Assessment of Water Quality, Sediment, Groundwater, and Tributaries of Easton Lake, Adams County, Wisconsin

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DRAFT REPORT TO THE DNR

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EXECUTIVE SUMMARY

Easton Lake is a 24 acre lake in Adams County, Wisconsin, that was created in 1855 when Campbell Creek in Adams County was dammed for a gristmill. It has an average depth of five feet and is popular locally for fishing. It receives water from a 13,440 acre drainage area within the Duck and Plainville Creek watershed. The land in the watershed is used primarily for agriculture with corn, soybeans, alfalfa, and potatoes as the principal crops. Much of the residential land use near the lake is occupied seasonally. The dam is currently owned by Adams County, which received ownership of the dam from Easton Lake District in 1997 (lake district formed in 1977).

This study was initiated by the Easton Lake District and the Adams County Land & Water Conservation Department working with the University of Wisconsin-Stevens Point (UWSP) Center for Watershed Science and Education to determine the current state of Easton Lake and to gather data for forming a lake management and protection plan. The objectives were to examine 1) groundwater quality and flow entering the lake, 2) stream water quality and quantity, 3) assess the current water quality of the lake, 4) determine the contributions of nutrients, and 5) assess how land use practices in the surface and ground watersheds may be impacting lake water quality.

Water samples were collected from March 2001 through January 2002. Stream and baseflow samples were collected at five locations. These samples were tested for chloride, nitrogen, phosphorus, suspended solids, and triazine (atrazine). In the deep portion of the lake turbidity, conductivity, and temperature and dissolved oxygen profiles were measured bimonthly from June through September 2001. Soft sediment samples were collected in January 2002 and were analyzed for phosphorus.

Within the lake, nitrogen levels are quite elevated and phosphorus levels are well above the level that will enhance algae/aquatic macrophyte growth. Phosphorus concentrations averaged 0.07 mg/L in the upper three feet during the summer (June-August). These concentrations are sufficient to generate algal blooms; however, the relatively short water residence time in the lake may limit those blooms to periods of slower flow and areas of the lake not readily flushed by flowing water. The phosphorus also contributes to the growth of submersed plants, particularly those which are rootless (e.g., Ceratophyllum “coontail”) and attached algae. Dense submergent and floating plant growth, along with algae growth, have plagued the lake for many years. The shallow water, easily penetrated by sunlight, combined with the nutrient rich sediment also promotes plant growth. The sources of phosphorus to the lake include runoff from land, atmospheric deposition, and groundwater inputs.

Testing showed Easton Lake to be a moderately hard water lake reflecting the contributions of calcium and magnesium from dissolved minerals in the ground and surface water. The average pH of 8.4 is moderately basic and may be increased by the abundant plant community Water clarity in Easton Lake is poor to fair, which can likely be attributed to the algal growth and sediment in the lake.

Shallow groundwater was assessed with mini-wells inserted in the lakebed around the perimeter of the lake. The predominant groundwater flow direction in the Easton Lake watershed is from east to west. Groundwater drains to streams in the watershed and directly into the lake. Near the lake, groundwater flows to the lake from the east and enters the lake from on the southeast and northeast. The eastern portion of the lake receives colder, deeper regional flow and the western side receives warmer, shallow, more localized groundwater. In some wells, high nitrate and chloride concentrations were found in the groundwater, which indicates input from road salts, septic systems, agricultural fertilizer, and/or local lawn and garden fertilizers. Comparison of reactive phosphorus and ammonium levels in the lake suggest that local land practices are impacting the groundwater flowing directly into Easton Lake.

The aquatic plant study conducted in the lake in 2001 showed that most of the aquatic plant species in Easton Lake are tolerant of poor water clarity and prefer soft sediments. The dominant plant was *Elodea Canadensis* (Canadian waterweed). Sub-dominant species were *Ceratophyllum demersum* (Coontail) and *Lemna minor* (Lesser Duckweed). This plant community suggests the presence of suspended sediments, poor water clarity, high alkalinity and hardness, and high pH. The floristic quality index indicated that Easton Lake's aquatic plant community consists of plants tolerant to disturbance. Although there is some protective buffer along the natural shoreline of the lake, transect data suggested that at least 39% of the shoreline has been disturbed. These factors lead to an aquatic macrophyte community index for Easton Lake that is below average for Wisconsin Lakes.

Results of the aquatic plant study are consistent with the water quality evaluations indicating Easton Lake is strongly influenced by its large watershed and high rate of water flow, sediment deposition, and nutrient concentrations. The residents can use the results of this study to form a management and protection plan to determine current and future uses of the lake. Some practices that might be considered for such a plan include engaging in efforts to reduce erosion and run-off into the streams that feed Easton Lake by protecting, expanding and/or restoring a buffer zones of natural shoreline along the lake and tributaries, and reducing shoreline erosion. Within the lake efforts could continue to harvest vegetation and provide open areas for boat and fish movement, and creating deeper areas in the lake to make permanent open water areas (where sunlight is less likely to reach the depths to promote plant growth). On the land, efforts to reduce the loss of soil and agri-chemicals to runoff and to groundwater will also benefit the lake.

INTRODUCTION

Easton Lake in Adams County, Wisconsin, is a 24 acre lake that is used locally for fishing and recreation. Historically, the lake has had problems with dense growth of submerged and floating plant growth during the summer months. To understand the water quality in Easton Lake, this study was designed with cooperation between the Center for Watershed Science and Education and the Adams County Land Conservation Department. The study objectives were to examine the flow and quality of groundwater entering Easton Lake and Campbell Creek, characterize the water quality in the lake, and determine nutrient contributions from surface water and groundwater.

DESCRIPTION OF STUDY AREA

The Bacon brothers created Easton Lake in 1855 when they installed a dam on Campbell Creek for a grist mill. Since that time the dam has changed hands many times and in 1997 the Easton Lake District became the most recent owner of the dam. The Easton Lake District was formed in 1977 when concerns arose about the lakes extensive weed growth. The Easton Lake District was the first Lake District formed in Adams County.

Easton Lake is located in Adams County, Wisconsin, on the impounded Campbell Creek in the Duck and Plainville Creek watershed. The lake presently covers 24 acres with an average depth of five feet. The lake has five inflow sites, three are perennial and two are intermittent, flowing only during spring melt and large flow events (Figure 2). The Easton Lake surface watershed encompasses approximately 13,440 acres (Figures 1 and 3). The land uses within the watershed are primarily agriculture while residential land is located on the western half of the lake. Many of these residents are seasonal.

OBJECTIVES

The objectives of the Easton Lake study were to:

- Examine the groundwater and surface water flow and quality entering Easton Lake and Campbell Creek.
- Assess the current water quality of Easton Lake.
- Evaluate nutrient contributions from surface and groundwater.
- Identify the land use practices within the surface and groundwater watersheds and determine their relationship to Easton Lake's water quality.

Figure 1. Location of the Easton Lake surface watershed in Adams County, Wisconsin.

Figure 2. Stream sample sites within the Easton Lake Watershed.

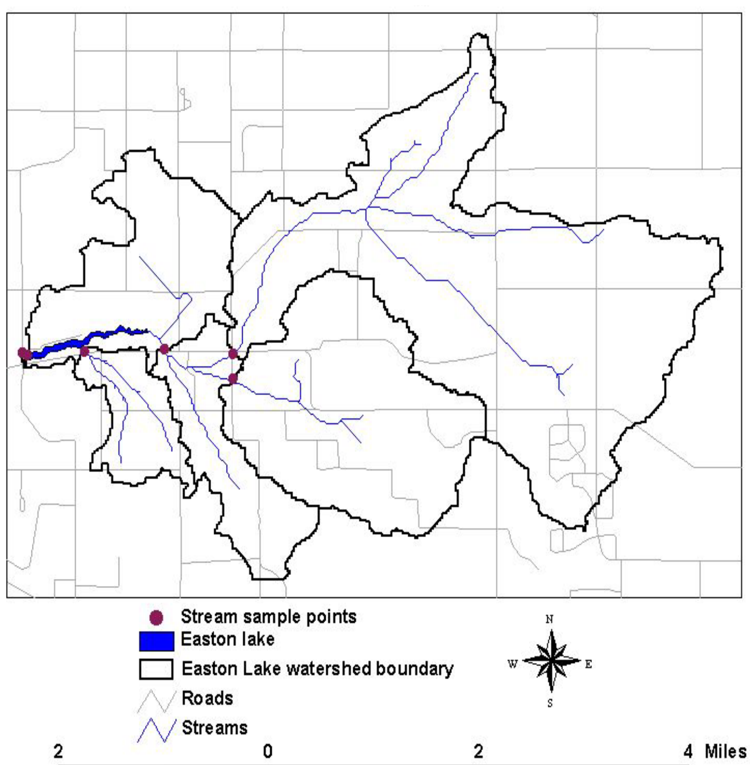
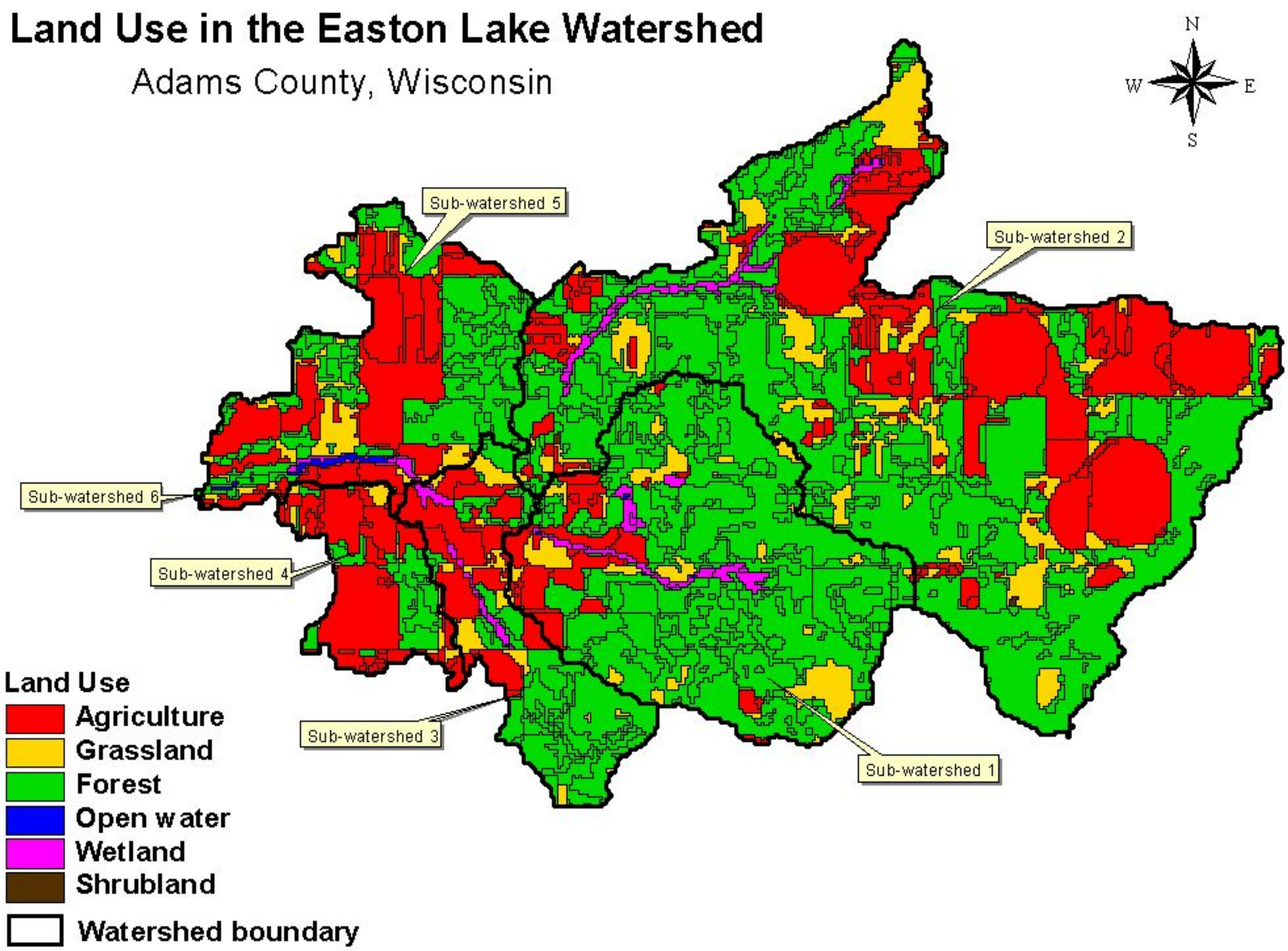


Figure 3. Land use within the Easton Lake surface water watershed.



