Phillips Chain of Lakes

Price County, Wisconsin

Comprehensive Management Plan

June 2011

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Lake Management Planning

Phillips Chain of Lakes
Price County, Wisconsin
Comprehensive Management Plan
June 2011

Acknowledgements

This management planning effort was truly a team-based project and could not have been completed without the input of the following individuals:

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1.0 INTRODUCTION

The Phillips Chain of Lakes, Price County (Map 1), comprises four lakes with a surface area of nearly 1,216 acres. These lakes are classified as an impoundment, and were formed through the damming of the Elk River. Before the dam was installed, Duroy, Elk, and Long Lakes were natural lakes and Wilson Lake did not exist. Instead, Wilson Creek flowed through the area and met the Elk River as a tributary stream. Although the lakes are connected, they vary greatly in many respects due to their morphology and substrate type. These differences are most apparent in the bathymetry of each lake (Map 2). This eutrophic system has a very large watershed when compared to the combined surface area of the lakes.

Lakes very different in structure and aquatic plant abundance. Steeply sloped sides and gravel-lined substrate likely keep plant growth down in Long and Elk Lakes. EWM growth in Wilson is substantial, dominating much of lake. Large, lush wetlands surround Duroy Lake with many emergent species present – great wildlife habitat here (Photo 1.0-1).

Photo 1.0-1. Duroy Lake, Phillips Chain of Lakes, Phillips, Wisconsin 2009

Lake at a Glance - The Phillips Chain of Lakes

		Duroy Lake	Elk Lake	Long Lake	Wilson Lake
Morphology	**Acreage**	379	88	418	351
	Max. Depth (ft)	18	25	54	11
	Volume (Acre-ft)	2,017	685	4,566	2,028
	Mean Depth (ft)	5.3	7.3	10.9	5.8
Vegetation	**Curly-leaf Survey Date**	June 2009*			
	Comprehensive Survey Date	June 2009			September 2007[†]
	Number of Native Species	28	12	26	33
	Non-Native Species	EWM, PL	EWM	EWM	EWM
	Threatened/Special Concern Species	None	None	Vasey's pondweed	None
Water Quality	**Trophic State**	Eutrophic			
	Limiting Nutrient	Phosphorus			
	pH	Range from 7.2 - 8.4			
	Sensitivity to Acid Rain	Non-sensitive			
	Watershed to Lake Area Ratio	104:1			

*Survey completed by Phillips Chain O' Lakes Association Volunteers, [†]Survey completed by WDNR, EWM = Eurasian water milfoil, PL = Purple loosestrife

The City of Phillips, it's chain of lakes, and the surrounding area sees a large amount of tourism due to an abundance of summer festivals, an annual triathlon, and all the outdoor recreational opportunities that a Northwood's Wisconsin city has to offer. Like many lakes in northern Wisconsin, invasive species establishment threatens the health and beauty of the Phillips Chain of Lakes, as well as the economy of the surrounding area. The Phillips Chain of Lakes is known to harbor Eurasian water milfoil, rusty crayfish, and banded mystery snail. In 2009, a small patch of purple loosestrife was found by Onterra staff on the shores of Duroy Lake. In particular, Eurasian water milfoil has become quite prevalent in the system and is of great concern to the Phillips Chain O' Lakes Association (PCOLA), as well as others. Eurasian water milfoil was first discovered in Duroy Lake in 2000. By 2002, it was confirmed in the rest of the Chain (Elk, Long, and Wilson lakes).

The management plan that has resulted from this project is the combination of scientific study results and the sociologic aspects of the Chain and its stakeholders. Many entities have contributed in to the progress of this management project, which is vital when a resource such as the Phillips Chain of Lakes is at stake. The results of those studies will not only lead to better management decisions, but also act as a reference point for future studies. The implementation plan found near the end of the document will act as a guide for the PCOLA as they continue to advocate responsible management of this resource.

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa. The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve the lake group as a whole or a focus group called a Planning Committee, the completion of a stakeholder survey, and updates within the lake group's newsletter.

The highlights of this component are described below in chronological order. Materials used during the planning process can be found in Appendix A.

Kick-off Meeting
On February 12th, 2009, a project kick-off meeting was held at the Price County Court House to introduce the project to the general public. The meeting was announced through a mailing and personal contact by PCOLA board members. The approximately 14 attendees observed a presentation given by Eddie Heath, an aquatic ecologist with Onterra. Mr. Heath's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Curly-leaf Pondweed Training Session
On May 5th, 2009, nine volunteers were trained by Eddie Heath and Sonya Rowe on aquatic invasive species identification and GPS mapping techniques. Once trained, the volunteers would be responsible for visually scouring the entire chain for curly-leaf pondweed during June which is when this plant is at its peak growth stage.

Stakeholder Survey
During April 2010, an eight-page, 33-question survey was mailed to 375 riparian property owners in the Phillips Chain of Lakes watershed. Roughly 55 percent of the surveys were returned and those results were entered into a spreadsheet by members of the Phillips Chain of Lakes Planning Committee. The data were summarized and analyzed by Onterra for use during the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussions of those results are integrated within the appropriate sections of the management plan.

Members of the PCOLA expressed interest in distributing the stakeholder survey not only to riparian property owners, but also to local business in the area. The goal was to gain insight into their thoughts related to the management planning process; however, because the survey is aimed at riparian property owners and lake users, technical advice from the WDNR suggested not to include local businesses in the survey.

Planning Committee Meeting

On November 13th of 2009, Tim Hoyman and Eddie Heath of Onterra met with ten members of the Phillips Chain of Lakes Planning Committee for nearly four hours. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed. Many concerns were raised by the committee, including water quality issues and also treatment options for Eurasian water milfoil and nuisance native aquatic plants.

Photo 2.0-1. Eddie Heath presenting at the Planning Committee Meeting.

Project Wrap-up Meeting

Planned for fall/winter 2011 to include the 2011 Eurasian water milfoil treatment results.

Management Plan Review and Adoption Process

In November 2010, a draft of the Phillips Chain Management Plan was supplied to the WDNR and the PCOLA Planning Committee. Comments were received from the planning committee within a few weeks after the draft report was made available.

The WDNR provided written comments to the draft management plan within two weeks after the draft was made available. Additional discussion occurred with the WDNR in preparation of the successfully funded grant application that was submitted in February 2011 to initiate further planning of a Eurasian water milfoil control strategy for the system. This report reflects the integration of WDNR and PCOLA comments. The final report will be reviewed by the PCOLA Board of Directors and a vote to adopt the management plan will be held during the association's next annual meeting.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

Reporting of water quality assessment results can often be a difficult and ambiguous task. Foremost is that the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, not all chemical attributes collected may have a direct bearing on the lake's ecology, but may be more useful as indicators of other problems. Finally, water quality values that may be considered poor for one lake may be considered good for another because judging water quality is often subjective. However, focusing on specific aspects or parameters that are important to lake ecology, comparing those values to similar lakes within the same region and historical data from the study lake provides an excellent method to evaluate the quality of a lake's water.

Many types of analysis are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the ecology of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality analysis are used to indicate not only the health of the lake, but also to provide a general understanding of the lake's ecology and assist in management decisions. Each type of available analysis is elaborated on below.

Comparisons with Other Datasets

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to similar lakes in the area. In this document, a portion of the water quality information available from the Phillips Chain of Lakes are compared to other lakes in the region and state (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Phillips Chain of Lakes water quality analysis:

Phosphorus is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both *algae* and *macrophytes*. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.

Chlorophyll-*a* is the green pigment in plants used during *photosynthesis*. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.

Secchi disk transparency is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by

lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

The parameters described above are interrelated. Phosphorus controls algal abundance, which is measured by chlorophyll-*a* levels. Water clarity, as measured by Secchi disk transparency, is directly affected by the particulates that are suspended in the water. In the majority of natural Wisconsin lakes, the primary particulate matter is algae; therefore, algal abundance directly affects water clarity. In addition, studies have shown that water clarity is used by most lake users to judge water quality – clear water equals clean water (Canter et al. 1994, Dinius 2007, and Smith et al. 1991).

Lillie and Mason (1983) is an excellent source of data for comparing lakes within specific regions of Wisconsin. They divided the state's lakes into five regions each having lakes of similar nature or apparent characteristics. Price County's lakes are included within the study's Northwest region (Figure 3.1-1) and are among 282 lakes randomly sampled from the region that were analyzed for water clarity (Secchi disk), chlorophyll-*a*, and total phosphorus. These data along with data corresponding to statewide natural lake means and historic data from the Phillips Chain of Lakes are displayed in Figures 3.1-2 – 3.1-4. Please note that the data in these graphs represent values collected only during the summer months (June-August) from the deepest location from each of the lakes (Map 1). Furthermore, the phosphorus and chlorophyll-a data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not

Figure 3.1-1. Location of the Phillips Chain of Lakes within the regions utilized by Lillie and Mason (1983).

greatly influenced by phosphorus being released from bottom sediments (see discussion under Internal Nutrient Loading on page 9). All analyzed samples were surface samples in the Phillips Chain of Lakes that were collected at a depth of 3 feet.

Apparent Water Quality Index

Water quality, like beauty, is often in the eye of the beholder. A person from southern Wisconsin that has never seen a northern lake may consider the water quality of their lake to be good if the bottom is visible in 4 feet of water. On the other hand, a person accustomed to seeing the bottom in 18 feet of water may be alarmed at the clarity found in the southern lake.

Lillie and Mason (1983) used the extensive data they compiled to create the *Apparent Water Quality Index* (WQI). They divided the phosphorus, chlorophyll-*a*, and clarity data of the state's lakes into ranked categories and assigned each a "quality" label from "Excellent" to "Very Poor". The categories were created based upon natural divisions in the dataset and upon their experience. As a result, using the WQI as an assessment tool is very much like comparing a

particular lake's values to values from many other lakes in the state. However, the use of terms like, "Poor", "Fair", and "Good" bring about a better understanding of the results than just comparing averages or other statistical values between lakes. The WQI values corresponding to the phosphorus, chlorophyll-*a*, and Secchi disk values for the Phillips Chain of Lakes are displayed on Figures 3.1-2 – 3.1-4.

Trophic State

Total phosphorus, chlorophyll-*a*, and water clarity values are directly related to the *trophic state* of the lake. As nutrients, primarily phosphorus, accumulate within a lake, its productivity increases and the lake progresses through three trophic states: *oligotrophic*, *mesotrophic*, and finally *eutrophic*. Every lake will naturally progress through these states and under natural conditions (i.e. not influenced by the activities of humans) this progress can take tens of thousands of years. Unfortunately, human influence has accelerated this natural aging process in many Wisconsin lakes. Monitoring the trophic state of a lake gives stakeholders a method by which to gauge the productivity of their lake over time. Yet, classifying a lake into one of three trophic states often does not give clear indication of where a lake really exists in its trophic progression because each trophic state represents a range of productivity. Therefore, two lakes classified in the same trophic state can actually have very different levels of production. However, through the use of a *trophic state index* (TSI), an index number can be calculated using phosphorus, chlorophyll-*a*, and clarity values that represent the lake's position within the eutrophication process. This allows for a more clear understanding of the lake's trophic state while facilitating clearer long-term tracking.

> **Trophic states** describe the lake's ability to produce plant matter (production) and include three continuous classifications: *Oligotrophic* lakes are the least productive lakes and are characterized by being deep, having cold water, and few plants. *Eutrophic* lakes are the most productive and normally have shallow depths, warm water, and high plant biomass. *Mesotrophic* lakes fall between these two categories.

Carlson (1977) presented a trophic state index that gained great acceptance among lake managers. Because Carlson developed his TSI equations on the basis of association among water clarity, chlorophyll-*a*, and total phosphorus values of a relatively small set of Minnesota Lakes, researchers from Wisconsin (Lillie et. al. 1993), developed a new set of relationships and equations based upon the data compiled in Lillie & Mason (1983). This resulted in the Wisconsin Trophic State Index (WTSI), which is essentially a TSI calibrated for Wisconsin lakes. The WTSI is used extensively by the WDNR and is reported along with lake data collected by Citizen Lake Monitoring Network volunteers.

Limiting Nutrient

The *limiting nutrient* is the nutrient which is in shortest supply and controls the growth rate of algae and some macrophytes within the lake. This is analogous to baking a cake that requires four eggs, and four cups each of water, flour, and sugar. If the baker would like to make four cakes, he needs 16 of each ingredient. If he is short two eggs, he will only be able to make three cakes even if he has sufficient amounts of the other ingredients. In this scenario, the eggs are the limiting nutrient (ingredient).

In most Wisconsin lakes, phosphorus is the limiting nutrient controlling the production of plant biomass. As a result, phosphorus is often the target for management actions aimed at controlling

plants, especially algae. The limiting nutrient is determined by calculating the nitrogen to phosphorus ratio within the lake. Normally, total nitrogen and total phosphorus values from the surface samples taken during the summer months are used to determine the ratio. Results of this ratio indicate if algal growth within a lake is limited by nitrogen or phosphorus. If the ratio is greater than 15:1, the lake is considered phosphorus limited; if it is less than 10:1, it is considered nitrogen limited. Values between these ratios indicate a transitional limitation between nitrogen and phosphorus.

Temperature and Dissolved Oxygen Profiles*

Temperature and dissolved oxygen profiles are created simply by taking readings at different water depths within a lake. Although it is a simple procedure, the completion of several profiles over the course of a year or more provides a great deal of information about the lake. Much of this information relates to whether the lake thermally stratifies or not, which is determined primarily through the temperature profiles. Lakes that show strong stratification during the summer and winter months need to be managed differently than lakes that do not. Normally, deep lakes stratify to some extent, while shallow lakes (less than 17 feet deep) do not.

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, fishkills are often the result of insufficient amounts of dissolved oxygen. However, dissolved oxygen's role in lake management extends beyond this basic need by living organisms. In fact, its presence or absence impacts many chemical process that occur within a lake. Internal nutrient loading is an excellent example that is described below.

> **Lake stratification** occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The *epiliminion* is the top layer of water which is the warmest water in the summer months and the coolest water in the winter months. The *hypolimnion* is the bottom layer and contains the coolest water in the summer months and the warmest water in the winter months. The *metalimnion*, often called the thermocline, is the middle layer containing the steepest temperature gradient.

*Temperature and dissolved oxygen profiles were not collected as a part of this project. The explanation provided under this heading is strictly for the information of the reader.

Internal Nutrient Loading*In lakes that support stratification, even if weak, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. In deeper lakes, with strong stratification, this may only occur in the spring and fall; however in shallow lakes that support periodic stratification and mixing, nutrient recycling may occur throughout the growing season. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae blooms decades after external sources are controlled.

Water quality data was not collected as a part of this project; therefore, it is beyond its scope to determine the significance of internal loading in the Phillips Chain. Mr. Craig Roesler, in his review of the first draft of this document brought forth information that does support the fact that internal loading may be a significant source of phosphorus throughout the growing season within

the chain. It may be in the best interest of the PCLA to pursue an investigation of this phenomenon in the chain sometime in the future.

Phillips Chain of Lakes Water Quality Analysis

Phillips Chain of Lakes Long-term Trends

Unfortunately, very little historic water quality data exists for the Phillips Chain of Lakes, making beneficial long-term trend analysis impossible. Despite the existence of sporadic data for the chain, it is unreasonable to attempt to draw conclusions on changes in water quality when significant gaps exist in the dataset. Natural annual fluctuations in water quality can and do occur in Wisconsin lakes, so without consistent annual data it is impossible to tell if perceived changes in water quality are due to environmental circumstances, the influence of human activities, or a combination of both. Additionally, data collection on the chain lakes has been inconsistent over the past three decades with some lakes having two or more samples collected over sporadic growing seasons and others having the same amount of data collected consistently over a few years. For example, Wilson Lake has seen considerably more water quality sampling than all of the other lakes with consistent data from 1998-2008, while the remaining lakes have datasets limited to information collected in the mid to early 2000's. Of those lakes, Elk has the most data, but the latest collection was completed in 2005.

Still, even with the severe lack of consistent data, we do have the opportunity to understand the general water quality of four Phillips Chain lakes to some degree. In the paragraphs that follow, the data are first discussed by averaging each lake's full set of data for total phosphorus, chlorophyll-*a*, and Secchi disk clarity. Then, the data set of each lake is presented individually for these same parameters.

Figure 3.1-2 contains average total phosphorus data collected from each of the Phillips Chain lakes. Summer averages are not all that dissimilar from averages seen in other Wisconsin impoundments, but are substantially higher than averages seen in other lakes within the Northwest region. Three of the lakes, Duroy, Elk, and Wilson, rank in the WQI as "Poor" while Long Lake ranks in an upper "Fair" category. While these phosphorus values may seem high, it can be seen from the Wisconsin impoundments average that this is to be expected for this type of waterbody.

Chlorophyll-*a* concentrations have been measured in all four of the Phillips Chain of Lakes (Figure 3.1-3). Although it may seem as though chlorophyll-*a* values vary between the lakes, it must be noted that the amount of data collected on each of the lakes varies greatly. As a result the differences in their averages are likely not as extreme as what is depicted in the chart. However, it is entirely possible that the lakes in the upper part of the chain (Duroy and Elk) hold less algal biomass during the summer seasons due to the flow of water carrying nutrients quickly towards Long Lake. Summer chlorophyll-*a* concentrations in Long and Wilson Lakes are similar to those found in Wisconsin impoundments, while it can cautiously be stated (due to a small and not-so-recent sample size) that concentrations found in Duroy and Elk lakes are fairly lower than those seen in impoundments, but on par when compared to other regional lakes.
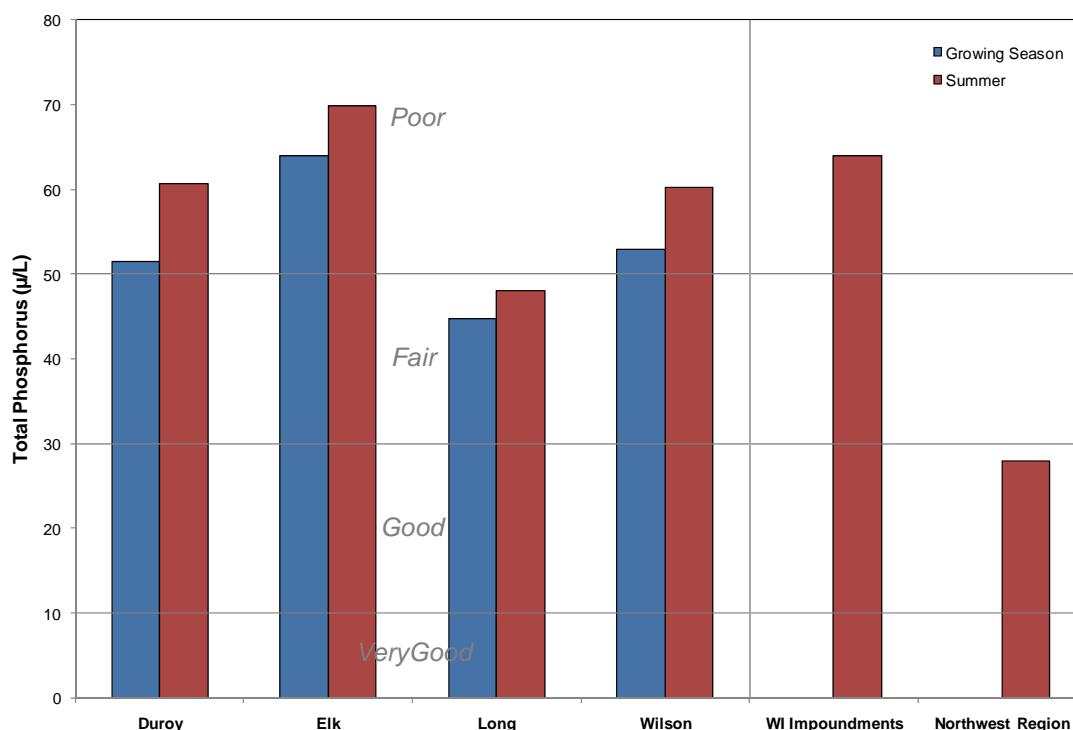
Figure 3.1-2. Phillips Chain of Lakes, regional, and state total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

Secchi disk clarity values for the Phillips Chain of Lakes can be found in Figure 3.1-4. Secchi disk clarity values rank in the WQI as "Very Poor" for Elk and Wilson Lakes, and "Poor" for Duroy and Long Lakes. These low readings are not that unexpected, however, as these data are often seen in Wisconsin impoundments. Along with the potential for abundant algae which often occurs in impoundments, the contributing watershed holds many acres of wetland and pine forests (see section 3.2 for details on the Phillips Chain of Lakes watershed). These land types contribute weak, organic acids that are the by-product of the decomposition of organic materials. These acids are harmless, but tend to discolor water to the point which clarity can be decreased.

Figure 3.1-3. Phillips Chain of Lakes, regional, and state chlorophyll-*a* concentrations.
Mean values calculated with summer month surface sample data. Water Quality Index values
adapted from Lillie and Mason (1983).

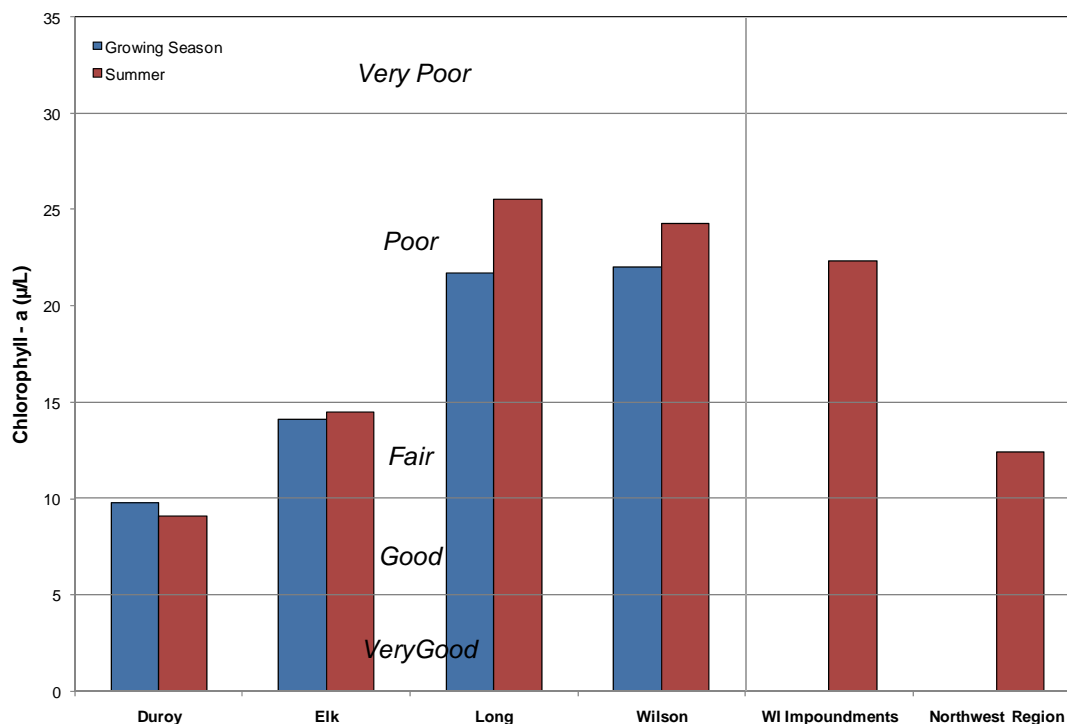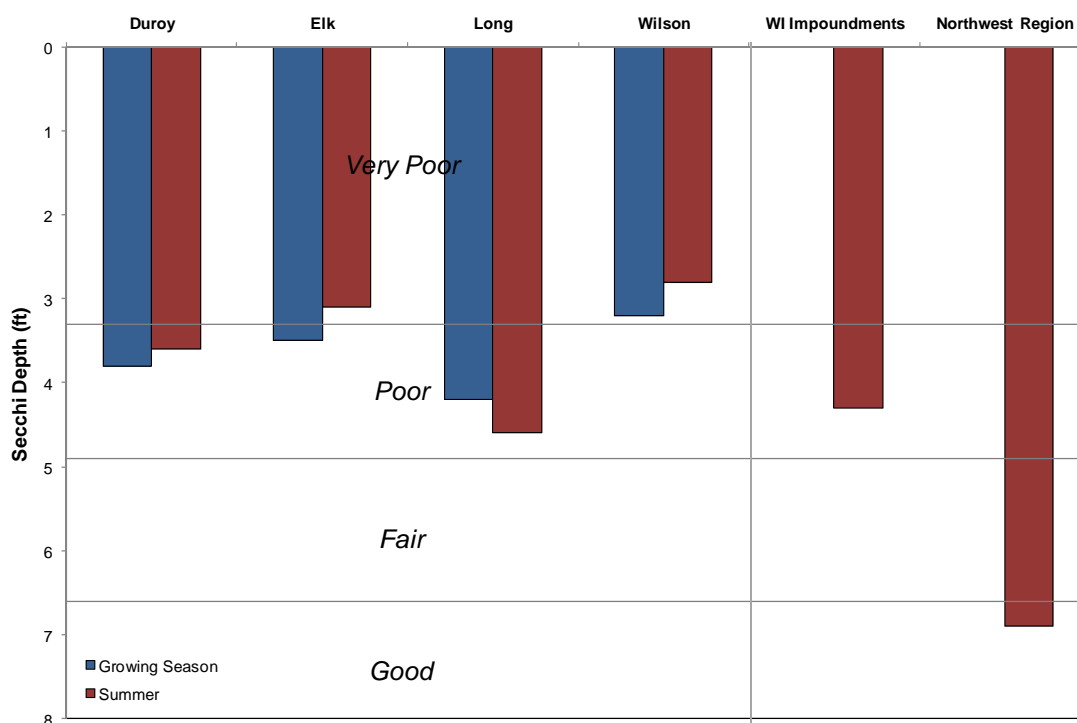**Figure 3.1-4. Phillips Chain of Lakes, regional, and state Secchi disk clarity values.**
Mean values calculated with summer month surface sample data. Water Quality Index values
adapted from Lillie and Mason (1983).

Phillips Chain of Lakes – Individual Lakes Water Quality

As discussed above, the lack of available data for some of the Phillips Chain Lakes makes trend analysis difficult. However, for several parameters in a few of these lakes, sufficient information exists to draw basic conclusions about their water quality. In this section, individual lake data are displayed and discussed in terms of trends where appropriate.

Duroy Lake

There are few conclusions that can be made about Duroy Lake's current water quality, due to the lack of available data (Table 3.1-1). As stated previously, average total phosphorus concentrations and Secchi disk transparency averages seem to correspond with those collected on other Wisconsin impoundments. However, the weighted average of the two chlorophyll-*a* samples collected on this lake are below the average concentration seen in impoundments. Whether this is always the case or just a result of isolated sampling cannot be determined.

Table 3.1-1. Available Water Quality data for Duroy Lake. Data retrieved from SWIMS.

