Review of Hagerman Lake Water Quality

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Date: October 15, 2015

WHITE WATER ASSOCIATES, INC.

Review of Lake Water Quality

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Review of Hagerman Lake Water Quality

Prepared By Angie Stine, B.S., Aquatic Biologist, White Water Associates, Inc.

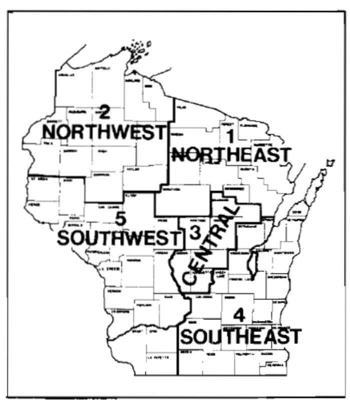
Introduction

Hagerman Lake is located in Iron County, Michigan. It is a 585 acre lake with a maximum depth of 54 feet. The purpose of this study is to develop baseline of water quality information the lake. This will allow assessment of changes in lake water quality and or biology in the future. Some water quality data was available from the USGS (2013) that was collected in 2007. White Water Associates collected data from Hagerman Lake in 2010, 2013, and 2015. This report updates the 2013 report with data collected by White Water Associates in 2015. The 2015 lab data are included as Appendix A.

Comparison of Hagerman Lake with other datasets

Lillie and Mason's *Limnological Characteristics of Wisconsin Lakes* (1983) are a good source to compare lakes within our region to a subset of lakes that have been sampled in Wisconsin. Wisconsin is divided into five regions of sampling lakes. Because of its proximity, Hagerman Lake can be compared to the Northeast region of Wisconsin (Figure 1).

Figure 1. Wisconsin regions in terms of water quality.



Temperature

Measuring the temperature of a lake at different depths will determine the influence it has on the physical, biological, and chemical aspects of the lake. Lake water temperature influences the rate of decomposition, nutrient recycling, lake stratification, and dissolved oxygen (D.O.) concentration. Temperature can also affect the distribution of fish species throughout a lake. Figure 2 presents several water temperature profiles for Hagerman Lake. In May, the temperature stayed constant from the surface to the bottom, which is an indication of spring overturn and thorough mixing of the lake. The August temperature levels show summer stratification. In September 2010, the lake showed no stratification up to 10 meters, which is an indication of fall overturn. On September 9, 2015, temperature stratification was still evident.

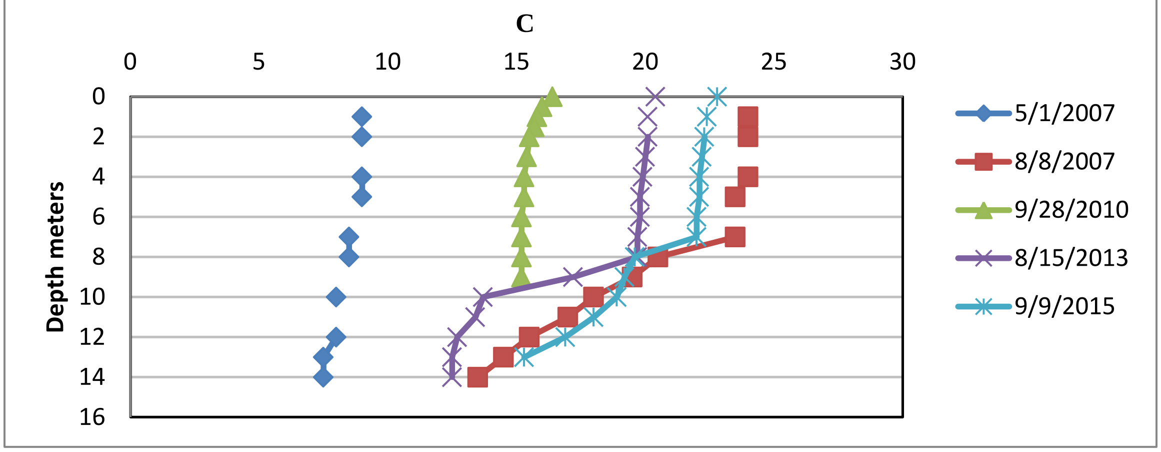


Figure 2. Hagerman Lake temperature profile.

Dissolved Oxygen

The dissolved oxygen (D.O.) content of lake water is vital in determining presence of fish species and other aquatic organisms. Dissolved oxygen also has a strong influence on the chemical and physical conditions of a lake. The amount of dissolved oxygen is dependent on the water temperature, atmospheric pressure, and biological activity. Oxygen levels are increased by aquatic plant photosynthesis, but reduced by respiration of plants, decomposer organisms, fish, and invertebrates. The amount of dissolved oxygen available in a lake, particularly in the deeper parts of a lake, is critical to overall health. D.O. levels were the highest in May of 2007, with 12.3 mg/L due to spring turnover (Figure 3). The D.O. levels tend to be between 8 and 9 mg/L and taper off to lower concentrations between 7 and 9 meters.

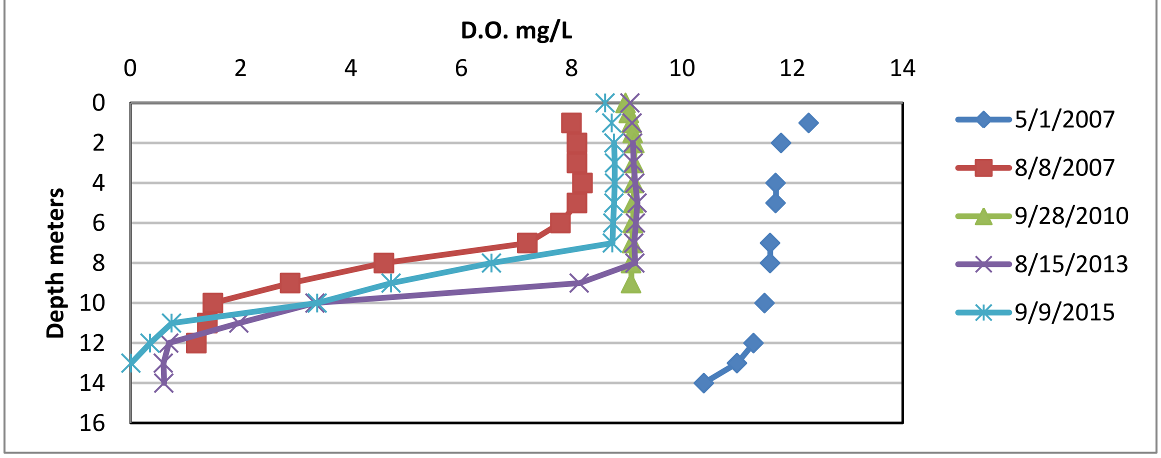


Figure 3. Hagerman Lake dissolved oxygen profile.