STUDY METHODS

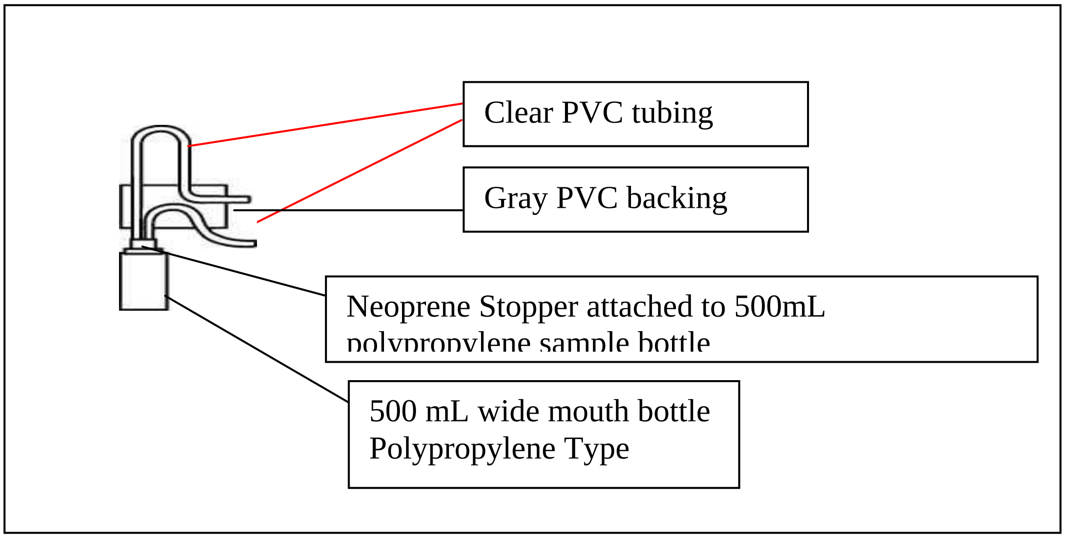
STREAM FLOW

Stream flow was measured from March 2001 to January 2002 at each site. Flow was measured using a Marsh McBirney Model 2000 portable current meter along with a 100-foot tape and two chaining pins. Measurements were taken at a constant interval across the river's width. Stream discharge was measured at Easton Lake's outflow and five inflow sites.

Samples were collected during both base and event flows. When a baseflow sample was taken three bottles were filled with samples from each site using a 60 mL plastic syringe. One 60 mL polyethylene bottle was preserved with 1 molar H_2SO_4 and filled with a filtered sample. Samples were filtered using an in-line plastic filter cassette screwed onto the plastic syringe. A 0.45 μm filter paper was used as the fine membrane filter and a 934/AH glass filter was used as a coarse prefilter. Both filters are 47 mm in diameter and were layered so the sample would move through the 934/AH filter paper first. The second bottle was a 60 mL polyethylene bottle, which was preserved with 1 molar H_2SO_4, and filled with unfiltered sample. The third bottle was a 500 mL polyethylene bottle that was left unpreserved and unfiltered. Samples were kept on ice prior to delivery to the state-certified UWSP Environmental Task Force Lab.

Event flow samples were gathered using both grab and siphon sampling techniques. The siphon sampler used for this study was modified from devices designed by the USGS (USGS Report 13 or described in Graczyk et al., 2000). The siphon sampler consists of two pieces of clear PVC sampling tubing, with an inside tube diameter of 0.28 inches, which are bent into the given configuration (Figure 4). The clear PVC sampling tubing is then inserted into a neoprene stopper and the stopper is inserted into the 500 mL polyethylene-sampling bottle. The clear PVC sampling tubing is supported by a flat piece of gray PVC (Figure 4), and the 500 mL sampling bottle apparatus is held in place with a schedule 40 white PVC bottle bracket. The bottle's bracket was slid onto a fence post that was pounded approximately 18 inches into the streambed. The siphon sampler was positioned to sample an anticipated rise in the stream from a storm event. Once the water crests the top of the lower tube, the river water enters the tubing and fills the 500 mL polypropylene sample bottle.

Figure 4. Diagram showing the runoff event siphon sampler assembly.



Samples that were collected for water quality analysis were stored on ice and delivered to the state-certified Environmental Task Force Lab (ETF) at the University of Wisconsin-Stevens Point. Baseflow samples were analyzed for nitrate + nitrite– N (NO_2 + NO_3), ammonium– N (NH_4), total Kjeldahl nitrogen (TKN), total and reactive phosphorus, total suspended solids (TSS), chloride (Cl^-), and triazine. The analyses run in the Environmental Task Force Lab followed the methodology displayed in Table 1.

The load and yield calculations help to interpret the nutrient inputs from a given sub-watershed. Both were calculated separately using discharge and nutrient concentrations for the samples collected on the respective dates. Load was calculated as the pounds of nutrient passing through a given point of stream per day. Yield was calculated as pounds of nutrient from a given sub-watershed per acre annually. These values are minimum values as they only consider concentrations/discharge during baseflow. Load and yield were calculated for all parameters mentioned in the previous paragraph except TSS, which was not analyzed in the baseflow samples.

Table 1. Analytical methods and corresponding detection limits for water quality analyses run in the UWSP Environmental Task Force Lab.

Analyses	Method	Method Detection Limit
Chloride	Automated Ferricyanide 4500 C1 E	0.2 mg/L
Nitrogen, Ammonia	Automated Salicylate 4500-NH_3 G	0.01 mg/L
Nitrogen, Nitrate + Nitrite	Automated Cadmium Reduction 4500-NO_3 F	0.021 mg/L
Nitrogen, Total Kjeldahl	Block Digester; Auto Salicylate 4500-NH_3 G	0.08 mg/L
Phosphorus, Reactive	Automated Colorimetric 4500 P F	0.003 mg/L
Phosphorus, Total	Block Digestor, Automated 4500 P F	0.012 mg/L
Total Suspended Solids	Gravimetric 2540 D	2.0 mg/L
Triazine	Enzyme Linked Immunosorbant assay	0.05 mg/L

MID-LAKE SAMPLING

Temperature and dissolved oxygen (DO) profiles were taken bi-monthly from June through September 2001 at the deepest area of the lake. The deep area of the lake was determined through the use a bathymetric map and an anchor rope marked at one-foot intervals. The deep spot location was marked with a global positioning system (GPS) and described by landmark telemetry. Dissolved oxygen and temperature readings were taken using a YSI Model 50B dissolved oxygen meter (4500-06, APHA 1995). Readings were taken every foot beginning at the one-foot mark and terminating at the lake bottom. The readings were used to determine stratification and depths for water sample collection. Samples were collected using an alpha bottle and integrated bailer. The samples were then transferred into a 500 ml unpreserved bottle and two-125ml bottles preserved with 1 molar H_2SO_4. One of the 125 ml bottles contained a sample that was filtered through a 0.45 micron membrane filter, using an in-line filtering apparatus, while the second sample was not filtered.

Easton Lake's turbidity for each sampling period was calculated by interpreting recorded Secchi disc and conductivity measurements. Turbidity measurements were used to determine the amount of water required to gather precise chlorophyll-*a* sample. Chlorophyll-*a* samples were field filtered. Filters were placed in aluminum foil that was sealed in a *Fisher* bag. Samples were transported on ice to the state certified Environmental Task Force Lab at the University of Wisconsin-Stevens Point. Analyses run on these samples include NO_2+NO_3-N, NH_4-N, TKN, total and reactive phosphorus, pH, conductivity, total hardness, alkalinity, calcium, Cl^-, and chlorophyll-*a*.

SHALLOW GROUNDWATER

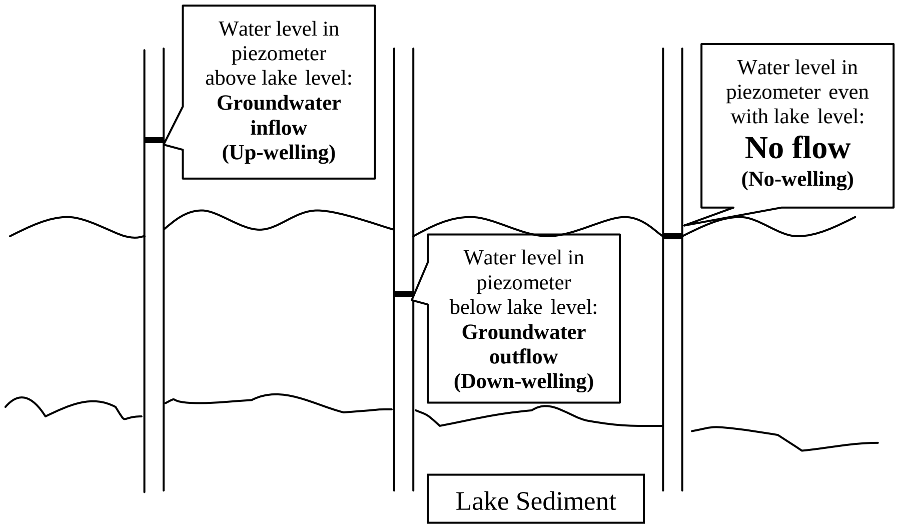
Shallow groundwater data was collected around the western side of Easton Lake at 200 foot intervals. On the east side, groundwater data was collected less frequently. Groundwater flow rates were estimated using slug tests and measurement of hydraulic head (groundwater levels) in mini-piezometers at specific locations and then extrapolated to the nearby areas. Slug tests estimate hydraulic conductivity at each site (Hvorslev, 1951). Determining the head level allowed identification of areas of groundwater flow into and out of the lake (Figure 5). Groundwater samples were taken for analysis from the inflow sites.

Mini-piezometers were constructed using a five-foot polypropylene tubing with a 4 mm inside-diameter. Plastic screws inserted inside one end of the tube. In the other end, holes were sewed into the tube. The holes reached up 2 inches from the bottom. After the holes were completed, a pipette tip was attached to act as a point in order to ease insertion. Mini-piezometers were inserted into the lake bottom in approximately 18 inches of water. A tile probe was used to initiate the hole into which the piezometer could be inserted. A stainless steel rod was inserted into the piezometer to ensure that it would be rigid. Mini-piezometers were inserted to a depth two feet below the lake bottom. Exceptions were made in areas without sufficient water depth or tough substrate, which made 2 feet of insertion impossible. A 60 ml syringe was used to develop the well by drawing up groundwater from the well until it was clear. A filtered (back-to-back 0.45 micron membrane filter and 1 micron glass fiber filter) and preserved (0.7 mls 1+1 H_2SO_4 per 250 mls of sample) sample was collected at each site for NO_2+NO_3, NH_4, Cl, and reactive P.

SEDIMENT TRAPS

Sediment traps were sampled by Adams County Land Conservation Department using equipment and methodology supplied by the US Army Corps of Engineers, Spring Valley, Wisconsin.

Figure 5. Diagram showing determination of groundwater inflow, outflow, and no-flow using mini-piezometers.



WINTER SEDIMENT SAMPLING

In January 2002 soft sediment samples were collected near Easton Lake's three sediment trap sites in. A KB coring device was used to extract the samples. To extract samples the coring device was carefully lowered through soft sediments until the bottom sediment was contacted. After sediments were in the tube, the suction was set on the coring device and the devise was removed. The collection tube was capped and stored in a cooler for delivery to the Lab. At the lab, tubes containing sediment samples were frozen. After freezing, soil cores were carefully pushed out of the tube. After removal, the cores were divided into one foot increment. Then, each 1 foot increment was divided into four 3 inch sections. Each 3 inch section had total phosphorus and percent solids measured.

RESULTS AND DISCUSSION

STREAMFLOW/ SURFACE WATER CHARACTERISTICS

Flow Characteristics

Easton Lake is an impoundment receiving water from a relatively large watershed. The approximately 13,440-acre watershed and 24-acre lake result in a watershed to lake ratio that exceeds 500. Easton Lake's large watershed to lake ratio results in a large amount of flow into the lake relative to the size of the lake. Much of Easton Lake's inflow comes from tributary streams. The tributary streams deliver surface runoff and groundwater flow from the watershed to the lake.

The average hydraulic residence in a lake is the amount of time on average that water spends in the lake. Hydraulic residence can be calculated by dividing the lake's volume by the rate at which water leaves the lake. Streamflow gauging at the Eason Lake outlet showed that discharge from the lake ranged from 8 to 35 cubic feet per second (cfs) and averaged 16 cfs. This flow out of Easton Lake represents the input of water from watershed-wide runoff, both surface and groundwater runoff. The measured flow rate was used to calculate the average water residence time in the lake. Easton Lake's 24 acre area and average depth of 5 feet cause residence time to ranges from approximately 2 days to 1 week.

Dissolved Oxygen and Temperature Profiles

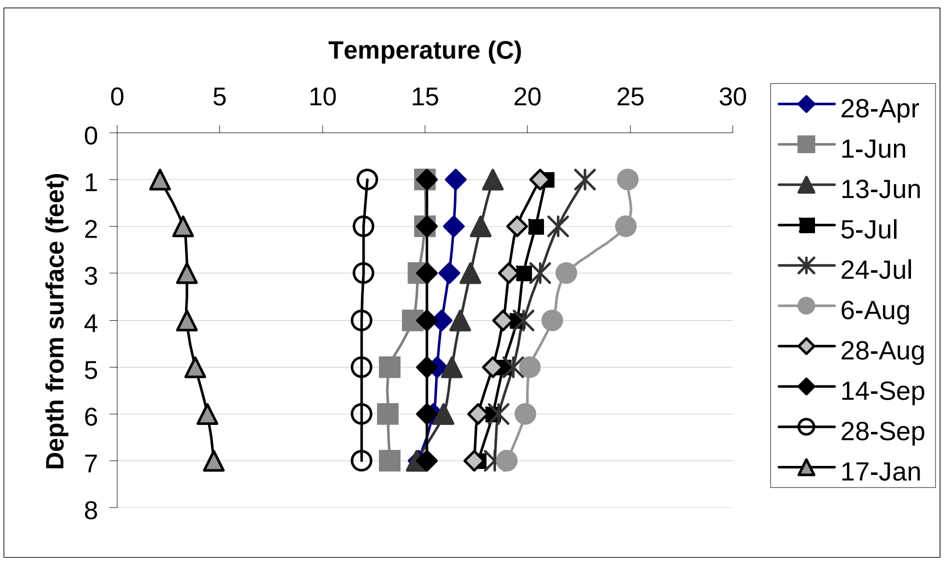
A lakes water quality and ability to support fish are affected by the extent to which water mixes. The depth, size, and shape of a lake are the most important factors influencing mixing, although climate, lakeshore topography, inflow/outflow from/to streams, and vegetation also play a role (Shaw et al., 2000).