	Secchi (feet)				Chlorophyll a (µg/L)				Phosphorus (µg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
Year	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1996	2.0	4.0	2.0	4.0	2.0	12.6	1.0	12.4	2.0	37.0	1.0	41.0
2000	5.0	3.7	3.0	3.4	3.0	8.0	3.0	8.0	4.0	58.8	3.0	67.3
All Years (weighted)		3.8		3.6		9.8		9.1		51.5		60.7
WI Impoundments				4.3				22.3				64.0
Northwest Region				6.9				12.4				28.0

Elk Lake

Through volunteer monitoring, there are a few more occurrences of water quality testing that have occurred on Elk Lake. Secchi disk clarity had been measured more frequently; however, this has not been the case in more recent years (Table 3.1-1 and Figure 3.1-5). The averaged measurements vary little from year to year, while chlorophyll-*a* and phosphorus concentrations display a bit more variability. Similar to Duroy Lake, the weighted average of a small number of chlorophyll-*a* samples are smaller than the average seen in other impoundments across the state.

Table 3.1-2. Available Water Quality data for Elk Lake. Data retrieved from SWIMS.

	Secchi (feet)				Chlorophyll a (µg/L)				Phosphorus (µg/L)			
	Growing Season		Summer		Growing Season		Summer		Growing Season		Summer	
Year	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1975									1.0	77.0		
1977									2.0	79.0		
1979									1.0	81.5	1.0	81.5
1980									1.0	46.0	1.0	46.0
1996	2.0	4.0	1.0	4.0	2.0	12.9	1.0	13.4	2.0	37.0	1.0	40.0
2000	10.0	3.8	4.0	3.5	3.0	8.7	3.0	8.7	4.0	63.5	3.0	74.7
2001	7.0	2.6	6.0	2.2	1.0	33.0	1.0	33.0	2.0	70.5	1.0	97.0
2002	5.0	3.6	4.0	3.6								
2003	2.0	3.4	1.0	3.3								
2004	4.0	3.9	1.0	3.5								
2005	3.0	3.7	2.0	3.6								
All Years (weighted)		3.5		3.1		14.1		14.5		64.0		69.8
WI Impoundments				4.3				22.3				64.0
Northwest Region				6.9				12.4				28.0
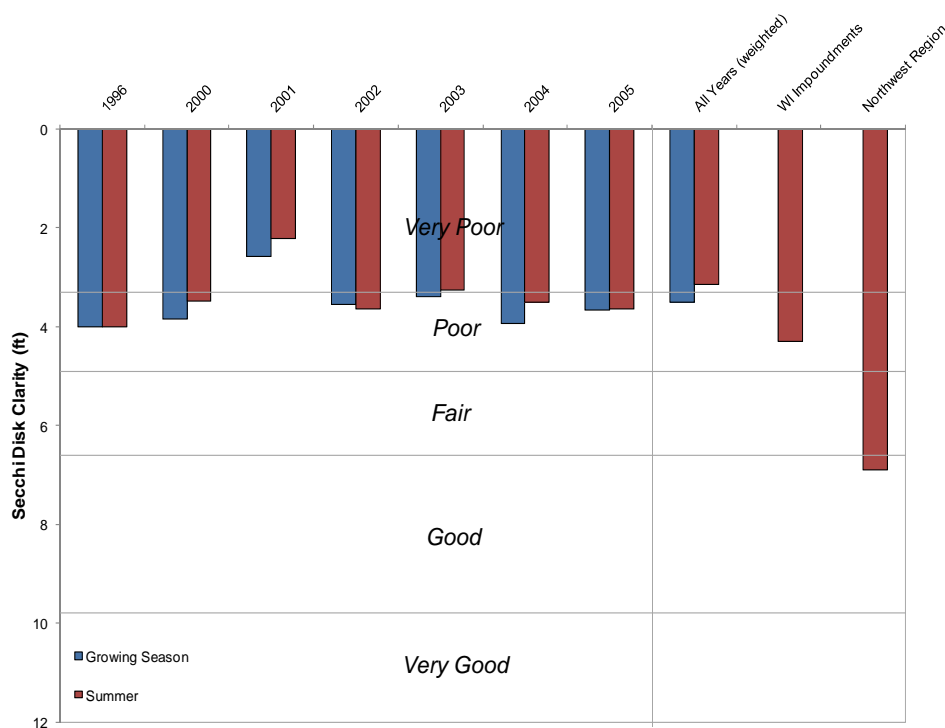
Figure 3.1-5. Elk Lake, regional, and state Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

Long Lake

As is the case for Duroy and Elk, there is a limited dataset of water quality information for Long Lake. Additionally, there is a lack of recently collected data. However, the few historical readings of Secchi disk clarity are very similar to data collected in other Wisconsin impoundments (Table 3.1-3).

Table 3.1-3. Available Water Quality data for Long Lake. Data retrieved from SWIMS.

| Year | Secchi (feet) | | | | Chlorophyll a (µg/L) | | | | Phosphorus (µg/L) | | | |
| | Growing Season | | Summer | | Growing Season | | Summer | | Growing Season | | Summer | |
	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
1996	2	4.1	1	4	2	21.65	1	25.5	1	42	1	42
1999	3	3.58	0	0								
2000	4	4.75	3	4.8					3	46	2	51
2003									1	40	0	
All Years (weighted)		4.2		4.6		21.7		25.5		43.8		48.0
WI Impoundments				4.3				22.3				64
Northwest Region				6.9				12.4				28

Wilson Lake

Of the lakes in the Phillips Chain, the most consistent and up-to-date water quality monitoring has taken place on Wilson Lake. As seen in Figure 3.1-5, total phosphorus values in Wilson Lake have displayed a bit of a downward trend from 2000 to 2008, with a few years of elevated concentrations likely due to fluctuating environmental conditions (heavier rainfall, etc). Similar trends can be seen in the chlorophyll-*a* and Secchi disk clarity datasets (Figures 3.1-6 and 3.1-7).
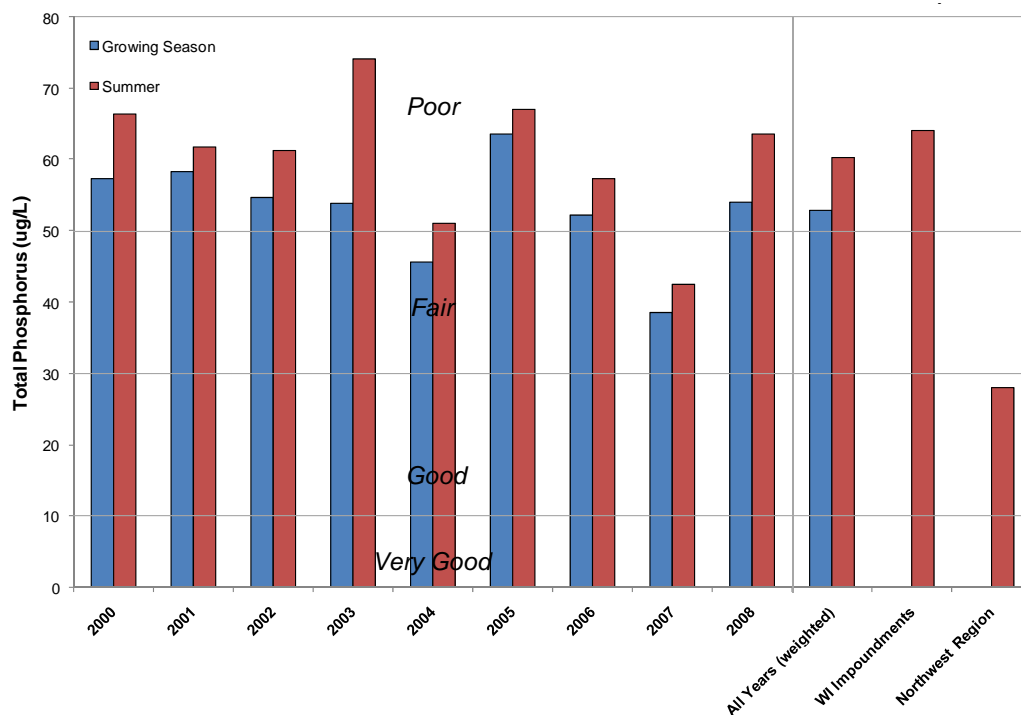
Figure 3.1-6. Wilson Lake, regional, and state total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).
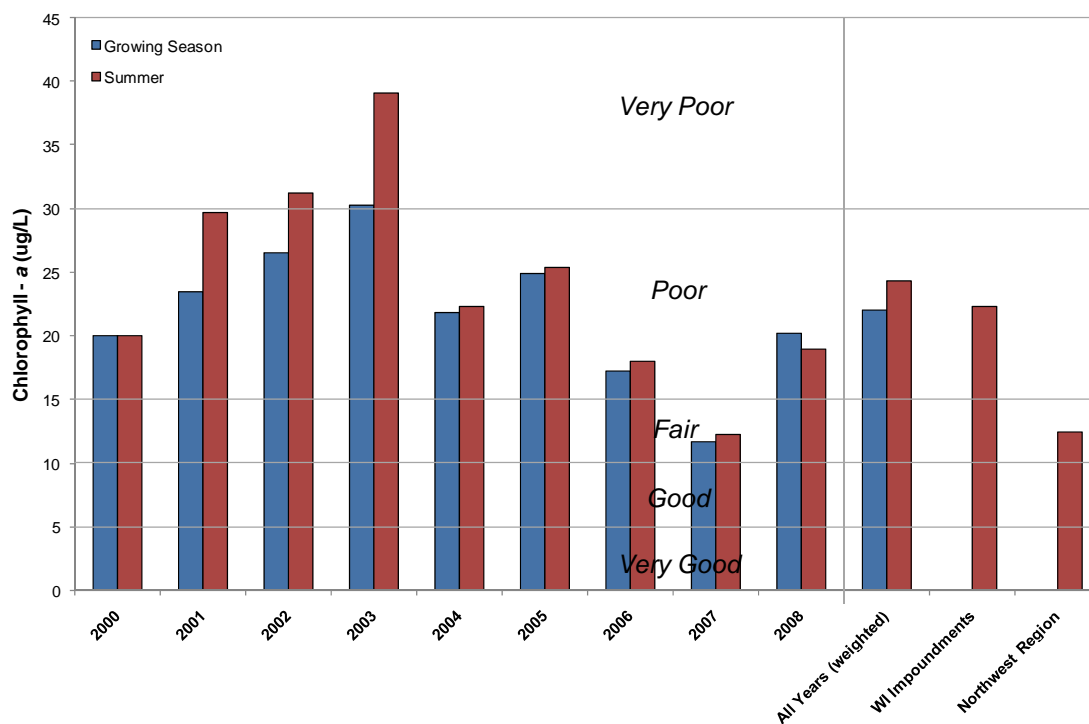
Figure 3.1-7. Wilson Lake, regional, and state chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).
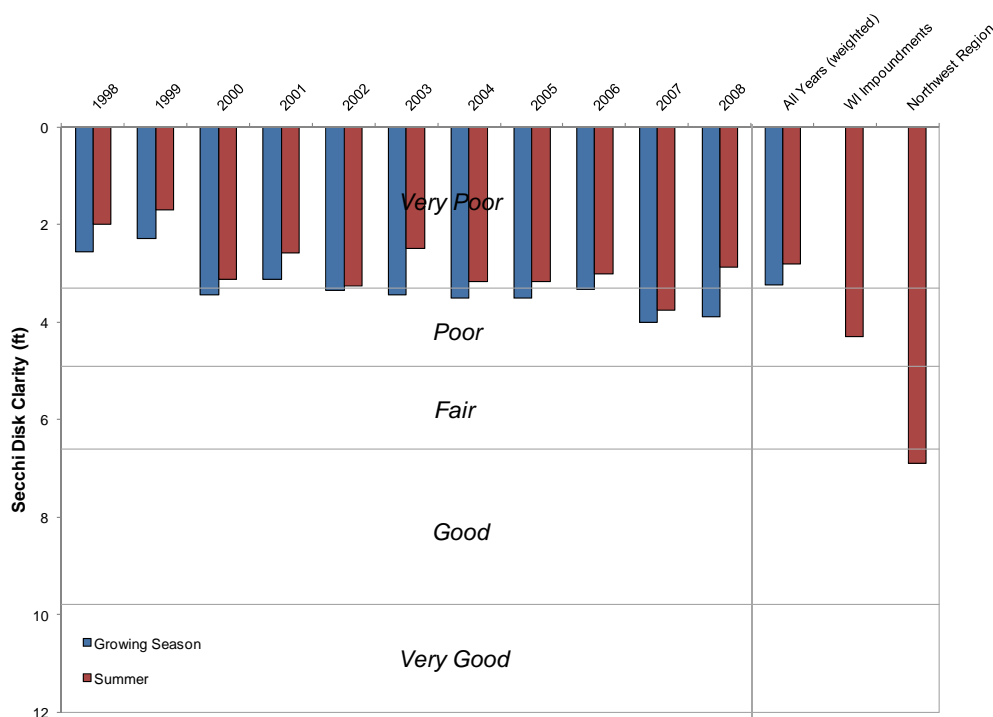
Figure 3.1-8. Wilson Lake, regional, and state Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

At the surface, there appears to be a noticeable trend in phosphorus, chlorophyll-*a* and Secchi disk transparency for Wilson Lake. In fact, trend lines placed on all three of the parameter datasets indicate a downward trend; however the trends for phosphorus and chlorophyll-*a* are much less supported based upon low correlation (r^2) values.

Closer examination of the phosphorus and chlorophyll-*a* charts reveals that during the years 2000-2002, there is a reverse relationship between the two parameters than we would normally expect - that relationship being that as phosphorus levels decrease we see an increase in chlorophyll-*a*. During those three years we also see fluctuating transparency levels. Considering these results, we must accept that something else besides phosphorus concentrations are controlling algal growth during those years. One possibility may be slight increases in water clarity due to decreasing levels of organic acids (decreased water color) over the three years. Essentially, there may have been a level of light limitation limiting algal growth in 2000 that decreased between then and 2003 resulting in more chlorophyll-*a*.

These trends may be attributed to changes in the plant biomass in this ecosystem, specifically the recent increase in Eurasian water milfoil biomass within Wilson Lake. The two primary aquatic plant groups, algae and macrophytes, both utilize nutrients such as phosphorus and nitrogen. In some lakes, macrophytes may use nutrients quickly, leaving smaller amounts of nutrients for algal growth. In other lakes, the algae outcompetes macrophytes for these necessary building-blocks. While this situation is entirely possible, we have no quantitative data indicating that the increased macrophyte biomass was proportioned more greatly in Eurasian water milfoil compared to native plants, or data indicating changing levels of macrophyte biomass in the lake.

Figure 3.1-9. Wilson Lake Secchi disk clarity trends, 1998-2008. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).
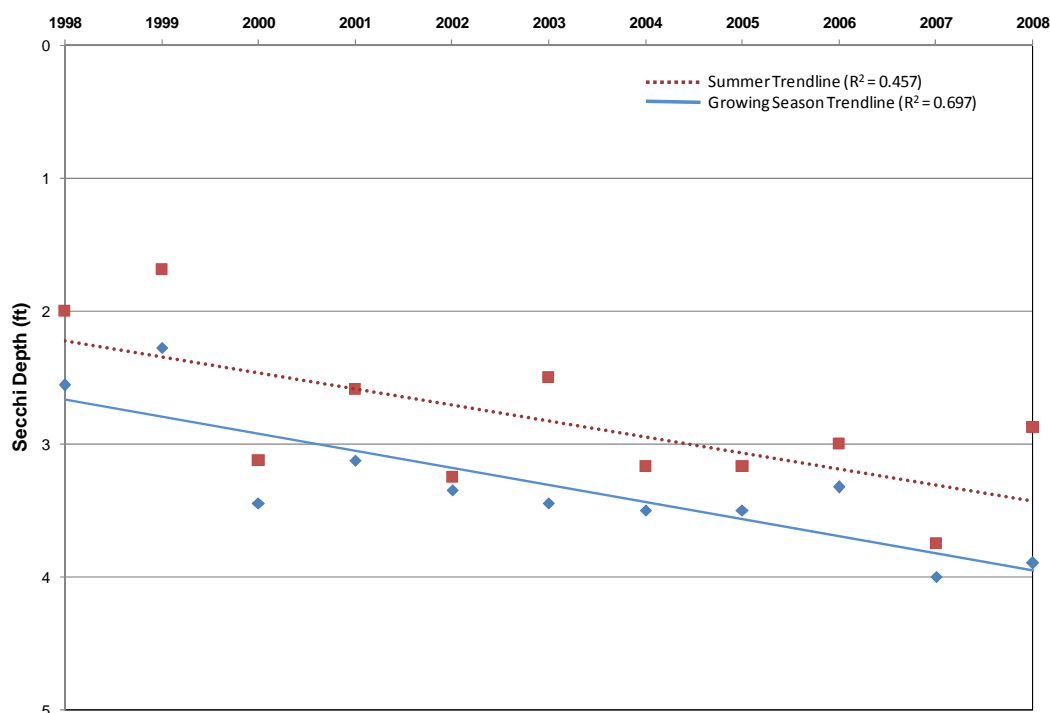
Limiting Plant Nutrient of the Phillips Chain of Lakes

Using 2000 midsummer nitrogen and phosphorus concentrations from the Phillips Chain of Lakes, a nitrogen:phosphorus ratio was calculated for each lake (Table 3.1-4). Based upon these limited data, Duroy and Elk Lakes likely fluctuate between nitrogen and phosphorus limitation, while Long and Wilson Lake, like most lakes in Wisconsin, are definitely phosphorus limited. Before management decisions could be made regarding these results, additional sampling would need to be completed to confirm which nutrient limits plant growth within the lakes.

Table 3.1-4. Phillips Chain of Lakes nitrogen to phosphorus ratios. Ratios calculated from data collected in 2000.

Lake	N:P
Duroy	12:1
Elk	11:1
Long	21:1
Wilson	21:1

Phillips Chain of Lakes Trophic State

Figure 3.1-9 contain the WTSI values for the Phillips Chain of Lakes. The WTSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values for each of the lakes in the Phillips Chain fall within the eutrophic category. Thus, it may be stated that each of these

lakes be categorized as eutrophic. This is not unlike most impoundments in Wisconsin, as these waterbody types generally have large watersheds that contribute both sediment and nutrients to their waters. See section 3.2 for more information regarding the Phillips Chain's large contributing watershed.
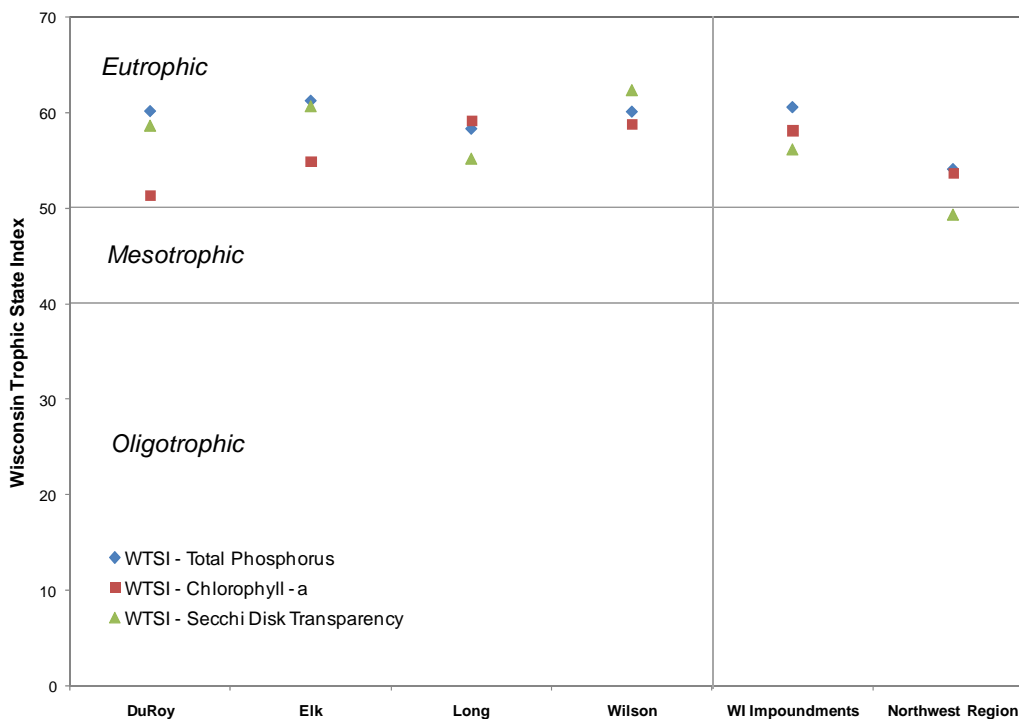
Figure 3.1-10. Phillips Chain of Lakes, regional, and state Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using Lillie et al. (1993).

Additional Water Quality Data for the Phillips Chain of Lakes

Calcium, pH, and Alkalinity

Calcium and pH data were collected on each of the Phillips Chain of Lakes in 2002, while alkalinity was measured in 2001 in Elk Lake. Alkalinity was measured at 46 mg/L of $CaCO^3$, indicating that the lakes in the Phillips Chain are not sensitive to acid rain. The chain's calcium concentrations ranged from 10 to 14 mg/L in 2002, which is at the very low end for zebra mussel suitability. The pH level ranged between 7.2 and 8.4, which is well within the optimal range for zebra mussel survival. In 2005 Elk Lake was sampled for zebra mussel veligers (the larvae of the adult mussels). No veligers were found within the sample.

Dissolved Oxygen

In 2010, a WDNR official collected winter dissolved oxygen readings on Wilson Lake. The data collected showed that in January, oxygen levels were sufficient in the upper 5 feet of the water column, whereas below this depth oxygen fell to near 1.0 mg/L and below (Figure 3.1-6). However, at the same location in February, the dissolved oxygen was below 1.0 mg/L very near the surface. WDNR fisheries biologists believe that sport fish can usually handle low dissolved oxygen levels under the ice, even for weeks at a time as long as the dissolved oxygen is depleted

gradually (Sommerfeldt unpublished data 1984-2010). Fish may sustain levels as low as 1.0 mg/L for 2-3 weeks.
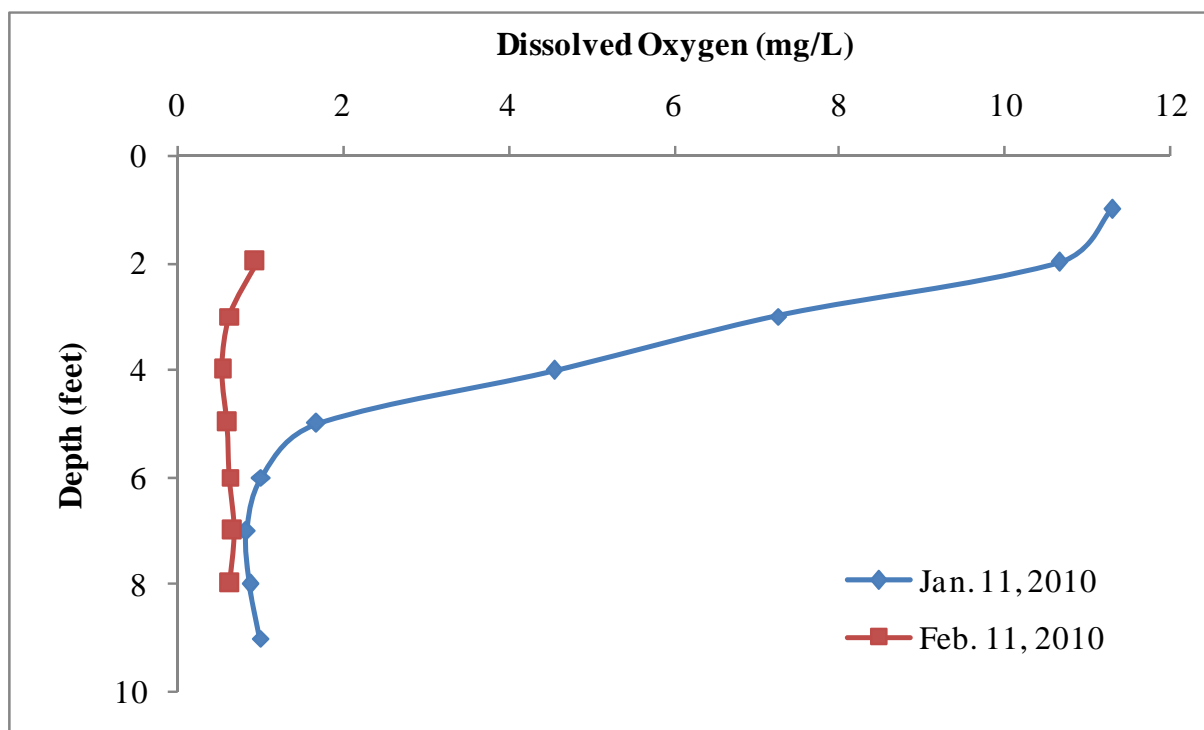
Figure 3.1-11. Wilson Lake 2010 dissolved oxygen profiles. Data collected by WDNR and graphed by Onterra.

Elk Lake Heavy Metal Contamination

As discussed in the Aquatic Plant section, Elk and Long Lakes both display very sparse plant communities with low density. While this can be partly attributed to the substrate (coarse and fine gravel) and morphology (steeply sloped, narrow littoral zone), there has been concern over contamination from a metal plating company that formerly discharged wastewater into Elk Lake (Appendix F). There was also speculation that these contaminants were impacting aquatic plant growth in Elk and Long Lakes. Results from sediment samples taken from Elk Lake in the 1970's showed that concentration of chromium and copper exceeded levels known as lethal to small, bottom-dwelling organisms called "benthos" (MacDonald and MacFarlane, 1999; MacDonald et. Al, 2000). Further testing in 2009 determined that chromium and copper concentrations had decreased somewhat, though this may be due to dilution by additional sediment deposition. Results for select metals from a 2005 sediment sample are summarized in Table 3.1-2. Threshold effect concentrations are based upon affects to benthic (bottom dwelling) organisms which are valuable indicator species of water pollution (WDNR, 2003).

Table 3.1-5. Heavy metal concentrations and Sediment Quality Guidelines from Elk Lake, 2005. Samples were collected by the WDNR near the Wastewater Treatment Plant outfall. Guidelines represent standards set for benthic organism tolerance levels.

Metal	Dry Wt (mg/kg)	Concern Level 1 (lowest) - 4 (highest)
Chromium	207	4
Copper	85.6	2
Lead	80	2
Silver	<0.5	1
Zinc	281	2

Elk Lake *Escherichia coli* monitoring

Fecal coliform bacteria are microorganisms found in the lower intestines of mammals. These bacteria are essential for mammals, as they play a role in the digestion of food. However, when found in lake or stream water, some types may pose as a health risk to humans. Furthermore, these organisms are used as *indicator organisms*, or organisms that when observed, alarm us to the possible presence of other pathogenic bacteria or viruses that originate from human and animal digestive systems. Essentially, the presence of fecal coliform bacteria in a waterbody indicates that fecal contamination might be occurring, and that contact with this water may pose a health risk.