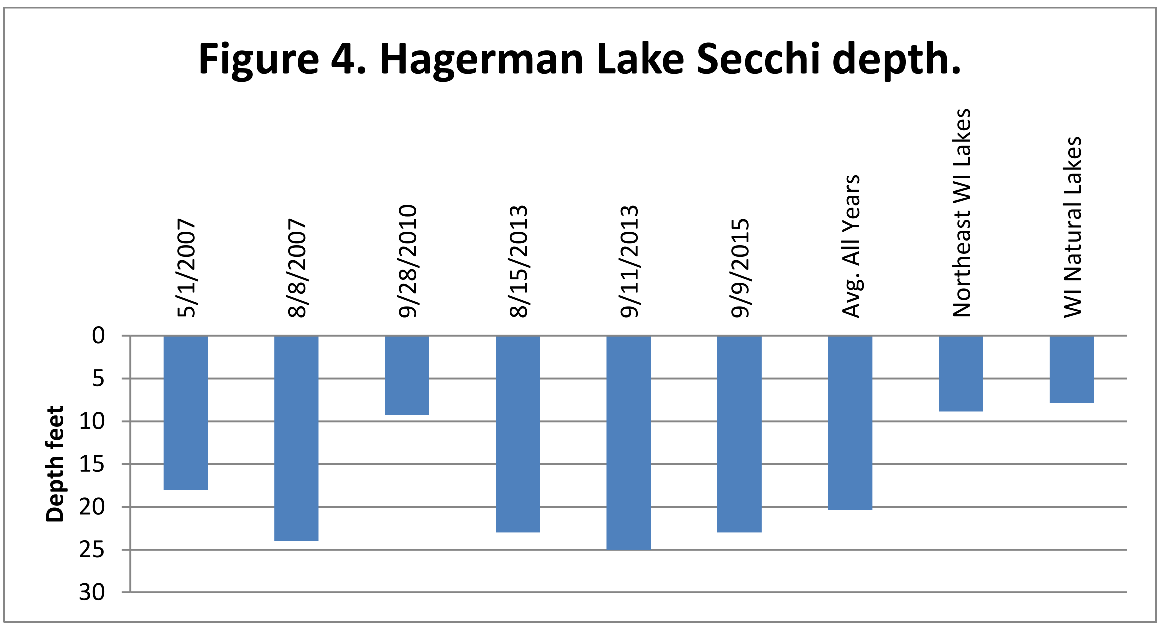
Water Clarity

Water clarity has two main components: turbidity (suspended materials such as algae and silt) and true color (materials dissolved in the water) (Shaw et al., 2004). Water clarity gives an indication of the overall water quality in a lake. Water clarity is typically measured using a Secchi disk (black and white disk) that is lowered into the water column on a tether. In simple terms, the depth at which the disk is no longer visible is recorded as the Secchi depth.

Figure 4 shows the Secchi depths from 2007, 2010, 2013, and 2015. The shallowest Secchi depth was 9.25 feet in 2010, and the deepest reading was at 25 feet in 2013 (Figure 4). According to Table 1, Hagerman Lake is "very good" with respect to water clarity.

Table 1. Water clarity index (Shaw et al., 2004).

Water clarity	Secchi depth (ft.)
Very poor	3
Poor	5
Fair	7
Good	10
Very good	20
Excellent	32



Turbidity

Turbidity is another measure of water clarity, but is caused by suspended particulate matter rather than dissolved organic compounds (Shaw et al., 2004). Particles suspended in the water dissipate light and reduce the depth at which the light can penetrate. This affects the depth at which plants can grow. Turbidity also affects the aesthetic quality of water. Water that runs off the watershed into a lake can increase turbidity by introducing suspended materials. Turbidity caused by algae is the most common reason for low Secchi readings (Shaw et al., 2004). In terms of biological health of a lake ecosystem, measurements less than 10 Nephelometric Turbidity Units (NTU) represent healthy conditions for fish and other organisms. Hagerman Lake turbidity has not been tested, and could be included in future water quality sampling.

Water Color

Color of lake water is related to the type and amount of dissolved organic chemicals. Its main significance is aesthetics, although it may also influence light penetration and in turn affect aquatic plant and algal growth. Many lakes have naturally occurring color compounds from decomposition of plant material in the watershed (Shaw et al., 2004). Units of color are determined from the platinum-cobalt scale and are therefore recorded as Pt-Co units. Shaw states that a water color between 0 and 40 Pt-Co units is low. Hagerman Lake color was analyzed 8/8/2007 and was below detection level.

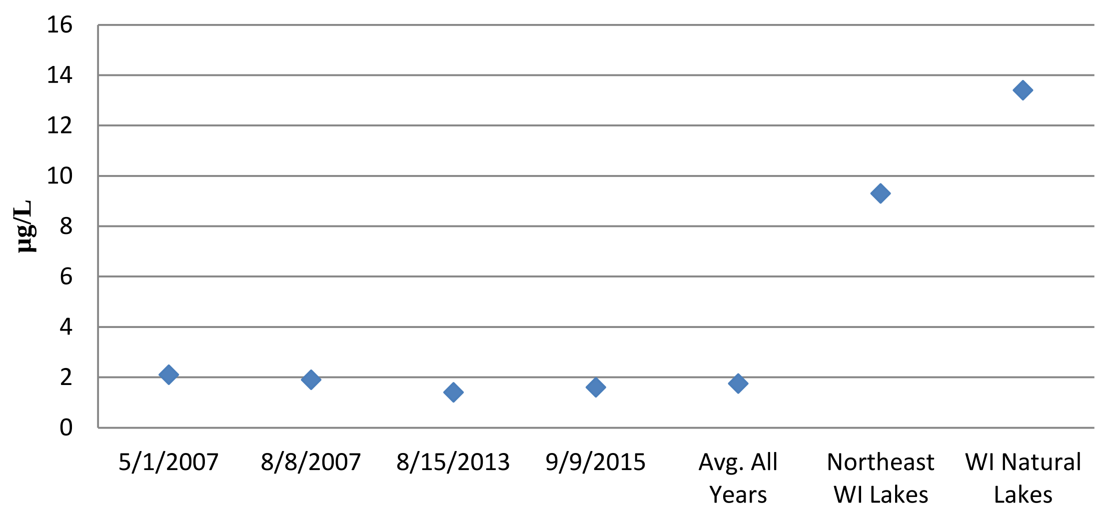
Water Level

Water levels have not been monitored on Hagerman Lake and could be included in future monitoring.

Chlorophyll *a*

Chlorophyll *a* is the photosynthetic pigment that makes plants and algae green. Chlorophyll *a* in lake water is therefore an indicator of the amount of algae. Chlorophyll *a* concentrations greater than 10 µg/L are perceived as a mild algae bloom, while concentrations greater than 20 µg/L are perceived as a nuisance. Chlorophyll *a* values were below nuisance levels and well below the average levels for Wisconsin natural lakes (Figure 5).

Figure 5. Hagerman Lake chlorophyll a.



Phosphorus

In more than 80% of Wisconsin's lakes, phosphorus is the key nutrient affecting the amount of algae and plant growth. If phosphorus levels are high, excessive aquatic plant growth can occur.

Phosphorus originates from a variety of sources, many of which are related to human activities. Major sources include human and animal wastes, soil erosion, detergents, septic systems and runoff from farmland or lawns (Shaw et al., 2004). Phosphorus provokes complex reactions in lakes. An analysis of phosphorus often includes both soluble reactive phosphorus and total phosphorus. Soluble reactive phosphorus dissolves in the water and directly influences plant growth (Shaw et al., 2004). Its concentration varies in most lakes over short periods of time as plants take it up and release it. Total phosphorus is considered a better indicator of a lake's nutrient status than soluble reactive phosphorus because its levels remain more stable (Shaw et al., 2004). Total phosphorus includes soluble phosphorus and the phosphorus in plant and animal fragments suspended in lake water. Ideally, soluble reactive phosphorus concentrations should be 10 µg/L or less at spring turnover to prevent summer algae blooms (Shaw et al., 2004). A concentration of total phosphorus below 20 µg/L for lakes should be maintained to prevent nuisance algal blooms (Shaw et al., 2004).

