Comprehensive Lake Management Plan

For

Lake Noquebay

Chuck Druckrey
Marinette County Land Information Department
Land & Water Conservation Division
October 2009

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Introduction & Setting

Lake Noquebay is a 2,406-acre drainage lake located in Marinette County, Wisconsin. It is the largest lake in the county and a popular tourist destination for fishing and motorized water sports. The privately held shoreline frontage is heavily developed with approximately 270 permanent and seasonal homes. The lake has three private resorts, a County owned park, swimming beach, and several boat landings. The State-owned Lake Noquebay Wildlife Area borders the lake to the east.

The purpose of this report is to develop a long-range sustainable plan for the management of aquatic plants in Lake Noquebay with an emphasis on: the control of variable-leaf watermilfoil (*Myriophyllum heterophyllum*); aquatic invasive species planning & prevention; and the preservation of sensitive areas and critical habitat.

Overview of Physical Characteristics of Lake Noquebay and its Watershed

Lake Noquebay is a hard water drainage lake with has light brown water of moderate transparency. A dam at the outlet maintains a head of approximately 3 feet during the summer months.

Although Lake Noquebay has a maximum depth of 52 feet, overall the lake is relatively shallow. Approximately 80 percent of the lake is less than 15 feet deep (Figure 1). Due to it's large size and shallow depth, the lake remains mixed throughout the year. Prolonged periods of calm hot weather can lead to stratification in deep basins of the lake.

Lake Noquebay's 86,500-acre watershed is located entirely in Marinette County. Approximately 46% of the watershed area is woodland and 30% is wetland. Agricultural land use makes up approximately 20,000 acres, or 23% of the watershed area.

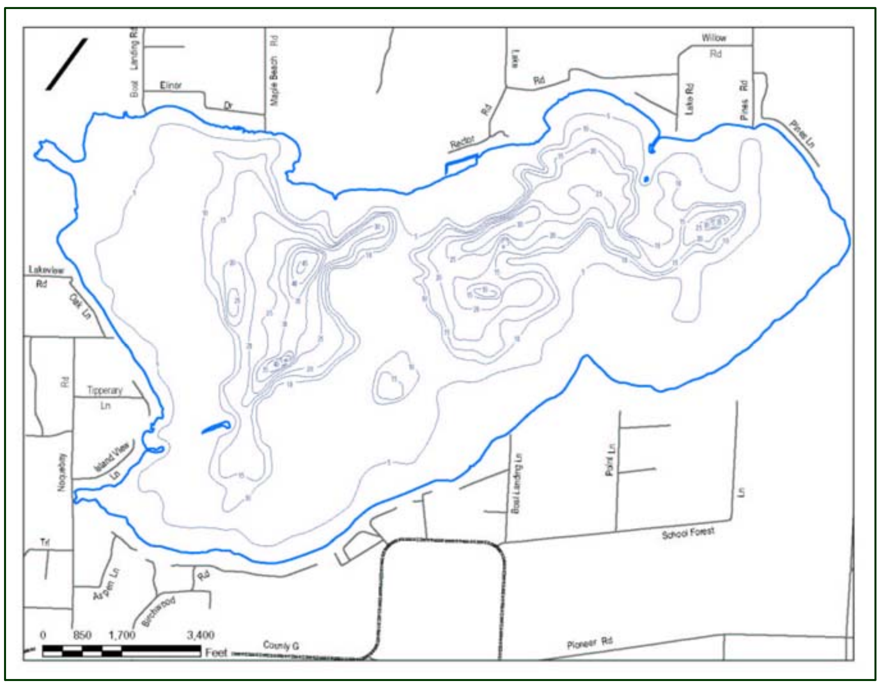


Figure 1. Lake Noquebay hydrographic map

Lake Noquebay Rehabilitation District

The Lake Noquebay Rehabilitation District (LNRD) was formed in 1975 to explore aquatic plant management options on the lake. Since 1978 the LNRD has overseen the annual harvest of aquatic plants from Lake Noquebay. The District has also worked cooperatively with Marinette County and the State of Wisconsin to operate and maintain a dam on the lake, to further characterize and track changes in water quality and aquatic macrophytes, and to manage runoff pollution sources in the lake's watershed.

History of Lake and Watershed Management Efforts

The LNRD, Marinette County Land & Water Conservation Division (LWCD) and Wisconsin DNR have a long history of protecting and improving Lake Noquebay's water quality. The earliest effort in 1964 was aimed at studying the incidence of swimmers itch and recommending control measures. In the early 70's several studies explored the increasing aquatic plant population and set the stage for long-term plant harvesting, which continues to this day.

More recently, in 1995 Lake Noquebay was designated a priority watershed by the Wisconsin DNR for the control of runoff pollution in the lakes watershed. When the watershed project ended in 2006 most of the active farms in the watershed had participated in the effort leading to an estimated reduction in the phosphorus load of 1,052 lbs. annually.

As a result of the numerous studies and due to its status as one of the largest lakes in Northeast Wisconsin the DNR and LWCD have amassed a relatively large body of water quality data for Lake Noquebay. With the data collected as part of this planning effort there is now a 30-year history of water quality data for Lake Noquebay.

Public Access & Recreational Use

Lake Noquebay is one of the most important recreational resources in Marinette County. In addition to its draw as a fishing destination, Lake Noquebay is popular with water skiers, personal watercraft users and other motorboat operators. The lake is home to the Crivitz Ski Cats, an amateur water ski club that practices and performs on the lake.

The lake offers a wide variety of public and private recreational opportunities. There are currently four active resorts on the lake offering cabins, boat rentals, and swimming areas. Lake Noquebay County Park on the south shore offers a swimming beach, boat launch with parking, picnic and play areas, and an indoor pavilion. Public boating access is adequate with two improved landings, each with space for more than 25 vehicles and trailers. Three smaller landings offer small boat launching with limited roadside parking. In addition to the boat landings, walk in access is available at one other road right-of-way, at the dam, and in the State wildlife area.

Landowner Identification of Problems and Threats to Lake Noquebay

A survey of waterfront property owners and association members was conducted during the spring of 2008 to examine how people use Lake Noquebay, what they perceive to be the problems facing the lake, and to explore attitudes towards the harvesting program and other management actions.

The survey was mailed to all 428 LNRD member households at their official residences. A total of 228 surveys were completed and returned for a 53.2% return rate. No follow up correspondence was used to increase response rate. A complete listing of survey results can be found in Appendix A.

Lake Use Patterns

A series of questions was asked to try and determine some basic history of the respondents, their familiarity with Lake Noquebay, and how they use the flowage. A large majority of respondents (80%) owned water frontage on Lake Noquebay. A slight majority (55%) are weekend/vacation residents while a third are permanent residents. The average respondent has been living on or coming to the lake for 29 years, the longest has been coming to Noquebay for 81 years. Respondents were also asked why they purchased property on Lake Noquebay. The top ranking reasons were proximity to the water (24%), beauty of the location (22%), boating (15%) and fishing (15%).

Perception of Water Quality Conditions & Fishing

The survey contained five questions designed to explore how landowners perceive the condition of Lake Noquebay and how conditions have changed over time. When asked about water clarity in the lake 66% had a favorable view. When asked about changes in water clarity 60% thought it has remained the same, 26% think clarity is improving and 11% think it is getting worse. Despite the favorable views regarding water clarity, more than half (52%) have an unfavorable view of the amount of algae in the lake and 35% think the amount of algae is increasing.

When the questions focus on aquatic plants the results are clear-cut. Nearly three quarters of the respondents felt the lake has too many aquatic plants and nearly half think the level of aquatic plant growth is increasing. Only 16% of respondents think aquatic plants are decreasing in Lake Noquebay.

On the question of fishing, 72% view the quality of fishing on the lake as favorable but nearly half think the quality of fishing is decreasing. Only 3% think fishing has been improving and 41% report there has been no change.

Asked about the severity of shoreline erosion on their individual lots, 32% report unfavorable levels of erosion. Only 13% report increased erosion on their shoreline while 60% report no change.

Issues of Concern

Respondents were asked to list the top three problems or concerns regarding Lake Noquebay (figure 2). Excessive aquatic plant growth topped the list with 27% choosing it as the top issue. Invasive aquatic species was second with 22% followed by failing septic systems at 16%.

A series of questions were also asked to further explore attitudes towards aquatic plants in Lake Noquebay. There was near unanimity in recognizing the importance of aquatic plants for fish and wildlife (91%). Still, when asked to consider the statement "Aquatic plants are only a nuisance when they interfere with boating and swimming", the split was close. 56% of respondents agreed with the statement and 41% disagreed. Similarly, 53% agreed that emergent plants such as bulrush and wild rice improve scenic beauty of the lake while 41% disagreed. Asked how aquatic plants impact their waterfront property, 64% reported that weeds washing up on their shore were a serious problem.

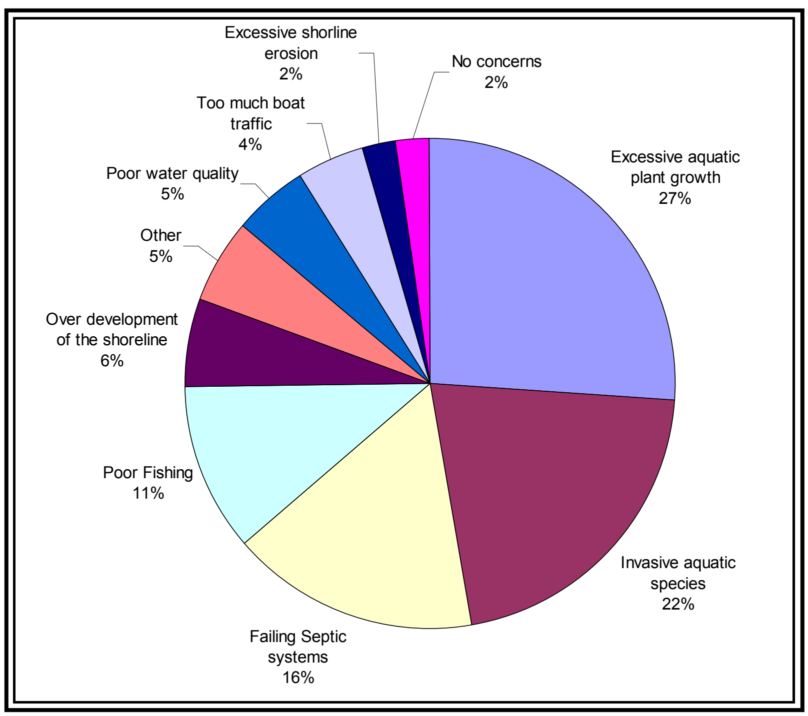


Figure 2. Top landowner concerns

Attitudes Toward LNRD Harvesting Program
In responses to questions about the existing aquatic plant harvesting program people are generally satisfied but feel more needs to be done in front of their home or cottage. A strong majority (66%) feels the harvesting program is effective or very effective at "Maintaining navigation and recreational potential on the lake". 23% think the harvesting program is somewhat ineffective and 5% feel it is ineffective. At the same time most of the respondents feel the harvesting program is less than effective in controlling plants in front of their property (48%) and in cleaning their shoreline in a timely manner (44%).

There were also some fairly strong opinions about modifying the harvesting program. A slim majority of respondents (56%) agreed "The level of aquatic plant harvesting needs to be increased". 36% disagreed. 63% of respondents think additional shoreline cleanup is needed and 60% think emergent plants (bulrush, wild rice etc.) and water lilies should be controlled.

Respondents were also asked to indicate areas that needed more aquatic plant control on a map of the lake. A compilation of the results can be seen in figure 3.

Aquatic Plant Control Alternatives
When asked about the need for alternative or additional plant control methods 60% agreed that harvesting is not enough and additional plant control measures are needed. However, when asked to identify which aquatic plant control measures they would support only harvesting received majority support with 88%. Biological controls and dredging received tepid support with 48% and 49% respectively. Chemical treatment was supported by only 39% of respondents with 44% opposed. Not surprisingly, 85% agreed that all lake users should share in the cost of managing aquatic plants on Lake Noquebay.

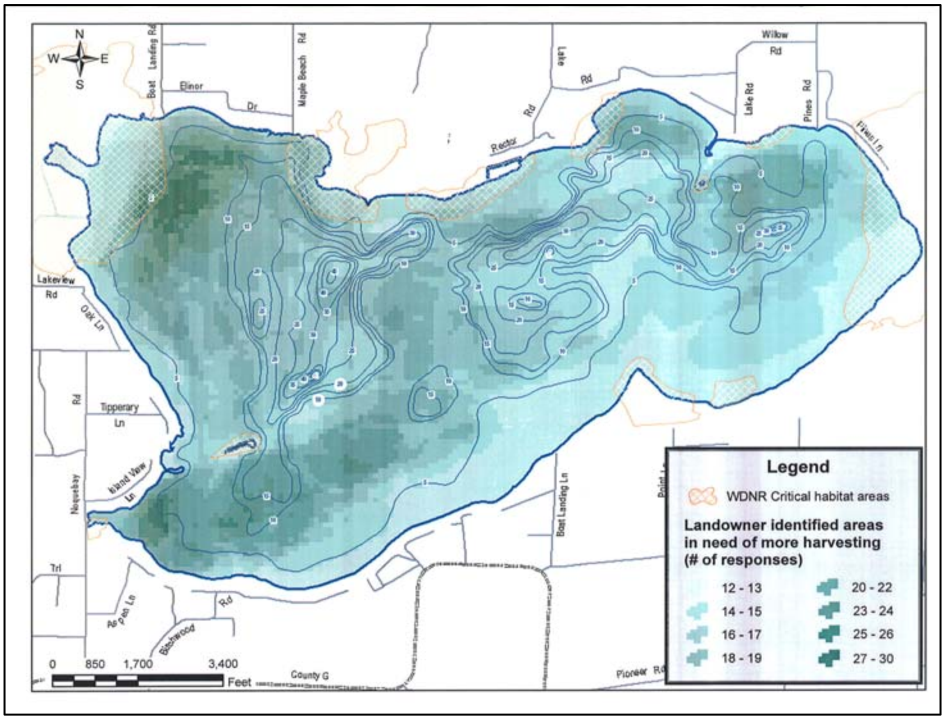


Figure 3. Areas identified by landowners as needing additional aquatic plant control.

Participation in Lake Organizations
According to the survey only 40% of respondents have attended an LNRD board meeting or annual meeting in the last three years. Nearly 60% haven't attended an LNRD meeting within the last five years and 38% have never attended a meeting. When asked if their should be a lake association to "promote, support, and participate in other activities to protect and improve Lake Noquebay" 83% said yes.

Support for other Lake Management Measures
Respondents were also asked several questions regarding activities and/or projects to protect and improve Lake Noquebay. Substantial majorities supported all of the suggestions that included; Aquatic invasive species monitoring (97%), Water quality monitoring (95%), Fish stocking (94%), Boat launch monitoring and aquatic invasive species education (94%), Supporting conservation measures to improve the lake (91%), Promoting policies and regulations to improve the lake (88%), Providing educational materials (82%), and Promoting community social events (66%).

Overview of Lake Noquebay Fish Community

As one of the largest lakes in northeast Wisconsin, Lake Noquebay is an important fishing destination. Known for its abundant panfish population, particularly bluegill, Lake Noquebay also supports a healthy population of bass, northern pike, and walleye. Musky are also present in the lake and brown trout can be found during the winter months.

Most of the panfish and gamefish in Lake Noquebay are sustained through natural reproduction. The DNR has stocked walleye in the past, most recently in 2005, and has been stocking about 1000 musky annually since 1990.

According to WDNR Fisheries Supervisor Michael Donofrio, fishing pressure on the lake is high but more than 70% of the catch is panfish, predominantly bluegill. On Lake Noquebay these higher harvest rates appear to be sustainable since fish surveys indicate high reproductive rates and a good size structure for bluegill and crappie.

Although much of the shoreline of Lake Noquebay is heavily developed the recently completed critical habitat designation report (Sabai 2009) did not note any obvious deficiencies in fish habitat. The report did identify several areas of critical habitat where alteration and disturbance should be limited to protect important habitat function and values.

Identification of Critical Habitat Areas

In 2006 the Wisconsin DNR, with assistance from the Marinette County LWCD, surveyed Lake Noquebay to identify areas of "critical habitat". The Critical Habitat Designation Program (CHD) was created to identify and provide protection for areas of lakes and streams that provide important fish and wildlife habitat, water quality protection, navigational routs, and natural scenic beauty.

Areas are designated as critical habitat if they have Public Rights Features, are Sensitive Areas, or both. Public rights features (defined in NR 1.06, Wis. Adm. Code) include the following:

- Fish and wildlife habitat;
- Physical features of lakes and streams that ensure protection of water quality;
- Reaches of bank, shore or bed that are predominantly natural in appearance;
- Navigation thoroughfares;
- Sensitive Areas, which are defined in Ch. NR 107 as: areas of aquatic vegetation identified by the department as offering critical or unique fish and wildlife habitat to the body of water.

Critical habitats are identified in the field and reviewed by DNR fisheries, wildlife and water resources staff. Data was also solicited from local units of government, conservation groups, federal agencies, and anyone who may have resource knowledge and information. The information was used to assemble maps to identify targets of focus related to fish, wildlife, endangered resources, and their habitats. Interestingly, when LNRD members were asked to identify "Areas of important habitat needing special attention in the management plan" they identified many of the same areas identified by the natural resource professionals (figure 4).

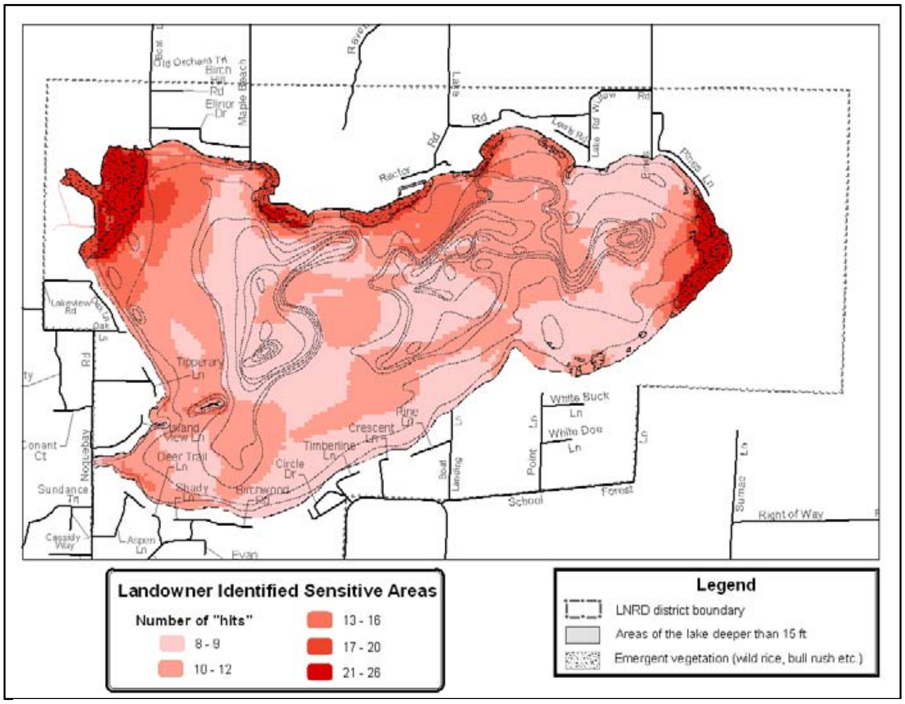


Figure 4. Landowner identified sensitive areas. Darker shading indicates more respondents identified the area as sensitive.

The Lake Noquebay Critical Habitat Designation Report was adopted in 2009 (Appendix B). Nine of the 11 areas were classified as critical habitat based on the presence of unique or important aquatic vegetation (figure 5) primarily stands of bulrush and wild rice, which provide critical spawning habitat and nursery areas for juvenile fish. Others include shallow marsh habitat with abundant floating leaf vegetation and/or high quality submersed plant communities with little various leaved milfoil.

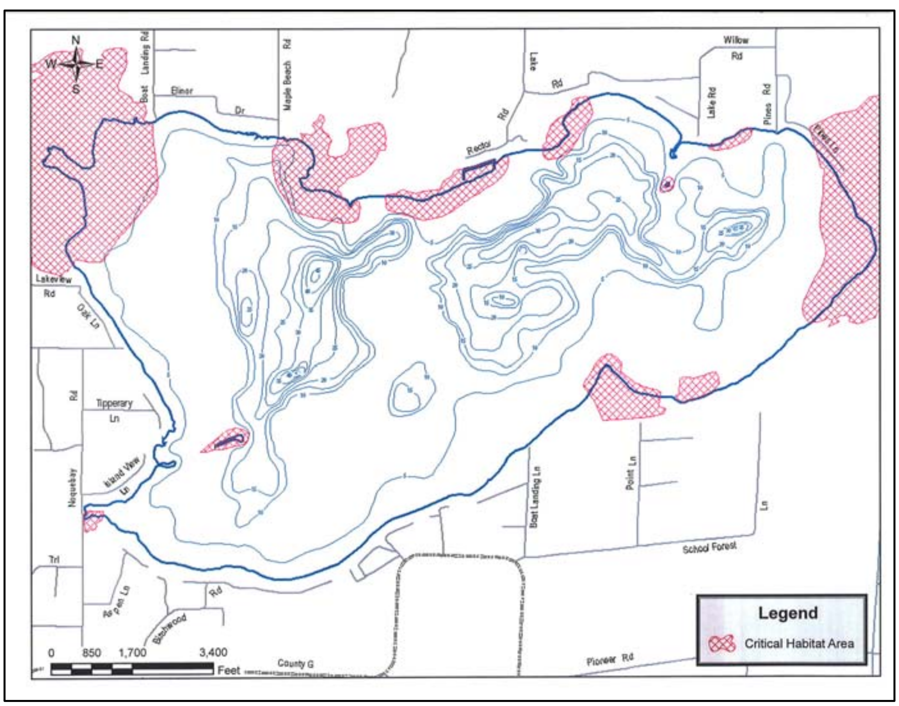


Figure 5. Wisconsin DNR critical habitat areas.

While the critical habitat designations areas are designed to protect the important aquatic plant communities the recommendations allow for the harvesting of vegetation to maintain navigation to docks that may be within the CHD areas. Specific management recommendations are incorporated in the harvesting plan.

State & Local Shoreline and Water Management Policy

Like all navigable waters, Lake Noquebay is subject to a variety of state and local policies and regulations that effect land use, building placement, habitat alteration, and ultimately water quality. Locally, the Towns of Lake and Middle Inlet have passed comprehensive land use plans to guide future development. Marinette County has, since 1968, regulated development and vegetation management in the shoreland zone. The state and federal government also regulate activities on navigable waters and adjoining wetlands. Together the goal of these policies and regulations is to protect water quality and preserve natural habitat.

Local Land Use Plans

Approximately 3.8 miles of the north shore of Lake Noquebay are located in the Town of Middle Inlet. The Town of Middle Inlet Comprehensive Plan (Vierbicher Associates, 2003) recognizes the importance of its natural resource amenities and sets forth goals to preserve and protect wildlife habitat and water quality, and to plan for the wise use of the town's natural resource base. To this end, plan objectives include working in cooperation with the Marinette County LWCD to implement its water quality and conservation programs, encouraging the county to adopt a storm water and erosion control ordinance, and consider the impacts of development on natural resources during the review process. The town also recommends working with the Lake Noquebay Rehabilitation District to improve water quality and advocates for the creation of lake and river associations.

The balance of Lake Noquebay shoreline (6.0 miles) is located in the Town of Lake. The Town of Lake Comprehensive Plan (Vierbicher Associates, 2004) recognizes the importance of its natural resource amenities and sets forth goals to preserve and protect wildlife habitat and water quality, plan for the wise use of the town's natural resource base, and provide long term and permanent protection of the town's natural resource base. Objectives include working in cooperation with the Marinette County LWCD to implement its water quality and conservation programs, working with the county to adopt a storm water and erosion control ordinance, and consider the impacts of development on natural resources during the review process. The town also advocates for the creation of lake and river associations and encourages the use of conservation easements and acquisition programs to protect natural resource areas from being developed.

Shoreland Zoning

Shoreland/wetland zoning is delegated to individual counties under Wisconsin NR 115. The current Marinette County shoreland/wetland zoning code was amended in 2003 to include a three-tiered lake and river classification system whereby undeveloped lakes and streams deemed more sensitive to the effects of development would require increased lot sizes. Lake Noquebay, due to its large size and existing level of development was placed in Class III, the least restrictive water classification. Lots on Class III waters must have 100 feet of water frontage and be at least 30,000 square feet in size. Marinette County rules exceed state minimum standards in several areas, most notably a 50-foot vegetation protection area (state mandated 35 feet), a mitigation requirement for expansion of nonconforming structures, and no setback averaging.

In February 2010 Wisconsin updated NR 115 to better protect shoreline habitat and water quality. The new rules, which must take effect by February 2012, contain several changes that will affect building and expansion of existing structures on Lake Noquebay. The new rule allows for the expansion of nonconforming structures if the structure is at least 35 feet from the water and the expansion will take place beyond the 75-foot setback. This is more restrictive than the counties current standard, which in some cases allows for expansion within 75 feet of the water. Like the current county code, the new rule requires mitigation for the expansion of nonconforming structures.

The most significant change in the new law is a limitation on impervious surfaces within 300 feet of the lake. Impervious surfaces include any hard surface that significantly restricts the infiltration of rainwater such as roofs, patios, driveways etc. Under the new rule impervious surfaces are limited to 15% of the lot area that is within 300 feet of the water. Impervious surface can be increased up to 30% of the area if an approved mitigation plan is implemented. NR 115 states the mitigation measures shall be "proportional to the amount and impacts of the impervious surface being permitted". According to NR115 mitigation activities may include such things as habitat restoration, constructing rain gardens or other practices designed to increase infiltration. Given the existing pattern of development and propensity for larger homes on Lake Noquebay the impervious surface standard is sure to affect many landowners on the lake as they seek to expand their homes or add garages, outbuildings etc.

State and Federal Rules
The Wisconsin DNR and US Army Corps of Engineers regulate activities, placement of structures, and filling and excavating on the bed of lakes and streams and in wetlands. These rules are designed primarily to protect aquatic and wetland habitat. The most common regulated activities include the placement of docks, shoreline erosion control projects, building or modification of "wet" boathouses, and dredging or depositing fill on the bed of the lake or adjacent wetlands. The two agencies have a combined permitting system in areas where both have regulatory authority.

Water Quality Conditions

Water quality in Lake Noquebay was monitored in 2007 and 2008 following Wisconsin DNR water chemistry monitoring protocol. Water samples were collected from the surface and one meter from the bottom at the deepest part of the lake located on the west end of Lake Noquebay. Samples were analyzed for total and dissolved phosphorus as well as nitrogen series at spring turnover. Temperature, dissolved oxygen, pH, and conductivity were measured at one-meter intervals. A complete listing of water quality results can be found in Appendix C.

Temperature and mixing
Temperature and mixing are important since the frequency of mixing plays a role in dissolved oxygen concentration and internal nutrient cycling. Shallow lakes typically remain mixed throughout the year while deep lakes often stratify during the summer months. Summer stratification is a separation of the water into two distinct layers, a warmer top layer (epilimnion) and a much cooler bottom layer (hypolimnion). These two layers are separated by a transition zone (metalimnion), which anglers know as the thermocline. A difference in density prevents these two layers from mixing until fall when the surface temperature falls and equals the temperature of the hypolimnion.

Due to its relatively shallow depth and large surface area exposed to the wind, Lake Noquebay remains fairly well mixed throughout the summer months. Prolonged sunny windless periods can lead to temporary stratification in the deep basins but this condition is localized.

Dissolved Oxygen
Dissolved oxygen is vital for fish and most other aquatic life. When D.O. levels fall below 3 mg/l, sport fish species will not survive long. Few fish can tolerate D.O. levels below 2 mg/l. The amount of

oxygen water can hold varies with temperature. Water at 33 degrees can hold approximately 14.2 mg/l while water at 75 degrees is saturated at 8.4 mg/l.

Dissolved oxygen comes from two sources, oxygen exchange with the atmosphere and oxygen production by aquatic plants and algae. Oxygen exchange with the atmosphere only occurs at the lake's surface. Plants and algae are found only to the depth of light penetration.

Since Lake Noquebay is relatively shallow it remains well mixed throughout the summer and the entire water column in areas less than 20 feet deep remains well oxygenated. Long-term monitoring indicates oxygen depletion below the 20-foot depth is common in deep areas during the months of July and August.

Nutrient Levels

Phosphorus and nitrogen are the two primary nutrients that regulate plant growth in a lake. When one of them is in short supply relative to the other it is the "limiting" nutrient. Increases in the limiting nutrient will lead to increased production in the form of plants and/or algae. Since nitrogen is water-soluble and can be absorbed from the atmosphere by some types of algae, it is typically found in abundance in lake water. Phosphorus, on the other hand, binds tightly to soil particles and is typically in short supply in lake water.

In Lake Noquebay the total nitrogen concentration in the spring of 2008 was 620 ug/l, which is average for lakes in Northeast Wisconsin. During the summer of 2007 and 2008 the average total phosphorus concentration was 22.2 ug/l, which is slightly below the statewide average for similar lakes (23 ug/l). The ratio of nitrogen to phosphorus (N:P ratio) in Lake Noquebay was approximately 31:1 during the sampling period. Lakes with an N:P ratio greater than 10:1 are considered to be phosphorus limited. However, there has also been some research which points to nitrogen in the lake sediment being important for rooted aquatic plant growth.

As the limiting nutrient it is important to maintain low phosphorus levels in the lake. Generally, surface phosphorus levels should be maintained below 20 ug/l to prevent nuisance algae blooms and poor water clarity. Major sources of phosphorus include surface water runoff and groundwater inputs. All surface runoff will contain some phosphorus. However, it has been shown that the concentration of phosphorus in runoff from urban areas, agricultural land use, and even typical lakefront development will be much higher than if the same area were forested. Phosphorus enriched groundwater is typically the result of failing septic systems and/or systems discharging to the surface.

Water Clarity

Water clarity was measured with a Secchi disk, an 8 inch black and white disk that is lowered into the water until it disappears. This distance is the Secchi disk depth. Secchi disk depth is affected by naturally stained water, suspended sediment and algae growth.

Lake Noquebay has clear, slightly stained water. The slight brown staining is due to tannins, dissolved organic compounds released by leaves and needles as they decompose in wetlands within the lakes watershed. The average Secchi disk depth during the 2-year study period was 11.1 feet. Overall, the Secchi disk depth for Lake Noquebay is better than the statewide average for similar lakes and better than would be expected based on phosphorus levels. This due to the fact that Noquebay is dominated by rooted aquatic plants. The plants tie up most of the phosphorus, leaving little for the algae.

Chlorophyll-a

Chlorophyll-a is a pigment found in all green plants. The amount of chlorophyll-a is used as an indicator of the amount of algae in the water. The average chlorophyll-a concentration for the sample period was 3.5 ug/l. This level is quite low and indicates limited production of planktonic (free floating) algae. This level is well below the statewide average and, again, due to the abundance of rooted aquatic plants which tie up phosphorus, making it unavailable for algae production.

Trophic State

Secchi disk depth, phosphorus concentration and chlorophyll-a concentration are commonly used to calculate a lakes trophic state. Trophic state index (TSI) is a measure of the nutrient enrichment level of a lake. Oligotrophic lakes (**<40**) are nutrient poor, these lakes are unproductive and have very clear water. Eutrophic lakes (**>50**) have excessive nutrients. These lakes are very productive (able to grow lots of plants, fish and insects) and usually weedy, or support large algae blooms, or both. Mesotrophic lakes (**40-50**) have moderate nutrient levels and fall somewhere between the two extremes in aquatic plant and fish productivity.

Using phosphorus as an indicator the trophic state for Lake Noquebay during the study period was 51.7 which is in the low range of eutrophic, or nutrient rich. However, the Secchi TSI (42.5) and chlorophyll-a TSI (42.9) indicate the lake is in the lower mesotrophic range. The disparity in trophic state indices is not uncommon in shallow lakes that are dominated by aquatic plants. It indicates that rooted plants instead of algae take up most of the nutrients in the lake.

Water Quality Trends

Lakes are complicated and dynamic systems. Seasonal variations in water quality can confuse the data and make the detection of trends difficult if not impossible. Fortunately, there are 30-years of reliable water quality data for Lake Noquebay. This long history of water quality monitoring allows us to see through the "noise" of annual variability and identify trends in water quality.

A review of trophic state values for the period between 1979 and 2008 (Figure 6) show some clear trends. The Chlorophyll-a TSI value, which measures the concentration of free-floating algae in the water, has declined since 1979, indicating fewer algae in the lake. The Secchi TSI has also decreased slightly during the period, indicating that water clarity on Lake Noquebay has improved slightly over the last 30 years.

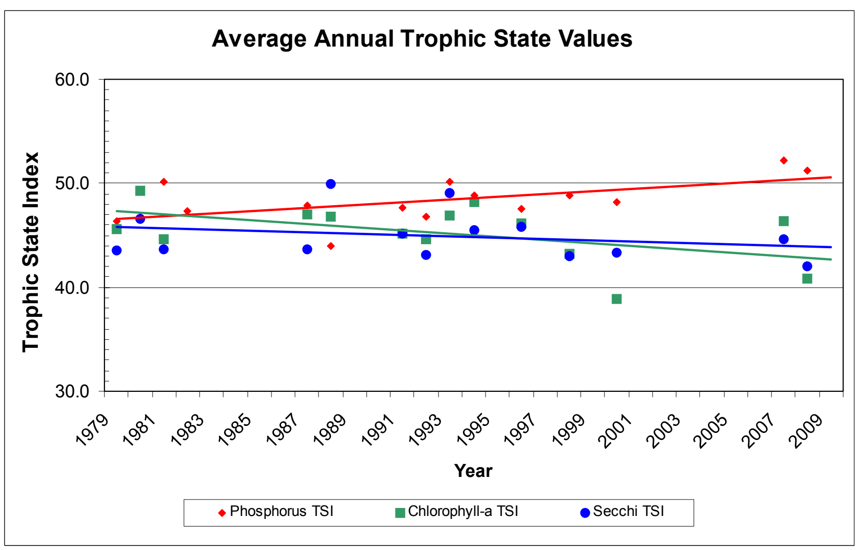


Figure 6. Lake Noquebay trophic state values.

While the Secchi and Chlorophyll TSI's indicate improving water quality, the phosphorus TSI has been steadily increasing over the last 30 years. A plot of all available phosphorus data for Lake Noquebay clearly shows an increase in the concentration of this important nutrient. This trend is seen when comparing both spring turnover and average summer phosphorus concentrations (figure 7).

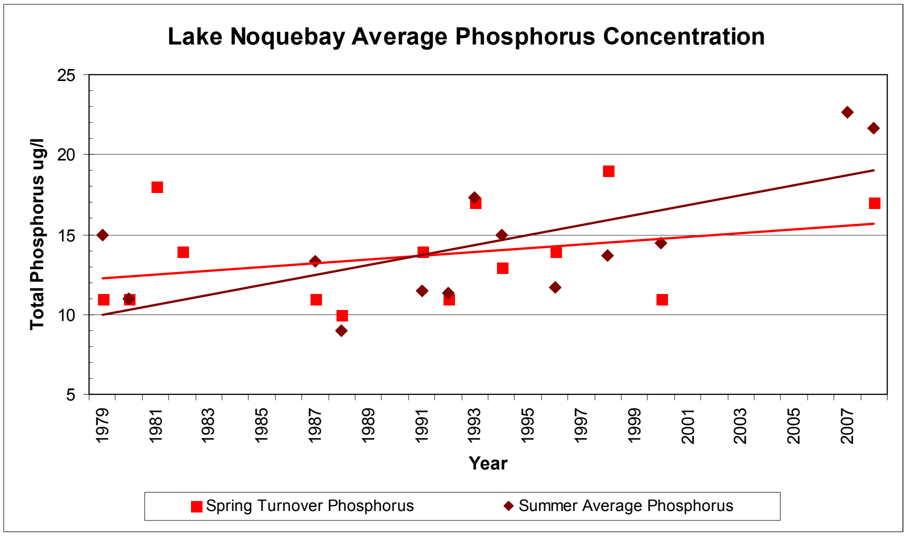


Figure 7. Average spring and summer phosphorus levels.

Since phosphorus is the limiting nutrient in the lake its increase is troubling. Ordinarily an increase in phosphorus would lead to increased algae production and decreasing water clarity. However, the presence of zebra mussels (*drissena polymorpha*) in the lake is a confounding factor. The zebra mussel is an exotic freshwater mussel native to Europe. They attach to any hard surface and feed by filtering algae and small zooplankton from the water. Since its discovery in Lake Noquebay in 2006 zebra mussels have expanded greatly and can now be found attached to rocks, dock posts, the shells of native clams, and even the stems of aquatic plants.

In the Great Lakes, where zebra mussels were first discovered they are responsible for improved water clarity and a resurgence of rooted aquatic plants. In Lake Noquebay they may also be playing an important role in suppressing algae populations and maintaining water clarity despite the increase in phosphorus.

Given their role in improving water clarity, it's tempting to look at zebra mussels as beneficial species. However, recent studies have linked zebra mussels to the increase in toxic blue-green algae (Raikow 2004) and other noxious filamentous forms of algae (Pillsbury, 2002). Both forms are unpalatable or unavailable to zebra mussels. Since they are at the base of the aquatic food web zebra mussels can also have negative effects on the rest of the lake ecosystem including fish communities as they also filter zooplankton from the water.

Phosphorus sources

While the monitoring has identified a notable increase in phosphorus concentration it does not identify the source. Sources of phosphorus include direct deposition, surface runoff, groundwater inputs, and internal loading. Internal phosphorus loading occurs when water overlying the sediment becomes anoxic (without oxygen) during periods of thermal stratification and reduced mixing. In deep lakes phosphorus is released from anoxic sediment below the thermocline and delivered to surface waters during spring and fall turnover. In shallow lakes, extremely dense plant growth and calm, hot weather can lead to stagnation and reduce circulation so much that anoxia can occur during the night when plants are using oxygen. This can result in phosphorus release from the sediment.

In Lake Noquebay thermal stratification is weak and the deep-water areas are small compared to the lakes volume so internal loading from deep sediment is unlikely. Significant phosphorus release from the sediment in shallow areas is also unlikely since most of the dense plant growth occurs in 5-12 feet of water where wind driven circulation is greatest.

At first glance increased phosphorus loading from agricultural areas seems unlikely. During the monitoring period the number of active farms in the watershed and acres under cultivation have declined considerably. In the last 15 years alone the number of active farms in the Lake Noquebay watershed have declined from 40 to 25. Also, most of the remaining farms have adopted best management practices to greatly reduce barnyard runoff and eliminate winter-spread manure. It is estimated that farms participating in the Lake Noquebay Priority Lake Project alone reduced annual phosphorus inputs to the watershed by 1,600 pounds and eliminated winter spreading of manure on more than 4,000 acres since 1995.

While agricultural inputs are declining, phosphorus inputs from residential development within the watershed are likely increasing. In recent years the number and the average size of new homes built on and around the lake has grown substantially. Numerous studies have reported that phosphorus loading from residential development is 4 to 8 times greater than forested areas. With high-density residential development, such as that found on the lakeshore, nutrient levels can exceed those from agricultural land use. The drastic increase is due to both increased phosphorus concentration in the runoff water and an increase in runoff volume due to impervious surfaces and compacted soils.

As the number and size of homes around the lake grows the phosphorus load from these areas increases substantially. Since the greatest increase in development has occurred close to the lake the likelihood of this runoff actually reaching the lake is very high.

Septic systems might also be responsible for increased phosphorus loading to the lake via shallow groundwater. Unfortunately groundwater inputs are difficult to estimate. Often a lake will have distinct areas of groundwater inflow and outflow. These patterns can be tracked through the use of piezometers, small temporary monitoring wells, located around the lake. Older septic systems, septic systems located in or close to the water table, and undersized systems are more likely to fail and export nutrients to the lake. Often systems that were adequate for a weekend cottage fail when the cottage is expanded or becomes a permanent residence.

During the priority watershed inventory it was estimated that 27% of the residences on Lake Noquebay were located on soils that are poorly suited to conventional septic systems due to high water table. While some of these residences have mound systems or holding tanks it is not known how many may be failing. While phosphorus typically binds tightly to soil particles, in its dissolved form it's more mobile and, with undersized and poorly maintained systems, the soils capacity to bind phosphorus can be overwhelmed. Failing septic systems can also discharge directly to the surface and run into the lake via surface runoff.

The recently introduced zebra mussels may also play a role in nutrient cycling in Lake Noquebay. Studies have shown that zebra mussels increase the cycling rate of phosphorus and other nutrients as they feed on algae and release soluble nutrients to the water column in the form of feces and psuedofeces. Increased nutrient cycling will be greatest during the summer months and could lead to even higher summer phosphorus concentrations.

Water Quality Protection Goals and Objectives

Despite the well documented increase in phosphorus levels, water clarity, and hence the perceived water quality in Lake Noquebay has remained very good. If the lakes water clarity is to be maintained the underlying phosphorus concentration needs to be controlled and ultimately reduced.

Goal: Reduce phosphorus concentration in Lake Noquebay to a level sufficient to maintain good water clarity.

Since every lake is unique it is difficult to predict the point at which increasing phosphorus concentration will lead to obvious reductions in water quality. With lakes such as Noquebay the search for an upper limit is confounded by the fact that shallow lakes have two stable states; aquatic plant dominated (clear water), or algae dominated (turbid water). A lake in the clear water state will tend to persist there as phosphorus levels rise well past the point where nuisance algae booms are possible. At some point the scales tip and the lake will quickly move into the turbid water state. Once in the turbid state negative feedback loops often drive even more nutrient release from unprotected sediment. Some new stressor such as a severe weather event, sudden surge in nutrients, or a disruption in the lake ecosystem brought about by invasive species often serves as a trigger to cause the shift in stable states.

Studies indicate that 25 ug/l seems to be the minimum phosphorus concentration needed to support high algae populations and maintain a lake in the turbid state (Moss 2003). Past this point, a shallow lake can persist in either state even as phosphorus levels reach100 ug/l or more! While nobody can say when a shift will take place, the chance that it will grows as phosphorus levels rise.

Experience shows it is very difficult, and expensive, to reverse the course and bring a lake back to the clear water state where aquatic plants can flourish. Given this fact, and recognizing the uncertainty in predicting when a stable state shift will take place, it makes sense to err on the side of caution and maintain phosphorus concentrations below 25 ug/l.

Objective: Maintain summer total phosphorus concentrations in Lake Noquebay below 25 ug/l.

The latest monitoring effort revealed an average summer phosphorus concentration of 22.2 ug/l during 2007-2008. Data also shows a clear upward trend in phosphorus levels. It follows that action needs to be taken quickly to quantify phosphorus inputs and adopt measures to reduce inputs where possible.

While the LNRD benefits from 30 years of water quality monitoring, there has never been a nutrient budget calculated for the lake. A detailed nutrient budget would greatly improve the ability to focus nutrient reduction efforts for maximum benefit.

Target – Develop a detailed nutrient budget for Lake Noquebay to guide phosphorus reduction efforts.

Routine water quality monitoring is a necessary part of any nutrient reduction program. While changes in water quality are often difficult to detect in the short term, additional water quality data would be a valuable addition to the existing data set and could be used to track long-term trends and determine if management efforts are working.

Target – Monitor water quality on a regular basis to track changes and evaluate management efforts.

Water Quality Protection Alternatives

Phosphorus and other plant nutrients in a lake can come from both internal and external sources. Internal loading occurs when phosphorus is recycled from the sediment back into the water. In shallow lakes such as Noquebay internal loading is typically stable, or at least predictable, as long as aquatic plants dominate the ecosystem. Shallow lakes dominated by algae (turbid water state) can have wide swings in internal loading as the algae population booms and crashes throughout the year.

External phosphorus sources include runoff from within the lakes watershed, groundwater inputs, and direct deposition from the atmosphere. Some external phosphorus sources, such as runoff from forested lands, can be considered "background" loading and is not amenable to control. Other sources, particularly those elevated by changing land use practices, can be managed more easily.

The following practices can be used to reduce internal and/or external sources of phosphorus:

Phosphorus Inactivation

Sediment bound phosphorus can be inactivated through the addition of aluminum sulfate, or alum. This method is typically used to reduce internal loading in stratified (deep) lakes and in shallow turbid lakes where algae growth is suppressing the aquatic plant community. Alum works by binding tightly with phosphorus in the sediment and preventing it from moving into the overlying water column. Assuming external sources are well controlled, it is not unreasonable to expect an alum treatment to control phosphorus release for a period of 8-10 years after which it may have to be repeated.

Since rooted aquatic plants get most of their nutrients from the sediment, alum treatments have little effect on their growth. In fact, alum is typically used in shallow turbid lakes to reduce algae production and allow for the reestablishment of rooted plants.

Bass Lake in Marinette County was treated with alum in 1999 at a cost of $1,500.00 per acre. However, alum treatments must be tailored to each lake based on water chemistry, depth, and sediment phosphorus concentration so cost can vary considerably. Alum treatments require a permit from the Wisconsin DNR.

Dredging

Dredging can be use to reduce internal phosphorus loading by physically removing highly enriched sediment. To be effective the underlying sediment must contain fewer nutrients. Additional "benefits" can be achieved if the increase in depth is sufficient to control plant growth by reducing light intensity.

Large-scale dredging is a very expensive management alternative, typically costing $10-$25 per cubic yard of sediment removed. Costs vary greatly depending on sediment type, dredge methods (hydraulic vs. mechanical) and available disposal options. State and federal permits are required for dredging.

Agricultural Nutrient Management

Nutrient management is an agricultural best management practice (BMP) designed to reduce nutrient inputs, and therefore nutrient runoff, to cropped fields while optimizing crop yields. Soil testing is conducted and a cropping plan is developed that best utilizes animal waste, crop inputs (i.e. nitrogen fixation by legumes), and commercial fertilizer to achieve realistic crop yields. Nutrient management planning is a cost-shareable practice under many state and federal programs and is typically required when cost-share funding is received for the construction of manure storage facilities.

In the Lake Noquebay watershed most farms are currently participating, or have participated in nutrient management planning. With current fertilizer and fuel costs it is in the farmers best economic interests to reduce outside nutrient inputs as much as possible.

Soil Conservation
Since phosphorus tightly binds to soil particles, reducing erosion from agricultural areas is key to reducing the nutrient concentrations in runoff. Soil conservation practices include source controls such as managing crop rotations and crop residue, contour cropping, and the planting of cover crops. Other practices such as vegetated waterways and sediment control basins are designed to trap pollutants before they enter perennial waters.