One type of coliform, *Escherichia coli* (E. coli), is commonly screened for in water quality samples as it is specific to fecal material from humans and other warm-blooded animals. Currently the Environmental Protection Agency (EPA) recommends E. coli as the best indicator of health risk in recreational waters. Through the Clean Water Act section 406(a), the EPA is required to publish monitoring and assessment guidelines and standards for coliform content on recreational beaches. These standards were adopted by the Wisconsin Beach Monitoring Program, and are as follows:
For single sample maximums,

- If the *E. coli* count is greater than 1000 MPN/100 mL, the beach is closed.
- If the *E. coli* count is greater than 235 MPN/100 mL but less than 1000 MPN/100 mL, an advisory is issued.
- If the *E. coli* count is under 235 MPN/100 mL, the beach has no advisories or warnings issued.

*MPN/100 mL – most probable number of colony forming units per 100 mL of water

In 2010, as part of a state sponsored Pathogen Monitoring on Inland Beaches program, the Phillips City Beach on Elk Lake was sampled 15 times during the swimming season (May through August) for E. coli (Figure 3.1-12). Fourteen of the 15 samples turned up values less than 235 MPN/100 mL, indicating that fecal coliform levels were low and a beach advisory was not necessary. On one occasion, in early August, E. coli was found at 548 MPN/100 mL, which is a sufficient density to warrant a beach advisory notice.
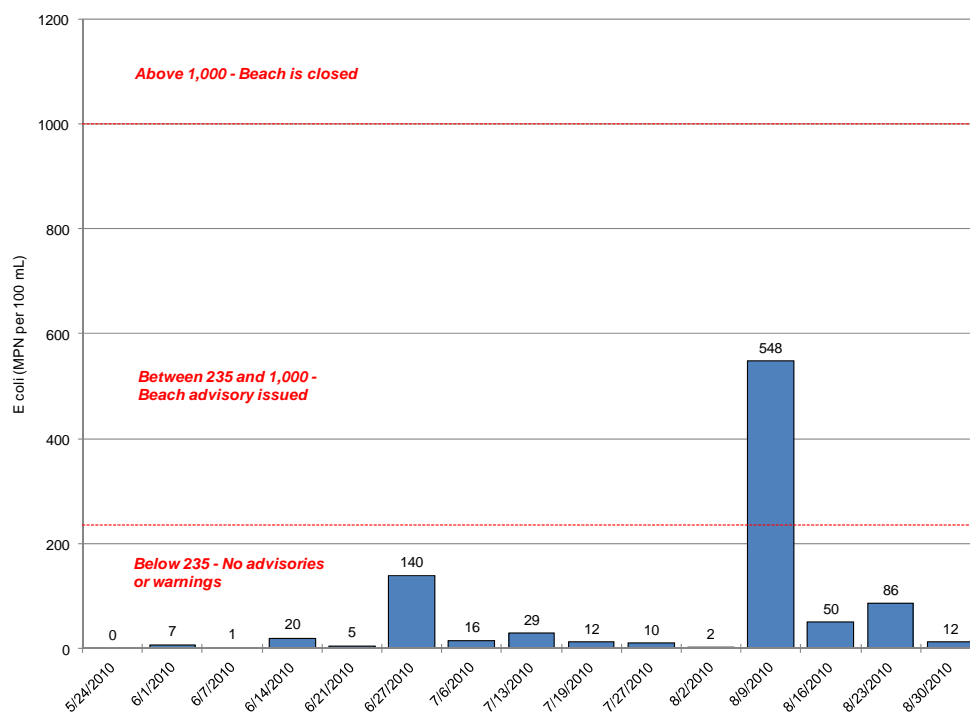
Figure 3.1-12. Elk Lake 2010 *Escherichia coli* monitoring. Data retrieved from SWIMS and graphically displayed by Onterra.

3.2 Watershed Assessment

Two aspects of a lake's watershed are the key factors in determining the amount of phosphorus the watershed exports to the lake; 1) the size of the watershed, and 2) the land cover (land use) within the watershed. The impact of the watershed size is dependent on how large it is relative to the size of the lake. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drains to each surface-acre of the lake. Larger ratios result in the watershed having a greater role in the lake's annual water budget and phosphorus load.

> A lake's **flushing rate** is simply a determination of the time required for the lake's water volume to be completely exchanged. **Residence time** describes how long a volume of water remains in the lake and is expressed in days, months, or years. The parameters are related and both determined by the volume of the lake and the amount of water entering the lake from its watershed. Greater flushing rates equal shorter residence times.

The type of land cover that exists in the watershed determines the amount of phosphorus (and sediment) that runs off the land and eventually makes its way to the lake. The actual amount of pollutants (nutrients, sediment, toxins, etc.) depends greatly on how the land within the watershed is used. Vegetated areas, such as forests, grasslands, and meadows, allow the water to permeate the ground and do not produce much surface runoff. On the other hand, agricultural areas, particularly row crops, along with residential/urban areas, minimize infiltration and increase surface runoff. The increased surface runoff associated with these land cover types leads to increased phosphorus and pollutant loading; which, in turn, can lead to nuisance algal blooms, increased sedimentation, and/or overabundant macrophyte populations.

In systems with lower WS:LA ratios, land cover type plays a very important role in how much phosphorus is loaded to the lake from the watershed. In these systems the occurrence of agriculture or urban development in even a small percentage of the watershed (less than 10%) can unnaturally elevate phosphorus inputs to the lake. If these land cover types are converted to a cover that does not export as much phosphorus, such as converting row crop areas to grass or forested areas, the phosphorus load and its impacts to the lake may be decreased. In fact, if the phosphorus load is reduced greatly, changes in lake water quality may be noticeable, (e.g. reduced algal abundance and better water clarity) and may even be enough to cause a shift in the lake's trophic state.

In systems with high WS:LA ratios, like those exceeding 10-15:1, the impact of land cover may be tempered by the sheer amount of land draining to the lake. Situations actually occur where lakes with completely forested watersheds have sufficient phosphorus loads to support high rates of plant production. In other systems with high ratios, the conversion of vast areas of row crops to vegetated areas (grasslands, meadows, forests, etc.) may not reduce phosphorus loads sufficiently to see a change in plant production. Both of these situations occur frequently in impoundments.

Regardless of the size of the watershed or the makeup of its land cover, it must be remembered that every lake is different and other factors, such as flushing rate, lake volume, sediment type, and many others, also influence how the lake will react to what is flowing into it. For instance, a deeper lake with a greater volume can dilute more phosphorus within its waters than a less

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voluminous lake and as a result, the production of a lake is kept low. However, in that same lake, because of its low flushing rate (high residence time, i.e., years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading may become a problem. On the contrary, a lake with a higher flushing rate (low residence time, i.e., days or weeks) may be more productive early on, but the constant flushing of its waters may prevent a buildup of phosphorus and internal nutrient loading may never reach significant levels.

The Phillips Chain of Lakes, like most flowages in Wisconsin, has an incredible amount of land included in its watershed (Map 3). This watershed covers approximately 127,981 acres, and largely consists of forests (70,623 acres or 55%) and wetlands (41,515 acres or 32%). Other contributing land cover types include pasture /grass (11%), open water surfaces (1%), and numerous land uses (medium and high density urban, mixed agriculture and row crop agriculture) that make up less than 1% of the watershed (Figure 3.2-1). The watershed to lake area ratio for this system is very large, at 104:1. The land cover acreage includes land draining to all four of the Phillips Chain lakes. Because the outlet for the Elk River occurs in the southwestern portion of Long Lake, downstream of the point at which Wilson Lake connects with Long Lake, there are essentially two sub-watersheds making up the chain's drainage basin. Duroy, Elk, and Long Lake all belong to a single watershed, while Wilson Lake collects water from lands to the south of those lakes. The flows from the two sub-watersheds combine within Long Lake prior to outfalling at the Jobes Dam. When broken down into sub-watersheds, it is apparent that although the size of these watershed differ, the land cover type percentages are fairly similar, indicating that the same land types are located in each watershed (Figures 3.2-2 and 3.2-3). The watershed to lake area ratios are dissimilar for these watersheds (28:1 for Wilson Lake, 134:1 for the other lakes combined) though are fairly large overall.

In this system, the natural flow of water begins with the Elk River, which enters Duroy Lake. From there, water flows into Elk Lake and then into Long Lake. Wilson Lake drains into Long Lake, and the water from these lakes exits the chain through the Jobes Dam, which is located in southwestern Long Lake (Map 3). Because the Phillips Chain is an impoundment, water flows very quickly through the chain. In fact, using the Wisconsin Lake Modeling Suite (WiLMS), it is estimated that water will flush Duroy, Elk, and Long Lakes every 21.9 days, or about 18 times a year. Because Wilson Lake's watershed is much smaller, there is less water pushing through this system; Wilson Lake will flush about every 73 days, or 5 times in a given year. Compared to a seepage or natural drainage lakes, a flowage benefits from this natural flushing by minimizing the rate at which nutrients will build up within the system's sediments, as well as mixing oxygen throughout at least a portion of the water column.

Because the Phillips Chain of Lakes is a flowage and drains many acres of land, it will likely always be highly productive (euthrophic). In other words, the size of the watershed, no matter what land cover it supports, will keep the lakes productive. However, one area where improvements could be made upon is the immediate shoreline. Simple practices such as installing and maintaining shoreland buffer areas, using phosphorus free fertilizers, and reducing impervious surfaces will help to minimize additional phosphorus loading to the Phillips Chain of Lakes.
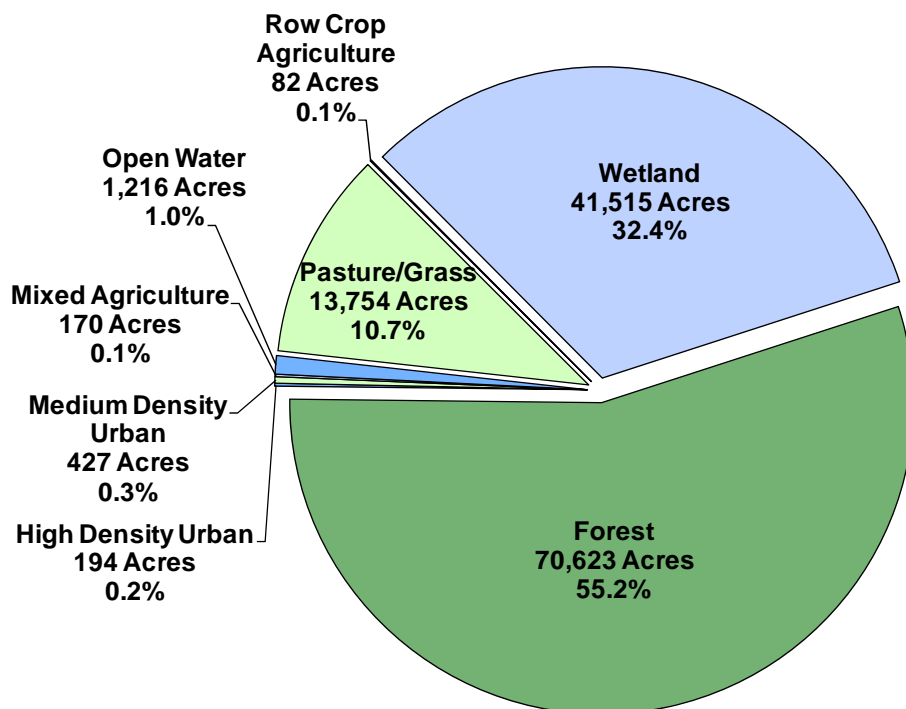
Figure 3.2-1. Phillips Chain of Lakes watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR, 1998).
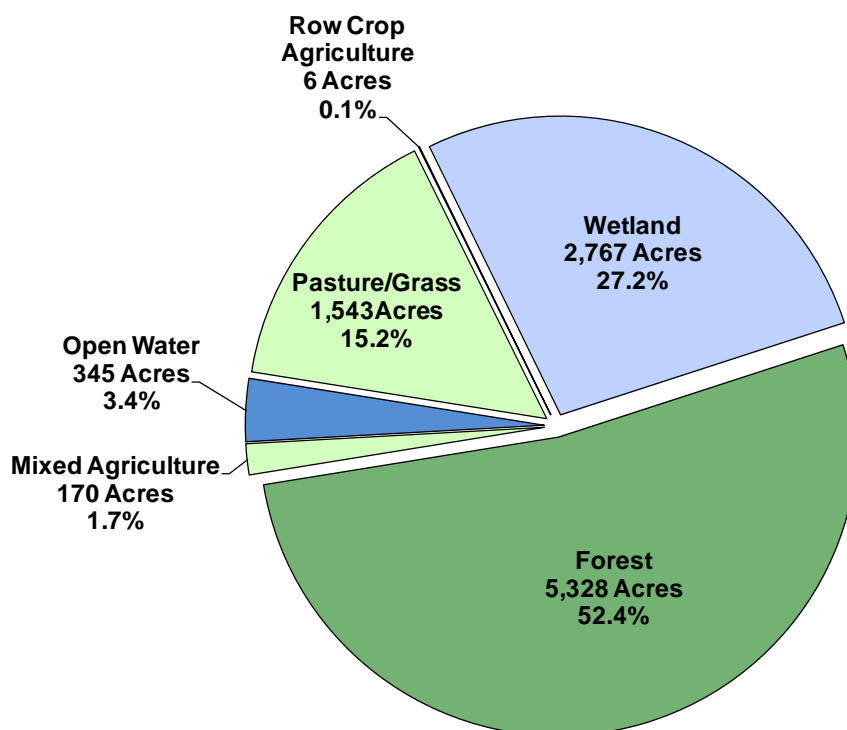
Figure 3.2-2. Wilson Lake watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR, 1998)..

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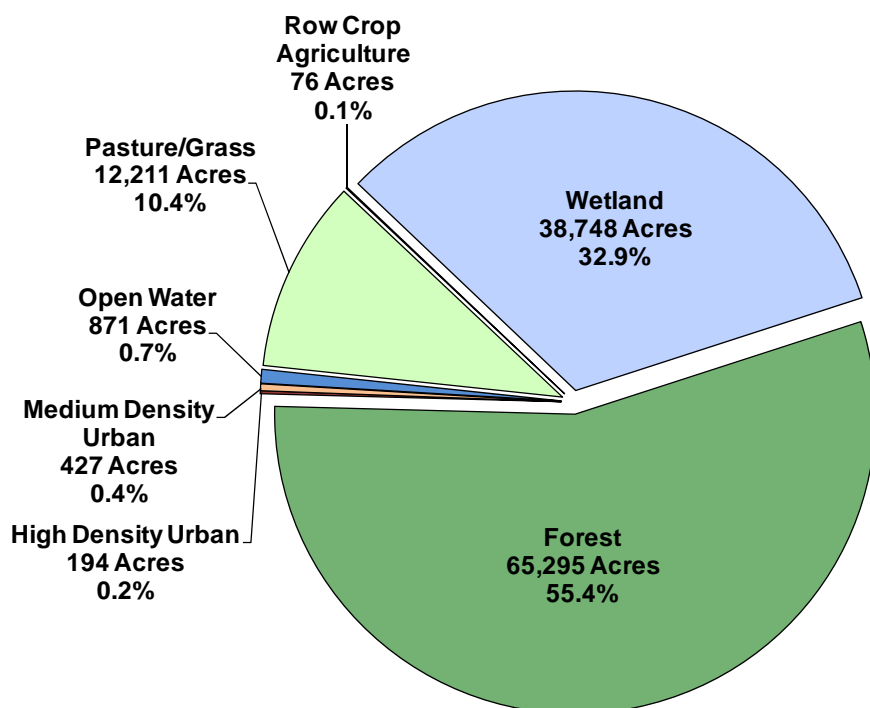
Figure 3.2-3. Duroy, Elk and Long Lakes watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR, 1998).

3.3 Aquatic Plants

Introduction

Although the occasional lake user considers aquatic macrophytes to be "weeds" and a nuisance to the recreational use of the lake, the plants are actually an essential element in a healthy and functioning lake ecosystem.   It is very important that lake stakeholders understand the importance of lake plants and the many functions they serve in maintaining and protecting a lake ecosystem. With increased understanding and awareness, most lake users will recognize the importance of the aquatic plant community and their potential negative effects on it.

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*) In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the *periphyton* attached to them as their primary food source. The plants also provide cover for feeder fish and *zooplankton*, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent shoreline erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by *phytoplankton*, which helps to minimize nuisance algal blooms.

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced predation by predator fish, which could result in a stunted pan-fish population.   *Exotic* plant species, such as Eurasian water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing *native* plants and reducing *species diversity*. These *invasive* plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

When plant abundance negatively affects the lake ecosystem and limits the use of the resource, plant management and control may be necessary. The management goals should always include the control of invasive species and restoration of native communities through environmentally sensitive and economically feasible methods. No aquatic plant management plan should only contain methods to control plants, they should also contain methods on how to protect and

possibly enhance the important plant communities within the lake. Unfortunately, the latter is often neglected and the ecosystem suffers as a result.

Aquatic Plant Management and Protection

Many times an aquatic plant management plan is aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that native aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community. Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, the herbivorous grass carp (*Ctenopharyngodon idella*) is illegal in Wisconsin and rotovation, a process by which the lake bottom is tilled, is not a commonly accepted practice.

> **Important Note:**
> Even though most of these techniques are not applicable to Phillips Chain of Lakes, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why particular methods are or are not applicable in their lake. The techniques applicable to Phillips Chain of Lakes are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Unfortunately, there are no "silver bullets" that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below.

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many aquatic plant management regulations. The rules for the regulations have been set forth by the WDNR as NR 107 and 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now, including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal occurs along no more than 30 feet of shoreline length and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within that 30 feet. This action can be conducted up to 150 feet from shore. Please note that a permit is needed in all instances if wild rice is to be removed. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR.

Permits are required for chemical and mechanical manipulation of native and non-native plant communities. Large-scale protocols have been established for chemical treatment projects covering >10 acres or areas greater than 10% of the lake littoral zone and more than 150 feet from shore. Different protocols are to be followed for whole-lake scale treatments (≥160 acres or ≥50% of the lake littoral area). Additionally, it is important to note that local permits and U.S. Army Corps of Engineers regulations may also apply. For more information on permit requirements, please contact the WDNR Regional Water Management Specialist or Aquatic Plant Management and Protection Specialist.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreline. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreline sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, Radomski and Goeman 2001, and Elias & Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a *shoreland buffer zone.* The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some of the shoreland's natural function.

Enhancement activities also include additions of *submergent*, *emergent*, and *floating-leaf* plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Cost

The cost of native, aquatic and shoreland plant restorations is highly variable and depend on the size of the restoration area, planting densities, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other factors may include extensive grading requirements, removal of shoreland stabilization (e.g., rip-rap, seawall), and protective measures used to guard the newly planted area from wildlife predation, wave-action, and erosion. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $4,200.

- The single site used for the estimate indicated above has the following characteristics:
  o An upland buffer zone measuring 35' x 100'.
  o An aquatic zone with shallow-water and deep-water areas of 10' x 100' each.
  o Site is assumed to need little invasive species removal prior to restoration.
  o Site has a moderate slope.
  o Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
  o Plant spacing for the aquatic zone would be 3 feet.
  o Each site would need 100' of biolog to protect the bank toe and each site would need 100' of wavebreak and goose netting to protect aquatic plantings.
  o Each site would need 100' of erosion control fabric to protect plants and sediment near the shoreline (the remainder of the site would be mulched).
  o There is no hard-armor (rip-rap or seawall) that would need to be removed.
  o The property owner would maintain the site for weed control and watering.

Advantages	*Disadvantages*
- Improves the aquatic ecosystem through species diversification and habitat enhancement. - Assists native plant populations to compete with exotic species. - Increases natural aesthetics sought by many lake users. - Decreases sediment and nutrient loads entering the lake from developed properties. - Reduces bottom sediment re-suspension and shoreline erosion. - Lower cost when compared to rip-rap and seawalls. - Restoration projects can be completed in phases to spread out costs. - Many educational and volunteer opportunities are available with each project.	- Property owners need to be educated on the benefits of native plant restoration before they are willing to participate. - Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in. - Monitoring and maintenance are required to assure that newly planted areas will thrive. - Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established.

Manual Removal

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however Wisconsin law states that all plant fragments must be removed. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent re-rooting and drifting onshore followed by decomposition. It is also important to preserve fish spawning habitat by timing the treatment activities after spawning. In Wisconsin, a general rule would be to not start these activities until after June 15th.

Cost
Commercially available hand-cutters and rakes range in cost from \$85 to \$150. Power-cutters range in cost from \$1,200 to \$11,000.

Advantages	*Disadvantages*
• Very cost effective for clearing areas around docks, piers, and swimming areas. • Relatively environmentally safe if treatment is conducted after June 15th. • Allows for selective removal of undesirable plant species. • Provides immediate relief in localized area. • Plant biomass is removed from waterbody.	• Labor intensive. • Impractical for larger areas or dense plant beds. • Subsequent treatments may be needed as plants recolonize and/or continue to grow. • Uprooting of plants stirs bottom sediments making it difficult to conduct action. • May disturb *benthic* organisms and fish-spawning areas. • Risk of spreading invasive species if fragments are not removed.

Water Level Drawdown

The primary manner of plant control through water level drawdown is the exposure of sediments and plant roots/tubers to desiccation and either heating or freezing depending on the timing of the treatment. Winter drawdowns are more common in temperate climates like that of Wisconsin and usually occur in reservoirs because of the ease of water removal through the

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outlet structure. An important fact to remember when considering the use of this technique is that only certain species are controlled and that some species may even be enhanced. Furthermore, the process will likely need to be repeated every two or three years to keep target species in check.

Cost

The cost of this alternative is highly variable. If an outlet structure exists, the cost of lowering the water level would be minimal; however, if there is not an outlet, the cost of pumping water to the desirable level could be very expensive. If a hydro-electric facility is operating on the system, the costs associated with loss of production during the drawdown also need to be considered, as they are likely cost prohibitive to conducting the management action.

Advantages	*Disadvantages*
• Inexpensive if outlet structure exists. • May control populations of certain species, like Eurasian water-milfoil for a few years. • Allows some loose sediment to consolidate, increasing water depth. • May enhance growth of desirable emergent species. • Other work, like dock and pier repair may be completed more easily and at a lower cost while water levels are down.	• May be cost prohibitive if pumping is required to lower water levels. • Has the potential to upset the lake ecosystem and have significant affects on fish and other aquatic wildlife. • Adjacent wetlands may be altered due to lower water levels. • Disrupts recreational, hydroelectric, irrigation and water supply uses. • May enhance the spread of certain undesirable species, like common reed (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*). • Permitting process may require an environmental assessment that may take months to prepare. • Unselective.

Mechanical Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 6 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants

from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor. Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the latter route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Costs

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $45,000 and $100,000. Larger harvesters or stainless steel models may cost as much as $200,000. Shore conveyors cost approximately $20,000 and trailers range from $7,000 to $20,000. Storage, maintenance, insurance, and operator salaries vary greatly.

Advantages	*Disadvantages*
• Immediate results. • Plant biomass and associated nutrients are removed from the lake. • Select areas can be treated, leaving sensitive areas intact. • Plants are not completely removed and can still provide some habitat benefits. • Opening of cruise lanes can increase predator pressure and reduce stunted fish populations. • Removal of plant biomass can improve the oxygen balance in the littoral zone. • Harvested plant materials produce excellent compost.	• Initial costs and maintenance are high if the lake organization intends to own and operate the equipment. • Multiple treatments are likely required. • Many small fish, amphibians and invertebrates may be harvested along with plants. • There is little or no reduction in plant density with harvesting. • Invasive and exotic species may spread because of plant fragmentation associated with harvester operation. • Bottom sediments may be re-suspended leading to increased turbidity and water column nutrient levels.

Chemical Treatment

There are many herbicides available for controlling aquatic macrophytes and each compound is sold under many brand names. Aquatic herbicides fall into two general classifications:

1. *Contact herbicides* act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.

2. *Systemic herbicides* spread throughout the entire plant and often result in complete mortality if applied at the right time of the year.

Both types are commonly used throughout Wisconsin with varying degrees of success. The use of herbicides is potentially hazardous to both the applicator

and the environment, so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use.

Applying herbicides in the aquatic environment requires special considerations compared with terrestrial applications. WDNR administrative code states that a permit is required if "you are standing in socks and they get wet." In these situations, the herbicide application needs to be completed by an applicator licensed with the Wisconsin Department of Agriculture, Trade and Consumer Protection. All herbicide applications conducted under the ordinary high water mark require herbicides specifically labeled by the United States Environmental Protection Agency.

Herbicides that target submersed plant species are directly applied to the water, either as a liquid or an encapsulated granular formulation. Factors such as water depth, water flow, treatment area size, and plant density work to reduce herbicide concentration within aquatic systems. Understanding concentration exposure times are important considerations for aquatic herbicides. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Some herbicides are applied at a high dose with the anticipation that the exposure time will be short. Granular herbicides are usually applied at a lower dose, but the release of the herbicide from the clay carrier is slower and increases the exposure time.

Below are brief descriptions of the aquatic herbicides currently registered for use in Wisconsin.

Fluridone (Sonar®, Avast!®) Broad spectrum, systemic herbicide that is effective on most submersed and emergent macrophytes. It is also effective on duckweed and at low concentrations has been shown to selectively remove Eurasian water-milfoil. Fluridone slowly kills macrophytes over a 30-90 day period and is only applicable in whole lake treatments or in bays and backwaters were dilution can be controlled. Required length of contact time makes this chemical inapplicable for use in flowages and impoundments. Irrigation restrictions apply.

Diquat (Reward®, Weedtrine-D®) Broad spectrum, contact herbicide that is effective on all aquatic plants and can be sprayed directly on foliage (with surfactant) or injected in the water. It is very fast acting, requiring only 12-36 hours of exposure time. Diquat readily binds with clay particles, so it is not appropriate for use in turbid waters. Consumption restrictions apply.

Endothall (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothall (Hydrothol®) is more toxic to fish and aquatic invertebrates, so the dipotassium salt (Aquathol®) is most often used. Fish consumption, drinking, and irrigation restrictions apply.

2,4-D (Navigate®, DMA IV®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water-milfoil without affecting many of our native plants, which are monocots. Drinking and irrigation restrictions may apply.

Triclopyr (Renovate®) Selective, systemic herbicide that is effective on broad leaf plants and, similar to 2,4 D, will not harm native monocots. Triclopyr is available in liquid or

granular form, and can be combined with Endothal in small concentrations (<1.0 ppm) to effectively treat Eurasian water-milfoil. Triclopyr has been used in this way in Minnesota and Washington with some success.

Glyphosate (Rodeo®) Broad spectrum, systemic herbicide used in conjunction with a *surfactant* to control emergent and floating-leaved macrophytes. It acts in 7-10 days and is not used for submergent species. This chemical is commonly used for controlling purple loosestrife (*Lythrum salicaria*). Glyphosate is also marketed under the name Roundup®; this formulation is not permitted for use near aquatic environments because of its harmful effects on fish, amphibians, and other aquatic organisms.

Imazapyr (Habitat®) Broad spectrum, system herbicide, slow-acting liquid herbicide used to control emergent species. This relatively new herbicide is largely used for controlling common reed (giant reed, *Phragmites*) where plant stalks are cut and the herbicide is directly applied to the exposed vascular tissue.

Cost

Herbicide application charges vary greatly between $400 and $1000 per acre depending on the chemical used, who applies it, permitting procedures, and the size of the treatment area.