Hagerman Lake total phosphorus (Figure 6) values were considered "good to very good," and are in comparison with the Northeast region Wisconsin values. It would be beneficial for Hagerman Lake to monitor total phosphorus on a routine basis. June 2009, the total phosphorus was high correlating to an algal bloom. The surface total phosphorus in 2013 and 2015 were below the detection limit (< 10 µg/L).

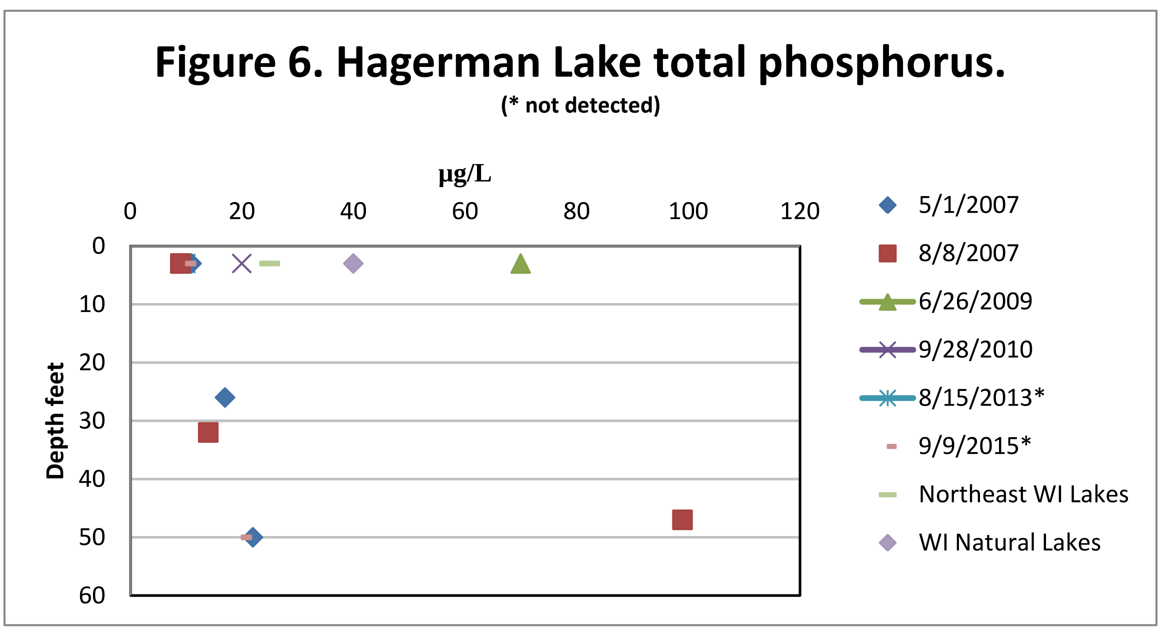
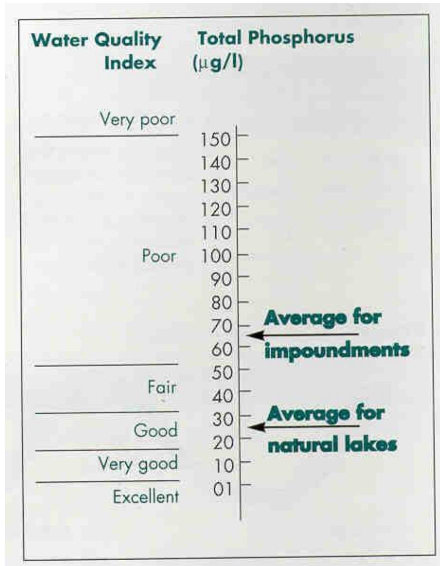


Figure 7. Total phosphorus concentrations for Wisconsin's natural lakes and impoundments (Shaw et al., 2004).



Trophic State

Trophic state is another indicator of water quality (Carlson, 1977). Lakes can be divided into three categories based on trophic state – oligotrophic, mesotrophic, and eutrophic. These categories reflect a lake's nutrient and clarity levels (Shaw et al., 2004).

Researchers use various methods to calculate the trophic state of lakes. Common characteristics used to make the determination are: total phosphorus (important for algae growth), chlorophyll *a* concentration (a measure of the amount of algae present), and Secchi disk readings (an indicator of water clarity) (Shaw et al., 2004) (Table 2).

Table 2. Trophic classification of Wisconsin Lakes based on chlorophyll *a*, water clarity measurements, and total phosphorus values (Shaw et al., 2004).

Trophic class	Total phosphorus µg/L	Chlorophyll *a* µg/L	Secchi Disk (ft.)
Oligotrophic	3	2	12
	10	5	8
Mesotrophic	18	8	6
	27	10	6
Eutrophic	30	11	5
	50	15	4

Trophic State Index (TSI) values for Hagerman Lake are presented in Figure 8. On average, Hagerman Lake is classified as "oligotrophic" based on these TSI values (Table 3). It would be beneficial to monitor

Secchi depth, chlorophyll *a*, and total phosphorus on a routine basis to see if there are any trends. On average, Hagerman Lake is classified as "oligotrophic" (Figure 8) (Table 3). Comparing 2013 and 2015 TSI shows little change. Levels were non-detectable (< 10 µg/L) for total phosphorus at the surface in 2013 and 2015.

