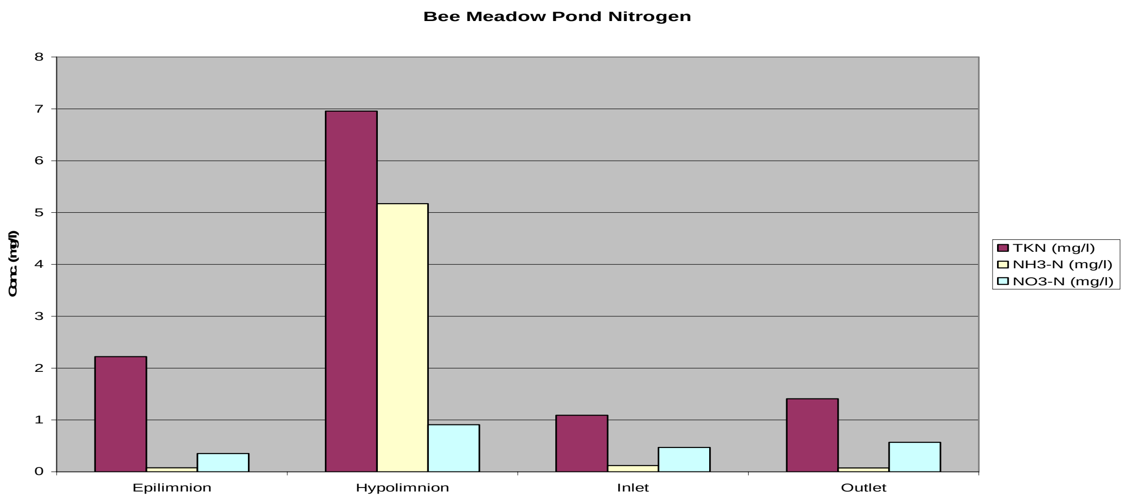


FIGURE 14 : Bee Meadow Pond Nitrogen

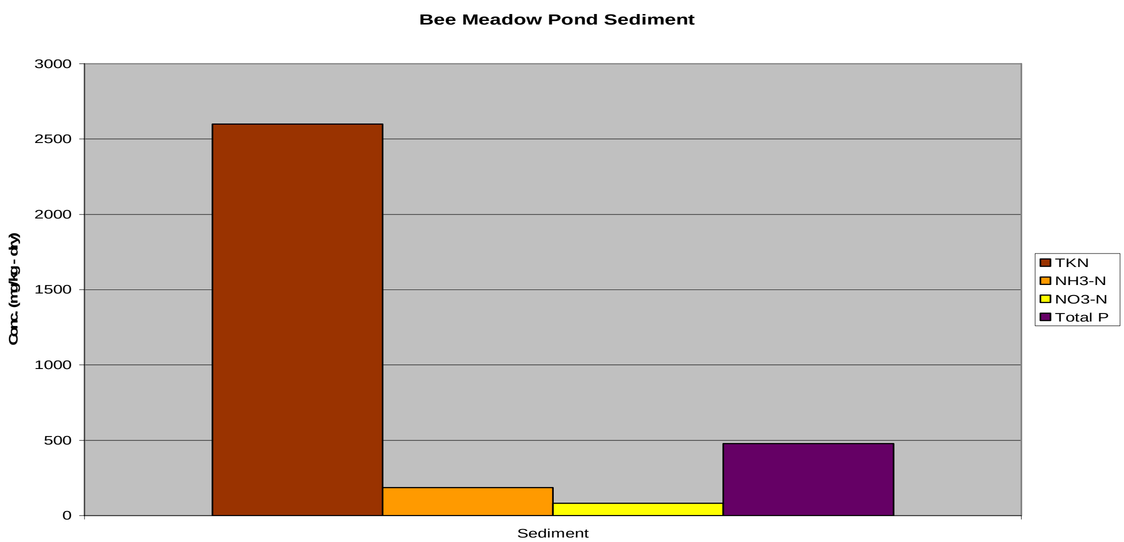


FIGURE 15: Bee Meadow Pond Sediments

Total phosphorus (**Figure 16** below) in the hypolimnium (0.78 mg/l) was much greater than the epilimnion concentration (0.03 mg/l). The lake sediments (**Figure 15** above) appear to be a significant source of total phosphorus. The total phosphorus concentration in the sediment sample was 478 mg/kg dry weight. The Ortho Phosphate concentration in the sediment was <20.1 mg/kg dry weight. Of all the water samples collected only the Lake hypolimnion sample (total phosphorus concentration of 0.78 mg/l) exceeded the NJDEP FW 2 total phosphorus criteria of 0.05 mg/l for lakes (and input to lakes). The Bee Meadow Pond outlet was discharging a total phosphorus concentration of 0.02 mg/l to West Brook.

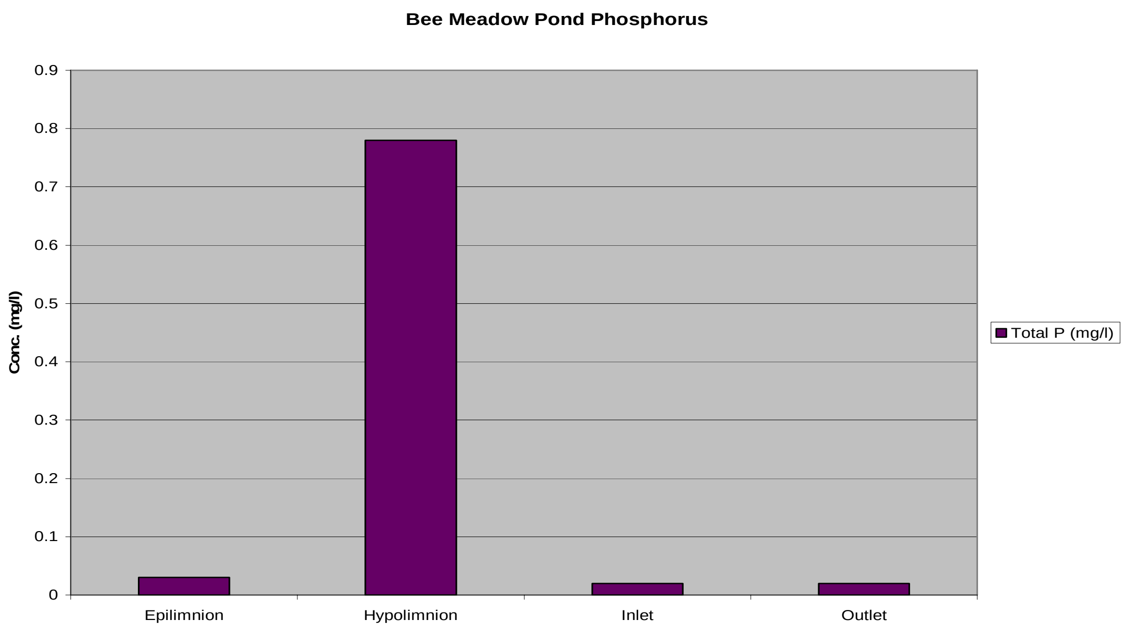


FIGURE 16: Bee Meadow Pond Total Phosphorus

Total suspended solids concentration (**Figure 17** below) in the hypolimnion was much higher than the epilimnion (70 mg/l and 1 mg/l respectively). The total dissolved solids concentration in the hypolimnion was slightly higher than the epilimnion (90 mg/l and 87 mg/l respectively). The epilimnion, inlet and outlet samples collected met the total suspended solids criteria (25 mg/l for FW2 TM) and total dissolved solids criteria (500 mg/l for all FW2 waters). The hypolimnion sample did not meet the total suspended solids criteria.

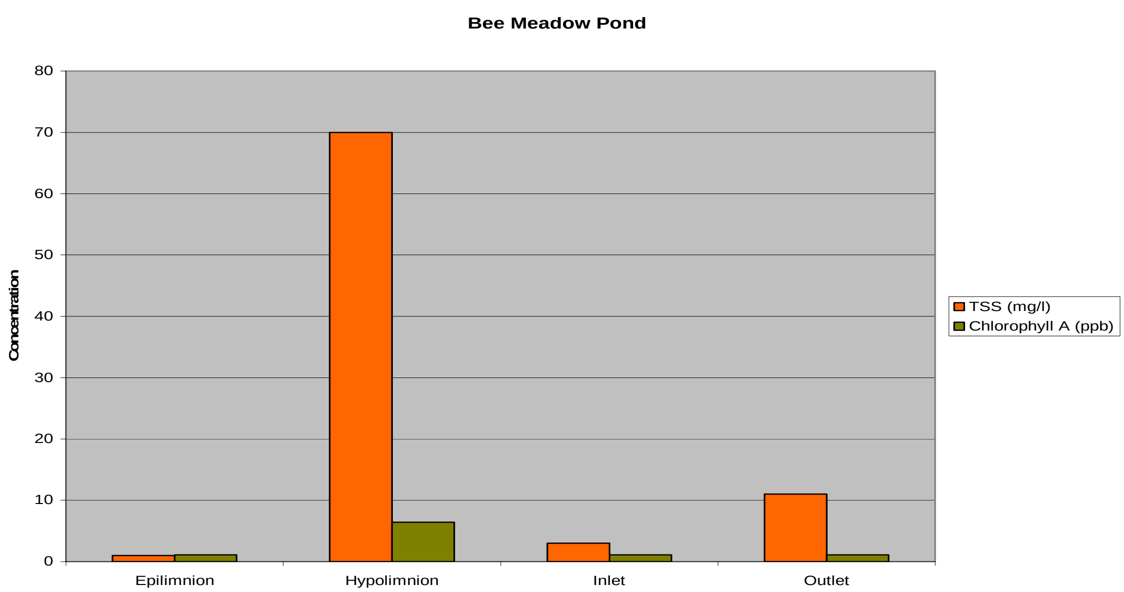


FIGURE 17: Bee Meadow Pond Total Suspended Solids and Chlorophyll A

See **Figure 2** and **Figure 17** above for Alkalinity and Chlorophyll A data. See **Figure 18** (below) for fecal coliform data. Please note that the fecal coliform standard for FW 2 waters (which include all surface waters sampled during this study) is as follows:

"Fecal coliform levels shall not exceed a geometric average of 200/100 ml nor should more than 10 percent of the total samples taken during any 30-day period exceed 400/100 ml."

Please note that both the inlet and outlet samples did not meet the NJDEP FW2 fecal coliform criteria.