Many lakes vary in temperature from top to bottom during the summer and winter seasons. Lakes that have a water column with varying temperatures often become stratified. Stratification is the layering of the lake due to changes in water density. Warm water is less dense than cold water. Cooler, denser water remains at the bottom of the lake and warmer water at the surface. After prolonged periods of warming, the less dense water at the surface mixes with the cooler, dense bottom waters. This can prevent oxygen mixing and the bottom layers can become depleted in oxygen. The greatest variation in the water columns temperature in the winter occurred on January 17 and in the summer on August 6. At both times, the temperature variation was relatively gradual from top to bottom.

Easton Lake lakes temperature profile did not show distinct stratification during any part of the year (Figure 6). The average temperature for the entire sampling period was 16.0°C, while the average for the summer months was 18.5°C. Easton Lake does not stratify because the lake is shallow and it has a relatively high, constant flow.

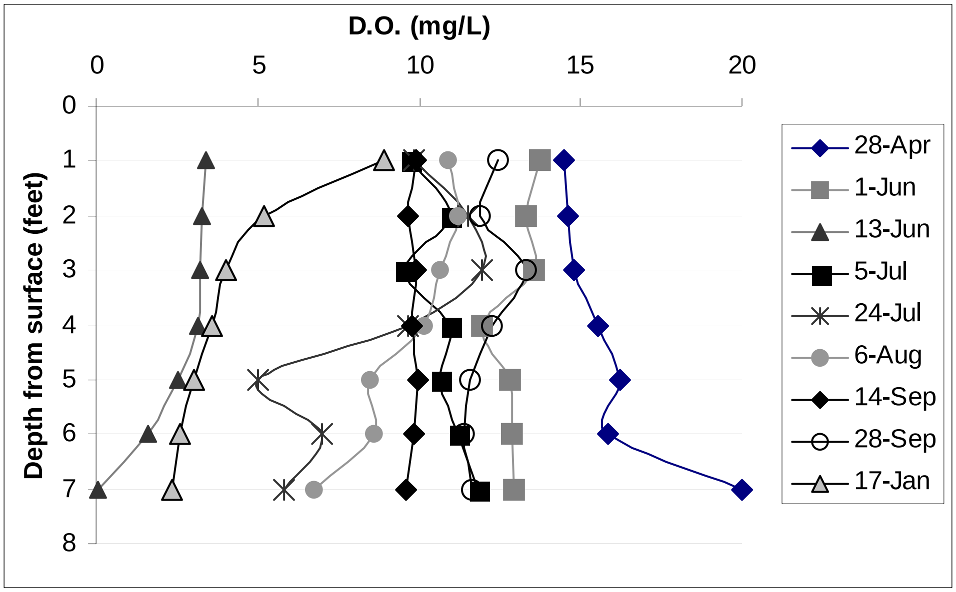
Dissolved oxygen concentration did not vary throughout the year. For example, at the beginning of June, when sampling took place after heavy rainfall, the lake was extremely clouded with sediment and the dissolved oxygen concentrations were significantly lower and became anoxic (D.O. < 2.0 mg/L) in the lower two feet of the lake. During this time, oxygen concentrations throughout the entire water column fell below 5 mg/L. These low oxygen concentrations threaten aquatic life. However, the sources of the low oxygen could not be determined. We suspect that runoff from rain events is introducing sediment to the lake that shades photosynthesizing plants and algae, which reduces plant and algae oxygen production. At the same time increased sedimentation delivers organic, oxygen demanding materials to the lake and biological decomposition of these acts to deplete the oxygen. Paired together, these two factors create a period of very low oxygen concentrations in Easton Lake.

Figure 6. Temperature profile in Easton Lake 2001-2002.



The lake has the most dissolved oxygen in the spring. Concentrations begin to decrease in the beginning of September and stabilize around 10 mg/L (Figure 7). Dissolved oxygen concentrations are fairly constant throughout the profile throughout July and August. Throughout this period a slight decrease in dissolved oxygen concentrations was observed near the lake bottom. In January of 2002 dissolved oxygen concentrations were highest at the surface of the lake and decreased to 2.3 mg/L near the bottom. The average dissolved oxygen content throughout the sampling period was 9.6 mg/L. Overall, the dissolved oxygen does not appear to limit biota except in extreme rainfall events as described above.

Figure 7. Dissolved oxygen concentrations in Easton Lake 2001-2002.



Secchi Depth, Chlorophyll-a, Turbidity, and Color

Secchi depth is a measure of water clarity and can be directly related to chlorophyll-*a*, which measures algae abundance. Secchi depth measurements vary throughout the summer due to fluctuations in both algae populations and true color (dissolved materials in the water). High chlorophyll-*a* concentrations are expected to reduce Secchi depth measurements.

Easton Lake's Secchi depth was always between 7 and 8 feet, and light penetrates to the bottom throughout most of the lake. Reduced Secchi depths were measured during the June 13 sampling period due to a heavy rain event the day before the sampling occurred that caused the lake to be extremely turbid (Secchi depth = 1 foot). In the future, Secchi depths should be monitored in order to provide an economical, long-term record of the lake's condition.

Chlorophyll-*a* values varied throughout the sampling period with the highest values occurring towards the end of July (18.7 mg/L). There was considerable variability in the chlorophyll-*a* values. The average chlorophyll-*a* value of 4.5 mg/L was comparable to other lakes in the area.

Normally, suspended algae have a greater influence on chlorophyll-*a* concentrations, but Easton Lake's relatively short residence time and extensive macrophyte growth reduces the amount of suspended algae present in the lake. Easton Lake's short residence time likely does not allow sufficient time for suspended algae to proliferate. The variability in chlorophyll-*a* concentrations might reflect flow conditions that preceded the sample collection.

Analyses for color and turbidity were only taken during the spring turnover-sampling period in April 2001. The value measured for turbidity was equal to 1 NTU, which means that the amount of suspended material was low during this time. The color value measured was 28 mg/L, which indicated low color as shown in Table 2.

Table 2. Lake Water Color Interpretations.

Measurement	Interpretation
0 – 40 mg/L	Low
40 – 100 mg/L	Medium
> 100 mg/L	High

**Adapted from Lillie and Mason, 1983*

Phosphorus

Phosphorus is reported to be the principal nutrient affecting algae and aquatic plant growth in more than 80% of Wisconsin lakes (Shaw et al., 2000). In fact, if all other elements are present in excess of physiological needs, phosphorus can theoretically generate 500 times its weight in living algae (Wetzel 2001).

Phosphorus enters lakes through numerous sources. Phosphorus is present in living and dead vegetation and falls into lakes from the shore. In impoundments, much of the phosphorus that enters flows into the lake with runoff and stream inflow. Increased phosphorus delivery to lakes occurs in areas where large amounts of sediment are suspended, where human and animal waste are carried in runoff, and where soil fertilizer is delivered to water bodies (Garn 2002). Small quantities of phosphorus are also added to lakes through precipitation and particulate deposition from the atmosphere.

Phosphorus concentrations are usually highest in areas where surface runoff is not filtered by vegetation or give the opportunity to react with soil. Groundwater phosphorus concentrations become elevated when the soil phosphorus holding capacity is exceeded. This can occur beneath septic drainfields, agricultural fields, and barnyards.

Phosphorus exists in a variety of forms, but these are usually analyzed as either soluble reactive phosphorus (SRP) or total phosphorus (TP). SRP is the form of phosphorus that is readily available to algae and aquatic macrophytes. Total phosphorus includes SRP and other forms of phosphorus associated with organic material or sediment. Concentrations of SRP can vary widely in most lakes over short periods of time because plants take up and release SRP frequently (Shaw et al. 2000). Typically, total phosphorus concentrations remain more stable than soluble reactive phosphorus because TP includes both soluble phosphorus and the phosphorus in sediments, plants, and animal fragments suspended in lake water (Shaw et al. 2000).

Phosphorus does not stay dissolved in water because phosphorus forms insoluble precipitates with calcium, iron, and aluminum, in addition to being taken up by plants. Phosphorus can adsorb to soil particles; however if the soil's capacity to hold phosphorus is exceeded, the phosphorus will be more likely to leach to the groundwater or be lost to runoff. In the lake, phosphorus can be adsorbed by marl (calcium carbonate) that forms in the lake. When the marl settles to the lake bottom, it can take phosphorus with it. Phosphorus settling in the sediment can remove phosphorus from the water, but this phosphorus can become available again for plant use when rooted macrophytes withdraw phosphorus from the sediment. Also, disturbance and mixing of lake sediments can cause phosphorus to be redistributed throughout the water column.

Easton Lake has high concentrations of phosphorus, which is typical for impoundments with large watersheds (Table 3). In order to prevent nuisance algal blooms, (Shaw et al., 2000) recommend that total phosphorus concentrations below 0.030 mg/L should be maintained. In Easton Lake, the total phosphorus concentrations were above 0.030 mg/L throughout the sampling period, ranging from 0.037–0.157 mg/L. Phosphorus was also measured at the five inflow streams. There are higher average concentrations of total phosphorus entering Easton Lake through the tributaries (0.159 mg/L) than was found in the water leaving Easton Lake (0.106 mg/L). Phosphorus can be reduced by biological uptake and sediment deposition. Overall, it appears that the concentrations of phosphorus in Easton Lake are consistent with the relatively high concentrations of phosphorus in the tributaries entering the lake. Short water residence time does not allow for substantial changes in water quality within the lake.

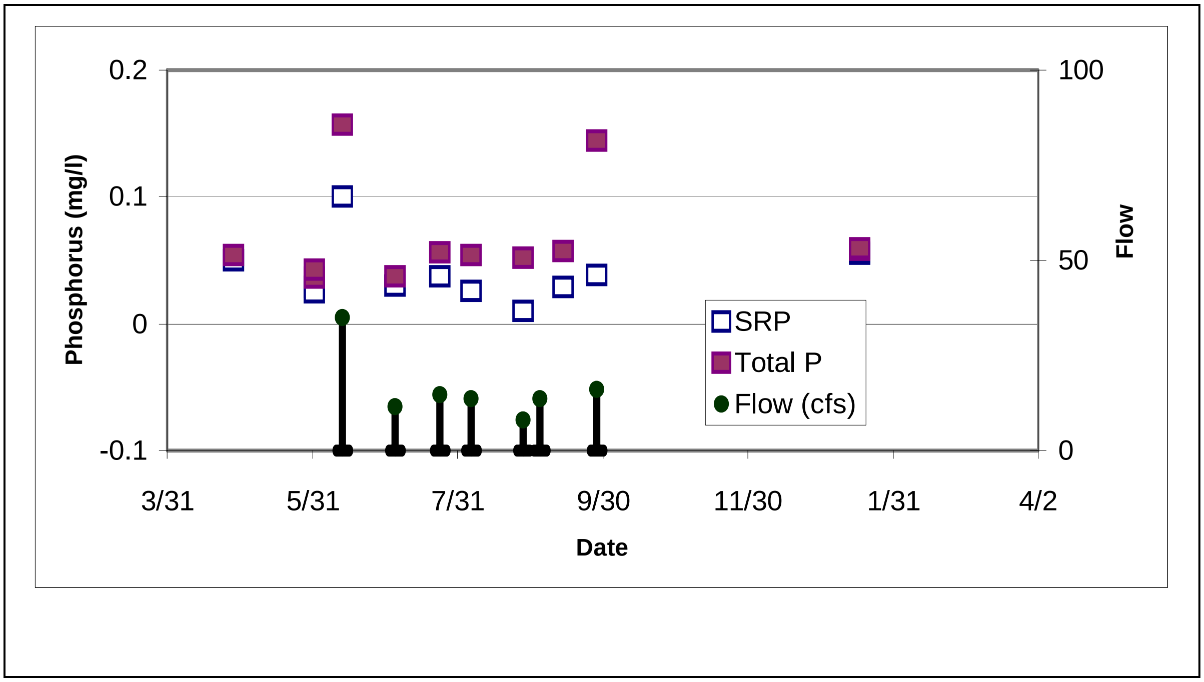
Table 3. Total phosphorus concentrations for Wisconsin's natural lakes and impoundments.

Water Quality Index	Total Phosphorus (mg/L)	Averages
Very Poor	0.150	
	0.140	
	0.130	
	0.120	
	0.110	
Poor	0.100	
	0.090	
	0.080	
	0.070	← **Easton Lake (0.071 mg/L)**
		← **Average for impoundments**
	0.060	
Fair	0.050	
	0.040	
Good	0.030	← Average for natural lakes
	0.020	
Very Good	0.010	
Excellent	0.001	

Phosphorus was also measured at the five inflow streams. There are higher average concentrations of total phosphorus entering Easton Lake through the tributaries (0.159 mg/L) than was found in the water leaving Easton Lake (0.106 mg/L). Phosphorus can be reduced by biological uptake and sediment deposition.