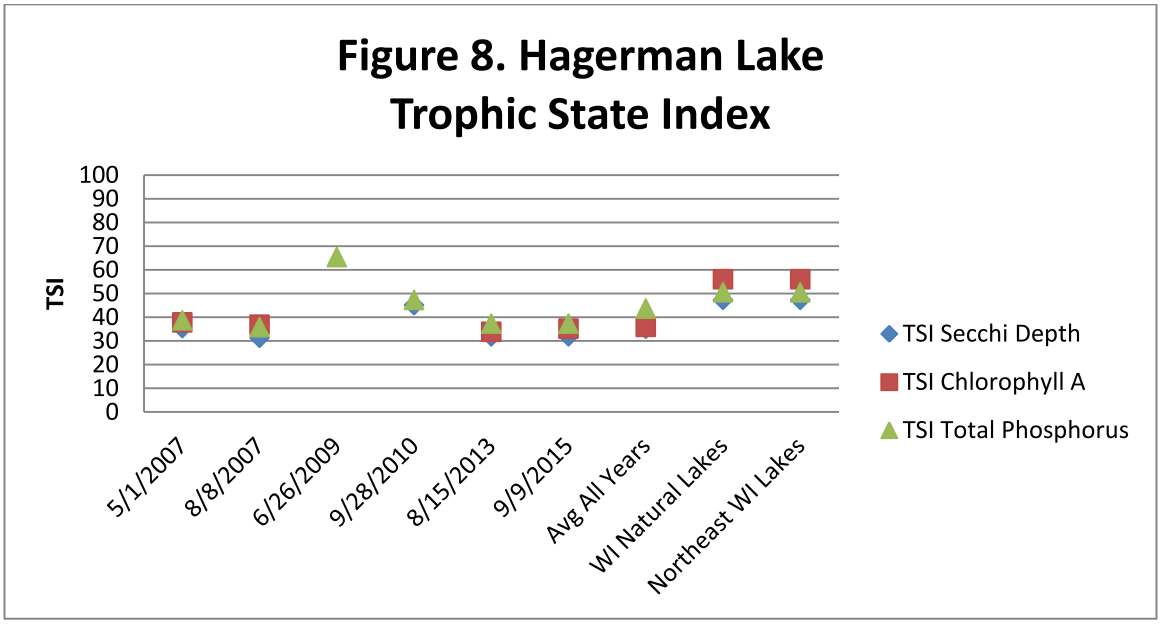


Table 3. Trophic State Index.	
30-40	**Oligotrophic:** clear, deep water; possible oxygen depletion in lower depths; few aquatic plants or algal blooms; low in nutrients; large game fish usual fishery
40-50	**Mesotrophic:** moderately clear water; mixed fishery, esp. panfish; moderate aquatic plant growth and occasional algal blooms; may have low oxygen levels near bottom in summer
50-60	**Mildly Eutrophic:** decreased water clarity; anoxic near bottom; may have heavy algal bloom and plant growth; high in nutrients; shallow eutrophic lakes may have winterkill of fish; rough fish common
60-70	**Eutrophic:** dominated by blue-green algae; algae scums common; prolific aquatic plant growth; high nutrient levels; rough fish common; susceptible to oxygen depletion and winter fishkill
70-80	**Hypereutrophic:** heavy algal blooms through most of summer; dense aquatic plant growth; poor water clarity; high nutrient levels

(WDNR October 2015)

Nitrogen

Nitrogen is second only to phosphorus as an important nutrient for aquatic plant and algae growth (Shaw et al., 2004). Human activities on the landscape greatly influence the amount of nitrogen in a lake. Nitrogen may come from lawn fertilizer, septic systems near the lake, or from agricultural activities in the watershed. Nitrogen may enter a lake from surface runoff or groundwater sources.

Nitrogen exists in lakes in several forms. Hagerman Lake was analyzed for total Kjeldahl nitrogen (Figure 9), total nitrogen (Figure 10), nitrate-nitrite (Figure 11), organic nitrogen (Figure 12) and ammonium (not detected 9/28/2010 and had a value of 0.02 mg/L at the epilimnion and not detected at the hypolimnion 9/9/2015). Nitrogen is a major component of all organic (plant and animal) matter. Decomposing organic matter releases ammonia, which is converted to nitrate if oxygen if present (Shaw et al., 2004). All inorganic forms of nitrogen can be used by aquatic plants and algae (Shaw et al., 2004). If these inorganic forms of nitrogen exceed 0.3 mg/L (as N) in spring, there is sufficient nitrogen to support summer algae blooms (Shaw et al., 2004). Elevated concentrations of ammonium, nitrate, and nitrite, derived from human activities, can stimulate or enhance the development, maintenance and proliferation of primary producers (phytoplankton, benthic algae, macrophytes), contributing to the widespread phenomenon of the cultural (human-made) eutrophication of aquatic ecosystems (Camargo et al., 2007). The nutrient enrichment can cause important ecological effects on aquatic communities, since the overproduction of organic matter, and its subsequent decomposition, usually lead to low dissolved oxygen concentrations in bottom waters, and sediments of eutrophic and hypereutrophic aquatic ecosystems with low turnover rates (Camargo et al., 2007). The nitrogen level in Hagerman Lake is low and below the average Northeast Wisconsin Lakes (Figure 10 and 12).

Figure 9. Hagerman Lake total Kjldahl nitrogen.

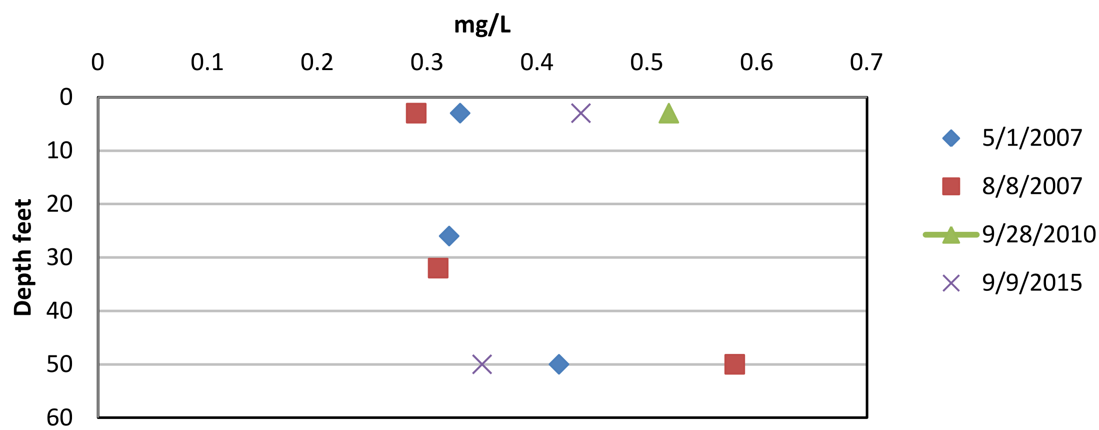


Figure 10. Hagerman Lake total nitrogen.