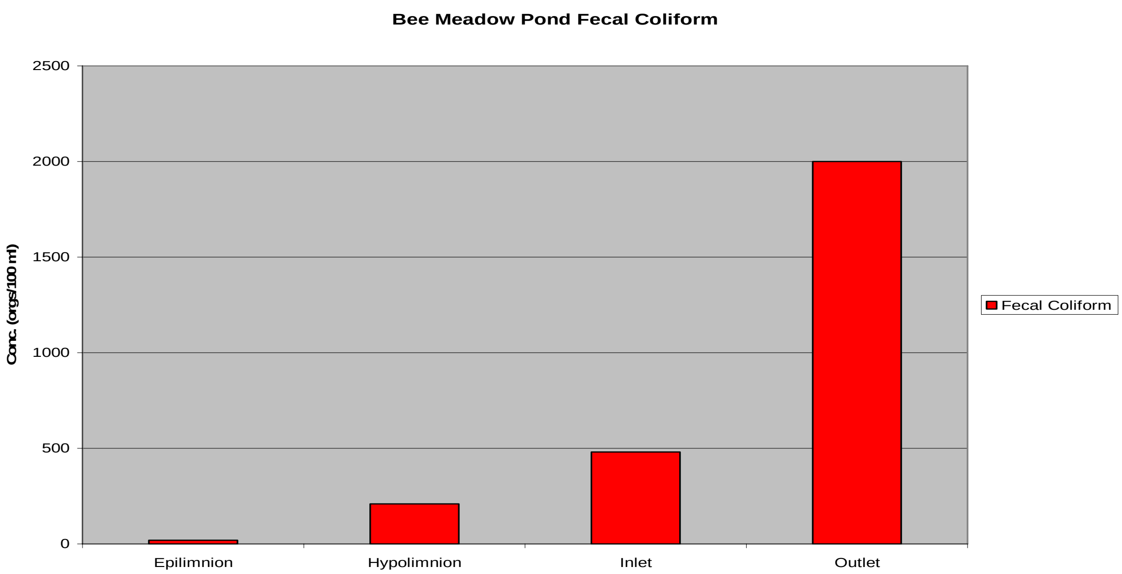


FIGURE 18 : Bee Meadow Pond Fecal Coliform

Speedwell Lake:

Samples collected on August 18, 2005, included lake water column (there was no thermal stratification), sediment, inlet (at Lake Road) and outlet (below Speedwell dam) samples. The secchi depth for the lake during sampling was greater than the lake depth. Temperature of the lake water column sample was 23.6 degrees C. Whippany River flow was 13 cubic feet per second as measured at the USGS gage at Morristown.

Dissolved oxygen **(Figure 19** below) and pH (**Figure 2** above) in the lake was 10.6 mg/l and 8.7 respectively. The elevated DO and pH were most likely due to the extensive amount of algal productivity (photosynthesis) occurring in the lake (time of sampling was 12:00PM, weather conditions were clear and sunny) during the time of sampling. During the time of sampling, all lake water, inlet and outlet samples collected met the NJDEP dissolved oxygen criteria for FW2 Trout Maintenance (not less than 5.0 mg/l at any time). Please note that the outlet sample was collected below Speedwell Dam. Results do reflect the effects of the dam with respect to dam reaeration. Lake inlet and outlet samples met the pH (6.5 to 8.5 standard units) criteria for FW2 TM and FW2 NT classifications. The pH of the lake sample was slightly more basic than the NJDEP criteria.

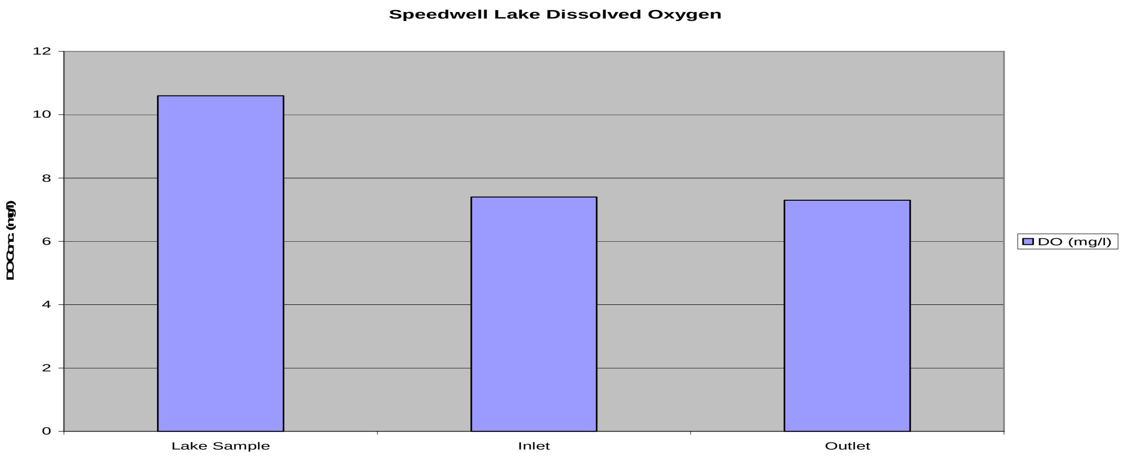


FIGURE 19 : Speedwell Lake Dissolved Oxygen

Total lake nitrogen (organic nitrogen, ammonia nitrogen, nitrite nitrogen and nitrate nitrogen) in the lake water column was 2.6 mg/l. Please refer to **Figure 20** below. In the lake water column, inlet and outlet samples the nitrate- nitrogen (1.63 mg/l, 3.94 mg/l and 2.23 mg/l respectively) was the predominant form of nitrogen. It is important to note that the Morris Township Butterworth Wastewater Treatment Plant discharges its effluent into the Whippany River approximately 0.3 miles upstream of this lake. Also, the Greystone State Hospital Wastewater Treatment Plant discharges to Watnong Brook which discharges to the Whippany River immediately upstream of Speedwell Lake (approximately 0.2 miles upstream of the Lake). The lake sediments (**Figure 21** below) appear to be a significant source of Nitrogen. The total nitrogen concentration (organic nitrogen, ammonia nitrogen and nitrate nitrogen) in the sediment sample was <1,824.9 mg/kg dry weight with organic nitrogen (1,759.8 mg/kg dry weight) being the predominant nitrogen species. All lake samples including inlets and outlet met the NJDEP NO3-N criteria of 10 mg/l for all FW2 waters.

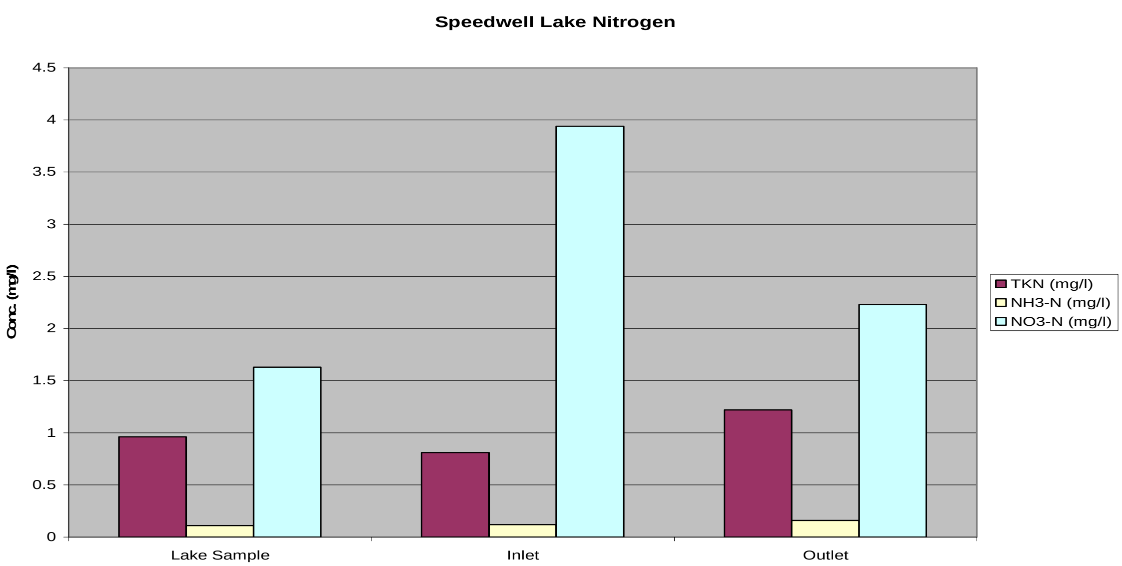


FIGURE 20: Speedwell Lake Nitrogen

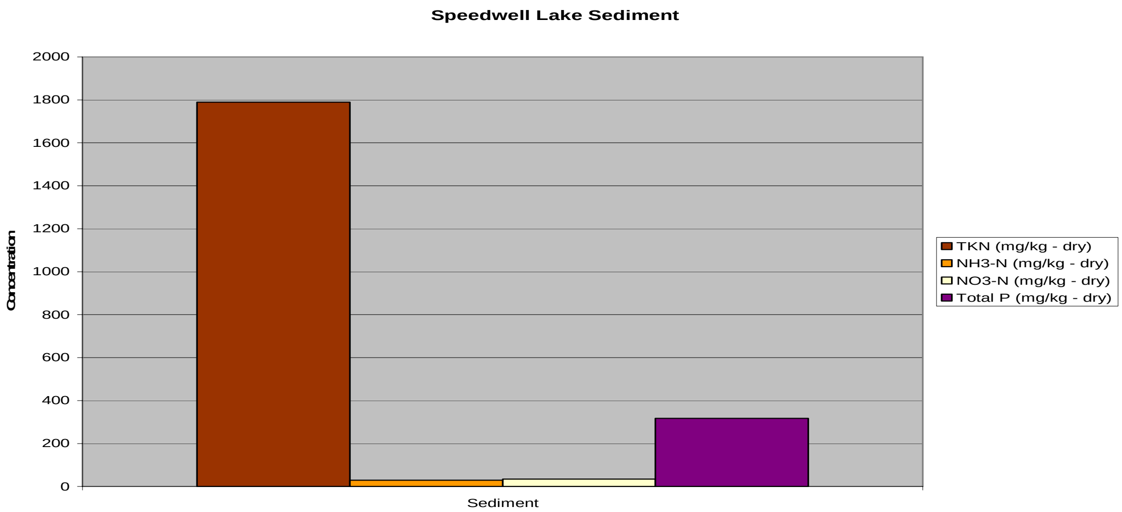


FIGURE 21: Speedwell Lake Sediments

Total phosphorus (**Figure 22** below) in the lake water column was 0.27 mg/l. The lake sediments (**Figure 21** above) appear to be a source of total phosphorus. The total phosphorus concentration in the sediment sample was 318 mg/kg dry weight. The lake inlet (Whippany River at Lake Road) appears to be a significant source of total phosphorus to the lake. Total phosphorus in the lake inlet was 1 mg/l. From historical data (dry weather data from Van Orden, 2003") the average dry weather total phosphorus and average dry weather nitrate nitrogen concentrations in the Whippany River at Lake Valley Road (which is approximately 0.4 miles upstream of the Lake) for the period from 2001 thru 2002 was 0.04 mg/l and 0.63 mg/l, respectively. Both the Morris Township Butterworth Wastewater Treatment Plant and the Greystone State Hospital Wastewater Treatment Plant are the only known point source discharges between Lake Valley Road and Lake Road (Speedwell Lake). The Butterworth Treatment Plant does, however, provide some phosphorus removal (Van Orden, 2003). This plant has a total phosphorus permit limit (NJPDES) of 2.3 mg/l. This plant normally discharges an average concentration which is < 1.0 mg/l. Neither of the above mentioned wastewater treatment plants perform denitrification (nitrogen removal). All of the water samples collected (lake water column, inlet and outlet) greatly exceeded the NJDEP FW 2 total phosphorus criteria of 0.05 mg/l for lakes (and inputs to lakes). The Speedwell Lake outlet was discharging a total phosphorus concentration of 0.37 mg/l. This shows a significant reduction in total phosphorus from lake inlet to outlet. This reduction could indicate that the extensive amount of plant growth in the lake may be removing phosphorus from the lake water column. It is important to note that the total phosphorus concentration in the Speedwell Lake sediment sample was the lowest when compared to the other lakes tested during this study. This could indicate a low rate of phosphorus sedimentation and/or high rate of phosphorus uptake from the sediments by attached aquatic plants. Also, please note that obtaining a sediment sample in Speedwell Lake was very difficult (due to the extensive amount of attached plant growth) and could have resulted in a sediment sample which was not representative of this system.