Advantages	*Disadvantages*
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • Some herbicides can be used effectively in spot treatments.	• Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many herbicides are nonselective. • Most herbicides have a combination of use restrictions that must be followed after their application. • Many herbicides are slow-acting and may require multiple treatments throughout the growing season. • Overuse may lead to plant resistance to herbicides

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as waterhyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control waterhyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla*

verticillata), respectively. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian water-milfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian water-milfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian water milfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian water milfoil.

Cost

Stocking with adult weevils costs about $1.20/weevil and they are usually stocked in lots of 1000 or more.

Advantages	Disadvantages
• Milfoil weevils occur naturally in Wisconsin. • Likely environmentally safe and little risk of unintended consequences.	• Stocking and monitoring costs are high. • This is an unproven and experimental treatment. • There is a chance that a large amount of money could be spent with little or no change in Eurasian water-milfoil density.

Wisconsin has approved the use of two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These beetles were imported from Europe and used as a biological control method for purple loosestrife. Many cooperators, such as county conservation departments or local UW-Extension locations, currently support large beetle rearing operations. Beetles are reared on live purple loosestrife plants growing in kiddy pools surrounded by insect netting. Beetles are collected with aspirators and then released onto the target wild population. For more information on beetle rearing, contact your local UW-Extension location.

In some instances, beetles may be collected from known locations (*cella* insectaries) or purchased through private sellers. Although no permits are required to purchase or release beetles within Wisconsin, application/authorization and release forms are required by the WDNR for tracking and monitoring purposes.

Cost

The cost of beetle release is very inexpensive, and in many cases is free.

Advantages	Disadvantages
• Extremely inexpensive control method. • Once released, considerably less effort than other control methods is required. • Augmenting populations many lead to long-term control.	• Although considered "safe," reservations about introducing one non-native species to control another exist. • Long range studies have not been completed on this technique.

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, like variable water levels or negative, like increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways; there may be a loss of one or more species, certain life forms, such as emergents or floating-leaf communities may disappear from certain areas of the lake, or there may be a shift in plant dominance between species. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide very useful information for management decisions.

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Phillips Chain of Lakes; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the species that were found within the lake, both exotic and native. The list also contains the life-form of each plant found, its scientific name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in life-forms that are present, can be an early indicator of changes in the health of the lake ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of Phillips Chain of Lakes, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, relative frequency of occurrence is used to describe how often each species occurred in the plots that contained vegetation. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

In the end, this analysis indicates the species that dominate the plant community within the lake. Shifts in dominant plants over time may indicate disturbances in the ecosystem. For instance, low water levels over several years may increase the occurrence of emergent species while decreasing the occurrence of floating-leaf species. Introductions of invasive exotic species may result in major shifts as they crowd out native plants within the system.

Onterra LLC
Lake Management Planning

Species Diversity

Species diversity is probably the most misused value in ecology because it is often confused with species richness. Species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because diversity also takes into account how evenly the species occur within the system. A lake with 25 species may not be more diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

A lake with high species diversity is much more stable than a lake with a low diversity. This is analogous to a diverse financial portfolio in that a diverse lake plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic

Figure 3.3-1. Location of Phillips Chain of Lakes within the ecoregions of Wisconsin. After Nichols 1999.

fluctuations. For example, a lake with a diverse plant community is much better suited to compete against exotic infestation than a lake with a lower diversity.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Phillips Chain of Lakes will be compared to lakes in the same ecoregion and in the state (Figure 3.3-1).

Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states.

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality.

Community Mapping

A key component of the aquatic plant survey is the creation of an aquatic plant community map. The map represents a snapshot of the important plant communities in the lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with surveys completed in the future. A mapped community can consist of submergent, floating-leaf, or emergent plants, or a combination of these life-forms. Examples of submergent plants include wild celery and pondweeds; while emergents include cattails, bulrushes, and arrowheads, and floating-leaf species include white and yellow pond lilies. Emergents and floating-leaf communities lend themselves well to mapping because there are distinct boundaries between communities. Submergent species are often mixed throughout large areas of the lake and are seldom visible from the surface; therefore, mapping of submergent communities is more difficult and often impossible.

Exotic Plants

Because of their tendency to upset the natural balance of an aquatic ecosystem, exotic species are paid particular attention to during the aquatic plant surveys. Two exotics, curly-leaf pondweed and Eurasian water milfoil are the primary targets of this extra attention.

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.3-2). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants. Curly –leaf pondweed begins growing almost immediately after ice-out and by mid-June is at peak biomass. While it is growing, each plant produces many turions (asexual reproductive shoots) along its stem. By mid-July most of the plants have senesced, or died-back, leaving the turions in the sediment. The turions lie dormant until fall when they germinate to produce winter foliage, which thrives under the winter snow and ice. It remains in this state until spring foliage is produced in early May, giving the plant a significant jump on native
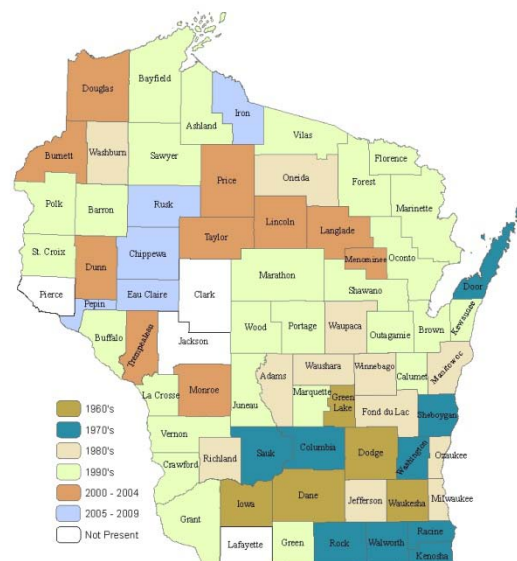
Figure 3.3-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2009 mapped by Onterra.

vegetation. Like Eurasian water-milfoil, curly-leaf pondweed can become so abundant that it hampers recreational activities within the lake. Furthermore, its mid-summer die back can cause algal blooms spurred from the nutrients released during the plant's decomposition.

Because of its odd life-cycle, a special survey is conducted early in the growing season to inventory and map curly-leaf pondweed occurrence within the lake. Although Eurasian water milfoil starts to grow earlier than our native plants, it is at peak biomass during most of the summer, so it is inventoried during the comprehensive aquatic plant survey completed in mid to late summer.

Aquatic Plant Survey Results – Chain-wide

As mentioned above, numerous plant surveys were completed as a part of this project. In June 2009, surveys were completed by trained volunteers of the Phillips Chain O' Lakes Association that focused upon curly-leaf pondweed. This meander-based survey did not locate any occurrences of curly-leaf pondweed. It is believed that this aquatic invasive species either does not occur in Phillips Chain of Lakes or exists at an undetectable level. Curly-leaf pondweed does exist in nearby Solberg Lake, Big Dardis Lake, and Musser Lake, which are all within 5 miles of the Phillips Chain and eventually flow into Duroy Lake. Routine surveys by volunteers will ensure early-detection if curly-leaf pondweed does make it into the Phillips Chain.

> **Median Value** This is the value that roughly half of the data are smaller and half the data are larger. A median is used when a few data are so large or so small that they skew the average value to the point that it would not represent the population as a whole.

The point intercept surveys were conducted on Duroy, Elk, and Long in July of 2009 by Onterra, while the point intercept survey on Wilson Lake was conducted in early September 2007 by the WDNR. Additional surveys were conducted on all four lakes by Onterra to create the aquatic plant community maps (Maps 3, 4, and 5) during July of 2009.

Table 3.3-1. Phillips Chain of Lakes point-intercept resolutions.

Lake Name	Point-intercept Resolution (meters)	Sample Points
Duroy Lake	78	231
Elk Lake	32	343
Long Lake	52	630
Wilson Lake*	78	225

* Completed by the WDNR in 2007

During the point-intercept and aquatic plant mapping surveys, 48 species of plants were located in Phillips Chain of Lakes (Table 3.3-2), two are considered non-native species: Eurasian water milfoil and purple loosestrife. Eurasian water milfoil was present in all four lakes and was the most frequently encountered aquatic plant species in the chain, while only one occurrence of purple loosestrife was located on the margins of Duroy Lake. Because of their importance, these species will be discussed in depth in separate sections. Vasey's pondweed, a species listed by the Natural Heritage Inventory Program as being of 'special concern' in Wisconsin, was located in Long Lake.

Table 3.3-2. Aquatic plant species located on the Phillips Chain of Lakes during 2007 and 2009 surveys. Species' drawdown data from Nichols and Vennie (1991).

Life Form	Scientific Name	Common Name	Reported Response to Winter Drawdown	Coefficient of Conservatism (C)	Duroy	Elk	Long	Wilson
Emergent	Acorus americanus	Sweet-flag	Not Reported	7			I	
	Calla palustris	Water arum	Not Reported	9			I	
	Carex comosa	Bristly sedge	Not Reported	5	I			X
	Carex utriculata	Common yellow lake sedge	Not Reported	7			I	
	Carex vesicaria	Blister Sedge	Not Reported	7			I	
	Eleocharis palustris	Creeping spikerush	Not Reported	6			I	I*
	Equisetum fluviatile	Water horsetail	Not Reported	7				I*
	Lythrum salicaria	Purple loosestrife	Not Reported	Exotic	I			
	Pontederia cordata	Pickerelweed	Not Reported	9	X	I		
	Sagittaria latifolia	Common arrowhead	Not Reported	3			I	
	Sagittaria rigida	Stiff arrowhead	Not Reported	8				I
	Schoenoplectus subterminalis	Water bulrush	Not Reported	9				I*
	Schoenoplectus tabernaemontani	Softstem bulrush	Increase	4	X		I	I*
	Typha latifolia	Broad-leaved cattail	Variable Response	1	I	I	I	I*
	Zizania palustris	Northern wild rice	Not Reported	8	X			I*
FL	Nuphar variegata	Spatterdock	Decrease	6	X	X	I	I*
	Nymphaea odorata	White water lily	Not Reported	6	X	X	X	X
FL/E	Sparganium eurycarpum	Common bur-reed	Not Reported	5	X	I	I	I*
	Sparganium fluctuans	Floating-leaf bur-reed	Not Reported	10	X			I*
	Sparganium angustifolium	Narrow-leaf bur-reed	Not Reported	9	I			
	Sparganium emersum	Short-stemmed bur-reed	Variable Response	8	X			
FF	Lemna turionifera	Turion duckweed	Not Reported	9		X	X	X
	Lemna trisulca	Forked duckweed	Not Reported	6			X	X
	Spirodela polyrhiza	Greater duckweed	Decrease	5			X	X
Submergent	Ceratophyllum demersum	Coontail	Variable Response	3	X	X	X	X
	Chara sp.	Muskgrasses	Variable Response	7	X			
	Elodea canadensis	Common waterweed	Variable Response	3	X	X	X	X
	Megalodonta beckii	Water marigold	Increase	8	X		X	
	Myriophyllum heterophyllum	Various-leaved water milfoil	Variable Response	7	X	X	X	I*
	Myriophyllum sibiricum	Northern water milfoil	Variable Response	7				X
	Myriophyllum spicatum	Eurasian water milfoil	Variable Response	Exotic	X	X	X	X
	Myriophyllum verticillatum	Whorled water milfoil	Not Reported	8				X
	Najas flexilis	Slender naiad	Increase	6	X		X	X
	Nitella sp.	Stoneworts	Not Reported	7	X			X
	Potamogeton alpinus	Alpine pondweed	Not Reported	9	X			
	Potamogeton amplifolius	Large-leaf pondweed	Variable Response	7	X	X	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	Variable Response	8	X	X	X	X
	Potamogeton natans	Floating-leaf pondweed	Increase	5	I			X
	Potamogeton obtusifolius	Blunt-leaf pondweed	Not Reported	9	X			X
	Potamogeton pusillus	Small pondweed	Not Reported	7	X	X	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	Variable Response	5	X			
	Potamogeton robbinsii	Fern pondweed	Decrease	8	X		X	X
	Potamogeton spirillus	Spiral-fruited pondweed	Not Reported	8	X		X	X
	Potamogeton vaseyi	Vasey's pondweed	Not Reported	10			X*	
	Potamogeton zosteriformis	Flat-stem pondweed	Variable Response	6	X		X	X
	Utricularia gibba	Creeping bladderwort	Not Reported	9				I*
	Utricularia vulgaris	Common bladderwort	Decrease	7				I*
	Vallisneria americana	Wild celery	Increase	6				X

FL = Floating-leaf, FL/E = Floating-leaf/Emergent, FF = Free-floating, X = Present, X* = Species of special concern, I = Incidental from Onterra, I* = Incidental from WDNR

Of the 46 native aquatic plant species observed, common waterweed, coontail, and white water lily were the three most frequently encountered native species chain-wide. Figure 3.3-3 displays the littoral frequency of occurrence of the six most frequently encountered native plant species in the Phillips Chain. Littoral frequency is reported as the frequency of occurrence (%) for a given species within areas that are less than or equal to the maximum depth of plant growth for each lake.
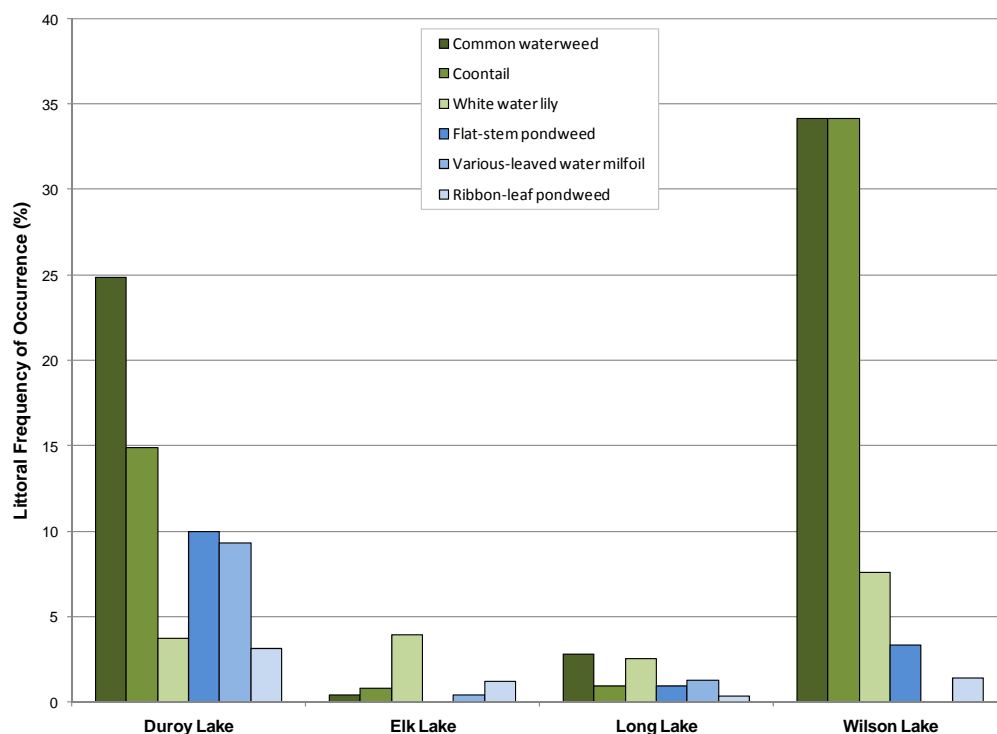
Figure 3.3-3 Phillips Chain of Lakes common native aquatic plant species' littoral frequency of occurrence. Displayed are the six-most frequently encountered native plant species common to all four lakes. Created using data from 2007 and 2009 surveys.

Common waterweed and coontail lack true root structures, often making their locations within a lake subject to water movement and their tendency to become entangled in other plants, rocks, or debris. Being non-rooted, they acquire the majority of their nutrients directly from the water reducing the nutrients available to free-floating algae, often improving water clarity. However, in highly productive systems with high nutrient levels like the Phillips Chain, these plants can often grow to nuisance levels and interfere with recreational activities. Yet, these dominant plants are an important source of structural habitat and food for many aquatic and terrestrial organisms.

Figure 3.3-4 displays the point-intercept sampling locations that fell below or equal to the maximum depth of plant growth (the littoral zone) in each lake. Please note that sampling points covered the entirety of each lake, but displayed are only the points that fell within the littoral zone. The sampling points which contained aquatic vegetation are colored green.

Of the four lakes, Wilson Lake had the highest occurrence of aquatic vegetation with approximately 70% of the sampling locations within the littoral zone containing aquatic vegetation. The majority of Wilson Lake is comprised of habitat suitable for aquatic plant growth; relatively shallow with soft sediments. Duroy Lake contains a moderate amount of aquatic vegetation which is concentrated in the shallower areas with soft sediments near the lake's inlets and wetland fringe. Approximately 48% of the sampling points that were within the littoral zone contained aquatic vegetation.

Conversely, Long Lake and Elk Lake are sparsely vegetated. Long Lake not only has a higher proportion of course substrates, but is deep with relatively steep sides, restricting the littoral zone to the shallower northern and southern portions of the lake as well as the lake margins. Only 6% of the sampling points within the littoral zone of Long Lake contained aquatic vegetation. Elk Lake also has a relatively small littoral zone with 15% of the sampling points within it containing aquatic vegetation. The lack of vegetation in Long Lake and Elk Lake may be due to the fact that they function more like river channels, with higher flow, deeper water, and more turbid conditions which make them less suitable for aquatic vegetation. Duroy Lake and Wilson Lake are likely remnant wetlands with slow-moving water which settles out incoming sediment, increasing water clarity and providing suitable substrate to support plant growth. Figure 3.3-5 displays the proportion of substrate types (muck, sand, and rock) in the littoral zone of each lake that were determined from the 2007 and 2009 point-intercept surveys. Both Elk Lake and Long Lake have higher proportions of sand and rock in their littoral zones, which is less suitable for aquatic vegetation. It is also possible that the lack of aquatic vegetation in Elk Lake and northern areas of Long Lake may also be due to heavy metal contamination within the lake's sediments which is discussed in more detail in the individual lake aquatic plant sections below.
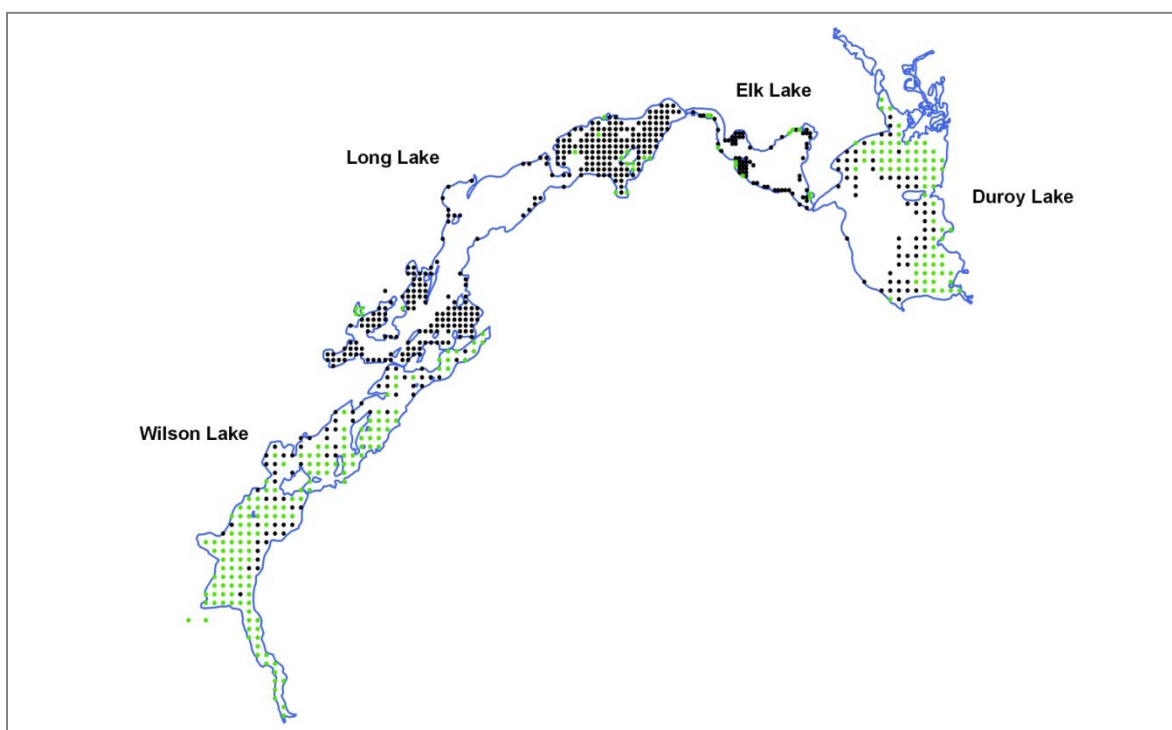
Figure 3.3-4 Phillips Chain of Lakes littoral point-intercept sampling locations. All points displayed fell at or below the maximum depth of plant growth. Green sampling points contained aquatic vegetation. Created using data from 2007 and 2009 surveys.
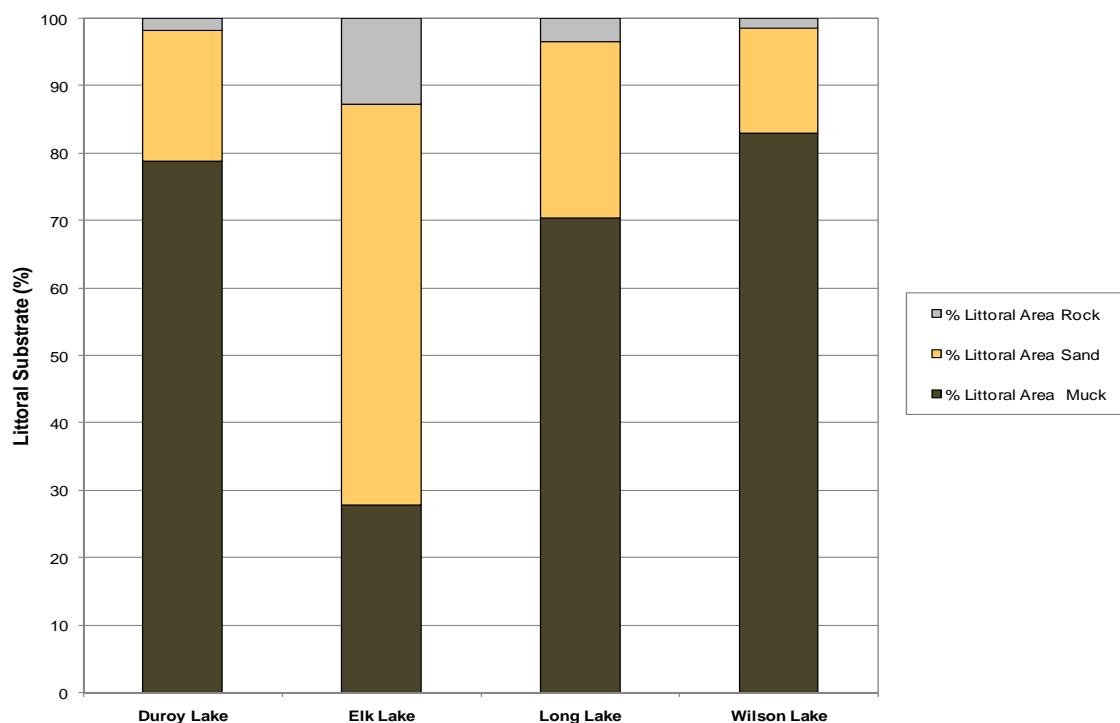
Figure 3.3-5 Proportions of substrate types within the littoral zones of the Phillips Chain of Lakes. Created from the 2007 and 2009 point-intercept surveys.

Flowages, such as the Phillips Chain of Lakes, tend to have higher species richness than natural lakes because flowages are generally larger and contain diverse habitats differing in substrate type, water depth, and water movement. Some aquatic plants, like coontail, are habitat generalists able to grow in many habitat types, while other species are more habitat-specific, like alpine pondweed which is usually found growing in shallow areas with quiet water and spiral-fruited pondweed, usually found growing in sandy substrates. All of these varying habitat characteristics generally lead to a species-rich environment, and this is what is observed in the Phillips Chain. However, as discussed earlier, the aquatic vegetation is not evenly distributed throughout the four lakes in the chain. Wilson Lake had the highest number of native aquatic plant species (33), followed by Duroy Lake (28), Long Lake (26), and Elk Lake (12). The number of native plant species for Wilson, Duroy, and Long Lakes are all above the Northern Flowages Ecoregion and state medians, while Elk Lake falls below both (Figure 3.3-6).

Because of the high number of aquatic plant species, one may assume that the system would also have high species diversity. As discussed previously, how evenly the species are distributed throughout the system also influences the system's diversity. Duroy Lake and Long Lake have high species diversity (0.91) (Figure 3.3-7), indicating that these lakes have relatively even distributions (relative frequencies) of plant species. However, Wilson Lake (0.84) and Elk Lake (0.73) have lower diversity values, signifying a more uneven distribution of plant species within these lakes. Another way to look at this is if two individual plants were randomly selected from Duroy Lake, there would be a 91% probability that the two individuals would belong to different species, or only a 9% chance that they would belong to the same species.
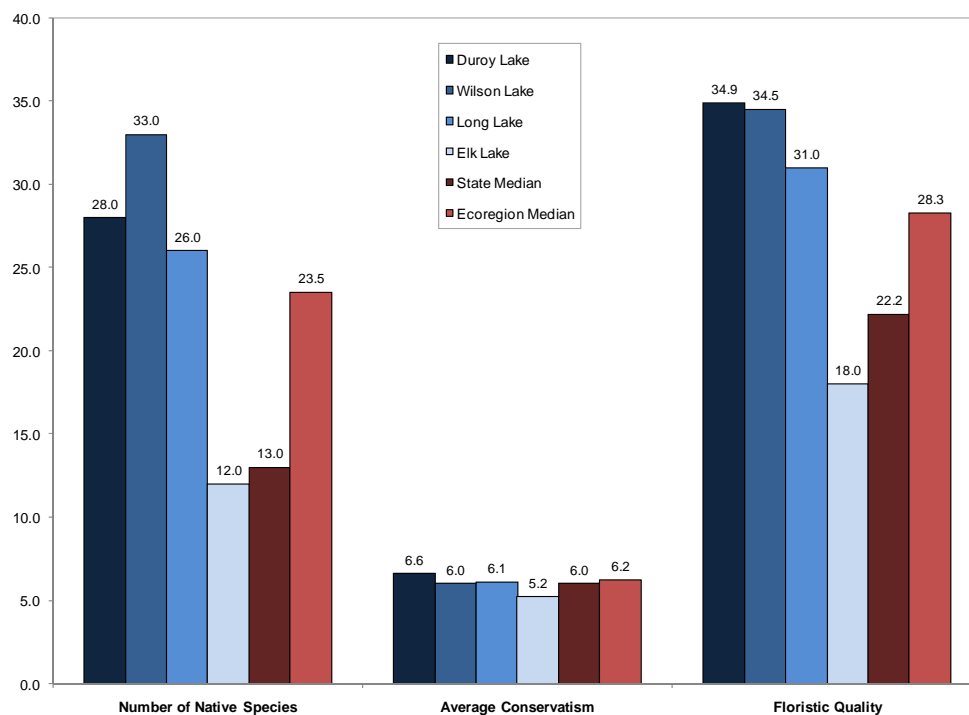
Figure 3.3-6. Phillips Chain of Lakes Floristic Quality Assessment. Created using data from 2007 and 2009 surveys. Analysis follows Nichols (1999).
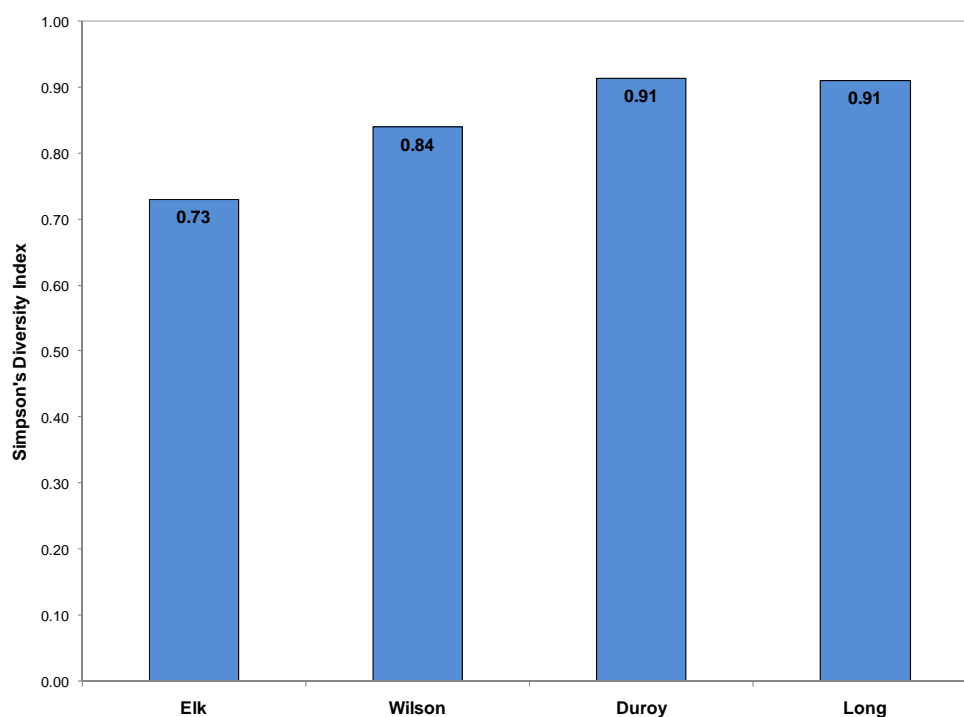
Figure 3.3-7. Phillips Chain of Lakes species diversity. Created using data from 2007 and 2009 surveys.