In the Noquebay watershed much of the highly erodable land has already been taken out of production for economic reasons as farms have gone out of business and cropland rental rates have fallen.

Animal Waste Management
Runoff from concentrated farm animals (barnyard runoff) and from winter-spread manure are two of the largest sources of agricultural runoff pollution. Best management practices to reduce animal waste runoff are primarily structural and include clean water diversion, barnyard runoff management, and animal waste storage. Manure storage in particular allows farm operators to more efficiently use manure for crop nutrients and further reduces outside fertilizer inputs on a farm.

The Lake Noquebay Priority Watershed Project was very successful at reducing both barnyard phosphorus runoff (110% of project goals) and winter-spread manure application (247% of goal). The Lake Noquebay Priority Watershed Project reached 23% of its goal for upland soil loss and 119% of its goal for gully erosion. Although no longer available through the priority watershed project, other state and federal sources of funding are still available to address animal waste runoff and funding is actively sought by the Marinette County LWCD when animal waste runoff problems are identified.

Residential Runoff Management
Runoff from high-density suburban development, such as found around Lake Noquebay, can be a significant source of nutrients. Studies show that phosphorus yields from lawns are 8-10 times higher than from forested areas (WDNR, 2003) (Graczyk, 2003). Runoff volume also increases substantially as development increases. Managing residential runoff can be accomplished by controlling nutrient inputs at the source, and by trapping nutrient laden runoff before it reaches the lake. An effective program typically includes both source controls and nutrient trapping.

Impervious Surface Reduction
Studies show that phosphorus export rates are controlled primarily by runoff volume (Panuska, 1995) and volume increases greatly as the amount of impervious surface in the watershed increases. Research shows that converting only 10 – 20% of the land area in a watershed to impervious surfaces will double the runoff volume (Schueler, 1994). Impervious surfaces are those that absorb little if any runoff. These include rooftops, roads, patios, sidewalks, and any other hard surface. Even gravel driveways are considered impervious due to extreme compaction of the underlying soil.

Reducing, or preventing an increase, in the amount of impervious surface around a lake is an effective way to manage nutrient loads. Limiting impervious surface area is best accomplished through zoning but can also be addressed in educational programs. Some structures such as patios and driveways can also be installed using pervious pavers and other structural methods to increase infiltration.

The Wisconsin DNR has recently updated statewide shoreland zoning regulations to limit the amount of impervious surface within 300 feet of a lake to 30% of any lot. New development or expansion that would increase impervious surfaces to more than 15% of a lot would require mitigation activities designed to increase infiltration and reduce the effects of impervious surfaces.

Nutrient Management
Studies clearly show that routine use of fertilizer on riparian lawns results in nutrient enriched runoff. The U.S. Geological Survey studied runoff from lawns under different management regimes and concluded that dissolved phosphorus concentration in regularly fertilized lawns was twice that for unfertilized and non-phosphorus fertilized lawns (Garn, 2002). Dissolved phosphorus is the least desirable form of the nutrient since it is immediately available to algae in its dissolved form. Reducing or eliminating fertilizer use, or switching to phosphorus-free fertilizer can greatly reduce the amount of phosphorus in runoff from riparian areas. Since phosphorus is rarely in short supply in our local soils lawn health does not typically suffer from the change.

Runoff Detention and Infiltration
When source controls are not feasible, the next best solution is to detain and infiltrate nutrient laden runoff before it can reach the lake. Several methods can be use including rain gardens, swales, detention basins, and shoreline buffers

<u>Rain gardens</u> are used primarily to infiltrate runoff from roofs. Typically roof runoff is collected and piped to a depression that is planted with species adapted for periodic flooding and wet soils. Runoff infiltrates and the plants absorb nutrients.

<u>Swales</u> are engineered ditches that are designed to slow runoff, provide for increased infiltration, and transport water to a planned discharge point. Often swales can be made to be inconspicuous. They are often combined with buffers and/or detention basins to increase infiltration and filtering. Where it is left intact, the natural ice-ridge berm that can be found on much of the lakeshore acts as a natural swale as it detains runoff before it reaches the lake.

<u>Detention basins</u> are designed to hold storm runoff for a specific period of time to allow for settling of sediment and other pollutants. Detention basins typically have an outlet structure that slowly releases stored runoff over a 24-48 hour period. Wet detention basins, which are designed to maintain a small permanent pool, are better at removing soluble pollutants than dry basins. Detention basins are most often used in commercial and industrial settings to remove nutrients from large parking lots and other intensive development.

<u>Shoreline buffers</u> are areas of grass or other dense vegetation designed to filter sediment and nutrients from runoff before it enters the lake. Buffer strips need to be at least 25 feet wide to function effectively although superior performance requires buffers at least 100 feet wide (Wagner, 2004). Buffers performance can be improved by shaping them to detain water and allow for increased infiltration.

With some creative design, buffers can be very aesthetically pleasing, often by using wildflowers and ornamental shrubs and incorporating them into a larger landscaping plan. For a more natural look, native species can be used. Native shoreline buffers also provide additional fish and wildlife habitat that is often in short supply on developed lakes.

Manage Septic Systems
All properties near Lake Noquebay are served by on-site septic systems. These are primarily conventional systems with a settling tank and leach bed, a mound system with settling tank, dosing chamber and leach bed, or holding tanks. Some of the older properties may have cesspool type systems with an open bottom tank.

The first step in managing septic systems on the lake would be to conduct an inventory of the existing systems. This requires working closely with the Marinette County Land Information Department that regulates private on-site sanitary systems. A study of shallow groundwater flow patterns would provide valuable information concerning septic system inputs and point out areas where septic system management is needed.

Even without a detailed survey there are basic practices that can be used to reduce the impact of septic systems. The first is routine inspection and pumping of the septic tank to remove accumulated solids. Currently every system installed since 1994 is required by state law to have their septic tank maintained (pumped and inspected) every three years. This mandate has recently been expanded and by October 2013 all septic systems will need to conduct routine maintenance. The Marinette County Land Information Department administers the septic system maintenance and inspection program.

Throughout Wisconsin most counties require septic systems to be inspected and failing systems replaced any time a property is sold. This is an efficient way of phasing out the old systems around many lakes. Unfortunately Marinette County does not require update at date of sale.

Lake and Watershed Management Recommendations to Protect Water Quality

Recommendations to protect water quality can be divided into three general categories. Monitoring and evaluation activities that will provide much needed information on which to make informed decisions; recommendations to reduce nutrient loading from the lakes watershed; and recommendations to reduce nutrient loading from riparian areas.

Recommendation #1 – Conduct a detailed study of nutrient loading to Lake Noquebay and develop a phosphorus budget for the lake.
A detailed phosphorus budget would be a valuable tool to help direct nutrient reduction efforts for maximum benefit. Completing a detailed budget requires monitoring nutrient inputs and flow on all of the lakes tributaries, monitoring nutrient export and flow at the outlet, and tracking in lake water quality and phosphorus release rates from the sediment. A complete budget will also track groundwater quality and flow direction to estimate septic inputs.

The Wisconsin Lake Management Planning Grant program provides cost-share assistance for lake management planning, monitoring projects, and other studies and assessments designed to understand lake ecosystems. Small-scale grants have a $3,000 limit while large-scale grants have a $10,000 limit. Both pay up to 75% of project costs.

Recommendation #2 – Inventory septic systems in the District and promote proper maintenance and replacement of failing systems.

The Marinette County Land Information Department permits septic systems and maintains septic system records. Good records exist for systems installed since 1980. Unfortunately records before that date provide little detailed information. As part of the expanded septic system maintenance and inspection program the Land Information Department will identify properties that have old septic systems and require that they be maintained and a licensed septic pumper or plumber submit records indicating they have been pumped or inspected and the tank is less than 1/3 full of sludge. While this effort will fill in many of the existing gaps in the data, and may lead to the obviously failing systems being replaced, it will not require that existing septic systems be inspected to ensure they are not discharging to the groundwater.

A detailed septic system inventory designed to identify all substandard systems would include a detailed inspection of the system and soils around the drainfield to determine if the system is discharging to the groundwater. Currently the LNRD cannot compel landowners to allow on-site septic system evaluations. Event he County needs to obtain an inspection warrant for entering private property if a landowner refuses an inspection request. Adopting sanitary district powers would allow the District to collect this information.

Recommendation #3 – Support a Marinette County ordinance requiring that all septic systems be inspected when properties are sold.

The LNRD should support efforts in Marinette County to enacting an ordinance requiring that septic systems be pumped and inspected by a certified plumber before a property is sold. Failing systems would have to be replaced, either by the seller or buyer, before the property transfer would be allowed. Since the turnover rate is so high for recreational properties an update-at-sale ordinance would greatly increase the rate at which failing septic systems are replaced.

Recommendation #4 – Use phosphorus-free fertilizer in riparian areas.

Since phosphorus is the nutrient most responsible for excessive weed and algae growth, reducing its concentration in runoff will help maintain good water quality. It has long been recommended that urban and lakefront property owners severely restrict the application of phosphorus to lawns. As of April 1, 2010 Wisconsin will ban the application of fertilizer containing phosphorus to established lawns unless a soil test shows them to be phosphorus deficient. The new law also restricts the marketing of fertilizer containing phosphorus.

The LNRD should publicize the phosphorus ban and educate landowners regarding the effect of phosphorus on the lake and the reasons for the ban.

Recommendation #5 – Support efforts to limit impervious surfaces in riparian areas.

Recent changes in NR115 require the Marinette County Land Information Department to update its shoreland/wetland zoning ordinance by February 2012. The LNRD should support efforts to limit the amount of impervious surface allowed on lakefront properties. The changes enacted in NR115 will slow, or even reverse, the increase in runoff volume and phosphorus reaching the lake from shoreline properties.

Recommendation #6 – Promote buffers, rain gardens, and other runoff infiltration measures.

Promoting the installation of practices to increase the infiltration of runoff will provide multiple benefits to the lake in the form of reduced nutrient loading and improved fish and wildlife habitat.

Currently the Marinette County Land & Water Conservation Division has a limited amount of cost-share assistance for buffer installation. State and federal funding sources are often available as well.

Recommendation #7 – Reduce sources of concentrated animal waste runoff in the Lake Noquebay Watershed.
A majority of active farms in the Noquebay watershed have already taken steps to reduce or eliminate animal waste runoff from barnyards and stored manure. Most received cost-share assistance through the Lake Noquebay Priority Watershed Project. While the priority watershed has expired, Targeted Runoff Management (TRM) funding is still available throughout Marinette County. The TRM grant program is competitive, with funding going to projects based on water quality benefits.

The Marinette County LWCD continues to work with farms throughout the county to identify contaminated runoff issues and find funding sources to address the problems. The department will continue to stress reducing agricultural runoff pollution in the Lake Noquebay watershed.

Recommendation #8 – Eliminate winter spread manure in the Lake Noquebay watershed.
The amount of cropland in the Noquebay watershed receiving winter-spread manure has been reduced by more than 80% since 1995, primarily through the installation of manure storage facilities and adoption of the nutrient management planning by farm operators. Statewide, efforts to eliminate the application of manure to frozen or snow covered ground should be supported. Locally, the County LWCD should work with any new farms to install manure storage facilities and eliminate manure spreading in the winter.

Recommendation #9 – Conduct routine water quality monitoring on Lake Noquebay.
Tracking long-term water quality data is the only way to evaluate the success or failure of nutrient reduction efforts. The LNRD should collect water clarity measurements during the summer months every year and conduct routine water sampling to track nutrient levels in the lake.

Throughout Wisconsin volunteers measure water clarity weekly during the summer months. Water clarity is measured by lowering a special disk (Secchi Disk) into the water and recording the maximum depth at which it can be seen. Since clarity is the most common factor attributing to peoples definition of water "quality" it provides valuable information that the layperson can relate to. Persons interested in participating in this volunteer monitoring effort can receive equipment and training through the Citizens Water Quality Monitoring Network.

While volunteer Secchi disk data provides an important tool for tracking water clarity, it is not a substitute for routing chemical analysis. At a minimum water from the lakes surface and just above the bottom at the deepest part of the lake should be analyzed for total and dissolved phosphorus four times each year; at spring turnover, June, July, and August. Much valuable information can also be gained from a late winter sample and from testing for total nitrogen, nitrates, and ammonia. Typically dissolved oxygen and temperature profiles of the water column are also measured at these times.

While more data is always better, it may not be feasible to conduct monitoring every year. A good compromise would be to conduct monitoring every other year or even every third year. Cost share funding for water quality monitoring can often be obtained from the DNR through the Lake Management Planning Grant Program.

Aquatic Plant Community

Lake Noquebay supports an abundant and diverse aquatic plant community dominated by muskgrass (*Chara sp.*), variable-leaf watermilfoil (*Myriophyllum heterophyllum*) and bushy pondweed (*Najas flexilis*), each found at more than 40% of sample sites. Other abundant plants including flat-stem pondweed (*Potamogeton zosteriformis*), variable-leaf pondweed (Potamogeton graminaeus), Illinois pondweed (*Potamogeton illinoensis*), coontail (*Ceratophyllum demersum*), and large-leaf pondweed (*Potamogeton amplifolius*) were found at more than 18% of sample points. Twenty-seven other species were identified during the 2007 aquatic plant survey for a total of 32 species.

During the summer of 2007 nearly 80% of the lake supported submersed aquatic plant growth. This includes all areas less than 15 feet in depth. Plant growth was most dense in water between 3 and 12 feet deep. Floating leaf plants, such as water lilies, are abundant locally but have a limited distribution in the lake. Emergent vegetation is more widespread, covering nearly 160 acres of the lake.

Exotic Species

No exotic plant species are known to exist in Lake Noquebay. While the exotic Eurasian watermilfoil (*Myriophyllum spicatum*) has been reported growing in Lake Noquebay in the past, its presence in the lake has never been verified and reports have been attributed to misidentification of variable-leaf watermilfoil (VWM), which is abundant in Noquebay and looks similar.

Zebra mussels (*Dreissena polymorpha*), an exotic invasive mussel from Eurasia, were found attached to clam shells and the stems of variable-leaf milfoil throughout the lake. Banded mystery snails (*Viviparus georgianus*) , a species native to the southern U.S. are also found in abundance in shallow water areas where they feed on attached algae and detritus in the sediment.

History of APM Efforts

The LNRD, DNR, and Marinette County Land & Water Conservation Division (LWCD) have been studying and managing aquatic plants on Lake Noquebay for more than 40 years. Early attempts were aimed at reducing aquatic plants and the incidence of swimmers itch. Copper sulfate was used on a limited basis in the 1950's and 1960's but was judged unsuccessful.

In the early 1970's, a three-phase interdisciplinary study was conducted to study the proliferation of variable-leaf watermilfoil and recommend management alternatives. Following this study, lake residents, town and county officials formed a "weed committee" to study the harvesting alternative. This committee was disbanded and the Lake Noquebay Rehabilitation District was formed in 1975. A management plan consisting of intensive harvesting, winter drawdown to dislodge plants in shallow water and spring harvesting of dislodged plant material was adopted to restore beneficial uses to the lake.

In 1978 an EPA clean lakes grant was received to help implement the harvesting plan. The five-year grant allowed for the purchase of two aquatic plant harvesters, one with a ten-foot cutting path and a smaller one with a five-foot cut. A second 10-foot harvester was purchased two years later by the LNRD. Since the mid 80's the LNRD has been operating two aquatic plant harvesters with a third dedicated to removing plant fragments that wash up on the shoreline.

Aquatic Plant Survey

Thanks to the efforts of the LNRD and state resource agencies several aquatic plant surveys have been conducted on Lake Noquebay. The most recent survey conducted in 2007 was by far the most comprehensive and provides a wealth of data from which future aquatic plant management decisions can be made.

Survey Methodology

Marinette County LWCD staff conducted the aquatic plant survey during the first week of August using the most recent Wisconsin DNR point/intercept sampling protocol. A point spacing interval of approximately 112 meters (137 feet) was used, yielding 822 individual sample locations. 773 points (94%) were actually surveyed, the balance were on land or located within a large emergent marsh in the northwest corner of the lake that was not navigable.

Coordinates for each sample points were loaded onto a Garmin Vista handheld GPS unit for navigation in the field. At each sample location a special double-headed garden rake on an extendable aluminum pole was used to determine the water depth and sediment type and to sample aquatic plants. Plants were collected for identification by dragging the rake across the bottom for approximately 0.75 meters and bringing it to the surface. Each species was noted and the overall abundance was estimated by assigning a score of 1 (sparse) to 4 (overflowing) based on the amount of vegetation on the rake.

The field survey was completed using a team of two individuals, a "driver/data recorder" and the "sampler". The driver navigated to each sample point using the GPS receiver. When the sample point was reached the "sampler" would probe for depth and sediment type then pull the plant sample. Typically the sampler could sort and call out the vegetation data before the next sample point was reached. Sample points that were clearly in excess of the maximum depth of colonization (15 ft) were not sampled but depth was recorded based on depth finder readings.

Data was entered and analysis was completed in Microsoft Excel and is reported in full in Appendix D. All sample location and associated data were mapped in the Marinette County Geographic Information Systems (GIS) database. Plant distribution maps for each species can also be found in Appendix D.

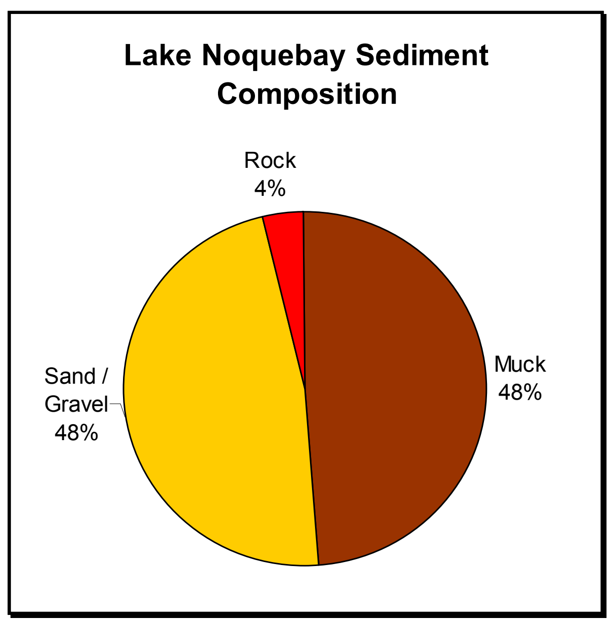


Figure 8. Lake Noquebay sediment composition.

Sediment Type

As part of the aquatic plant survey sediment type was determined for each sample location shallower than the maximum depth of plant growth. Sediment type was determined by "feel" using the metal rake head attached to an aluminum pole. Data was recorded as muck, sand & gravel, or rock. Soft unconsolidated sediment was recorded as muck. Rock included everything from cobble size rock (2-3 inches) to boulders. Sand and gravel are often mixed and difficult to distinguish by feel so they were grouped together.

Analysis of the data shows a nearly equal division between sand & gravel (49%) and muck (47%) with lesser amounts of rock (4%). A map of Lake Noquebay sediments (figure 8) shows that sand is the dominant sediment type in the eastern half of the lake and in water less than 5 feet deep while muck is more prevalent in deep water and in the western half of the lake.
Sediment type is important because aquatic plants have differing sediment preferences. Muck generally supports the greatest diversity of aquatic plants and often more dense plant growth as well.

Aquatic Plant Community Structure

Lake Noquebay supports an abundant and diverse aquatic plant population with 32 native species identified during the survey. While variable-leaf milfoil is one of the dominant plants, under the current management strategy it cannot be said to dominate the population.

A cursory review of the data shows that three plants were found at nearly half of the sample locations (Figure 9). Five plants were found at nearly 20% of sample locations and three additional plants were found at 10% or more sample locations. Together these plants account for more than 85% of the plant population.

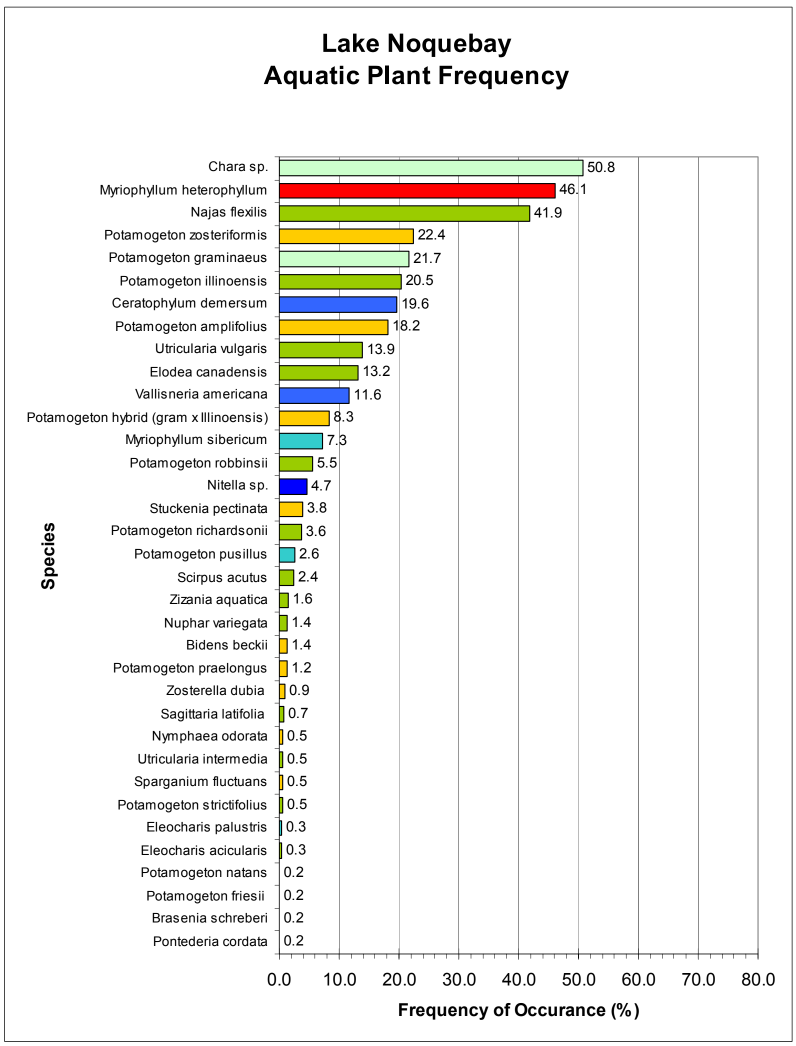


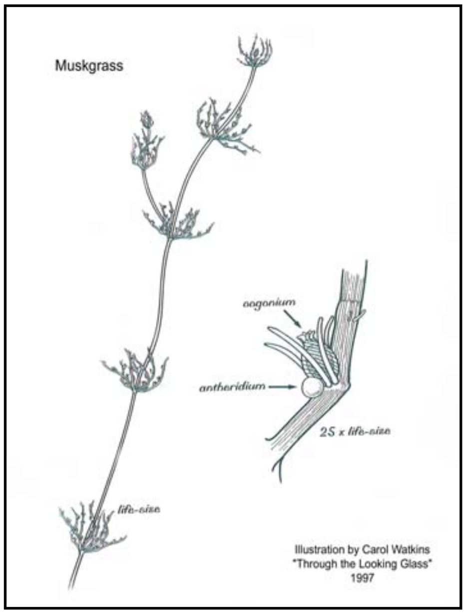
Figure 9. Dominant plants in Lake Noquebay.

Common Aquatic Plants

The following descriptions are taken from *Through the Looking Glass, a Field Guide to Aquatic Plants* (Boreman 1997), a publication of the Wisconsin Lakes Partnership. Distribution maps for each species can be found in Appendix D.

Muskgrass
Muskgrass (*Chara sp.*) is the most widely distributed aquatic plant in Lake Noquebay. It was found growing at 51% of vegetated sites.

While outwardly appearing like many other aquatic plants, muskgrass is actually a type of colonial algae. Each "stem" and "leaf segment" is actually a separate algae cell. Muskgrass has branching slender "stems" with whorls of "leaves" at each joint. The main branches have ridges and the entire plant is often encrusted with calcium



carbonate giving the plant a gritty or crusty feel. Muskgrass can be easily identified by its smell. When crushed the plant smells like skunk!

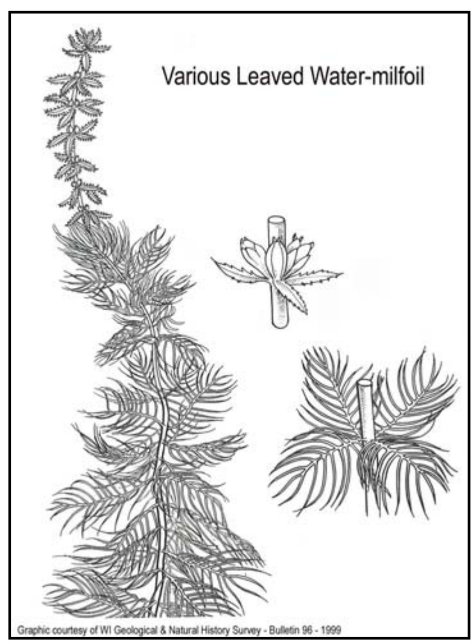
Muskgrass is found in hard water lakes and prefers firm sediment. In Lake Noquebay muskgrass shows a strong preference for sand and rock (91% of sites) over muck (9% of sites). Muskgrass also prefers shallow water. In Lake Noquebay it is found most often in water less than five feet deep and most abundant in 2 to 4 feet of water. Muskgrass tends to hug the bottom and rarely grows more than two feet tall. Due to its short stature muskgrass is seldom viewed as a nuisance species.

Muskgrass is a favorite food of waterfowl and provides excellent fish habitat. In very shallow sandy areas used by newly hatched fry (juvenile fish), muskgrass is often the dominant plant.

Variable-leaf watermilfoil (VWM)

Variable-leaf watermilfoil (*Myriophyllum heterophyllum*) is the species that causes the most concern in the lake and is the primary target of the harvesters. It was found at 46% of sample sites and would surely be the most abundant plant in Lake Noquebay by mass.

Like most milfoils this species VWM has soft feather like leaves arranged in whorls of four along a long thin stem. Each leaf is divided into 7-10 pairs of thread-like leaflets. The whorls in variable-leaf milfoil are very closely spaced (1/8"-1/4") along the stem giving the plant the appearance of a thick rope. Various-leaf milfoil gets it name from the toothed bracts "leaves" that form on the plants seed head when it emerges from the water. This typically only happens in calm shallow water where plant growth is very dense.



VWM overwinters by hardy rootstocks, rhizomes, and older stems that can survive the winter. Like its exotic cousin Eurasian watermilfoil (*Myriophyllum spicatum*) it spreads primarily by fragmentation, a process where even small fragments of the plant separated by boats or wave action drift to a new place and take root. The rapid growth, ease of spread, and its canopy forming habit, allows VWM to out compete many of the slower growing native plants.

In Lake Noquebay VWM shows a distinct preference for muck (57%) over sand (11%). While it was found growing as deep as 14 feet, variable-leaf milfoil is most common in water between 5 and 9 feet deep.

While native to the United States, it is thought that variable-leaf milfoil may not be native to Lake Noquebay. This plant is more common in the Tennessee Valley area and other southern states. The latest research also points out that there are at least three distinct genotypes of VWM in the US including a very aggressive form common in New Hampshire that has been causing problems in southern lakes where it is out-competing the native strain (Netherland, 2009). It would be interesting to see which strain in present in Lake Noquebay. While it can be a nuisance, the milfoil provides important deep-water habitat in the lake, especially early in the season since it begins growing earlier than many of the pondweeds.

Bushy Pondweed (Slender Naiad)

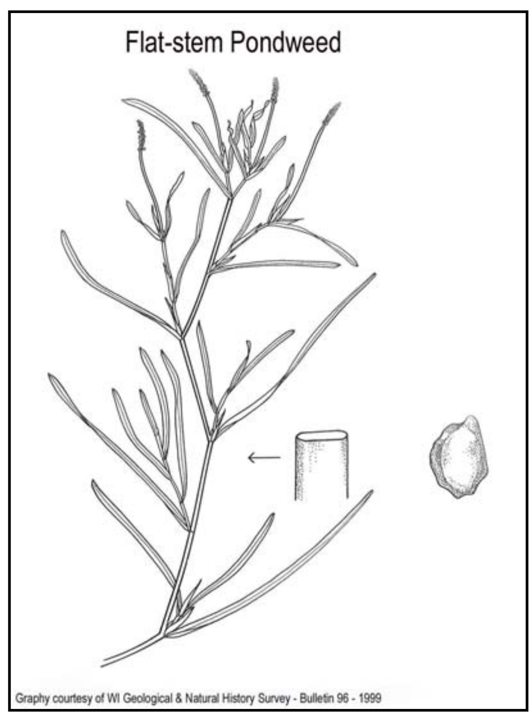
Bushy pondweed (*Najas flexilis*) was found at 42% of vegetated sites in Lake Noquebay. This plant varies greatly in growth form, compact and bushy in shallow water, long and wiry with widely scattered leaves in deep water. The leaves are very narrow (1/16th inch wide) with a broad base where they attach to the stem. Plants generally grow no more than 2 feet tall and prefer a firm substrate.

Bushy pondweed is rather unique in that it's one of the few annual aquatic plants. It dies each winter and depends on seed to grow new plants each year. The plants and the seeds, which are produced in great number each year, are important food for waterfowl.

In Lake Noquebay bushy pondweed is a true generalist. It shows a slight preference for muck sediment (48%) but grows nearly as well in sand (33%). It is also nearly as abundant in 14 feet of water as it is in 3 feet, showing only a slight preference for water between 7 and 10 feet deep.

Due to its short stature bushy pondweed is seldom reported as a nuisance plant and the harvester rarely picks it up. Aquatic plant trend data indicates that the harvesting program may be benefiting the bushy pondweed as will be discussed later in the report.

Bushy pondweed is one of the most important aquatic plants for waterfowl as both the vegetation and seeds are eaten by a wide variety of ducks. It also provides shelter for fish, particularly in very shallow sandy areas where bushy pondweed is often the only cover available.



Flat-stem Pondweed

Flat-stem pondweed (*Potamogeton zosteriformis*) is identified, as the name implies, by its strongly flattened stems. The leaves are long (4"-8"), narrow (1/8"-1/4") and very stiff. The plant produces no floating leaves.

Flat-stem pondweed is a perennial that rarely reproduces by seed. Typically the entire plant dies back each year and re-grows from the root system. Like many of the pondweeds, flat-stem pondweed spreads by producing winter buds, specialized leaves packed in a tight cluster that form at the end of the season on some side branches. When the plant dies back the winter buds detach and fall to the sediment where they take root.

In Lake Noquebay flat-stem pondweed was found at nearly a quarter of the sample locations (22%). It shows a strong affinity for muck sediment (81%) and water between 8 and 12 feet deep. It was the most abundant plant in water over 9 feet deep.

Because of its affinity for deep water, flat-stem pondweed provides important foraging habitat for panfish and edge cover for gamefish. It also serves as a food source for waterfowl that graze on its leaves and eat the seeds.

Variable pondweed

Variable pondweed (*Potamogeton gramineus*) was also found at found at 22% of vegetated sites on the lake. As the name implies it varies greatly in growth form even within the same lake depending on depth and sediment type where it is found. Typically the plant has lance shaped leaves 1-3 inches long and 1/16" – 1/8" wide. The plant branches repeatedly and the side braches are very bushy. In Lake Noquebay variable-leaf pondweed growing in deep water tends toward the upper end of the size range and the entire plant may be several feet tall. In shallow sandy areas the plant is typically short and very bushy with small narrow leaves. Identification is complicated by the fact that variable-leaf pondweed often crosses with the larger Illinois pondweed which is also common in Lake Noquebay.

Like all of the true pondweeds (Potamogeton sp.), variable-leaf is a perennial that dies back in the fall. It spreads by seeds that are produced on stalks held above the water surface. When flowering it forms small floating leaves that are wider and more ellipse shaped than the submerged leaves.

In Lake Noquebay variable-leaf pondweed shows a distinct preference for sand (50%) and rock (35%) substrate. It is most common in water between 2 and 5 feet deep.

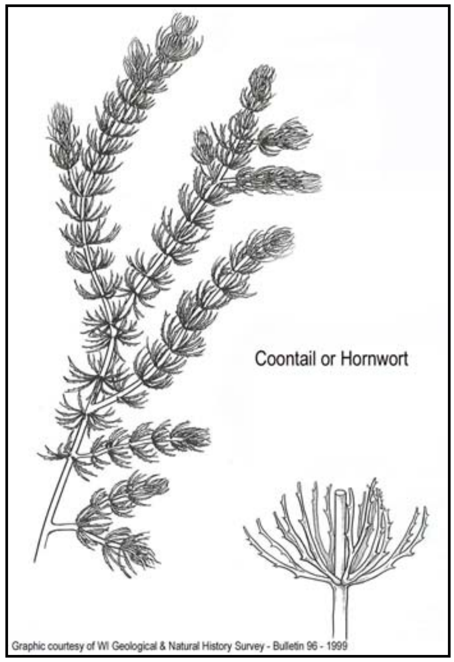
Illinois pondweed

Illinois pondweed (*Potamogeton illinoensis*), found at more than 20% of sample sites, looks very much like a larger version of variable-leaf pondweed, with which it often crosses. In Noquebay its lance shaped leaves are typically ½" to 1" wide and 3 to 8 inches long with pointed tips. When flowering it can produce large ellipse-shaped floating leaves. Fruit are produced on a thick stalk held above the waters surface. Illinois pondweed is a perennial with winter-hardy rhizomes but it can occasionally overwinter green.

Illinois pondweed is much larger in stature than variable-leaf pondweed and is typically found growing in deeper water (6-8 feet). Illinois pondweed shows a strong preference for muck sediment (68%). Fishermen often refer to Illinois pondweed, along with its cousin large-leaf pondweed, as "cabbage". It provides important deep-water fish habitat and is often found growing on the edge of drop-offs.

Coontail

Coontail (*Ceratophyllum demersum*) may be the most common aquatic plant in Wisconsin. In Noquebay it was found at 20% of vegetated sites. Like milfoil, coontail has long trailing stems with leaves arranged in whorls around the stem. Unlike milfoil the leaves of coontail are very stiff with teeth along the margins. The leaf whorls tend to be dense near the ends of the stem, giving them the appearance of a bushy raccoon tail. The plant often forms dense mats on the bottom and can be a nuisance in shallow water areas.



Coontail has no true roots but anchors to the sediment by modified stems wherever it touches the bottom. It rarely produces seed and spreads primarily by fragmentation. Due to its poor "rooting" ability, coontail shows a strong preference for muck (86%). It also shows an affinity for deep water, being found most often at a depth of 8-12 feet.

Coontail is important for fish habitat since it is slow to decompose and often stays alive under the ice. This habit makes it excellent winter habitat, attracting aquatic insects and the fish that feed on them.

Large-leaf pondweed

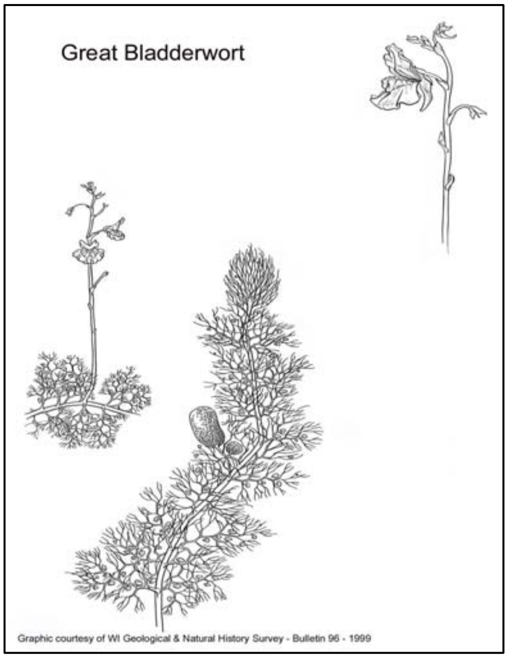
Large-leaf pondweed (*Potamogeton amplifolius)* is the largest of the pondweeds in Lake Noquebay where it was found growing at 18% of the sample sites. It can be identified by its wide (1-2 in) arching leaves and by its thick seed stalk that is held above the surface.

In Lake Noquebay large-leaf pondweed can be found throughout the lake in two to eight feet of water where it provides excellent fish habitat. No sediment preference was found although it is known to prefer firm sediment.

Like many of the pondweeds, large-leaf pondweed has the same habitat preference as VWM and is often displaced by the exotic species. Several other large pondweeds were also found in the lake at lower frequency.

Common bladderwort

Common bladderwort (*Utricularia vulgaris*) is the largest and most visible bladderwort. In Noquebay it was found at 14% of the sites.

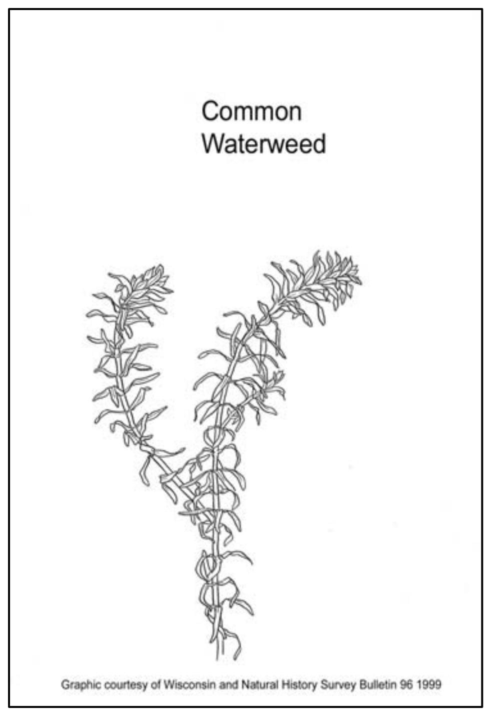


Common bladderwort has long floating stems that are densely covered with fine leaf-like branches, each forked 3-7 times. The branches contain many bladders that are bright green when young and turn purple to black as they age. If you pull a plant from the water you can often hear it snapping like Rice Krispies as the bladders snap open. The bladders are small pouches that trap protozoans and small insect larvae. When set they are sealed shut and spring open when prey brushes against the trigger hairs near the bladder opening. When triggered they suck the prey inside where it is slowly digested.

In late summer common bladderwort forms dense winter buds on the ends of the stem that fall off and lie dormant on the sediment until the following spring.

Common bladderwort is free and prefers sheltered areas and deep water with dense vegetation where it is protected from wave action. For this reason it is most common in areas of muck sediment. It shows no strong depth preference.

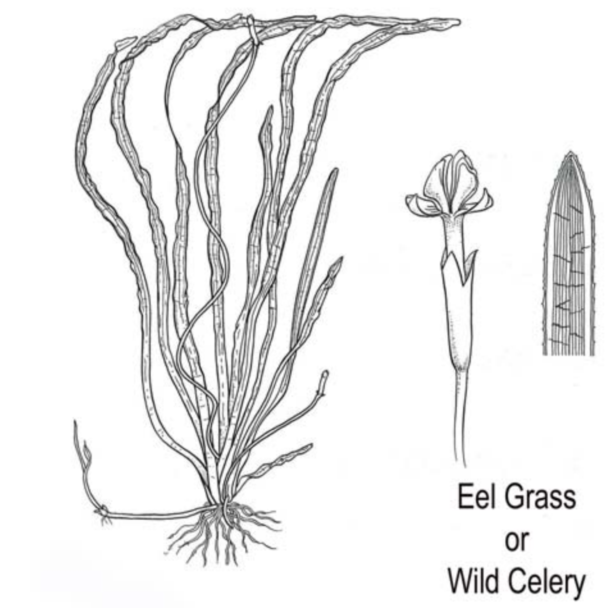
Common waterweed
Common waterweed (*Elodea Canadensis*) has small lance shaped leaves (1/16th to 1/8th inch wide, ¼ to ¾ inches long) attached directly to the stem in whorls of three. The plant branches profusely and often forms tangled mats.



Common waterweed bears male and female flowers on separate plants but seldom produces seed, spreading primarily by fragmentation. In Noquebay it's found almost exclusively in areas of muck sediment (91%). It can be found at almost any depth but prefers water 8 to 10 feet deep.

Common waterweed is important in the lake ecosystem because it overwinters green and continues to produce oxygen under the ice in very low light conditions. Waterfowl eat the plant and it provides good winter habitat for fish and aquatic insects.

Wild Celery
Wild celery (*Vallisneria americana*) is identified by its long ribbon shaped leaves ¼ to ½ inch wide and up to 7 feet long. The leaves have a prominent central stripe and a cellophane-like consistency. The leaves emerge from a central rosette on the bottom. Often the leaf tips grow to the surface where they trail out just under the surface. Late in the summer water celery produces tiny male flowers under water that break free and float up to the surface. The white female flowers are found at the end of a long coiled stalk that extends the flower up to the surface where it is pollinated. After pollination it is withdrawn below the surface and a long narrow seed capsule develops. Water celery prefers a firm substrate and is quite tolerant of turbid water.



Graphic courtesy of WI Geological & Natural History Survey - Bulletin 96 - 1999

Water celery is a perennial plant that spreads primarily by vegetative means, not by seed. Water celery produces abundant tubers just under the sediment surface each summer. These tubers lie dormant during the winter and resume growth in the spring. While waterfowl eat all parts of the plant, these starchy tubers are especially prized. Canvasback ducks are almost completely dependent on the tubers of wild celery during their migration flights. Wild celery also provides important fish habitat.

In Noquebay wild celery was found at 12% of sample sites where it shows a preference for muck bottom (60%). An analysis of its depth preference showed two spikes, one at 5-7 feet and a second at 10-12 feet.

Infrequent Aquatic Plants

The following aquatic plants were found at fewer than 10% of the survey points on Lake Noquebay. This does not necessarily mean they are rare. The survey methodology tends to under sample some plants due to their location or their growth form, especially floating leaf plants and emergent vegetation. Descriptions are taken from *Through the Looking Glass, a Field Guide to Aquatic Plants* (Boreman 1997).

Hybrid (variable-leaf x Illinois) pondweed
Two of the most common pondweeds in lake Noquebay, Illinois pondweed and variable-leaf pondweed, are known to cross freely. The hybrid pondweed (*Potamogeton graminaeus x illinoensis*) is found throughout the lake and complicates identification of the two parent species.

Plants designated as hybrid pondweeds during the survey shared characteristics of both parents. They were typically larger in stature with leaves that were ¼ -½ inches wide and 3-6 inches long although leaves on the same plant varied greatly. Plants were often found superficially resembled Illinois pondweed but had side branches that were strongly branched and had smaller leaves typical of variable pondweed.
In Noquebay the hybrid pondweed was found at 8% of sample points. It was found primarily in water between 5 and 7 feet deep, midway between its parent plants. Like Illinois pondweed it shows a strong preference for muck sediment (60%).

Northern watermilfoil
Northern watermilfoil (*Myriophyllum sibericum*) is probably the most common native milfoil species in Wisconsin. Like the more abundant variable-leaf milfoil, it has feather shaped leaves arranged in whorls of 4 around a central stem. However, leaf spacing along the stem is much greater (1/4 inch or more) and the leaves are stiff and generally hold their shape when out of the water.

Northern watermilfoil is a perennial that overwinters by hardy rootstalks and winter buds. Winter buds are cylindrical growths of small tightly packed leaves that form on the end of some side branches. The buds fall to the sediment when the plant dies back in the fall then sprout to form new plants in the spring.

Northern watermilfoil has a strong preference for muck sediment (98%) and has a fairly broad range of depths at which it can be found (3-8 feet). Northern watermilfoil was found at 7% of sample points, primarily in the northwest corner of the lake near lower middle inlet and in other areas where harvesting is limited. Since it shares similar habitat preferences with variable-leaf milfoil it is likely suppressed by its more aggressive cousin.

Other "Large" pondweeds
Several common large pondweeds were found in Lake Noquebay at low frequency including white-stem pondweed (*P. praelongus*) and clasping-leaf pondweed (*P. richardsonii*). Together with large-leaf and Illinois pondweed fishermen know them as "cabbage" or "musky weed". Also found in the lake were fern pondweed (*P. robbinsii*) and floating-leaf pondweed (*P. natans*). The latter is often viewed as a floating leaf plant since it had no obvious underwater leaves.

Most of the large pondweeds prefer muck sediment and deep water (>5 feet). They are typically the largest submersed plants in a lake and provide excellent fish habitat.

Small pondweeds
Three small narrow-leaved pondweeds were also found in the lake. The most common was small pondweed (*Potamogeton pusillus*) followed by stiff pondweed (*P. strictifolius*) and Fries' pondweed (*P. fresii*). All have fine leaves and prefer moderate depths and muck sediment. The shape of the winter buds, glands, and leaf sheaths differentiate these species.

Sago pondweed (*Stuckenia pectinata*) was also found. Once in the potamogeton family it has been re-classified. Sago is one of the most valuable waterfowl plants in the lake. It grows in shallow water and produces abundant seeds and starchy tubers that most puddle ducks feed on.

Other submersed plants
Several other submersed aquatic plants were also identified in Lake Noquebay. Water marigold (*Bidens beckii*) is often mistaken for a milfoil but can be distinguished by its branching instead of feather-like leaves. Flat-leaf bladderwort (*Utricularia intermedia*) is another "predacious" aquatic plant in the lake.

Water stargrass (*Zosterella dubia*) and floating-leaf bur-reed (*Sparganium fluctuans*) have long grass-like leaves and superficially look very similar. Hairgrass (*Eleocharis acicularis*) is an "emergent" plant that rarely emerges from the water and has very fine hair-like stems when submerged. Also found in the lake is stonewort (*Nitella sp.*), a translucent green algae that looks like a higher plant. Like muskgrass, each "stem segment", "branch", and "leaf" is actually a separate algal cell.

Floating-Leaf Plants

Floating-leaf plants include those with underwater stems and leaves that float on the waters surface. While many pondweeds also produce floating leaves when they flower, their primary leaves are under water. Floating leaf plants found in Lake Noquebay include White pond lily (*Nymphaea odorata*), spatterdock lily (*Nuphar variegata*), and watershield (*Brasenia schreberi*).

None of the floating-leaf plants were found in any significant number during the aquatic plant survey. However, it should be noted that the survey methods do a poor job of sampling the floating leaf community. The point grids tend to under-sample very shallow areas where they grow best and due to their growth form and tough stems the sampling gear often fails to collect the plants. To better describe the community, areas containing floating leaf plants and emergent plants were mapped and described. Figure 10 shows the results of the mapping effort.

The largest concentration of lilies is can be found in the northwest corner where Lower Middle Inlet enters the lake. Here more than 70 acres of dense water lilies can be found mixed with wild rice and other emergent vegetation. The plant density was so great in the area it was impossible to get a boat very far into the plant bed. Smaller areas near the mouth of Middle Inlet and Finnegan's Bay also supported similarly dense water lilies. Elsewhere in the lake floating-leaf vegetation was limited mixed with rushes or found in a narrow band near the shore where it was protected from wave action by dense stands of bulrush.