The ortho-phosphate concentrations in the lake water column, inlet and outlet samples were 0.24 mg/l, 1.07 mg/l and 0.33 mg/l, respectively. Therefore, most of the total phosphate detected was in the ortho-phosphate form (a generally soluble form more readily available to plants).

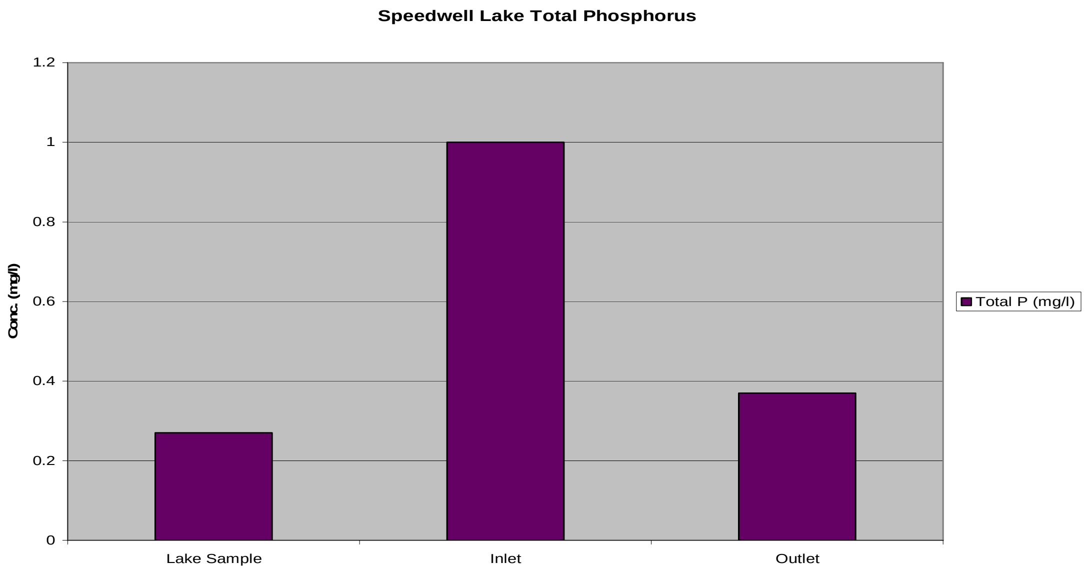


FIGURE 22 : Speedwell Lake Phosphorus

Total suspended solids concentration (**Figure 23** below) in the lake water column was 1 mg/l. The total dissolved solids concentration in the lake water column was 317 mg/l. All water samples collected (lake sample, inlet sample and outlet sample) met the total suspended solids criteria (25 mg/l for FW2 TM) and total dissolved solids criteria (500 mg/l for all FW2 waters).

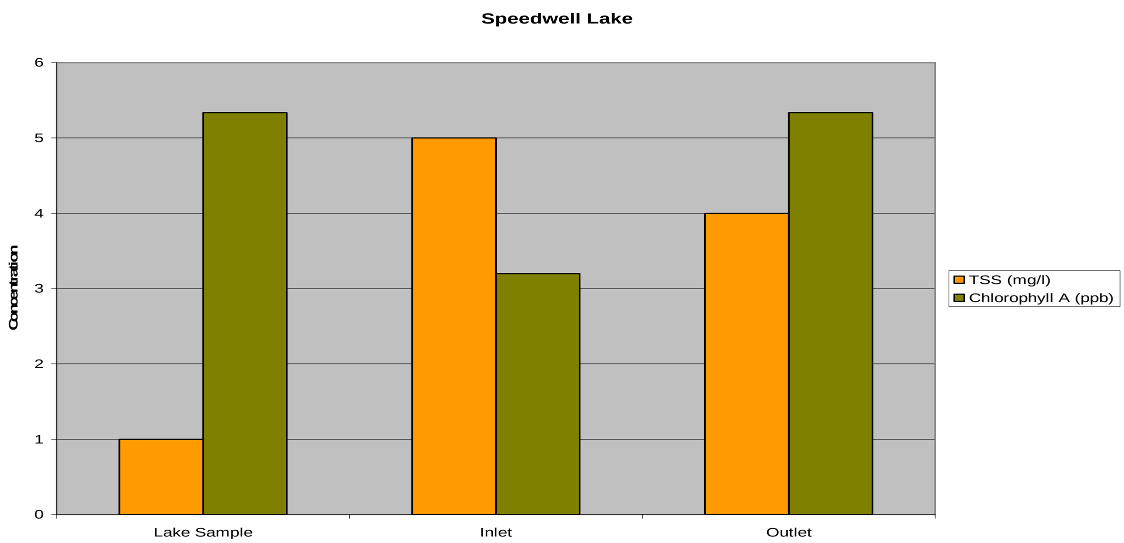


FIGURE 23 : Speedwell Lake Total Suspended Solids and Chlorophyll A

See **Figure 2** and **Figure23** above for Alkalinity and Chlorophyll A data. The chlorophyll A concentration reported above only reflects the phytoplankton chlorophyll A concentration in the water column. It is not a measure of the attached growth chlorophyll A. It is important to note that macrophytes are the dominant form of plant life in Speedwell Lake. Speedwell Lake is very shallow. The algal density (as determined through visual observation of the attached macrophytes) was significantly greater in Speedwell Lake when compared to the other lakes in this study. Dense attached growth was observed in at least 95% of the lake bottom. The attached growth (mostly filamentous) was so dense it was extremely difficult to obtain a sediment sample. See **Figure 24** (below) for fecal coliform data. Please note that all water samples collected (lake, inlet and outlet) met the FW2 fecal coliform criteria.

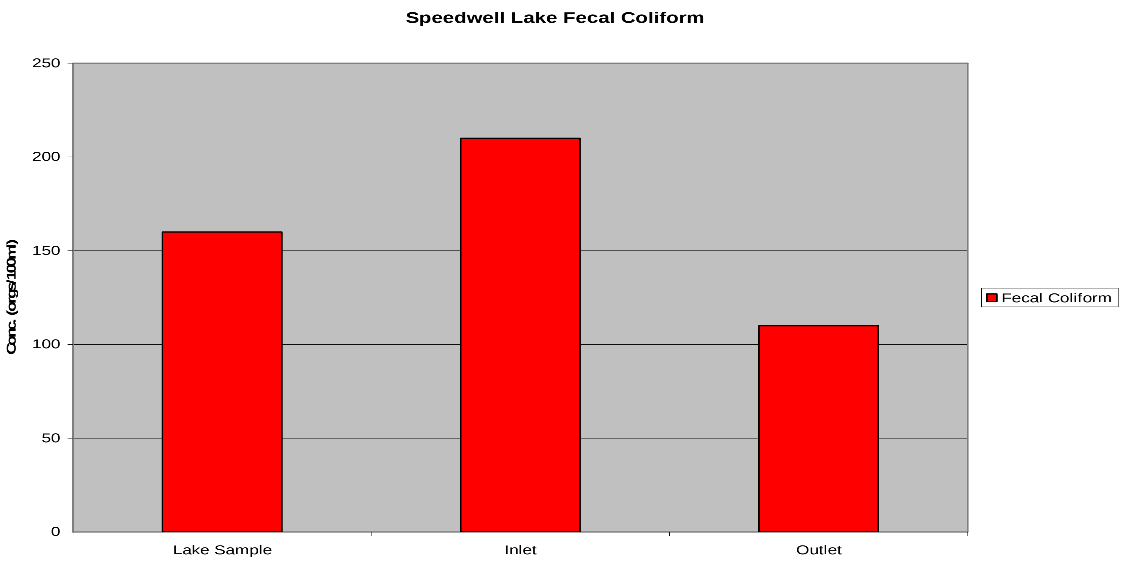


FIGURE 24: Speedwell Lake Fecal Coliform

Sunrise Lake :

Samples collected on August 20, 2003, included lake epilimnion, hypolimnion and sediment samples, two inlet samples and one outlet sample. The secchi depth for the lake during sampling was 6 feet. Temperature of the lake epilimnion was 5.8 degrees C higher than the hypolimnion (27.8 degrees C and 22.0 C degrees respectively). Thermal stratification was observed at Sunrise Lake. Dissolved oxygen conditions in the hypolimnion were similar to those observed in the Bee Meadow Pond hypolimnion. However, the nutrient concentration (nitrogen and phosphorus) found in the Sunrise Lake hypolimnion was significantly less than the nutrient concentration found in the Bee Meadow hypolimnion. Turnover, as discussed in Bee Meadow Pond above, is a concern with respect to dissolved oxygen. However, the potential for either a fish kill (do to lake of dissolved oxygen) or phytoplankton bloom (do to increase of nutrients from the hypolimnion) is not as great in Sunrise Lake when compared to Bee Meadow Pond. The hypolimnion in Sunrise Lake is less than 2.25 feet in thickness (mean lake depth was 5.4 feet with a standard deviation of 2.0 feet and range of 2 to 9 feet) and represents a much small percent of the total lake volume when compared to Bee Meadow Pond's hypolimnion.

Dissolved oxygen **(Figure 25** below) and pH (**Figure 2** below) was lower in the hypolimnion (1.6 mg/l and 6.8 respectively) than the epilimnion (9.2 mg/l and 8.5 respectively). During the time of sampling, the lake epilimnion, inlets and the outlet samples met the NJDEP dissolved oxygen criteria for FW2 Trout Maintenance (not less than 5.0 mg/l at any time). The lake hypolimnion sample did not meet the NJDEP dissolved oxygen criteria for FW 2 waters. All surface water samples collected met the pH (6.5 to 8.5 standard units) criteria for FW2 waters.