The reactive phosphorus concentration in Easton Lake ranged from 0.01 to 0.10 mg/L with an average of 0.04 mg/L, compared to a total phosphorus concentration that ranged between 0.04 to 0.16 mg/L with an average concentration of 0.07 mg/L. At times, a high percentage of the total phosphorus in Easton Lake was soluble reactive phosphorus. Figure 8 compares the TP, SRP, and outflow from the lake during the sampling. The relatively high percentage of TP that is SRP coincides with the periods of intermediate flow and early in the growing season. The difference between total and soluble phosphorus during periods of very high flow (June sampling) could reflect the passage of sediment through the lake since during this sampling the lake was very turbid. Later in the season, low flow periods could allow sufficient time to also develop more suspended algal communities. The average TP concentration in Easton Lake is close to the average for impoundments in Wisconsin.

Figure 8. Total phosphorus (Total P), soluble reactive phosphorus (SRP) concentrations (mg/L), and flow (cfs) during the 2001 mid-lake sampling.



Easton Lake's phosphorus concentrations are above 0.03 mg/L, which creates the possibility of enhanced algae and aquatic macrophyte growth in Easton Lake. However, impoundments phosphorus concentrations will vary from year to year based on the environmental conditions that occur. High SRP concentrations provide phosphorus for biota. Easton Lake water's short residence time may provide inadequate time for suspended algal communities to proliferate in the lake and phosphorus use could be dominated by aquatic plants and attached algae. However, during periods of low water flow and increased water residence, phosphorus concentrations may encourage the growth of suspended algae.

Nitrogen

Nitrogen is the second most important nutrient for plant and algae growth in surface water with only phosphorus being more important (Shaw et al., 2000). Total nitrogen is calculated by adding total Kjeldahl nitrogen (TKN) and nitrate + nitrite nitrogen ($NO_2^- + NO_3^-$). TKN includes both ammonium (NH_4^+) and organic nitrogen. Both ammonium and nitrate/nitrite nitrogen are used by aquatic plants and algae. They can be transformed to organic nitrogen after uptake (Shaw et al., 2000). Ammonium is the most available form of nitrogen to aquatic plants but does not move as readily through soil as nitrate. When oxygen is present, the ammonium form of nitrogen will oxidize to nitrate in a process known as nitrification. Nitrate is very mobile in soil and groundwater. If nitrate exceed 0.3 mg/L in a lake in spring, there is sufficient nitrogen to support summer algae blooms (Shaw et al., 2000).

In Wisconsin, nitrogen does not occur naturally in soil minerals, but is a major component of organic matter (Shaw et al., 2000). Nitrogen is found in precipitation. State-wide, precipitation concentrations of nitrate ranged from 1.2 to 1.7 mg/L in 2001 (NADP 2001). According to Shaw et al., (2000) precipitation may be the primary nitrogen source for pristine seepage and some drainage lakes. However, Easton Lake's main source of nitrogen comes from the lakes large surface and groundwater drainage area. Watershed-wide contributions of nitrogen are influenced by agricultural fertilizers and animal wastes. Nitrogen can also be increased through local land use where septic systems or lawn and garden fertilizer are used on lakeshore property.

In Easton Lake, the highest concentrations of total nitrogen occurred in June and July (3.0 and 3.1 mg/L). Overall concentrations of all nitrogen forms were low for the lake. NO_2^- + NO_3^- concentrations remained fairly constant for the entire sampling period and ranged from 1.7 to 2.7 mg/L and averaged around 2.2 mg/L. Ammonium concentrations ranged from 0.01 to 0.24 mg/L and averaged around 0.08 mg/L. TKN concentration ranged from 0.06 to 1.30 mg/L and averaged around 0.42 mg/L. Total nitrogen ranged from 2.2 to 3.1 mg/L and averaged around of 2.6 mg/L.

Typically nitrate + nitrite nitrogen and ammonium do not appear in detectable concentrations together. Nitrate is the oxidized form of nitrogen, while ammonium is the anoxic form. Large precipitation events in the middle of June occurred one day before a sampling date. During this sampling date, water clarity was extremely low, while water quality results showed increased ammonium and decreased nitrate concentrations. During this time frame, the water became anoxic, likely due to an influx of oxygen-demanding sediment and dissolved organic material. In addition, the reduction in light penetration reduced photosynthetic oxygen production. Figure 7 above, showed the recovery of oxygen in the water column after this event.

Total Nitrogen to Total Phosphorus Ratio

The Total N:Total P ratio evaluates whether nitrogen or phosphorus is the limiting nutrient for plant growth. When the TN:TP ratio is greater than 15:1, plant growth is limited by the amount of available phosphorus (Carlson 1980). The average TN:TP ratio in Easton Lake (April–January) was 44:1, suggesting that phosphorus was the limiting nutrient in Easton Lake. Phosphorus was expected to be limiting based on previous studies of impoundments in Wisconsin.

Alkalinity, Total Hardness, pH, & Conductivity

The types of minerals in the soil and the watershed's bedrock affect a lake's hardness and alkalinity. Easton Lake is located primarily in sandy deposits, which overlay loam and clay. These were glacially-deposited materials and contain carbonate rock particles, which can contribute hardness and alkalinity ions to the groundwater. The average alkalinity for the lake was 107 mg/L, while the average total hardness was 120 mg/L. Overall, the lake is classified as a moderately hard lake and is not sensitive to acid rain due to the high alkalinity, which buffers the water against pH change (Shaw et al., 2000).

The pH is an index of whether the lake is acid or basic. Many chemical constituents are impacted by the lake pH, and consequently, very high or very low pH can result in water quality problems. In Wisconsin, pH ranges from 4.5 in some acid bog lakes to over 8 in hard water marl lakes (Shaw et al., 2000). The pH of Easton Lake is relatively high (8.4) and likely reflects the high pH buffering from the groundwater which enters the lake, and the active photosynthesis of the plants and attached algae in the lake. Photosynthesis consumes carbon dioxide and increases surface water pH. When organic matter at the bottom of the lake breaks down it consumes oxygen and gives off carbon dioxide making the lake more acidic. Because of this, deeper portions of a lake will often be more acidic than the surface water. A high pH is not necessarily bad because lakes with low pH values have an increase in the movement of metals. In low pH water, aluminum, zinc, and mercury concentrations increase if they are present in lake sediment or watershed soils (Shaw et al., 2000). The high pH and buffering capacity of Easton Lake ensures that toxic metals will not immediately play a major role in lake water quality.

Conductivity measures water's ability to conduct an electric current. Conductivity is reported in either micromhos per centimeter (umhos/cm) or microSiemens per centimeter and is directly related to the total dissolved inorganic chemicals in the water. In Wisconsin values are commonly two times the water hardness unless the water is receiving high concentrations of contaminants introduced by humans (Shaw et al., 2000). Conductivity readings ranged from 211 to 258 umhos/cm with an average of 243 umhos/cm. This is roughly double the total hardness, indicating most of the dissolved ions are related to hardness. During the entire sampling period conductivity, pH, alkalinity, and total hardness were fairly constant. The only exception to this was in the middle of June when the extreme rain event occurred. This phenomenon is discussed earlier.

Chloride

Chloride is not common in Wisconsin soils, rocks, or minerals and generally leads to low concentrations in groundwater. According to Lillie and Mason (1983), lakes in southeastern Adams County have chloride concentrations of less than 3 mg/L. Chloride behaves much like nitrate in that it is readily leached through the soil and into the groundwater. Chloride is a common constituent in animal and human wastes, potash fertilizer (potassium chloride), and often a component of road deicing agents. Chloride can be derived from the dissolution of halite (road salt) that is applied to roads in the winter months (Boutt 1999). As microorganisms do not degrade or use chloride, it's more long-lived then nitrate. In fact, septic systems do not effectively remove chloride due to its anionic and it's conservative or non-reactive nature and as a result are often an indication of contamination from man-made sources.

According to Shaw et al. (2000), chloride does not affect plant and algae growth and is not toxic to aquatic organisms at most levels found in Wisconsin. The presence of chloride where it does not occur naturally or concentrations greater than its natural levels is commonly considered an indicator of human activity (Shaw et al., 2000). Chloride concentrations in Easton Lake ranged from 3.7 to 4.5 mg/L with an average of 4.2 mg/L. This is close to the background concentration of 3 mg/L described by Lillie and Mason.

Sulfate

Lake water sulfate is mostly related to types of minerals found in a watershed or to acid rain. Industries and utilities that burn coal release sulfur compounds into the atmosphere that are carried into the lakes by rainfall (Shaw et al., 2000). According to Lillie and Mason (1983), the highest lake sulfate levels are found in the southeast portion of the state where acid rain is more common. Sulfate concentrations in Easton Lake fit regional predictions (~10 mg/L) at an average of 10.4 mg/L.

Atrazine

Atrazine belongs to the chemical class Triazine. Atrazine, an herbicide, is one of the most frequently used selective pesticides in the United States. Its primary function is to control broadleaf and annual grasses (NCSWQG 2002). Atrazine is taken up through plant roots and foliage. Although this process uses the atrazine from the shallow subsurface, it inhibits the growth of the plants by limiting photosynthesis (Oregon State University 1996). Atrazine was most widely used between 1987 and 1989 throughout the Midwest, including Wisconsin, however it is still quite widely used today (EPA Consumer Fact Sheet – Atrazine 2001). If atrazine is used, following current best management practices can reduce its effects on the aquatic environment.

Atrazine is classified as being very persistent in the soil substrate, although soil microorganisms can degrade atrazine at shallow depths (Oregon State University, 1996). In areas of low to medium clay content, atrazine is very mobile through the soil horizons, therefore threatening groundwater. Wisconsin has a 3 ug/L (part per billion) drinking water standard for atrazine. Atrazine can move to water bodies via overland flow during rainstorms or via groundwater discharging to the water bodies. In a lake or river, the primary concern with this chemical is the effects to aquatic biota. Toxicity to aquatic plants occurs above 10 ug/L, however, more sensitive species can be affected by lower concentrations (USEPA 2001).

Sodium and Potassium

According to Shaw et al. (2000), natural levels of sodium and potassium ions in soil and water are very low, and their presence may indicate lake pollution caused by human activities. Sodium is often associated with chloride while potassium is a component of potash fertilizers and abundant in animal waste. Sodium and potassium are retained by soils and therefore are not good indicators of pollution. Easton Lake has minimal levels of both sodium (2.1 mg/L) and potassium (0.7 mg/L) indicating no significant impacts to the lake.

Total Suspended Solids

Total suspended solids (TSS) are the sediment and algae particles that are floating in the water column. TSS can be an indicator of runoff from sources such as agricultural fields, construction sites, and other sources of bare soil. High concentrations of TSS can transport other constituents, such as pesticides, nutrients, and bacteria that adhere to soil colloids and travel into the river through overland flow during a storm event (EPA – Turbidity and Solids, 2000). Excess TSS can also turn water murky; therefore, limiting the amount of sunlight able to reach the river bottom. The decrease in sunlight can inhibit rooted aquatic plant growth in a river. Another problem associated with high TSS is an increase in water temperature. When the river is a dark, murky color it will absorb light, therefore increasing the water temperature and potentially inhibiting invertebrate and fish habitat by lower oxygen concentrations (Murphy, 2000).

SOFT SEDIMENT

Soft sediment samples were collected in January 2002 near the sediment trap sites to determine the depth and phosphorus content of the sediment in Easton Lake. The upper site yielded the shallowest sample totaling two inches of soft sediment. The middle site yielded a three-foot core. The core was divided into a total of six samples comprised of four 3-inch segments in the upper foot and two 1-foot segments. The lower reservoir sample site was a total of 27 inches. This sample was also divided into six sub-samples, with the bottom sample representing the lower 24-27 inches of soft sediment.

The rate of sediment deposition within Easton Lake was estimated using sediment traps located at three locations. The traps capture settling sediment in a plastic tube. The four-inch diameter tubes were located in the western, middle and eastern portions of the lake. Collection of sediment and analysis for total sediment and phosphorus suggested an average deposition rate of 10-17 grams of sediment/m2/day during July and August. The phosphorus deposition rate within the lake for the same period averaged 25-50 mg P. These rates of sediment deposition confirm the movement of suspended solids and phosphorus into and/or through Easton Lake. These materials accumulate in the lake bottom and contribute to the growth of aquatic plants in the lake.

The concentration of phosphorus in the settling material varied from 0.1% to 0.6%. This range is consistent with that observed in other studies, but confirms that the movement of sediment into and through the lake is a source of additional phosphorus. Some of this phosphorus can become available for plants and dissolve in the water.

The combination of a thick layer of nutrient-rich bottom material deposited over the past 125 years and adequate penetration of sunlight into the clear, shallow water provide ideal conditions for prolific growth, typical of many dammed rivers.