All of the water lilies are found in relatively shallow water in areas with loose organic sediment. All have large fleshy rhizomes that anchor the plants and store nutrients that allow new plant growth to reach the surface in the spring. In areas with very flocculent muck these rhizomes often break loose and float to the surface where they decay and become rather unsightly.

Emergent Vegetation

Plants such as cattails, bulrushes and others that reach above the surface of the lake are known as emergent vegetation. Many of these plants grow in the lake or in saturated soil on the shoreline. Most are adapted to fluctuating water levels and are unharmed, or actually stimulated, by low water periods. Due to their location on the shoreline emergent plants are greatly under-sampled in grid surveys. For this reason, emergent vegetation on Lake Noquebay was mapped and described (Figure 10).

The most abundant emergent plant in Lake Noquebay is hardstem bulrush (*Scirpus acutus*), which can be identified by its long green leafless stems. Hardstem bulrush is typically found in areas with a hard sand bottom. It forms large stands in shallow water on the north and east sides of the lake. Bulrush stands provide vital habitat functions in the lake. Early in the year northern pike and yellow perch deposit their eggs on the submerged dead stems of last years growth. Later bluegill and bass make their beds in the cover of the bulrush stands. As fish of all species hatch they spend their early weeks and months feeding in the warm shallow water in these same bulrush stands.

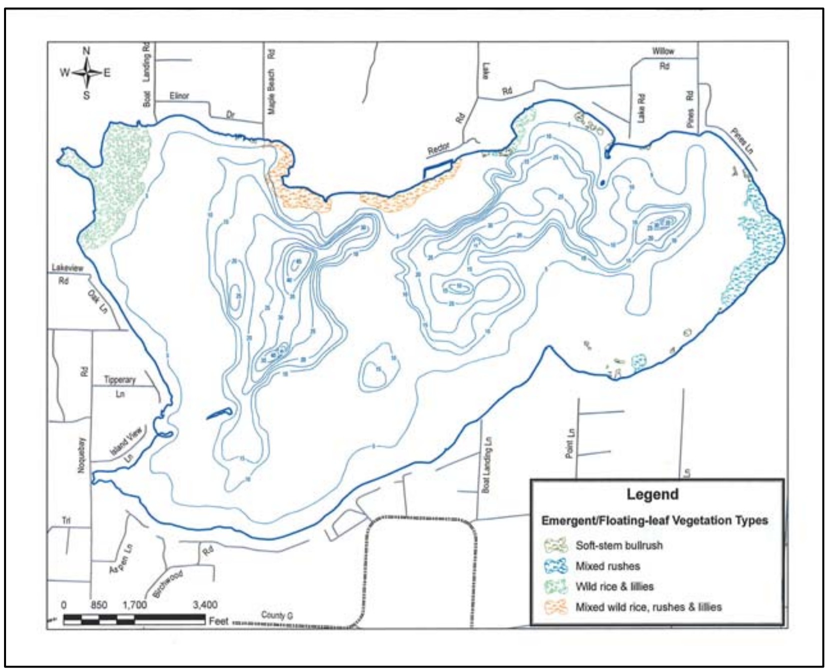


Figure 10. Emergent and floating-leaf vegetation map.

Wild rice (Zizania aquatica) is also found throughout the lake, primarily along the north shore. Wild rice is an annual plant that re-seeds itself every year. Early in the season wild rice has only submerged leaves that float at the surface. As it matures a stem emerges and the seed head develops. Unlike bulrush, wild rice prefers soft organic sediment. State law identifies wild rice as a high value aquatic plant. The plant and its seeds are eaten by a wide variety of waterfowl and muskrats graze the stems. Like all emergent aquatics it provides valuable fish habitat as well.

Other emergent plants identified in the survey include creeping spikerush (*Eleocharis palustris*), common arrowhead (*Sagittaria lattifolia*) and pickerelweed (*Pontederia cordata*). A more intensive survey of shoreline vegetation would certainly show even more species including many types of sedge, rushes and other wetland vegetation.

Floristic Quality Index

One measure of the "health" of a lakes' plant community is the Floristic Quality Index (FQI), which is based on the number of native species and their relative sensitivity to environmental stressors. Each species of plant found in Wisconsin has been assigned a "coefficient of conservatism" which represents how typical the plant is in pristine conditions. The FQI is based solely on the presence of a plant, not its abundance or dominance. Statewide, the average FQI for lakes is 22.2. The FQI for Lake Noquebay was 35.9, indicating a high quality aquatic plant population with good diversity.

Aquatic Plant Distribution

Each species of aquatic plant has habitat preferences that determine where it grows or potentially can grow. These include such factors as depth, light exposure and sediment type. A discussion of these factors and their effect on the plant community of Lake Noquebay follows.

Depth

The area of a lake where aquatic plants can grow is called the littoral zone and is determined by water clarity. Field investigation reveals that the maximum depth of plant colonization in Noquebay is approximately 15 feet. Although beyond the 12-foot depth growth was limited in both variety and density. More than half of the sample points between 13 and 15 feet deep contained no vegetation at all. Approximately 1,925 acres, or 80% of the lake is shallower than 15 feet deep and therefore capable of supporting aquatic vegetation.

The extent of the littoral zone is determined by light penetration (water clarity), which can be effected by suspended sediment, algae, and color. In Lake Noquebay color is primarily responsible for limiting light penetration. The water in Lake Noquebay typically has a light brown color caused by tannins, which are naturally occurring dissolved organic compounds that come from decomposing plants. These compounds are flushed into the lake during spring runoff and large rain events so the amount of staining can very from year-to-year with changing runoff conditions.

Within the littoral zone each species has a depth preference and a maximum depth at which it can grow. In some cases the maximum depth is limited by growth form such as water lilies that have floating leaves attached at the end of long underwater stalks, or emergent plants that must stand above the surface. Submersed plants are limited by the amount of available light, which decreases rapidly as depth increases. Most aquatic plants are perennials that die back to the sediment surface each year. Others sprout anew from specialized plant fragments (winter buds) lying on the lake bottom. These

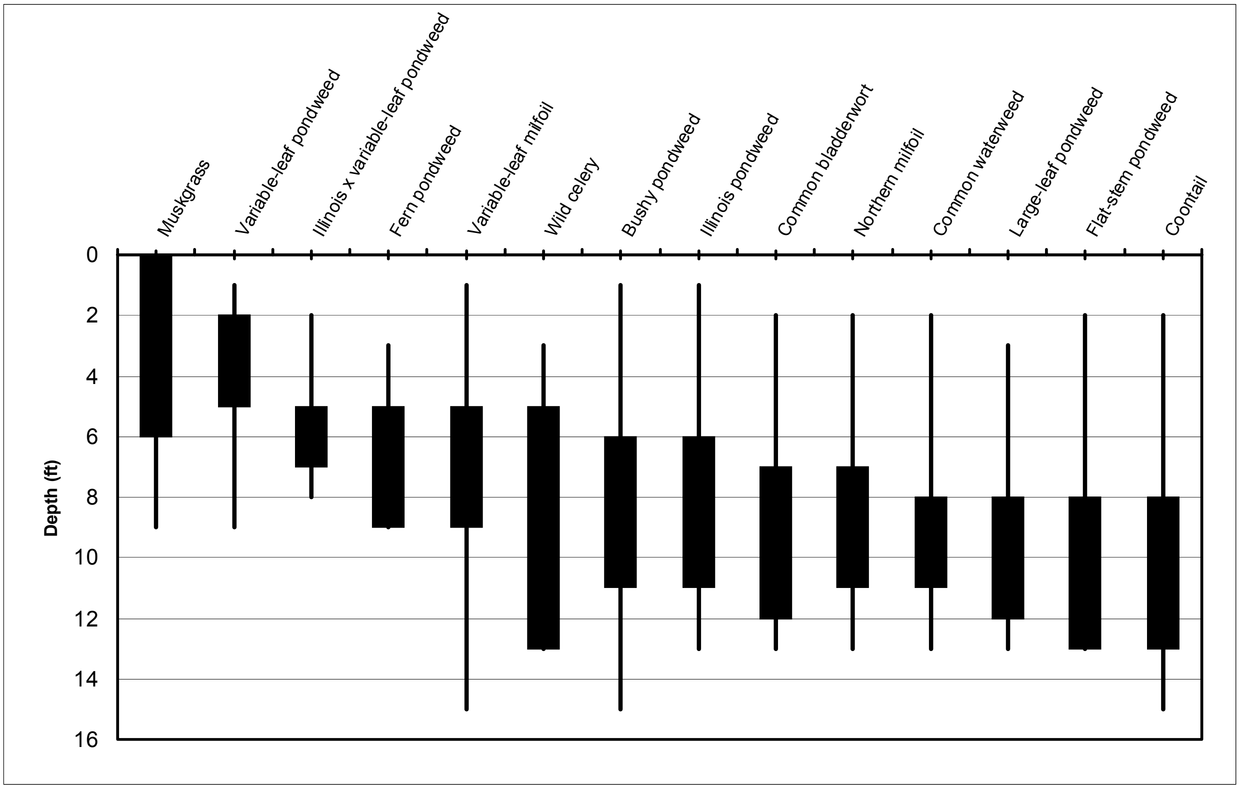


Figure 11. Depth preference of dominant aquatic plants. Solid bar indicates common occurrence while line indicates upper and lower limits of growth.

plants use energy stored in the roots or winter buds to extend upward towards the light each year. They must grow high enough and fast enough to reach the sunlight then grow and export nutrients to the roots to start next year's growth. Different species vary in their ability to grow in low light conditions and fewer species are typically found at greater depth.

Of the dominant species found in Lake Noquebay, muskgrass and variable-leaf pondweed showed the strongest preference for shallow water with most of the plants found in 5 feet of water or less (figure 11). Plants showing the strongest preference for deep water (greater than 10 feet) included large-leaf pondweed, flat-stem pondweed, and coontail. The intermediate depths (5-10 feet) supported the greatest variety of plants and consistently dense plant growth. Variable-leaf milfoil, bushy pondweed, and coontail showed the greatest variability in depth preference.

Sediment

Sediment type also plays a major role in aquatic plant distribution and abundance. Sediment preference can be related to physical properties of the sediment (coarseness, grain size, compaction) or in the chemical properties of the sediment such as pH, or nutrient availability.

Most rooted aquatic plants get their nutrients from the sediment, not the overlying surface water. Because of this, even lakes with low to moderate nutrient levels in the water column can support abundant aquatic plants if sediment nutrient levels and water clarity is sufficient. Sediment that erodes from upland sources is typically high in nutrients. Impounded water such as Noquebay typically has nutrient rich sediment in shallow areas that were historically upland or wetland areas.

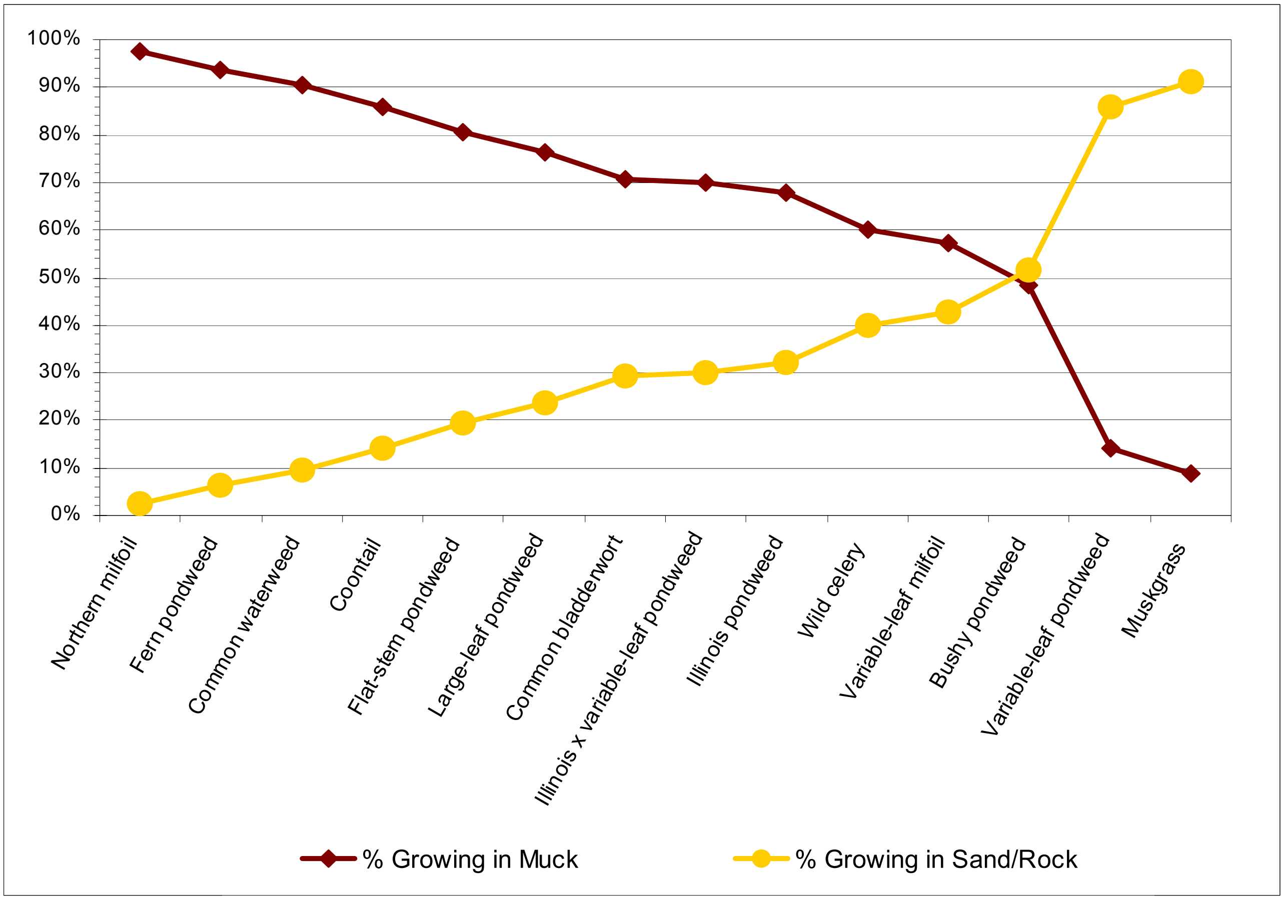


Figure 12. Sediment preference of dominant aquatic plants.

Nutrient availability is closely tied to sediment coarseness. What most people refer to as muck is typically silt with a high percentage of organic particles from decomposing plant material. Organic sediment is typically high in nutrients. Sand, by itself can be very nutrient poor, however there is typically sufficient fine silt and organic matter mixed in to provide good growing medium for plants. Rock by itself will not support plant growth but it is often found mixed with sediment that will. Of the dominant species only musk grass and variable-leaf pondweed showed a strong preference for sandy sediment (figure 12). Many more species show a strong preference for muck including northern milfoil, most of the large pondweeds, bladderworts and coontail. Bushy pondweed was the only common plant that showed no real sediment preference. Wild celery and variable-leaf milfoil had only a weak preference for muck.

Aquatic Plant Abundance

In addition to describing patterns of aquatic plant distribution in Lake Noquebay, the survey was designed to determine total plant abundance. At each sample point a rake "fullness" measure of 1 (sparse) to 4 (abundant) was used to estimate aquatic plant abundance at that site. Overall the data shows abundant plant growth throughout the lake with an average rake fullness of 2.8 at sties shallower than the maximum rooting depth (15 ft). However, abundance did vary considerably by depth and sediment type.

As shown in figure 13, aquatic plants were very abundant in 5-11 feet of water with a rake fullness rating of nearly 4. In 3-4 feet of water the abundance drops to around 3. In water less than 3 feet deep overall plant abundance is moderate or low.

In shallow water most of the difference in abundance can be attributed to sediment type. Most of the points with a sand/gravel or rock substrate were found in shallow water. At these sites abundance was typically low and the dominant plant species are typically small in stature. In deep water muck is the dominant substrate and overall plant abundance is limited by light intensity. The data shows a sharp decline in plant abundance beyond the 12- foot depth. At these depths plants were typically sparse.

Although the abundance of individual species was not estimated, overall abundance is affected by the dominant species at the site. Certain species such as coontail, bushy pondweed, and muskgrass tend to form dense mats and are weakly rooted in areas with a mucky bottom. The sampling gear easily collects plants with this sprawling growth form. Others plants, such as most of the pondweeds have a more upright growth form and are not as easily sampled.

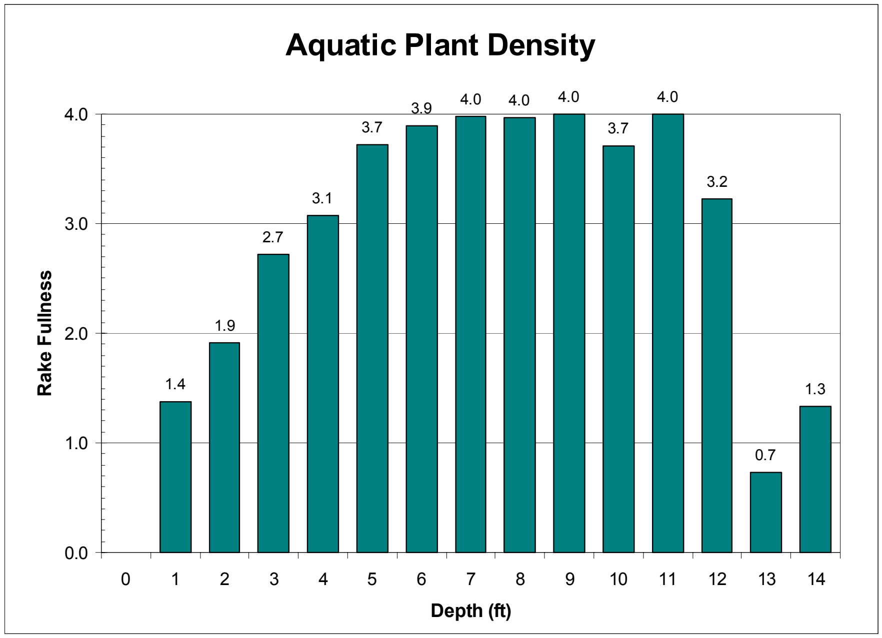


Figure 13. Aquatic plant density as measured by rake fullness.

Changes in the Aquatic Plant Community

Changes in the aquatic plant community of Lake Noquebay have been fairly well documented. Early aquatic plant surveys (1931, 1942, and 1968) provide species lists for the lake with limited information concerning abundance and distribution. Later surveys conducted in 1982, 1992 and 2000 used a modified point intercept method where each sample point was divided into four quadrants in which species presence/absence data was collected. This data was tabulated assuming each quadrant was an individual sample point.

In all four aquatic plant surveys (1982, 1992, 2000, 2007) variable leaf milfoil was found at approximately half of the sample points. Similarly, Illinois pondweed was found at roughly one quarter of the surveyed points. For most other species there are significant differences among the surveys. Many of which can be attributed to variations in sample size.

The surveys conducted in 1982 and 1992 used the same 27 sample locations with four individual survey points at each location for a total of 108 individual data points. Clearly the number and distribution of sample points in these earlier surveys was insufficient to describe the aquatic plant community in any detail. Seventeen species were found in each of the surveys with 15 identified in

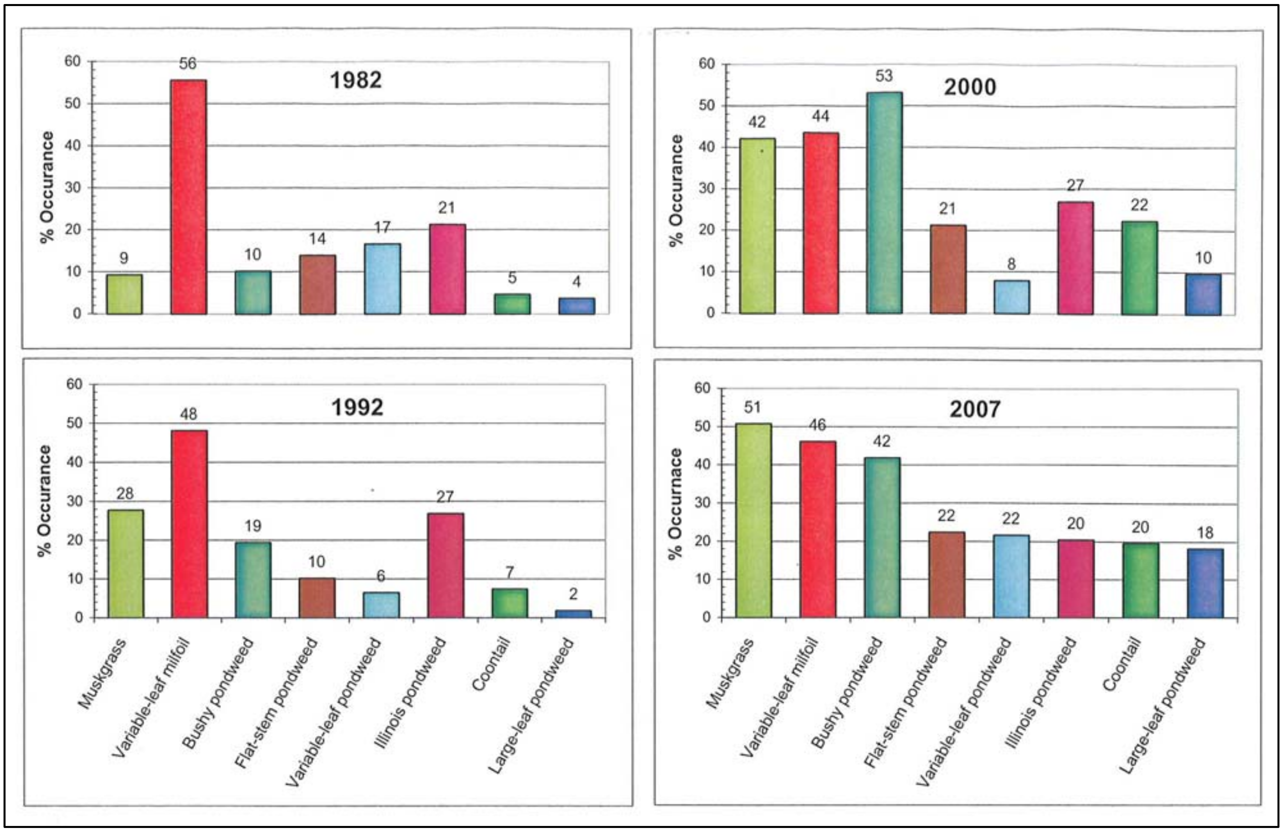


Figure 14. Changes in aquatic plant frequency over a 25-year period.

both. In both surveys variable-leaf milfoil was the most frequent species. Muskgrass, bushy pondweed, flat-stem pondweed, variable-leaf pondweed, and Illinois pondweed were the dominant species in both surveys but their frequency was much lower than in most recent surveys.

The 2000 aquatic plant survey was conducted using the same methodology but the number of sample locations was doubled resulting in 216 individual data points. As a result of the increased sample frequency the number of species identified increased to 25. A broad evaluation of the data shows significant similarities to the 2007 data in both the frequency and distribution of species (figure 14). In 2000 the most abundant plant in Lake Noquebay, measured by frequency of occurrence was bushy pondweed (53%) followed closely by variable-leaf watermilfoil (44%) and muskgrass (42%). Most of the large pondweeds also showed similar frequencies of occurrence. The most notable differences were noted for variable-leaf pondweed, large-leaf pondweed, and common bladderwort which all showed significantly higher frequency of occurrence in 2007. All of the species found in 2007 that were not identified in 2000 were found at fewer than 5% of sample points.

While changes in methodology and sample size make it difficult to directly compare data from the four aquatic plant surveys, there are some broad trends that can be seen over the last 25 years:

- The frequency and distribution of VWM in Lake Noquebay has not changed appreciably.
- The frequency and distribution of muskgrass, bushy pondweed and coontail have increased dramatically.
- The frequency and distribution of large pondweeds has increased.

- Aquatic plant diversity has increased substantially as measured by the number of plants found at 10% of more of the sample points.

Taken together these trends point to a much-improved aquatic plant community in Lake Noquebay. While VWM can still be found throughout the lake, the increase in low-growing species such as muskgrass and bushy pondweed prevent it from dominating the aquatic plant community as it once did. The increase in overall plant diversity is especially promising since it's a good measure of the lakes health.

LNRD Aquatic Plant Harvesting Program

The Lake Noquebay Rehabilitation District has been harvesting aquatic plants on Lake Noquebay for more than 30 years. Harvesting operations began in 1978 with one 10-foot harvester but quickly expanded to include three harvesters.

Since its inception the goal of the LNRD's aquatic plant management operation has been improving navigation in the lake by managing dense beds of variable-leaf milfoil. The primary focus throughout the years has been harvesting VWM in offshore areas, typically in water more than 5 feet deep. Controlling vegetation in and around swim areas and docks has been the responsibility of individual landowners.

A typical harvesting plan includes 15 weeks of harvesting using two harvesters operating 40 hours per week. The third harvester is used for shoreline cleanup three days each week to collect dislodged and cut plants that wash up on the shore. A more intensive 2-3 week shoreline cleanup is also completed each year at the beginning of the harvest season to remove plants accumulated on the shore.

A Harvesting Foreman conducts weekly reconnaissance on the lake to determine where harvesting and shoreline cleanup are needed. Areas in need of harvesting are marked with buoys to guide the harvesters. Most areas are only cut once each year. Shoreline cleanup is directed at the areas of greatest plant accumulation and is determined largely by wind direction. In addition to directing daily harvesting operations the foreman maintains personnel and plant harvesting records.

Analysis of Long-term Harvest Data

During the last 30 years the total number of acres harvested annually has ranged from a low of 120 to more than 500 acres. This variability is due to many factors including weather conditions, mechanical problems with equipment, changes in operating procedures, and more recently the introduction of invasive aquatic species.

Analysis of the available harvest data shows a relatively consistent harvesting effort of 300 to 400 acres annually between 1980 and 1996 (figure 15). However, despite a relatively consistent effort the amount of plant material harvested fell by half from 14 tons/ac to 7 tons/ac. This is consistent with the experience of the harvesting crew who report that in the early 80's in many areas of the lake it was possible to cut a full harvester load (approximately 2.8 tons) in 15 to 20 minutes. By the mid 90's it was taking 45 minutes to one hour to cut a full load.

Between 1996 and 2002 there was a small but steady decline in harvested area followed by a significant (50%) reduction in 2003 and 2004. The drastic reduction in harvest area can be attributed to an unusual rain event in late June 2002 when most of the Lake Noquebay watershed received between 5

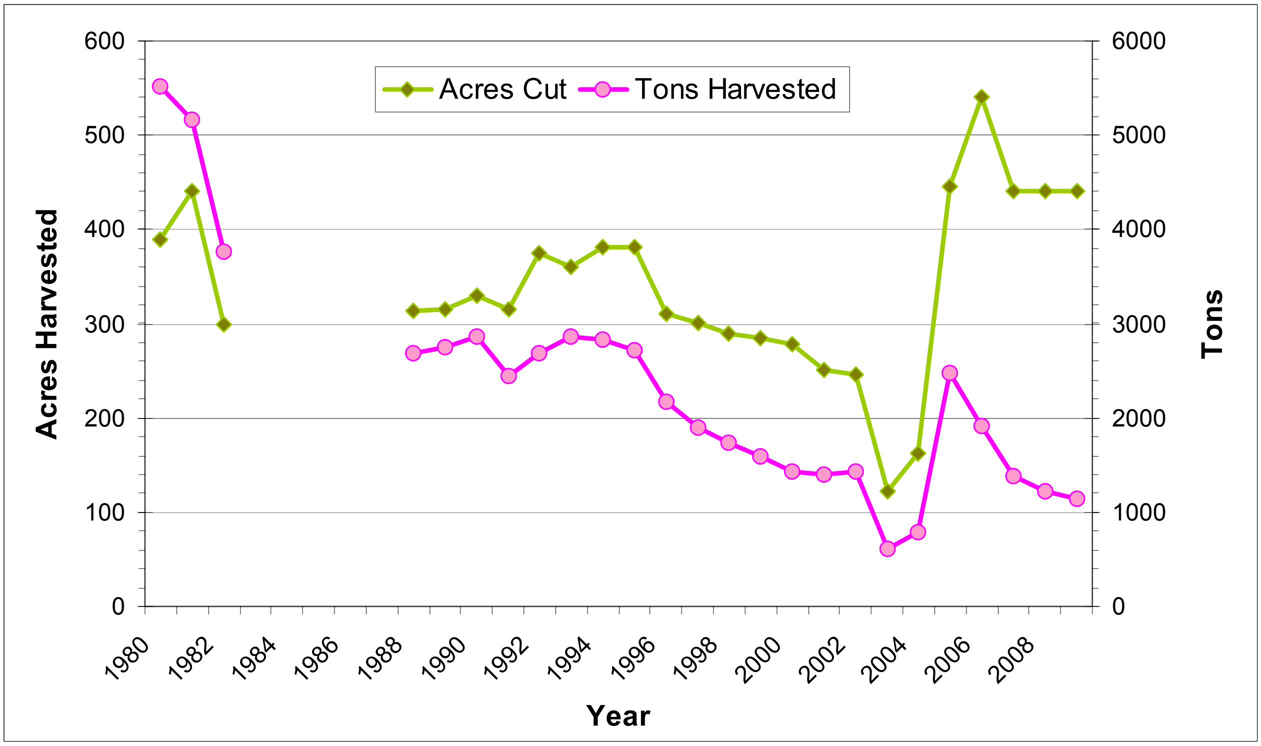


Figure 15. Annual aquatic plant harvesting data for Lake Noquebay.

and 7 inches of rain in a 24-hour period. Sediment and tannins that flushed into the lake reduced Secchi disk visibility from an average of 9.5 feet in 2001 to 3.3 feet in 2002. The reduction in light intensity caused a heavy die-off of bushy pondweed and significantly reduced aquatic plant growth throughout the lake. Although visibility increased the following year, aquatic plant production did not rebound until the summer of 2005.

In 2005 the LNRD adopted several changes in operating procedures that significantly increased the number of acres harvested. Changes included modernizing the harvester fleet, adding a second shoreline conveyor and greatly improving efficiency of the harvesting operation. Despite these changes the harvesting yield has continued to decrease, to a low of 3 tons/ac in 2008.

Zebra mussels (*Drissena polymorpha*) were discovered in Lake Noquebay in the summer of 2006. Since their discovery it has become clear they are having a suppressing effect on VWM in the lake. VWM typically remains standing through the winter and begins growing in early spring, reaching the water surface long before the slower growing pondweeds. During the last few years it appears the overwintering milfoil stems have been dragged to the bottom due to the weight of attached zebra mussels. As a result it takes longer for the VWM to reach a harvestable height.

Role of Aquatic Plant Harvesting in Plant Community Changes

While environmental factors can explain some year-to-year variability in the aquatic plant population, and zebra mussels appear to have had a significant impact since their introduction, neither explains the steady decline in harvest yield observed during the last 30 years. The only consistent stressor acting on the aquatic plant community during the period, and the likely cause of plant community changes, is aquatic plant harvesting.

Typically, aquatic plant harvesting is not viewed as a selective management tool. However, in Lake Noquebay much of the harvesting involves cutting to a depth of 5 feet in 6 to 12 feet of water, effectively topping the larger aquatic plants and opening up the canopy. While the harvesting has not reduced the distribution of VWM in Lake Noquebay, it has lead to a substantial increase in the frequency of muskgrass, bushy pondweed, and coontail.

In the final analysis it appears that sustained aquatic plant harvesting has lead to significant improvements in the plant community of Lake Noquebay as measured by increased plant diversity, a reduction in milfoil dominance, an increase in the frequency of low growing species, and a reduction in the need for harvesting.

Other APM Measures

Water level management
The Lake Noquebay Dam was constructed at its current location in 1929. In 1969 ownership of the dam was received by Marinette County and a permit was issued requiring that the lake level be maintained between 92.00 feet and 92.40 feet measured on the "Railroad Commission Datum" which was established at the time of construction.

In 1972 the DNR authorized an annual lake drawdown of 15 inches (to 90.75 feet) between October 26 and ice out each year to suppress milfoil growth in shallow areas and reduce shoreline damage from ice. In 1993 the drawdown date was moved up to October 15 each year.

Since the drawdown was implemented before any reliable aquatic plant data was available, and due to the fact that recent aquatic plant survey methods do not adequately sample very shallow areas, it's not possible to determine how effective winter drawdown has been as an aquatic plant management tool. However, submersed aquatic plant growth is typically sparse in water less than two feet deep. Also, according to landowners, the drawdown has been very effective at reducing the incidence of shoreline damage from ice heaving.

Aquatic herbicide use
Since its formation the LNRD has not used aquatic herbicide application as a management tool. According to DNR personnel the number of permitted aquatic herbicide treatments on Lake Noquebay is very low, averaging 1-2 per year. However, several instances of illegal herbicide use have been investigated. In most cases of illegal herbicide use the target of control has been emergent vegetation.

Aquatic Plant Management Goals & Objectives

The goal of the Lake Noquebay Rehabilitation District is to: **Develop and implement a sustainable aquatic plant management program for Lake Noquebay to reduce variable-leaf milfoil dominance and maintain the navigational potential of the lake while protecting fish and wildlife habitat.** To achieve this goal specific management objectives have been identified and targets have been set to gauge success and guide selection of management options.

Goal: Develop a sustainable aquatic plant management program for Lake Noquebay.

A sustainable aquatic plant management program will be cost-effective, socially acceptable and should, as much as possible, be relatively easy to repeat as needed. In determining cost effectiveness the District needs to consider annual management cost, duration of control and permitting requirements.

Objective: Increase efficiency and effectiveness of the current aquatic plant harvesting program.

Since the District has already invested heavily in a successful aquatic plant harvesting program emphasis should be placed on increasing the effectiveness of the program and looking for efficiencies to reduce cost and/or better meet the needs of LNRD members. Annual evaluation of the harvesting program will be easier if adequate records are kept and presented in a clear manner.

Target – Collect detailed records of annual harvesting efforts and areas harvested.

Keeping the harvesters in good repair and replacing equipment at the optimal times to reduce maintenance costs can minimize the cost of the harvesting program.

Target – Implement a routine maintenance program to reduce harvester downtime.

The Wisconsin Waterways Commission harvester grant program cedes any interest in cost-shared equipment after 10 years. Assuming additional grant funding is available it makes sense to replace harvesters after 10 years when their re-sale value is greatest.

Target – Continue replacing harvesters on a 10-year cycle as state grant funds allow.

While aquatic plant harvesting is the primary aquatic plant management tool employed by the District, other alternatives should be explored.

Objective: Explore other aquatic plant management options for potential effectiveness, cost and public acceptability.

A review of common aquatic plant management alternatives is explored on page 48. The alternatives should be reviewed and updated as conditions on the lake change or new management alternatives become available.

Target - Provide District members with copies of the management plan to educate them about various management alternatives.

An aquatic plant management program that is sustainable over the long-term also needs to adapt as environmental conditions and aquatic plant populations change. To make the required adjustments those responsible for making management decisions need current information upon which to base their decisions.

Objective: Track changes in the aquatic plant population so to evaluate management efforts.
The recommended frequency of plant surveys depends on the frequency of changes in management methods. When new management methods are adopted surveys should be completed to track changes and determine management effectiveness. If, however management is routine the amount of time between plant surveys can be lengthened.

Target - Conduct pre and post management aquatic plant surveys to evaluate effectiveness of new management tools.

Target - Conduct a full point/intercept survey of the lake every 10 years unless management conditions call for more frequent surveys.

Even in the absence of formal point/intercept surveys landowners and the aquatic plant harvesting crew should be routinely monitoring the lake for early detection of new invasive species.

Target – Train volunteers and aquatic plant harvesting crew in aquatic plant identification and aquatic invasive species monitoring methods.

Target - Conduct annual surveys of the lake for new aquatic invasive species according to DNR AIS monitoring protocol.

For any management program to be sustainable LNRD members need to understand and take ownership of the program. Good communication is essential so members are realistic about the expected outcomes and understand what they as landowners can do to help.

Objective: Increase efforts to effectively communicate with LNRD members.
Annual meeting reports, while important, do not reach a significant portion of the membership. To increase the scope of its communication and education efforts the District Board should use other avenues to reach LNRD members. This could include assisting with the formation of a Lake Association that could help with education and communication efforts.

Target - Publish a regular newsletter to keep members informed about management practices and outcomes, and to share success stories.

Target – Develop a website to help disseminate information.

Target - Provide aquatic invasive species educational materials to members.

Goal: Prevent variable-leaf watermilfoil (VWM) dominance in Lake Noquebay.

The impetus for forming the LNRD and managing aquatic plants was the rapid expansion of VWM, which, at one time rendered hundreds of acres of Lake Noquebay unnavigable. Currently VWM can be found in abundance in most waters between 3 and 10 feet deep in an area that covers approximately 1,000 acres, or 40% of the lake. Throughout the Lake VWM is still the species primarily responsible for nuisance conditions.

There are no management tools currently available that will allow for the eradication of VWM from the lake. Also, most aquatic plants are opportunistic and any areas that can support plant growth will be colonized in short order if plants are removed. Invasive species and certain aggressive natives such as VWM are especially good at colonizing available habitats. For this reason it is unrealistic to try and eradicate milfoil or any other aquatic plants from areas that will support them. The only realistic objective is to reduce the abundance of nuisance species.

Objective: Choose management practices that allow selective control of variable-leaf watermilfoil whenever possible.

A plant can be "controlled" by reducing its frequency (where it is found in the lake) and/or by reducing its abundance (the amount, or density of plants at a location). Various management strategies differ in method of control and in the potential to selectivity control milfoil. These differences can be found in the review of aquatic plant management alternatives on page 48. The current harvesting program works primarily by reducing milfoil abundance and creating room for native plants to grow. Many of these native plants, including bushy pondweed and stonewort are low growing plants that seldom cause nuisance conditions. Increasing the frequency and density of these good aquatic plants will alleviate nuisance conditions while preserving habitat.

Target - Decrease variable-leaf watermilfoil abundance in the lake.

Target - Increase the frequency and abundance of stonewort, bushy pondweed and other species where experience shows them to be beneficial (or at least less of a nuisance).

There are still areas in the lake where native species dominate and VWM is rare. Extra care should be taken in these areas to prevent radical disturbances that will open areas and invite milfoil expansion.

Target – Prevent spread of variable-leaf watermilfoil in areas that are currently dominated by native pondweeds and other high quality native plant communities.

Goal: Maintain the navigational potential of Lake Noquebay.

Although variable-leaf watermilfoil is the species primarily responsible for nuisance conditions in Lake Noquebay, it is not the only species capable of obstruction navigation. Many of the larger pondweeds, coontail, and other species have the potential to grow to the surface and become a problem. To maintain navigation on the lake areas with dense vegetation at the surface should be managed even when dominated by otherwise "good" aquatic plants.

Objective: Manage vegetation in all areas where navigation and recreation are restricted due to dense plant growth.

When managing areas of excessive plant growth efforts should be made to prevent unnecessarily opening the areas to invasion by VWM. Methods should be chosen that address the nuisance conditions but do not remove all plants.

Target – Outside of Critical Habitat Areas, eliminate areas where navigation is seriously hindered due to canopy forming plants.

Target – Where pondweeds and other desirable vegetation are dominant prevent shifting the population to VWM.

Goal: Protect fish and wildlife habitat on Lake Noquebay.

Lake Noquebay is a locally and regionally important resource for anglers and hunters alike. Its know widely for its abundant bass and bluegill populations as well as northern pike, walleye and Musky fishing. The lake and the 1,300-acre Lake Noquebay Wildlife Area to the east are also popular with waterfowl hunters.

Since aquatic vegetation is such an important habitat component on Lake Noquebay, aquatic plant management options should be evaluated for their potential effects on fish and wildlife populations. Extra care should be taken when managing uncommon habitat types and/or habitat known to be critically important.

Objective: Protect critical habitat on Lake Noquebay.

Sine the inception of the harvesting program the Department of Natural Resources has prohibited the harvesting of emergent and floating-leaf vegetation on the lake. These habitat types are relatively uncommon and provide spawning and nursery habitat for fish as well as absorbing wave energy and reducing shoreline erosion. The DNR has also restricted harvesting in Finnegan's Bay as it is home to a high quality submersed plant community that has resisted VWM invasion.

In 2006 the DNR delineated critical habitat areas on Lake Noquebay. The final results were published in 2009 in the Lake Noquebay Critical Habitat Designation Report. The result was the designation of 11 distinct critical habitat, or "sensitive areas" as shown in figure 16. Restrictions on aquatic plant management within the designated areas include:

- (LN1) No aquatic plant harvesting;
- (LN2) Protect emergent vegetation; and
- (LN3 – LN11) Aquatic vegetation removal limited to maintaining a 30-foot navigation channel to docks with a Wisconsin DNR permit.

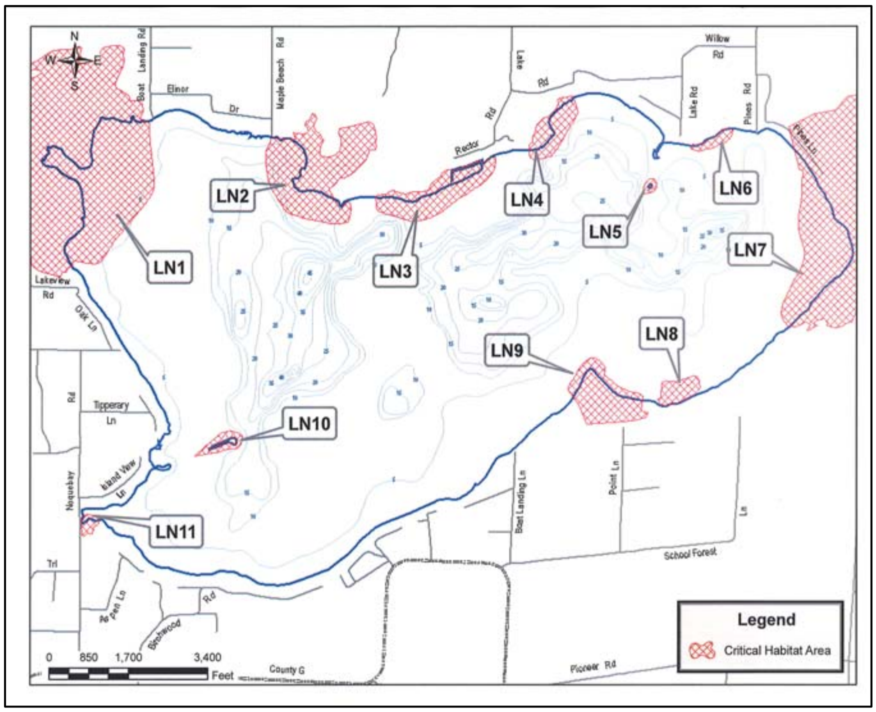


Figure 16. WDNR designated Critical Habitat Areas.

Target – Incorporate critical habitat recommendations into harvesting plan and any future aquatic plant control strategies.

Scattered emergent vegetation outside of designated critical habitat areas also provide important spawning habitat for centrarchid fish (bass, bluegill & sunfish) and should be protected. These areas also provide spawning habitat for yellow perch, nursery areas for juvenile fish, feeding areas for gamefish, and waterfowl habitat.

Target – Protect Emergent vegetation where it occurs outside of officially designated critical habitat areas.

Aquatic Plant Management Alternatives

A successful aquatic plant management strategy must be tailored to the plants and water body in question and will typically utilize multiple control methods as appropriate. A comprehensive review of aquatic plant management alternatives follows. While each of the alternatives may be beneficial in certain situations, not all are applicable to managing aquatic plants in Lake Noquebay.

Do Nothing

Doing nothing is inexpensive, easy to do, and relatively uncontroversial. In rare cases it can also be effective. Lakes are complicated ecosystems and aquatic plant populations fluctuate within them due to a variety of factors. Large-scale climactic conditions and local weather cycles can impact water levels, temperature, and clarity, all of which effect aquatic plant growth. Plant populations also vary because of disease, species introduction, competition and other internal processes. Left to its own devices the plant community in Lake Noquebay will continue to change over time.

However, In the case of variable-leaf watermilfoil, history shows that doing nothing will likely lead to milfoil domination of the aquatic plant community. There is no reason to believe that a hands-off approach will lead to natural declines in the variable-leaf watermilfoil population.

Chemical Control

When properly planned and executed, chemical control of aquatic plants can be effective. However, if care is not taken in the selection, timing, and application of aquatic herbicides the results can be less than desirable, or worse, have unintended negative consequences.

There are several herbicides approved for aquatic use in Wisconsin, each with differing modes of action and species it controls. Contact herbicides kill exposed plant material but can leave the root system intact. Plant re-growth can be problem with these types of herbicides. Systemic herbicides are transported to the roots and kill the entire plant. Systemic herbicides provide longer-term control but may act slower than contact herbicides. Herbicides can also be grouped into two general groups, "broad-spectrum" and "selective". Broad-spectrum herbicides control a broad range of plants. Selective herbicides, as the name implies, are more-or-less selective and control fewer species while leaving many others unharmed. Often selectivity is a function of timing or concentration of the herbicide.

Variable-leaf watermilfoil (VWM) is susceptible to several common aquatic herbicides. The plant is especially susceptible to formulations of 2,4-D. Since most pondweeds and many other native aquatic plants are resistant or only slightly susceptible to 2,4-D the chemical can be used to selectively control milfoil while protecting many native species (Parsons, 2001). Cost depends primarily on the chemical formulation and application rate. In 2009 the actual cost to treat Eurasian milfoil in three Marinette County Lakes with 2,4-D at a rate of 150 lbs/ac was $700 per acre. In water over 10 feet deep the rate was increased to 200 lbs/ac at a cost of $900 per acre.

Fluridone has proven effective for the selective control of VWM when used at concentrations of 10 ppb or higher. However, due to its mode of action it is only appropriate for whole lake treatments. Fluridone is very slow acting and needs to be maintained at the proper concentration for 60 to 120 days to achieve effective control (ENSR, 2005). It is reported that fluridone application costs range from $500 to $2,000 per acre depending on the form of fluridone used and any necessary re-treatment needed to maintain the required concentration. At the concentration required for VWM control negative impacts on non-target species can be expected.

Triclopyr is a fast acting systemic herbicide that also shows promise for selective control of VWM. While milfoil control is excellent, pondweeds and other monocotyledonous species are minimally affected at label doses (ENSR, 2005). Costs for Triclopyr treatments range from $600 to $800 per acre.