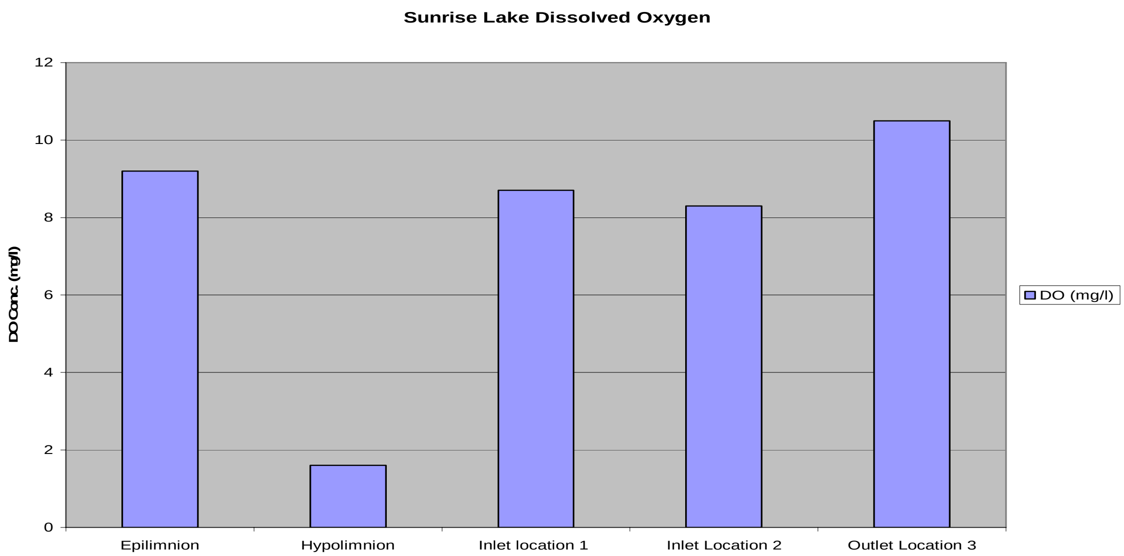


FIGURE 25 : Sunrise Lake Dissolved Oxygen

Total lake nitrogen (organic nitrogen, ammonia nitrogen, nitrite nitrogen and nitrate nitrogen) in the hypolimnion (1.85 mg/l) was slightly higher than in the epilimnion (<1.03 mg/l). Please refer to **Figure 26** below. In both the epilimnion and hypolimnion , the organic nitrogen (<0.74 mg/l and 1.33 mg/l respectively) was the predominant form of nitrogen. Organic nitrogen was calculated as the difference between Total Kjeldahl Nitrogen (TKN) and Ammonia Nitrogen (NH3-N). The lake sediments (**Figure 27** below) appear to be a significant source of Nitrogen. The total nitrogen concentration (organic nitrogen, ammonia nitrogen and nitrate nitrogen) in the sediment sample was <9,155 mg/kg dry weight with organic nitrogen (<8,925 mg/kg dry weight) being the predominant nitrogen species followed by NH3-N (125 mg/kg dry weight). Of the inputs sampled, Lake input 1 had a total nitrogen concentration of <1.33 mg/l and lake input 2 had a total nitrogen input of <0.96 mg/l. All lake samples including inlets and outlet met the NJDEP NO3-N criteria of 10 mg/l for all FW2 waters.

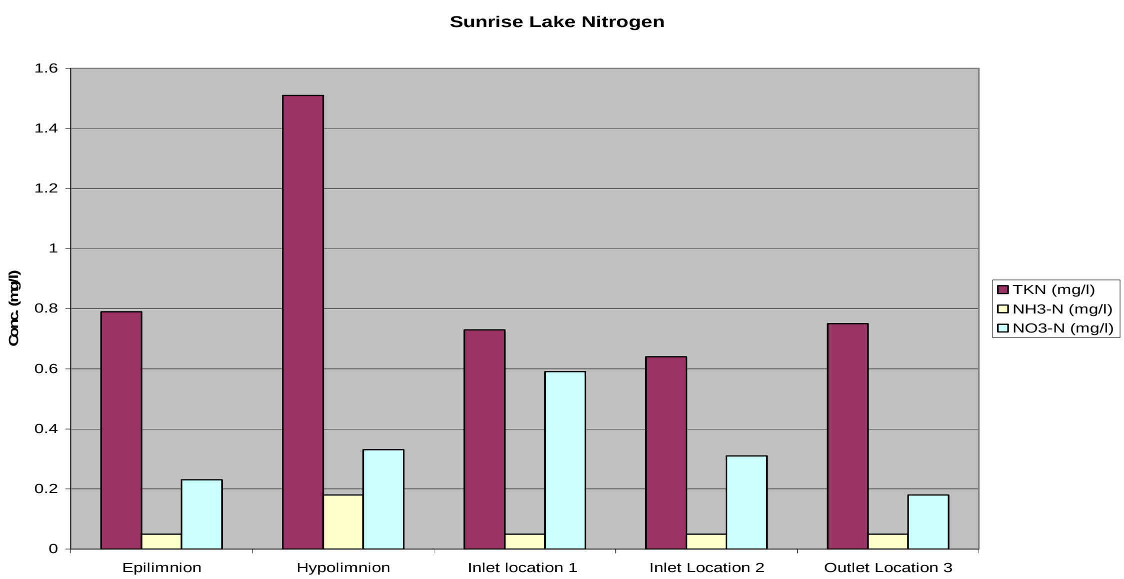


FIGURE 26 : Sunrise Lake Nitrogen

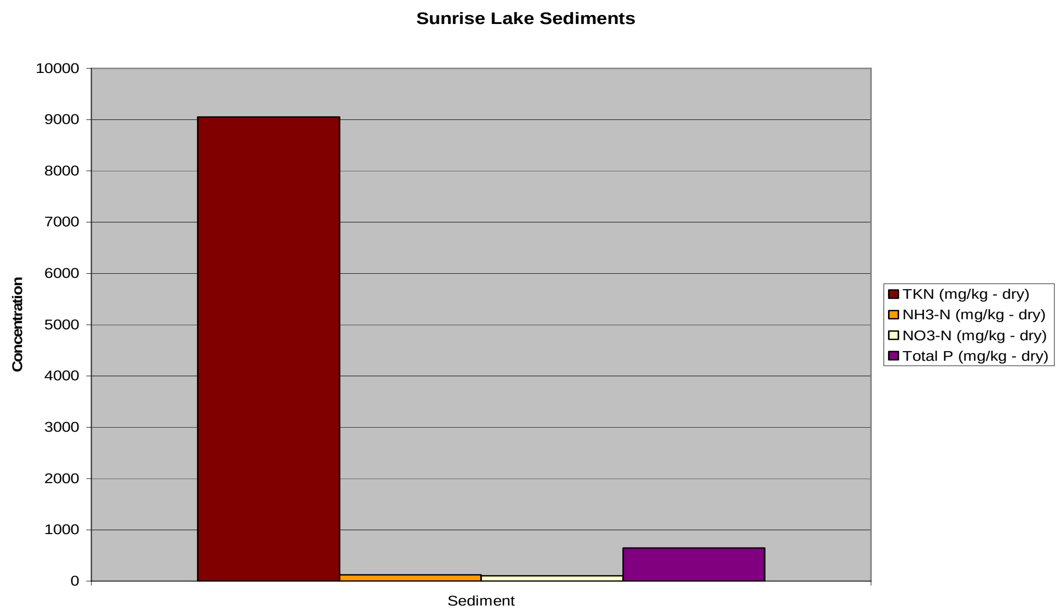


FIGURE 27: Sunrise Lake Sediments

Total phosphorus (**Figure 28** below) in the hypolimnium (0.03 mg/l) was slightly higher than the epilimnion concentration (0.02 mg/l). The lake sediments (**Figure 27** above) appear to be a significant source of total phosphorus. The total phosphorus concentration in the sediment sample was 642 mg/kg dry weight. The Ortho Phosphate concentration in the sediment was 161 mg/kg dry weight. All of the water samples collected met the NJDEP FW 2 total phosphorus criteria of 0.05 mg/l for lakes (and input to lakes). The Sunrise Lake outlet was discharging a total phosphorus concentration of 0.02 mg/l to the Whippany River.

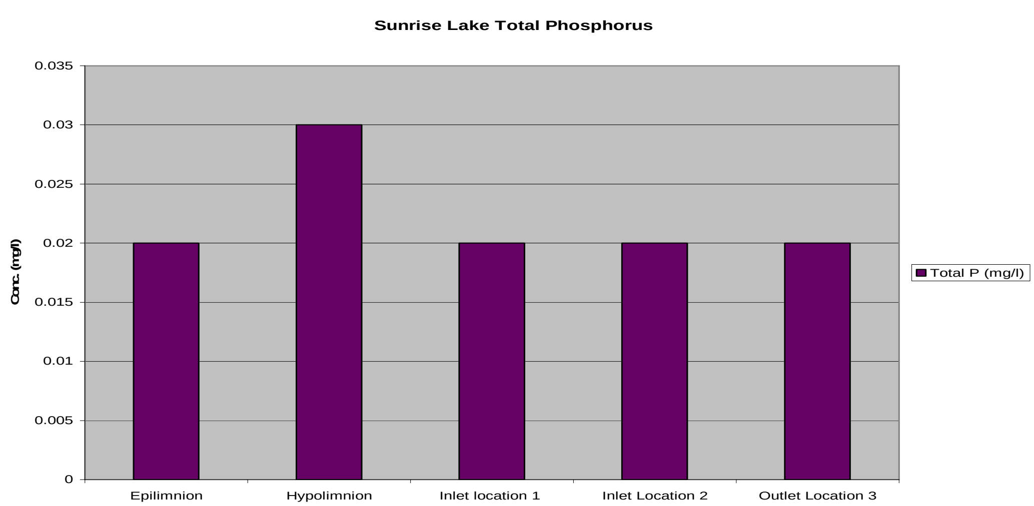


FIGURE 28: Sunrise Lake Total Phosphorus

Total suspended solids concentration (**Figure 29** below) in the hypolimnion was slightly higher than the epilimnion (6 mg/l and 4 mg/l respectively). Regarding the total dissolved solids, however, the reverse was true. The total dissolved solids concentration in the epilimnion was higher than the hypolimnion (80 mg/l and 62 mg/l respectively). All water samples collected (lake samples, inlet samples and outlet sample) met the total suspended solids criteria (25 mg/l for FW2 TM) and total dissolved solids criteria (500 mg/l for all FW2 waters).