Data collected from the aquatic plant surveys indicate that the average conservatism value for Duroy Lake (6.6) was above the Northern Flowages Ecoregion and state medians, Long Lake (6.1) and Wilson Lake (6.0) had values similar to the ecoregion and state medians, and Elk Lake's value (5.2) is below the ecoregion and state medians (Figure 3.3-6). This indicates that when compared to other aquatic plant communities of impounded lakes in the ecoregion and state, Duroy Lake's is of higher quality, Long and Wilson Lakes' are of similar quality to other impounded lakes, and Elk Lake's is of lower quality.

Looking at the aquatic plant species chain-wide, seventeen species had conservatism values of 8 or greater and over half of the species had values of 7 or greater (Figure 3.3-8). The average conservatism value for the Phillips Chain is 6.7, indicating that the plant community is of higher quality than most impoundments in the ecoregion and the state.

The Floristic Quality Index (FQI) was calculated for each lake by combining the species richness and average conservatism values (equation shown below). The FQI values for Duroy, Long, and Wilson Lakes were well above the ecoregion and state median, while Elk Lake's FQI value fell well below both (Figure 3.3-6).

$$FQI = Average\ Coefficient\ of\ Conservatism * \sqrt{Number\ of\ Native\ Species}$$
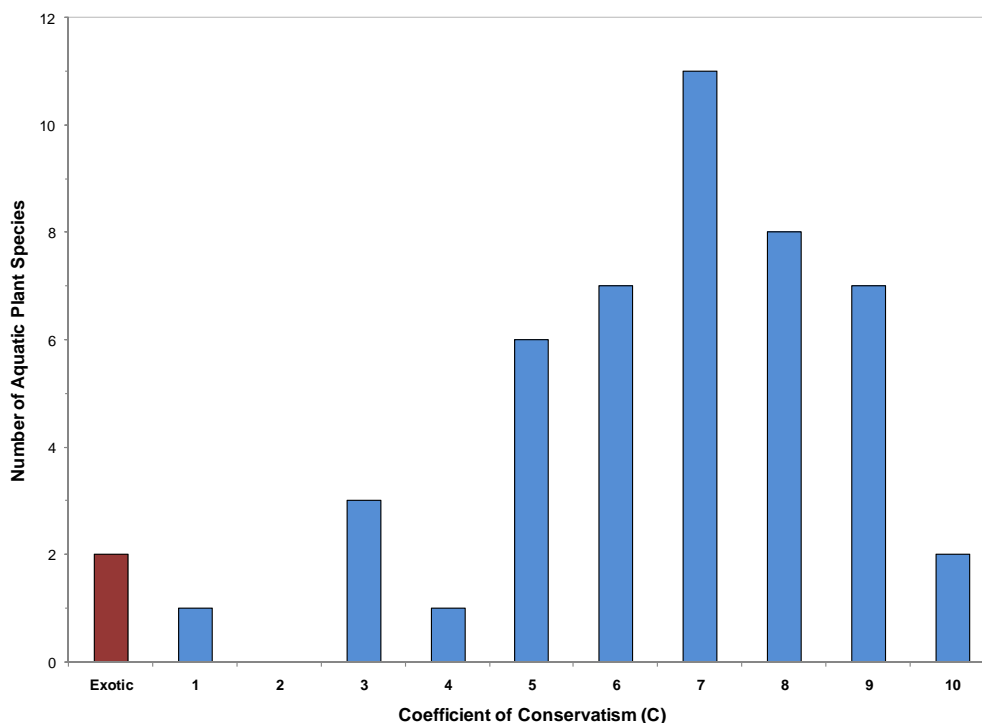
Figure 3.3-8. Phillips Chain of Lakes plant species' coefficient of conservatism frequency distribution. Created using data from 2007 and 2009 surveys.

The quality of the Phillips Chain's plant community is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas of the chain. The 2009 community map indicates that approximately 140 acres (11%) of the chain contains these types of plant communities (Table 3.3-2). Twenty species of emergent and floating-leaf species were

located during the 2007 and 2009 aquatic plant surveys. However, these plant communities, like the submergent plant communities, were not evenly distributed among the four lakes. Approximately 97% of the total acreage of the emergent and floating-leaf communities is located within Duroy and Wilson Lakes. As discussed earlier, these lakes are remnant wetlands; relatively shallow with slow-moving water and soft sediments, excellent habitat for these types of plant communities.

These large areas of emergent and floating-leaf plant communities are an essential component the chain ecosystem, providing valuable habitat for fish and other wildlife. They are also important where structural habitat, such as trees and other forms of coarse-woody debris, are sparse. Continuing the analogy that the community map represents a 'snapshot' of the emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within the Phillips Chain of Lakes. This is important because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goemen (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in the abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Table 3.3-3. Phillips Chain of Lakes acres of emergent and floating-leaf community types. Created using data from the 2009 aquatic plant mapping surveys.

Plant Community	Acres				
	Duroy	Elk	Long	Wilson	Chain-wide
Emergent	9.0	0.0	0.0	0.7	9.7
Floating-leaf	20.7	0.5	0.4	3.8	25.4
Mixed Emergent and Floating-leaf	49.4	1.2	2.7	51.7	105.0
Total	79.1	1.7	3.0	56.2	140.1

Traditional forms of disturbance that often affect lakes include human development of the lakes' shoreline and motorboat traffic. The stakeholder survey of the Phillips Chain of Lakes indicates that motorboats with a 25 horsepower or greater motor are the most prevalent watercraft on the chain (Appendix B, Question #13). Many studies have documented the adverse effects of motorboat traffic on aquatic plants (e.g. Murphy and Eaton 1983, Vermaat and de Bruyne 1993, Mumma et al. 1996, Asplund and Cook 1997). In all of these studies, lower plant biomass and/or declines and higher turbidity were associated with motorboat traffic. Eurasian water milfoil infestation can also be viewed as a disturbance and can cause a shift of the aquatic plant community, particularly in respect to those species with higher coefficients of conservatism (Table 3.3-2).

Aquatic Plant Survey Results – Individual Lake Analysis

Duroy Lake

During the point-intercept and aquatic plant mapping surveys, 30 species of plants were located in Duroy Lake, two of which are considered non-native species: Eurasian water milfoil and purple loosestrife. Two large areas of dominant Eurasian water milfoil were mapped during the peak-biomass survey (Map 7). One occurrence of purple loosestrife was documented on the extreme western shore of Duroy Lake (Map 4). Both of these species will be discussed in more detail in a section below.

As discussed in the Chain-wide Aquatic Plant Section, the species richness, average conservatism, and floristic quality of Duroy Lake are all higher than the Northern Flowages Ecoregion and Wisconsin state medians. Duroy Lake has the highest average conservatism (6.6) of the four lakes in the Phillips Chain, indicating that the plant community contains a higher number of aquatic plant species that are sensitive to environmental disturbance and is more indicative of a pristine condition than those found in most impounded lakes in the state and ecoregion. The fact that the northern, eastern, and southern shorelines remain undeveloped wetland has probably minimized human disturbance in these areas.

Approximately 48% of the point-intercept sampling locations that fell within the maximum depth of aquatic plant growth (7 feet) on Duroy Lake contained aquatic vegetation. Figure 3.3-9 shows that common waterweed was the most frequently encountered plant species in Duroy Lake, followed by Eurasian water milfoil, coontail, and flat-stem pondweed. Although Eurasian water milfoil is the second-most prevalent plant species in the lake, the plant community is still comprised of a relatively high number of native species (species richness). The plant species present in Duroy Lake are relatively evenly distributed, as indicated by a high diversity index value (0.91).

The only other milfoil species found in Duroy Lake is various-leaved water milfoil. Various-leaved water milfoil is native to Wisconsin and was observed forming dense stands, most notably in the shallows of the northeastern portion of the lake. Like Eurasian water milfoil, it possesses feathery foliage, but this species can be distinguished from Eurasian water milfoil by having fewer (7-10) pairs of leaflets, whorls of leaves closely spaced apart with some leaves found growing scattered on the stem. Its closely spaced whorls of leaves provide ample surface area for periphyton (microbes, algae, detritus, etc.) to grow which provide food and important habitat for aquatic invertebrates.

Two less frequently encountered species in Wisconsin, alpine pondweed and blunt-leaf pondweed were also found growing in Duroy Lake. While these species are not listed as threatened or endangered in Wisconsin, they are relatively uncommon and are both given high coefficients of conservatism (9).
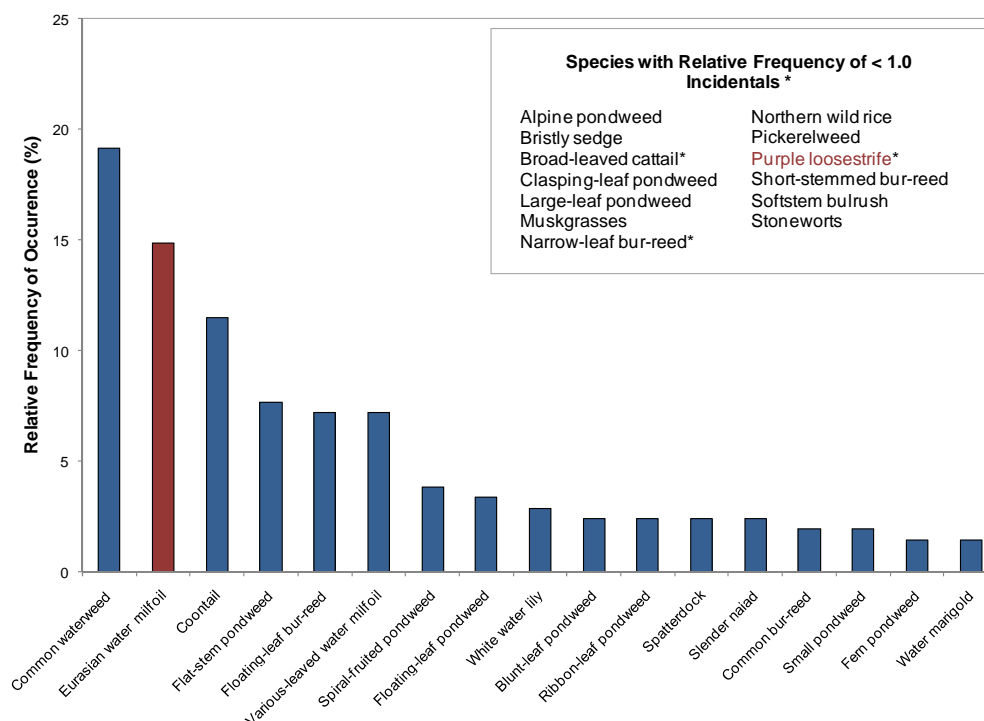
Figure 3.3-9. Duroy Lake aquatic plant occurrence analysis. Created using data from July 2009 surveys. Exotic species indicated with red.

Approximately 79 acres (21%) of Duroy Lake contains emergent and floating-leaf plant communities (Map 4). The majority of these plant communities are found along the northeastern and southeastern shorelines at the mouths of the inlets feeding in to Duroy Lake. These inlets bring in rich, organic material that eventually settles, creating shallow, nutrient-rich areas where these emergent and floating-leaf communities can thrive.

Elk Lake

Of the point-intercept sampling points in Elk Lake that fell within the maximum depth of plant growth (5 feet), 12 (15%) contained aquatic vegetation, making the plant community of Elk Lake essentially nonexistent. One small sprig of the non-rooting coontail was pulled up from a depth of 9 feet. However, no other aquatic vegetation was observed between 5 and 9 feet, and it is probable that this coontail was not actively growing and its location at this depth was due to water movements.

As can be expected with a depauperate aquatic plant community, only 13 species of aquatic plants were located during the point-intercept and aquatic plant community mapping surveys, one of which is considered a non-native species: Eurasian water milfoil (EWM). Only two single EWM plants were located growing near the northwestern shoreline (Map 7). As mentioned above, Eurasian water milfoil will be discussed in more detail in a section below. The average conservatism value (5.2) and floristic quality (18.0) for Elk Lake are the lowest in the Phillips Chain and are well below the Northern Flowages Ecoregion and Wisconsin state medians.

As discussed in the Phillips Chain Water Quality Section, besides substrate and lake morphology characteristics, the lack of aquatic vegetation in Elk Lake may in part be due sediment contamination by heavy metals as indicated above in the Water Quality Section. In a laboratory study conducted by Muhittin et al. (2009), increasing concentrations of heavy metals induced oxidative stress in common waterweed, a very common plant found in the Phillips Chain. Oxidative stress is a condition occurring when reactive oxygen species that can cause cellular damage, exceed the plant's ability to neutralize and eliminate them. It is possible that these metals are having a negative impact on aquatic plant growth. While aquatic plants have been used to remediate heavy metal contamination, the concentrations in Elk Lake may be too high to sustain a substantial and healthy aquatic plant community.

Of the aquatic plants that are present in Elk Lake, the most frequently encountered species was white water lily, a floating-leaf species (Figure 3.3-10). The most frequently encountered submersed species was ribbon-leaf pondweed, a species that does well in flowing waters. Like Duroy Lake, the native various-leaved water milfoil was the only other milfoil other than Eurasian water milfoil observed in Elk Lake.

The small amount of emergent and floating-leaf plant communities on Elk Lake further illustrate the lack of a significant plant community (Map 4). Approximately 1.7 acres (2%) of the 88-acre lake contain these types of plant communities. It is unclear whether the lack of these communities is due to heavy metal contamination or the channelized morphology of Elk Lake.
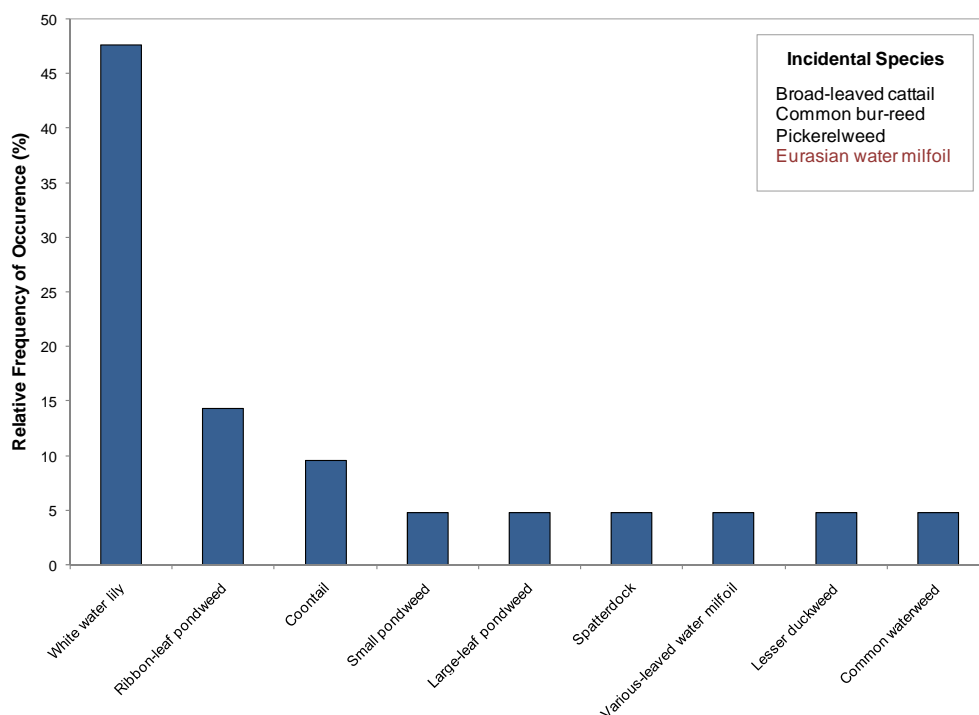
Figure 3.3-10. Elk Lake aquatic plant occurrence analysis. Created using data from July 2009 surveys. Exotic species indicated with red.

Long Lake

During the point-intercept and aquatic plant mapping surveys, 27 species of aquatic plants were located in Long Lake, one of which is considered a non-native species: Eurasian water milfoil (EWM). Long Lake had relatively little EWM, and it was only observed growing in the northern portion of the lake (Map 7). As mentioned above, Eurasian water milfoil will be discussed in more detail in a section below.

While Long Lake has relatively high species richness, most of the lake area was devoid of aquatic vegetation, with most of plants occurring in a few isolated, backwater bays. Only around 6% of the point-intercept locations sampled within the maximum depth range of plant growth (10 feet) contained aquatic vegetation. The absence of aquatic vegetation in the northern portion of Long Lake may also be related to sediment contamination by heavy metals discharged into Elk Lake, which is just upstream from Long Lake (Appendix F).

Although aquatic plants are sparse in Long Lake, the communities that do exist are diverse and of relatively high quality. Like Duroy Lake, Long Lake has high species diversity meaning the plant species have a relatively even distribution (relative frequency). Figure 3.3-11 shows that common waterweed was the most frequently encountered species, followed by white water lily, various-leaved water milfoil and Eurasian water milfoil. One plant species observed in a bay near the southern end of the lake is of particular interest; Vasey's pondweed, which is listed by the Natural Heritage Inventory Program as being a species of 'special concern' in Wisconsin (WDNR 2010). While this species' populations are apparently secure globally, its populations are rare in Wisconsin.

Figure 3.3-11. Long Lake aquatic plant occurrence analysis. Created using data from July 2009 surveys. Exotic species indicated with red.
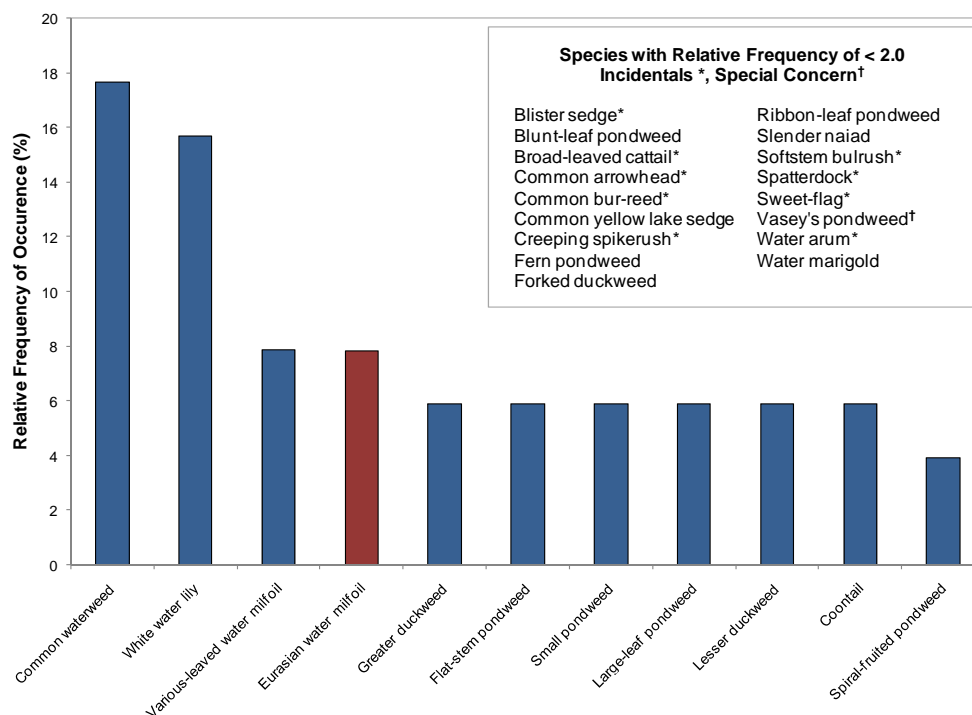
Long Lake also had a relatively low incidence of emergent and floating-leaf plant communities. The 2009 community map for Long Lake indicates that approximately 3 acres (0.7%) of the 418-acre lake contained these types of plant communities; the majority occurring in southwestern and northeastern bays (Map 5). The steep and rocky shorelines of this lake are not conducive to emergent and floating-leaf plant communities. They are also vulnerable to shoreline development, which is quite high on Long Lake.
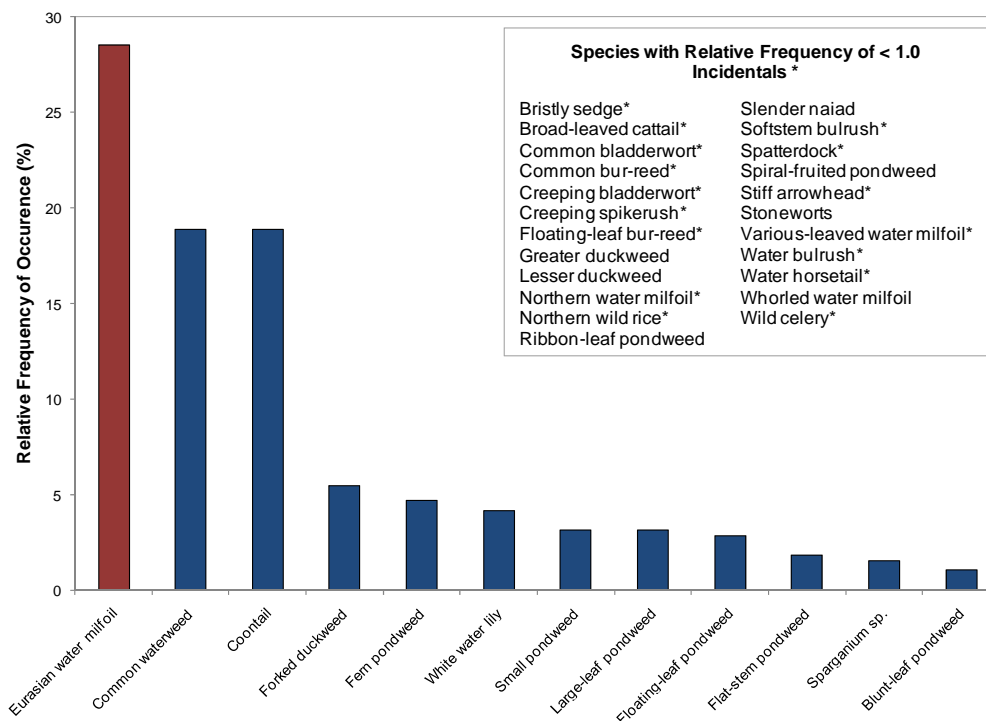
Wilson Lake

During the point-intercept survey conducted by the WDNR and the aquatic plant mapping surveys conducted by Onterra, 34 species of plants were located in Wilson Lake, which is the highest of the four lakes in the chain. One non-native species, Eurasian water milfoil was found growing throughout most of Wilson Lake with the largest areas of nuisance (surface matting) Eurasian water milfoil located within the southern half of the lake (Map 7). Approximately 180 acres (51%) of the lake contained Eurasian water milfoil.

Eurasian water milfoil was the most frequently encountered species from the WDNR's point-intercept survey, followed by common waterweed and coontail (Figure 3.3-12). Unlike Elk and Long Lakes which were very sparsely vegetated, the majority (70%) of the point-intercept sampling locations in Wilson Lake within the maximum depth of plant growth (8.5 feet) contained aquatic vegetation. Although Wilson Lake contains the highest number of native plant species in the chain (species richness), the species diversity (0.84) is the third lowest. This means that the aquatic plants within the Wilson Lake plant community have a relatively uneven distribution (relative frequency), and in this case, is dominated by Eurasian water milfoil, common waterweed, and coontail. The fourth most frequently encountered species, forked duckweed, is a free-floating species that is often found entangled amongst submersed vegetation, and its high occurrence within Wilson Lake is likely due to the large amount of submersed vegetation present.

In addition to Eurasian water milfoil, three additional milfoil species were found growing in Wilson Lake: various-leaved water milfoil, whorled water milfoil, and northern water milfoil. All three of these species are native to Wisconsin. Of the three, northern water milfoil is arguably Wisconsin's most common native milfoil species and morphologically is the most similar to Eurasian water milfoil, often being falsely identified as such. Northern water milfoil tends to take on the 'reddish' appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses, especially if water levels decrease over the course of the summer. Because northern water milfoil requires relatively high water transparency, its populations are declining state-wide as lakes are becoming more eutrophic.

Although the majority of the species that comprise Wilson Lake's plant community are rather tolerant to environmental disturbance, a few sensitive species such as blunt-leaf pondweed and water bulrush were located. Both of these species are designated a coefficient of conservatism of 9, meaning they are sensitive to disturbance and are usually only found growing in near pristine conditions. Wilson Lake was also the only lake in the chain in which carnivorous bladderworts (*Utricularia*) were observed. Two bladderwort species were observed in Wilson Lake, of which they are named for their small, sac-like 'bladders' they produce that allows them to trap and digest small zooplankton prey in addition to gathering energy through photosynthesis like other plants.