With the use of selective herbicides it is possible to get multi-year control of VWM. This is most likely to be achieved when the native community is relatively vigorous and can resist VWM reestablishment. Eventually VWM will return so even selective management will have to be repeated on a regular basis.

Improper or excessive use of aquatic herbicides can have unintended consequences. Widespread use of broad-spectrum herbicides can leave large areas of suitable habitat exposed to colonization by nuisance species. Many of the more common nuisance plants, such as VWM, are aggressive pioneer species that can quickly invade disturbed areas. The decomposition of tons of aquatic plants also releases large amounts of nutrients to the water column. These nutrients can trigger algae blooms and fuel additional aquatic plant growth

Chemical treatment of aquatic plants in Wisconsin always requires a permit from the Wisconsin DNR. This is to ensure that the proposed chemical treatment will use appropriate chemical(s), at the correct concentration and at the proper time of the year. In almost all situations the chemical must be applied by a Wisconsin Department of Agriculture Trade and Consumer Protection licensed applicator.

The LNRD does not currently use chemical treatment as a management tool. Individual landowners can apply for permits from the DNR. Currently there are no State cost-share programs that will provide funding for the chemical treatment of VWM

Benthic Barriers

Benthic, or sediment barriers cover the sediment and prevent the growth of aquatic plants. The barriers work by physically disrupting plant growth or eliminating light at the sediment surface. When installed properly benthic barriers are very effective at eliminating all plant growth. However the difficulty of installing and maintaining these barriers prevent their widespread use.

Benthic barriers can be made of naturally occurring materials (sand and gravel) or artificial (synthetic plastic sheeting). Sand or pea gravel is commonly used to create weed free swim areas. However, there are several common problems with sand and gravel benthic barriers. If deposited on soft sediment it can sink in and mix with the native sediment. Also, over time new sediment is deposited on top of the barrier. All of these factors will lead to failure of the barrier.

Artificial barriers typically consist of sheets of polypropylene, polyethylene, fiberglass or nylon (Wagner 2004). All must be weighted to hold them in place against water currents, waves, and boat wake. If constructed of non-porous material benthic barriers will be subject to billowing and may float free of the sediment as gasses from decomposition build up beneath them. Porous barriers are less subject to billowing but plant fragments that settle on top are better able to root through them. Both types of barriers require annual maintenance since sediment accumulation on top of the barriers will build up and support new aquatic plant growth. Artificial benthic barriers are difficult to install and maintain. Maintenance consists primarily of annually removing accumulated sediment, which typically requires removal and replacement of the barrier. The use of any type of benthic barrier requires a DNR permit.

Dyes and Floating Covers
Dyes are liquid chemicals that are applied to change the color of the water. Covers physically cover the water surface. Both control aquatic plants by reducing the amount of light reaching the sediment.

Dyes typically color the water a deep blue or even black. For small ponds they are relatively inexpensive, long lasting, and effective. Effectiveness is limited in shallow water (2 feet or less) where the light reduction is seldom enough to prevent plant growth. Dyes must stay in the water throughout much of the growing season. Because of their dark color, dyes increase light absorption and can result in higher water temperatures. The increase water temperature can in-turn result in stronger stratification, increased algae growth, lower dissolved oxygen and widespread changes in the aquatic community (Wagner 2004). Dyes are not an option in larger lakes and those with significant outflow.

Floating covers disrupt plant growth by reducing light levels at the sediment surface. However, unlike dyes the floating covers prevent virtually all water use while they are in place. Floating covers can be difficult to install and effectively anchor and are not practical for use in large areas.

Both dyes and floating covers require DNR permits. The main permitting issue with floating covers is the disruption of public water rights (fishing and navigation) that they cause while installed.

Harvesting
Aquatic plant harvesting is a widely accepted aquatic plant management alternative that can be effective on a large or small scale. Individual landowners often manually clear small areas around their dock or swim area. Typically this is accomplished by using one of several specially designed aquatic plant rakes and/or hand-held cutting implements. Under current Wisconsin Law landowners can manually harvest plants without a permit if the plant removal is not in a DNR designated sensitive area and is limited to a 30-foot wide area (measured parallel to shore). There is no limit on how far out into the lake a landowner can harvest by hand if they stay within the 30-foot wide corridor. The control area must be around existing piers, boat lifts, and swim rafts and the cut plants must be removed from the water.

In Lake Noquebay, large scale harvesting is done with three specially designed aquatic plant harvesters. These machines are capable of cutting plants in a 10-foot wide swath up to 6-feet deep. Plants are cut and collected in one operation and each machine can hold more than 16,000 lbs of vegetation.

Like most aquatic plant management alternatives harvesting seldom eliminates plants. Much like cutting your lawn, harvesting leaves the root system intact and plants will re-grow. In some cases repeated harvesting close to the sediment surface can stress plants enough to cause mortality. Species that depend on seed production for their spread may be partially controlled by harvesting if seeds are repeatedly removed. Plants that spread by fragmentation such as VWM and coontail can actually be spread through harvesting when cut fragments escape the harvester and drift to other areas of the lake.

As a management tool harvesting is only minimally selective and most appropriate where nuisance species are dominant and widespread. Harvester operators can control where they cut but it is impossible to target individual species that grow in mixed assemblages.

Plant re-growth depends on the species present, timing of harvest, and cutting depth. Studies have shown that very deep cutting with specialized harvesters can even have multiple year effects on milfoil and other aquatic plants.

Repeated harvesting can also have impacts on the aquatic plant community that go beyond the initial cutting. In Lake Noquebay repeated harvesting has led to measurable shifts in the aquatic plant community. When harvesting began in 1978 the lake was dominated by VWM. After 28 years of harvesting the plant community has changed noticeably. Harvesting tonnage has gone down and many areas of the lake are dominated by muskgrass and bushy pondweed, low growing natives that typically stay below the maximum cutter depth. Many pondweeds and other native species can also be found growing with the VWM. Repeated harvesting of the VWM prevents it from forming a canopy and shading out other vegetation.

Large Scale mechanical harvesting is an expensive proposition. The LNRD currently spends more than $96,000 per year (2009) to operate its harvesting program. This includes operation & maintenance costs for three 10-foot harvesters as well as funds to replace aging equipment. Capital equipment costs are also quite high. A new harvester can range from $50,000 to $100,000 depending on the size of machine and options. Other necessary equipment includes a truck to transport plants to a disposal site and a shoreline conveyor to transfer cut plants from the harvester to the truck. Wisconsin does provide financial assistance for harvester and related equipment purchases through the Wisconsin Waterways Commission. Grants are awarded on a competitive basis and cover 50% of equipment purchase price. The LNRD has received grant funding for all of the harvesters and shoreline conveyors currently in use.

Mechanical harvesting requires a Wisconsin DNR approved aquatic plant management plan and permit. The approved management plan is also a requirement for receiving a Waterways Commission grant for equipment purchase.

Dredging

Typically a practice known for increasing depth to aid in navigation, dredging can also be an effective, and expensive, aquatic plant control technique. As a plant control measure dredging has two primary modes of action: changing sediment type, and increasing the depth to sediment.

Where a layer of nutrient rich organic sediment overlies a nutrient poor layer of mineral soil the organic layer can be removed to expose the sand or gravel layer that is less capable of supporting plant growth. Typically such removal will change the plant community structure, not eliminate all plant growth. Removing the upper layers of sediment also eliminates plant roots and most viable seeds. Unfortunately, the result of organic sediment removal is seldom long lived since many plants will colonize mineral soil where they quickly begin the process of building new organic matter. Very little organic matter is needed to support dense plant growth.

Eliminating all submersed aquatic plants requires dredging the lake to a depth where light availability limits plant growth. In Lake Noquebay the lower limit of aquatic plant growth is about 14 feet with sparse plant growth beyond the 12-foot depth.

There are two major types of dredging, hydraulic and mechanical. Hydraulic dredging is accomplished by pumping a sediment/water slurry out of the lake to a disposal/dewatering area. Hydraulic dredging is best suited to loose organic sediment. Mechanical dredging employs heavy equipment deployed on barge or shore to dig out the sediment and transfer it to trucks for removal.
It should come as no surprise that dredging is typically a very expensive alternative. Rough estimates for mechanical dredging range from $8.00 to $25.00 per cubic yard (Wagner 2004) depending on the type of sediment, accessibility and disposal costs.

As a practical matter, large scale dredging to reduce VWM growth on Lake Noquebay would not be feasible. While VWM grows best in muck it can grow in any firm sediment. As a management tool in very limited areas it may be of some benefit but, as mentioned, in shallow areas the benefit is not long lasting.

Any type of dredging requires, at a minimum, a Wisconsin DNR and US Army Cops of Engineers permit. Permits must describe in detail the scope of the proposed dredging, dewatering and disposal of spoils, and the effects the project will have on fish, wildlife, and public water rights.

Drawdown

Temporarily lowering water levels (drawdown) can be a valuable aquatic plant management tool. Its effectiveness depends on the season and duration of the drawdown. Currently the water level in Lake Noquebay is drawn down each winter by 1.5 feet (19 inches). The drawdown was first implemented in an effort to help control milfoil. It was thought milfoil at the surface would freeze in the ice and could be uprooted when the water was raised in the spring. While it never worked as intended the drawdown was continued because it significantly reduces the amount of shoreline damage from ice heaving. The winter drawdown does help control aquatic plants in very shallow water (less than three feet deep).

Winter drawdown controls plants by exposing their root systems to freezing conditions. In winter the duration of the drawdown is less important than the timing. It is important that frost penetrates to the root zone before snow insulates the lakebed. Summer drawdown, on the other hand, kills some species through desiccation of the root system. This is often difficult in organic sediments since they retain moisture. Also, many plants are stimulated by changing water levels and can increase with summer drawdown.

The response of aquatic plants to drawdown is well known for some species but not for others. To complicate matters, accounts in the scientific literature do not always agree. Table 1 lists the species found in Lake Noquebay and their reported susceptibility to winter drawdown according to Nichols (1991). While its susceptibility to winter drawdown is listed as variable, the lack of VWM in shallow waters of Lake Noquebay suggests it is adequately controlled by repeated winter drawdown.

The primary drawbacks to drawdown include loss of recreational use during the low water period (minimal with a winter drawdown) and potentially lowering water levels in shallow wells adjacent to the lake. Other impacts may include unintended effects on fish and aquatic life. Since Lake Noquebay has ample deep water a limited drawdown has little direct impact on fish.

The maximum drawdown is controlled by the height of the dam and the downstream water elevation. The sill of the Noquebay dam is 3.6 feet below the normal pool elevation and 2 feet below the currently permitted winter drawdown level. Since there is approximately a foot of backwater even at low flows the water level in Noquebay could only be reduced by another foot during the winter months. Not enough to have a significant effect on VWM distribution.

Decreases	Variable response / Unknown	Increases
White water lily Spatterdock Lily Common bladderwort Robbins pondweed	Variable-leaf watermilfoil (V) Muskgrass (V) Variable leaf pondweed (V) Small pondweed (V) Large-leaf pondweed (V) White-stem pondweed (U) Common waterweed (V) Flat-stem pondweed (V) Northern watermilfoil (V) Illinois pondweed (U) Stonewort (U) Sago pondweed (V) Richardson's pondweed (V)	Coontail Bushy pondweed Floating-leaf pondweed Water celery Hard-stem bulrush

Table 1. Response of common aquatic plants to winter drawdown.

Automated Mechanical Bottom Disturbance

Several automated systems exist that control plants by physically disrupting them throughout the growing season. Modes of action include physically raking, rolling, or spraying the sediment with jets of water. The Weed Roller™ is one of the more common devises. It has a central motor that attaches to a dock, boatlift or other fixed point. The motor drives a series of cylindrical rollers back and forth across the bottom of the lake in an arc of up to 270 degrees. Fins on the rollers disturb the sediment and plants, removing existing plants and preventing the establishment of new ones.

In two studies weed rollers were found to cause a significant reduction in fine sediment and a nearly complete elimination of aquatic plants (James 2004, James 2006). Sediment removed from the site was often fond to be deposited immediately outside of the impacted area.

These devices are only appropriate for small areas in shallow water to maintain swimming areas etc. Negative environmental impacts include sediment disturbance, which may lead to local increases in turbidity and suspended phosphorus. This may lead to major nutrient increases if the practice is widespread. While studies have not been conducted on the impact these devices have on aquatic organisms, the periodic bottom disturbance likely reduces or eliminates many aquatic insects and would surely prevent successful fish spawning in the impacted area.

Cost for the Weed Roller™ starts at approximately $3,000 for motor, mounting hardware, and a 21-foot roller. Other comparable devises have similar price tags. This and other automated mechanical bottom disturbing devises require a Wisconsin DNR permit.

Control/Reduce Nutrient Inputs

Aquatic plant response to nutrient input varies by species and source of nutrients. For the most part, rooted aquatic plants absorb their nutrients through the root system so nutrient additions to the sediment are more important than dissolved nutrients in the water column. Dissolved nutrients however can become sediment bound nutrients when they fuel algae growth that dies and sinks to the bottom.

Studies have shown that many aquatic plants are particularly stimulated by nitrogen additions to the sediment. Rogers (1995) reported that nitrogen additions to sediment significantly increased wild celery growth. Nitrogen is a water-soluble nutrient. Septic systems intensive irrigation and excessive nitrogen fertilizer use have all been shown to cause increased nitrogen concentrations in groundwater. Reducing these sources of nutrients will help control aquatic plant growth and expansion in the lake.

Biological Plant Control
Biological control (biocontrol) typically utilizes bacteria, fungi, or insects to control an unwanted plant. Biocontrol of exotic species often involves finding the natural control mechanism in the exotic plants country of origin and importing it to the US. Since there is always a risk that introducing a new organism may lead to unintended impacts to non-target species a lot of study is required to approve the use of new biocontrol agents. Currently there are no known biocontrol agents that target VWM specifically.

The use of grass carp, an exotic fish species that feeds on vegetation, has also been used to control unwanted vegetation in lakes. However, grass carp typically prefer native pondweeds to milfoil so they can increase milfoil dominance in a lake. Grass carp also uproot vegetation and stir up the bottom, greatly increasing turbidity and dissolved nutrients in the overlying water. In many lakes the introduction of grass carp for vegetation control has lead to massive algae blooms and a near complete destruction of the plant community. For this and other reasons the Wisconsin DNR prohibits the introduction of grass carp into Wisconsin waters.

Exotic Species Monitoring and Prevention
As is often the case, an ounce of prevention is worth a pound of cure. With exotic species this is doubly true. In most lakes, and for most exotic species the primary mode of introduction is by boat, boat trailer, or bait bucket.

Once established in a water body it is extremely difficult to eradicate an exotic species. In the few cases where eradication has been successful the introduction was detected early. For this reason routine monitoring to detect new invasive species is an important step in any aquatic plant management effort. The Wisconsin DNR and University of Wisconsin Extension have many good publications and websites to help the layperson identify exotic species. Periodically these agencies also offer exotic species identification and control training to landowners.

The DNR also provides grants and training to conduct watercraft inspections and provide educational materials at boat landings. The "Clean Boats, Clean Waters" program utilizes volunteers and/or paid staff to hand out educational materials at boat landings that educate boaters about practices they can use to reduce the likelihood of spreading aquatic invasive species between lakes. As a locally and regionally important resource, Lake Noquebay is at high risk of additional AIS invasions from nearby Green Bay and is a likely source for the spread of zebra mussels to other inland lakes.

Aquatic Plant Management Recommendations

Since the District has already invested a great deal of time and money in a successful aquatic plant harvesting program the plan should focus on increasing the efficiency of aquatic plant harvesting. At the same time, the District needs to explore all available options to maintain navigation and control variable-leaf watermilfoil.

Recommendation #1 – Continue harvesting to maintain the navigational and recreational potential of the lake.
The current harvesting program has proven effective at reducing excessive aquatic plant growth on Lake Noquebay and remains more economical than other large-scale aquatic plant management options, including repeated chemical control. The LNRD should continue to implement the harvesting program outlined in Figure 17, and described in table 2, to prevent aquatic plants from impeding navigation on the lake.

Recommendation #2 – Intensively harvest areas dominated by variable-leaf watermilfoil.
Areas dominated by VWM (more than 50% coverage as seen from the surface) should be targeted for the most intensive harvesting as described in table 2. Where possible, the harvesters cutting bar should be lowered to its maximum depth when harvesting these areas. Figure 17 shows areas dominated by VWM during the 2007 survey.

Recommendation #3 – Maintain areas dominated by large pondweeds by reducing harvesting pressure in these areas.
When areas dominated by native pondweeds and other beneficial aquatic plants are impeding navigation they should be harvested at a lesser depth to prevent opening the area to VWM invasion. Past experience has shown that cutting to a depth of 3 feet or less in deep water (> 5 feet) will provide relief from nuisance conditions while preserving the existing plant community. The downside to reduced cutting depth is increased cutting frequency, but the payoff is a healthier aquatic ecosystem. Figure 17 shows areas that were dominated by native pondweeds and had good plant diversity during the 2007 survey.

Recommendation #4 – Take advantage of state cost-share dollars and replace equipment on a routine basis.
The Wisconsin Waterways Commission continues to provide 50% cost-share assistance for the purchase of aquatic plant harvesting equipment. The Commission retains an interest in the equipment for 10 years after which time the grant recipient has full ownership of the equipment. The LNRD should continue to replace its harvesting equipment on a 10-year schedule to receive maximum benefit from the grant program while getting the best price when selling the used equipment.

Recommendation #5 – Continue winter drawdown on Lake Noquebay.
The winter drawdown is at least partially responsible for the sparse vegetation in shallow water (less than 2 feet) and reduces shoreline damage from ice heaving. It should be continued as practiced.

Recommendation #6 – Protect critical fish spawning and nursery areas on Lake Noquebay.
Do not harvest aquatic plants in Wisconsin DNR designated sensitive areas except to maintain a 30-foot wide corridor between open water and docks as recommended in the Lake Noquebay Critical Habitat Designation Report (Appendix B). Mechanical and manual harvesting of plants within designated critical habitat areas requires a WDNR permit. A detailed map of critical habitat areas should be kept on the harvesters at all times for reference.

Recommendation #7 – Explore alternative management options as they become available.
While harvesting is currently the most cost effective method of controlling aquatic plant growth in the lake, changes in the plant community and new developments in aquatic plant management may call for new approaches. The LNRD board should keep and open mind and evaluate alternatives as conditions change and new management options become available.

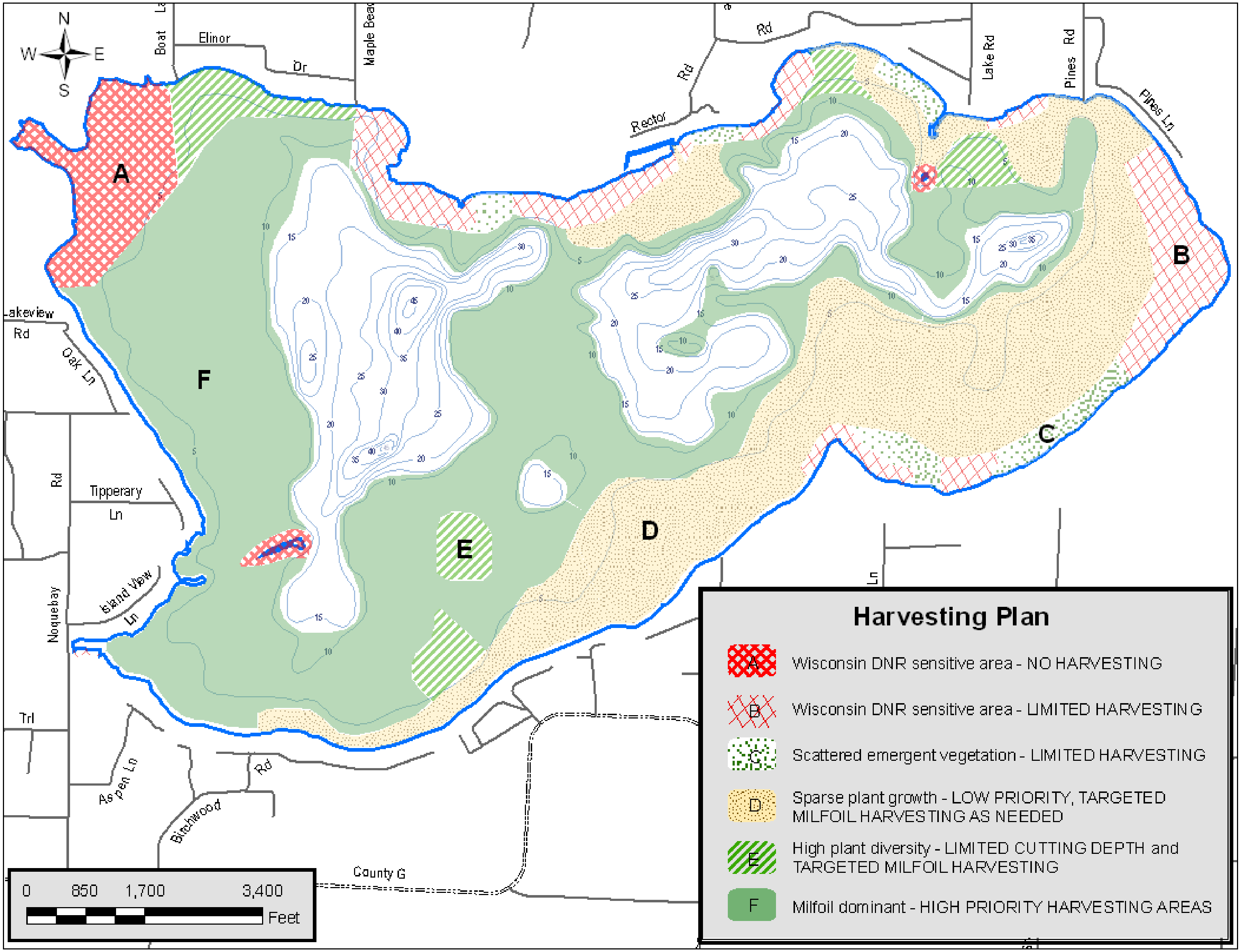


Figure 17. Recommended harvesting plan map for Lake Noquebay

Area	Zone	Acres	Description & Management Measures
A	Wisconsin DNR identified sensitive areas	96	Selected areas of the lake that contain significant stands of emergent plants (rushes, wild rice etc.) and/or floating-leaf plants (water lilies) that provide important fish & wildlife habitat, or contain other important fish spawning habitat. These areas do not front on developed properties and should be preserved.
			No harvesting of aquatic plants in these areas.
B	Wisconsin DNR identified sensitive areas	152	Selected areas of the lake that contain significant stands of emergent plants (rushes, wild rice etc.) and/or floating-leaf plants (water lilies) that provide important fish and wildlife habitat, or contain uncommon fish habitat. These areas should be preserved.
			Mechanical harvesting of emergent and floating-leaf plants is limited to a 30-foot wide corridor to allow boat access to docks. Boating corridors should be sited and/or combined as needed to minimize the impact on emergent and floating-leaf aquatic plants.
			LNRD shoreline cleanup of dead and dislodged plant material around docks is allowed where practical and the plants can be accessed without destroying emergent and floating-leaf plants.
C	Scattered emergent plants	48	Areas that contain scattered stands of emergent plants providing important fish and wildlife habitat. Submersed aquatic plants are typically sparse in these areas. Emergent vegetation should be preserved.
			No harvesting of emergent aquatic plants.
D	Sparse aquatic plant growth	509	Sandy areas that typically contain sparse aquatic plant growth. Most submersed plants are low growing native varieties.
			Target harvesting efforts on scattered VWM clones as needed.
E	High plant diversity	95	Areas with abundant aquatic plants that also have excellent plant diversity, including both low growing species and native pondweeds. Dense stands of VWM can also be found growing in these areas.
			Reduce harvesting depth to three feet in mixed plant beds.
			Where found, harvest dense stands of VWM at full depth of cut.
F	Milfoil dominant	921	Areas where submersed aquatic plant growth is typically dense and VWM is the dominant species.
			Harvest as needed to maintain navigation and open the plant canopy.

Table 2. Recommended aquatic plant management measures for Lake Noquebay.

Monitoring and Evaluation Plan

In order to evaluate and make changes to the management program the District needs to keep detailed management records and track changes in the aquatic plant community. The aquatic plant management program for Lake Noquebay needs to be evaluated on a regular basis and changed to meet shifting needs and address new challenges.

Recommendation #4 – Improve record keeping to better evaluate the harvesting program.
Improving record keeping is a quick and inexpensive way to collect important data that will allow the LNRD to evaluate the harvesting program and make necessary changes. The Harvesting Foreman should collect the following information on a daily/weekly basis:

- Size and location of all areas harvested. A GPS should be used to accurately record harvest buoy locations.
- Hours spent harvesting each area
- Number of harvester loads taken from each area.
- Location of the offloading site used.

The previous information should also be collected for shoreline cleanup activities. A sample harvest record sheet is included in appendix E.

Recommendation #2 – Conduct periodic aquatic plant surveys to track changes in the lakes aquatic plant community and evaluate management practices.
Aquatic plant surveys are valuable tools, essential in evaluating new and ongoing aquatic plant management practices. The frequency at which aquatic plant surveys should be conducted depends on changes in management and changes in the plant community.

Survey frequency should be dictated by changes in management practices and the aquatic plant community. Previous aquatic plant surveys of Lake Noquebay were completed in 1982, 1992, 2000, and 2007. Assuming no new invasive aquatic species introductions or obvious changes to the aquatic plant community a complete survey of the lake should be conducted in 2015 and every 8 to 10 years after that. If new aquatic invasive species are discovered, or if unexplained changes in the plant community are noticed a new survey should be conducted immediately. Likewise changes in management practices should be accompanied by aquatic plant surveys to evaluate practice effectiveness. Often these surveys can be conducted on a few representative areas where management changes are implemented.

Future lake surveys should be conducted according to Wisconsin DNR aquatic plant management protocol. Lake-wide surveys should utilize the same sample locations used in 2007. Surveys designed to evaluate new management tools should be conducted before and after treatment and should be scaled appropriately to accurately describe the plant community. DNR or County Land & Water Conservation Department staff should be consulted when designing survey methods.

Recommendation #3 – Continue evaluating the harvesting program and new aquatic plant management practices on an annual basis.
The LNRD Board currently evaluates harvesting activities on a monthly basis. The Board or designated committee should continue to review harvesting data and the plant community and recommend changes to the aquatic plant management program as needed.

Information & Education Plan

A strong information and education effort is an important part of any AIS prevention program. It is also important to effectively communicate with district members when trying to implement a flexible aquatic plant management plan.

Recommendation #1 – Maintain signage at the boat landings and provide educational materials to visitors to Lake Noquebay.
Maintain educational signage at the public boat landings to inform visitors to Lake Noquebay about the danger of AIS and how they can help prevent the spread. Signage should be clear and uncluttered. Handouts should be provided through the "Clean Boats, Clean Waters" program during busy periods. Signage and educational materials can be obtained from the Peshtigo DNR office or on line at Wisconsin Lakes Partnership or UW Extension Lakes Program websites.

Recommendation #2 – Form a Lake Association to assist in educational efforts and other lake and AIS management efforts.
The District should support/assist in the formation of a separate Lake Association to conduct AIS and lake management education. A separate association would free up the District Board to focus on aquatic plant management efforts. While a standing committee of the LNRD could fill the need, a separate association would be eligible for grants to implement AIS education efforts and undertake lake studies.

Recommendation #3 – Publish a regular newsletter, provide educational materials, and update lake residents about AIS management efforts.
A regular newsletter is a good way to distribute educational materials and keep members abreast of lake management issues. With the abundance of home computers in use many members cold receive an e-newsletter, reducing printing and distribution costs. Every member of the District should also be signed up to receive the Lake Tides newsletter, a free quarterly publication by the Wisconsin Lakes Partnership.

Recommendation #4 – Continue as a member of the Wisconsin Association of Lakes and take advantage of their resources.
The Wisconsin Association of Lakes (WAL) is a statewide lake organization that promotes sound lake policy and provides training opportunities for lake groups throughout the state. The District should send a few members each year to the annul lakes convention, a three day event featuring numerous speakers, workshops and presentations concerning lake management, operating effective lake organizations, and current issues of concern to Wisconsin lake residents.

Aquatic Invasive Species Prevention, Monitoring and Rapid Response Plan

Locally, Marinette County is at the front lines of a rapid expansion of Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*). Even more concerning is the fact that Lake Noquebay is less than 25 miles from the Bay of Green Bay, which is home to almost every invasive aquatic species in the Midwest! The best way to deal with these invaders is to be proactive and prevent their introduction. The LNRD should also adopt an exotic species monitoring plan to detect early invasions and a rapid response plan to deal with new invasive species if they are found.

Prevention

An effective AIS prevention plan should focus on the most common routes of AIS invasion, boats, and water gardens. Boats traveling between lakes can carry plant fragments or exotic mussels attached to the boat or trailer. Water in the boat or bait buckets can carry plants, snails, mussels, zooplankton, algae, and disease causing organisms. While the information and education program can provide valuable information regarding the spread of AIS a more effective case can be made when delivering the message face-to-face.

Recommendation #1 – Participate in the "Clean Boats, Clean Waters" watercraft inspection and information program.

Volunteers should be trained to conduct watercraft inspections at Lake Noquebay public landings and talk to boaters about the danger of spreading invasive species. State grant funding is available to conducting "CBCW" watercraft inspections. Many lake organizations partner with local scout or other youth organization to conduct watercraft inspection and education programs.

Recommendation #2 – Promote/support watercraft inspection and AIS education at nearby source waters.

Studies show it is more efficient to target AIS efforts at the source waters than at the receiving water. In Marinette County the most likely source waters are Green Bay, High Falls Flowage, Cauldron Falls Flowage, and the Menominee River Flowages. The LNRD should promote and support AIS education and watercraft inspection efforts at these waters.

Recommendation #3 – Focus education efforts on the most common modes of AIS introduction.

The most important pathway for introduction of AIS is through the movement of watercraft between waterbodies. Increasingly, however, intentional and unintentional introductions have been traced to private water gardens. A recent investigation of the water garden industry found that plants known to be invasive are available and routinely shipped around the country. Contamination of orders with other species, including invasive species, is also rampant (Maki, 2004). AIS education efforts aimed at lake residents and visitors should focus on these modes of infestation.

Monitoring

Effective management of AIS is much easier when the invader is detected early. In some cases it may even be possible to eradicate an invasive species if it is discovered early enough.

Recommendation #1 – LNRD weed harvesting staff and additional volunteers should be trained to conduct aquatic invasive species monitoring.

All LNRD harvesting staff should be trained to identify aquatic invasive species. Also, while the While the information & education program should equip many District members with a basic knowledge of invasive species, interested volunteers should receive detailed training in AIS monitoring protocols.

The Marinette County LWCD in cooperation with the Citizen Lake Monitoring Network holds workshops to train volunteers in AIS monitoring protocols. Workshop participants receive instructions and materials needed to monitor for the presence of several aquatic invasive species including plants, snails, minnows, mollusks, and zooplankton.

Recommendation #2 – Volunteer AIS monitors should conduct annual AIS surveys of the lake.
Aquatic plant surveys, although very beneficial, are not designed to find many types of aquatic invaders and may even miss pioneer plant invasions. A better method is to look specifically for different invasive species at the optimal time of year and in the most likely habitats. The ideal monitoring time varies by species but can typically be covered with one early season inspection and one late season inspection.

Trained volunteers should conduct annual invasive species surveys. Findings should be reported to the District and the Citizen Lake Monitoring Network. The harvesting crew should carry AIS identification material on the harvesters and marker buoys that can be quickly deployed to mark suspicious plants.

Recommendation #3 – Report any suspected aquatic invasive species to local resource professionals. If any suspected exotic species are found report it immediately to the Peshtigo DNR office or the County LWCD. Collect a sample of the invasive species for positive identification. And mark or record the location of suspect plants.

Rapid Response

When a new invasive species is positively identified the District needs to act quickly. Depending on the species found, length of time since invasion, and where the pioneer colony is found, there may be a possibility for eradication. The following steps should be followed:

Step #1 – Notify LNRD Board and local resource agencies and explore grant funding opportunities. The District Board should immediately arrange a meeting with the Wisconsin DNR to explore control measures and determine if obtaining an AIS Rapid Response grants is appropriate. These grants were designed to deal with pioneer AIS infestations. The typical grant application process is bypassed so grant funds can be made available within weeks in hopes of eradication.

Step #2 – Notify membership of the discovery and what the Board plans to do about it. Notify Lake District members of the discovery and advise them of any measures they can take to prevent its further spread within the lake or to other waters. Let them know how the Board plans on dealing with the invasion.

Step #3 – Conduct a thorough survey of the lake to determine the extent of the AIS infestation. Working with County LWCD or DNR staff, conduct a thorough survey of the lake. Map location of the invasive species and record its density as well as any other physical data that may be important such as water depth, sediment type etc.

Step #4 – Determine if eradication is a possibility or if management is the only option. Work with local resource agencies and outside experts where necessary to determine if eradication is possible. Where eradication is not feasible begin revising the lake management plan to deal with the new species.

Step #5 – Develop an action plan based on species and extent of invasion. Work closely with the experts to develop a customized plan aimed at eradication or control. If outside consultants are needed for things like herbicide treatment or scuba diving bring them into the process. Many consultants can also help with things like mapping and planning.

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Comprehensive Lake Management Plan
For
Lake Noquebay

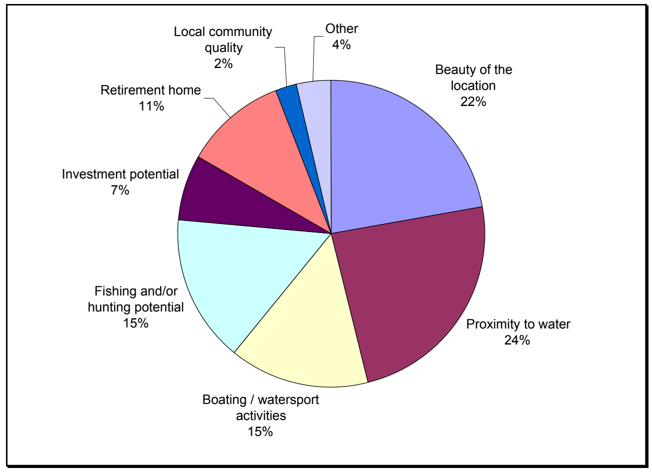
APPENDIX A

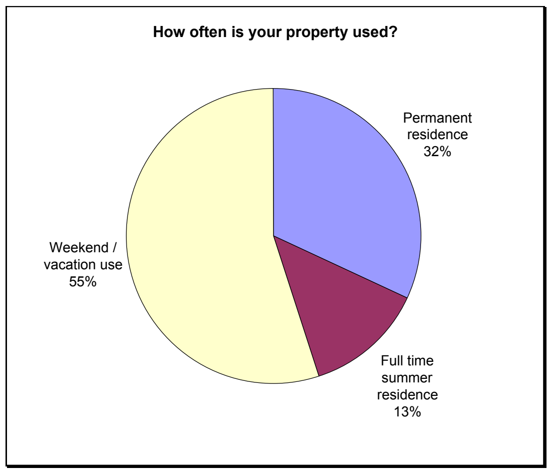
Landowner Survey Results

#1. Which reasons best describe why you purchased your Lake Noquebay property?

	Reason	Number 1st	2nd	3rd	Percent 1st cl	2nd cl	3rd choice
A.	Beauty of the location	58	41	37	26%	19%	17%
B.	Proximity to water	58	57	23	26%	26%	11%
C.	Boating/watersport activities	21	40	52	9%	18%	25%
D.	Fishing and/or hunting potential	25	45	37	11%	21%	17%
E.	Investment potential	16	12	20	7%	6%	9%
F.	Retirement home	29	16	23	13%	7%	11%
G.	Local Community quality	3	3	16	1%	1%	8%
H.	Other	12	3	4	5%	1%	2%
	Sum	222	217	212			

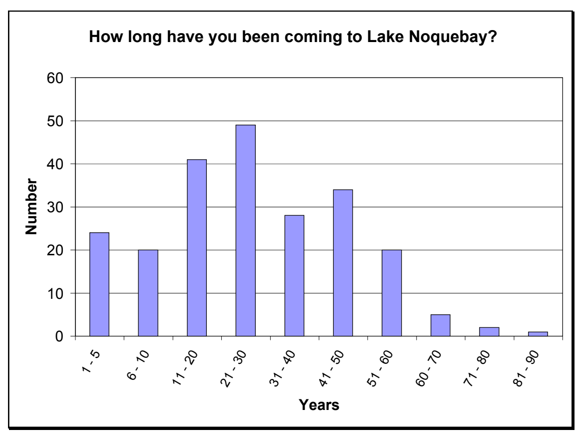
	Reason		
A.	Beauty of the location	293	22%
B.	Proximity to water	311	24%
C.	Boating/watersport activities	195	15%
D.	Fishing and/or hunting potential	202	15%
E.	Investment potential	92	7%
F.	Retirement home	142	11%
G.	Local Community quality	31	2%
H.	Other	46	4%
	Sum	1312	





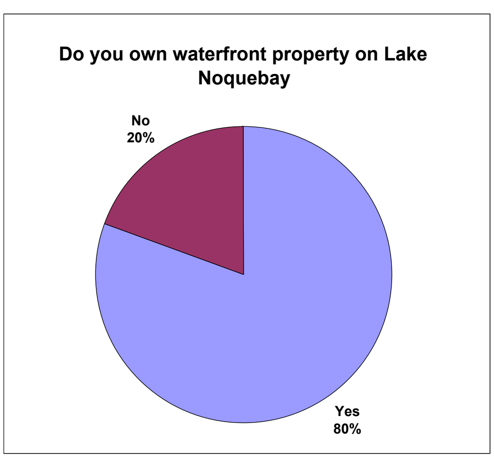
#2. How often is your property used?

		NUMBER	PERCENT
A.	Year round (perm. residence)	72	32%
B.	Full time summer residence	30	13%
C.	Weekend/vacation use (approx. __ days/year)	124	55%
	Sum	226	



#3. How long have you been coming to Lake Noquebay?

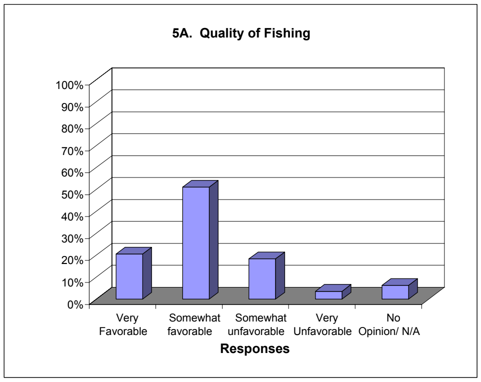
Average= 29 years



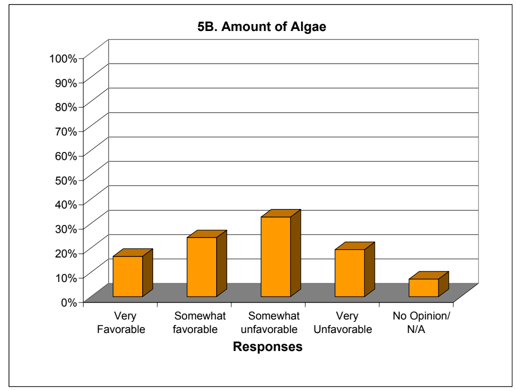
#4. Do you own waterfront property on Lake Noquebay?

Yes 79%
No 19%

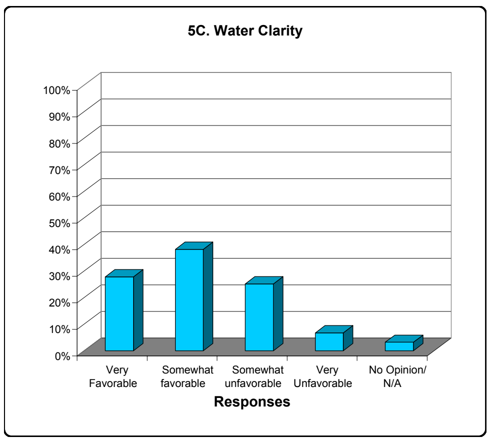
#5. How favorable or unfavorable do you percieve the following issues or concerns regarding Lake Noquebay?



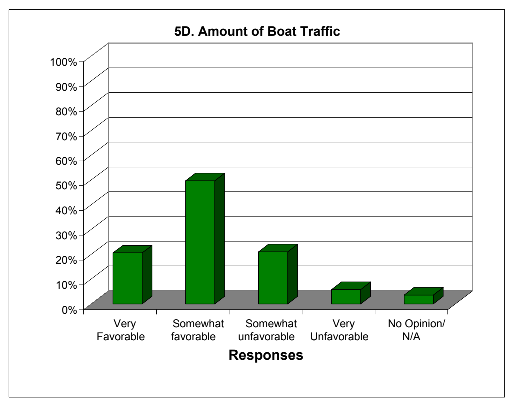
A.	Quality of Fishing	
	Very Favorable	21%
	Somewhat favo	51%
	Somewhat unfa	18%
	Very Unfavorab	4%
	No Opinion/ N/	6%



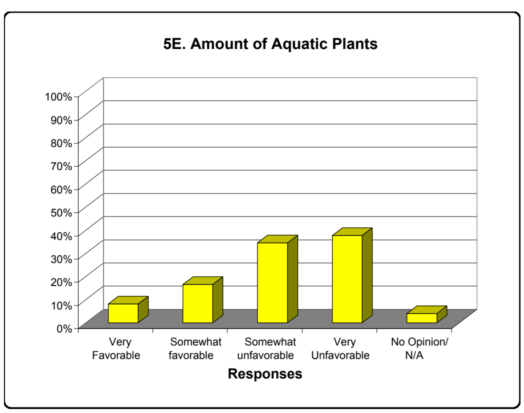
B.	Amount of algae	
	Very Favorable	17%
	Somewhat favo	24%
	Somewhat unfa	33%
	Very Unfavorab	19%
	No Opinion/ N/	7%



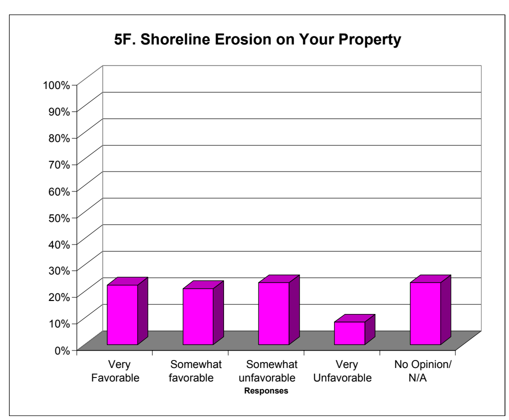
C.	Water Clarity	
	Very Favorable	28%
	Somewhat favo	38%
	Somewhat unfa	25%
	Very Unfavorab	7%
	No Opinion/ N/	3%



D.	Amount of boat traffic	
	Very Favorable	21%
	Somewhat favo	50%
	Somewhat unfa	21%
	Very Unfavorab	6%
	No Opinion/ N/	4%



E.	Amount of aquatic plants	
	Very Favorable	8%
	Somewhat favo	17%
	Somewhat unfa	35%
	Very Unfavorab	38%
	No Opinion/ N/	4%

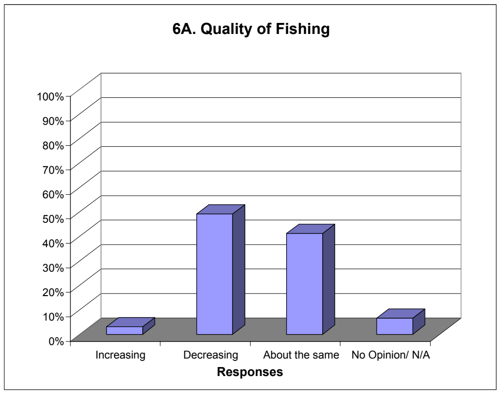


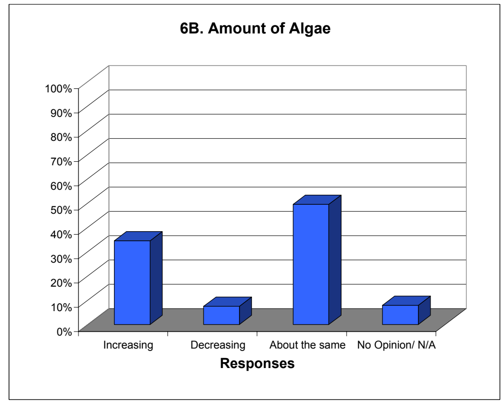
F.	Shoreline erosion on your property	
	Very Favorable	22%
	Somewhat favo	21%
	Somewhat unfa	23%
	Very Unfavorab	9%
	No Opinion/ N/	23%

#6. Would you say each of the following relating ot Lake Noquebay is "increasing", "decreasing", or staying "about the same"?