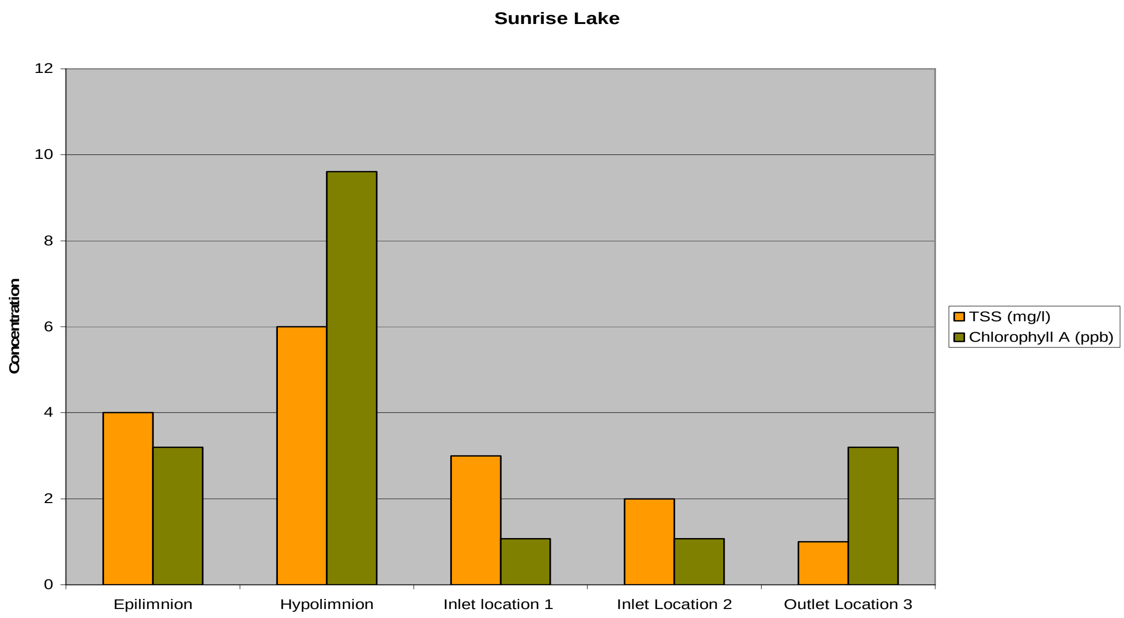


FIGURE 29 : Sunrise Lake Total Suspended Solids and Chlorophyll A

See **Figure 2** and **Figure 29** above for Alkalinity and Chlorophyll A data. See **Figure 30** (below) for fecal coliform data.

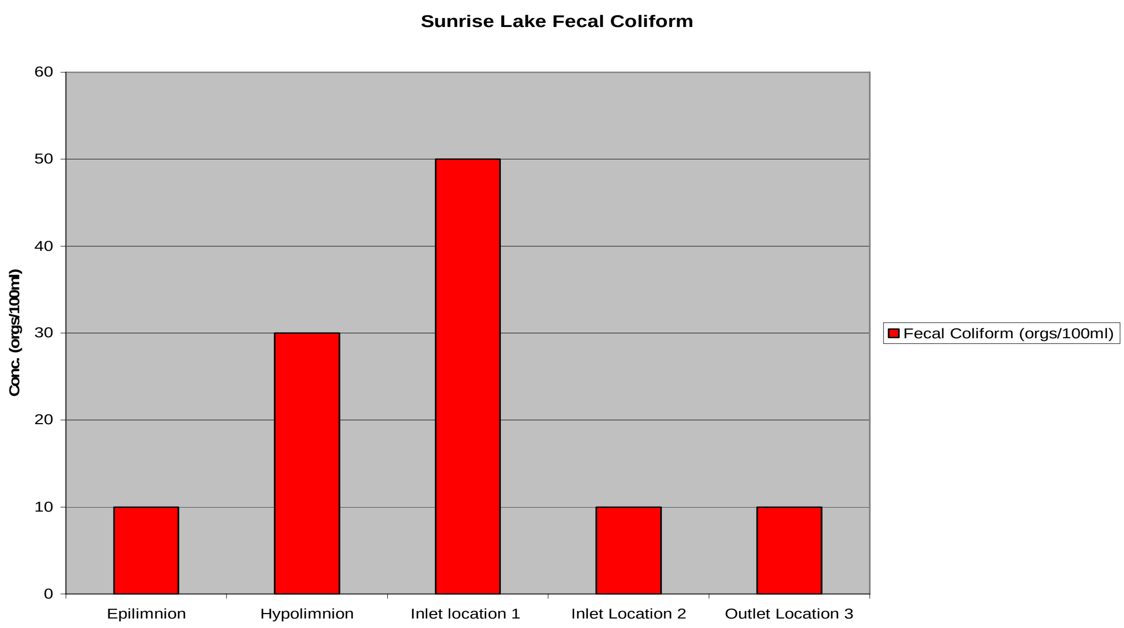


FIGURE 30: Sunrise Lake Fecal Coliform

Please note that all samples collected did meet the NJDEP FW2 fecal coliform criteria.

Comparison Of Lakes (Data) In Study

The following graphs were constructed in an effort to show a comparisons of all lakes studied with respect to the selected parameters:

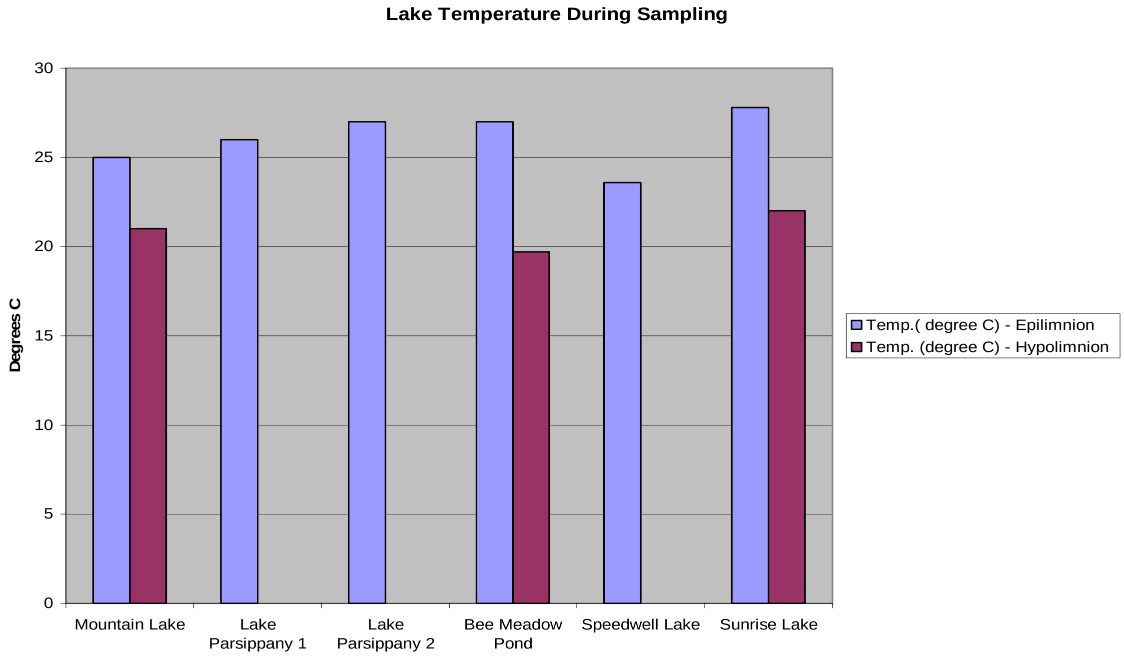


FIGURE 31: l: Lake Temperature

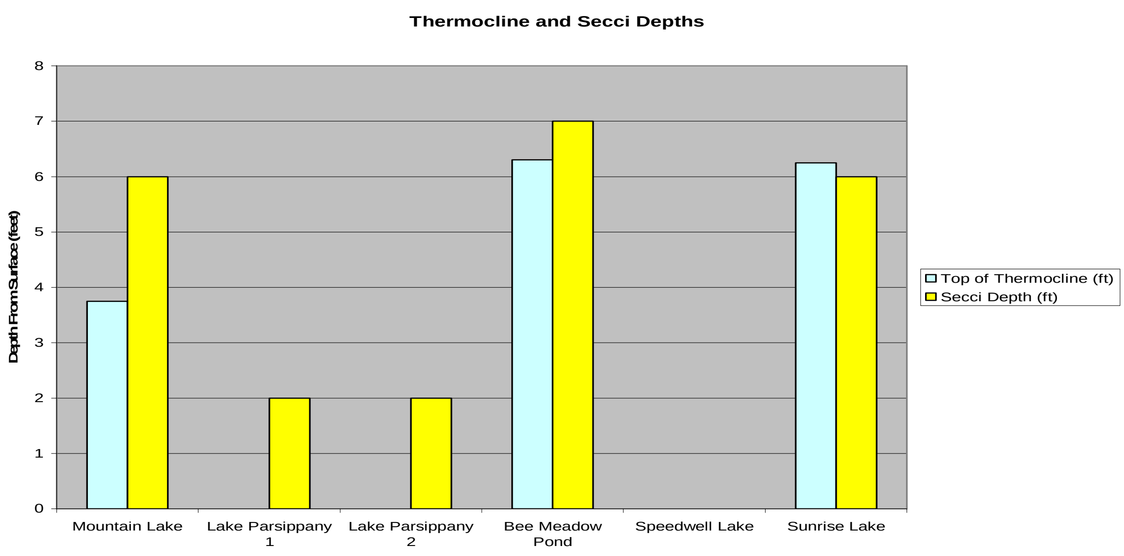


FIGURE 32: Lake Thermocline and Secchi Depths

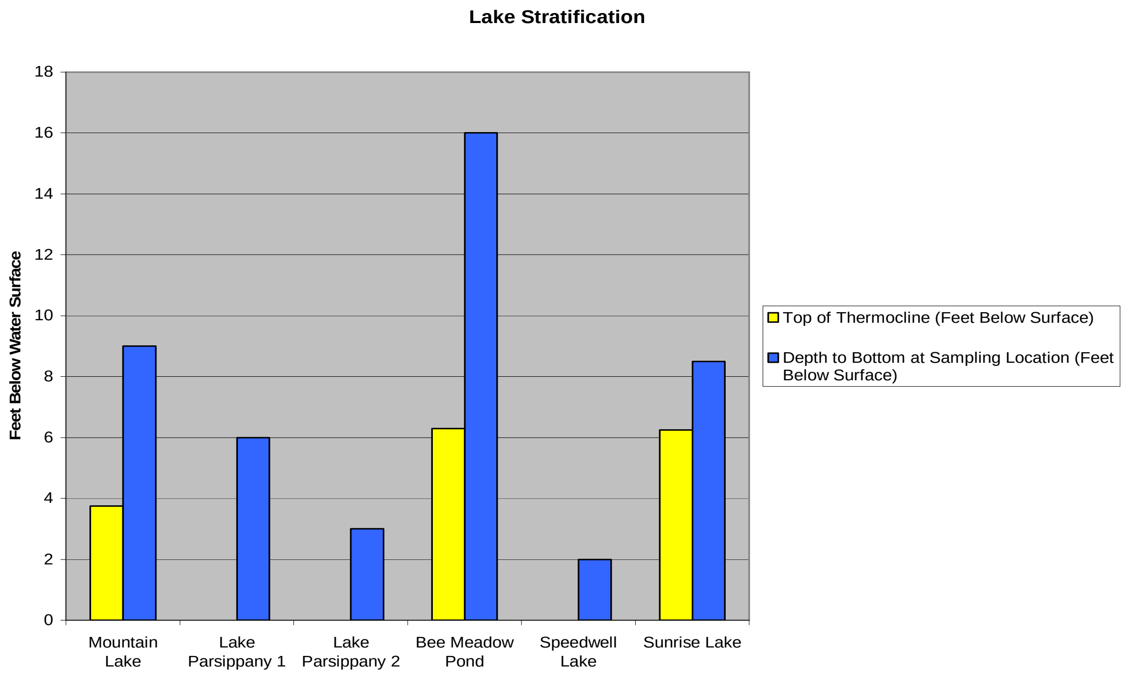


FIGURE 33: Lake Depth to Bottom and Depth to Thermocline

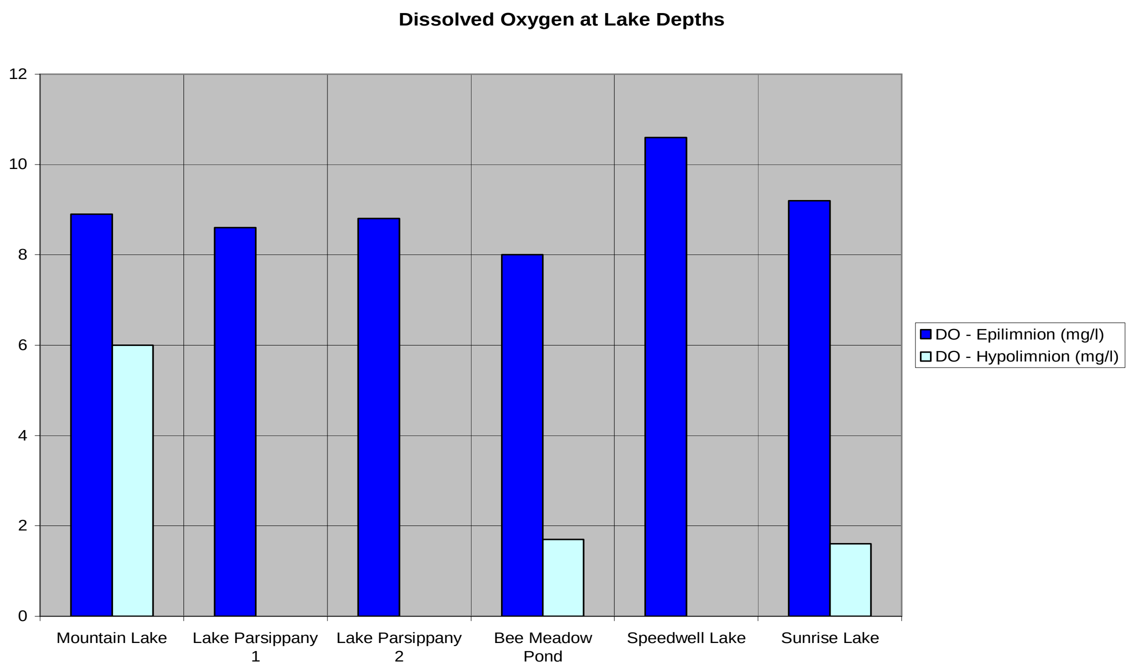


FIGURE 34: Lake Dissolved Oxygen

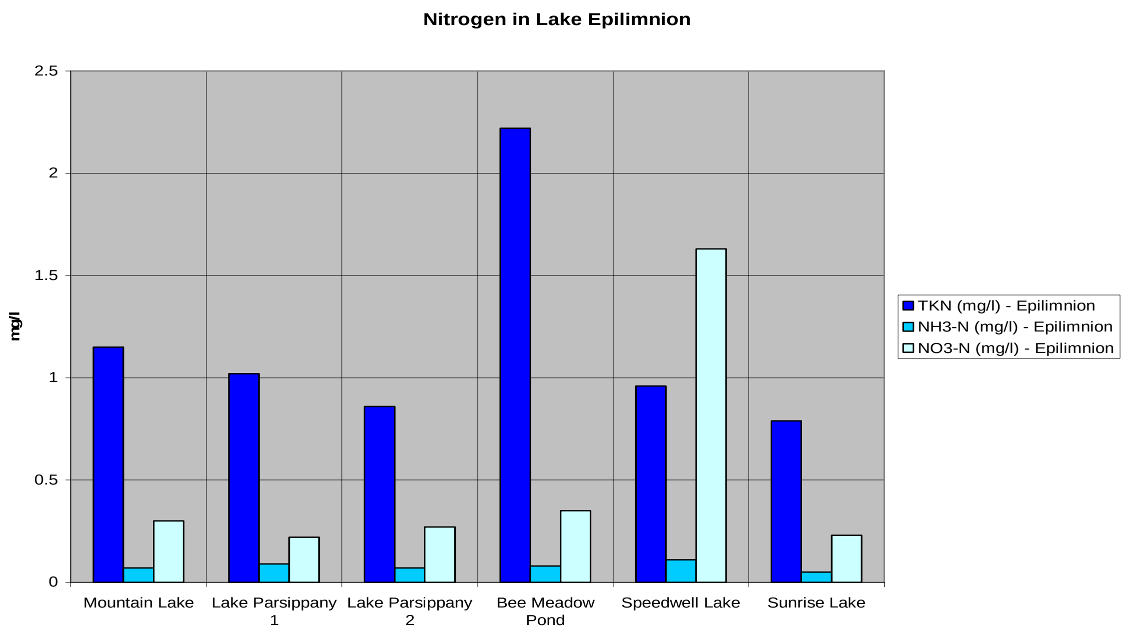


FIGURE 35: Lake Nitrogen –Epilimnion

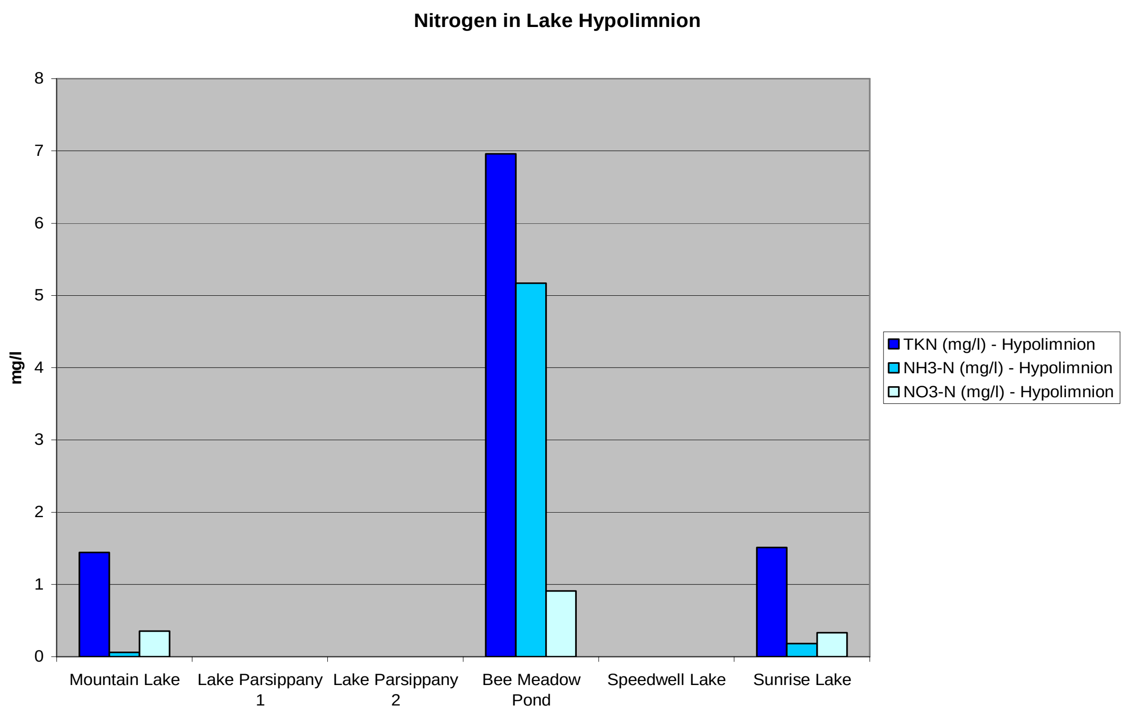


Figure 36: Lake Nitrogen - Hypolimnion

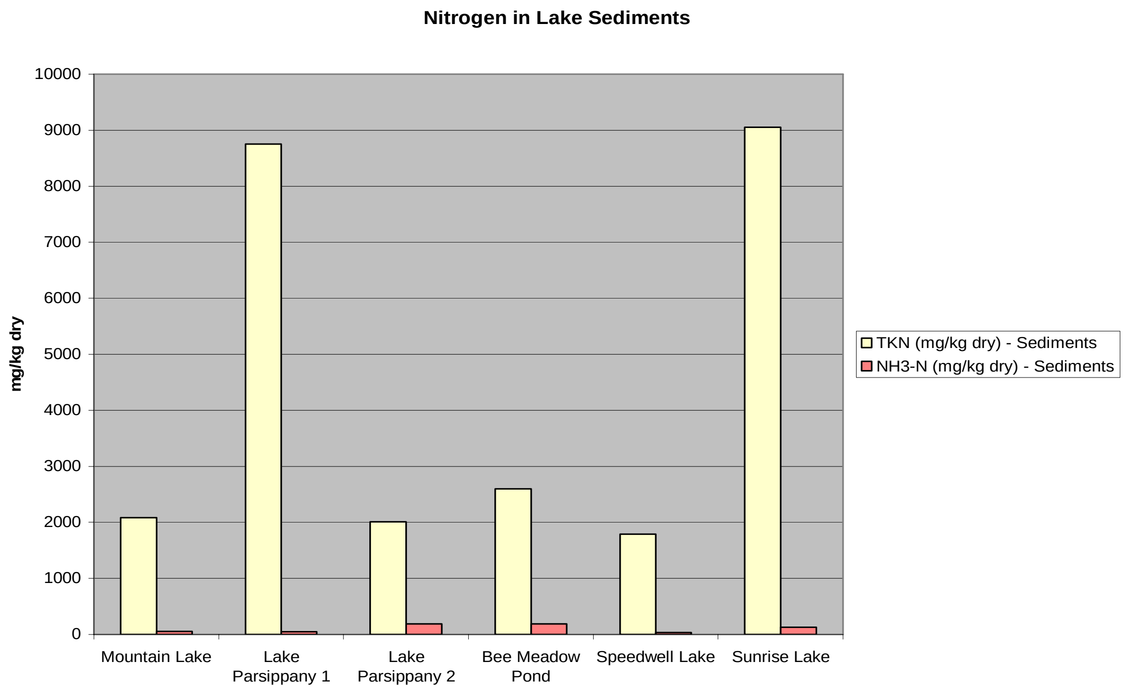


FIGURE 37: Lake Nitrogen - Sediments

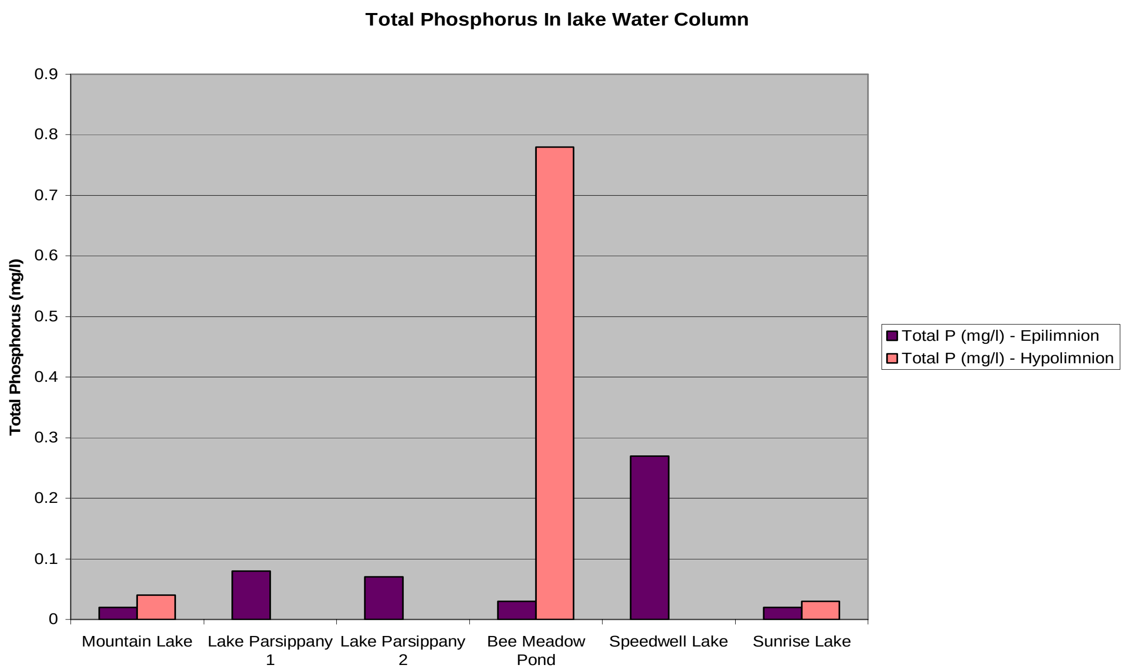


FIGURE 38: Lake Phosphorus – Water Column

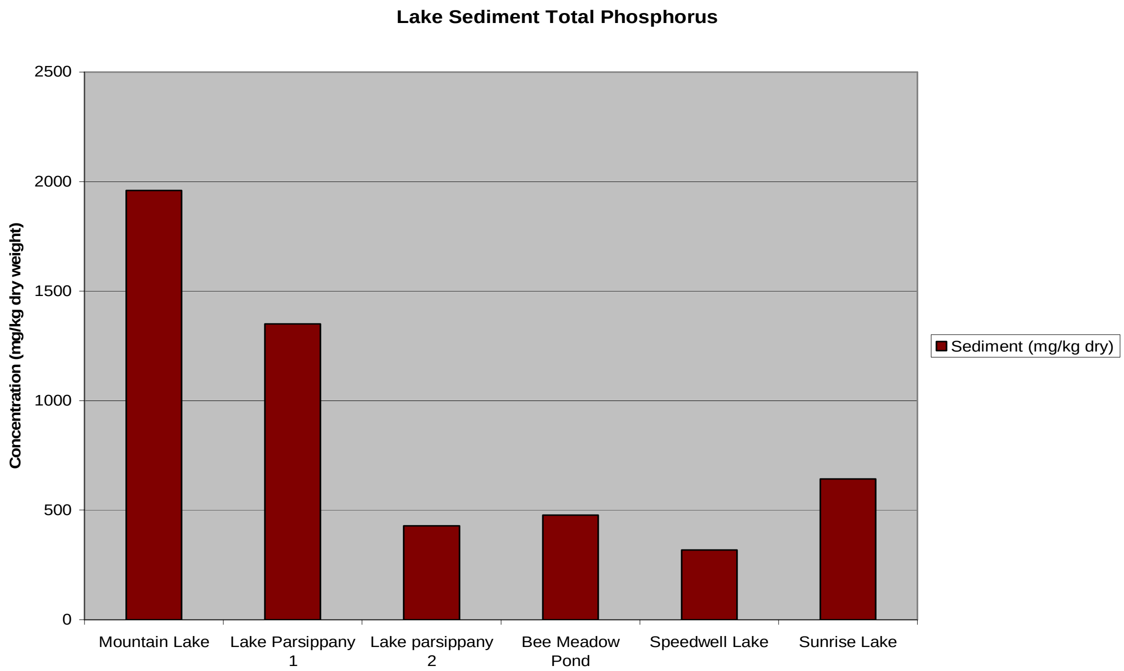


FIGURE 39 : Lake Phosphorus – Sediments

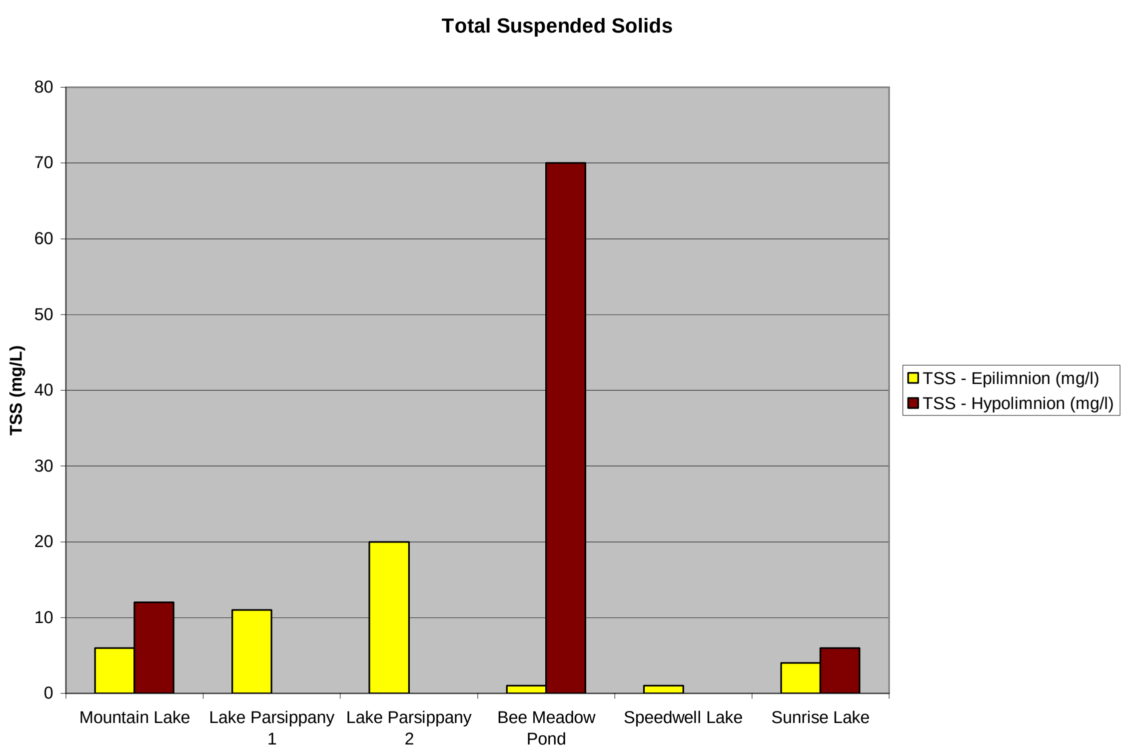


FIGURE : Lake Total Suspended Solids

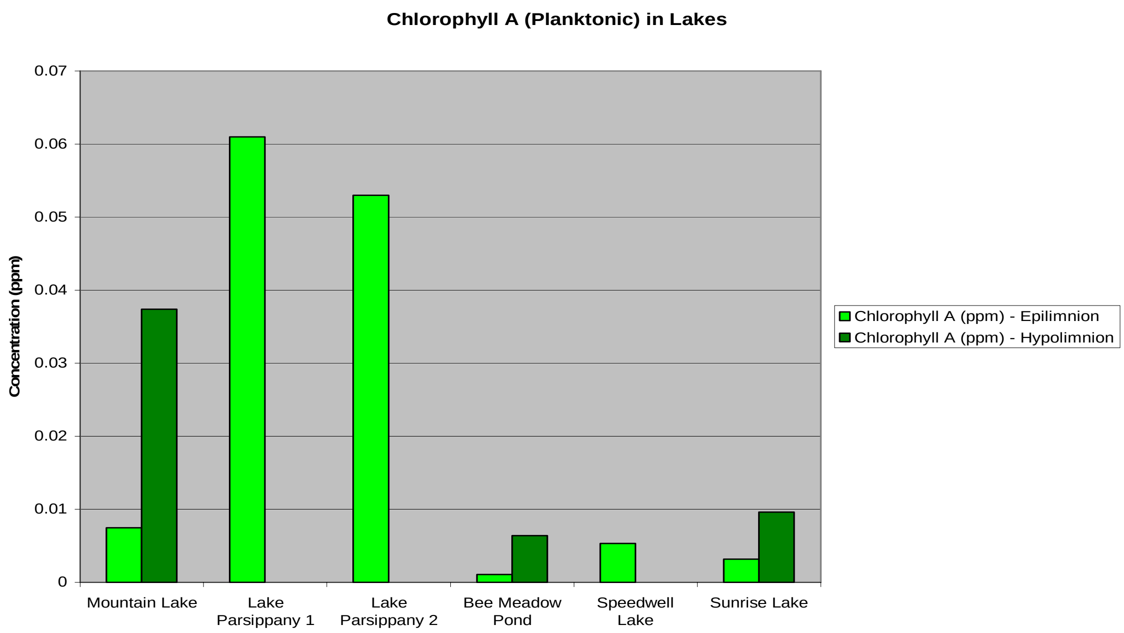


FIGURE 41: Lake Phytoplankton Chlorophyll A

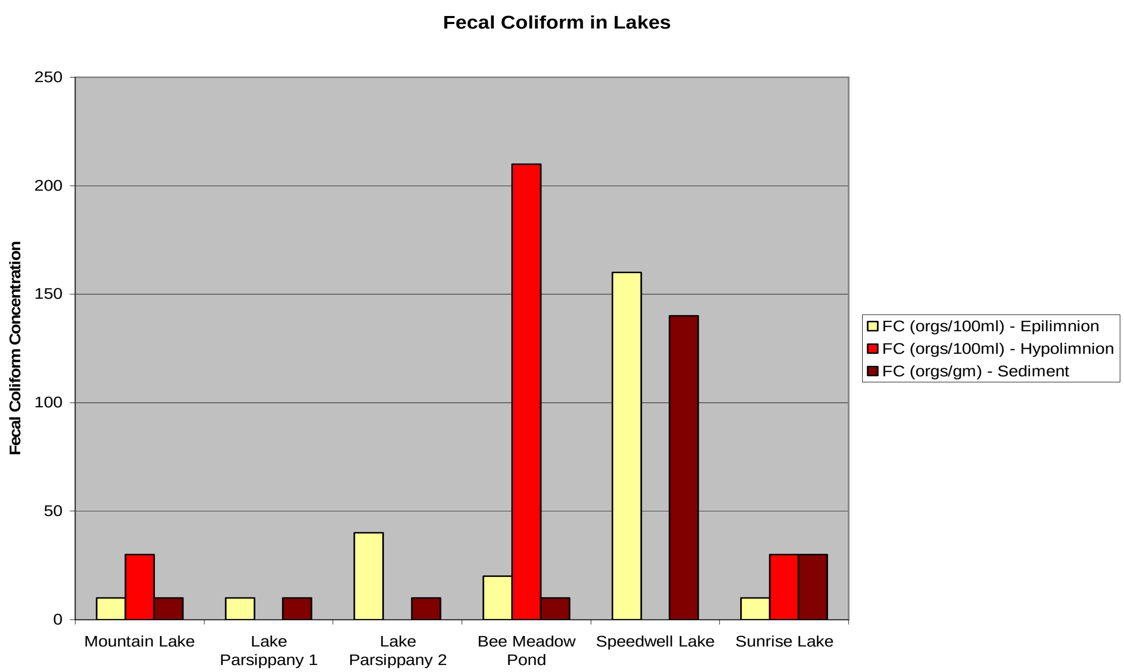


FIGURE 42: Lake Fecal Coliform

CONCLUSION/RECOMMENDTIONS

During dry weather conditions, Mountain Lake and Sunrise Lake met the NJDEP FW2 criteria for fecal coliform, pH, Nitrate nitrogen, total suspended solids and total phosphorus. Lake Parsippany did not meet the pH and total phosphorus criteria. Bee Meadow Pond's hypolimnion did not meet the total suspended solids and total phosphorus criteria. Speedwell Lake did not meet the pH and total phosphorus criteria. All lakes met the NJDEP FW2 total dissolved solids criteria. The NJDEP dissolved oxygen criteria for FW2 trout maintenance (24 hour average not less than 6.0 mg/l and not less than 5.0 mg/l at any time) was met for the lakes which did not show thermal stratification (Lake Parsippany and Speedwell Lake). Dissolved oxygen compliance was based on the " 5.0 mg/l at any time" criteria since DO measurements were taken only at the time of sampling and a daily average, over a 24 hour period, could not be calculated. Of the lakes which stratified (Mountain Lake, Bee Meadow Pond and Sunrise Lake), all epilimnion samples met the above mentioned DO criteria. The hypolimnions of Bee Meadow Pond and Sunrise Lake did not meet the NJDEP criteria for DO. The hypolimnion of Mountain Lake did meet this criteria. However, it is important to note that DO measurements of the stratified lakes were taken during different times of the year. Both Sunrise Lake and Bee Meadow Pond DO measurements were taken during a late summer (August) month while Mountain Lake was measured during a late spring (early June) month. During the time of stratification (spring, early summer) the DO in the hypolimnion would be relatively high and should be similar to the DO in the epilimnion. As time progresses (from early summer to late summer or fall) the DO in the hypolimnion is expected to decrease. Using this rational, the assumption can be made that the DO measured in the Mountain lake hypolimnion reflects a DO level immediately after stratification and that DO would decrease over time and eventually approach that which was observed in both the Bee Meadow Pond and Sunrise Lake hypolimnions (< 2.0 mg/l) when measured in late summer (August).