Figure 3.3-12. Wilson Lake aquatic plant occurrence analysis. Created using data from WDNR 2007 and Onterra 2009 surveys. Exotic species indicated with red.

As shown by the Wilson Lake community map, Wilson Lake has a high incidence of emergent and floating-leaf plant communities (Map 6). Approximately 56 acres (16%) of the 351-acre lake contain these types of plant communities. Eleven floating-leaf and emergent species were located in Wilson Lake, providing valuable fish and wildlife habitat. The majority of these plant communities were found along the eastern and southern shores of Wilson Lake.

Nuisance Native Aquatic Plants

In a survey sent to Phillips Chain stakeholders, 74% responded that they have reduced their recreational time on Wilson Lake due to Eurasian water milfoil (Appendix B, Question #21). Stakeholders also indicated that they believe aquatic invasive species and excessive aquatic plant growth are the top two factors negatively impacting the Phillips Chain (Appendix B, Question #22). While Eurasian water milfoil is clearly negatively impacting recreational activities in Wilson Lake and parts of Duroy Lake, it is believed that some native aquatic plant species may also be impeding riparian recreation. While excessive native aquatic plant growth was not observed in Elk and Long Lakes, there were some large areas with thick, matted colonies of coontail and/or common waterweed in parts of Duroy Lake and much of Wilson Lake.

It is unrealistic to quantitatively define the term "nuisance," as this designation is subjective by nature. However, as stated above WDNR Science Services researchers indicate that nuisance levels of a given aquatic plant species likely occur when frequency of occurrences exceed 35% (Alison Mikulyuk, personal comm.). In Duroy Lake, none of the species observed reached this lake-wide benchmark, and nuisance levels that would interfere with navigation appeared to be isolated to northern portions of the lake. However, in Wilson Lake, while Eurasian water milfoil

was well above nuisance levels, both coontail and common waterweed during the 2007 WDNR survey had frequencies of occurrence (34%) near the somewhat arbitrary nuisance level threshold discussed here. Figure 3.3-13 shows the littoral frequency of common waterweed and coontail within the Phillips Chain along with Eurasian water milfoil.

In early July 2010, ecologists from Onterra visited Wilson Lake for a quick look at the excessive plant growth in the southern portion of the lake per request of the PCOLA (Richard Norton). Compared to 2009, the Eurasian water milfoil had increased in some areas and decreased in others. However, the growth of coontail was severe, and seemed to be out-competing Eurasian water milfoil in many areas. It has been our experience on impounded systems with unstable conditions that the dominant plant species, in this case Eurasian water milfoil, coontail, and common waterweed, can shift slightly in their relative frequencies of occurrence; one becoming the dominant plant one year and the other becoming dominant the next. While there is no quantitative evidence that this occurred in 2010, it appeared that although there was still a significant amount of Eurasian water milfoil, coontail had increased in abundance and was playing a larger role in interfering with recreational activities. Potential strategies for reducing recreational interference from nuisance native aquatic plants can be found in the Implementation Plan below.

Non-native Aquatic Plants

Eurasian water milfoil

Eurasian water milfoil (EWM) was first located in Duroy Lake of the Phillips Chain in 2000. Soon after, in 2002, EWM was located in Elk, Long, and Wilson Lakes. In August 2009 during the aquatic plant community mapping surveys, Onterra ecologists mapped existing areas of EWM within the Phillips Chain. A total of 210 acres (17%) of the 1,236-acre chain contained Eurasian water milfoil. However, as we have seen with native vegetation, the Eurasian water milfoil is not evenly distributed among all four lakes (Table 3.3-3, Figure 3.3-13). Respondents to the stakeholder survey indicated that AIS were the greatest negative threat to the Phillips Chain of Lakes (Appendix B, Question #22) and almost 85% of respondents felt that aquatic plant control was needed on the system (Question #25).

Eurasian water milfoil was most prevalent in Wilson Lake, with approximately 180 acres of the lake containing EWM, much of which is at highly dominant or surface matting densities where navigability is greatly reduced or halted (Map 7). The littoral frequency of occurrence of Eurasian water milfoil was well above the 35% nuisance level benchmark (Figure 3.3-13). Again, Wilson Lake is nutrient-rich, shallow system with soft sediments and a large littoral area - conditions that are very conducive for supporting abundant Eurasian water milfoil. In Duroy Lake, approximately 26 acres of Eurasian water milfoil were mapped in the northern and southeastern portions of the lake (Map 7). It is likely restricted to these areas of the lake as the western portion contains courser substrate and water that is too deep to support aquatic vegetation.

In Elk Lake, two single Eurasian water milfoil plants were located growing in the western portion of the lake (Map 7). It is likely that lake's morphology (steeper sides, course substrate) and/or the sediment contamination by heavy metals is preventing Eurasian water milfoil and other aquatic vegetation from becoming established. In Long Lake, the Eurasian water milfoil

was only found to exist in the northern portion of the lake in shallow areas along the shoreline (Map 7). The small littoral area of Long Lake along with the course substrate creates a limited habitat for Eurasian water milfoil to colonize.

Table 3.3-4. Phillips Chain of Lakes acres of Eurasian water milfoil. Created using data from the 2009 aquatic plant surveys.

Lake Name	EWM Acreage	% of Total EWM Acreage
Duroy Lake	26.2	12.4
Long Lake	4.0	1.9
Wilson Lake	180.2	85.7
Total	210.4	100.0
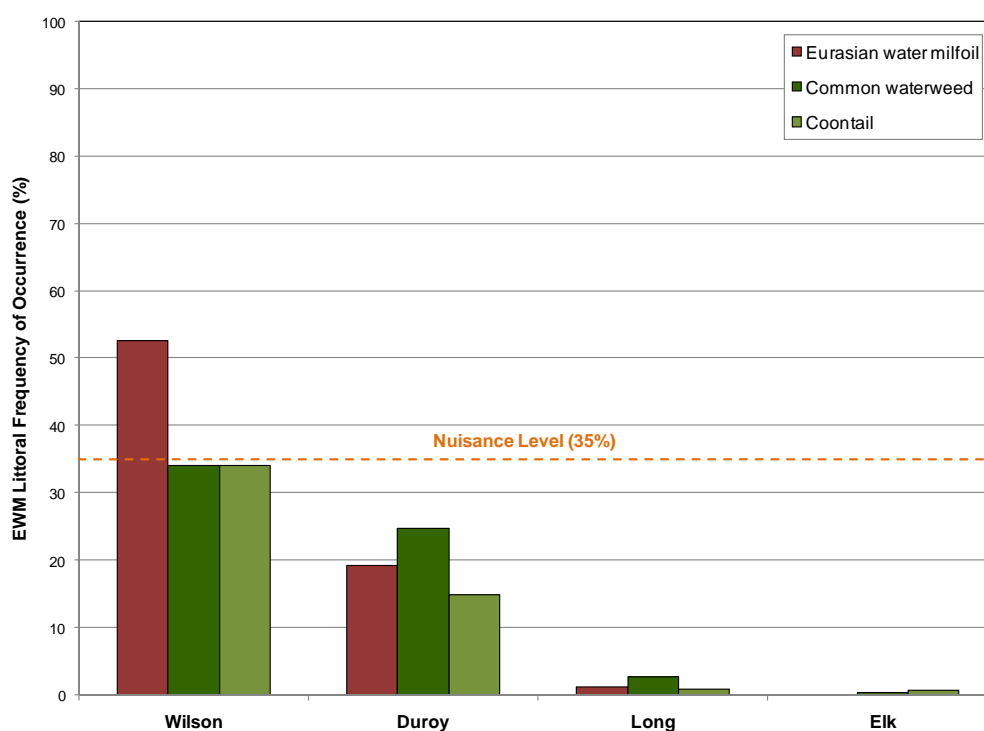
Figure 3.3-13. Phillips Chain of Lakes littoral frequency of EWM, common waterweed, and coontail. Created using data from WDNR 2007 and Onterra 2009 surveys. Exotic species indicated with red.

With the amount of Eurasian water milfoil present on the Phillips Chain, especially in Wilson and Duroy Lakes, it is believed that a water level drawdown would likely be the most viable option for controlling it. Figure 3.3-14 shows the minimum, average, and maximum depth of Eurasian water milfoil growth in each lake along with the water level drawdown depth necessary to include 50%, 75%, or 90% of the existing Eurasian water milfoil. For instance, a 7 foot drawdown of water within the chain would potentially dry out and freeze 90% of the existing Eurasian water milfoil. A more detailed discussion of a water level drawdown on the Phillips Chain can be found in the next section.
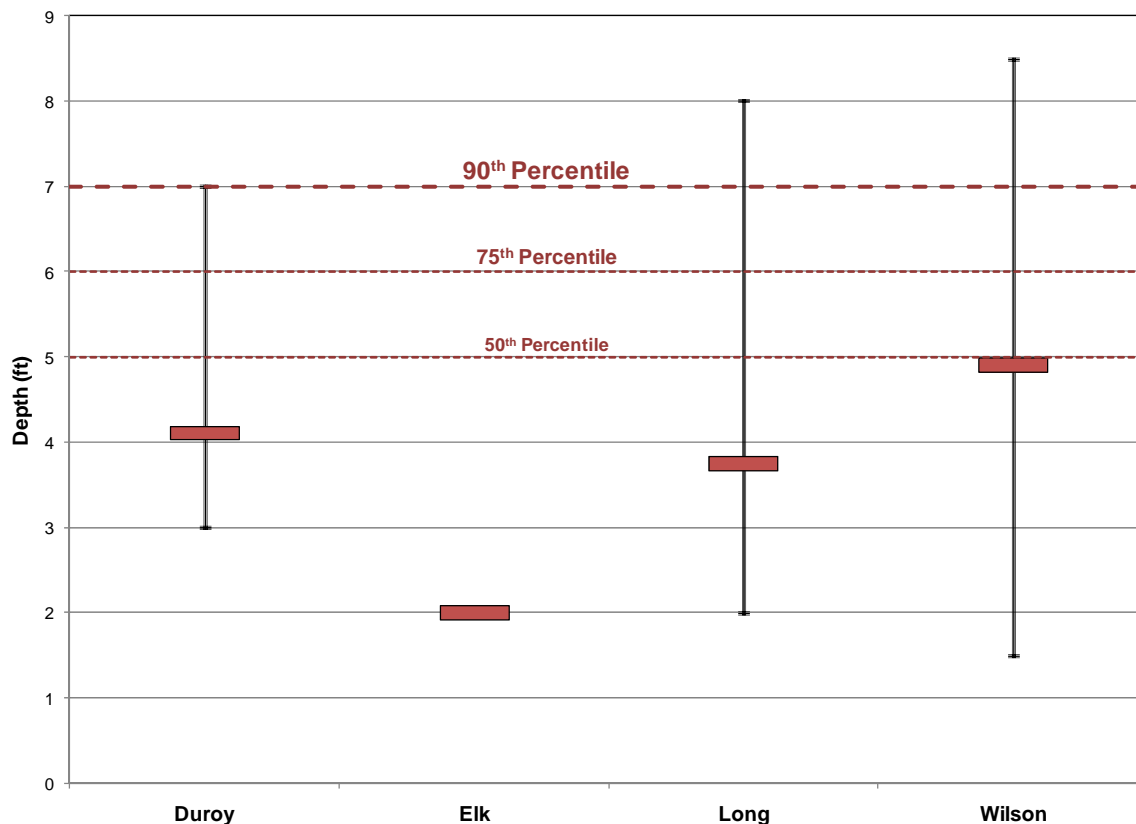
Figure 3.3-14. Phillips Chain of Lakes minimum, average, and maximum depth of Eurasian water milfoil. Created using data from WDNR 2007 and Onterra 2009 surveys.

Purple loosestrife

Purple loosestrife is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped its garden landscape and into wetland environments where it is able to out-compete our native plants for space and resources and create dense monocultures. A single purple loosestrife plant was located along the eastern shore of Duroy Lake during the aquatic plant community mapping survey in 2009 (Map 4).

The WDNR has been monitoring two small purple loosestrife colonies on DuRoy Lake. Craig Roesler, WDNR biologist, released *Galleracella* spp. beetles on these locations in 2007 and 2008. The fact that these colonies were not observed by Onterra ecologists during the community mapping survey indicates that the beetles likely have been effective at controlling these occurrences, at least limiting suppressing the ability for the plant to produce its distinctive flowers.

There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by beetles, and manual hand removal. At present, hand removal by volunteers is the best option as only one purple loosestrife plant was located. For this and future isolate purple loosestrife occurrence, once the property owner grants permission (if applicable) to remove the plant, it should be dug out of the ground, roots and all. If flowers or seeds are present at the time of the extraction, the flower heads should be carefully cut off and bagged to make sure seeds don't inadvertently get spread around during removal. Plants and

seed heads should either be burned or bagged and put into the garbage. Additional purple loosestrife monitoring would be required to ensure hand-removal was successful at eradication it and to quickly identify new areas of infestation.

4.0 SUMMARY & CONCLUSIONS

The design of this project was intended to fulfill three objectives;

1) Collect baseline data to increase the general understanding of the Phillips Chain of Lakes ecosystem.

2) Collect detailed information regarding invasive plant species within the lake with a primary focus on Eurasian water milfoil.

3) Collect sociological information from Phillips Chain stakeholders regarding their use of the Chain and their thoughts pertaining to the past and current condition of the Chain and its management.

The three objectives were fulfilled during the project and have lead to a good understanding of the Phillips Chain of Lakes ecosystem, the people that care about the lakes, and what needs to be completed to protect and enhance the lakes.

Three primary aspects of the Phillips Chain of Lakes ecosystem were studied as a part of this management planning project; the system's water quality, its native and non-native aquatic plant community, and the watershed of the flowage. The paragraphs that follow cover the highlights of the studies that were completed and elaborate on the conclusions that were drawn from them.

Performing long-term trend analysis using the limited amount of available water quality data is difficult, so the discussion within the Water Quality section are short, especially in regards to Duroy, Elk, and Long Lakes. Roughly a decade's worth of data was available from Wilson Lake and some trends were noted within this section, possibly as a result of increased plant biomass in the lake.

The Water Quality Index (WQI) labels the various water quality parameters of the Phillips Chain of Lakes as "poor" and sometimes "very poor". In most cases, the use of the WQI assists laypersons in the understanding of the water quality of their lake by relating it to water clarity, which in general, is what people tend to use to judge lake water quality. In the case of the Phillips Chain, the use of the WQI may paint an overly negative picture of the lakes' water quality. In the end, the water quality of the chain is acceptable and as described in the Watershed section and below, is largely controlled by the system's large watershed, which in terms of land use, is largely in low nutrient and sediment exporting categories.

The water quality of the Phillips Chain of Lakes is controlled by its massive watershed. The vast majority of the watershed contains quality land cover types like grasslands, forests, and wetlands, so not a great deal of phosphorus is delivered on an acre-by-acre basis. However, there are very many acres within the watershed and each exports some phosphorus to the lake. Cumulatively, this leads to a great deal of phosphorus making its way to the chain and as a result, the total phosphorus values for the system are quite high. Fortunately, that large watershed also supplies a great deal of water to the chain. Enough in fact, that the chain's water is flushed nearly every 18 days. The system's high flushing rate and stained water prevent a great deal of algae build up to occur, so the lake does not become pea-green and visually the water quality appears to be good.

Assuming the greater watershed will remain as it is currently, attention must be turned to the immediate watershed around the lakes. This area includes the shoreland properties around each lake. If these areas are maintained as an urban lawn or there are faulty septic systems, there can be localized affects of nutrient-rich runoff and groundwater inputs. So, even though the greater watershed cannot really be improved, the immediate watershed must be focused upon to minimize its negative impacts on the chain of lakes.

Numerous plant surveys were completed on the Phillips Chain of Lakes in order to better understand the native and exotic plant communities that exist within it. The results of these surveys are used as a baseline for future studies that will result in to more effective management strategies.

Sixty-four native species were located within the chain while only 11 were common to all 4 lakes. A species of special concern was located within the chain as were numerous species considered to be rare within the state. Floristic quality analysis concluded that while the lakes all support high quality plant communities above those found as indicated by the majority of lakes in the state and ecoregion, some of the lakes contain signs of disturbance in the species that make up their aquatic plant communities. All the lakes in the chain except Wilson were found to have average conservatism values below that of median values from lakes within the northern ecoregion. Some of the disturbance that is indicated by the plant communities can be attributed to the inherent fact that the chain is man-made system. Also there is a high rate of recreational use that occurs on the lakes and the increasing levels of development occurring on their shorelands.

As discussed within the Water Quality Section, elevated concentrations of specific heavy metals were observed on Elk Lake. Within the Aquatic Plant Section, it is noted that heavy metals may inhibit aquatic plant growth and may be the reason that Elk Lake contains such a depauperate plant community.   However, the available research does not provide guidelines to the concentrations thresholds that affect plant growth. Therefore linking metal concentrations with a lack of plants in Elk Lake cannot be scientifically proven at this time. During the planning committee meeting, it was suggested that the PCOLA conduct a more extensive sediment study to better understand the levels of these metals in the chain. While this would allow for a spatial understanding of the metal concentrations (i.e. are the levels similarly high in other parts of the chain), their affects on the plant population would continue to remain unknown. The PCOLA may choose to conduct such a survey in the future, but for now is going to focus its efforts and resources on the control of Eurasian water milfoil in the system.

Nuisance quantities of native plants have been observed in recent years on the Phillips Chain of Lakes. Concerned over the increase in native plants in the chain, a 4-foot drawdown was planned in 1996. A water level drawdown is a management tool used on many flowages to increase recreational opportunities that are hindered by dense aquatic vegetation and to consolidate the highly organic sediments often found in these types of systems.   During drawdown conditions, aquatic plants are controlled through processes of desiccation (dry out) and freezing. Some plants are more susceptible to the effects of drawdown, whereas populations of other plants (particularly emergent plant species) are enhanced (Table 3.3-2). As discussed in the Aquatic Plant section, this reiterates the importance of having a balanced (diverse) aquatic plant community.   Eurasian water milfoil is particularly susceptible to drawdowns and it

typically takes a number of years for the species to recolonize as propagation from a seed bank is minimal.

Drawdowns are typically started after Labor Day to limit the effects on seasonal tourism. Drawing a system down slowly at a rate of 6 inches per day or less allows the lake's amphibians and reptiles to migrate with the receding water level and have time to burrow into the lake sediments and hibernate (Personal Comm. Scott Provost, WDNR). Once the drawdown is complete, further altering the water level either up or down at that time of year would be detrimental to these organisms and is one of the reasons why the lake is not brought back up until April of the following year. If the system is brought to full pool before the middle of May, the effects on fish spawning is greatly reduced.

The 1996 drawdown began on September 23 and by October 23, the lake was down 48 inches. Numerous complaints were raised by riparians that noticed problems with their private wells. The flowage creates a mounding of the water table, artificially elevating the height of the water table above what it would be if the dam was removed and the system was returned to its original state as a flowing river. With the flowage being partially de-watered during the drawdown, the water table was also lowered and shallow wells (i.e. non-conforming sand point wells) were inadvertently dewatered as well.

The City of Phillips water supply is fed by three high-capacity wells. During the 1996 drawdown, these wells began to cavitate (draw air) when dewatered 36 inches. Under these conditions, the wells cannot operate at their normal capacity. Terry Stroba, former Director of Public Works for Phillips, indicated that while it was likely that the wells could probably meet the needs of the community's water supply under the reduced operation, the city would be vulnerable during an extreme demand situation like a major fire (Appendix G). Bill Dobbins, WDNR Regional Drinking Water Engineer, also investigated this issue and came to a similar conclusion.

On October 31, 1996, efforts to refill the system began and were brought back to winter operating level (8 inches lower than summer level) by November 8, 1996. Many people expressed concerns about the reliance of a municipal water source on a dam owned and operated by a separate unit of government (Price County). It also became apparent that if the Jobes Dam, the water control structure that artificially forms the Phillips Chain of Lakes, was to fail; the water supply for the City of Phillips would be greatly affected. Due to this fact, the City of Phillips may want to evaluate their water supplies.

In 2000, Eurasian water milfoil was located in Duroy and by 2002 was observed in all four lake s of the chain. Concerned over the amount of Eurasian water milfoil in the chain, the PCOLA began planning a 2-foot drawdown during the winter of 2005-2006. At this level, many of the issues that halted the 1996 drawdown would not develop. In preparation for this management action, Craig Roesler, WDNR biologist, and PCOLA volunteers assessed the system. The assessment seemed to indicate that Eurasian water milfoil populations had declined since the 2002 survey (Appendix G). These declines were theorized to be caused by herbivory of a species of native milfoil weevil which was observed during the survey. The drawdown was halted to monitor the lakes and observe whether this biological control agent would prove successful.

Mr. Roesler visited the system again in 2007 and performed a point-intercept survey on Wilson Lake. The results of the 2007 point-intercept survey indicate that EWM exists in approximately 52% of the littoral zone (area of the lake where plants grow). It was apparent that the native weevil was not going to be the *silver bullet* hoped for by the PCOLA and they again began the process of planning a drawdown.

A WDNR Aquatic Invasive Species Education, Prevention and Planning Grant was successfully applied for during February 2008 which would have offset the costs of monitoring the efficacy of the proposed drawdown. After the funds were secured, a public information meeting was held on April 9, 2008 to discuss the control project with the general public. Many questions were raised at the meeting and are summarized by an article in the local newspaper and a summary document (Appendix G). Planners of the drawdown were optimistic that the past issues involving the private and municipal wells could be resolved. New issues were also brought forth including the fact that the outfall pipe for the wastewater treatment plant that empties into Elk Lake would no longer be submersed during a 5-foot drawdown. This pipe needs to remain submerged to properly allow mixing. However, Lonn Franson, City of Phillips Wastewater Engineer, indicated that the outfall pipe could be extended.

As with most drawdowns, fisheries impacts were also of concern to riparians. Two aeration systems were proposed to be implemented during the drawdown to aid in oxygenating the water. Many also felt that special fisheries regulations would need to be implemented in order to protect the concentrated fish that may be overexploited by anglers. The WDNR would implement emergency regulations if an emergency condition became apparent, but thought that having the association promote voluntary compliance with reduced bag limits during the drawdown would be the best first step.

During the winter of 2008-2009, it became apparent that a drawdown was not in the near future and the PCOLA was encouraged by the WDNR to undergo a management planning project in which baseline studies and specific management goals and associated actions would be constructed to help protect and enhance the Phillips Chain of Lakes. The PCOLA hired Onterra and amended their existing WDNR grant to reallocate finances for the planning process.

A water level drawdown was seriously considered as a management tool because it is likely the best way to control a significant Eurasian water milfoil infestation on a system the size of the Phillips Chain of Lakes. Serious and productive discussions were held with various members of the City of Phillips, Price County, and the WDNR, but the same roadblocks that were encountered in 1996 made this alternative infeasible.

At the present time, the most feasible method for bringing Eurasian water milfoil under control by reducing its frequency is through herbicide applications. A major portion of the Implementation Plan details the strategy that will be used to control Eurasian water milfoil on the Phillips Chain of Lakes through herbicide applications.

5.0 IMPLEMENTATION PLAN

The intent of this project was to complete a *comprehensive* management plan for the Phillips Chain of Lakes. As described in the proceeding sections, a great deal of study and analysis were completed involving many aspects of the Phillips Chain of Lakes ecosystem. This section stands as the actual "plan" portion of this document as it outlines the steps the PCOLA will follow in order to manage the lake, its watershed, and the association itself.

The implementation plan is broken into individual *Management Goals*. Each management goal has one or more management actions that if completed, will lead to the specific management goal being met. Each management action contains a timeframe for which the action will be taken, a facilitator that will initiate or carry out the action, a description of the action, and if applicable, a list of prospective funding sources and specific actions steps.

Management Goal 1: Increase Phillips Chain O' Lakes Association's Capacity to Communicate with Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety, and quality of life on the Phillips Chain of Lakes

Timeframe: Begin summer 2011

Facilitator: Association Board of Directors to form Education Committee

Description: Education is a good tool to address issues that impact water quality such as lake shore development, lawn fertilization and other issues, such as air quality, noise and boating safety. An Education Committee will be created to promote lake protection and the quality of life through a variety of educational efforts.

Currently, the Phillips Chain O Lakes Association does not regularly publish newsletters to association members. The need for formal communication within the lake group is important because it builds a sense of community while facilitating the spread of important association news, educational topics, and even social happenings. It also provides a medium for the recruitment and recognition of volunteers. Perhaps most importantly, the dispersal of a well written news release can be used as a tool to increase awareness of many aspects of lake ecology and management among association members. By doing this, meetings can often be conducted more efficiently and misunderstandings based upon misinformation can be avoided. Educational pieces within the association newsletter may contain monitoring results, association management history, as well as other educational topics listed below.

Example Educational Topics:
   Aquatic invasive species identification
   Encouraging anglers harvesting slightly smaller size classes of panfish
   Noise, air, and light pollution
   Boating safety
   Shoreland restoration and protection
   Improving aquatic plant diversity
   Septic system maintenance

Specific topics brought forth in other management actions

Action Steps:
1. Recruit volunteers to form Education Committee.
2. Investigate if WDNR small-scale Lake Planning Grant would be appropriate to cover initial setup costs.
3. The PCOLA Board will identify a base level of annual support for educational activities to be undertaken by the Education Committee.

Management Goal 2: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.

Timeframe: Begin Summer 2011

Facilitator: Planning Committee

Description: Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. The lack of this type of historical information hampered the water quality analysis during this project. Early discovery of negative trends may lead to an understanding as to why the trend is developing. The Citizens Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Water quality data collection through the CLMN has never occurred on Duroy Lake. Secchi disk transparency data has been collected between 2000 and 2005 on Elk Lake and in the early 1990's on Long Lake. Water clarity and water chemistry data is currently being collected by volunteers on Wilson Lake as a part of the advanced CLMN program.

Volunteers trained by the WDNR as a part of the CLMN program begin by collecting Secchi disk transparency data for at least one year, then if the WDNR has availability in the program, the volunteer may enter into the *advanced program* and collect water chemistry data including chlorophyll-a, and total phosphorus. The Secchi disk readings and water chemistry samples are collected three times during the summer and once during the spring. Note: as a part of this program, these data are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS). At a minimum, CLMN volunteers collecting Secchi disk data should be in place on all lakes in the chain.

Winter dissolved oxygen levels were shown to be quite low on Wilson Lake. If increasing concerns about these levels exist within the PCOLA, the association should purchase a dissolved oxygen probe. This would allow this parameter to be monitored in conjunction with the regularly scheduled CLMN water sample collection. A WDNR small-scale Lake Planning Grant would be applicable for the costs of the equipment purchase.

Action Steps:
> Please see description above.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to Phillips Chain of Lakes.

Timeframe: Begin 2011
Facilitator: Education Committee
Description: As the watershed section discusses, the Phillips Chain of Lakes has an extremely large watershed draining to it and as a result, the impacts that are most controllable at this time originate along the lake's immediate shoreline. These sources include faulty septic systems, shoreland areas that are maintained in an unnatural manner, and impervious surfaces.