A. Quality of Fishing

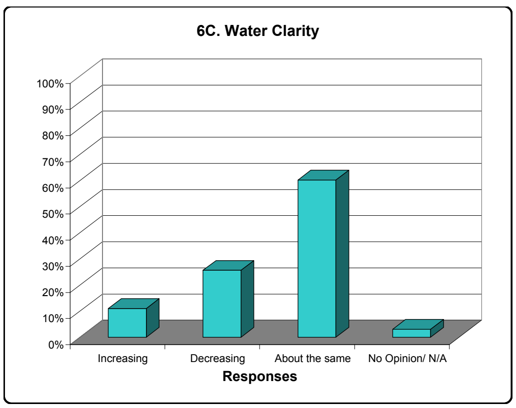
Increasing	3%
Decreasing	49%
About the same	41%
No Opinion/ N/A	7%





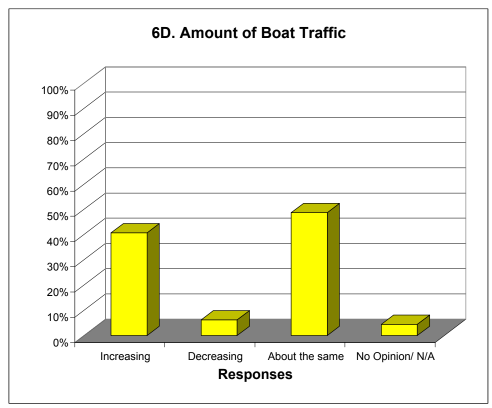
B. Amount of algae

Increasing	35%
Decreasing	8%
About the same	50%
No Opinion/ N/A	8%



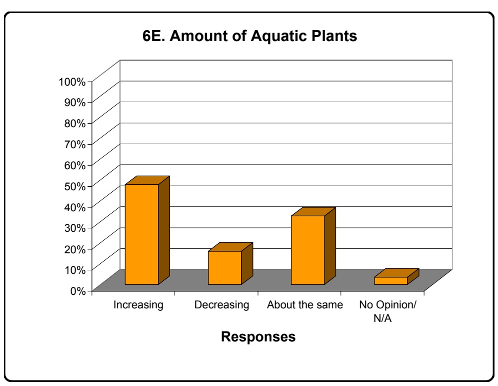
C. Water clarity

Increasing	11%
Decreasing	26%
About the same	60%
No Opinion/ N/A	3%



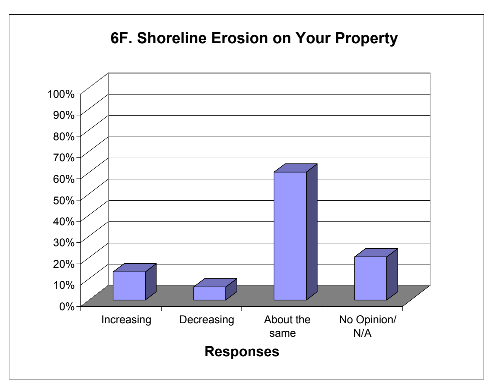
D. Amount of boat traffic

Increasing	41%
Decreasing	6%
About the same	49%
No Opinion/ N/A	4%



E. Amount of aquatic plants

Increasing	48%
Decreasing	16%
About the same	33%
No Opinion/ N/A	4%

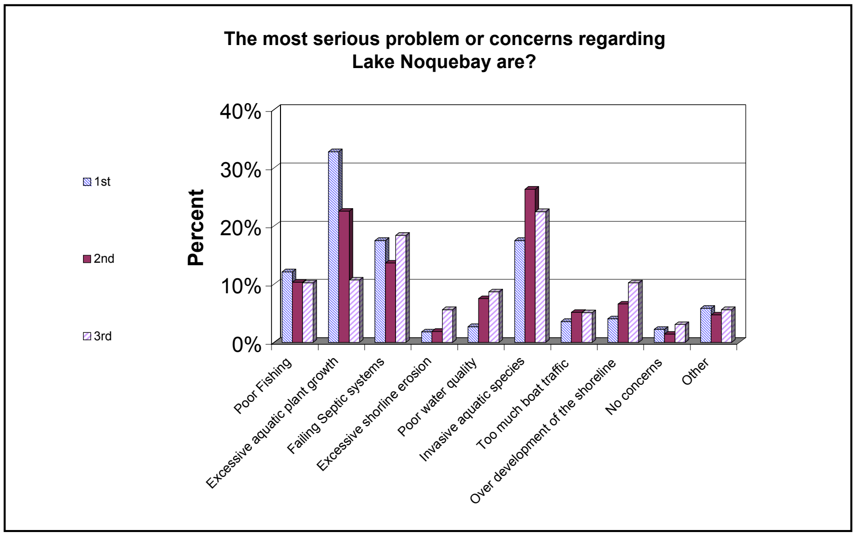


F. Shoreline erosion on your property

Increasing	13%
Decreasing	6%
About the same	60%
No Opinion/ N/A	20%

#7 The most serious problem or concerns regarding Lake Noquebay are? (Top 3, in order)

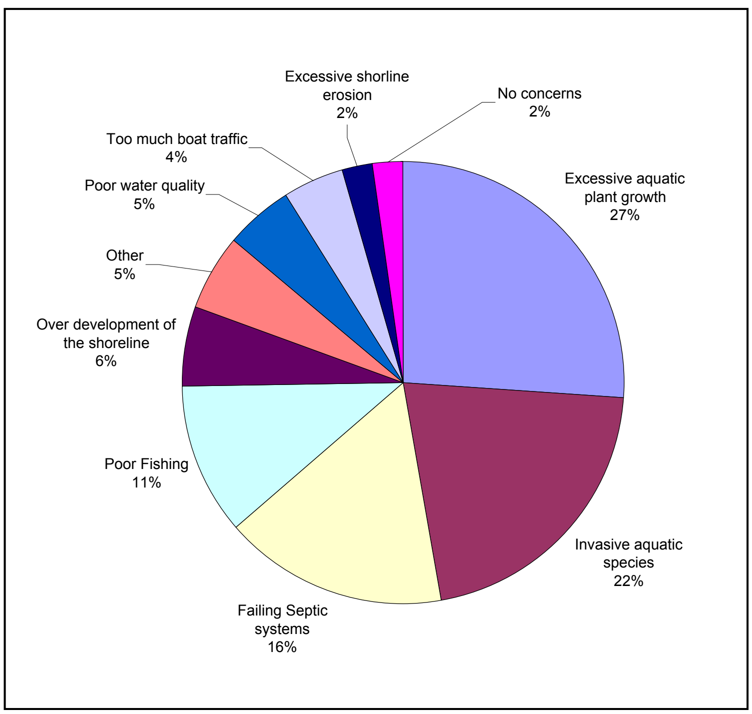
		1st	2nd	3rd	1st	2nd	3rd
A.	Poor Fishing	27	22	20	12%	10%	10%
B.	Excessive aquatic plant growth	73	48	21	33%	23%	11%
C.	Failing Septic systems	39	29	36	17%	14%	18%
D.	Excessive shorline erosion	4	4	11	2%	2%	6%
E.	Poor water quality	6	16	17	3%	8%	9%
F.	Invasive aquatic species	39	56	44	17%	26%	22%
G,	Too much boat traffic	8	11	10	4%	5%	5%
H.	Over development of the shoreline	9	14	20	4%	7%	10%
I.	No concerns	5	3	6	2%	1%	3%
J.	Other	13	10	11	6%	5%	6%
	Sum	**223**	**213**	**196**			



The most serious problem or concerns regarding Lake Noquebay are? (Top 3, in order)

		Number			Weighted score				
		1st	2nd	3rd	1st	2nd	3rd	Sum	
A.	Poor Fishing	27	22	20	81	44	20	145	**11%**
B.	Excessive aquatic plant growth	73	48	21	219	96	21	336	**26%**
C.	Failing Septic systems	39	29	36	117	58	36	211	**16%**
D.	Excessive shorline erosion	4	4	11	12	8	11	31	**2%**
E.	Poor water quality	6	16	17	18	32	17	67	**5%**
F.	Invasive aquatic species	39	56	44	117	112	44	273	**21%**
G,	Too much boat traffic	8	11	10	24	22	10	56	**4%**
H.	Over development of the shoreline	9	14	20	27	28	20	75	**6%**
I.	No concerns	5	3	6	15	6	6	27	**2%**
J.	Other	13	10	11	39	20	11	70	**5%**
							Sum	**1291**	

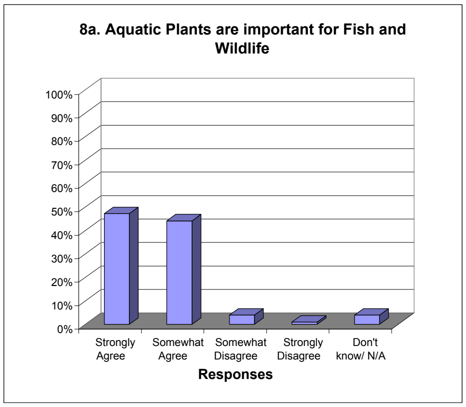
Excessive aquatic plant growth	**26%**
Invasive aquatic species	**21%**
Failing Septic systems	**16%**
Poor Fishing	**11%**
Over development of the shoreline	**6%**
Other	**5%**
Poor water quality	**5%**
Too much boat traffic	**4%**
Excessive shorline erosion	**2%**
No concerns	**2%**



#8 How much do you agree or disagree with the following statements regarding aquatic plants in Lake Noquebay?

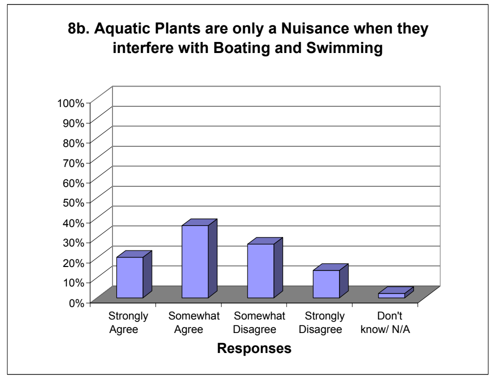
A. Aquatic plants are important for fish and wildlife

Strongly Agree	47%
Somewhat Agree	44%
Somewhat Disagree	4%
Strongly Disagree	1%
Don't know/ N/A	4%



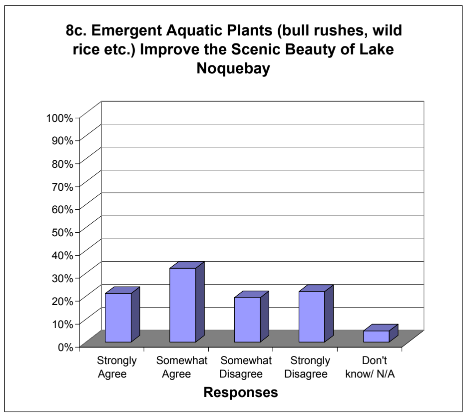
B. Aquatic plants are only a nuisance when they interfere with boating and swimming

Strongly Agree	20%
Somewhat Agree	36%
Somewhat Disagree	27%
Strongly Disagree	14%
Don't know/ N/A	2%



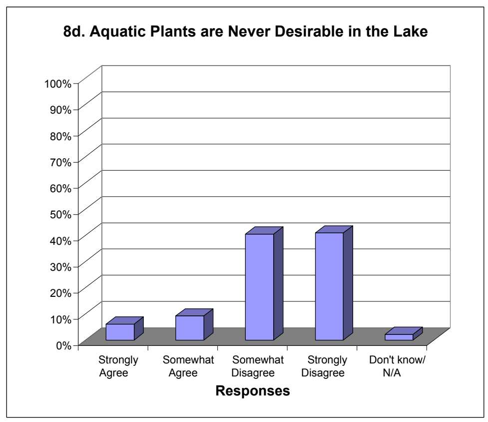
C. Emergent aquatic plants (bull rushes, wild rice etc.) improve the scenic beauty of Lake Noquebay

Strongly Agree	21%
Somewhat Agree	32%
Somewhat Disagree	19%
Strongly Disagree	22%
Don't know/ N/A	5%



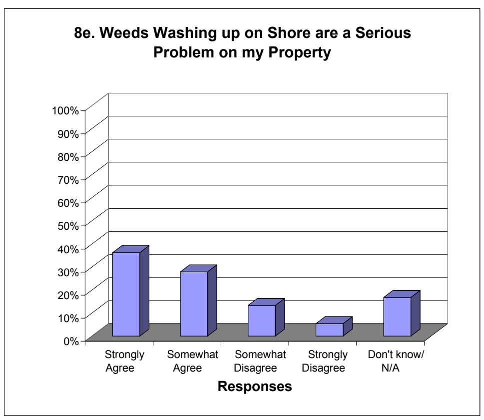
D. Aquatic plants are never desirable in the lake

Strongly Agree	6%
Somewhat Agree	9%
Somewhat Disagree	41%
Strongly Disagree	41%
Don't know/ N/A	2%



E. Weeds washing up on shore are a serious problem on my property

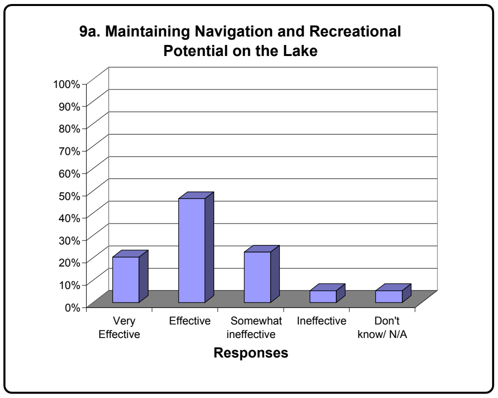
Strongly Agree	36%
Somewhat Agree	28%
Somewhat Disagree	13%
Strongly Disagree	5%
Don't know/ N/A	17%



#9 How effective to you feel the current harvesting program is regarding each of the following?

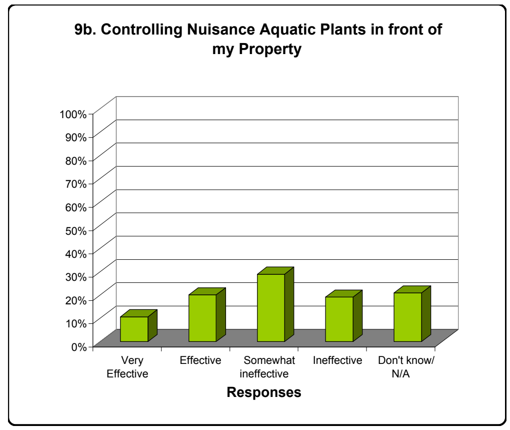
A. Maintaining navigation and recreational potential on the lake

Very Effective	20%
Effective	46%
Somewhat ineffective	23%
Ineffective	5%
Don't know/ N/A	5%



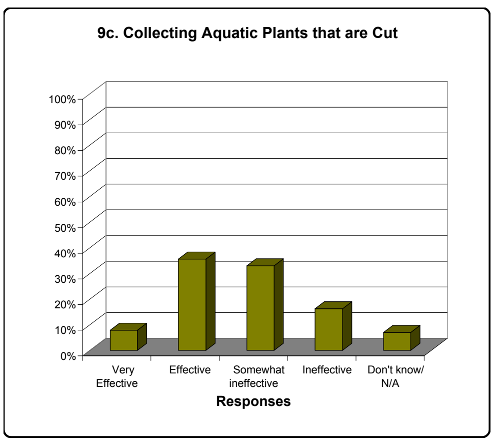
B. Controlling nuisance aquatic plants in front of my property

Very Effective	11%
Effective	20%
Somewhat ineffective	29%
Ineffective	19%
Don't know/ N/A	21%



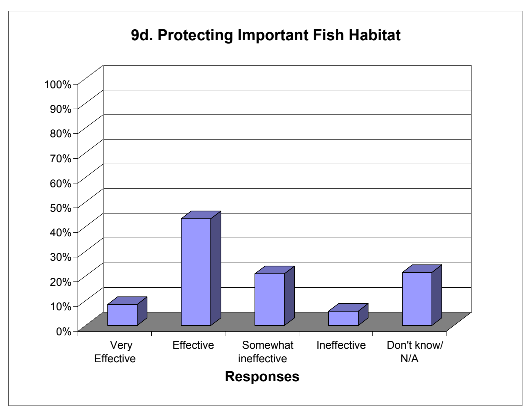
C. Collecting aquatic plants that are cut

Very Effective	8%
Effective	36%
Somewhat ineffective	33%
Ineffective	16%
Don't know/ N/A	7%



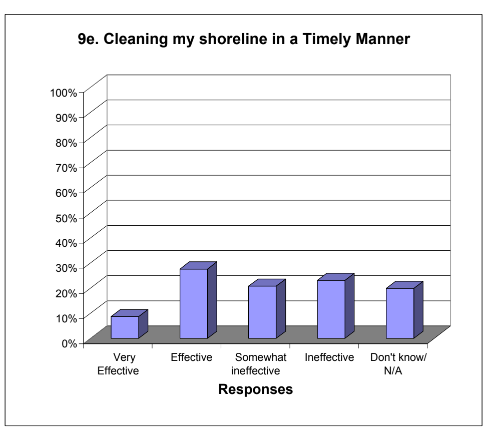
D. Protecting important fish habitat

Very Effective	8%
Effective	43%
Somewhat ineffective	21%
Ineffective	6%
Don't know/ N/A	21%



E. Cleaning my shoreline in a timely manner

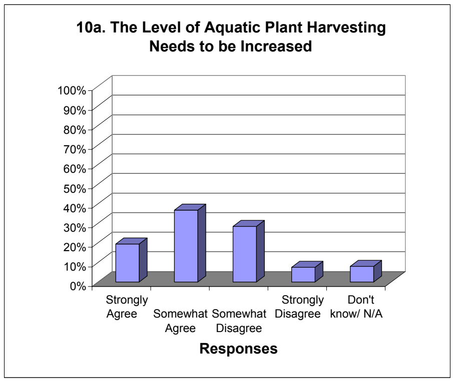
Very Effective	9%
Effective	28%
Somewhat ineffective	21%
Ineffective	23%
Don't know/ N/A	20%



#10 How much do you agree or disagree with the following statements regarding aquatic plant management on Lake Noquebay?

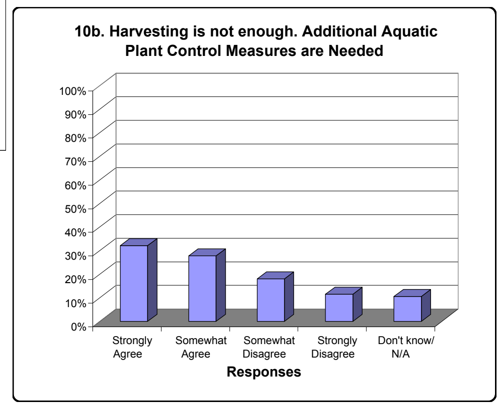
A. The level of aquatic plant harvesting needs to be increased

Strongly Agree	19%
Somewhat Agree	37%
Somewhat Disagree	28%
Strongly Disagree	8%
Don't know/ N/A	8%



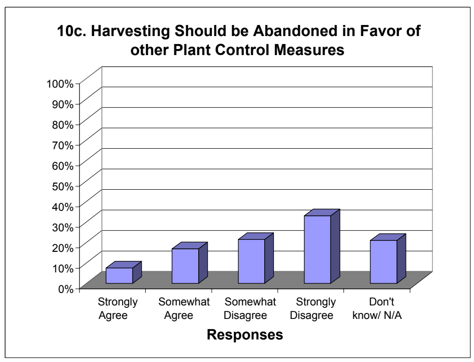
B. Harvesting is not enough. Additional aquatic plant control measures are needed

Strongly Agree	32%
Somewhat Agree	28%
Somewhat Disagree	18%
Strongly Disagree	11%
Don't know/ N/A	11%



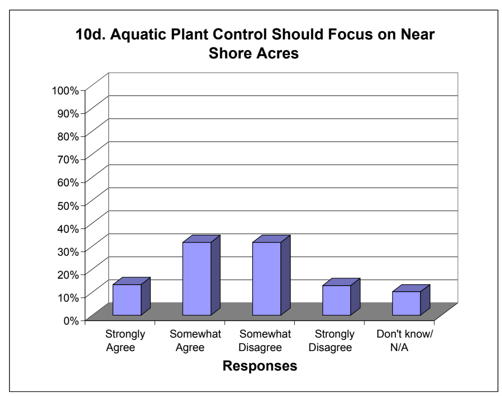
C. Harvesting should be abandoned in favor of other plant control methods

Strongly Agree	8%
Somewhat Agree	17%
Somewhat Disagree	21%
Strongly Disagree	33%
Don't know/ N/A	21%



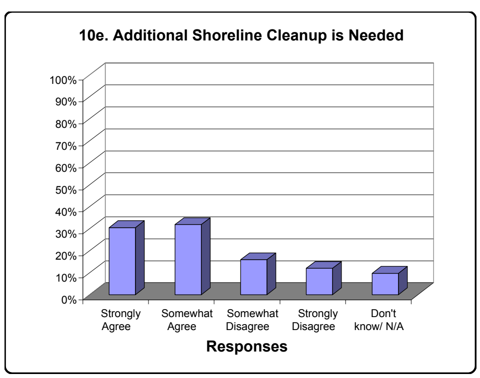
D. Aquatic plant control should focus more on near shore acres

Strongly Agree	13%
Somewhat Agree	32%
Somewhat Disagree	32%
Strongly Disagree	13%
Don't know/ N/A	10%



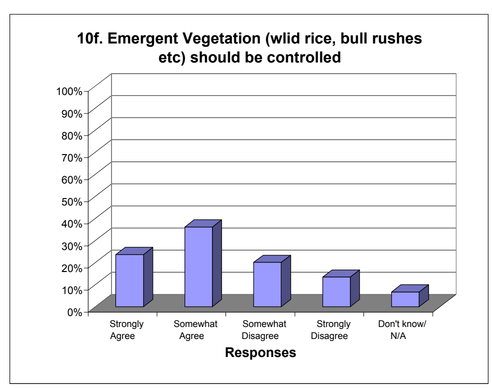
E. Additional shoreline cleanup is needed

Strongly Agree	31%
Somewhat Agree	32%
Somewhat Disagree	16%
Strongly Disagree	12%
Don't know/ N/A	10%



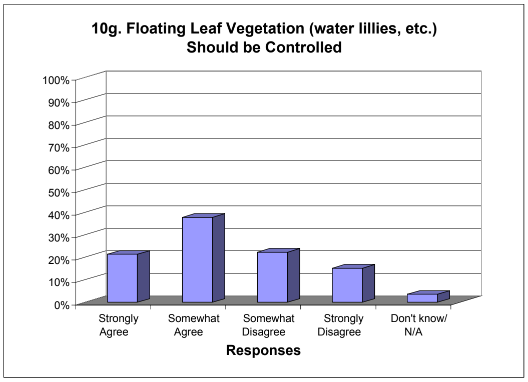
F. Emergent vegetation (wild rice, bull rushes etc.) should be controlled

Strongly Agree	24%
Somewhat Agree	36%
Somewhat Disagree	20%
Strongly Disagree	13%
Don't know/ N/A	7%



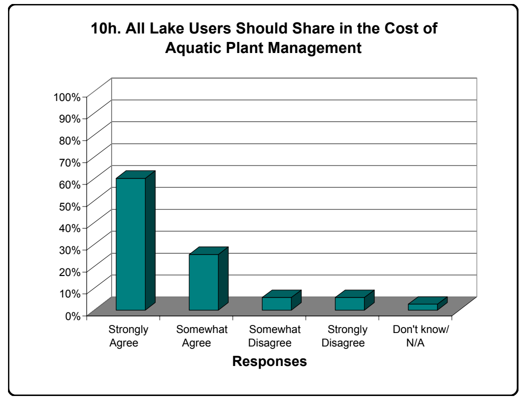
G. Floating leaf vegetation (water lillies, etc.)
should be controlled

Strongly Agree	21%
Somewhat Agree	38%
Somewhat Disagree	22%
Strongly Disagree	15%
Don't know/ N/A	4%

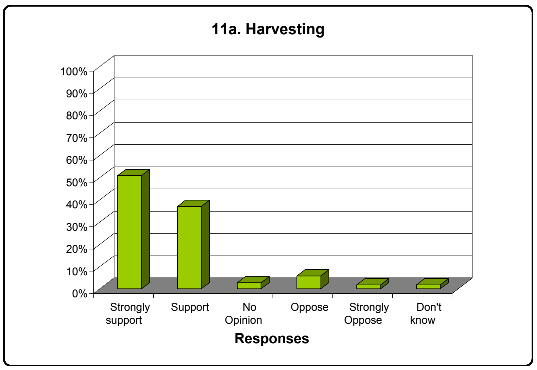


H. All lake users should share in the cost
of aquatic plant management

Strongly Agree	60%
Somewhat Agree	25%
Somewhat Disagree	6%
Strongly Disagree	6%
Don't know/ N/A	3%

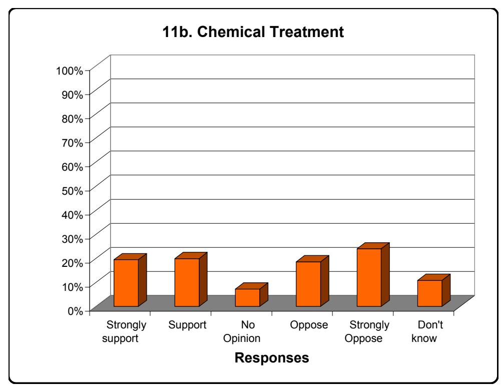


#11 To what extent do you support or oppose the following aquatic plant management efforts?



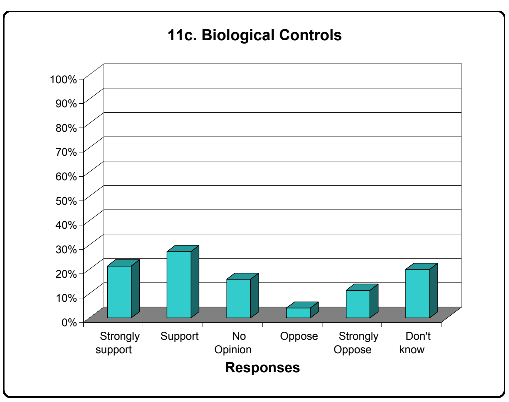
A. Harvesting

Strongly suppo	51%
Support	37%
No Opinion	3%
Oppose	6%
Strongly Oppos	2%
Don't know	2%



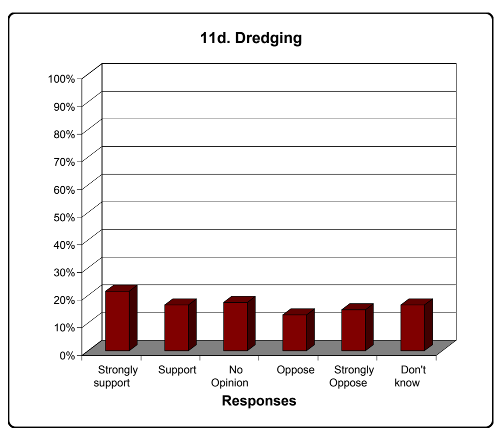
B. Chemical treatment

Strongly suppo	19%
Support	20%
No Opinion	7%
Oppose	19%
Strongly Oppos	24%
Don't know	11%



C. Biological controls

Strongly suppo	21%
Support	27%
No Opinion	16%
Oppose	4%
Strongly Oppos	11%
Don't know	20%

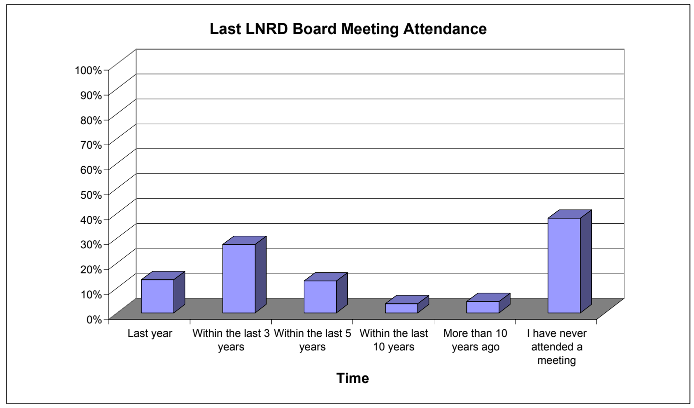


D. Dredging

Strongly suppo	22%
Support	17%
No Opinion	17%
Oppose	13%
Strongly Oppos	15%
Don't know	17%

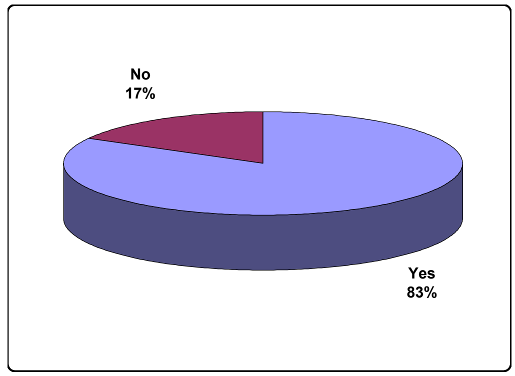
#16 When was the last time you attended a Lake Noquebay Rehabilitation District boad meeting or annual meeting?

A.	Last year	13%
B.	Within the last 3 years	28%
C.	Within the last 5 years	13%
D.	Within the last 10 years	4%
E.	More than 10 years ago	5%
F.	I have never attended a meeting	38%



#17 Should Lake Noquebay have a Lake Association that could promote, support, and participate in other activities to protect and improve Lake Noquebay?

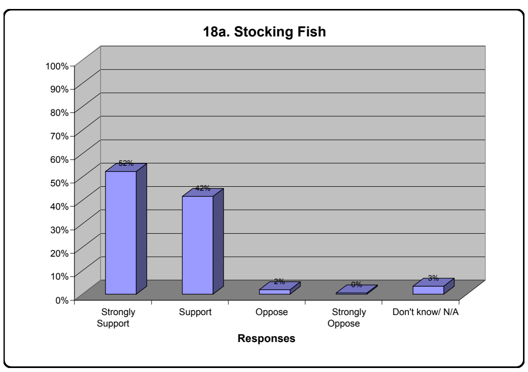
Yes 157
No <u>32</u>



#18 Please indicate your level of support for the following activities/programs/projects to protect and improve Lake Noquebay

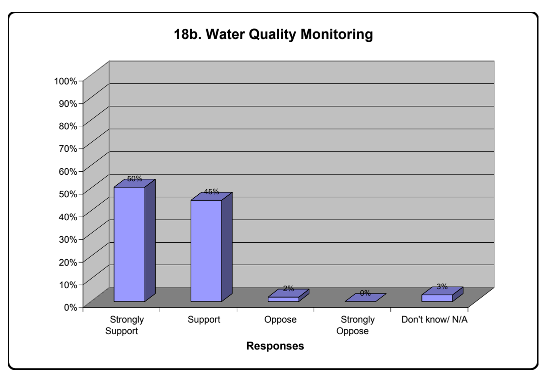
A. Stocking Fish

Strongly Support	52%
Support	42%
Oppose	2%
Strongly Oppose	0%
Don't know/ N/A	3%



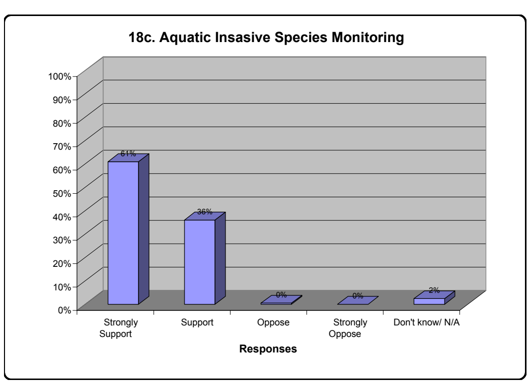
B. Water quality monitoring

Strongly Support	50%
Support	45%
Oppose	2%
Strongly Oppose	0%
Don't know/ N/A	3%



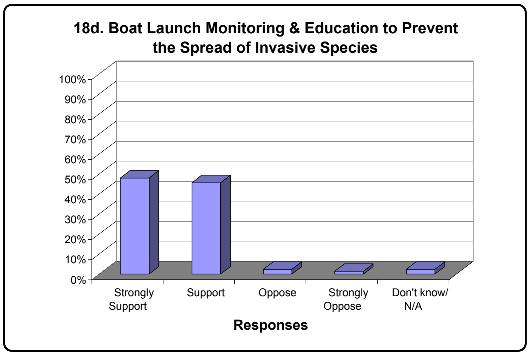
C. Aquatic invasive species monitoring

Strongly Support	61%
Support	36%
Oppose	0%
Strongly Oppose	0%
Don't know/ N/A	2%



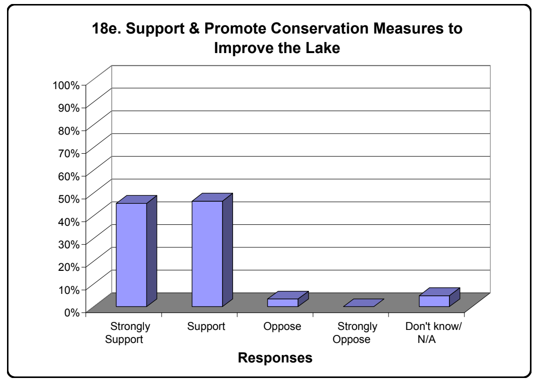
D. Boat launch monitoring & education to prevent the spread of invasive species

Strongly Support	48%
Support	46%
Oppose	2%
Strongly Oppose	1%
Don't know/ N/A	2%



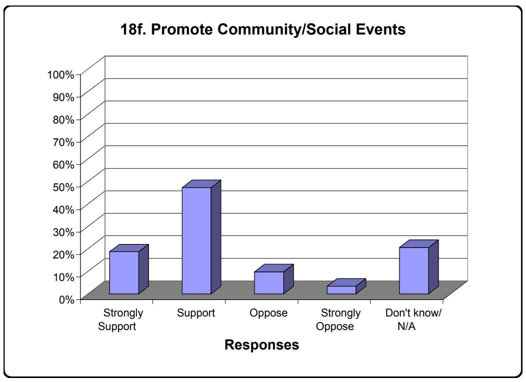
E. Support & promote conservation measures to improve the lake

Strongly Support	45%
Support	46%
Oppose	3%
Strongly Oppose	0%
Don't know/ N/A	5%



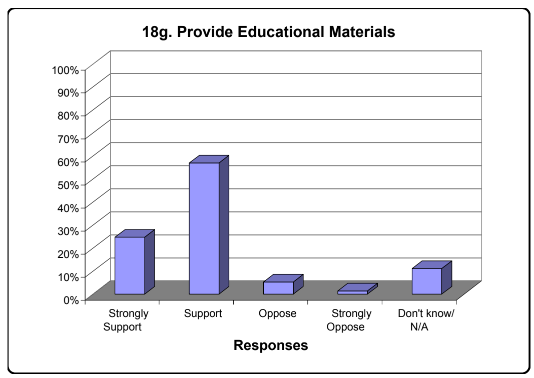
F. Promote community/social events

Strongly Support	19%
Support	47%
Oppose	10%
Strongly Oppose	3%
Don't know/ N/A	21%



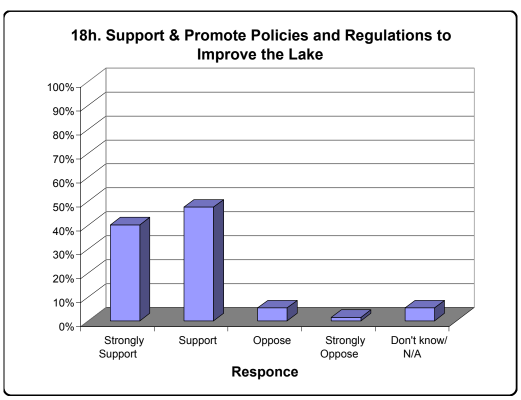
G. Provide educational materials

Strongly Support	25%
Support	57%
Oppose	5%
Strongly Oppose	1%
Don't know/ N/A	11%



H. Support & promote policies and regulations to improve the lake

Strongly Support	40%
Support	48%
Oppose	5%
Strongly Oppose	1%
Don't know/ N/A	5%



Comprehensive Lake Management Plan
For
Lake Noquebay

APPENDIX B

WDNR Critical Habitat Designation Report

Lake Noquebay Critical Habitat Designation Report

Site Evaluators:	Greg Sevener: Watershed Specialist	
	Justine Hasz/Tom Meronek: Fish Managers	
	John Huff : Wildlife Biologist	
	Robert Rosenberger: Water Management Specialist	
	Chuck Druckrey: Marinette County Water Resource Specialist	
Authors:	Andrew Sabai: Critical Habitat Coordinator	
	Greg Sevener: Watershed Specialist	
	Michael Donofrio: Fisheries Supervisor	
Contact:	Greg Sevener: Watershed Specialist	715-582-5013
	Andrew Sabai: Critical Habitat Coordinator	920-303-5442

Lake Noquebay Critical Habitat Designation Report

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Lake Noquebay Critical Habitat Designation Report

Lake Noquebay (WBIC 525900) is located in southern Marinette County in Middle Inlet Township and Town of Lake. The lake covers 2,409 acre with a shoreline of 9.83 mi and a maximum depth of 51 ft. It has been designated as an Area of Special Natural Resource Interest. Three named streams flow into the lake, the Upper Inlet (WBIC 530100), and the trout streams, the Lower Middle Inlet (WBIC 529100). Drainage of the lake is regulated by a 7.3 foot high dam at The Outlet (WBIC 525500) at the southwestern corner of the lake.

Many species of wildlife make Lake Noquebay their home including species listed as threatened or of special concern by the Department of Natural Resources. Birds that utilize the lake include the Black Tern, Bald Eagle, and Osprey. A species of special concern, the Blanding's turtle has been found near the lake.

Lake Noquebay has a diverse aquatic plant community with many species that are of high value to fish and wildlife. Currently it is free of the invasive species Eurasian water-milfoil (*Myriophyllum spicatum* and Curly-leaf pondweed (*Potamogeton crispus*). The native species various-leaved water-milfoil (*Myriophyllum heterophyllum*) has been invasive since it became established in the lake. Farwell's water-milfoil (*Myriophyllum farwellii*) is listed by the DNR as a species of special concern is found in the lake. The harvest of Wild Rice is regulated on the lake. Lake Noquebay has many areas of bulrush beds that are in need of protection.

Table 1. High Value species listed under NR 107 found in sensitive areas and public rights features on Lake Noquebay.

Eleocharis sp.	Spike-rush sp.
Potamogeton amplifolius	Large-leaf pondweed
Potamogeton illinoensis	Illinois pondweed
Potamogeton pectinatus	Sago Pondweed
Potamogeton richardsonii	Clasping-leaf pondweed
Potamogeton robbinsii	Fern pondweed
Schoenoplectus sp.	Bulrush sp.
Vallisneria americana	Wild celery
Zizania aquatica	Wild rice

Fishery

The Marinette County Land & Water Conservation is responsible for the operation and maintenance of Lake Noquebay Dam located in the Town of Lake in the southeast corner of the lake. The Lake Noquebay Dam was constructed in 1929. It consists of an earthen embankment with concrete and steel sing walls on the upstream face.

The Lake Noquebay Rehabilitation District performs the daily operation and water level adjustments under a contract with the Land & Water Conservation. Water levels in the lake are held between 666.2 feet and 666.6 feet of elevation except during the draw down period. Between October 15 and spring ice out, the lake is drawn down to 664.95 feet. Lake Noquebay is drawn down to prevent shoreline erosion due to ice movement and as a control measure for Variable Leaf Milfoil (*Myriophyllum heterophyllum*).

Lake Noquebay supports a very good panfish population which provides the major emphasis of the fishery. A 1982 creel survey revealed 87% of the angler catch was panfish. The next creel survey will be in 2010. The lake also contains gamefish species of largemouth bass, northern pike, walleye and muskellunge. Since it's the largest lake in Marinette county and only an hour drive from Green Bay, Noquebay receives heavy fishing pressure throughout the year.

This lake is routinely surveyed by WDNR fishery staff. The last comprehensive fishery survey occurred in 1996 and the next one is scheduled for 2009. In 1996, during spring netting, we caught 330 walleye from 9.2 to 27.2 inches and mean size of 16.8 inches; 612 northern pike from 8.2 to 37.2 inches and mean size of 16.0 inches; 345 bluegill with a size range of 3.6 to 9.4 inches and mean size of 5.5 inches; and 62 largemouth bass ranging from 5.7 to 18.7 inches and average size of 14.7 inches. The above facts demonstrated a balanced fishery in 1996 but 13 years have elapsed and this year's survey will either confirm that status or reveal the need for management changes. During the 1996 survey, we did not catch any muskellunge and they have been stocked annually since then so the 2009 survey should yield that species and related impacts on the fishery communities as well as other impacts from angler harvest.

Critical Habitat Designation Program

The Critical Habitat Designation Program was created to identify and provide protection for areas of lakes and streams that provide important fish and wildlife habitat, water quality and quantity protection, navigational routes, and natural scenic beauty. The department of natural resources is given the authority to make Critical Habitat Designations (CHD) under NR 105 and NR 107. It provides waterfront property owners with information that will help them protect the health of waterways where they live, and recreate. The identified areas are often locations of valuable fish spawning habitat, diverse aquatic plant communities, springs that provide water flow, and natural shorelines.

Critical Habitat Designations affect lake front landowners with critical habitat in front of their shoreline. There are no prohibitions of activities within CHD. However, the DNR will work with the landowners through a permit process to minimize the impact of activities such as, aquatic plant removal, pier installations, and shore protection. For example if a lake front property owner wants to place a pier within a CHD. DNR Staff would work with the property owner to design the pier in a manner that does not adversely impact the area. This may mean the pier extends to a greater depth out past a high quality fish spawning area or the pier is positioned to one side of the property where the impact would be the least.

Critical Habitat Designations fall into two categories. The first is a Sensitive Area Designation (SAD). Sensitive Area designations are made to protect aquatic plants that are sensitive to human disturbance. Aquatic plants are vital to maintain water quality, and healthy fish and wildlife populations. The second category is a Public Rights Feature (PRF). These identify areas of a water body that are important for fish, wildlife, navigation, scenic beauty, and have features that protect water quality.

Lake Noquebay Critical Habitat Designations

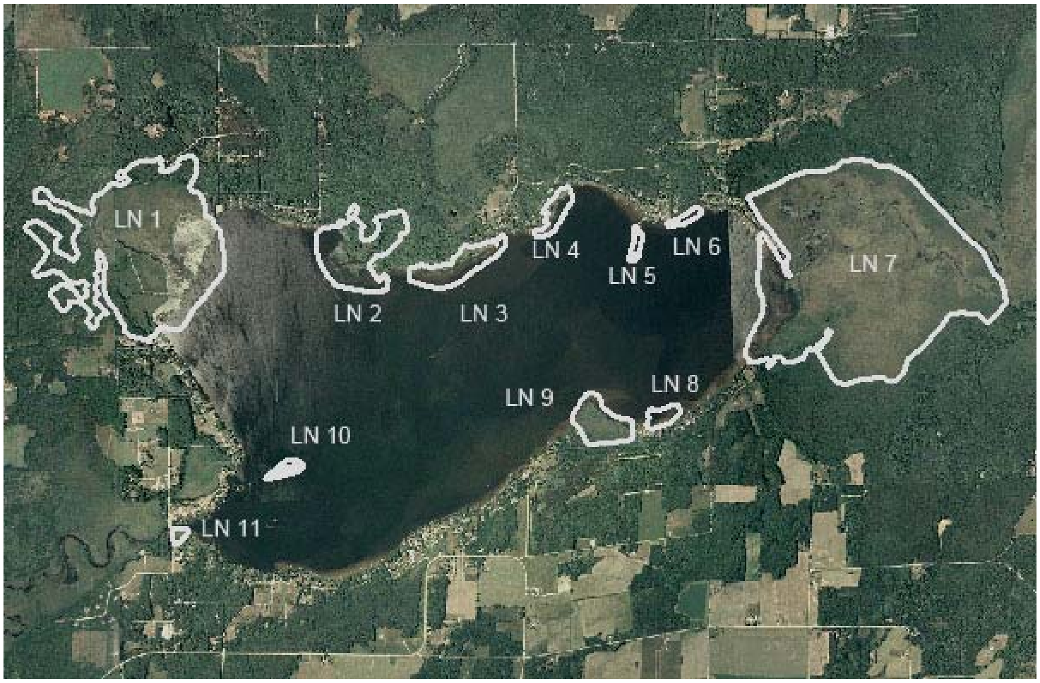


Figure 1. Lake Noquebay Critical Habitat Designations

Sensitive Area Designation LN1

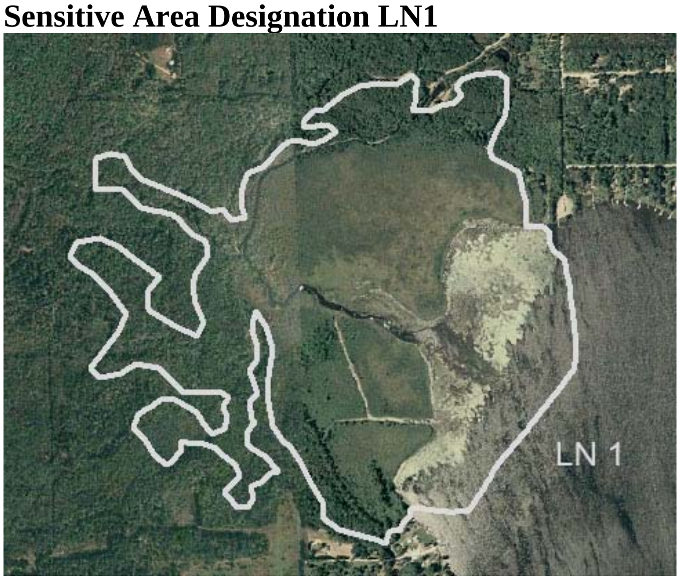


Figure 2: LN 1 aerial view

This site is located in the northwest corner of the lake. Several habitats are found within the sensitive area including the Lower Middle Inlet flowing through the area into the lake

lake. LN1 includes undeveloped areas bordered by on the northeast by an unnamed stream (river system WBIC 5007111) and residential lakefront properties to the south.

This site was selected because of its diverse and undisturbed habitats that benefit fish, wildlife, water quality, and the scenic beauty of Lake Noquebay. LN1 includes the riparian area which is 100% wetland and the adjacent littoral zone. The only significant human disturbance is a manmade channel through the marsh that intersects the Lower Middle Inlet and the lake.

The combined habitats are important for nesting and feeding areas for song birds and waterfowl. The black tern has been known to nest within the littoral zone. The habitats are also used by furbearers, macro invertebrates (insects), amphibians and reptiles. This area is a possible spawning area for black crappie, northern pike, and muskellunge. Submergent plants provide nurseries for game fish and forage areas for adults. The aquatic plant community provides a physical buffer zone that prevents shoreline erosion, enhances lake sediment stabilization, and reduces the likelihood of exotic invasions and affords protection of black tern nesting area.

The Lower Middle Inlet is a classified as an exceptional resource water and a class I trout stream. It provides the lake with a source of clear cold water. This influx of cold water provides temperature fluctuations which can increase biodiversity.

Management Recommendations

Protect emergent vegetation.
No aquatic plant harvest.
Recommend no-wake zone.

Sensitive Area Designation LN 2

Figure 3. LN 2 aerial and water views

This site on the northern shore of the lake includes habitats within the lakes littoral zone and the Middle Inlet, which is surrounded by wetland area. Middle Inlet is classified as class I trout water and a designated outstanding resource water upstream of CTH X and downstream flowing into Lake Noquebay it is a class II trout and smallmouth bass stream. The Middle Inlet provides the lake with cold water and increases the diversity of the lake. Brown trout that overwinter in the lake come from this stream. Ice conditions in this area are always treacherous.

Within this sensitive area are areas of sand, silt, and muck substrates. Large woody cover is present along the shoreline and provides fish habitat. Submergent and emergent plants provide spawning, nursery and forage areas for game fish and forage fish. Wild rice is abundant and important waterfowl food.

Management Recommendations LN 2

Do not remove fallen trees along shoreline.
Maintain current habitat
Maintain snag trees / cavity trees
Protect emergent vegetation

Sensitive Area Designation LN 3

Figures 4 and 3. LN 3 areal and water views

LN3 is located on central part of the north shore of Lake Noquebay is bordered by a dredge channel and includes a sedge meadow. Bulrushes dominate the aquatic plant community and along with wild rice provide important waterfowl foods.