With respect to nutrients (nitrogen and phosphorus), the highest concentration of total nitrogen (in water column) was found in the Bee Meadow Pond hypolimnion (7.9mg/l total nitrogen) followed by the Speedwell Lake (2.6 mg/l total nitrogen). Water column total nitrogen (for all lakes studied) ranged from 1.0 mg/l (Sunrise Lake epilimnion) to 7.9 mg/l (Bee Meadow Pond hypolimnion). The average total nitrogen concentration was 2.4 mg/l with a standard deviation of 2.1 mg/l. Organic nitrogen was the predominant form of nitrogen in most water column samples with the exception of Bee Meadow Pond's hypolimnion where ammonia nitrogen is the predominant form of nitrogen. The Bee Meadow Pond epilimnion sample had the highest concentration of organic nitrogen at 2.14 mg/l. Bee Meadow Pond had the highest ammonia nitrogen concentration (5.17 mg/l NH_3-N in the hypolimnion). The level of ammonia nitrogen found in the Bee Meadow Pond hypolimnion can potentially have a toxic effect on the aquatic life (after overturn). The NJDEP FW2 trout maintenance criteria (toxic substances) for ammonia nitrogen was calculated (acute aquatic life protection as a three hour average for a temperature of 19.7 degrees C and pH of 7.1) as 0.09 mg/l (un-ionized). The temperature used in the calculation was 19.7 degrees C which was the hypolimnion temperature during sampling and represents the epilimnion (and lake water column) temperature which must be reached for overturn to occur. The pH used in the calculation was 7.1 which represent the pH after overturn (this was the pH observed in 2001 during the Bee Meadow Pond fish kill where the assumption was made that the fish kill occurred after an overturn event in early October). The ammonia nitrogen concentration observed in the Bee Meadow Pond hypolimnion greatly exceeds this "toxic effect" criteria. Bee Meadow Pond is the only water body in this study which showed the potential for a toxic event associated with ammonia nitrogen.

The highest concentration of total nitrogen in lake sediment was found in Sunrise Lake (9,155 mg/kg dry weight) followed by Lake Parsippany – sample location 1 (8,889 mg/kg dry weight). Total nitrogen in lake sediment (for all lakes) ranged from 1,825 mg/kg dry weight (Speedwell Lake) to 9,155 mg/kg dry weight (Sunrise Lake) with a mean lake sediment concentration of 4,489 mg/kg dry weight and standard deviation of 3,524 mg/kg dry weight. Organic nitrogen was the predominant form of nitrogen in lake sediments.

Two of the five lakes studied (Mountain Lake and Sunrise Lake) met the NJDEP FW2 criteria for total phosphorus in lakes (0.05 mg/l as P). The lowest concentration of water column total phosphorus was found in the epilimnions of both Mountain Lake and Sunrise Lake (0.02 mg/l). The highest concentration of water column total phosphorus was found in the hypolimnion of Bee Meadow Pond (0.78 mg/l). The mean water column total phosphorus for all the lakes was 0.15 mg/l with a standard deviation of 0.25 mg/l and range from 0.02 mg/l to 0.78 mg/l. The mean ortho phosphate concentration was 0.12 mg/l with a standard deviation of 0.24 mg/l and range from 0.01 to 0.71 mg/l. Total phosphorus in the sediment was lowest in Speedwell Lake (318 mg/kg dry weight). The highest concentration of total phosphorus in the sediment was found at Mountain Lake (1960 mg/kg dry weight). The mean sediment total phosphorus concentration was 862.8 mg/kg dry weight with a standard deviation of 651.6 mg/kg dry weight and range from 318 to 1960 mg/kg dry weight. The mean sediment ortho phosphate concentration (based on sediment from 3 lakes) was 95 mg/kg dry weight with a standard deviation of 70.9 mg/kg dry weight and range from 20.1 to 161 mg/kg dry weight.