GROUNDWATER FLOW CHARACTERSTICS

(Contributed by Adam Freihoefer)

Regional groundwater flow into the Easton Lake area flows southeasterly towards Easton Lake and Campbell River as shown in Figure 9. Much of the groundwater in the watershed enters tributaries which drain to Easton Lake, but some of the groundwater drains directly to the lake. The temperature of the groundwater was used to determine whether the flow paths were shallow or deep; the deeper flow paths tend to have colder groundwater. The temperature of the groundwater indicated that the eastern portion of Easton Lake was receiving colder, deeper more regional flow contributions compared to areas on the western side of the lake that were receiving warmer, shallow more local groundwater.

Shallow groundwater was sampled through the installation of 40 mini-piezometers inserted in 200-foot intervals around Easton Lake between August 15 and August 20, 2001 (Figure 10). Of the 40 mini-piezometers, only 24 sites could be sampled, the remaining 16 sites yielded no sample due to fine sediments.

Figure 9. Regional groundwater contour and flow path lines for Easton Lake.

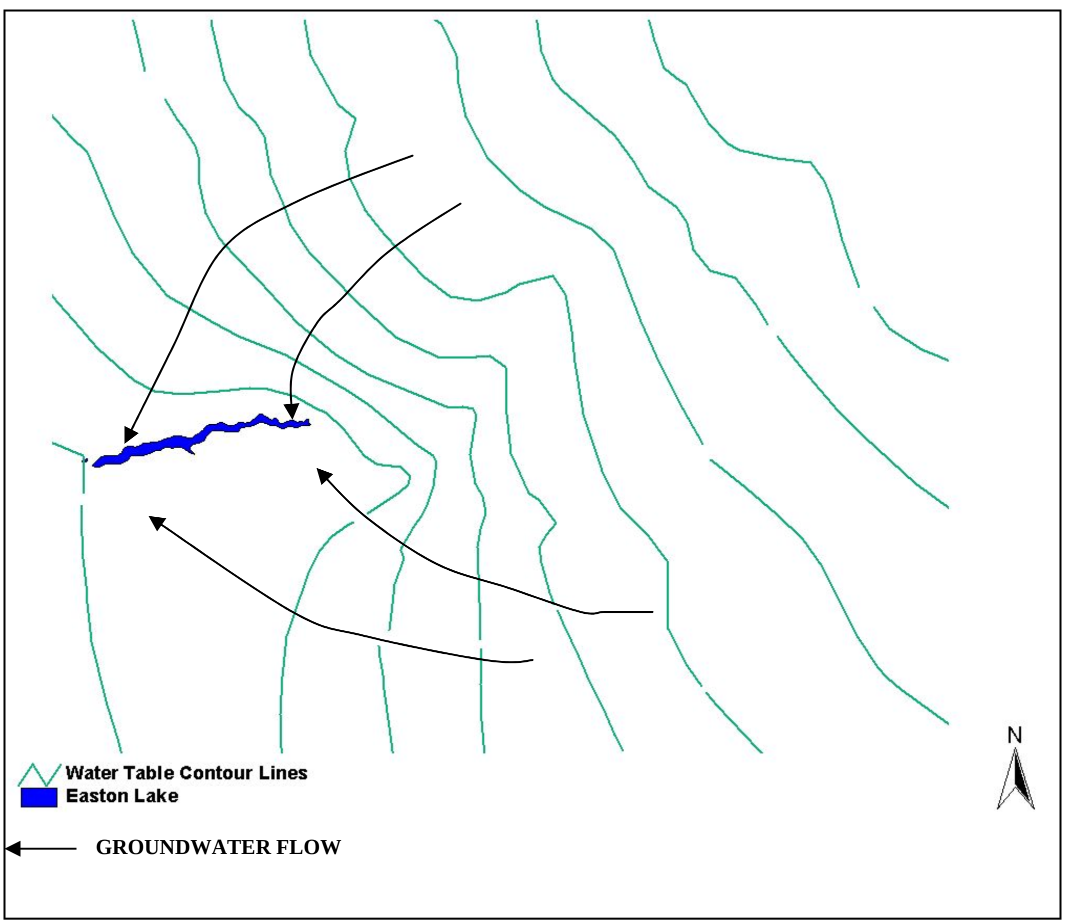
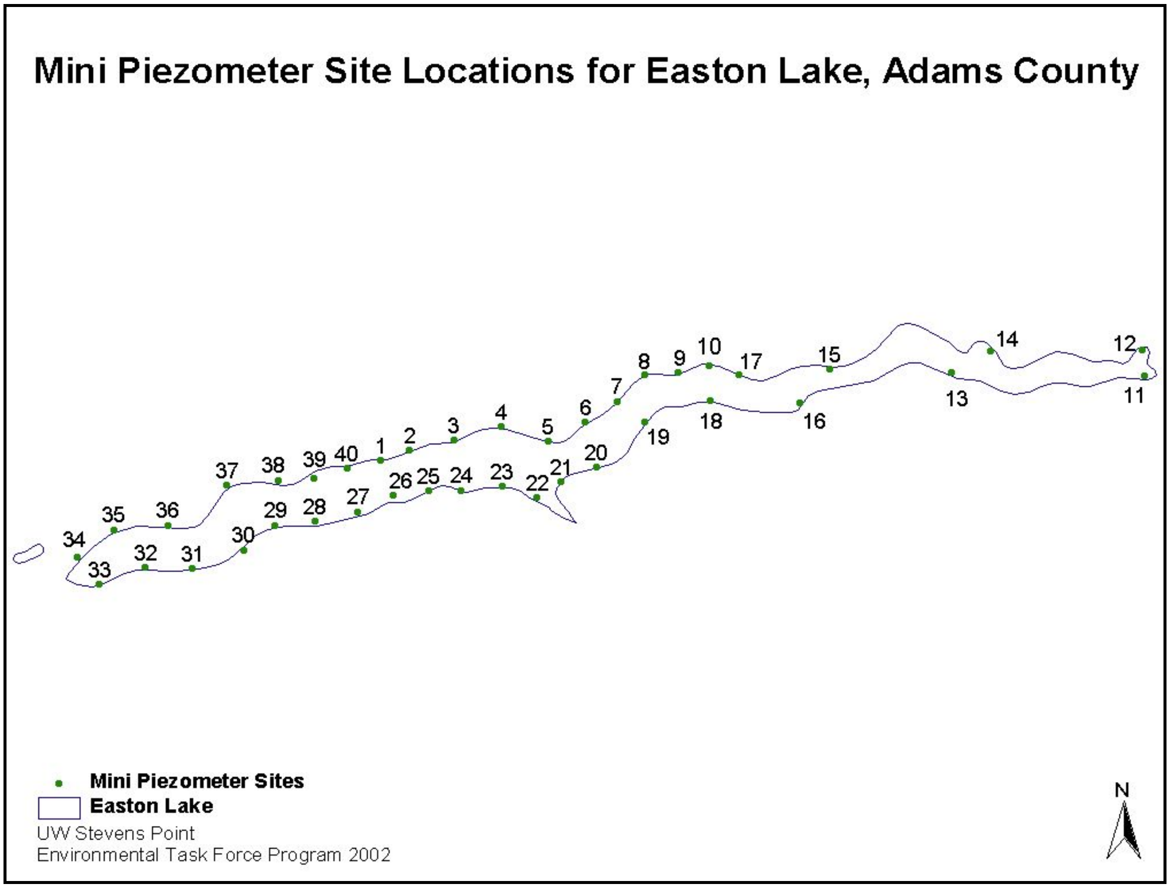
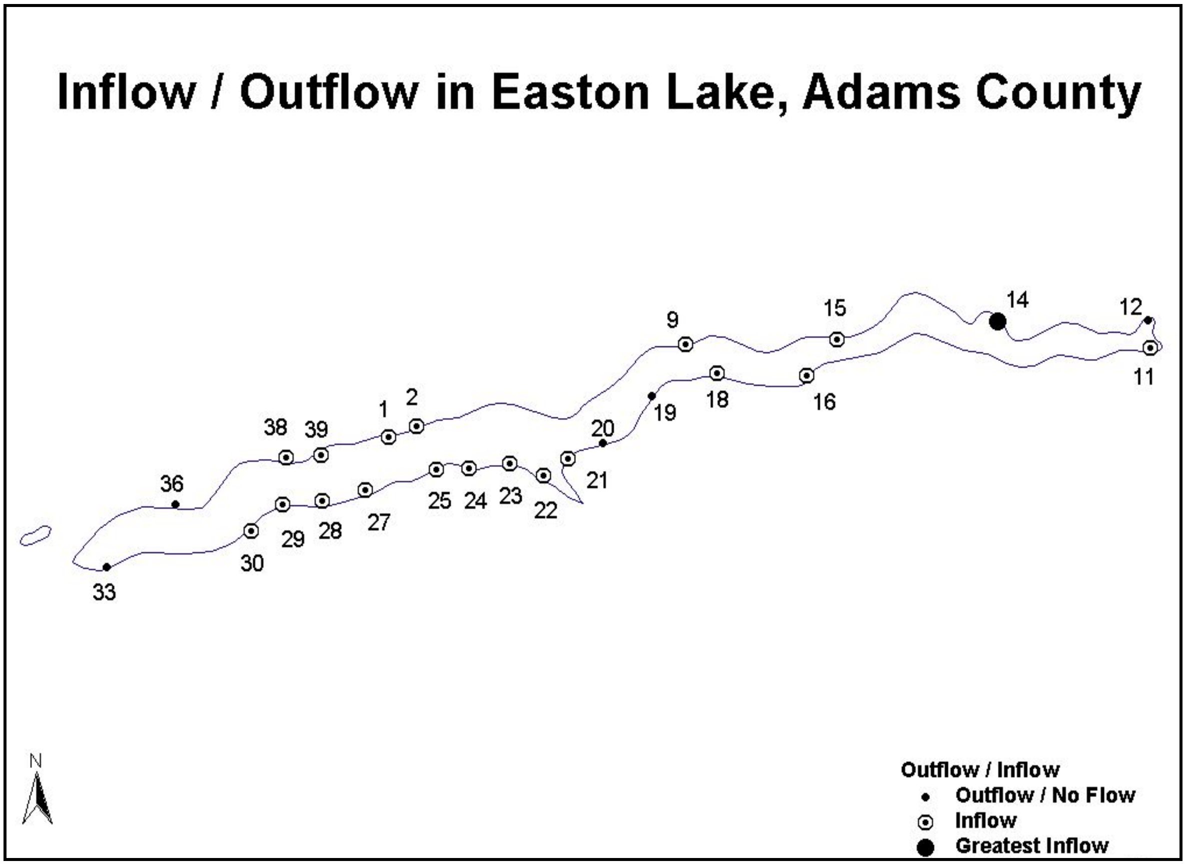


Figure 10. Mini-piezometer sample site location and IDs for shallow groundwater study in Easton Lake, Adams County.



Each of the 24 sites were evaluated for inflow, outflow, or no-flow groundwater influence (Figure 11), and samples were collected for nutrient and chloride analysis from inflow sites. The mini-piezometer sites that were designated as inflow contributed groundwater to Easton Lake. The area of greatest groundwater inflow came from the eastern shoreline of Easton Lake, although inflow did exist sporadically around the rest of the lake. The western portion of the lake exhibited no-flow due to the material put in place to prevent leakage around the dam. Concentrations of nutrients and chloride in the groundwater were used to identify possible sources of inputs. These determinations are complicated by the convergence of flow from groundwater to surface waters. Recharging groundwater from fairly large areas converges in discharge zones at surface waters.

Figure 11. Mini-piezometer sites around Easton Lake showing groundwater inflow and outflow.



Nitrate

The groundwater collected from the eastern portion of Easton Lake had nitrate concentrations less then 1 mg/L. The southwestern shoreline had several localized sites with high nitrate concentrations (Figure 12). Sites 28 and 29 had nitrate concentrations of 18.3 and 17.6 mg/L, respectively. Site 9 also had an elevated nitrate concentration of 6.1 mg/L. The average nitrate concentration entering Easton Lake, excluding sites 16, 28, and 29, was 0.5 mg/L.

The high nitrate concentrations and elevated chloride at sites 16, 28, and 29 could reflect impacts from septic systems, local lawn and garden fertilizer application, or deeper flow paths from the watershed with elevated fertilizer nitrogen and chloride. Within the watershed, regionally the nitrate concentrations average less then 2 mg/L. This would indicate that much of the nitrate that is entering Easton Lake, via groundwater, is coming from local sources.

Figure 12. Shallow groundwater (mini-piezometer) nitrate concentrations for Easton Lake, Adams County.