> On April 14th, 2009, Governor Doyle signed the "Clean Lakes" bill (enacted as 2009 Wisconsin Act 9) which prohibits the sale of lawn fertilizers containing phosphorus starting in April 2010. Phosphorus containing fertilizers were identified as a major contributor to decreasing water quality conditions in lakes by fueling plant growth. While this law also bans the display and sale of phosphorus containing fertilizers, educating lake stakeholders about the regulations and their purpose is important to ensure compliance.

> To reduce these negative impacts, the PCOLA will initiate an educational initiative aimed at raising awareness among shoreland property owners concerning their impacts on the lake. This will include newsletter articles and guest speakers at Association meetings.

> Topics of educational items may include benefits of good septic system maintenance, methods and benefits of shoreland restoration, including reduction in impervious surfaces, and the options available regarding conservation easements and land trusts.

Action Steps:
1. Recruit facilitator.
2. Facilitator gathers appropriate information from WDNR, UW-Extension, Price County, and other sources.
3. Facilitator summarizes information for newsletter articles and recruits appropriate speakers for Association meetings.

Management Action: Complete Shoreland Condition Assessment as a part of next management plan update

Timeframe: Begin 2009
Facilitator: Planning Committee
Description: As discussed above, unnatural shorelands can negatively impact the health of a lake, both by decreasing water quality conditions as well as removing valuable habitat for fish and other aquatic species that reside within the lake. Understanding the shoreland conditions around the Phillips Chain of Lakes will serve as an educational tool for lake stakeholders as well as identify areas that

would be suitable for restoration. Shoreland restorations would include both in-lake and shoreline habitat enhancements. In-lake enhancements would include the introduction of course woody debris and shoreline enhancements would include leaving 30-foot no-mow zones or by planting native herbaceous, shrub, and tree species as appropriate for Price County.

Projects that include shoreline condition assessment and restoration activities will be better qualified to receive state funding in the future. These activities could be completed as an amendment to this management plan and would be appropriate for funding through the WDNR small-scale Lake Planning Grant program.

Action Steps: See description above.

Management Goal 3: Control Existing and Prevent Further Aquatic Invasive Species Infestations within the Phillips Chain of Lakes

Management Action: Initiate Clean Boats Clean Waters watercraft inspections at Phillips Chain of Lakes Public Boat Landings.

Timeframe: Begin 2011

Facilitator: Education Committee

Description: The Phillips Chain of Lakes is a popular destination by recreationists and anglers, making the system vulnerable to new infestations of exotic species. Although the lake already contains the following aquatic invasive species: Eurasian water milfoil, purple loosestrife, Chinese banded mystery snail, and rusty crayfish; it is still important to minimize the chance of new infestations of aquatic invasive species to be introduced and ensure that the Phillips Chain of Lakes is not the source of aquatic invasive species for other waterbodies. Volunteers would be trained through the Clean Boats Clean Waters program and monitor the public boat landings throughout the summer with higher intensity monitoring occurring during periods of higher use (e.g. weekends and holidays. WDNR Deputy Water Guards have aided in the monitoring of the public landings on the Phillips Chain of Lakes and coordination of the volunteers with these individuals would be beneficial.

Action Steps:
1. Members of association attend Clean Boats Clean Waters training session
2. Training of additional volunteers completed by those trained
3. Begin inspections during high-risk weekends in coordination with WDNR Deputy Water Guards
4. Report results to WDNR and PCOLA
5. Promote enlistment and training of new of volunteers to keep program fresh

Management Action: Control Eurasian water milfoil infestations within the Phillips Chain of Lakes using herbicide applications.

Timeframe: Initiated in 2011

Facilitator: Board of Directors with professional help as needed

Description: As described in the Aquatic Plant section the most pressing threat to the health of the Phillips Chain of Lake's aquatic plant community is Eurasian water milfoil. Approximately 210 acres of the system contains varying densities of Eurasian water milfoil (Map 7) with over 85% (180 acres) of that acreage being from Wilson Lake.

As indicated in the Summary and Conclusions, a water level drawdown would likely be the most effective method to control Eurasian water milfoil on the Phillips Chain of Lakes. But as discussed within that section, the use of that technique is highly unlikely, at least in the near-term. At this time, the most feasible method of control would be herbicide applications, specifically, early-spring treatments with 2,4-D. The treatments would occur each year before June 1 and/or water temperatures reach 65°F. The responsible use of this technique is supported by Phillips Chain of Lakes stakeholders as indicated by approximately 59% of stakeholder survey respondents (excluding those that stated they need more information) indicating that they are at least moderately supportive of an herbicide control program (Appendix B, Question #26).

During the planning process, PCOLA stakeholders discussed the difference between the control of Eurasian water milfoil for nuisance relief or for ecological restoration. Applicable management actions for the Phillips Chain of Lakes aimed at alleviating the nuisance conditions caused by this plant would likely include the use of herbicides to create access lanes in strategic locations around the system as indicated within Management Goal 4.

There are two distinct strategies implemented to control Eurasian water milfoil using herbicides: 1) spot treatments and 2) large-scale treatments. As the name suggests, spot treatments are when a particular "spot" or area is treated with an herbicide such that when the herbicide dilutes out of that area, the concentration is insignificant to cause significant effects outside of the area treated. Spot treatments to control Eurasian water milfoil typically target between 2.0 ppm acid equivalent (a.e.) and 4.0 ppm a.e. with an understanding that the herbicide will dissipate quickly (within hours to a few days) out of the treatment area. Large-scale treatments specifically target a dose that will be effective when the herbicide mixes and reaches equilibrium throughout the entire volume of a lake (or bay). These strategies often involve using liquid herbicides at much lower doses than would be applied during spot treatments.

A current study by the WDNR and the United States Army Corps of Engineers (USACOE) is investigating the use of liquid 2,4-D; most specifically, the associated herbicide concentrations in the water column (residuals) at different locations and lengths of time after treatment. Preliminary findings indicate that the liquid herbicide quickly (within a few days) diffuses through the waterbody and reaches an equilibrium concentration within the entire volume of the lake. It

appears that seasonal control is reached when residual concentrations are between 100 and 150 µg/L for 10-15 days and long-term control can be achieved at higher concentrations. WDNR and USACOE researchers have indicated that 2,4-D concentrations of greater than 300 µg/L for this duration provided exceptional control of the target species, but have had impacts on the native plant community.

The PCOLA would like to attempt to impact Eurasian water milfoil on a chain-wide level in an effort to improve the health of their lake ecosystem. One way to address Eurasian water milfoil on this level is to treat Wilson Lake using large-scale techniques and target specific areas of the rest of the system with spot treatments.

Using large-scale treatments remains experimental in Wisconsin and the PCOLA and the WDNR agree that the first step would be to conduct limited (under 10 acres) spot treatments in Wilson Lake to understand the effectiveness of the herbicide in the system and understand any collateral effects to native plants. This was initiated during the spring of 2011 (Map 9). Discussions during the fall/winter of 2011-2012 utilizing the data collected on Wilson Lake during 2011 and on other lakes in the state will determine if a large-scale treatment is applicable to Wilson Lake.

Concerns were also raised by the WDNR about the use of a liquid herbicide because it was thought that the flow of water through Wilson Lake would be too high which would cause the liquid herbicide to dissipate too rapidly, thus not exposing the EWM for a sufficient amount of time to cause mortality. Case studies will be examined from similar treatments (e.g. Scattering Rice Lake of the Eagle River Chain, Vilas County and Bridge Lake of the Rice River Reservoir, Lincoln and Oneida Counties) to further examine this rationale.

Large-scale Control Plan Specifics for Wilson Lake
The lake survey map of Wilson Lake from 1967 reports the lake's volume to be 2,028 acre-feet. At this time, it appears that the most prudent approach would be to apply liquid 2,4-D to the approximately 180 accessible-acres of Wilson Lake that contain Eurasian water milfoil at a dose allowing herbicide concentrations and exposure times to be in line with current WDNR and USACOE research findings. Table 5.0-1 presents the theorized whole-lake concentration on Wilson Lake at different herbicide doses. As indicated in the Watershed section, the residence time of Wilson Lake was calculated to be 73 days, showing that there is a fair amount of flow in Wilson Lake which may dilute the concentration and reduce the exposure time of the herbicide. Bob Lepke, Price County Dam Tender, doubts the ability of the Jobes Dam to be manipulated to significantly increase the water retention time in Wilson Lake surrounding a herbicide treatment. Both granular and liquid herbicide options will be effected by the flow in the system and attention will be needed to make sure the dose is sufficient to account for some level of dilution.

Further correspondence between the PCOLA, the WDNR, and professional lake managers will yield specifics regarding dose and anticipated whole-lake residual

concentrations. One of the most complex components of this discussion relates to exposure time and degradation of herbicide concentrations – areas that researchers continue to prioritize as missing pieces of the puzzle.

Table 5.0-1. Calculated whole-lake herbicide concentrations in Wilson Lake with varying doses.

Acres of EWM (no buffer)	210	acres
Ave. Depth of Treatment Area (2007 PI Survey)	4.5	feet
Volume of Treatment Area	945.0	acre-feet
Volume of Wilson Lake (1967 Survey Map)	2,028.0	acre-feet

	Treatment Area Concentration		
Calculated Concentration Scenario	**0.5 ppm**	**0.6 ppm**	**0.7 ppm**
Mix throughout lake	0.220 ppm	0.265 ppm	0.310 ppm

A very rough cost estimate of treating 210 acres of EWM within Wilson Lake at 0.7 ppm a.e. liquid 2,4-D would be between \$27,000 and \$30,000. Please note that Onterra does not offer herbicide application services and therefore this estimate is for reference only. It would be the responsibility of the association to contract with a commercial aquatic pesticide applicator, certified with the Wisconsin Department of Agriculture and Consumer Protection and licensed by the WDNR to perform the *early season* treatments of Eurasian water milfoil.

If a large-scale treatment is conducted on Wilson Lake, an intensive monitoring program would need to be in place. Monitoring herbicide treatments and defining their success incorporates both quantitative and qualitative methods. As the name suggests, quantitative monitoring involves comparing number data (or quantities) such as plant frequency of occurrence before and after the control strategy is implemented. Qualitative monitoring is completed by comparing observational data such as Eurasian water milfoil colony density ratings before and after the treatments.

Quantitative monitoring of a large-scale treatment on Wilson Lake would be completed by conducting whole-lake point-intercept surveys the summer before and two summers after the treatment. While, the first post treatment survey (summer following herbicide application) will show the immediate effects of the treatment, the second post treatment survey will provide a better understanding of trends. Quantitatively, the large-scale treatment will be deemed successful if the Eurasian water milfoil frequency following the treatments is statistically reduced by at least 50%.

Qualitative monitoring of the herbicide treatment would be conducted by completing a Eurasian water milfoil peak biomass survey during the summer before the treatment to compare against a post treatment survey. Qualitatively, a successful treatment on the Phillips Chain of Lakes would include a reduction of

Eurasian water milfoil density as demonstrated by a decrease in density rating (e.g. dominant reduced to scattered).

This strategy would greatly benefit from having residual water samples taken in association with the large-scale treatment. This would allow for an understanding of whether the herbicide dose was high enough and sustained long enough to kill the Eurasian water milfoil. It would also be advantageous to understand if the dose was too high or sustained for too long in which unintended collateral damage to the lake's native plants occurs. Combining this information with the vegetation surveys completing on the lake, much information will be learned that would lead to an effective long-term control plan being developed for Wilson Lake.

While 2,4-D is thought to be selective towards broad-leaf (dicot) species at the concentration and exposure times suggested here, emerging data from the WDNR and US Army Corps of Engineers suggests that some narrow-leaf (monocot) species may also be impacted by this herbicide. Unpublished data suggests that common waterweed (monocot) and coontail (dicot) are two plants that seem particularly susceptible to long exposures of low-dose 2,4-D. It is important to note that along with Eurasian water milfoil, these two species overwhelmingly dominate the plant community of Wilson Lake. Actually, these plants are in such high biomass that they are the primary justification for initiating a management action to increase navigability in Wilson Lake. While the collateral effects on these plants may not be overwhelmingly concerning, their effect on dissolved oxygen needs to be considered. The dying plants are decomposed by bacteria which actively consume dissolved oxygen. This can be a potential problem with large-scale treatments, especially those that occur later in the season when plant biomass and water temperatures are high.

Spot Treatment Control Plan Specifics for the Phillips Chain

As stated above, spot treatment strategies are likely applicable for the majority of the Eurasian water milfoil colonies located on the chain outside of Wilson Lake. Also, if a large-scale treatment is conducted on Wilson Lake, remnant Eurasian water milfoil colonies may be best controlled using spot treatment efforts.

Quantitative evaluation methodologies for spot treatments would follow WDNR protocols in which point-intercept data is collected within treatment areas both the summer before and the summer immediately following the treatments take place. Data would be collected at point-intercept sub-sample points within the spot treatment areas at a resolution of approximately 4 points per acre. By comparing those data, it can be determined if there is differences in native and non-native plant abundances between the surveys. Again, a statistically valid 50% reduction in Eurasian water milfoil frequency of occurrence would be needed for a treatment to be considered successful.

Qualitatively, a successful treatment on a particular site would include a reduction of Eurasian water milfoil density as demonstrated by a decrease in density rating (e.g. highly dominant to dominant). In terms of a treatment as a whole, at least

75% of the acreage treated that year would decrease by one level of density as described above for an individual site.

Long-Term Control Plan
It should be noted that it is highly unlikely that any single herbicide treatment will completely control Eurasian water milfoil in any lake. The objective is to bring the invasive species down to more easily controlled levels. In other words, the goal is to reduce the amount of Eurasian water milfoil to levels that would only require spot treatments to keep them under control. To complete this objective efficiently, a cyclic series of steps is used to plan and implement the treatment strategies. The series includes:

1. A chain-wide assessment of Eurasian water milfoil completed while the plant is at peak biomass.
2. Creation of treatment strategy for the following spring.
3. Verification and refinement of treatment plan immediately before treatments are implemented (not applicable to whole-lake treatments).
4. Completion of treatments.
5. Assessment of treatment results.

Once Step 5 is completed, the process would begin again that same summer with the completion of a peak biomass survey. The survey results would then be used to create the next spring's treatment strategy.

If Eurasian water milfoil populations are brought down to levels requiring smaller treatments of specific colonies, treatment monitoring activities would follow protocols currently being developed by the WDNR and in general, use guidance supplied in Aquatic Plant Community Evaluation with Chemical Manipulation (2010 Draft). This form of monitoring may be required for all large scale herbicide applications (exceeding 10 acres in size or 10% of the area of the water body that is 10 feet or less in depth; and treatment areas that are more than 150 feet from shore) and grant-funded projects where scientific and financial accountability are required.

Action Steps:
1. Retain qualified professional assistance to develop a specific project design utilizing the cyclic series of steps discussed above.
2. Initiate control plan
3. Revisit control plan in 5-7 years
4. Update management plan to reflect changes in control needs and those of the lake ecosystem.

Management Goal 4: Maintain Navigability of the Phillips Chain of Lake

Management Action: Support reasonable and responsible actions by shoreland property owners to gain navigational access to open water areas of the Phillips Chain of Lakes.

Timeframe: 2012 or later

Facilitator: Richard Norton and Association Board of Directors

Special Note: This management action was developed as a part of the planning process and included within the first draft of the management plan. Upon review, it was determined that an effort of this scale at this time was more aggressive than the WDNR was comfortable with, especially in tandem of developing a Eurasian water milfoil control strategy for the Wilson Lake and the rest of the chain. While a smaller scale management action may better received by the WDNR, this management goal is really constructed to be completed in entirety due to the reliance on interconnectivity of the lanes.

This management goal has been included here as a place holder in the event that Eurasian water milfoil control efforts are not successful and the association needs to entertain this type of strategy. This goal may also be useful if after Eurasian water milfoil efforts are conducted, native plants continue to cause navigational issues. By including this goal within the management plan, an amended plan will not be required to implement these activities in the future.

Description: Overwhelmingly, 84.4% of respondents of the stakeholder survey believed aquatic plant control is needed (answered *definitely yes* or *probably yes*) on the Phillips Chain of Lakes. (Appendix B, Question #25). Nuisance levels of aquatic plants, along with aquatic invasive species, were stated to be the greatest factors negatively impacting the chain (Appendix B, Question #22 and #23).

Aside from some very specific areas on Elk and Long Lakes, nuisance levels of aquatic plants from the chain are confined to Duroy and Wilson Lake. Duroy Lake is relatively unpopulated and users are often able to avoid these areas. On the opposite end of the spectrum, Wilson Lake is quite developed and contains numerous resorts. Of the 134 stakeholder survey respondents that stated they purposefully decrease their recreation time on the system due to Eurasian water milfoil (75%) (Appendix B, Question #20), all but one indicated that they reduce this time on Wilson Lake (Appendix B, Question #21). As shown on Map 7, Eurasian water milfoil is likely the number one cause of the impacted navigation. Large amounts of coontail, common waterweed, and flat stem pondweed also reduce navigability in Wilson Lake. Even if a control program is successful at reducing EWM populations within Wilson Lake, these native plants will likely continue to cause navigational issues on the lake.

The PCOLA supports reasonable and environmentally sound actions to facilitate access to open water areas of the Phillips Chain of Lakes consistent with Aquatic Plant Management Strategy Northern Region WDNR (Appendix H). These actions would target nuisance levels of aquatic plants in order to restore watercraft access to open water areas of the system. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area required to permit the access. These actions do not include areas that can be controlled through manual removal such as riparian swimming areas. This guidance document clearly states that no individual permits will be issued.

Three possibilities exist to maintain access to open water from the impacted riparian properties: 1) manually remove the plants, 2) contract to have the plants cut and removed through mechanical harvesting, and 3) apply herbicides to kill the plants. With any of these options, the ecology of the area must be seriously considered. Loss of native plants in any area of a lake is unfortunate because they are the foundation of the lake ecosystem.

Understanding where navigation issues occur on Wilson Lake, PCOLA members graphically indicated on a large format aerial photograph map (orthophoto) where they believe navigation lanes could be placed to increase their navigability. This map was digitized by Onterra and minor adjustments were made to decrease the incidents of these lanes going through emergent and/or floating-leaf plant communities (Map 8). These areas would be suitably controlled using mechanical harvesting or herbicide application in predefined navigation lanes (20 feet wide).

The PCOLA would like to consider both options listed below as the advantages/disadvantage pertain to specific areas of the lake or extrapolated to other lakes of the chain. An integrated approach may be the most effective where mechanical harvesting activities are applied in some areas (high use and no navigational obstacles) and herbicide application techniques are applied in the others (shallow, highly dominated by certain plants such as coontail).

The PCOLA understands that management activities are **not** to include:
- Removing large areas (*clear cutting*) for any reason.
- Removing plants to increase a riparians ability to fish off of their dock.
- Creating an access lane from a riparian's property if there is already a sufficient alternative (i.e. path to the lake).
- Creating a lane when manual removal techniques could be used.

Analysis of Mechanical Harvesting

Lake groups facilitate harvesting by operating a harvester they have purchased or by contracting with a harvesting firm. While the cost of contracting the harvesting is more expensive then operating owned equipment, the initial capital investment of purchasing the equipment is quite high. Based on the perceived

needs of the PCOLA, contracting a company to mechanically harvest the areas shown on Map 8 would be the most feasible option.

A rough cost estimate of contracting these activities would be approximately $6,168 for a single cutting of the 15.2 acres shown on Map 8. This is based off a contractor being able to cut 0.5 acres per hour at a cost of $170 per hour and $1000 to mobilize the equipment needed to complete the task (e.g. mechanical harvester, off-loading conveyor, dump truck, etc).

As with all aquatic plant management techniques, harvesting has its advantages and disadvantages. Advantages include the removal of plants and associated nutrients from the waterbody, immediate relief of nuisance plants, harvesting is less controversial than chemical use, and specific areas can be treated accurately. Disadvantages include sediment re-suspension, fragmentation of plants, need for repeated treatments within a single year, and no ability to select specific plant species for treatment. Mechanical harvesting in areas that contain aquatic invasive species may increase the rate of spread of these species as it 'drags' cut fragments to other parts of the system. With Eurasian water milfoil occurring in almost all areas of Wilson Lake, this concern is not substantiated as natural auto-fragmentation of this species is likely a much greater contributor to its spread about the lake. However, the use of mechanical harvesting activities on other lakes of the chain may increase the spread of Eurasian water milfoil.

Analysis of Chemical Herbicides

Contracting a firm to apply an herbicide to kill the plants within these areas may also be a suitable option. Because the target plants are a combination of dicots (Eurasian water milfoil, coontail) and monocots (common water weed), a non-selective contact herbicide will likely be needed. A rough estimate of contracting these activities in the areas shown on Map 8 would be approximately $15,500 based on application costs of $1,000 per acre and $300 to mobilize the equipment and herbicide.

Advantages of chemical use include the immediacy and longevity of results. Also, personal communication with a mechanical harvesting contractor indicates that shallow water and some target species (water lilies) may inhibit the use of a mechanical harvester in these instances whereas herbicide application through the use of more maneuverable equipment and outstretched booms would be. Disadvantages include; unknown ecological risks, the plant biomass is not removed from the waterbody, but instead the plant tissue is left to decay; high per acre cost; and the use of herbicides is often controversial among stakeholders.

Action Steps:
1. Association contracts professional herbicide application or mechanical harvesting services, follows the general guidelines listed above, and conforms to the restrictions indicated on WDNR permit.
2. Annual summary report is provided to the WDNR after each season.

6.0 METHODS

Watershed Analysis

The watershed analysis began with an accurate delineation of the Phillips Chain of Lakes drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the Wisconsin initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) were then combined to determine the watershed land cover classifications. Flushing rates were determined using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003)

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on The Phillips Chain of Lakes during June 2009 by trained volunteers from the Phillips Chain O'Lakes Association in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on the system to characterize the existing communities within each lake and included inventories of emergent, submergent, and floating-leaved aquatic plants within them. In 2007, the WDNR surveyed Wilson Lake. The remaining 3 lakes in the chain were surveyed by Onterra in 2009. The point-intercept method as described in "Appendix C" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin - Draft, (April 20, 2006) was used to complete the studies. Based upon advice from the WDNR, the following point spacing and resulting number of points comprised the surveys:

Lake	Point-intercept Resolution	Number of Points	Survey Dates
Duroy	78m	231	7/13/2009
Elk	32m	343	7/8/2009
Long	52m	630	7/14/2009
Wilson	78m	225	9/14-15/2007*

Wilson Lake was surveyed in 2007 by the WDNR

Community Mapping

During the species inventory work, the aquatic vegetation community types within each lake (emergent and floating-leaved vegetation) were mapped using a Trimble GeoXT Global Positioning System (GPS) with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for each of the lakes.

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Lake Management Planning

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Jobes Dam

Long Lake

Elk Lake

Duroy Lake

City of Phillps

Wilson Lake

13

Price County
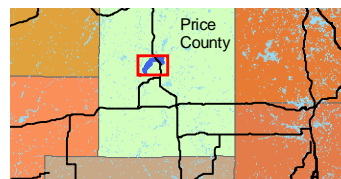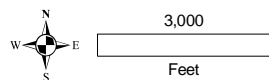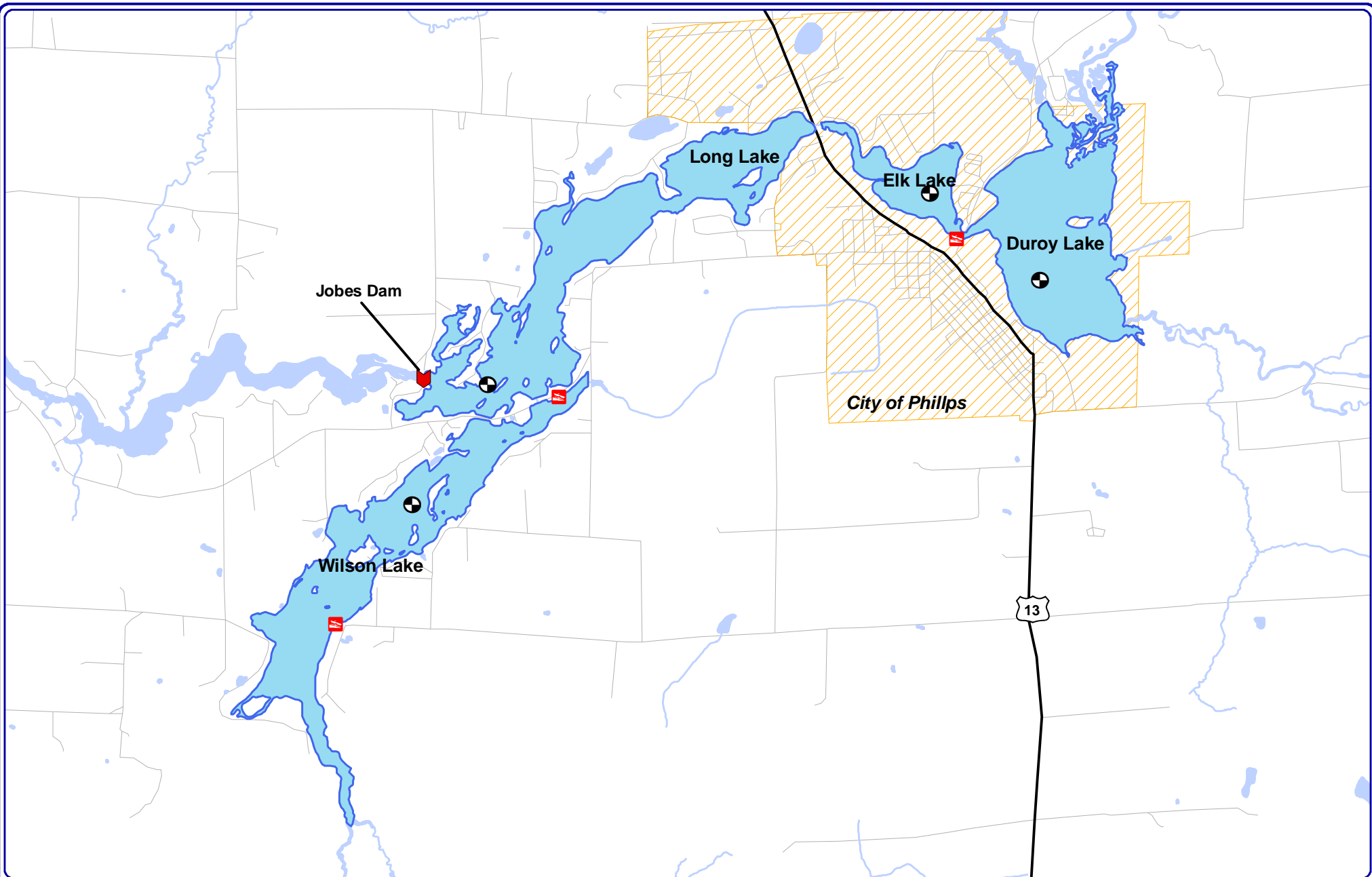
Extent of large map shown in red.