Of the five lakes studied, the most adverse conditions were observed at Speedwell Lake (nutrients and plant growth) and Bee Meadow Pond (nutrients, dissolved oxygen in the hypolimnion and ammonia toxicity). Conditions observed at Mountain Lake, Lake Parsippany and Sunrise Lake appear to be more acceptable. In all lakes, under dry weather conditions, the sediments appear to be a significant source of nutrients. Non-point sources appear to be a major source of nutrients for all lakes. Speedwell Lake is the only lake affected by point sources. The point source discharges above Speedwell Lake appear to provide a significant sources of nutrients.

Under the current NJDEP municipal storm water regulations (NJAC 7:8-1.1 et seq.) municipalities are required to develop stormwater management plans, adopt stormwater control ordinances and implement best management practices which will reduce the quantity and improve the quality of stormwater runoff. These regulations include programs which will address public education, post-construction stormwater management in new development and redevelopment, improper disposal of waste (pet waste, litter, dumping into storm drain systems, wildlife feeding, yard waste, and illicit connections), street sweeping, stormwater facility maintenance, erosion, and maintenance yard housekeeping. Goose management is not required but should be strongly encouraged. Also, the NJDEP has proposed changes to area water quality management plans (Proposed Amendments to the Northeast, Upper Raritan, Sussex County, Upper Delaware Water Quality Management Plans) which would require all municipalities within the Whippany River Watershed to adopt and enforce a “low phosphorus fertilizer” ordinance. The proper implementation of these requirements should reduce the nutrient load to lakes with respect to stormwater runoff. With respect to the point source discharges above Speedwell Lake, the above mentioned changes to area water quality management plans (requiring a Total Maximum Daily Loads for phosphorus) will significantly reduce the amount of phosphorus being discharged by wastewater treatment facilities along the entire Whippany River. Therefore, the above mentioned measures should significantly reduce the amount of nutrient loading into the above mentioned lakes. If this occurs, the nutrient concentration in both the water column and sediments should decrease over time (long term reduction). However, there are concerns in both Bee Meadow Pond (hypolimnion DO, ammonia nitrogen toxicity, fish kills and phytoplankton blooms) and Speedwell Lake (excessive macrophytic productivity, sedimentation) which should be address as quickly as possible. Some short term restoration solutions which could address these issues may include sediment removal and harvesting (if possible due to the shallow nature of the lake) for Speedwell Lake and hypolimnetic aeration and phosphorus precipitation for Bee Meadow Pond. A more extensive study of both lake systems is needed before an appropriate (cost effective) restoration plan can be developed and implemented.

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