The substrate is sand. Yellow perch utilize the common large woody cover along the shoreline. The area is also important spawning area for centrarchid fish.

Management Recommendations LN 3

Aquatic vegetation removal allowed only to maintain a 30 foot navigational channel to docks.

Sensitive Area Designation LN 4

Figure 5. LN 4 aerial view

This sensitive area is located in the north central area of the lake. The shore line is composed of wetland. A unique feature of this sensitive area is that it is bordered by a steep drop off to 15 feet of water.

This area provides an excellent spawning ground for centrarchid fish and yellow perch.

The emergent vegetation consists of abundant bulrush and bur-reed, both important sources of waterfowl and muskrat food. Wild rice is also growing in the area. The submergent vegetation is dominated by *Potamogeton* species and *Myriophyllum heterophyllum.* The high value aquatic plants *Potamogeton richardsonii* and *P. robbinsii* are common here.

<u>Management Recommendations LN 4</u>

Do not remove fallen trees along shoreline.
Aquatic vegetation harvest allowed only to maintain a 30 foot navigational channel to docks.

Public Rights Feature LN 5

Figures 6 and 7. LN 5 aerial view and island.

This area is located around East Island in the northeastern part of the lake. The primary reason for this designation is for fish habitat preservation. This is the primary site for walleye spawning on the lake. The site is also benefits the lakes small mouth bass fishery which is much smaller than in the past. The substrate around the island is primarily rubble and gravel. Aquatic plants are mostly found south and east of the island.

Management Recommendations LN 5

No alteration of littoral zone unless to improve spawning habitat.
Aquatic vegetation removal allowed only to maintain a 30 foot navigational channel to docks.

Public Rights Feature LN6

Figure 8 and 9. LN 6 aerial and water views

This area on the northeastern shore of the lake is primarily protected because of its undeveloped shoreline and the unique habitat that is found here. The riparian zone is wooded with a narrow wetland fringe. The wetland fringe is undercut with overhanging trees and shrubs. Large woody habitat is abundant providing excellent fish habitat along with the undercut banks.

<u>Management Recommendations LN 6</u>
Aquatic vegetation harvest allowed only to maintain a 30 foot navigational channel to docks.

Sensitive Area Designation LN7

Figures 10-12. LN 7 aerial and water views

Much of this area is within the Lake Noquebay Wildlife Area which is composed of wetland vegetation. The littoral zone margin in the lake consists of bulrush, wild rice and various submerged vegetation.

A warm water stream, the Upper Inlet flows through this area and into the lake and is an important habitat for wildlife and fish. Bald Eagles and Ospreys nest inland on the margins of this area.

Management Recommendations LN 7
Aquatic vegetation harvest allowed only to maintain a 30 foot navigational channel to docks.

Sensitive Area Designation LN8

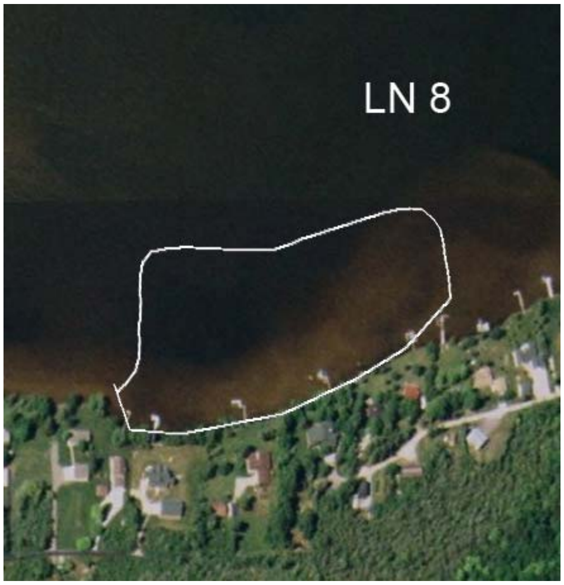


Figure 13. LN 8 aerial view

This area is located on the southeastern shore of the lake. The shoreline is completely developed with lawns, docks and some trees. The area is primarily being designated for its scattered dense bulrush beds which provide wildlife habitat and spawning areas for centrarchid fish. The littoral zone has a sandy substrate.

Management Recommendations LN 8
Aquatic vegetation harvest allowed only to maintain a 30 foot navigational channel to docks.

Public Rights Feature LN9

Figure 14 and 15. LN 9 aerial and water views

This site is located on the southeastern shore. It includes a wide variety of habitats: sedge meadow, shrub carr, bog, and littoral zone. These wetland habitats provide scenic beauty, nesting areas for birds and protection for shoreline erosion.

The eastern third of the shoreline is abundant with large woody cover. The littoral zone has a gravel substrate and is a possible spawning area for centrarchid and a nursery area for esocids.

The wetland at this site was the land in question during the landmark 1972 court case Just v Marinette County. Ronald and Kathryn Just filled in part of wetland in violation of Marinette County's new shoreland zoning. The case went to the Wisconsin State Supreme Court on appeal and they held up the constitutionality of shoreland zoning, and that it did not result in a "taking" by the county of private property.

Management Recommendations LN9

Aquatic vegetation harvest allowed only to maintain a 30 foot navigational channel to docks.

Public Rights Feature LN10

Figure 16. LN 10 aerial view

This area surrounding a small island in the southwest section of the lake provides uncommon fish habitats. The granite riprap that prevents erosion of the island provides micro environment not common on the Lake Noquebay for various fish species. This island is also a potential spawning habitat for walleye.

The aquatic plant community is diverse.

<u>Management Recommendations</u>
Do not remove fallen trees along shoreline.
No alteration of littoral zone unless to improve spawning habitat
Aquatic vegetation harvest allowed only to maintain a 30 foot navigational channel to docks.

Sensitive Area Designation LN11

Figure 17. LN 11 aerial view

This site is located on the southwest end of the lake along a channelized area where Lake Noquebay's hydrological drainage outlet flows over a dam into The Outlet. This dam is used to manage the Lake Noquebay water level. This area includes a sedge meadow and shrub carr. The aquatic community in the channel consists of mainly *Potamogeton sp*. and *Najas*. An active marina is located along the shoreline of this area.

Management Recommendations
Aquatic vegetation harvest allowed only to maintain a 30 foot navigational channel to the docks.
Protect wetland habitat.

Acknowledgements

The WDNR like to thank the Chuck Druckrey and Marinette County for assistance with, and sharing plant and GIS data. We would also like to thank the efforts of the Lake Noquebay Rehabilitation District and property owners committed to the conservation of Lake Noquebay. We would also like to acknowledge WI. DNR Fish Technician Greg Kornely for his input and perspective regarding fishery uses in the designated areas.

Appendix A

An informational meeting was held on Lake Noquebay Critical Habitat Designation on June 17, 2009, 6:00 pm at Crivitz Town Hall. Information was presented on what critical habitats are, what they mean to landowners, the process of designation, the location of the designations and why they were designated. Background on Lake Noquebay's wildlife and a summary of a 2009 fisheries survey were also presented. Opportunity was provided for written and verbal comments. The public provided us with many constructive comments at the meeting and afterward. Some of these comments were taken into consideration in making the following changes to the draft report and the final location of the locations of the designations.

Changes to Lake Noquebay Draft Report

LN 1 was redrawn to exclude the area around the boat landing.

LN 2 redrawn to exclude docks on west side

LN 3 redrawn to exclude navigational channel on north side

LN 4 redrawn to exclude houses. Original delineation was based on Wisconsin Wetland Inventory maps, which were, in this case inaccurate.

The recommendation that there be no alteration to the littoral zone was removed from LN 1, 2, 3, 4. The recommendation is kept for LN 5 and 10 to protect walleye spawning areas.

Appendix b

September 2003 Vegetation Sampling: Species followed by a * are considered to have high value under NR 107
D = Dominant, A = Abundant, C = Common, P = Present

		LN 1	LN 2	LN 3	LN 4	LN 5	LN 6	LN 7	LN 8	LN 9	LN 10	LN 11
Wet edge plants												
Alnus incana	Tag alder	-	-	A	A	-	C	P	-	-	-	A
Carex sp.	Sedge sp.	-	-	D	-	-	-	A	-		-	A-D
Cornus sp.	Dogwood sp.	-	-	C	P	-	C	P	-	-	P	C
*Eleocharis sp.**	Spike-rush sp.*	-	-	-	-	-	-	A	-	-	-	P
Iris versicolor	Northern blue flag	-	-	C	-	-	-	-	-	-	-	-
Juncus sp.	Rush sp.	-	-	-	-	-	-	-	-	-	-	C
Lobelia cardinalis	Cardinal-flower	-	-	P	-	-	-	-	-	-	-	-
Lobelia sithilitica	Great Blue Lobelia	-	-	P	-	-	-	-	-	-	-	-
Onoclea sensibilis	Sensitive Fern	-	-	C	-	-	-	-	-	-	-	-
Osmunda regalis	Royal Fern	-	-	C	-	-	-	-	-	-	-	-
Salix sp.	Willow sp.	-	-	-	-	-	-	-	-	-	P	C
Scientific Name	Common Name											
Spirea sp.	Meadowsweet sp.	-	-	C	P	-	P	P	-	-	-	-
Thelypteris sp.	Marsh Fern sp.	-	-	C	-	-	-	-	-	-	-	-
	Grasses	-	-	A-D	-	-	-	-	-	-	-	A-D
Aquatic Emergents												
Scientific Name	Common Name											
Pontederia cordata	Pickerelweed	C	C	P	C	-	-	P	-	-	-	-
Sagittaria sp.	Arrowhead sp.	-	-	P	P	-	P	P	P	P	-	-
Schoenoplectus sp.	Bulrush	-	A	C-D	C	-	-	C	D	P	-	-
Sparganium sp.	Bur-reed sp.	-	-	-	A	-	-	-	-	-	-	C

Typha sp.	Cattail sp.	A	C	-	C	-	-	C	-	-	-	A
Zizania aquatica	Wild rice*	A	A	C	A	-	-	C	-	P	-	C

Aquatic Floating Leaf

Scientific Name	Common Name											
Nuphar variegata	Bullhead lily	A-D	A	P	-	-	-	A	-	P	-	-
Nymphaea	Water-lily sp.	A-D	C	-	-	-	-	P	-	-	C	C
Spirodela polyrhiza	Large duckweed	-	-	-	A	-	-	-	-	-	-	C

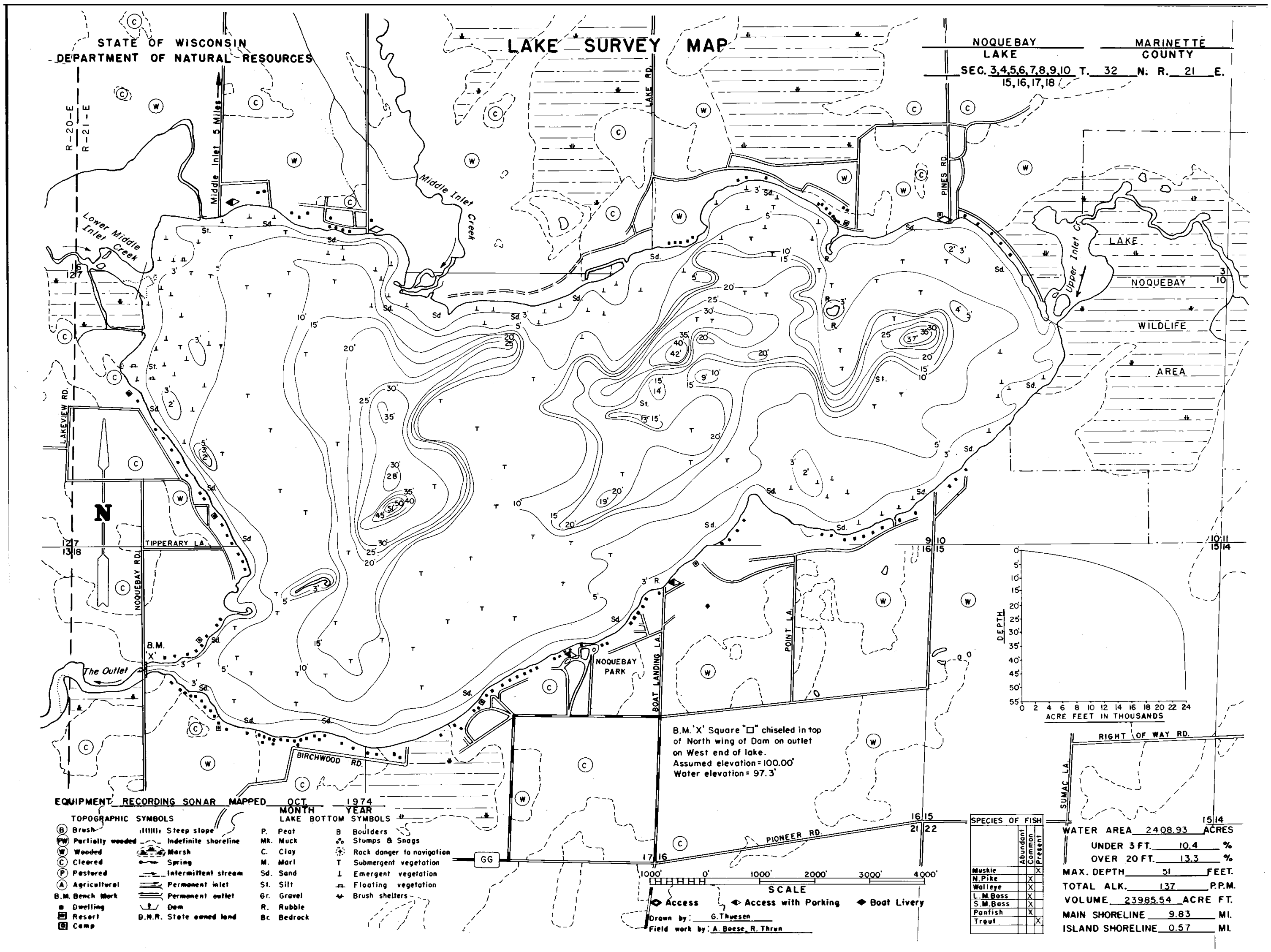
Aquatic Submergents

Scientific Name	Common Name											
Ceratophyllum sp.	Hornwort sp.	C	C	-	P	-	-	P	-	-	-	-
Elodea sp.	Waterweed	P	-	-	-	-	-	P	-	-	P	P
Megalodonta beckii	Water beggar-ticks	-	-	-	-	-	-	-	-	-	-	C
Myriophyllum heterophyllum	Two-leaf water-milfoil	P	C	P	P	C	C	P	-	-	A	P
Myriophyllum sibiricum	Northern water-milfoil	-	P	-	-	-	-	P	-	-	C	C
Najas sp.	Water-nymph sp.	A-D	A	-	C	-	-	-	-	-	A	A-D
Potamogeton amplifolius	Large-leaf pondweed*	P	P	-	P	-	-	-	-	-	A	C
Potamogeton foliosus	Leafy Pondweed	-	-	-	-	-	-	P	-	-	-	-
Potamogeton gramineus	Variable pondweed	P	C	C	C	C	A	P	P	P	C	C
Potamogeton illinoensis	Illinois pondweed*	P	C	C	A	C	A	P			P	P
Potamogeton natans	Floating-leaf pondweed	-	C	P	-	-	-	C	-	P	-	-
Potamogeton pectinatus	Sago Pondweed*	C	P	-	-	P	-	C	-	-	-	-
Potamogeton richardsonii	Clasping-leaf pondweed*	-	P	-	C	C	-	A	-	-	P	P
Potamogeton robbinsii	Fern pondweed*	C	-	P	A	-	-	-	-	-	P	-
Potamogeton zosteriformis	Flat-stem pondweed	A-D	C	-	A	-	A	-	-	-	C	C

Ranunculus sp	Buttercup/water crowfoot	-	-	-	C	-	-	-	-	-	-	-
Schoenoplectus subterminalis	Water-bulrush	-	-	-	-	-	-	P	-	-	-	-
Utricularia sp.	Bladderwort sp.	C	C	-	-	-	-	C	-	-	P	P
Utricularia vulgaris	Common Bladderwort	-	-	-	-	-	-	P	-	-	-	-
Vallisneria americana	Wild celery*	-	C	C	A	C	C	-	-	-	C	C
Zosterella dubia	Water stargrass	P	P	-	-	-	-	-	-	-	C	-

Algae

Scientific Name	Common Name											
Chara sp.	Muskgrass sp.	-	C	A-D	A	-	A	C	P	C	-	A
Nitella sp.	Stonewort sp.	-	-	-	-	-	-	-	-	-	-	P



STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES
LAKE SURVEY MAP
NOQUEBAY LAKE
MARINETTE COUNTY
SEC. 3,4,5,6,7,8,9,10 15,16,17,18 T. 32 N. R. 21 E.
R-20-E
R-21-E
Middle Inlet 5 Miles
Middle Inlet Creek
Lower Middle Inlet Creek
LAKE RD.
PINES RD.
Upper Inlet Cr.
LAKE NOQUEBAY WILDLIFE AREA
LAKEVIEW RD.
TIPPERARY LA.
NOQUEBAY RD.
The Outlet
B.M. 'X'
BIRCHWOOD RD.
NOQUEBAY PARK
BOAT LANDING LA.
POINT LA.
SUMAC LA.
RIGHT OF WAY RD.
PIONEER RD.
GG
B.M. 'X' Square "□" chiseled in top of North wing of Dam on outlet on West end of lake.
Assumed elevation = 100.00'
Water elevation = 97.3'
DEPTH
ACRE FEET IN THOUSANDS
EQUIPMENT RECORDING SONAR MAPPED OCT. 1974
MONTH YEAR
TOPOGRAPHIC SYMBOLS
Brush
Partially wooded
Wooded
Cleared
Pastured
Agricultural
B.M. Bench Mark
Dwelling
Resort
Camp
Steep slope
Indefinite shoreline
Marsh
Spring
Intermittent stream
Permanent inlet
Permanent outlet
Dam
D.N.R. State owned land
LAKE BOTTOM SYMBOLS
P. Peat
Mk. Muck
C. Clay
M. Marl
Sd. Sand
St. Silt
Gr. Gravel
R. Rubble
Br. Bedrock
B Boulders
Stumps & Snags
Rock danger to navigation
T Submergent vegetation
Emergent vegetation
Floating vegetation
Brush shelters
SCALE
1000' 0' 1000' 2000' 3000' 4000'
Access
Access with Parking
Boat Livery
Drawn by: G. Thuesen
Field work by: A. Boese, R. Thrun
SPECIES OF FISH
Abundant Common Present
Muskie X (Present)
N. Pike X (Common)
Walleye X (Common)
L.M. Bass X (Common)
S.M. Bass X (Common)
Panfish X (Common)
Trout X (Present)
WATER AREA 2408.93 ACRES
UNDER 3 FT. 10.4 %
OVER 20 FT. 13.3 %
MAX. DEPTH 51 FEET.
TOTAL ALK. 137 P.P.M.
VOLUME 23985.54 ACRE FT.
MAIN SHORELINE 9.83 MI.
ISLAND SHORELINE 0.57 MI.

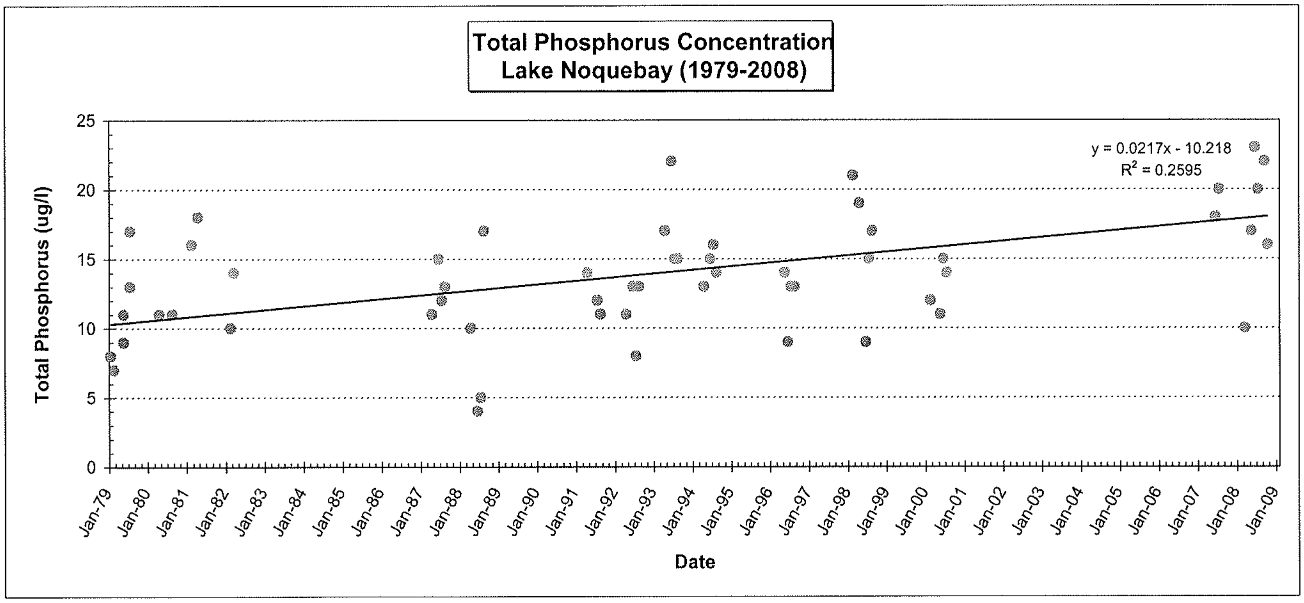
Comprehensive Lake Management Plan
For
Lake Noquebay

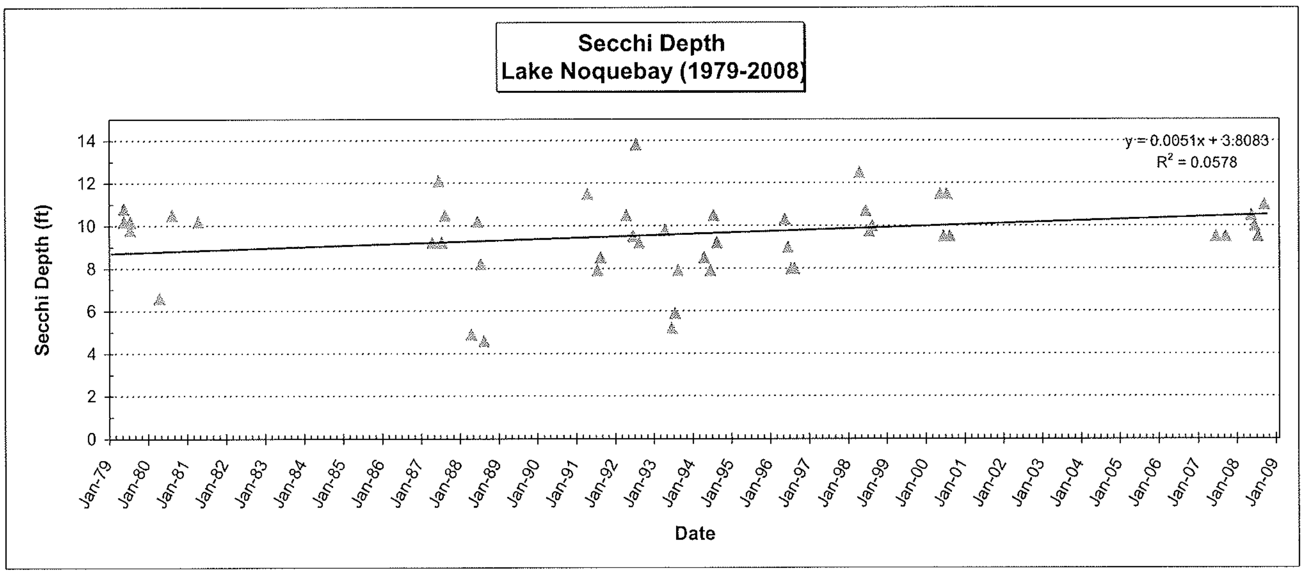
APPENDIX C

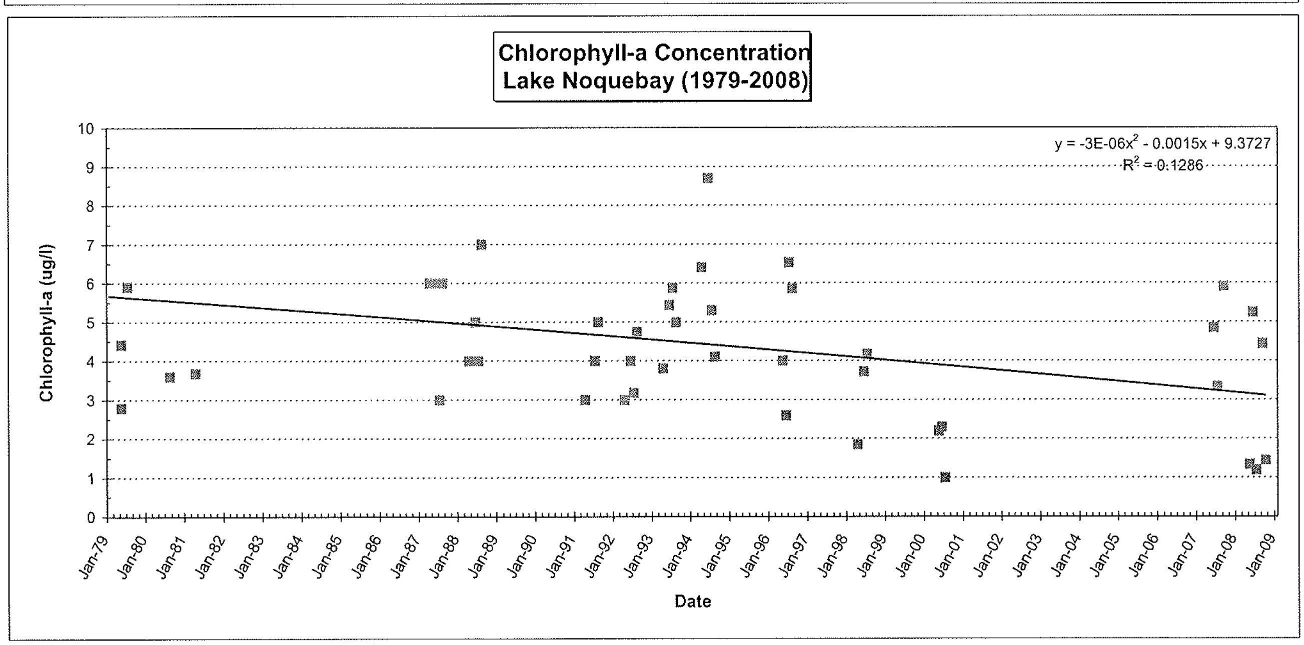
Water Quality Data
For
Lake Noquebay

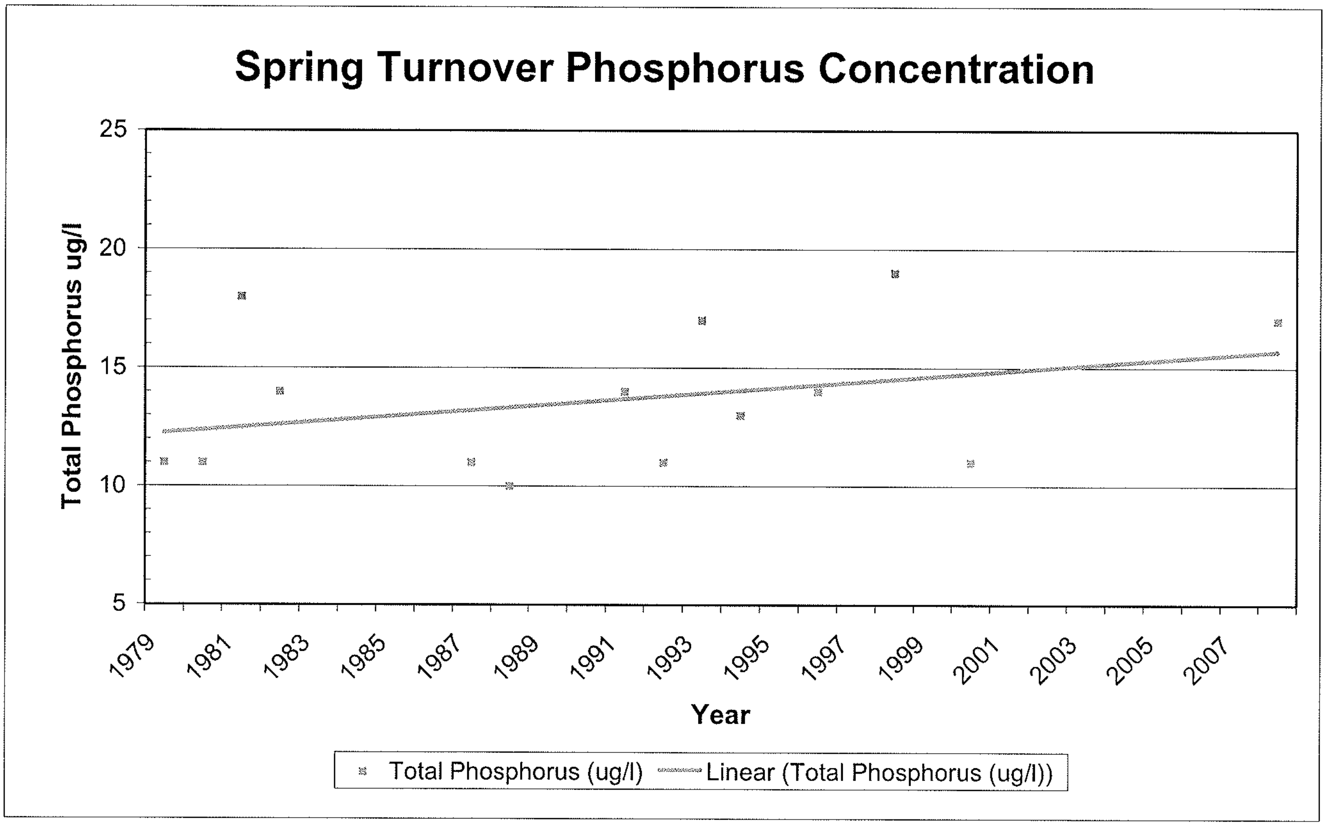
LAKE NOQUEBAY Marinette County WI SURFACE WATER QUALITY SAMPLES

Date	Total P ug/l	Ortho P ug/l	TKN ug/l	No2-No3 ug/l	NH3 ug/l	Chlor-a ug/l	Secchi ft	Phosporus TSI	Chlor-a TSI	Secchi TSI
01/29/79	8	2	300	200				44.3		
02/26/79	7	4		220				43.3		
05/04/79	11	5	520	60	10	2.79	10.8	46.8	42.6	42.8
05/29/79	9	4	700	30	30	4.42	10.2	45.2	46.1	43.6
07/02/79	13	3	560	10	20	5.91	9.8	48.1	48.3	44.2
07/31/79	17	3					10.2	50.2		43.6
03/12/80		4	600	40	40					
04/23/80	11	3	670	90		12.6	6.6	46.8	54.0	49.9
08/27/80	11	7	620	40	40	3.6	10.5	46.8	44.5	43.2
02/25/81	16	5	810	280	250			49.7		
04/30/81	18	16	450	110		3.68	10.2	50.6	44.7	43.6
02/11/82	10	7						46.0		
03/23/82	14	10	390	360				48.6		
04/23/87	11	8	600	90	10	6	9.2	46.8	48.4	45.1
06/12/87	15	8				6	12.1	49.2	48.4	41.2
07/16/87	12					3	9.2	47.5	43.1	45.1
08/16/87	13	8				6	10.5	48.1	48.4	43.2
04/21/88	10	2				4	4.9	46.0	45.3	54.2
06/24/88	4					5	10.2	39.0	47.0	43.6
07/27/88	5					4	8.2	40.7	45.3	46.8
08/29/88	17					7	4.6	50.2	49.5	55.1
04/15/91	14	4				3	11.5	48.6	43.1	41.9
07/16/91	12					4	7.9	47.5	45.3	47.3
08/27/91	11					5	8.5	46.8	47.0	46.3
04/27/92	11	2				3	10.5	46.8	43.1	43.2
06/09/92	13					4	9.51	48.1	45.3	44.6
07/28/92	8					3.18	13.8	44.3	43.6	39.3
08/25/92	13					4.74	9.2	48.1	46.6	45.1
03/04/93										
04/28/93	17					3.8	9.8	50.2	44.9	44.2
06/28/93	22					5.43	5.2	52.1	47.6	53.4
07/26/93	15					5.88	5.9	49.2	48.2	51.5
08/16/93	15					4.99	7.9	49.2	47.0	47.3
02/21/94										
04/20/94	13					6.4	8.5	48.1	48.9	46.3
06/28/94	15					8.7	7.9	49.2	51.2	47.3
07/21/94	16					5.3	10.5	49.7	47.4	43.2
08/18/94	14					4.1	9.2	48.6	45.5	45.1
03/12/96		ND								
05/02/96	14	ND	500	31	ND	4	10.3	48.6	45.3	43.5
06/19/96	9	ND				2.59	9	45.2	42.0	45.4
07/16/96	13	ND				6.53	8	48.1	49.0	47.1
08/15/96	13	ND				5.86	8	48.1	48.2	47.1
02/23/98	21	3						51.8		
04/29/98	19	ND	380	71	ND	1.84	12.5	51.0	39.4	40.7
06/18/98	9	2				3.72	10.7	45.2	44.8	42.9
07/16/98	15	ND				4.17	9.75	49.2	45.6	44.3
08/18/98	17	ND					10	50.2		43.9
02/23/00	12							47.5		
05/02/00	11	ND	590	22	19	2.2	11.5	46.8	40.8	41.9
06/13/00	15	ND	510	10	10	2.3	9.5	49.2	41.1	44.7
07/18/00	14	ND	560			1	11.5	48.6	34.8	41.9
08/15/00							9.5			44.7
			508	33.5						
06/20/07	18	2	73	ND	15	4.85	9.5	50.6	46.8	44.7
07/31/07	20	ND				3.33		51.4	43.9	
09/06/07	30	3				5.91	9.5	54.5	48.3	44.7
03/04/08	10	2						46.0		
05/01/08	17	3	620	120	19	1.33	10.5	50.2	37.0	43.2
06/24/08	23	ND				5.24	10	52.5	47.3	43.9
07/28/08	20					1.19	9.5	51.4	36.1	44.7
09/10/08	22	ND				4.44	11	52.1	46.1	42.5
10/22/08	16					1.44	17.5	49.7	37.6	35.8

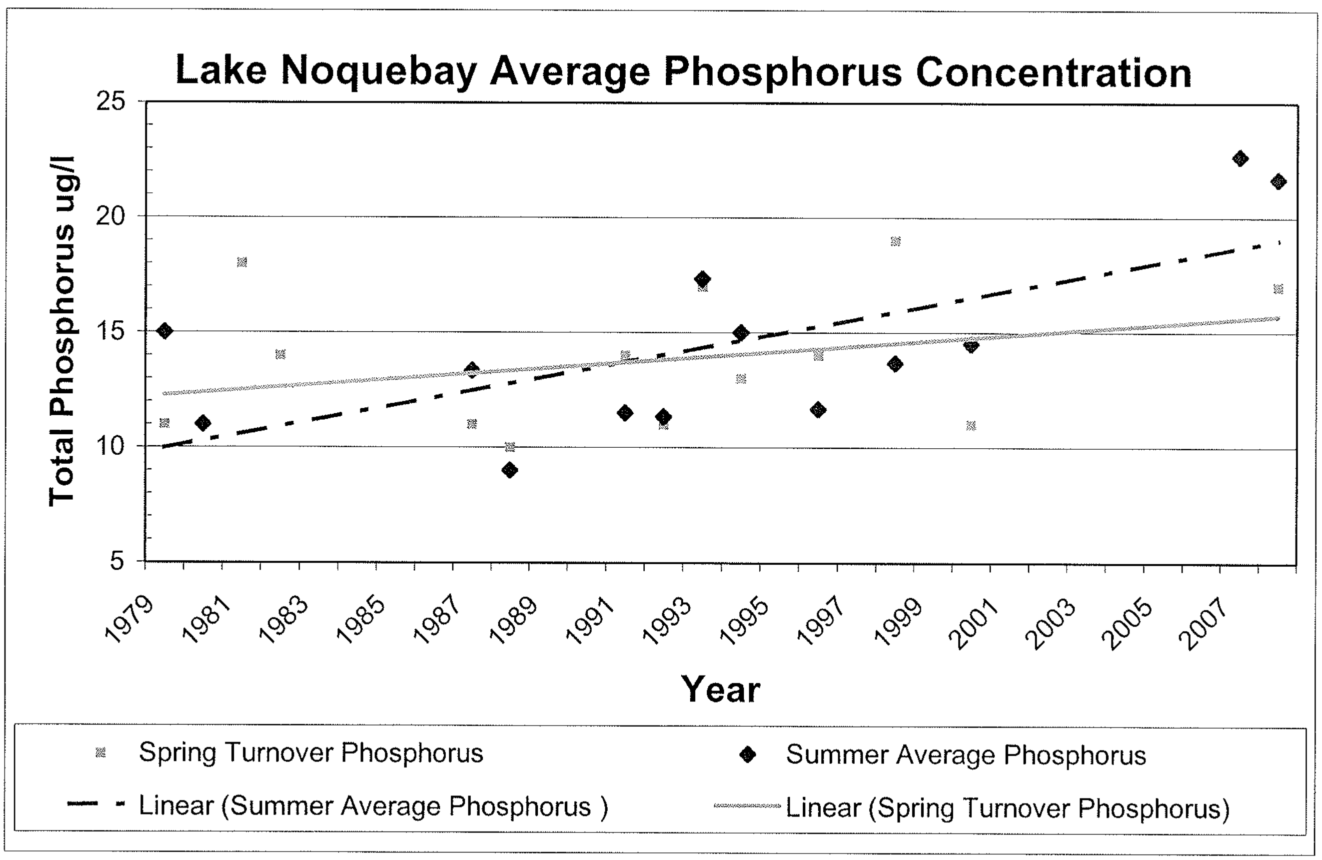

Total Phosphorus Concentration
Lake Noquebay (1979-2008)
y = 0.0217x - 10.218
R² = 0.2595
Total Phosphorus (ug/l)
Date


Secchi Depth
Lake Noquebay (1979-2008)
y = 0.0051x + 3.8083
R² = 0.0578
Secchi Depth (ft)
Date

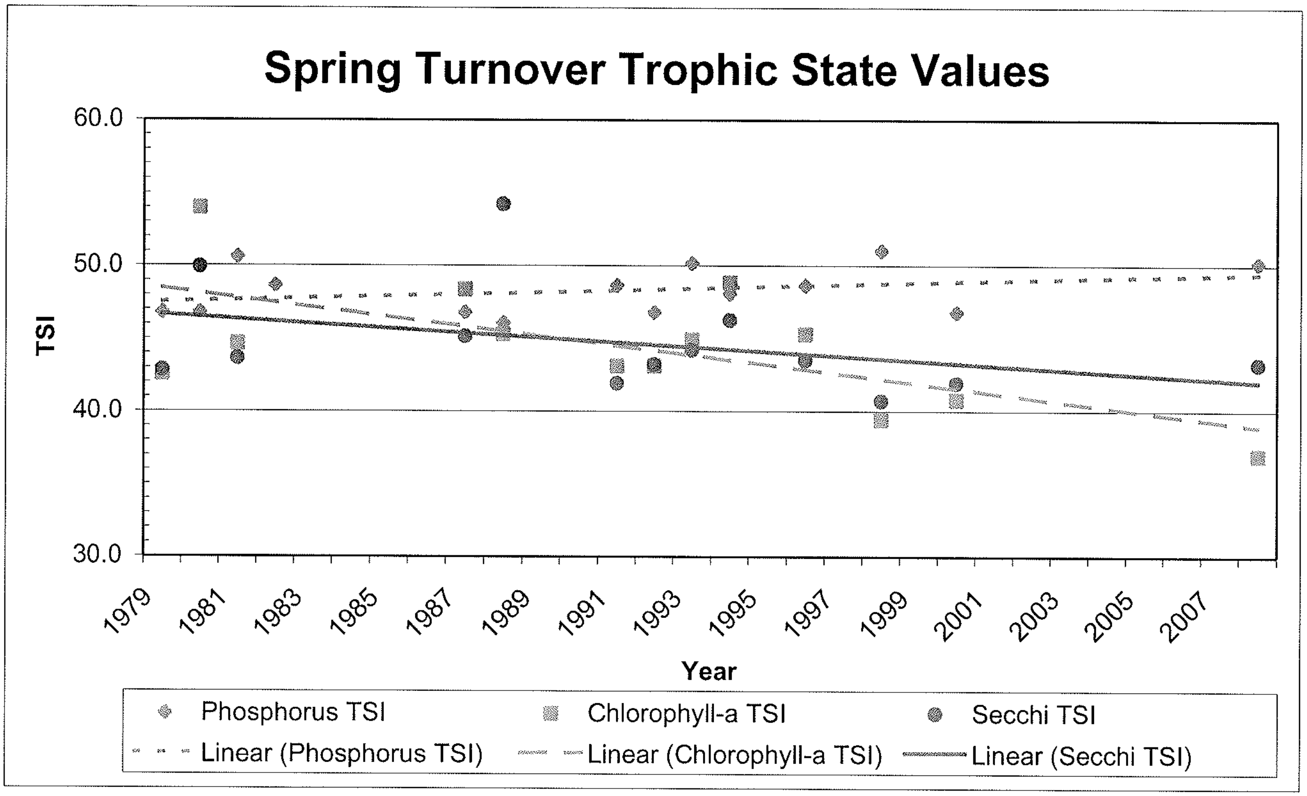

Chlorophyll-a Concentration
Lake Noquebay (1979-2008)
y = -3E-06x² - 0.0015x + 9.3727
R² = 0.1286
Chlorophyll-a (ug/l)
Date

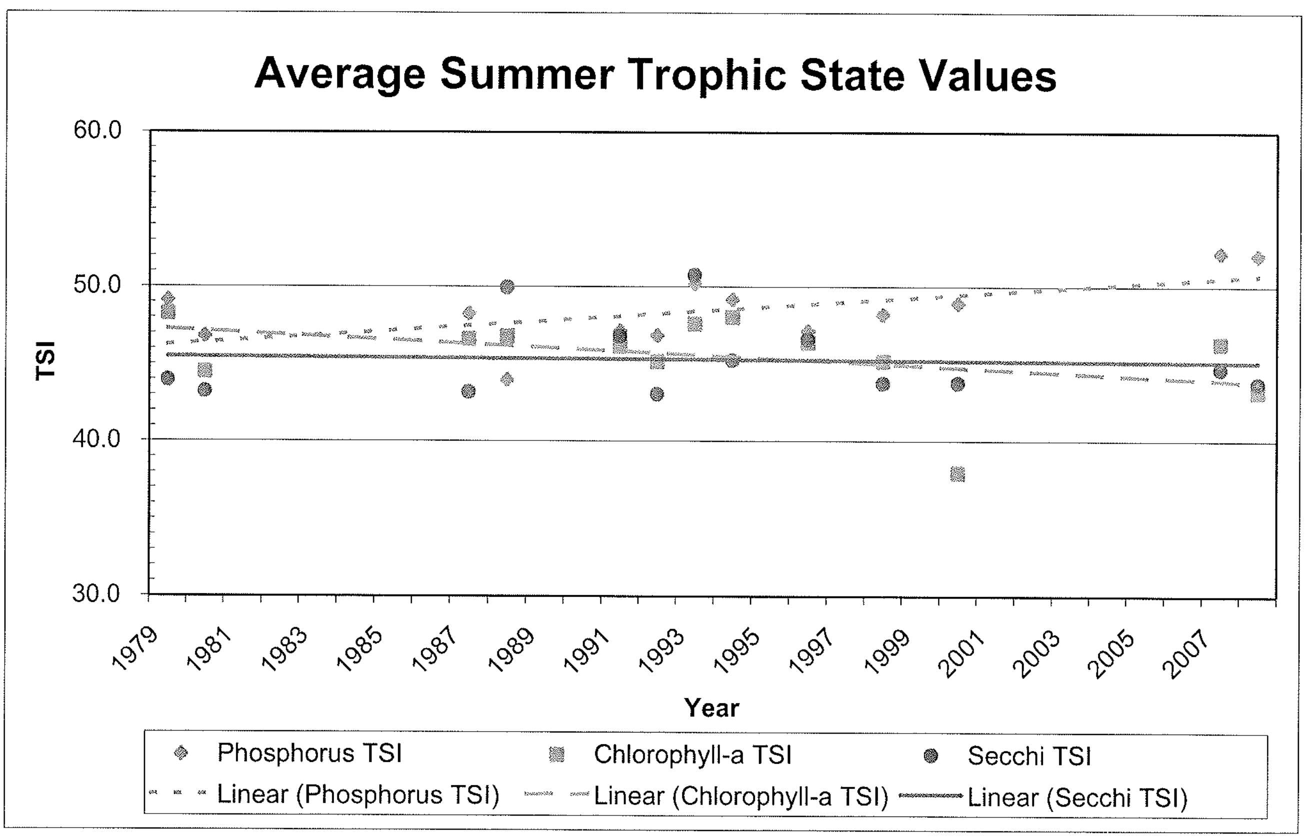


Spring Turnover Phosphorus Concentration
Total Phosphorus ug/l
25
20
15
10
5
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
Year
Total Phosphorus (ug/l)
Linear (Total Phosphorus (ug/l))



Lake Noquebay Average Phosphorus Concentration
Total Phosphorus ug/l
25
20
15
10
5
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
Year
Spring Turnover Phosphorus
Summer Average Phosphorus
Linear (Summer Average Phosphorus)
Linear (Spring Turnover Phosphorus)


Spring Turnover Trophic State Values
60.0
50.0
40.0
30.0
TSI
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
Year
Phosphorus TSI
Chlorophyll-a TSI
Secchi TSI
Linear (Phosphorus TSI)
Linear (Chlorophyll-a TSI)
Linear (Secchi TSI)


Average Summer Trophic State Values
60.0
50.0
40.0
30.0
TSI
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
Year
Phosphorus TSI
Chlorophyll-a TSI
Secchi TSI
Linear (Phosphorus TSI)
Linear (Chlorophyll-a TSI)
Linear (Secchi TSI)