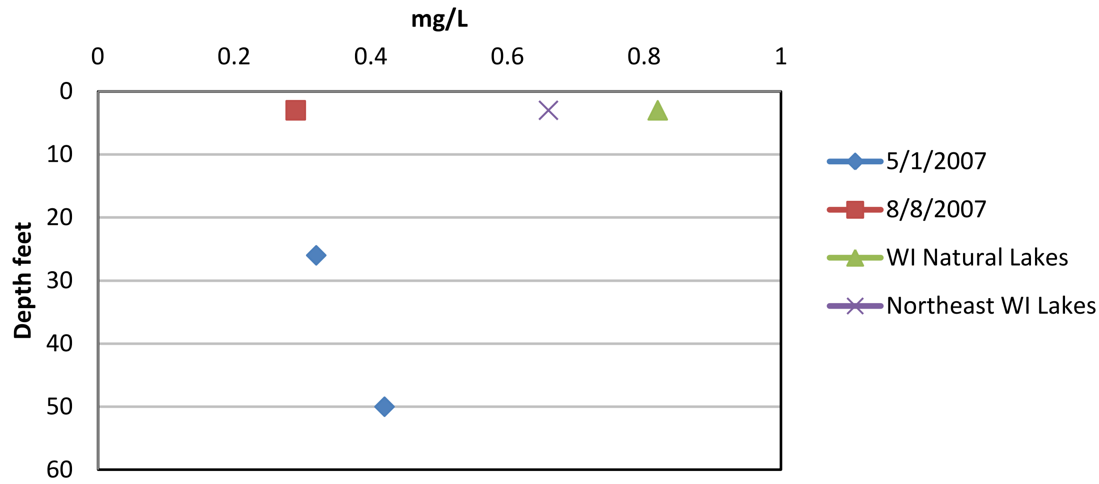
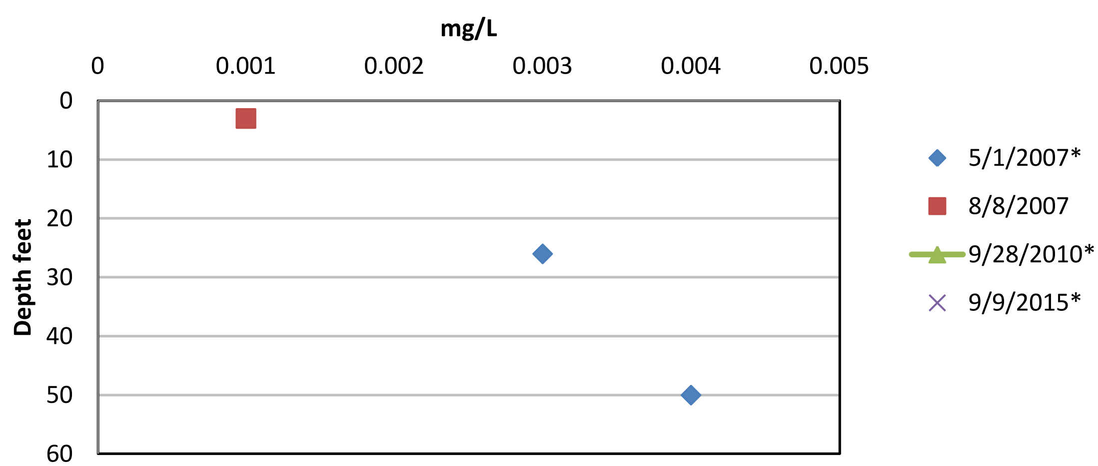
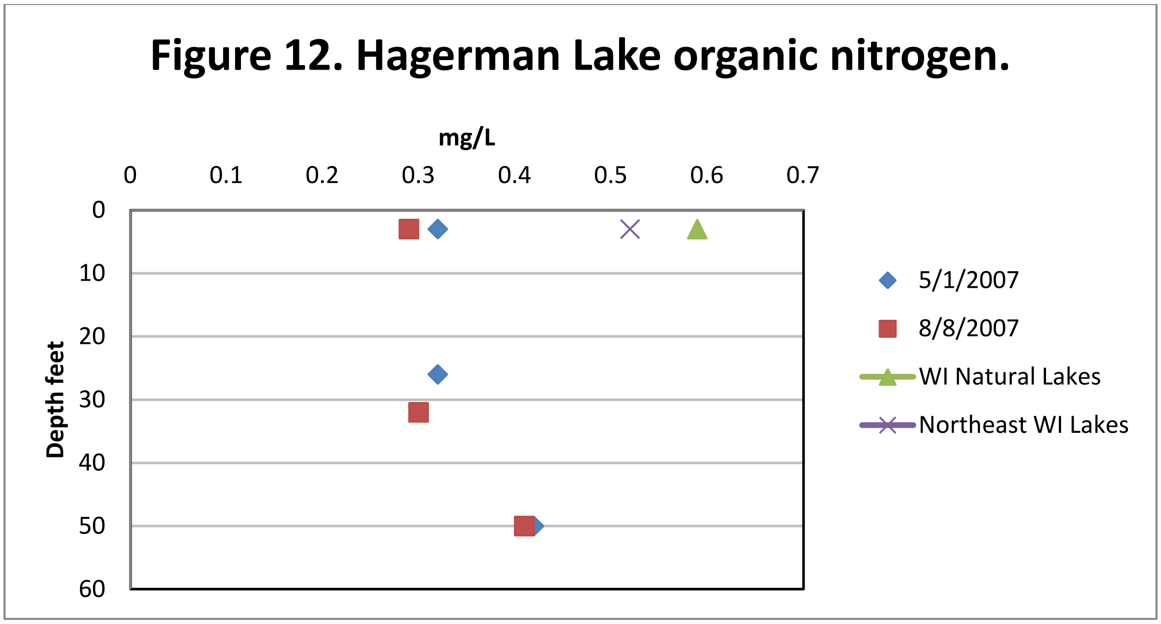


Figure 11. Hagerman Lake nitrate/nitrite.

If * not detected (<0.010mg/L)





Chloride

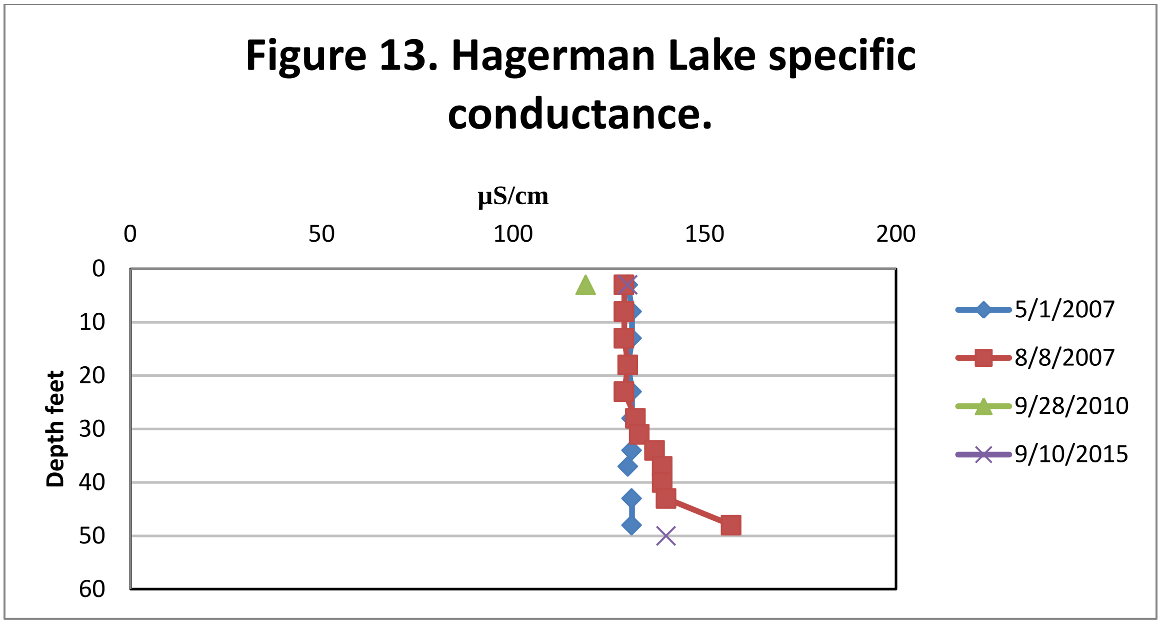
The presence of chloride (Cl^-) where it does not occur naturally indicates possible water pollution (Shaw et al., 2004). Chloride does not affect plant and algae growth and is not toxic to aquatic organisms at most of the levels found in Wisconsin (Shaw et al., 2004). Chloride concentrations in Hagerman Lake were well below the generalized distribution gradient of chloride found in surface waters in Wisconsin. Only trace amounts of chloride were found in Hagerman Lake (1 mg/L) 5/1/2007.

Sulfate

Sulfate in lake water is primarily related to the types of minerals found in the watershed, and to acid rain (Shaw et al., 2004). Sulfate concentrations are noted to be less than 10 mg/L in Northeastern region of Wisconsin (Lillie and Mason, 1983). Sulfate (5 mg/L) was analyzed in 5/1/2007 indicating concentrations were low for Hagerman Lake.

Conductivity

Conductivity is a measure of the ability of water to conduct an electric current. Conductivity is reported in micromhos per centimeter **(**µmhos/cm) and is directly related to the total dissolved inorganic chemicals in the water. Usually, values are approximately two times the water hardness, unless the water is receiving high concentrations of human-induced contaminants (Shaw et al., 2004). Hagerman Lake has average conductivity in comparison to northeast Wisconsin. We expect to see an increase in conductivity with depth during the summer (Figure 13).



pH

The acidity level of a lake's water regulates the solubility of many minerals. A pH level of 7 is considered neutral. The pH level in Wisconsin lakes ranges from 4.5 in acid, bog lakes to 8.4 in hard water, marl lakes (Shaw et al., 2004). Natural rainfall in Wisconsin averages a pH of 5.6. Some minerals become available under low pH (especially aluminum, zinc, and mercury) and can inhibit fish reproduction and/or survival. Mercury and aluminum are not only toxic to many kinds of wildlife, but also to humans (especially those that eat tainted fish). The pH scale is logarithmic, so every 1.0 unit change in pH increases the acidity tenfold. Water with a pH of 6 is 10 times more acidic than water with pH of 7. A lake's pH level is important for the release of potentially harmful substances and affects plant growth, fish reproduction and survival. A lake with neutral or slightly alkaline pH is a good lake for fish and plant survival.