Legend

Project Waters

Water Quality Sampling Location

Map 1
Phillips Chain of Lakes
Price County, Wisconsin
**Project Location & Water
Quality Sampling Locations**

Map 2
Phillips Chain of Lakes
Price County, Wisconsin

Bathymetry
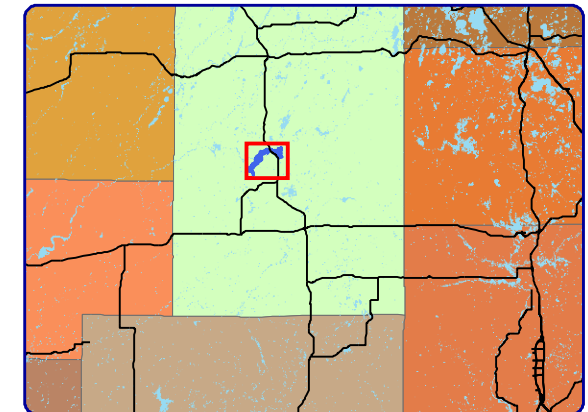
Extent of large map shown in red.

Jobes Dam

City of Phillips

Legend

Bathymetry (feet)

- 0-3
- 3-5
- 5-10
- 10-15
- 15-20
- 20-25
- 25-30
- 30-35
- 35-40
- 40-45
- 45-50
- 50

2,400

Feet

N
W E
S

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Map 3
Phillips Chain of Lakes
Price County, Wisconsin

Watershed and
Land Cover Types
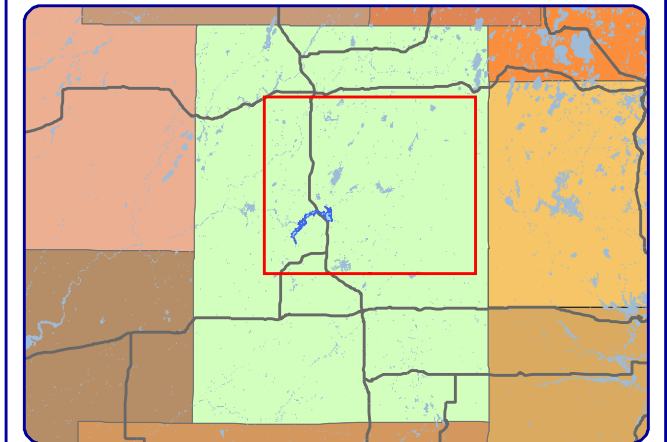
Extent of large map shown in red.

Legend

⬡ Watershed Boundary

Land Cover Types

- Mixed Agriculture
- Row Crop Agriculture
- Pasture/Grass
- Forest
- Open Water
- Wetland
- Medium Density Urban
- High Density Urban

Jobes Dam

Sources:
Watershed: WDNR & Onterra
Landcover: WISCLAND
Roads & Hydro: WDNR
Orthophotography: NAIP, 2005
Map Date: May 20, 2010
File Name: Map3_PhilChainWatershed.mxd

1.8

Miles

N W E S

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Map labels

Spatterdock
White water lily
Northern wild rice

Spatterdock
Common bur-reed
Northern wild rice
Floating-leaf bur-reed
White water lily

Common bur-reed
Pickerelweed
Spatterdock
White water lily

White water lily
Spatterdock
Pickerelweed
Common bur-reed

White water lily

White water lily
Pickerelweed
Broad-leaved cattail

Northern wild rice
Floating-leaf bur-reed

Pickerelweed

Softstem bulrush
Pickerelweed
White water lily
Spatterdock
Northern wild rice
Floating-leaf bur-reed
Common bur-reed

White water lily

Spatterdock
Northern wild rice

Common bur-reed
Spatterdock
White water lily

White water lily
Floating-leaf bur-reed
Northern wild rice
Spatterdock

Floating-leaf bur-reed

Broad-leaved cattail

White water lily

Water arum

White water lily
Common bur-reed
Floating-leaf bur-reed
Northern wild rice

Floating-leaf bur-reed
Common bur-reed

Common bur-reed

Common bur-reed

Broad-leaved cattail
Needle spikerush

White water lily
Pickerelweed
Common bur-reed

Pickerelweed

Common bur-reed
Broad-leaved cattail

Pickerelweed
Softstem bulrush
Creeping spikerush

White water lily

Spatterdock

Spatterdock
White water lily
Pickerelweed
Floating-leaf bur-reed

Floating-leaf bur-reed
Spatterdock
White water lily

Spatterdock
Pickerelweed
Narrow-leaf bur-reed
Common bur-reed

Floating-leaf bur-reed

Broad-leaved cattail
Common bur-reed
Spatterdock
Northern wild rice

Common bur-reed

Creeping spikerush
Common bur-reed

Common bur-reed

Softstem bulrush

Common bur-reed

White water lily
Spatterdock

Broad-leaved cattail
Creeping spikerush
Softstem bulrush

Common bur-reed

Pickerelweed

Floating-leaf bur-reed

Pickerelweed
Common bur-reed

Spatterdock
White water lily
Floating-leaf bur-reed
Northern wild rice

Inset map

Price County

Extent of large map shown in red.

Legend / title block

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Sources:
Roads & Hydro: WDNR
Aquatic Plant Survey: Onterra, 2009

Map Date: October 26, 2010

File Name: Map4_ElkDuroy_Comm_July09.mxd

1,000
Feet

Legend

Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Purple Loosestrife

Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Map 4
Elk & Duroy Lakes
Price County, Wisconsin

Aquatic Plant Communities

Water arum
Creeping spikerush
Common bur-reed

White water lily

White water lily

Common bur-reed

Common bur-reed
White water lily
Creeping spikerush
Water arum

Broad-leaved cattail
Water arum
White water lily

White water lily

Lake sedge

Common bur-reed

Sweetflag

White water lily
Common bur-reed

Spatterdock
White water lily

White water lily

Softstem bulrush
Lake sedge

White water lily

White water lily
Common bur-reed
Softstem bulrush

Common bur-reed
Softstem bulrush

Common bur-reed

White water lily
Common bur-reed

Sedge

Sedge

Softstem bulrush

Common bur-reed

Common bur-reed
White water lily

Common bur-reed
Lake sedge

Softstem bulrush
White water lily

Common bur-reed

White water lily

White water lily

Sedge

White water lily
Softstem bulrush
Common bur-reed

White water lily
Common bur-reed

White water lily
Sedge

Spatterdock

White water lily

Common bur-reed

Common bur-reed
Water arum
Common arrowhead

White water lily
Common bur-reed
Sedge

Legend

Small Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Large Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Map 5
Long Lake
Price County, Wisconsin
**Aquatic Plant
Communities**

N
W E
S

1,500
Feet

Extent of large map shown in red.

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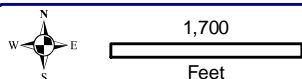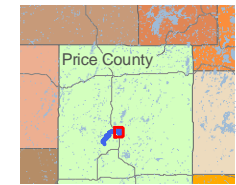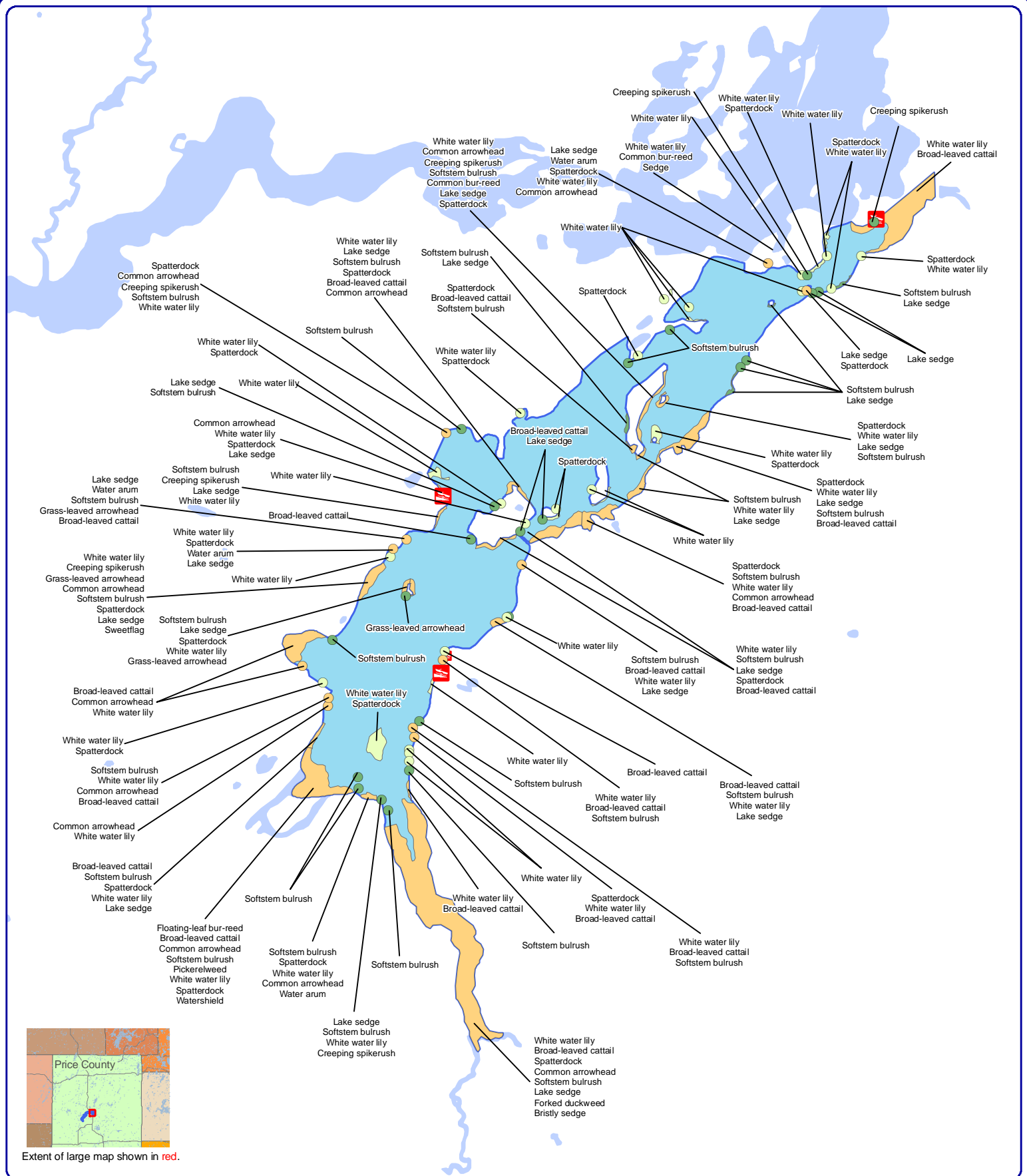*De Pere, WI 54115*
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Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2009
Map Date: April 12, 2010
File Name: Map5_Long_Comm_July09.mxd

Creeping spikerush

White water lily
Spatterdock

White water lily

Creeping spikerush

White water lily
White water lily

Spatterdock
White water lily

White water lily
Broad-leaved cattail

White water lily
Common arrowhead
Creeping spikerush
Softstem bulrush
Common bur-reed
Lake sedge
Spatterdock

Lake sedge
Water arum
Spatterdock
White water lily
Common arrowhead

White water lily
Common bur-reed
Sedge

Spatterdock
White water lily

White water lily

Spatterdock
Common arrowhead
Creeping spikerush
Softstem bulrush
White water lily

White water lily
Lake sedge
Softstem bulrush
Spatterdock
Broad-leaved cattail
Common arrowhead

Softstem bulrush
Lake sedge

Spatterdock

Softstem bulrush
Lake sedge

Softstem bulrush

Softstem bulrush
Lake sedge

Lake sedge
Spatterdock

Lake sedge

White water lily
Spatterdock

Softstem bulrush
Lake sedge

Spatterdock
Broad-leaved cattail
Softstem bulrush

White water lily
Spatterdock

White water lily
Spatterdock

Spatterdock
White water lily
Lake sedge
Softstem bulrush

Lake sedge
Softstem bulrush

White water lily

Common arrowhead
White water lily
Spatterdock
Lake sedge

Broad-leaved cattail
Lake sedge

White water lily
Spatterdock

Spatterdock

Softstem bulrush
White water lily
Lake sedge

Spatterdock
White water lily
Lake sedge
Softstem bulrush
Broad-leaved cattail

Softstem bulrush
Creeping spikerush
Lake sedge
White water lily

Lake sedge
Water arum
Softstem bulrush
Grass-leaved arrowhead
Broad-leaved cattail

Broad-leaved cattail

White water lily

Spatterdock
Softstem bulrush
White water lily
Common arrowhead
Broad-leaved cattail

White water lily
Spatterdock
Water arum
Lake sedge

White water lily

White water lily
Creeping spikerush
Grass-leaved arrowhead
Common arrowhead
Softstem bulrush
Spatterdock
Lake sedge
Sweetflag

Grass-leaved arrowhead

Softstem bulrush
Lake sedge
Spatterdock
White water lily
Grass-leaved arrowhead

Softstem bulrush

White water lily

Softstem bulrush
Broad-leaved cattail
White water lily
Lake sedge

White water lily
Softstem bulrush
Lake sedge
Spatterdock
Broad-leaved cattail

Broad-leaved cattail
Common arrowhead
White water lily

White water lily
Spatterdock
White water lily

White water lily
Spatterdock

Softstem bulrush

Softstem bulrush
White water lily
Common arrowhead
Broad-leaved cattail

Common arrowhead
White water lily

White water lily

Softstem bulrush

White water lily
Broad-leaved cattail
Softstem bulrush

Broad-leaved cattail

Broad-leaved cattail
Softstem bulrush
White water lily
Lake sedge

Broad-leaved cattail
Softstem bulrush
Spatterdock
White water lily
Lake sedge

Floating-leaf bur-reed
Broad-leaved cattail
Common arrowhead
Softstem bulrush
Pickerelweed
White water lily
Spatterdock
Watershield

White water lily
Spatterdock

White water lily

Softstem bulrush
Spatterdock
White water lily
Common arrowhead
Water arum

Softstem bulrush
Spatterdock
White water lily
Broad-leaved cattail

Spatterdock
White water lily
Broad-leaved cattail

Softstem bulrush

Lake sedge
Softstem bulrush
White water lily
Creeping spikerush

Softstem bulrush

White water lily
Broad-leaved cattail
Softstem bulrush

White water lily
Broad-leaved cattail
Spatterdock
Common arrowhead
Softstem bulrush
Lake sedge
Forked duckweed
Bristly sedge

Price County

Extent of large map shown in red.

N
W E
S

1,700
Feet

Legend

Small Plant Communities

Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Purple Loosestrife

Large Plant Communities
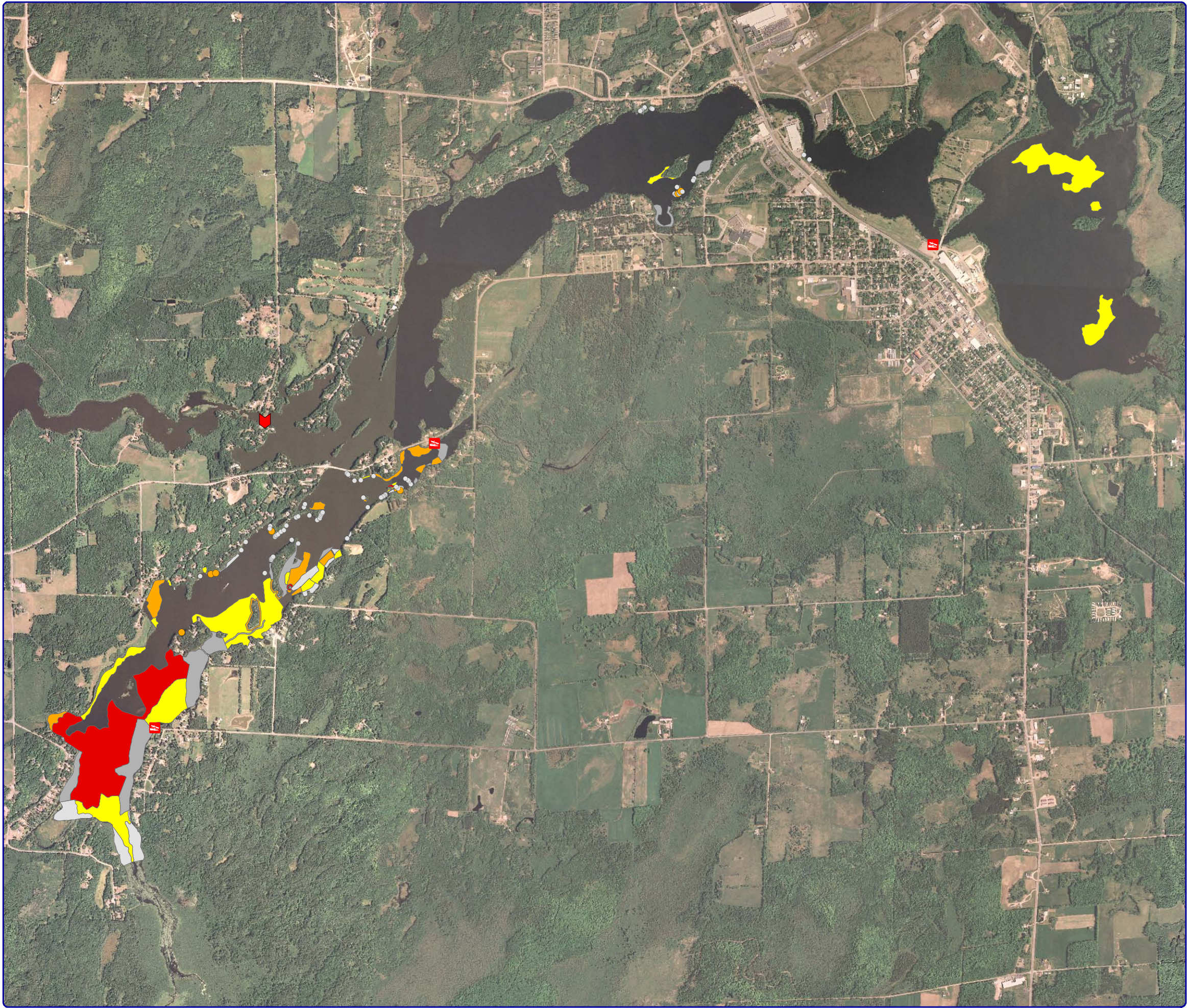
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent

Map 6
Wilson Lake
Price County, Wisconsin

Aquatic Plant Communities

Map 7

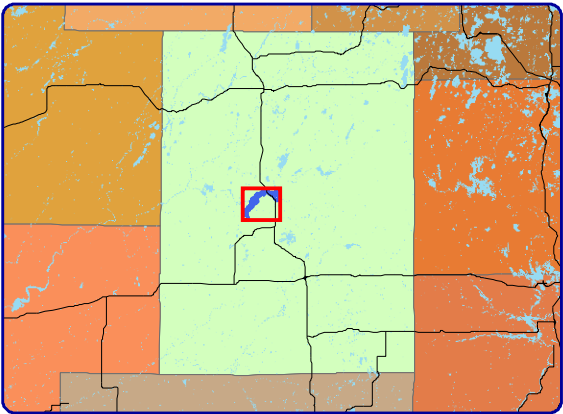## Phillips Chain of Lakes

Price County, Wisconsin

2009 EWM
Survey Results

Extent of large map shown in red.

EWM Survey Results
(July 2009)

- ⬤ Single Plants
- ⬤ Clump of Plants
- ⬤ Small Plant Colony
- Highly Scattered
- Scattered
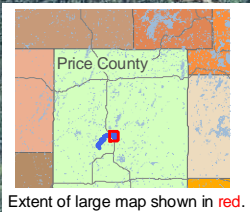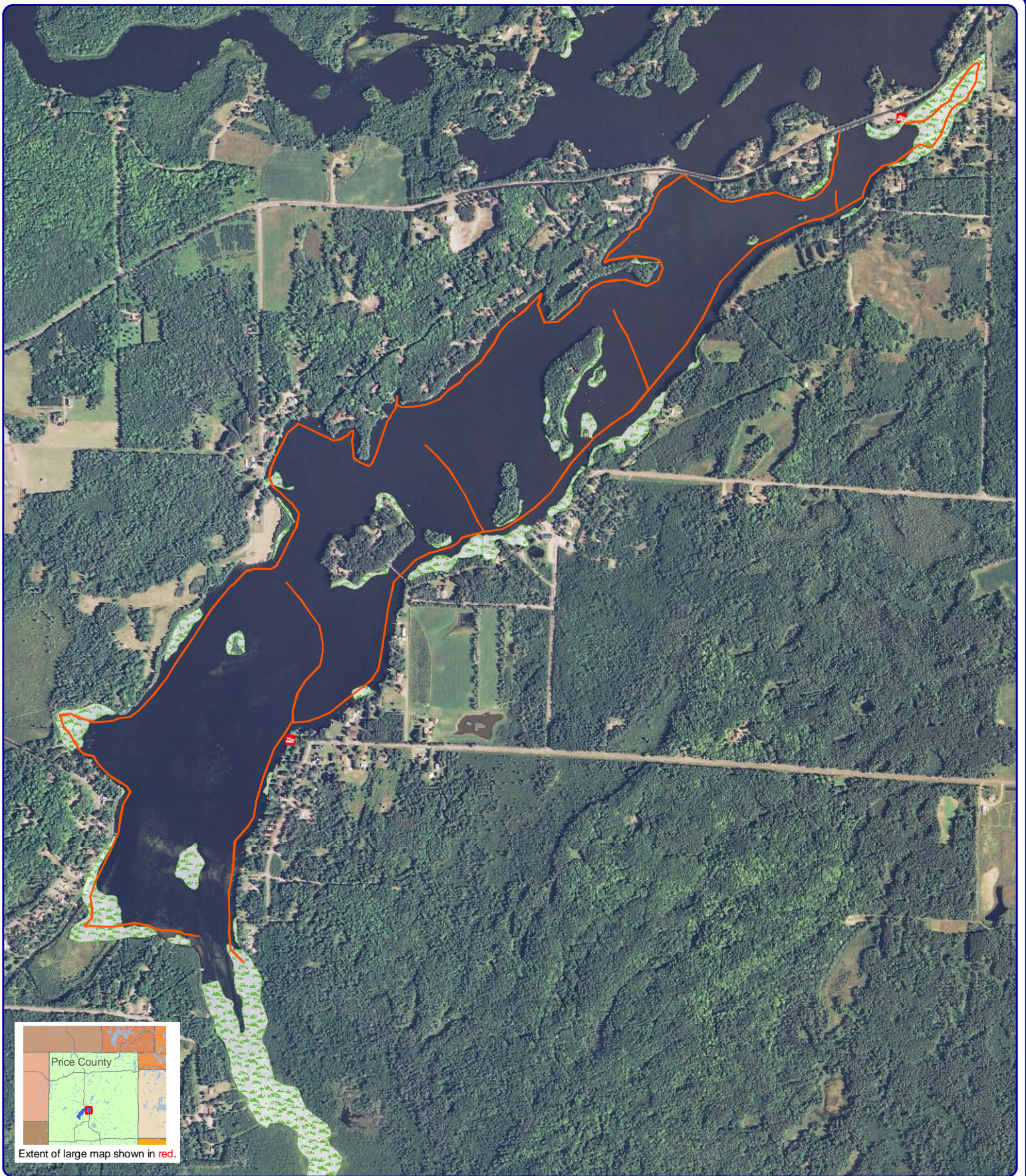- Dominant
- Highly Dominant
- Surface Matting

2,000

Feet

N
W E
S

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Price County

Extent of large map shown in red.

N
W E
S

1,700

Feet

Legend

Emergent and/or Floating-leaf Plant Community

20ft Wide Navigation Lane
(33,010 linear ft, 15.2 acres)

Map 8
Wilson Lake
Price County, Wisconsin
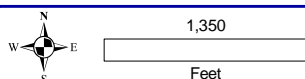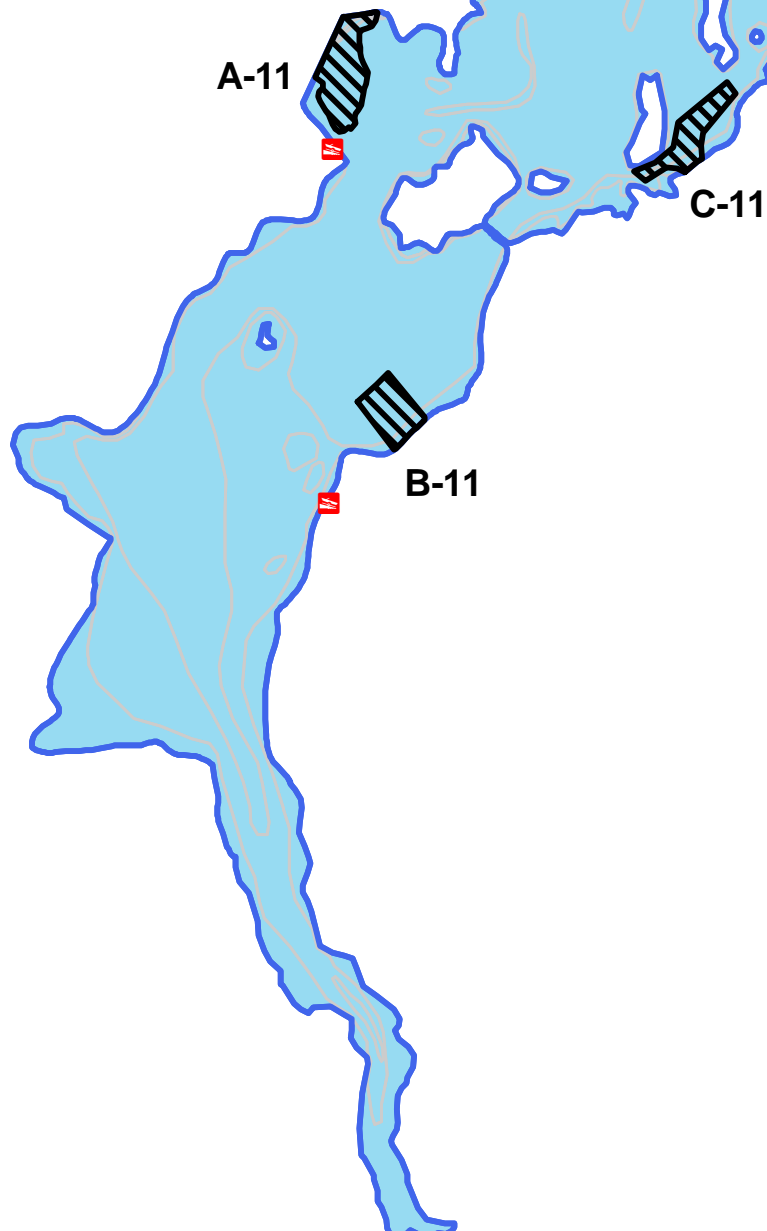
Nuisance Aquatic Plant
Managment Plan

Final Liquid 2,4-D Treatment Areas

@ 2.5 ppm a.e.

Site	Final Acres	Ave. Depth (feet)	Volume (ac-ft)
A-11	4.2	5	21.0
B-11	2.6	4	10.4
C-11	2.8	4	11.2
Total	*9.6*		*42.6*

A-11

C-11

B-11

1,350

Feet

N
W E
S

Project Location in Wisconsin

Legend

2011 Final EWM
Treatment Areas

Map 9

Wilson Lake

Price County, Wisconsin

2011 Final EWM Treatment Areas