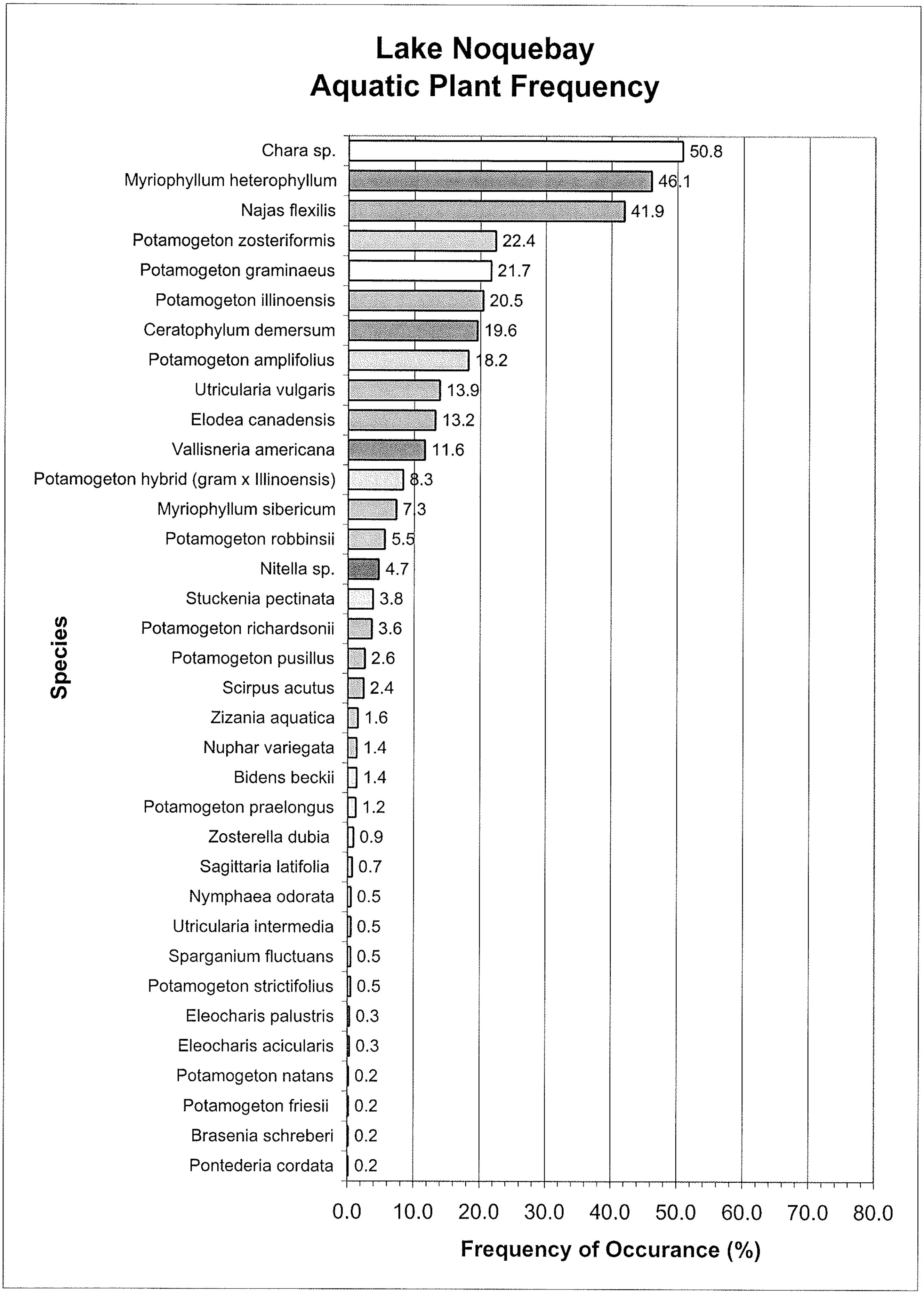
Comprehensive Lake Management Plan
For
Lake Noquebay

APPENDIX D

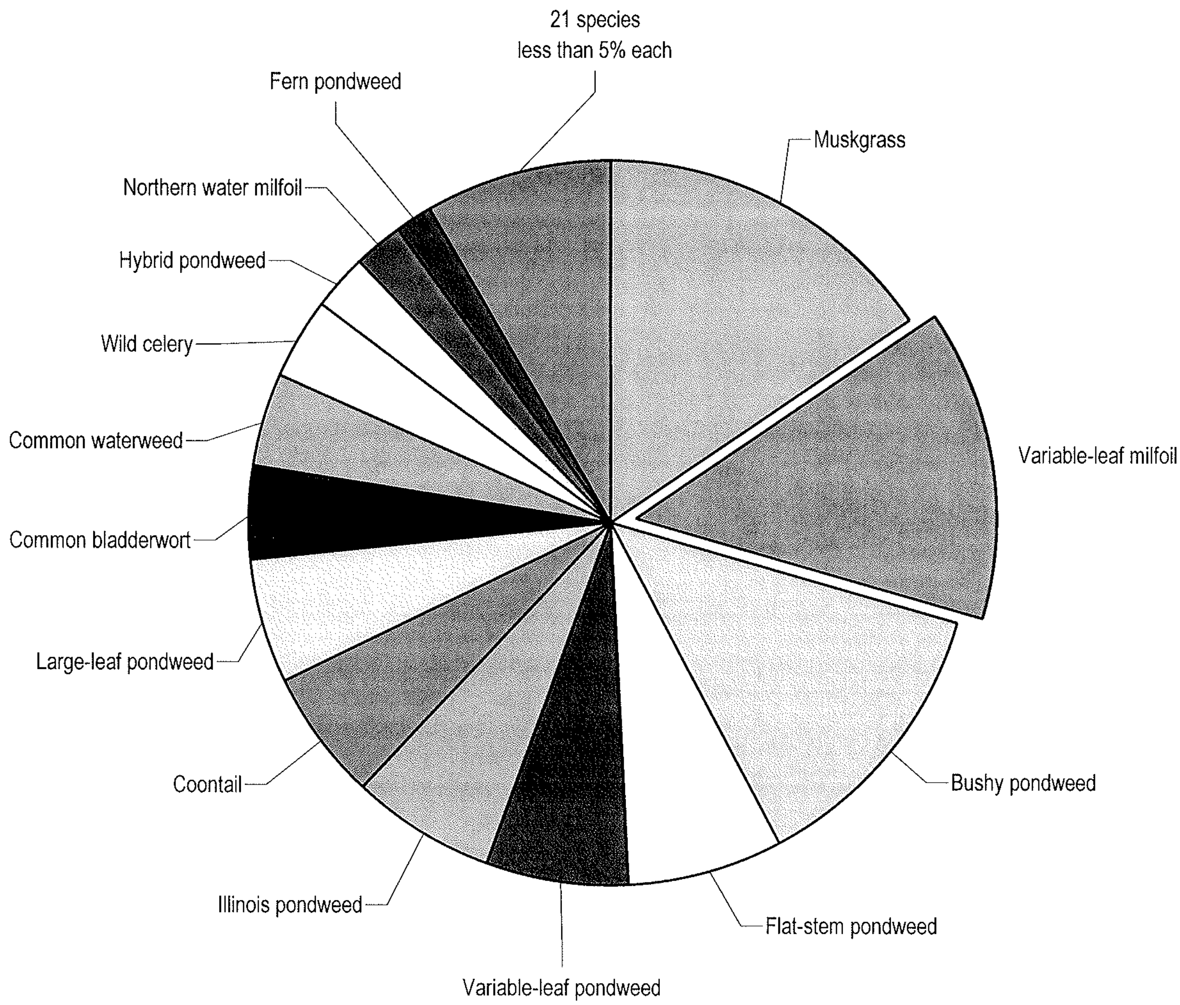
Aquatic Plant Survey Data
For
Lake Noquebay

Frequency of occurance
(sorted by frequency)

Species	Common Name	Frequency	Relative Frequency
Chara sp.	Muskgrass	50.8	15.5
Myriophyllum heterophyllum	Variable-leaf milfoil	46.1	14.0
Najas flexilis	Bushy pondweed	41.9	12.8
Potamogeton zosteriformis	Flat-stem pondweed	22.4	6.8
Potamogeton graminaeus	Variable-leaf pondweed	21.7	6.6
Potamogeton illinoensis	Illinois pondweed	20.5	6.2
Ceratophylum demersum	Coontail	19.6	6.0
Potamogeton amplifolius	Large-leaf pondweed	18.2	5.5
Utricularia vulgaris	Common bladderwort	13.9	4.2
Elodea canadensis	Common waterweed	13.2	4.0
Vallisneria americana	Wild celery	11.6	3.5
Potamogeton hybrid (gram x Illinoensis)	Illinois x variable-leaf pondweed	8.3	2.5
Myriophyllum sibericum	Northern milfoil	7.3	2.2
Potamogeton robbinsii	Fern pondweed	5.5	1.7
Nitella sp.	Stonewort	4.7	1.4
Stuckenia pectinata	Sago pondweed	3.8	1.2
Potamogeton richardsonii	Clasping-leaf pondweed	3.6	1.1
Potamogeton pusillus	Small pondweed	2.6	0.8
Scirpus acutus	Hard-stem bulrush	2.4	0.7
Zizania aquatica	Wild rice	1.6	0.5
Nuphar variegata	Spatterdock lily	1.4	0.4
Bidens beckii	Water marigold	1.4	0.4
Potamogeton praelongus	White-stem pondweed	1.2	0.4
Zosterella dubia	Water star grass	0.9	0.3
Sagittaria latifolia	Common arrowhead	0.7	0.2
Nymphaea odorata	White water lily	0.5	0.2
Utricularia intermedia	Flat-leaf bladderwort	0.5	0.2
Sparganium fluctuans	Floating-leaf burreed	0.5	0.2
Potamogeton strictifolius	Stiff pondweed	0.5	0.2
Eleocharis palustris	Hairgrass	0.3	0.1
Eleocharis acicularis	Creeping spikerush	0.3	0.1
Potamogeton natans	Floating-leaf pondweed	0.2	0.1
Potamogeton friesii	Fries' pondweed	0.2	0.1
Brasenia schreberi	Watersheild	0.2	0.1
Pontederia cordata	Pickerel weed	0.2	0.1


Lake Noquebay
Aquatic Plant Frequency
Chara sp. 50.8
Myriophyllum heterophyllum 46.1
Najas flexilis 41.9
Potamogeton zosteriformis 22.4
Potamogeton graminaeus 21.7
Potamogeton illinoensis 20.5
Ceratophylum demersum 19.6
Potamogeton amplifolius 18.2
Utricularia vulgaris 13.9
Elodea canadensis 13.2
Vallisneria americana 11.6
Potamogeton hybrid (gram x Illinoensis) 8.3
Myriophyllum sibericum 7.3
Potamogeton robbinsii 5.5
Nitella sp. 4.7
Stuckenia pectinata 3.8
Potamogeton richardsonii 3.6
Potamogeton pusillus 2.6
Scirpus acutus 2.4
Zizania aquatica 1.6
Nuphar variegata 1.4
Bidens beckii 1.4
Potamogeton praelongus 1.2
Zosterella dubia 0.9
Sagittaria latifolia 0.7
Nymphaea odorata 0.5
Utricularia intermedia 0.5
Sparganium fluctuans 0.5
Potamogeton strictifolius 0.5
Eleocharis palustris 0.3
Eleocharis acicularis 0.3
Potamogeton natans 0.2
Potamogeton friesii 0.2
Brasenia schreberi 0.2
Pontederia cordata 0.2
Species
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Frequency of Occurance (%)

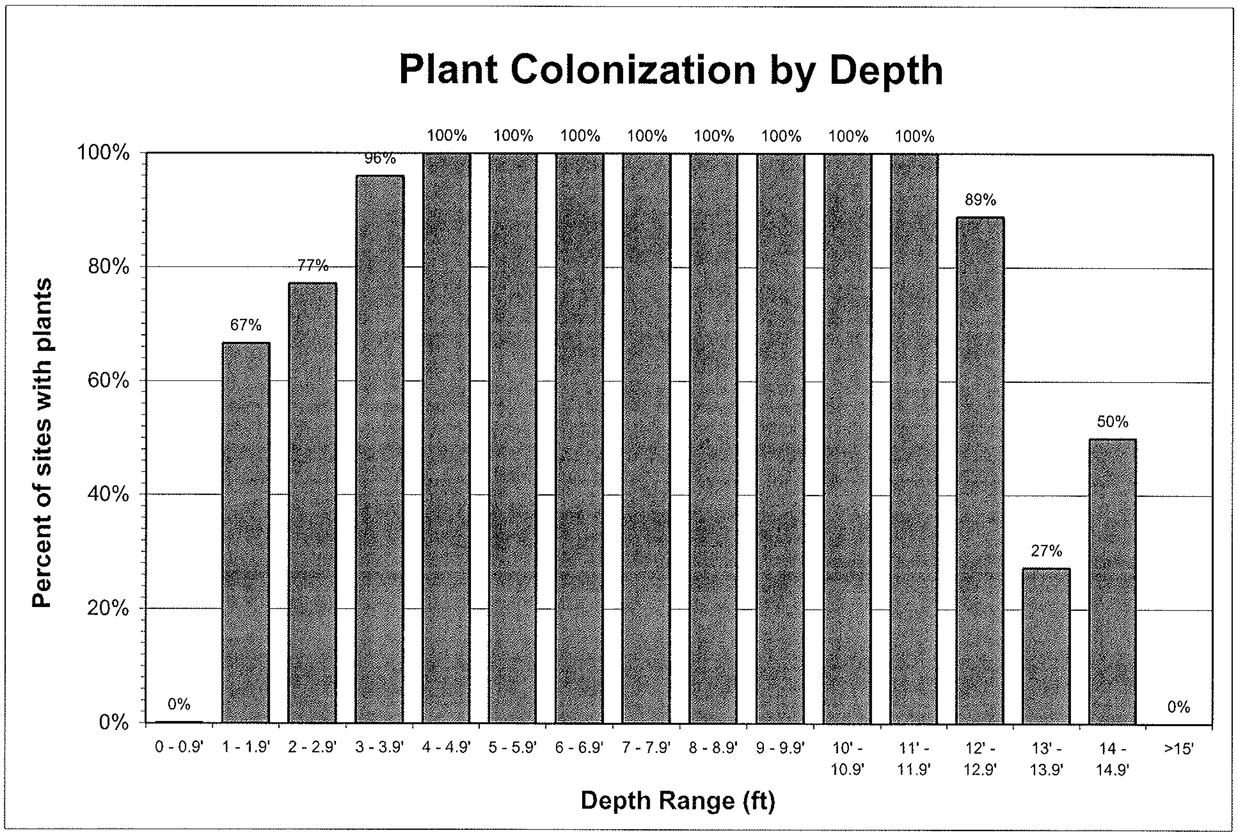
Dominant Aquatic Plants in Lake Noquebay
(Relative Frequency of Occurance)

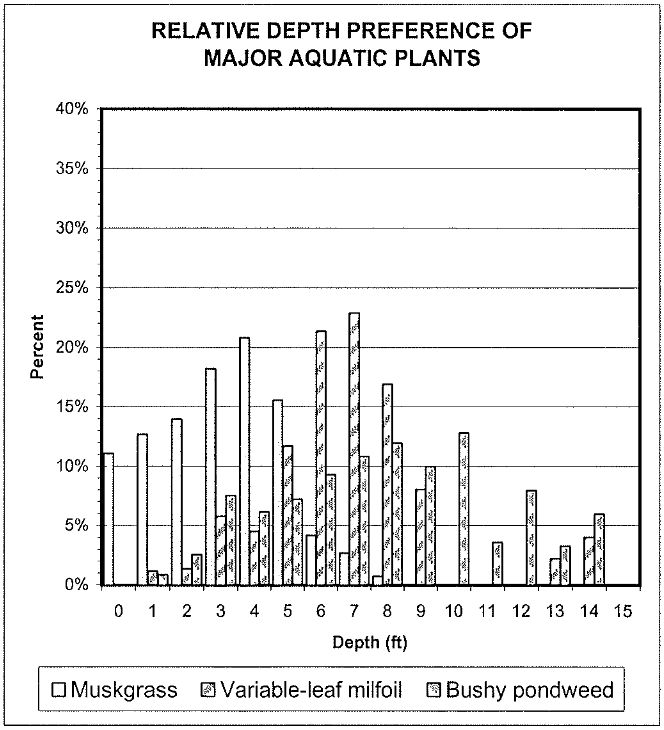


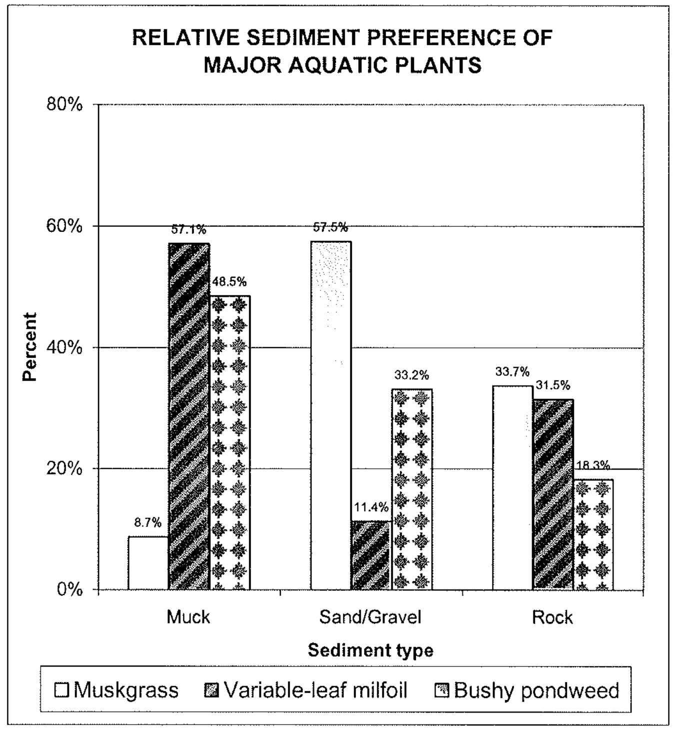
Plant Colonization by Depth (all plants)

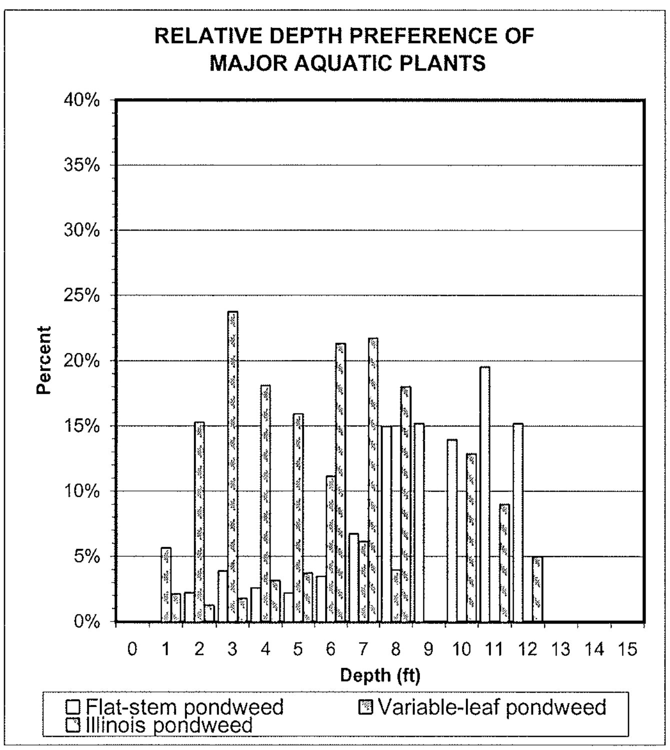
All Plants

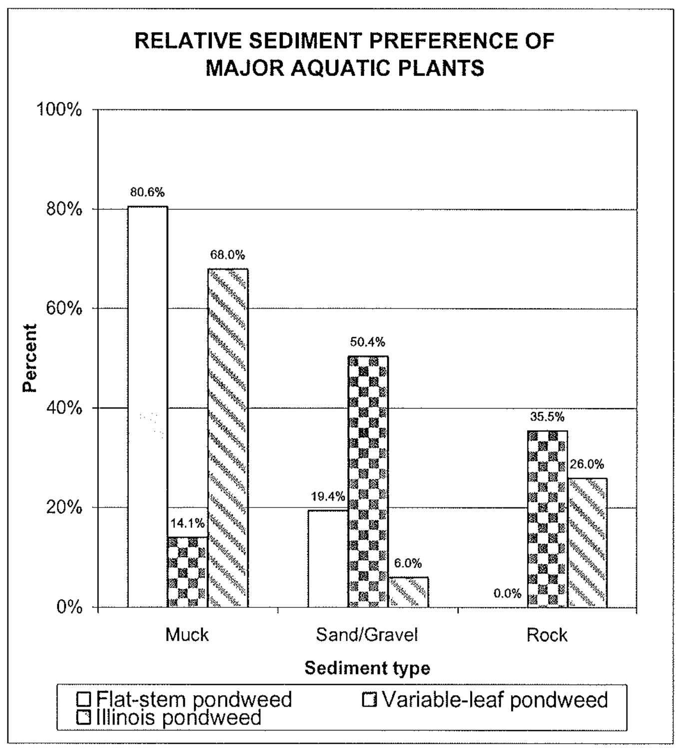
Depth Range	# of sites	# of sites with plants	% of sites with plants
0 - 0.9'	2	1	0%
1 - 1.9'	21	14	67%
2 - 2.9'	35	27	77%
3 - 3.9'	50	48	96%
4 - 4.9'	128	128	100%
5 - 5.9'	97	97	100%
6 - 6.9'	112	112	100%
7 - 7.9'	58	58	100%
8 - 8.9'	30	30	100%
9 - 9.9'	9	9	100%
10' - 10.9'	7	7	100%
11' - 11.9'	5	5	100%
12' - 12.9'	9	8	89%
13' - 13.9'	11	3	27%
14 - 14.9'	6	3	50%
>15'	150	0	0%
Total	730	550	1206%

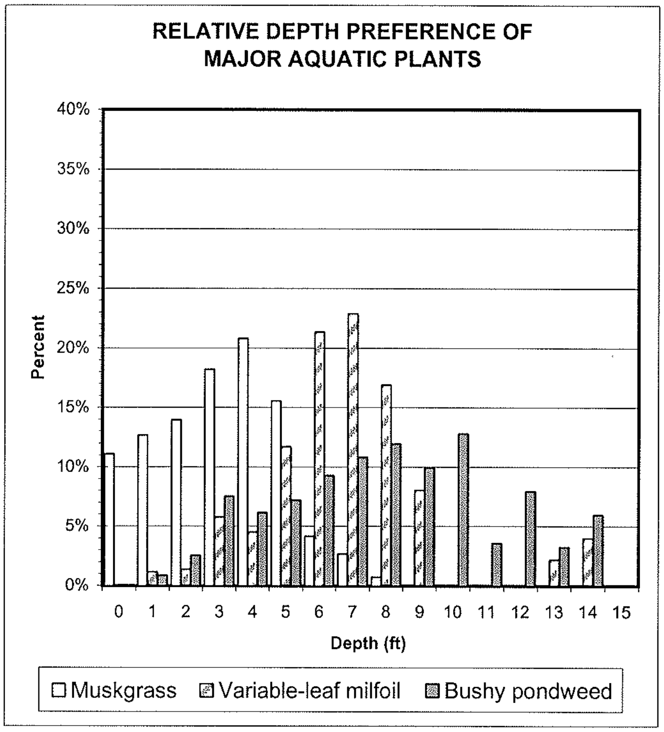


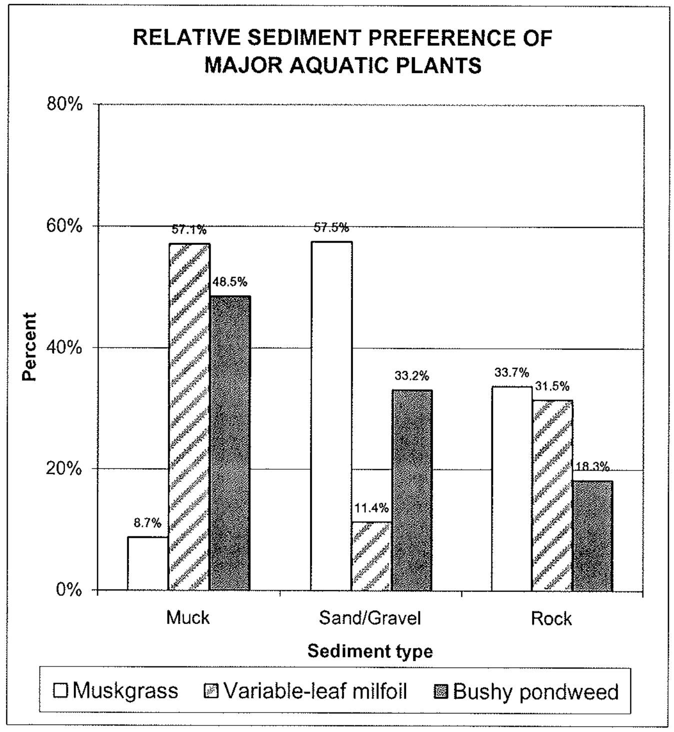

RELATIVE DEPTH PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
40%
35%
30%
25%
20%
15%
10%
5%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Depth (ft)
Muskgrass
Variable-leaf milfoil
Bushy pondweed

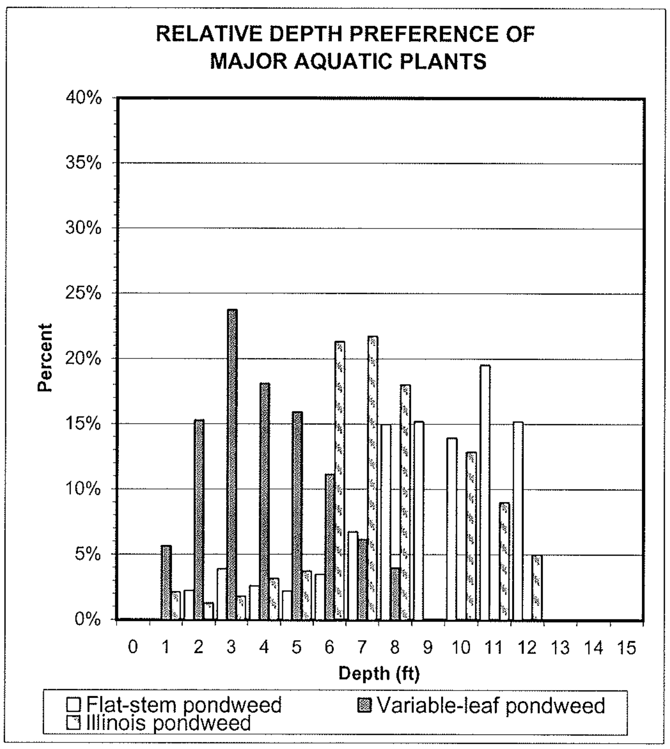

RELATIVE SEDIMENT PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
80%
60%
40%
20%
0%
57.1%
48.5%
57.5%
33.2%
33.7%
31.5%
18.3%
11.4%
8.7%
Muck
Sand/Gravel
Rock
Sediment type
Muskgrass
Variable-leaf milfoil
Bushy pondweed

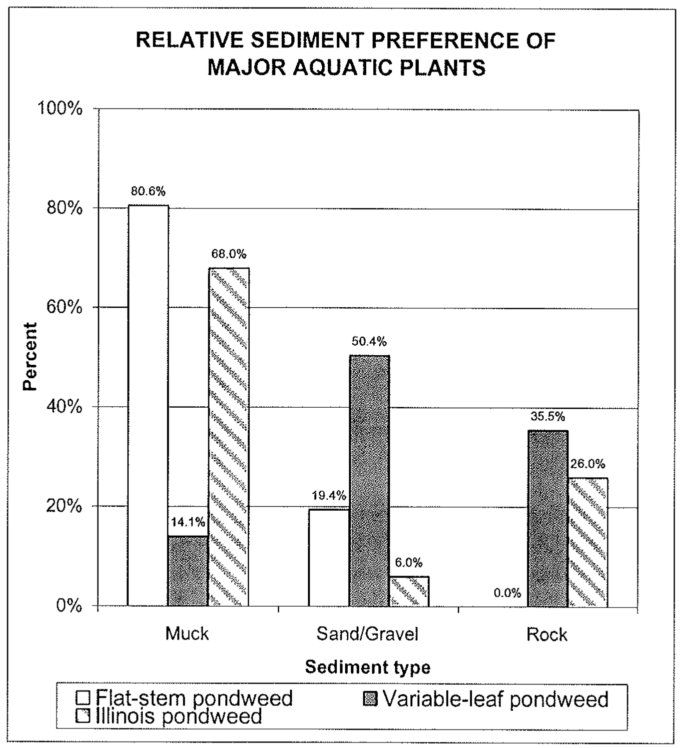

RELATIVE DEPTH PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
40%
35%
30%
25%
20%
15%
10%
5%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Depth (ft)
Flat-stem pondweed
Variable-leaf pondweed
Illinois pondweed

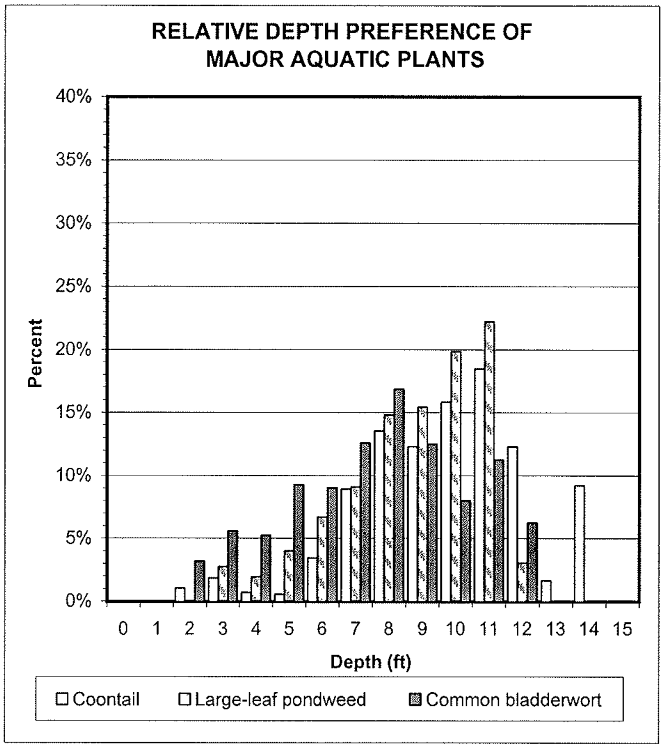

RELATIVE SEDIMENT PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
100%
80%
60%
40%
20%
0%
80.6%
68.0%
50.4%
35.5%
26.0%
19.4%
14.1%
6.0%
0.0%
Muck
Sand/Gravel
Rock
Sediment type
Flat-stem pondweed
Variable-leaf pondweed
Illinois pondweed

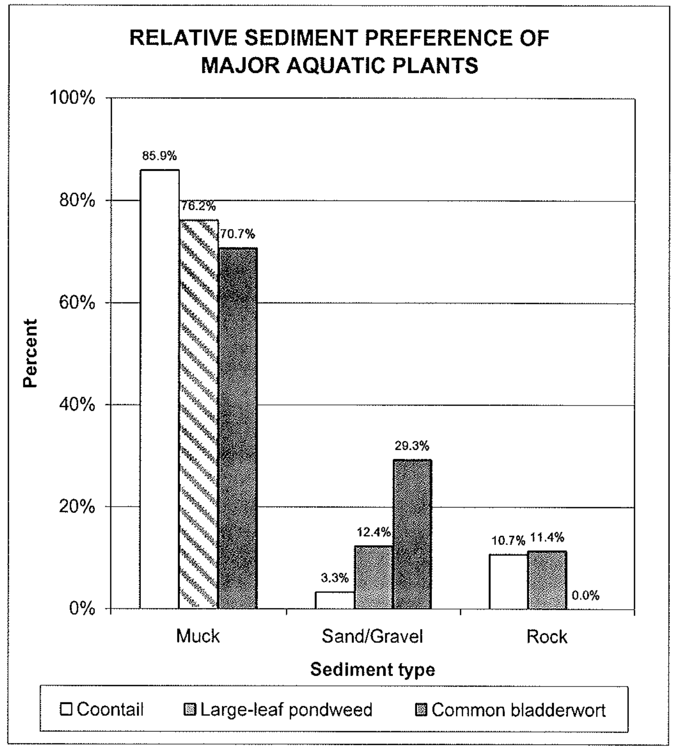

RELATIVE DEPTH PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
40%
35%
30%
25%
20%
15%
10%
5%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Depth (ft)
Muskgrass
Variable-leaf milfoil
Bushy pondweed

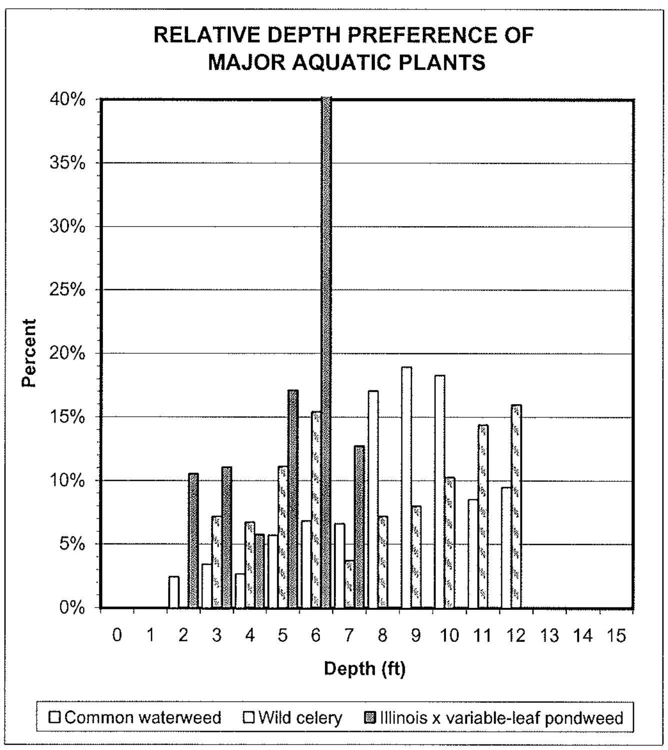

RELATIVE SEDIMENT PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
80%
60%
40%
20%
0%
57.1%
48.5%
8.7%
57.5%
33.2%
11.4%
33.7%
31.5%
18.3%
Muck
Sand/Gravel
Rock
Sediment type
Muskgrass
Variable-leaf milfoil
Bushy pondweed

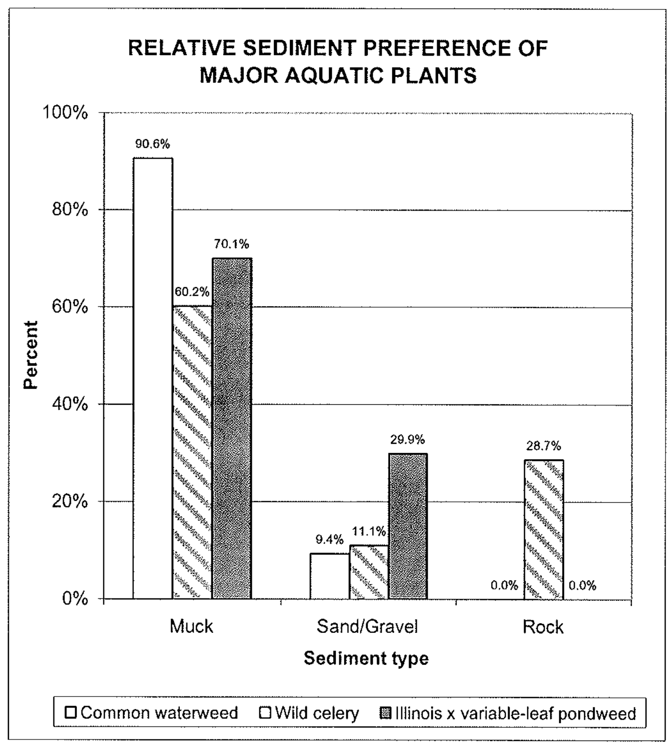

RELATIVE DEPTH PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
40%
35%
30%
25%
20%
15%
10%
5%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Depth (ft)
Flat-stem pondweed
Variable-leaf pondweed
Illinois pondweed

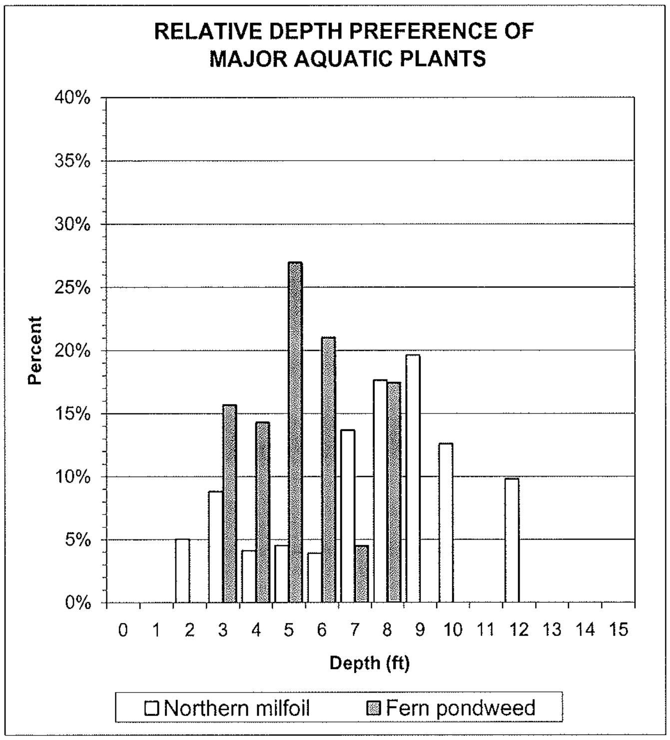

RELATIVE SEDIMENT PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
100%
80%
60%
40%
20%
0%
80.6%
14.1%
68.0%
19.4%
50.4%
6.0%
0.0%
35.5%
26.0%
Muck
Sand/Gravel
Rock
Sediment type
Flat-stem pondweed
Variable-leaf pondweed
Illinois pondweed


RELATIVE DEPTH PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
40%
35%
30%
25%
20%
15%
10%
5%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Depth (ft)
Coontail
Large-leaf pondweed
Common bladderwort

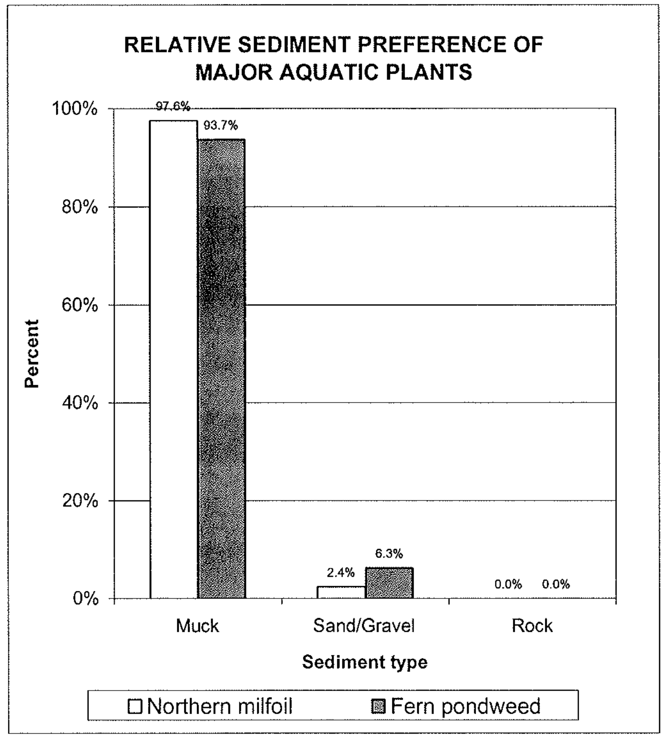

RELATIVE SEDIMENT PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
100%
80%
60%
40%
20%
0%
85.9%
76.2%
70.7%
3.3%
12.4%
29.3%
10.7%
11.4%
0.0%
Muck
Sand/Gravel
Rock
Sediment type
Coontail
Large-leaf pondweed
Common bladderwort


RELATIVE DEPTH PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
40%
35%
30%
25%
20%
15%
10%
5%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Depth (ft)
Common waterweed
Wild celery
Illinois x variable-leaf pondweed

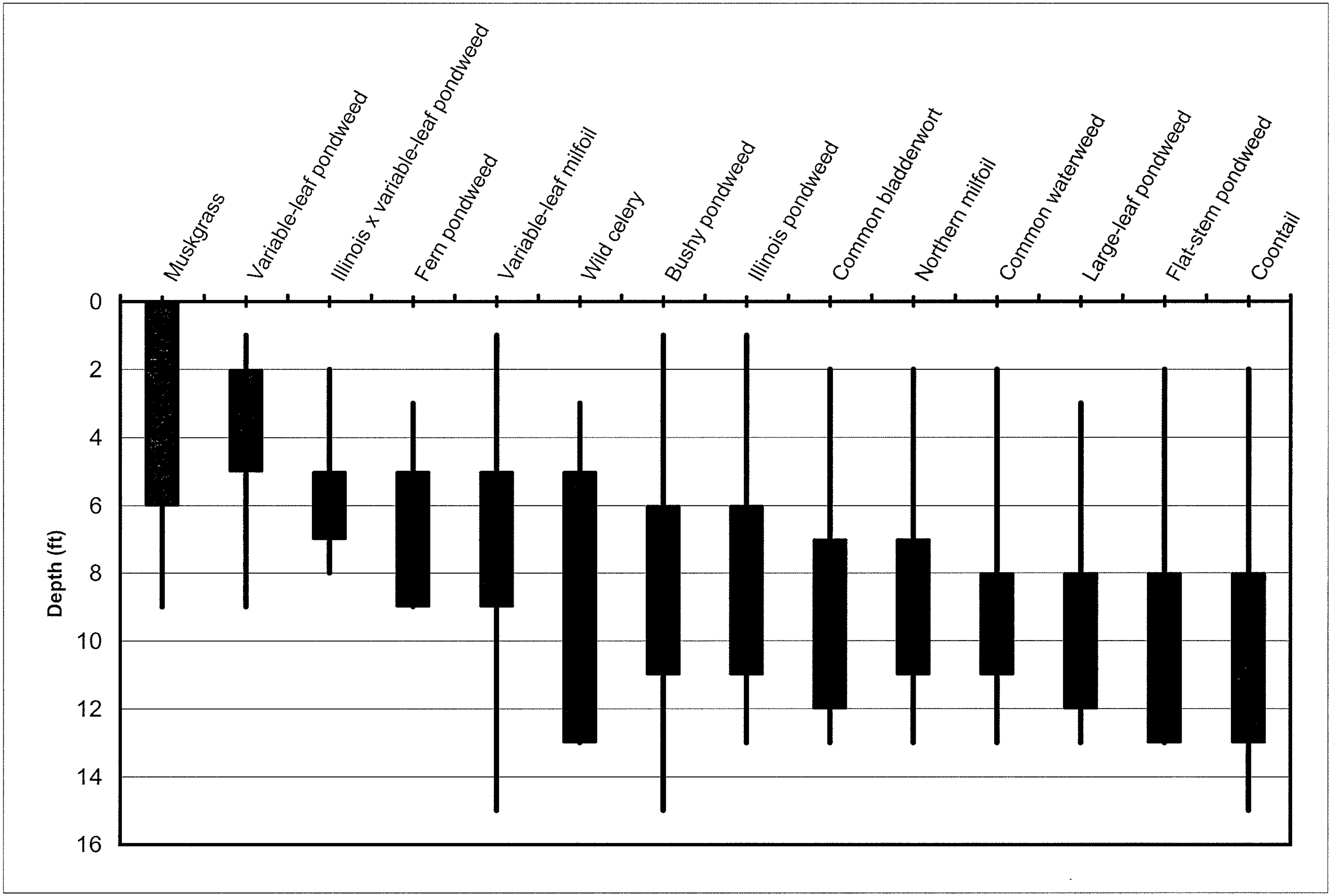

RELATIVE SEDIMENT PREFERENCE OF MAJOR AQUATIC PLANTS
Percent
100%
80%
60%
40%
20%
0%
90.6%
60.2%
70.1%
9.4%
11.1%
29.9%
0.0%
28.7%
0.0%
Muck
Sand/Gravel
Rock
Sediment type
Common waterweed
Wild celery
Illinois x variable-leaf pondweed



RELATIVE DEPTH PREFERENCE OF MAJOR AQUATIC PLANTS
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percent
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Depth (ft)
Northern milfoil
Fern pondweed

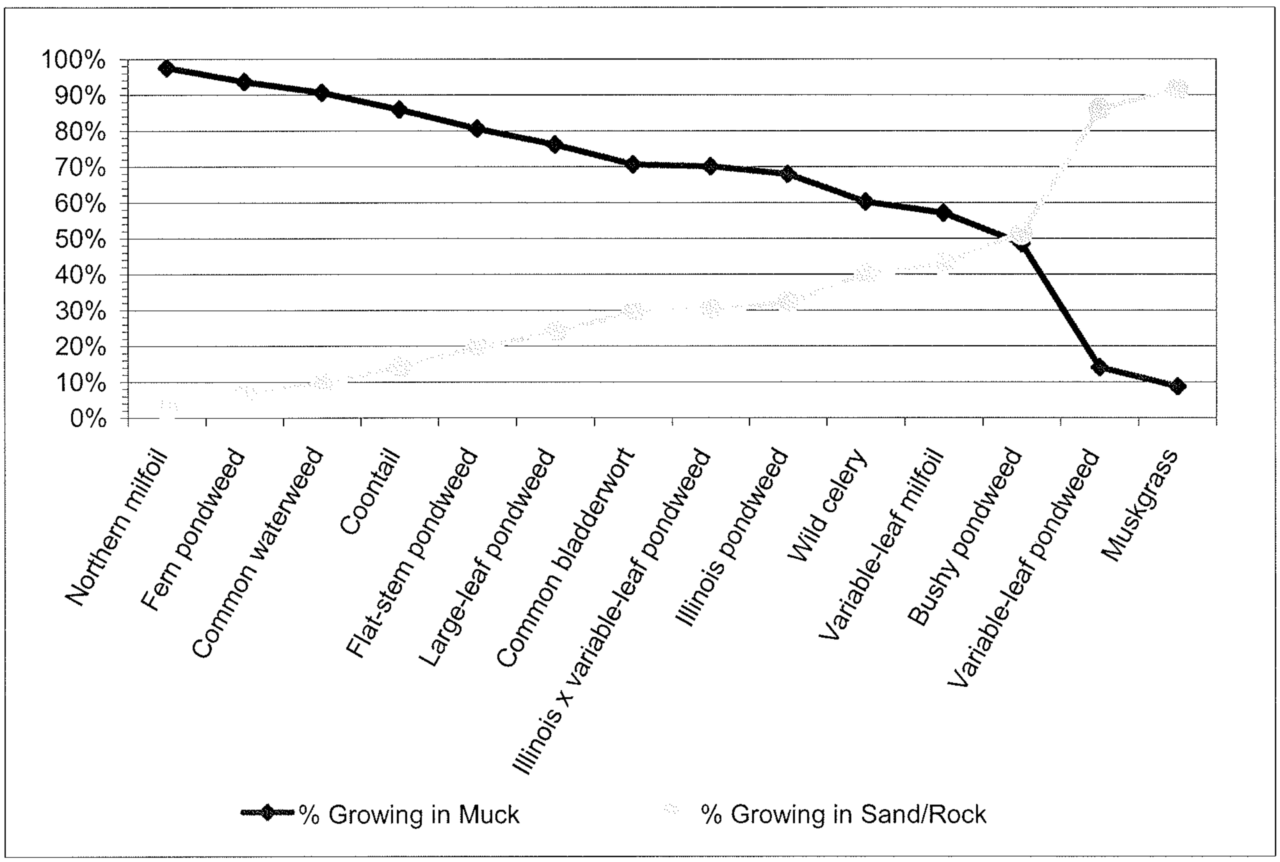


RELATIVE SEDIMENT PREFERENCE OF MAJOR AQUATIC PLANTS
100%
80%
60%
40%
20%
0%
Percent
97.6%
93.7%
2.4%
6.3%
0.0%
0.0%
Muck
Sand/Gravel
Rock
Sediment type
Northern milfoil
Fern pondweed