The pH for Hagerman Lake appears to be alkaline (Figure 14) indicating a good lake for fish and plant survival in 2007. The pH was 7.06 in 2010 and 8.0 (epilimnion) and 7.2 (hypolimnion) 9/9/2015 which is neutral to slightly alkaline.

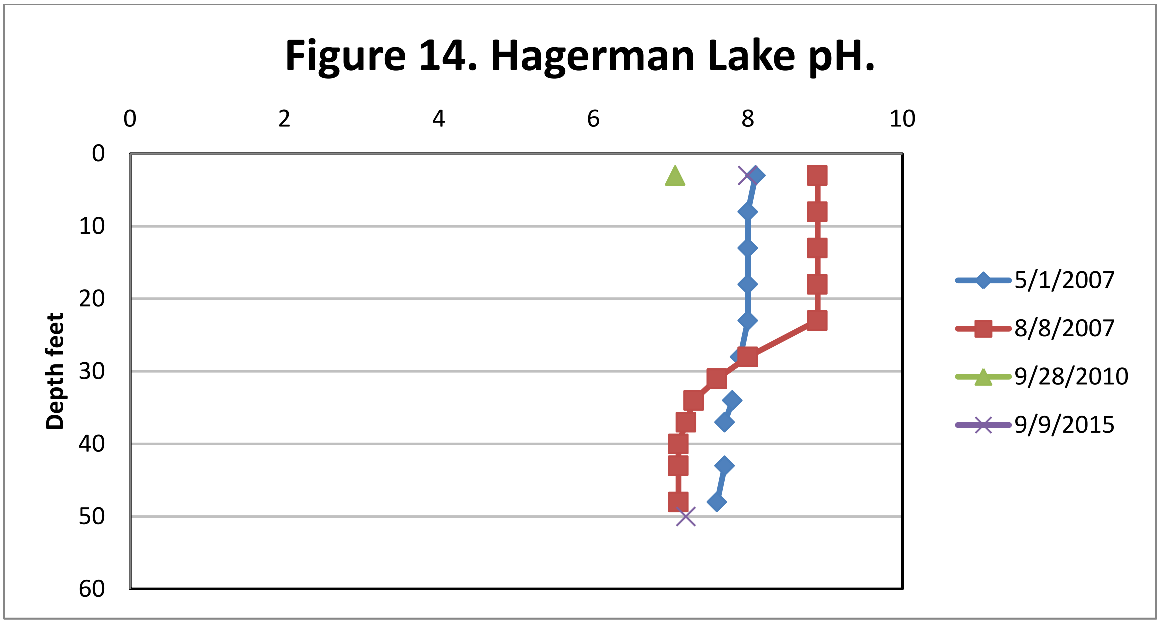


Table 4 indicates the effects pH levels less than 6.5 will have on fish. While moderately low pH does not usually harm fish, the metals that become soluble under low pH can be important. In low pH waters, aluminum, zinc, and mercury concentrations increase if they are present in lake sediment or watershed solids (Shaw et al., 2004).

Table 4. Effects of acidity on fish species (Olszyk, 1980).

Water pH	*Effects*
6.5	Walleye spawning inhibited
5.8	Lake trout spawning inhibited
5.5	Smallmouth bass disappear
5.2	Walleye & lake trout disappear
5	Spawning inhibited in most fish
4.7	Northern pike, sucker, bullhead, pumpkinseed, sunfish & rock bass disappear
4.5	Perch spawning inhibited
3.5	Perch disappear
3	Toxic to all fish

Alkalinity

Alkalinity levels in a lake are affected by the soil minerals, bedrock type in the watershed, and frequency of contact between lake water and these materials (Shaw et al., 2004). Alkalinity is important in a lake to buffer the effects of acidification from the atmosphere. Acid rain has long been a problem with lakes that have low alkalinity levels and high potential sources of acid deposition. The alkalinity was 63 mg/L

(9/28/2010), 58 mg/L (epilimnion), and 62 mg/L (hypolimnion) on 9/9/2015. Hagerman Lake's alkalinity is high in comparison to the Northeast region and other lakes in Wisconsin with an average of 37 mg/L $CaCO_3$. Because of this, Hagerman Lake is not sensitive to acid rain.

Hardness

Hardness levels in a lake are affected by the soil minerals, bedrock type in the watershed, and frequency of contact between lake water and these materials (Shaw et al., 2004). One method of evaluating hardness is to test for calcium carbonate ($CaCO_3$). Hagerman Lake had a total hardness of 61 mg/L (5/1/2007), 62.1 mg/L (9/28/2010), 66 mg/L (epilimnion) and 67 mg/L (hypolimnion) 9/9/2015 which categorizes the lake to have "moderately hard" water (Table 5).

Table 5. Categorization of hardness (mg/L of calcium carbonate ($CaCO_3$)) (from Shaw et al., 2004).

Soft water	0-60
Moderately hard water	61-120
Hard water	121-180
Very hard water	>180

Calcium and Magnesium Hardness

The carbonate system provides acid buffering through two alkaline compounds: bicarbonate and carbonate. These compounds are usually found with two hardness ions: calcium and magnesium (Shaw et al., 2004). Calcium is the most abundant cation found in Wisconsin lakes. Its abundance is related to the presence of calcium-bearing minerals in the lake watershed (Shaw et al., 2004). Aquatic organisms such as native mussels use calcium in their shells. The aquatic invasive zebra mussel tends to need calcium levels greater than 20 mg/L to maintain shell growth. Hagerman Lake had borderline calcium levels (15 mg/L) 5/1/2007 and 15.9 mg/L (9/28/2010) which is an indication that zebra mussels could establish if introduced. A magnesium level of 5.7 mg/L (5/1/2007) is comparable to lakes in the Northeast region of Wisconsin (5 mg/L).

Sodium and Potassium

Sodium and potassium are possible indicators of human pollution in a lake, since naturally occurring levels of these ions in soils and water are very low. Sodium is often associated with chloride and gets into lakes from road salting, fertilizations, and human and animal waste (Shaw et al., 2004). Potassium is the key component of commonly-used potash fertilizer, and is abundant in animal waste. Both of these elements are held by soils to a greater extent than is chloride or nitrate; therefore, they are not as useful as indicators of pollution impacts (Shaw et al., 2004). Although not normally toxic themselves, they provide a strong indication of possible contamination by more damaging compounds (Shaw et al., 2004). Hagerman Lake had low levels of sodium (1.2 mg/L) and potassium (0.6 mg/L) 5/1/2007.

Dissolved Organic Carbon

Dissolved Organic Carbon (DOC) is a food supplement, supporting growth of microorganisms, and plays an important role in global carbon cycle through the microbial loop (Kirchman et al., 1991). In general, organic carbon compounds are a result of decomposition processes from dead organic matter such as plants. When water contacts highly organic soils, these components can drain into rivers and lakes as DOC. DOC is also extremely important in the transport of metals in aquatic systems. Metals form extremely strong complexes with DOC, enhancing metal solubility while also reducing metal bioavailability. Base flow concentrations of DOC in undisturbed watersheds generally range from 1 to 20 mg/L carbon. Hagerman Lake DOC has not been tested, and could be included in future water quality sampling.