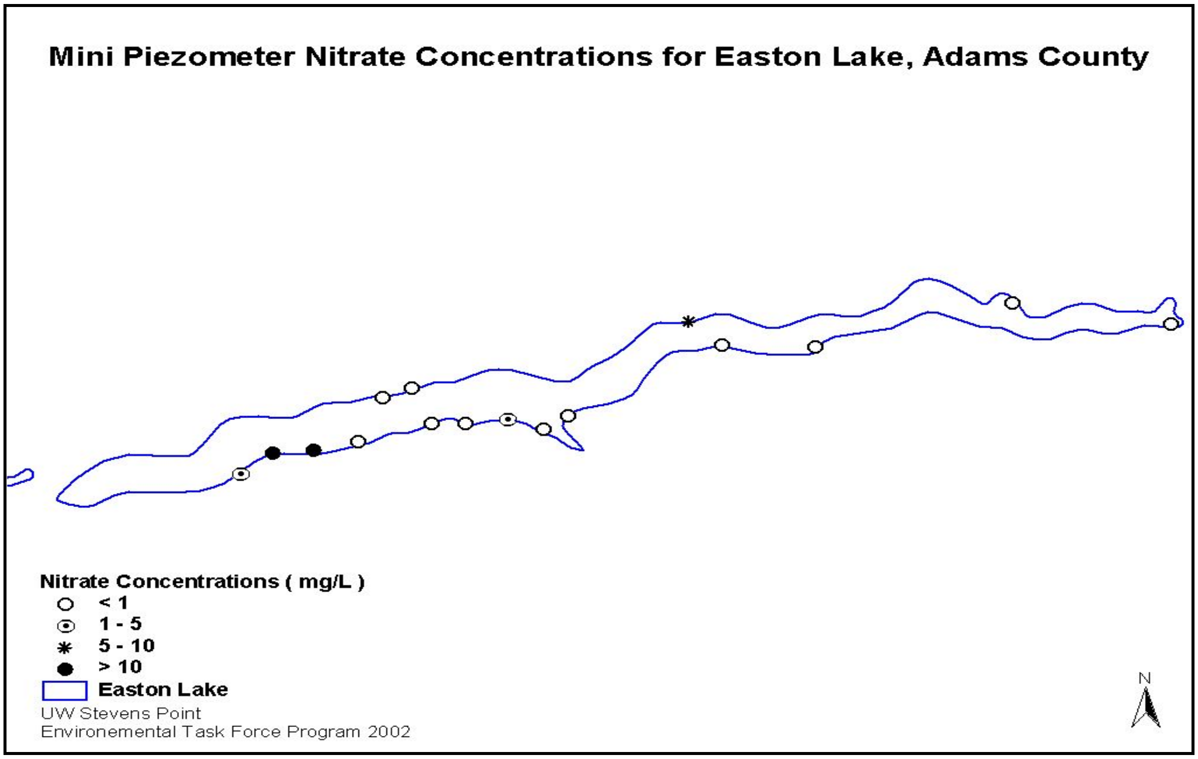
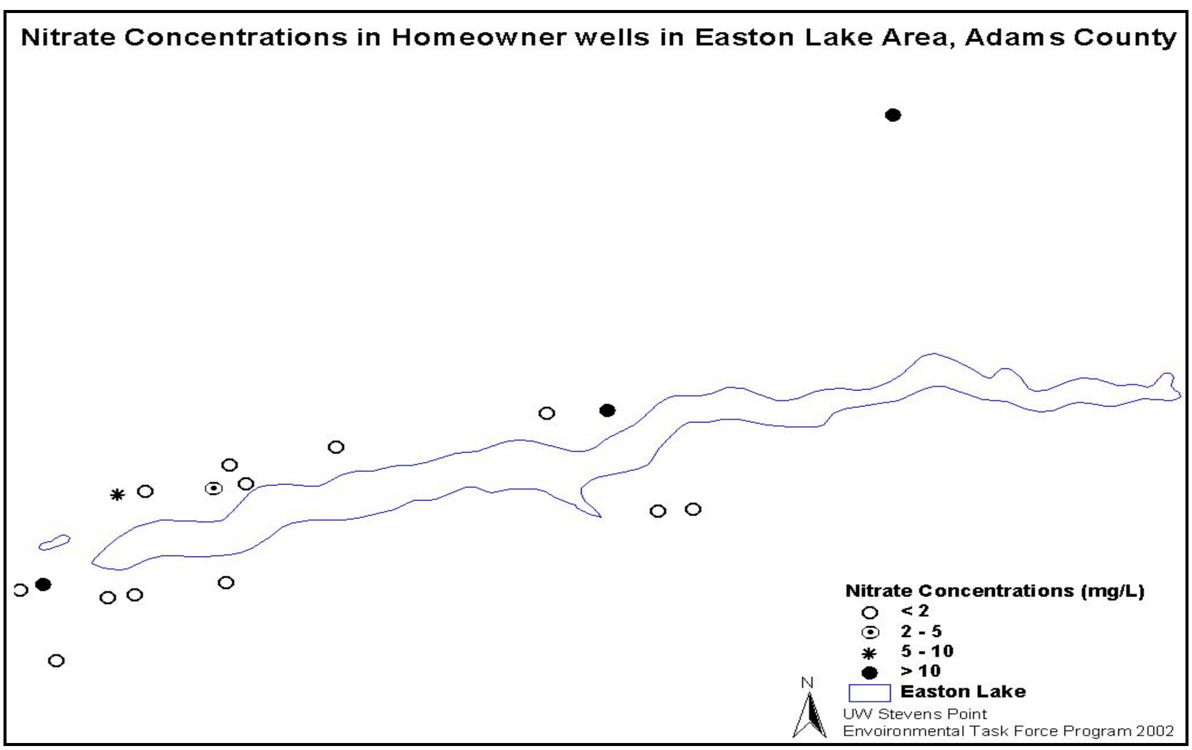


Figure 13. Nitrate concentrations in private well samples near Easton Lake, Adams County.



Chloride

Chloride is generally found in low concentrations (less than 3 mg/L) in groundwater in Adams County. Elevated chloride concentrations were found in about one-third of the mini-piezometers that were sampled. Chloride concentrations are generally higher on the western side of the Easton Lake (Figure 14). The greatest chloride concentrations were measured at sites 29 and 30, with concentrations of 13 and 28 mg/L, respectively. The northern shoreline also had elevated chloride concentrations. Sites 1, 2, and 9 all had chloride concentrations ranging between 6 and 10 mg/L.

Chloride concentrations in private wells adjacent to the lake had concentrations greater than 10 mg/L, which is not uncommon for agricultural areas in Wisconsin's central sand plain. A comparison of shallow groundwater collected from mini-piezometers to deeper groundwater collected from private wells indicate that chloride is moving to Easton Lake from both local sources and regional impacts further out in the watershed. Sources of chloride could include road salt, which is applied to nearby roads, septic influences, as well as fertilizers and animal waste.

Figure 14. Shallow groundwater chloride concentrations for Easton Lake, Adams County.

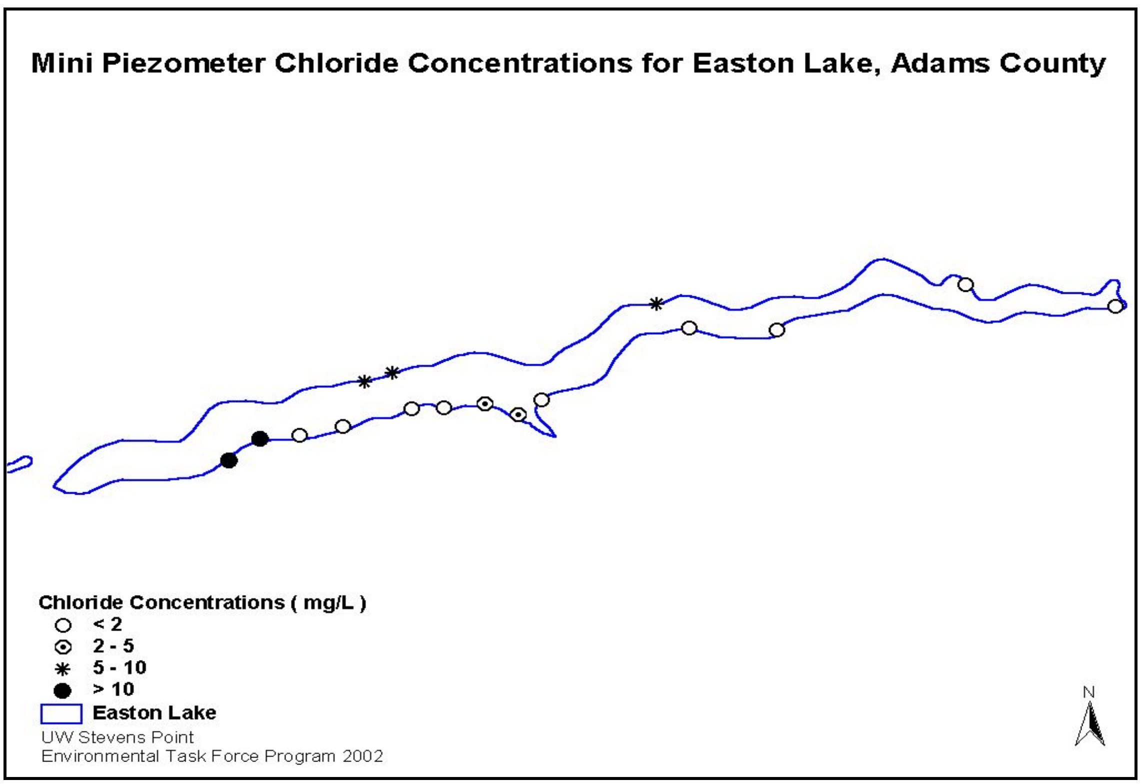
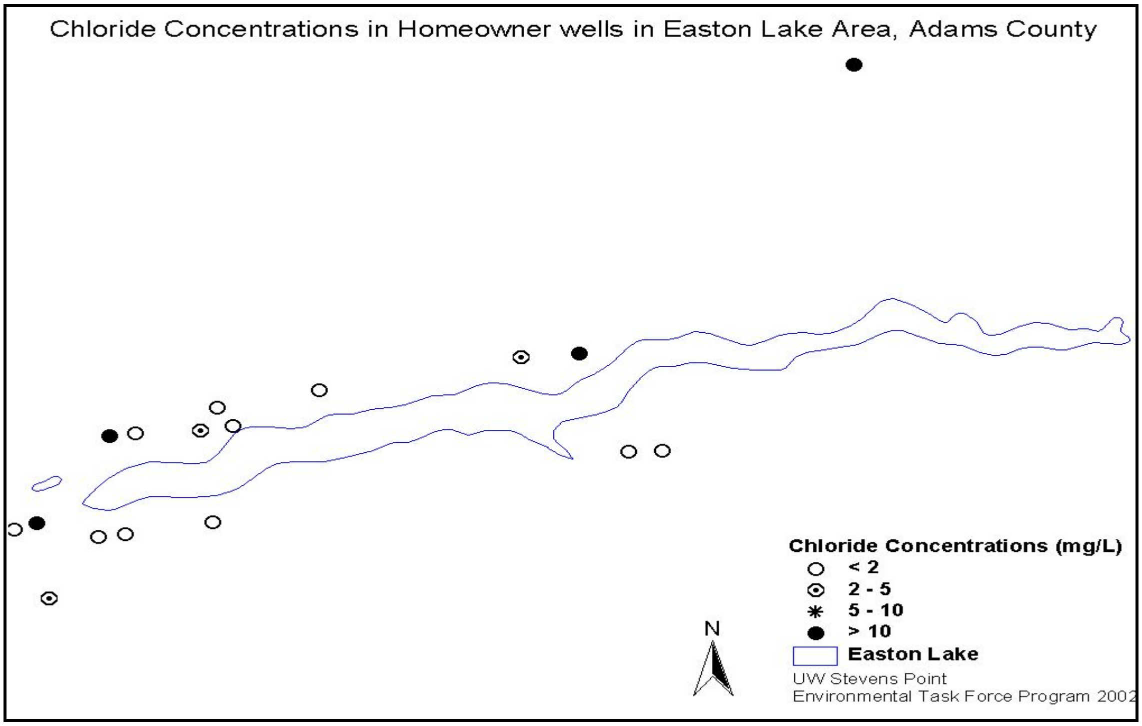


Figure 15. Deep groundwater chloride concentrations in private wells near Easton Lake, Adams County.

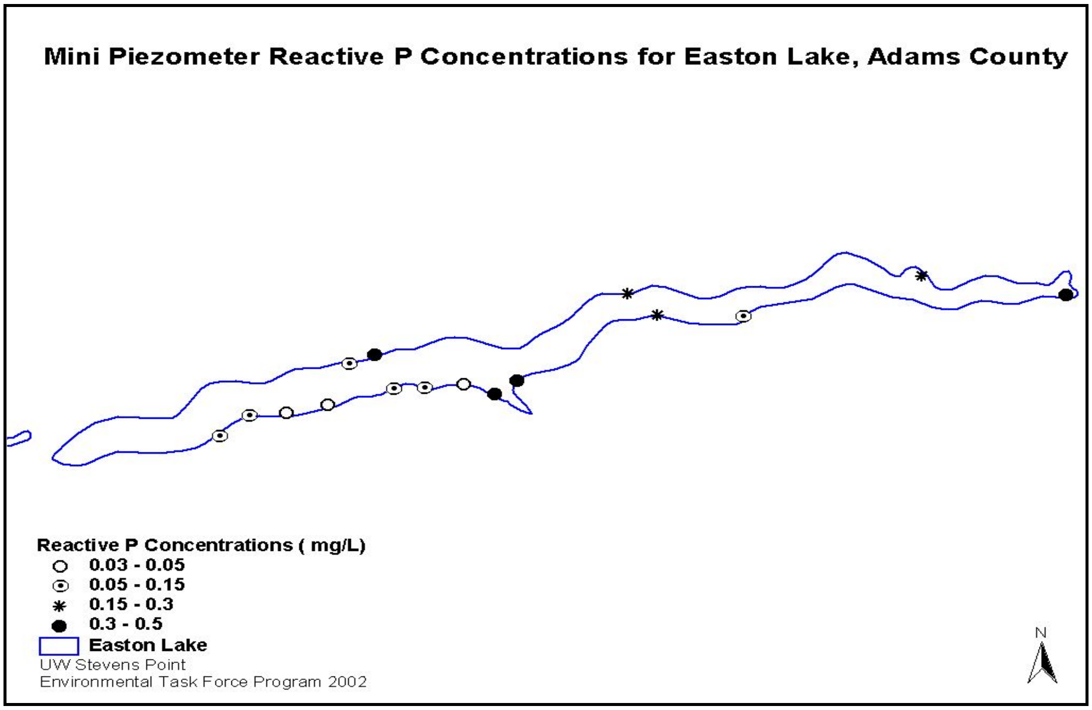


Reactive Phosphorus

Phosphorus tends to adsorb to soil particles and be held in the soil rather then leach to the groundwater. However, if the soil's capacity to hold phosphorus is exceeded, which occurs when soils have constant phosphorus loading, the phosphorus can leach into the groundwater. Examples of constant phosphorus loading include barnyards and septic drain fields. Phosphorus in shallow groundwater can also result from the decomposition of organic material.