Silica

The earth's crust is abundant with silicates or other compounds of silicon. The water in lakes dissolves the silica and pH can be a key factor in regulating the amount of silica that is dissolved. Silica concentrations are usually within the range of 5 to 25 mg/L. Generally lakes that are fed by groundwater have higher levels of silica. Because silica concentration is unknown for Hagerman Lake, future water quality sampling could include measurement of this parameter.

Aluminum

Aluminum occurs naturally in soils and sediments. In low pH (acidic) environments aluminum solubility increases greatly. With a low pH and increased aluminum values, fish health can become impaired. This can have impacts on the entire food web. Aluminum also plays an important role in phosphorus cycling in lakes. When aluminum precipitates with phosphorus in lake sediments, the phosphorus will not dissolve back into the water column as readily. Because aluminum levels are unknown in Hagerman Lake, future water quality sampling could include measurement of this parameter.

Iron

Iron also forms sediment particles that store phosphorus when dissolved oxygen is present. When oxygen concentration gets low (for example, in winter or in the deep water near sediments) the iron and phosphorus dissolve in water. This phosphorus is available for algal blooms. Hagerman Lake iron levels have not been tested, and could be included in future water quality sampling.

Manganese

Manganese is a mineral that occurs naturally in rocks and soil. In lakes, manganese is usually in particulate form. When the dissolved oxygen levels decrease, manganese can convert from an insoluble form to soluble ions. Hagerman Lake manganese levels have not been tested, and could be included in future water quality sampling.

Sediment

Lake bottom sediments are sometimes analyzed for chemical constituents that they contain. This is especially true for potentially toxic metals such as mercury, chromium, selenium, and others. Lake sediments also tend to record past events as particulates settle down and become part of the sediment. Biological clues for the historic conditions in the lake can be gleaned from sediment samples. Examples include analysis of pollen or diatoms that might help understand past climate or trophic states in the lake. Sediment data was not collected for Hagerman Lake, and future sampling could include measurements of this constituent.

Total Suspended Solids

Total suspended solids are all particles suspended in lake water. Silt, plankton, and wastes are examples of these solids and can come from runoff of agricultural land, erosion, and can be produced by bottom-feeding fish. As the suspended solid levels increase, they absorb heat from sunlight which can increase the water temperature. They can also block the sunlight that plants need for photosynthesis. These events can in turn affect the amount of dissolved oxygen in the lake. Lakes with total suspended solids levels less than 20 mg/L are considered "clear," while levels between 40 and 80 mg/L are "cloudy." Because total suspended solids data has not been collected for Hagerman Lake, future water quality sampling could include measurement of this parameter.

E. Coli

A fecal indicator sample was taken at the beach 9/10/2015 for *Eschericia coli* (*E. coli*). The E. coli analysis resulted in a value of 4.1 MPN/100 mL (most probable number per 100 milliliters). For Michigan beach monitoring the samples have to be below 300 *E. coli* per 100 milliliters for it to be considered safe for swimming. They take a minimum of five sampling events (consisting of at least three samples per event) collected within a 30-day period for the results to be considered a reliable indication of water quality. This 30-day geometric mean must be below 130 *E. coli* per 100 ml for the water to be considered safe for swimming (Department of Environmental Quality 2015).

Aquatic Invasive Species

In 2009, zebra mussels were identified on a dock in Hagerman Lake. Monitoring has been done since the observation and no zebra mussels have been detected. The University of Wisconsin-Madison's Aquatic Invasive Species Smart Prevention program classifies Hagerman Lake as "borderline suitable" for zebra mussels, based on calcium and pH levels found in the lake (UW-Madison). There are no other aquatic invasive species documented in Hagerman Lake to date.

Clean Boats Clean Waters is a program that inspects boats for aquatic invasive species and in the process educates the public on how to help stop the spread of invasive species. Volunteer monitoring would benefit educating the lake patrons on aquatic invasive species and to visually look for any attached invasives. The Hagerman boat wash was installed by the Ottawa National Forest in 2012 and should be used when entering and leaving Hagerman Lake. Early detection and rapid response is the key to aquatic invasives. When using the lake please keep your eye out for anything unusual in terms of aquatic or terrestrial invasive species.

White Water Associates, Inc. has been retained in 2015 to conduct monitoring of Hagerman Lake (Iron County, Michigan) for the Hagerman Lake Property Owners Association. As part of this work, Angie Stine (White Water Associates, Aquatic Biologist) conducted a thorough search of likely habitats for aquatic invasive species with special focus on the boat landings and beach area and other points of most likely introduction or colonization. Angie Stine along with Bill Reed and Pete Wedegartner conducted a meander survey (9/10/2015) using Pete's pontoon and the following day Angie used a kayak and an aqua scope to survey areas by the boat landing and walked the beach. There were no invasives found at this time. A zooplankton tow was used to check for spiny water fleas and just native zooplankton were present.

Resources

Camargo, Julio A., Álvaro Alonso (Lead Author); Raphael D. Sagarin (Topic Editor). 02 April 2007. *Inorganic nitrogen pollution in aquatic ecosystems: causes and consequences.* In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). Retrieved January 24, 2012. <http://www.eoearth.org/article/Inorganic_nitrogen_pollution_in_aquatic_ecosystems:_causes_and_consequences>

Carlson, R.E. 1977. *A Trophic State Index for Lakes.* Limnology and Oceanography. 22: 361-369.

Department of Environmental Quality. 2015. <. *http://www.michigan.gov/deq/0,4561,7-135-3313_3681_3686_3730-11005--,00.html*>. Retrieved October 15, 2015.

Kirchman, David L.; Suzuki, Yoshimi, Garside, Christopher, Ducklow, Hugh W. (15). 1991. *High turnover rates of dissolved organic carbon during a spring phytoplankton bloom.* Nature 352 (6336): 612–614. Doi:10.1038/352612a0. Retrieved 2012. <http://www.nature.com/nature/journal/v352/n6336/abs/352612a0.html.>

Lillie, R. A. and J. W. Mason. 1983. *Limnological Characteristics of Wisconsin Lakes.* Wis. Dept. of Natural Resources Tech. Bull. Page 138. Madison, WI.

Olszyk, D. 1980. *Biological Effects of Acid Rain*. Testimony, Wis. Public Service Commission Docket No. 05-EP-2. 5 pp.

Shaw, B. Mechenich, C, and Klessig, L. 2004. *Understanding Lake Data (G3582).* Board of Regents of the University of Wisconsin System. Madison, WI.

U.S.G.S. 2013. Michigan Water Data. < http://nwis.waterdata.usgs.gov/mi/nwis/qwdata**>.** Retrieved October 11, 2013.

Appendix A

2015 White Water Associates Laboratory Report

ANALYTICAL REPORT

White Water Associates, Inc.