Reactive phosphorus inflow to Easton Lake was greater than 0.03 mg/l in most of the mini- piezometer samples along shoreline (Figure 16). Phosphorus can be adsorbed by sediment, and when changes in pH, temperature, and oxygen occur, the absorbed phosphorus can re-release into the water column and become available for aquatic plant uptake.

Figure 16. Mini-piezometer reactive phosphorus concentrations for Easton Lake, Adams County.



Ammonium

Ammonium concentrations in mini-piezometer samples were relatively low on average (Figure 17). The eastern portion of the lake received higher ammonium concentrations, most likely due to the presence of organic substrate/wetlands within the eastern portion of Easton Lake. The wetlands have enriched sediments which can release ammonium into the water column. Site 11 has an ammonium concentration of 1.98 mg/L along with elevated phosphorus; however, the chloride concentrations are low. This is indicative of the natural organic matter source of ammonium.

Another source of ammonium is septic systems, although conversion of the ammonium can occur in the drainfield. Such ammonium is usually correlated with chloride and/or phosphorus. Sites 1 and 2 have ammonium concentrations of 0.54 and 0.87 mg/L, respectively. The chloride and phosphorus concentrations from these sites are elevated as well.

Reactive phosphorus and ammonium are released together during the natural process of decomposition in wetlands, creating elevated concentrations and a strong positive correlation for the constituents. Site 11, which is located in a wetland area of Easton Lake, has an ammonium concentration of 1.98 mg/L and a reactive phosphorus concentration of 0.32 mg/L. When reactive phosphorus and ammonium do not demonstrate a strong positive correlation the influence is likely something other than wetlands. Figure 18 shows all the mini-piezometer reactive phosphorus concentrations compared to the ammonium concentrations. Many of the samples with higher ammonium concentration also had relatively high phosphorus. In other cases, relatively low phosphorus concentrations were associated with the ammonium. The absence of a consistent trend between the parameters is consistent with a variety of sources of both in the shallow groundwater discharging to Easton Lake.

Figure 17. Mini-piezometer ammonium concentrations for Easton Lake, Adams County.

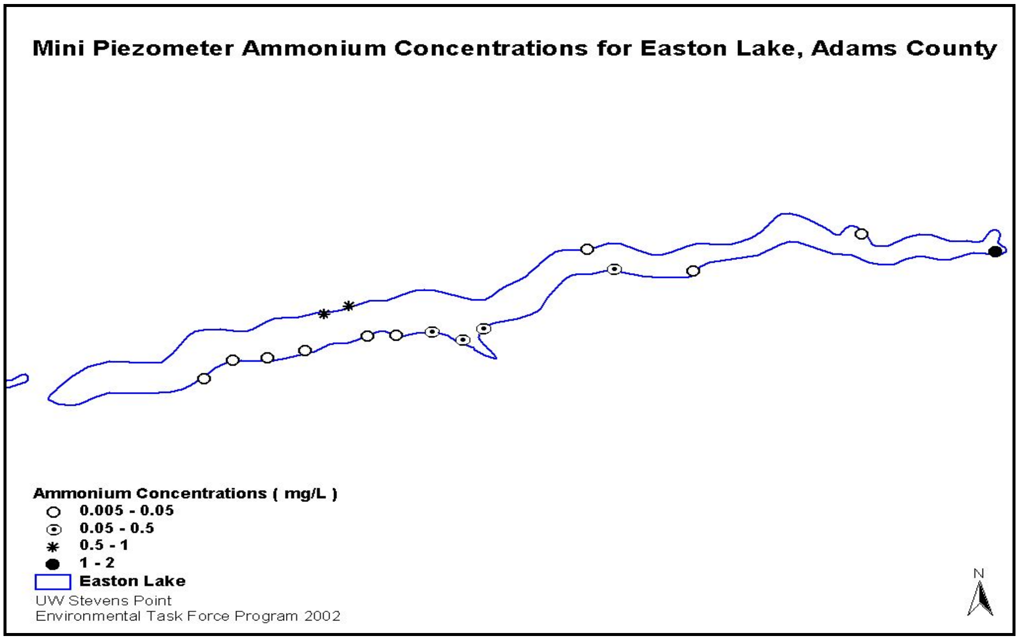
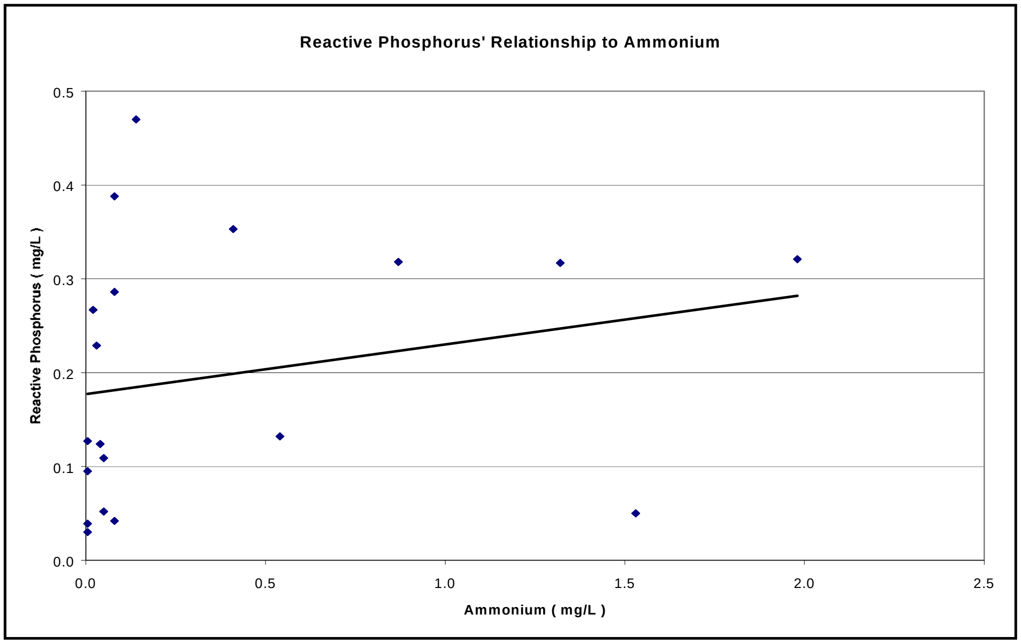


Figure 18. Mini-piezometer reactive phosphorus versus ammonium concentrations in Easton Lake.



Groundwater Summary

The groundwater evaluation performed on the perimeter of Easton Lake evaluated groundwater draining directly to the lake. Those results must be interpreted with the understanding that groundwater discharging directly to the lake is likely a small portion of the total water flow which enters the lake. The streams entering Easton Lake drain a relatively large watershed. Much of their streamflow is likely derived from groundwater, and that groundwater originates within upstream regions of the watershed. Mini-piezometer samples were analyzed for nitrate, ammonium, reactive phosphorus, and chloride. The analysis of the aforementioned constituents allowed relationships to be derived between constituents and their sources.

Sites 1, 2, 12, 22, and 36 had elevated concentrations of chloride and reactive phosphorus (Table 4). The relationship of elevated chloride and reactive phosphorus could be indicative of impacts from septic systems.

An area where there was a large release of reactive phosphorus and ammonium with minimum nitrate and chloride indicates the natural release of nutrients from wetlands (Table 5). Eastern Easton Lake possesses a large area of natural wetland buffer.

Table 4. Chloride and reactive phosphorus concentrations for Sites 1, 2, 12, 22, 36.

Site Number	Chloride (mg/L)	Reactive Phosphorus (mg/L)
1	9.0	0.132
2	6.0	0.318
12	6.0	0.388
22	5.0	0.353
36	7.0	0.050

Table 5. Reactive phosphorus and ammonium concentrations for Sites 14, 16, 24, 25, and 27.

Site Number	Reactive P (mg/L)	Ammonium (mg/L)
14	0.229	0.030
16	0.095	0.005
24	0.124	0.40
25	0.127	0.10
27	0.039	0.10

INFLOW/OUTFLOW STREAM CHARACTERISTICS

Discharge measurements and water quality samples were collected on 5 inflow sites and 1 outflow site from March 2001 to January 2002. Samples were taken during baseflow conditions and during event flow situations (see methods section). The surface watershed was divided up into 6 sub-watersheds, which corresponds to each sample point. Figure 2 shows the location of the sample points and their corresponding sub-watersheds.

Stream Site/Sub-watershed Descriptions

Land use within the surface and groundwater watersheds plays an important role in the water quality of an aquatic ecosystem. As described above, the average flow out of Easton Lake is consistent with approximately ten inches of water per year across the entire watershed. This water contacts the land prior to recharging groundwater or running into streams. According to the 1993 Wisconsin land use cover map (WDNR, WISCLAND) over half (60%) of the Easton Lake surface watershed is forested. Agriculture is the next dominant land use, comprising approximately 30% of the watershed. Grassland areas cover about 10% of the watershed. Figure 3 shows the land uses within the Easton Lake surface watershed. The surface watershed was divided into 6 sub-watersheds based on sampling sites shown in Figure 2.

Table 6. Percent land use within each sub-watershed.

Sub-Watershed	Agriculture	Grassland	Forest	Water	Wetland	Shrubland
1	9.7	8.3	78.9	0.1	3.0	
2	30.7	10.8	56.9	<0.1	1.4	0.1
3	32.0	9.1	55.2	0.1	3.6	
4	70.0	6.0	25.0	<0.1		
5	44.0	9.0	45.0	1.0	1.0	
6 (Outflow)	29.9	9.6	58.4	0.2	1.9	0.1

Sub-watershed 1

Sub-watershed 1 is a 2,211-acre sub-watershed with land use dominated by forests. Within this sub-watershed forest covers almost 80%, agricultural lands cover 10%, grasslands cover 8%, and wetlands cover approximately 3%.

Water quality results are shown in Table 7. There are relatively low concentrations of nitrogen and total suspended solids during both baseflow and events. Triazine is present during both baseflow and events. Total P is elevated during baseflow and increases significantly during events.

Table 7. Minimum, mean, and maximum water chemistry concentrations in Site 1 baseflow and event samples.

		$NO_2 + NO_3$ (N) (mg/L)	NH_4 (mg/L)	TN (mg/L)	Total P (mg/L)	SRP (mg/L)	TSS (mg/L)	Chloride (mg/L)	Triazine (ug/L)
Baseflow	**Min**	0.34	0.02	0.68	0.033	0.021		3.0	0<.05
	Average	0.94	0.16	1.89	0.071	0.034		4.3	0.108
	Max	1.88	0.39	3.10	0.132	0.060		5.5	0.190
Event	**Min**	0.20	0.02	0.56	0.027	0.008	2	0.5	0<.05
	Average	0.68	0.34	2.50	0.314	0.221	13	4.1	0.165
	Max	1.60	1.30	5.17	0.937	0.596	24	6.0	0.560

Sub-watershed 2

Sub-watershed 2 is the largest sub-watershed, covering 4,901 acres of the watershed. The land use in this sub-watershed is dominated by forests, which cover nearly 60% of the sub-watershed, while agricultural lands and grasslands cover approximately 30% and 10%, respectively.

The water quality in this sub-watershed shows some impacts, predominantly from triazine, phosphorus, and suspended solids (Table 8). These impacts are greatest during runoff events; therefore, efforts should be made to improve the management of manure, fertilizers, herbicides, and soil.

Table 8. Minimum, mean, and maximum water chemistry concentrations in Site 2 baseflow and event samples.

		$NO_2 + NO_3$ (N) (mg/L)	NH_4 (mg/L)	TN (mg/L)	Total P (mg/L)	SRP (mg/L)	TSS (mg/L)	Chloride (mg/L)	Triazine (ug/L)
Baseflow	**Min**	1.26	0.01	1.69	0.021	0.007		1.5	0<.05
	Average	1.59	0.02	1.96	0.038	0.021		2.7	0.123
	Max	1.91	0.02	2.29	0.047	0.029		4.0	0.220
Event	**Min**	1.18	0.01	1.74	0.026	0.017	3	0.5	0<.05
	Average	1.51	0.05	2.13	0.063	0.032	28	2.8	0.106
	Max	1.80	0.10	2.80	0.145	0.059	93	5.0	0.350

Sub-watershed 3

Sub-watershed 3 covers approximately 813 acres of the watershed. The land use in this sub-watershed was dominated by forests, which covers 55% of the sub-watershed, while agricultural lands cover 32%, grasslands cover 9% and wetlands cover about 4%.