429 River Lane • PO Box 27 Amasa, MI 49903 • Ph (906) 822-7889 • Fax -7977

Cover Page

Client: Premo, Dean **WWA Job #:** 59398

Project: Lake Monitoring

Date Received: 9/10/2015 **Date Reported:** 10/12/2015

Sample Number	Client Sample ID	Date Sampled	Sample Matrix
59398-001	Hagerman Lake, Epi	09/09/15	Water
59398-002	Hagerman Lake, Hypo	09/09/15	Water
59398-003	e.coli sample from beach area	09/10/15	Water

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Cover Page..continued

Client: Premo, Dean **WWA Job #:** 59398

Comments (if any):

Key to Laboratory Flags:

*: RPD exceeds limits.
B: The analyte was found in the associated blank as well as in the sample.
J: The quantitation is an estimated value because the result is less than the sample quantitation limit but greater than the detection limit.
M: A matrix effect was present.
Q: Batch QC data associated with the analysis does not meet the stated objectives
H: Indicates analytical holding time exceedance.
U: The analyte was analyzed for, but not detected.
P: A manual peak selection or manual integration was performed to correct an erroneous software selection.

ND = Not Detected, MDL = Method Detection Limit, MQL = Method Quantitation Limit
ppm = mg/L (liquid) or mg/kg (solid), ppb = ug/L (liquid) or ug/kg (solid)
For coliform, Negative = No coliform bacteria detected, Positive = Coliform bacteria detected

Sample Types:
S = Solids, DW = Drinking water, D = Dissolved, T = Total, TC = TCLP extract, SP = SPLP extract

All samples were received intact and properly preserved unless otherwise noted. The results reported relate only to the samples tested. This report shall not be reproduced, except in full, without the written approval of this laboratory. The Chain of Custody is attached.

This report satisfies the requirements of your project but has not been prepared to comply with NELAP reporting requirements.

I certify that the data contained in this Final Report has been generated and reviewed in accordance with approved methods and White Water Associates Standard Operating Procedures. Exceptions, if any, are discussed in the accompanying sample narrative. Release of this Final Report is authorized by White Water Associates management, as is verified by the following signature.

Approved By: ______________________

WI DNR Lab Certification Number: 999971280
MI DEQ Certification Number: 9306
DoD-ELAP Accreditation Number: 65802
ISO/IEC 17025:2005 Accredited

ANALYTICAL REPORT

WHITE WATER ASSOCIATES, INC.

429 River Lane • PO Box 27 Amasa, MI 49903 • Ph (906) 822-7889 • Fax -7977

Client: Premo, Dean **WWA Job #:** 59398

Project: Lake Monitoring

Date Received: 9/10/2015 **Date Reported:** 10/12/2015

Sample Results

Sample No. / ID / Description / Matrix	Result	Flags	Units	Date	Method	MDL	MQL
59398-001 / Hagerman Lake, Epi / Water							
General Chemistry Parameters							
Alkalinity (t)	58		mg/L	9/11/2015	310.2	10	20
Ammonia-N	0.02	J	mg/L	9/14/2015	350.1	0.01	0.04
chlorophyll a	1.6		mg/m3	9/15/2015	10200H	NA	NA
Conductivity	130		umho/cm	9/10/2015	2510B	1	2
Hardness (d)	66		mg/L	9/21/2015	2340B	0.3	0.7
Nitrate-N	ND		mg/L	9/11/2015	4500-NO3- F	0.06	0.20
Nitrite-N	ND		mg/L	9/10/2015	4500-NO3- F	0.01	0.02
pH	8.0		pH Units	9/10/2015	4500H+ B	0.10	0.20
Total Kjeldahl Nitrogen (t)	0.44	J	mg/L	9/15/2015	351.2	0.07	0.50
Total Phosphorus (t)	ND		mg/L	9/15/2015	365.4	0.02	0.04
59398-002 / Hagerman Lake, Hypo / Water							
General Chemistry Parameters							
Alkalinity (t)	62		mg/L	9/11/2015	310.2	10	20
Ammonia-N	ND		mg/L	9/14/2015	350.1	0.01	0.04
Conductivity	140		umho/cm	9/10/2015	2510B	1	2
Hardness (d)	67		mg/L	9/21/2015	2340B	0.3	0.7
Nitrate-N	ND		mg/L	9/11/2015	4500-NO3- F	0.06	0.20
Nitrite-N	ND		mg/L	9/10/2015	4500-NO3- F	0.01	0.02
pH	7.2		pH Units	9/10/2015	4500H+ B	0.10	0.20
Total Kjeldahl Nitrogen (t)	0.35	J	mg/L	9/15/2015	351.2	0.07	0.50
Total Phosphorus (t)	0.02	J	mg/L	9/15/2015	365.4	0.02	0.04

ND = Not Detected, MDL = Method Detection Limit, MQL = Method Quantitation Limit,
ppm = mg/l (liquid) or mg/kg (solid), ppb = ug/l (liquid) or ug/kg (solid)

WHITE WATER ASSOCIATES, INC.
429 River Lane • PO Box 27 Amasa, MI 49903 • Ph (906) 822-7889 • Fax -7977

Client: Premo, Dean **WWA Job #:** 59398

Project: Lake Monitoring

Date Received: 9/10/2015 **Date Reported:** 10/12/2015

Sample Results

Sample No. / ID / Description / Matrix	Result	Flags	Units	Date	Method	MDL	MQL
59398-003 / e.coli sample from beach area / Water							
General Chemistry Parameters							
E. coli	4.1		MPN/100 mL	9/10/2015	Modified Colitag	1	1

ND = Not Detected, MDL = Method Detection Limit, MQL = Method Quantitation Limit,
ppm = mg/l (liquid) or mg/kg (solid), ppb = ug/l (liquid) or ug/kg (solid)

Job # (WWA office use): 59398

CHAIN-OF-CUSTODY RECORD

WHITE WATER ASSOCIATES, INC.

429 River Lane, P.O. Box 27
Amasa, Michigan 49903

Phone: (906) 822-7889, Fax -7977
Web: white-water-associates.com

CLIENT NAME / BILL TO: Dean Premo Hagerman Lake	EMAIL ADDRESS
ADDRESS	TELEPHONE
CITY / STATE / ZIP	CONTRACT / PO / PROJECT NAME / WSSN#
SAMPLER NAME (print first/last name): Angie Stine	COUNTY OF LOCATION / PAGE 1 OF 1 (Indicate if more than one page of COC records used)
SAMPLER'S SIGNATURE: [signature]	Check off preservatives for each bottle upon arrival and indicate total number of bottles. WWA database contains bottle preservation details.

ANALYSIS TYPE REQUESTED (Attach list if neeeded)

SAMPLE ID AND LOCATION (Containers for each sample may be combined on one line.)	DATE	TIME	SAMPLE MATRIX: Drinking water	Aqueous	Sed.	Soil	Other:	CONTAINERS / PRESERVATIVES: None	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Na Thio	Total Number of Containers	Chlorophylla	pH cond	Hardness	Alk	TP NH3 NO3 TKN	NO2	e.coli			
1 Epi	9/9/15	14:45		X				X							5	X	X	X	X	X	X				
2 Hypo	"	"		X				X							4		X	X	X	X	X				
3. E. coli Sample	9/10/15	14:12		X										X								X			

Instructions to White Water
Send my report by:
_____ email
_____ mail

Unless otherwise noted, drinking water report copies are sent to MDEQ and Health Dept.

REMARKS (Note any special instructions provided by client or conditions of receipt noted by WWA lab staff. Also note any residual chlorine.)

Relinquished by:	Date:	Time:	Received by:	Date:	Time:
[signature]	9-10-15		[signature]	9-10-15	1540

Comments / Sample temperature on receipt: 18.5

WHITE - RETURN W/ REPORT CANARY - W/ SAMPLES PINK - CUSTOMER