Sub-watershed 3 has the poorest water quality, despite the fact that the major land use category is forest (Table 9). Effects of agriculture are seen with the triazine, which is present during both baseflow and runoff events. Total suspended solids, total P, organic N, and nitrate all have the greatest concentrations in this sub-watershed.

Table 9. Minimum, mean, and maximum water chemistry concentrations in Site 3 baseflow and event samples.

		$NO_2 + NO_3$ (N) (mg/L)	NH_4 (mg/L)	TN (mg/L)	Total P (mg/L)	SRP (mg/L)	TSS (mg/L)	Chloride (mg/L)	Triazine (ug/L)
Baseflow	**Min**	0.04	0.02	1.32	0.046	0.021		2.0	0<.05
	Average	1.08	0.05	1.55	0.064	0.036		2.7	0.123
	Max	1.79	0.08	1.79	0.087	0.050		3.5	0.220
Event	**Min**	0.70	0.01	1.62	0.053	0.048	<2	3.0	0.070
	Average	1.95	0.12	4.03	0.402	0.094	1919	6.1	0.133
	Max	5.10	0.27	7.36	1.250	0.129	9420	15.5	0.260

Sub-watershed 4

Sub-watershed 4 covers approximately 501 acres of the surface watershed. The land use in this sub-watershed was dominated agricultural lands, which cover 70% of the sub-watershed, while forests cover 25% and grasslands cover about 5%.

Sub-watershed 4 has the greatest inputs of nitrogen, mostly in the form of nitrate (Table 10). Chloride and triazine are also elevated during baseflow conditions indicating that these constituents are moving to the stream via groundwater. Land use practices to reduce the movement of land-applied chemicals to groundwater should be implemented in this sub-watershed.

Table 10. Minimum, mean, and maximum water quality concentrations in Site 4 baseflow and event samples.

		$NO_2 + NO_3$ (N) (mg/L)	NH_4 (mg/L)	TN (mg/L)	Total P (mg/L)	SRP (mg/L)	TSS (mg/L)	Chloride (mg/L)	Triazine (ug/L)
Baseflow	**Min**	6.60	0.01	7.73	0.053	0.036		11.5	0.290
	Average	7.57	0.03	8.26	0.122	0.065		13.8	0.315
	Max	8.61	0.04	8.61	0.221	0.108		15.0	0.340
Event	**Min**	2.40	0.02	2.68	0.048	0.037	<2	3.5	0.060
	Average	10.66	0.12	11.20	0.122	0.068	17	16.1	0.225
	Max	19.20	0.21	19.77	0.216	0.117	74	19.5	0.320

Sub-watershed 5

Sub-watershed 5 is comprised of approximately 1,354 acres. The land use in this sub-watershed is dominated by forests and agricultural lands, which both cover approximately 45% of the sub-watershed, while grasslands cover 9% and wetlands and water both cover about 1%.

Sub-watershed 5 has the lowest concentrations of phosphorus (Table 11). However, nitrogen is quite elevated, mostly in the form of organic N. Chloride concentrations are slightly elevated, indicating the nutrient inputs are partially from land use practices. Triazine was detected in all samples.

Table 11. Minimum, mean, and maximum water chemistry concentrations in Site 5 baseflow and event samples.

		$NO_2 + NO_3$ (N) (mg/L)	NH_4 (mg/L)	TN (mg/L)	Total P (mg/L)	SRP (mg/L)	TSS (mg/L)	Chloride (mg/L)	Triazine (ug/L)
Baseflow	**Min**	1.84	0.01	2.37	0.023	0.034		2.5	0.120
	Average	2.27	0.17	2.67	0.063	0.048		3.5	0.170
	Max	2.60	0.39	2.86	0.107	0.055		4.5	0.220
Event	**Min**	1.90	0.01	2.19	0.044	0.013	<2	3.5	0.060
	Average	2.16	0.06	2.62	0.094	0.045	12	3.9	0.180
	Max	2.60	0.11	2.83	0.163	0.087	33	4.5	0.320

Sub-watershed 6

Sub-watershed 6 is located below the outflow of Easton Lake. The land area draining to sample site 6 is comprised of the entire watershed, which totals approximately 9,800 acres. The water quality samples show that some nitrogen, phosphorus, and solids are leaving Easton Lake, but much of what is entering is staying in the lake (Table 12). Phosphorus concentrations are above 0.30 mg/L during all sampling events. Triazine concentrations that enter Easton Lake do not all stay within the lake, but can actually be measured in the outflow.

Table 12. Minimum, mean, and maximum water chemistry concentrations in Site 6 baseflow and event samples.

		$NO_2 + NO_3$ (N) (mg/L)	NH_4 (mg/L)	TN (mg/L)	Total P (mg/L)	SRP (mg/L)	TSS (mg/L)	Chloride (mg/L)	Triazine (ug/L)
Baseflow	**Min**	2.50	0.05	2.77	0.074	0.046		3.5	
	Average	2.50	0.05	2.77	0.074	0.046		3.5	
	Max	2.50	0.05	2.77	0.074	0.046		3.5	
Event	**Min**	1.80	0.01	2.19	0.044	0.027	2	3.5	0<.05
	Average	2.28	0.11	2.72	0.098	0.058	14	4.0	0.201
	Max	2.70	0.30	3.24	0.251	0.141	55	4.5	0.580

WATER QUALITY MODELING

The land use in the watershed and estimates of flow were used to understand their influence on water quality in Easton Lake. Studies in Wisconsin have shown that land use influences the quantity of phosphorus lost from land to water. As described above, phosphorus is important to water quality because it is usually one of the most limiting factors to algal growth. As phosphorus concentrations increase, algal concentrations and related forms of biological productivity can increase.

Sources of phosphorus to Easton Lake were estimated based on the different land uses in the watershed and corresponding phosphorus release to water described in previous studies. Table 13 shows the land use by sub-watershed and corresponding phosphorus loads.

The phosphorus loads estimated from different land uses were combined with estimates of stream flow and lake volume to predict the phosphorus concentrations in Easton Lake. A variety of approaches are available to estimate in-lake phosphorus, and we used the Wisconsin Lake Modeling Suite (WILMS) developed by the Wisconsin Department of Natural Resources (2002).   WILMS is a group of lake water quality models combined with tools to estimate the phosphorus contribution from different land uses.

Table 13. Area of each sub-basin (in acres) within different land use categories (based on DNR WILMS Landuse).

Subbasin	1	2	3	4	5	6
Agriculture	208.4	1499.0	265.8	339.7	593.5	0.6
Grassland	192.6	539.2	77.0	24.6	118.1	0.0
Forest	1742.7	2796.6	447.1	132.0	611.2	2.5
Open Water	1.9	3.8	0.6	0.0	15.2	0.0
Wetland	64.4	65.7	28.4	0.0	17.7	0.0
Other	0.0	5.1	0.0	0.6	0.0	0.0

The lake water quality models in WILMS show that as lake residence time decreases, more of the phosphorus that enters the lake will contribute to the in-lake water phosphorus concentration. Deeper lakes, which often have long water residence times, can have a substantial fraction of the phosphorus settle and become relatively unavailable for use by plants and algae. Shallow lakes such as Easton Lake; do not allow the phosphorus to be removed from the system and most of the phosphorus which enters the lake likely remains available for use by plants and algae.

The lake water quality models in WILMS use estimates of water flow, lake size, and phosphorus contributed from different land uses to estimate the phosphorus concentration in the lake. The results of applying simulation models which link land use and in-lake phosphorus concentration are summarized in Table 14 below. In general, the phosphorus concentration estimated was similar to that measured when we used phosphorus transfer from land to water was lower than the statewide “most likely” values. Based on the WILMS simulations, it appears that the phosphorus concentration in Easton Lake is more accurately predicted using land use phosphorus transfer rates that are lower than those typical for much of Wisconsin. Although this could reflect better land management in parts of the watershed, it is probably also linked to the relatively permeable soils and high infiltration rates in many areas of Adams County. Phosphorus delivery to surface water is generally reduced when more water infiltrates rather than runs off directly carrying sediment and vegetation. Although groundwater can contribute phosphorus to the lake and the results of the water testing suggest areas of relatively high groundwater phosphorus concentration, phosphorus delivery to surface water can be increases with runoff of vegetation and sediment.

Table 14. Estimated phosphorus concentrations using various modeling techniques.

Model	**Scenario 1 Prediction**	**Scenario 2 Prediction**	**Phosphorus Concentration Predicted**	**Phosphorus Concentration Measured in 2001**
Phosphorus Loading Estimated (pounds/year) *	3153	1618		
1 (Walker, 1977)	118	67	Growing Season Mean	71
2 (Canfield, Bachman, 1981)	92	52	Spring Overturn	54
3 (Reckhow, 1979)	115	59	Growing Season Mean	71
	Uses the State-wide “most likely” values for land use	Uses the 50% of the “most likely” values for agriculture, grassland and forested areas		

- Based on export from agricultural land, grassland, forest, wetlands, and atmospheric deposition on surface water. Does not separately include groundwater or septic effluent discharge (assuming 30 homes w/ 2 residents and 50% occupancy, an upper estimate on phosphorus from septic systems would be 30 pounds per year, or a relatively small percentage of the total phosphorus load estimated for the lake).
- Land Use Export Coefficients (coefficients halved for scenario 2 to reflect greater infiltration and reduced runoff for soils in the Easton Lake watershed).

Table 15. Land use coefficients for several modeling scenarios.

Land Use	Annual Phosphorus Export (pounds/acre-year)	
	Scenario 1	Scenario 2
Agriculture	0.8	0.4
Grassland	0.3	0.15
Forest	0.1	0.05
Open Water	0.3	0.3
Wetland	0.1	0.1
Other	0.3	0.3

The water quality modeling does suggest that the phosphorus entering Easton Lake is consistent with the land use in the watershed. The results indicate phosphorus loading to the lake could exceed 1,500 pounds of phosphorus per year and much of that could reasonably be attributed to export anticipated from the land use in the watershed. Other sources of phosphorus to Easton Lake include recycling of phosphorus already in the lake sediments into the water column through plant uptake and release. The sediment evaluation showed deposits of sediment within the lake and abundant macrophyte growth.

This watershed-based water quality model shows how nutrients from the watershed impact nutrient levels in a lake. Although these are preliminary water quality simulations, in that they do not account for local variations in soils and management practices, they do suggest that reductions in nutrient loss from the watershed is likely to reduce nutrient levels in the lake.

CONCLUSIONS AND RECOMMENDATIONS

Relatively high groundwater recharge rates and the large watershed to lake area results in high flow through Easton Lake and a short average water residence time.

Temperature profiles in Easton Lake confirm that the lake is not strongly stratified. Variations in dissolved oxygen vertically do occur, apparently reflecting oxygen depletion rate near the organic-rich sediments, and production of oxygen through photosynthesis.

Phosphorus concentrations in Easton Lake averaged 0.07 mg/L during the testing. This concentration while relatively high is similar to that found in impoundments in Wisconsin. Much of the phosphorus was dissolved and reactive, suggesting it is available for biological uptake. The abundance of aquatic plants and attached and filamentous algae is supported by these phosphorus concentrations.

Phosphorus is entering Easton Lake from all of its tributaries in both dissolved and total forms. Sub-watershed 3 has the greatest concentrations of total phosphorus and suspended sediment. It is recommended that best management practices designed to keep soil in place on the land be implemented and that manure management be utilized in all sub-watersheds. Reducing surface runoff to tributaries through efforts to increase upland infiltration and establish stream buffers should also reduce phosphorus loading.

Groundwater flow into the lake was examined for nutrients and chloride. Elevated nutrients and chloride in some locations shows the importance of local land use on water quality. Steps should be taken to reduce nutrient inputs from septic systems and lawn/garden fertilizers.

Although this study did not evaluate relative contributions of local groundwater and tributary inflow, it is likely that most of the flow into the lake enters through the tributaries. Greatest concentrations of nitrate and chloride were found in the water sampled from sub-watershed 4. Best management practices to reduce groundwater inputs of nutrients are recommended.

Triazine was detected in the water samples from all the tributaries. Care should be taken to reduce the use of this herbicide. Drinking water wells within the Easton Lake watershed should be tested for triazine. Triazine was the only pesticide that was measured in this study, so it should be noted that it is possible that others are in the groundwater and surface water in Easton Lake and its tributaries.

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Table Number?

DATE	Secchi	Cond	pH	Total Hardness	Alk.	DRP	TP	NH4	TKN	$N0_2+NO_3$	TN	CL	ChlA
Min	**1.0**	**211**	**7.45**	**104**	**94**	**0.01**	**0.04**	**0.01**	**0.06**	**1.67**	**2.21**	**3.7**	**0.05**
Max	**8.0**	**258**	**8.92**	**136**	**116**	**0.10**	**0.16**	**0.24**	**1.30**	**2.65**	**3.03**	**4.5**	**18.70**
Mean	**6.5**	**243**	**8.41**	**119**	**107**	**0.04**	**0.07**	**0.08**	**0.42**	**2.19**	**2.61**	**4.2**	**4.47**
Summer Ave	6.5	243	8.43	120	108	0.04	0.07	0.08	0.45	2.12	2.56	4.2	4.47