Muskgrass
Variable-leaf pondweed
Illinois x variable-leaf pondweed
Fern pondweed
Variable-leaf milfoil
Wild celery
Bushy pondweed
Illinois pondweed
Common bladderwort
Northern milfoil
Common waterweed
Large-leaf pondweed
Flat-stem pondweed
Coontail
Depth (ft)
0
2
4
6
8
10
12
14
16

Relative Sediment Preference

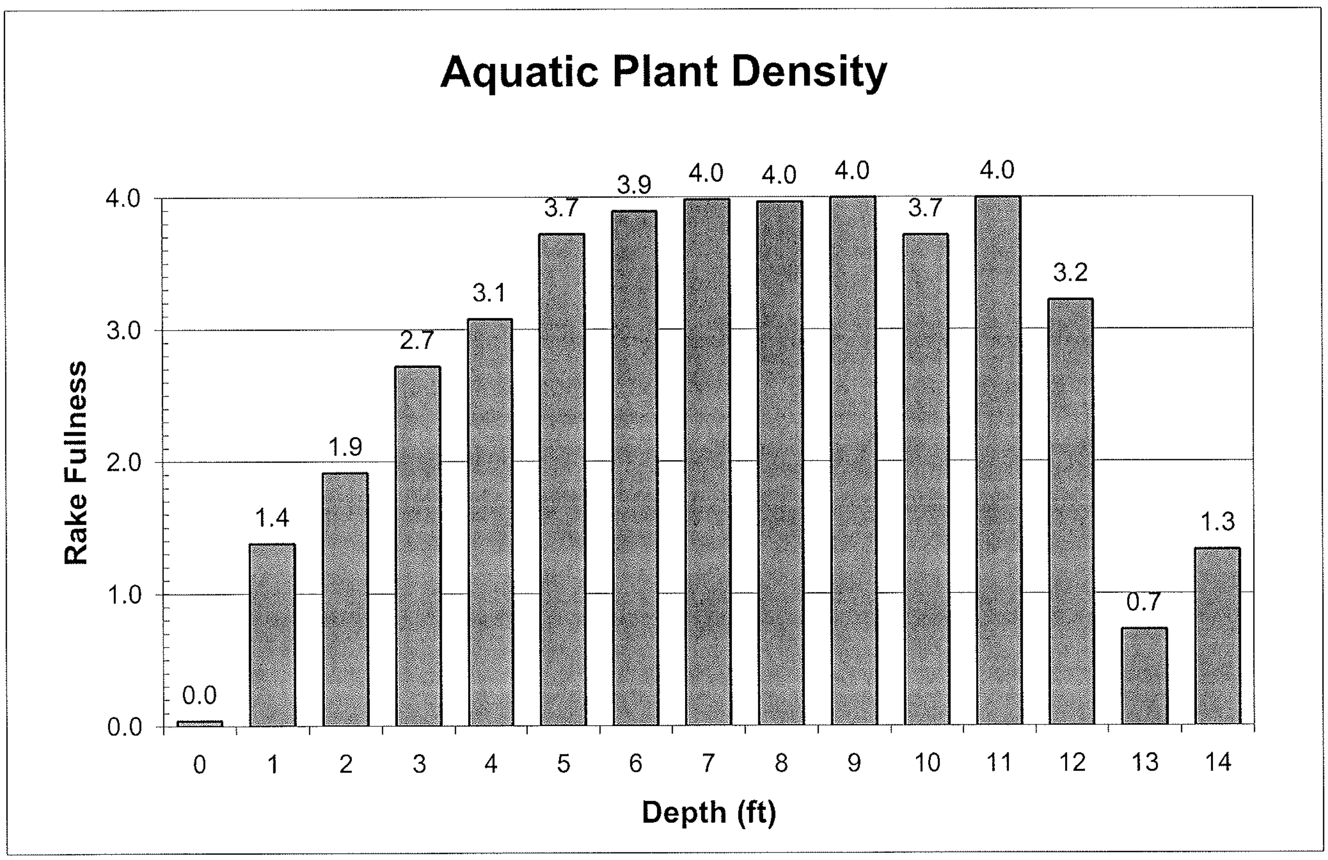
Species	Muck	Sand	Rock	Sand & Rock
Northern milfoil	97.6%	2.4%	0.0%	2.4%
Fern pondweed	93.7%	6.3%	0.0%	6.3%
Common waterweed	90.6%	9.4%	0.0%	9.4%
Coontail	85.9%	3.3%	10.7%	14.1%
Flat-stem pondweed	80.6%	19.4%	0.0%	19.4%
Large-leaf pondweed	76.2%	12.4%	11.4%	23.8%
Common bladderwort	70.7%	29.3%	0.0%	29.3%
Illinois x variable-leaf pondweed	70.1%	29.9%	0.0%	29.9%
Illinois pondweed	68.0%	6.0%	26.0%	32.0%
Wild celery	60.2%	11.1%	28.7%	39.8%
Variable-leaf milfoil	57.1%	11.4%	31.5%	42.9%
Bushy pondweed	48.5%	33.2%	18.3%	51.5%
Variable-leaf pondweed	14.1%	50.4%	35.5%	85.9%
Muskgrass	8.7%	57.5%	33.7%	91.3%



Aquatic Plant Density by Depth

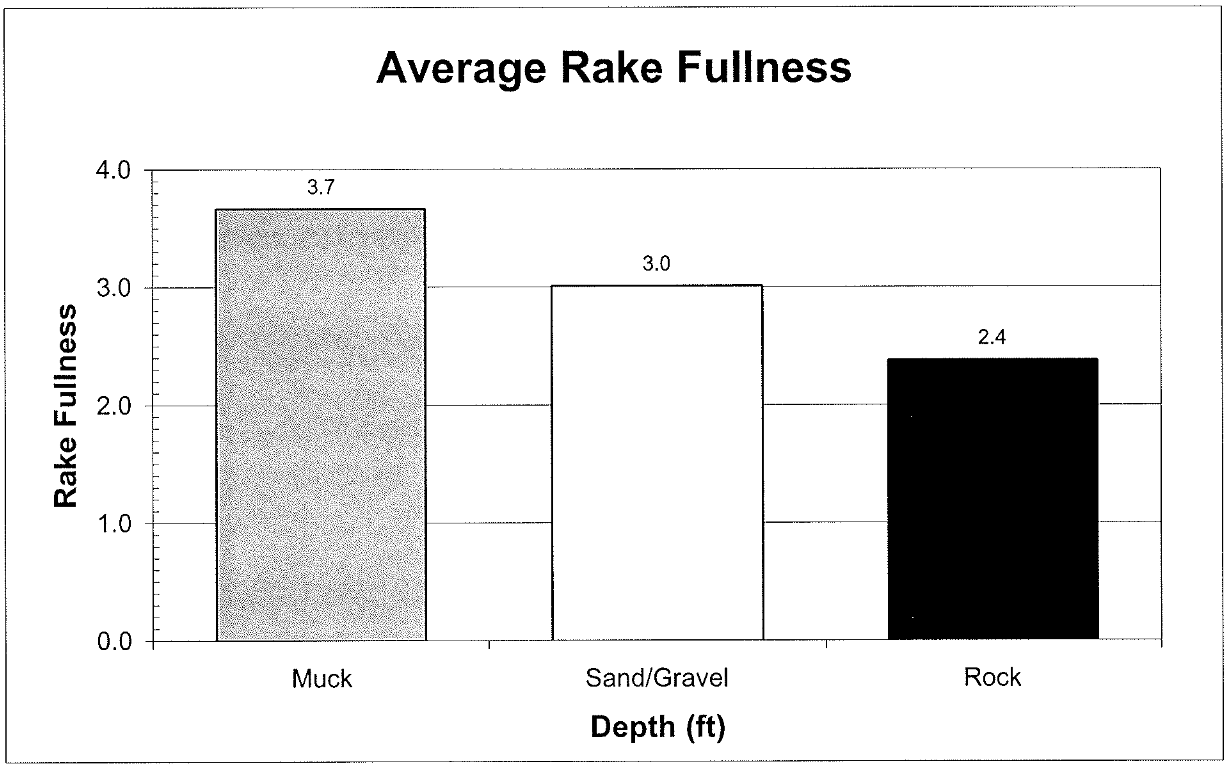
All Plants

Depth Range	Depth	# of sites	Avg. Rake Fullness
0 - 0.9'	0	2	0.0
1 - 1.9'	1	21	1.4
2 - 2.9'	2	35	1.9
3 - 3.9'	3	50	2.7
4 - 4.9'	4	128	3.1
5 - 5.9'	5	97	3.7
6 - 6.9'	6	112	3.9
7 - 7.9'	7	58	4.0
8 - 8.9'	8	30	4.0
9 - 9.9'	9	9	4.0
10' - 10.9'	10	7	3.7
11' - 11.9'	11	5	4.0
12' - 12.9'	12	9	3.2
13' - 13.9'	13	11	0.7
14 - 14.9'	14	6	1.3
>15'	15	150	



Aquatic Plant Density by Sediment Type

Sediment Type	# of sites shallower than max depth of plants	Avg rake fullness
Muck	280	3.7
Sand/Gravel	272	3.0
Rock	21	2.4
Total	573	

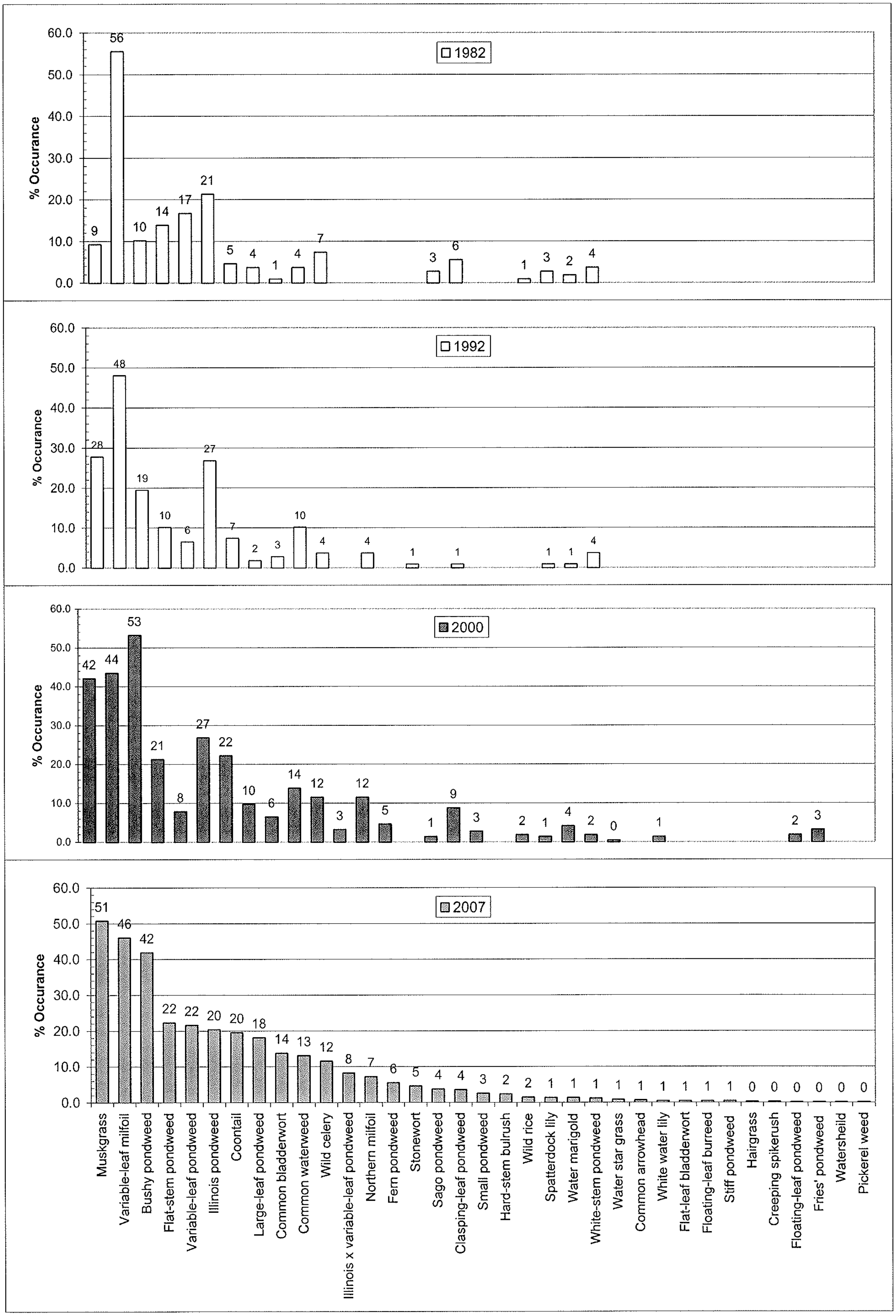


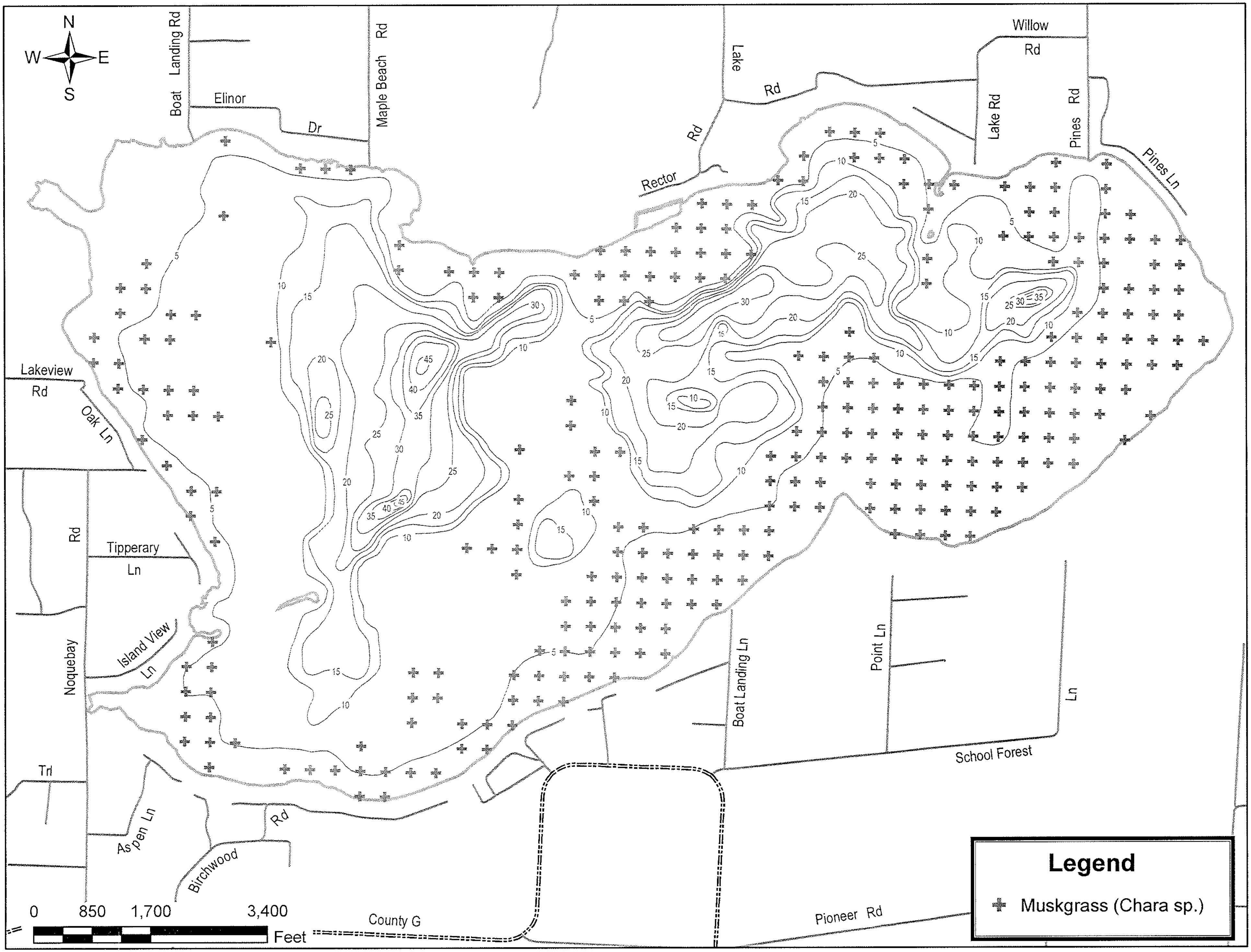
Historical Aquatic Plant Survey Data for Lake Noquebay

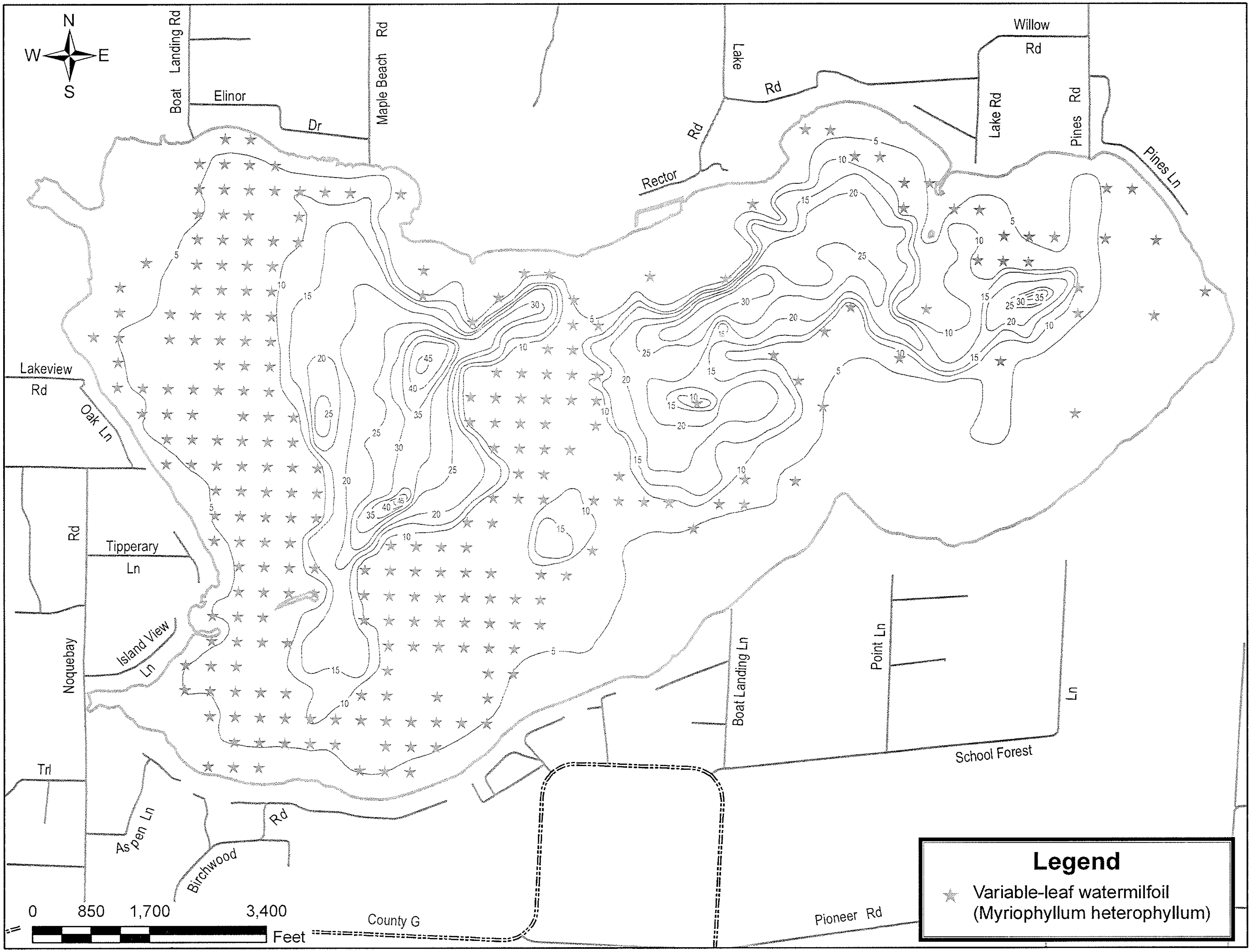
1982 & 1992 - Conducted by Nothern Lake Service. Presence/absence surveys at 27 ample locations with 4 sample points each (n = 108 points)
2000 - Conducted by Chuck Druckrey. Presence/absence survey at 54 sample locations with 4 sample points each (n = 216 points)
2007 - Conducted by Chuck Druckrey. Presence/absence survey at 732 sample locations (n = 732 points, n = 579 below max depth of plant growth))

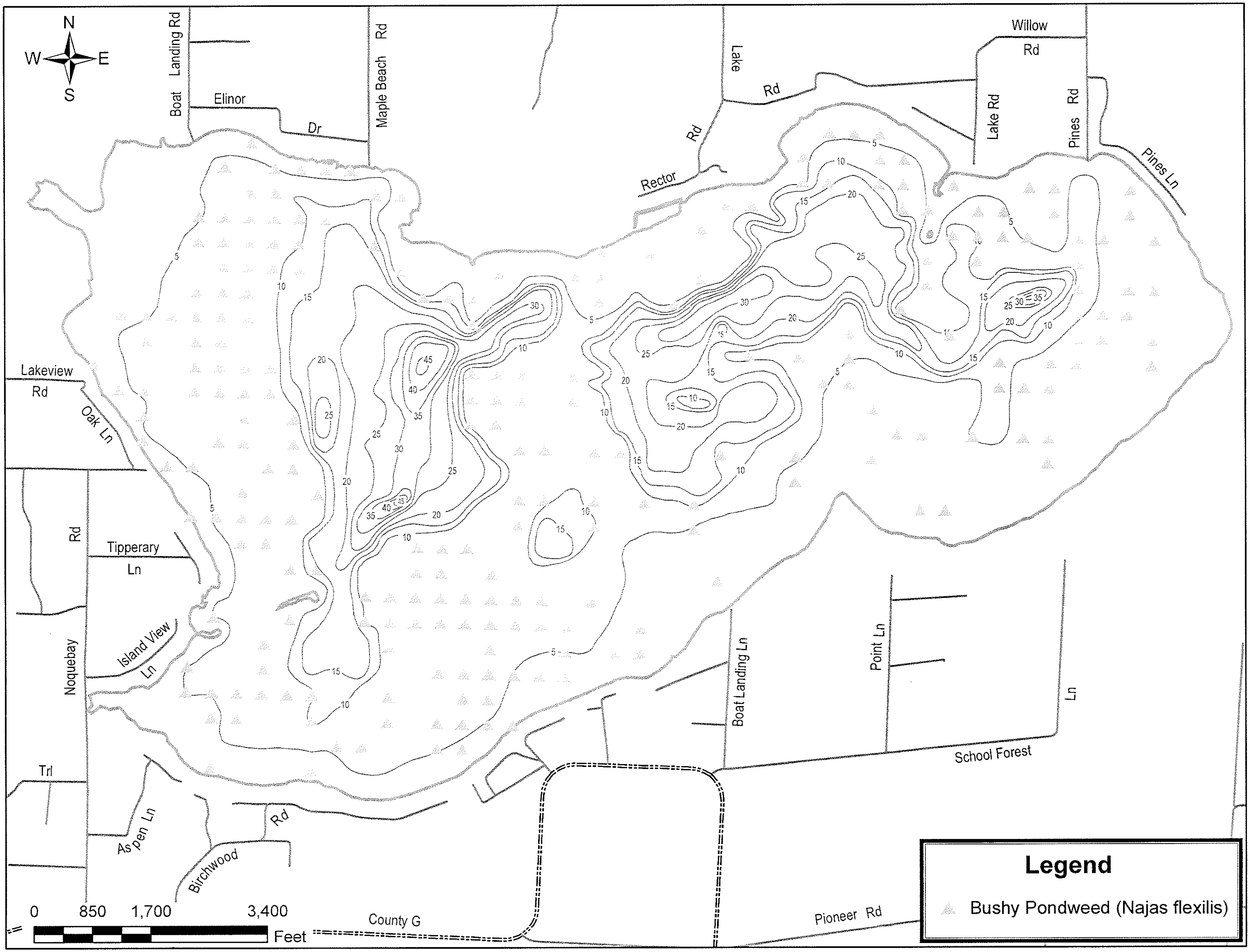
Sorted by Frequency (2007)

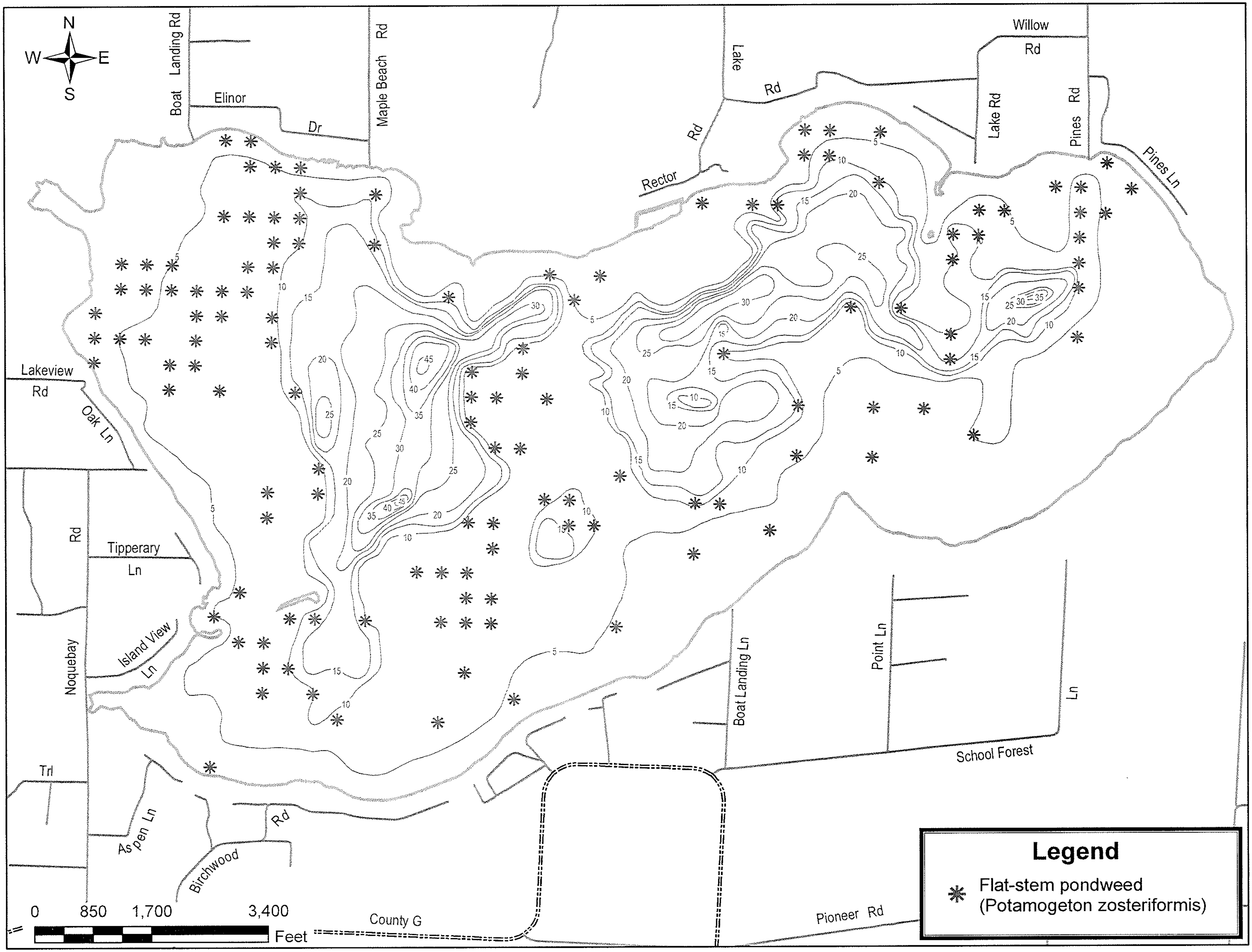
Species	Common Name	2007 Frequency	Relative Frequency	2000 Frequency	Relative Frequency	1992 Frequency	Relative Frequency	1982 Frequency	Relative Frequency
Chara sp.	Muskgrass	50.8	15.5	42.1	13.7	27.78	15.8	9.3	5.6
Myriophyllum heterophyllum	Variable-leaf milfoil	46.1	14.0	43.5	14.2	48.15	27.4	55.6	33.7
Najas flexilis	Bushy pondweed	41.9	12.8	53.2	17.3	19.44	11.0	10.2	6.2
Potamogeton zosteriformis	Flat-stem pondweed	22.4	6.8	21.3	6.9	10.19	5.8	13.9	8.4
Potamogeton graminaeus	Variable-leaf pondweed	21.7	6.6	7.9	2.6	6.48	3.7	16.7	10.1
Potamogeton illinoensis	Illinois pondweed	20.5	6.2	26.9	8.7	26.85	15.3	21.3	12.9
Ceratophylum demersum	Coontail	19.6	6.0	22.2	7.2	7.41	4.2	4.6	2.8
Potamogeton amplifolius	Large-leaf pondweed	18.2	5.5	9.7	3.2	1.85	1.1	3.7	2.2
Utricularia vulgaris	Common bladderwort	13.9	4.2	6.5	2.1	2.78	1.6	0.9	0.6
Elodea canadensis	Common waterweed	13.2	4.0	13.9	4.5	10.19	5.8	3.7	2.2
Vallisneria americana	Wild celery	11.6	3.5	11.6	3.8	3.7	2.1	7.4	4.5
Potamogeton hybrid (gram x Illinoen	Illinois x variable-leaf pondweed	8.3	2.5	3.2	1.1				
Myriophyllum sibericum	Northern milfoil	7.3	2.2	11.6	3.8	3.7	2.1		
Potamogeton robbinsii	Fern pondweed	5.5	1.7	4.6	1.5				
Nitella sp.	Stonewort	4.7	1.4			0.93	0.5		
Stuckenia pectinata	Sago pondweed	3.8	1.2	1.4	0.5			2.8	1.7
Potamogeton richardsonii	Clasping-leaf pondweed	3.6	1.1	8.8	2.9	0.93	0.5	5.6	3.4
Potamogeton pusillus	Small pondweed	2.6	0.8	2.8	0.9				
Scirpus acutus	Hard-stem bulrush	2.4	0.7						
Zizania aquatica	Wild rice	1.6	0.5	1.9	0.6			0.9	0.6
Nuphar variegata	Spatterdock lily	1.4	0.4	1.4	0.5	0.93	0.5	2.8	1.7
Bidens beckii	Water marigold	1.4	0.4	4.2	1.4	0.93	0.5	1.9	1.1
Potamogeton praelongus	White-stem pondweed	1.2	0.4	1.9	0.6	3.7	2.1	3.7	2.2
Zosterella dubia	Water star grass	0.9	0.3	0.5	0.2				
Sagittaria latifolia	Common arrowhead	0.7	0.2						
Nymphaea odorata	White water lily	0.5	0.2	1.4	0.5				
Utricularia intermedia	Flat-leaf bladderwort	0.5	0.2						
Sparganium fluctuans	Floating-leaf burreed	0.5	0.2						
Potamogeton strictifolius	Stiff pondweed	0.5	0.2						
Eleocharis palustris	Hairgrass	0.3	0.1						
Eleocharis acicularis	Creeping spikerush	0.3	0.1						
Potamogeton natans	Floating-leaf pondweed	0.2	0.1	1.9	0.6				
Potamogeton friesii	Fries' pondweed	0.2	0.1	3.2	1.1				
Brasenia schreberi	Watersheild	0.2	0.1						
Pontederia cordata	Pickerel weed	0.2	0.1						
	Total	**328.6**	**100.0**	**307.4**	**100.0**	**175.94**	**100.0**	**164.8**	**100.0**


□ 1982
□ 1992
■ 2000
■ 2007
% Occurance
Muskgrass
Variable-leaf milfoil
Bushy pondweed
Flat-stem pondweed
Variable-leaf pondweed
Illinois pondweed
Coontail
Large-leaf pondweed
Common bladderwort
Common waterweed
Wild celery
Illinois x variable-leaf pondweed
Northern milfoil
Fern pondweed
Stonewort
Sago pondweed
Clasping-leaf pondweed
Small pondweed
Hard-stem bulrush
Wild rice
Spatterdock lily
Water marigold
White-stem pondweed
Water star grass
Common arrowhead
White water lily
Flat-leaf bladderwort
Floating-leaf burreed
Stiff pondweed
Hairgrass
Creeping spikerush
Floating-leaf pondweed
Fries' pondweed
Watersheild
Pickerel weed


N
W
E
S
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Rd
Noquebay
Island View Ln
Trl
Aspen Ln
Birchwood Rd
Boat Landing Ln
Point Ln
Ln
School Forest
County G
Pioneer Rd
0
850
1,700
3,400
Feet
Legend
Muskgrass (Chara sp.)


N
W
E
S
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Rd
Tipperary Ln
Noquebay
Island View Ln
Trl
Aspen Ln
Birchwood Rd
County G
Boat Landing Ln
Point Ln
Ln
School Forest
Pioneer Rd
0
850
1,700
3,400
Feet
Legend
Variable-leaf watermilfoil
(Myriophyllum heterophyllum)


N
W
E
S
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Noquebay Rd
Island View Ln
Trl
Aspen Ln
Birchwood Rd
Boat Landing Ln
Point Ln
School Forest Ln
County G
Pioneer Rd
0
850
1,700
3,400
Feet
Legend
Bushy Pondweed (Najas flexilis)



N
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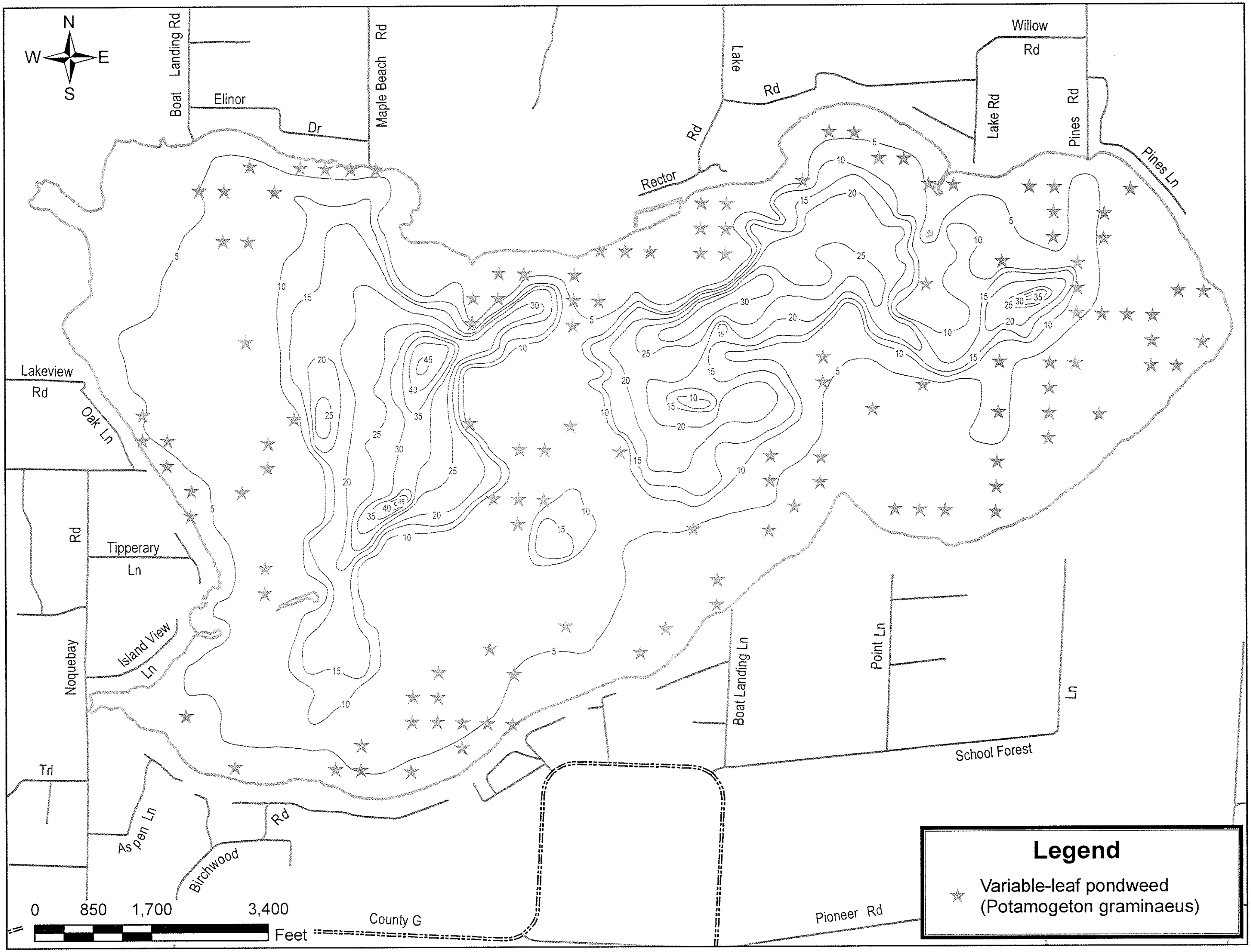
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Rd
Noquebay
Island View Ln
Trl
Aspen Ln
Birchwood Rd
Boat Landing Ln
Point Ln
Ln
School Forest
County G
Pioneer Rd
0
850
1,700
3,400
Feet
Legend
Flat-stem pondweed
(Potamogeton zosteriformis)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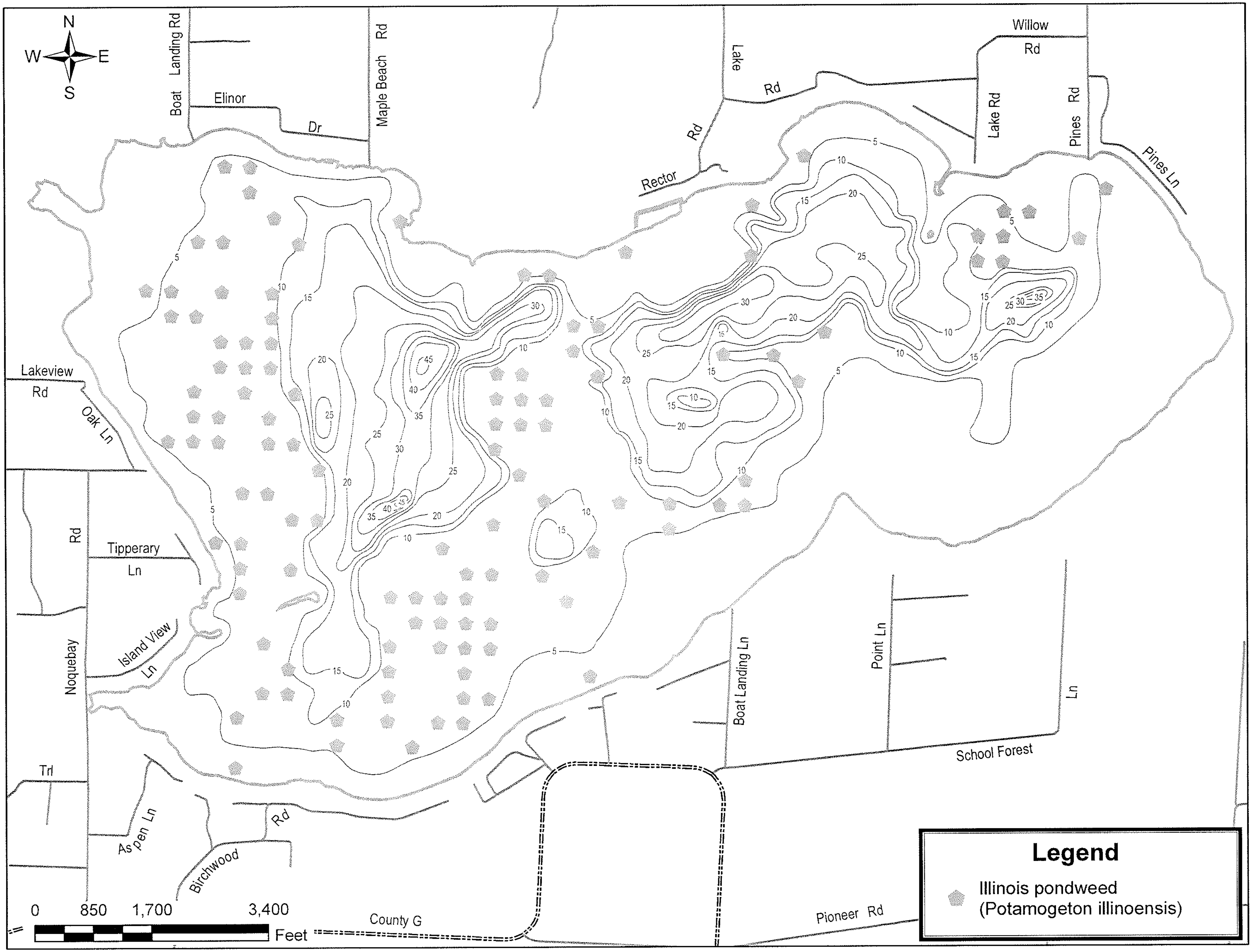
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Noquebay Rd
Island View Ln
Trl
Aspen Ln
Birchwood Rd
Boat Landing Ln
Point Ln
School Forest Ln
County G
Pioneer Rd
0 850 1,700 3,400 Feet
Legend
Variable-leaf pondweed (Potamogeton graminaeus)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Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Noquebay Rd
Island View Ln
Trl
Aspen Ln
Birchwood Rd
Boat Landing Ln
Point Ln
School Forest Ln
County G
Pioneer Rd
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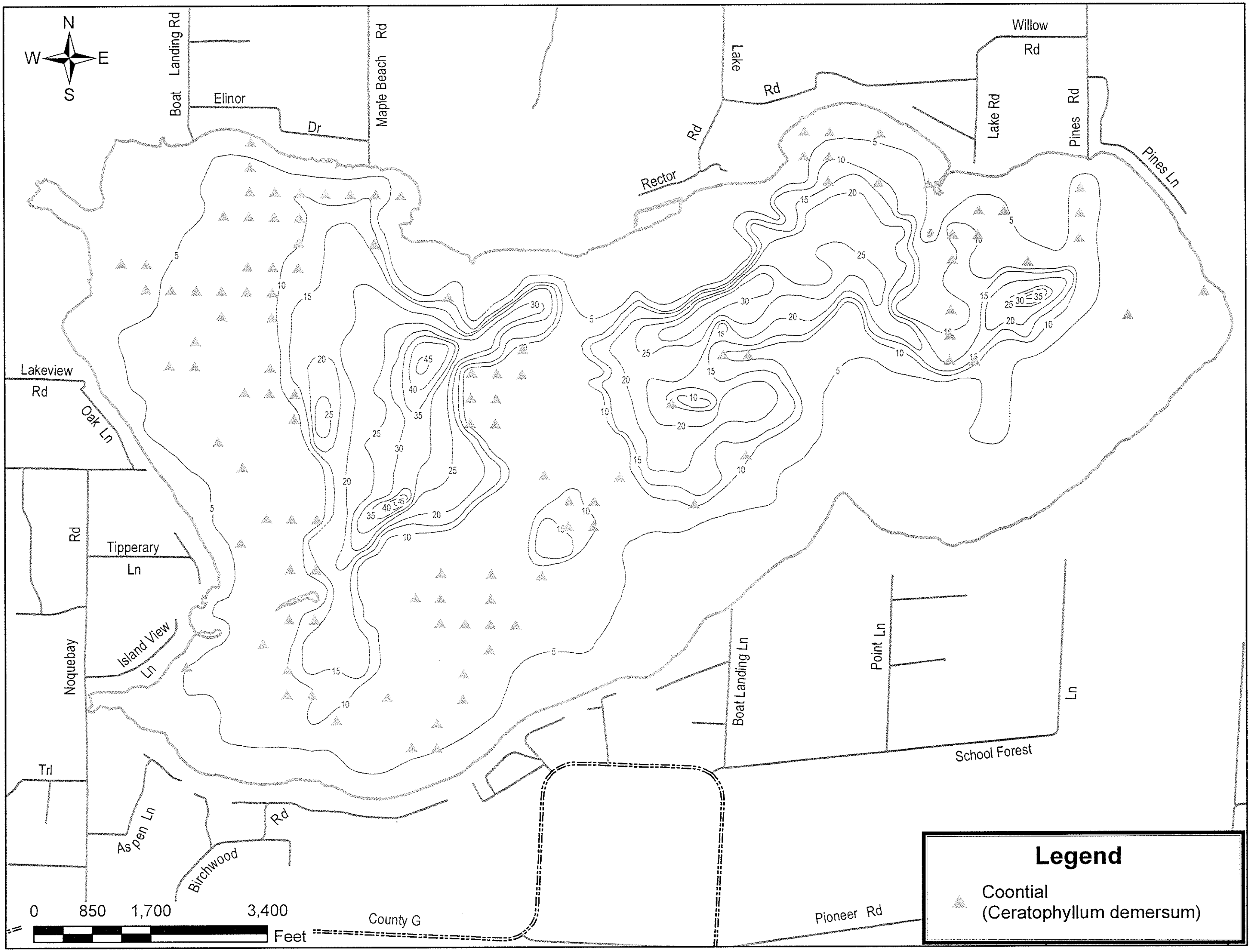
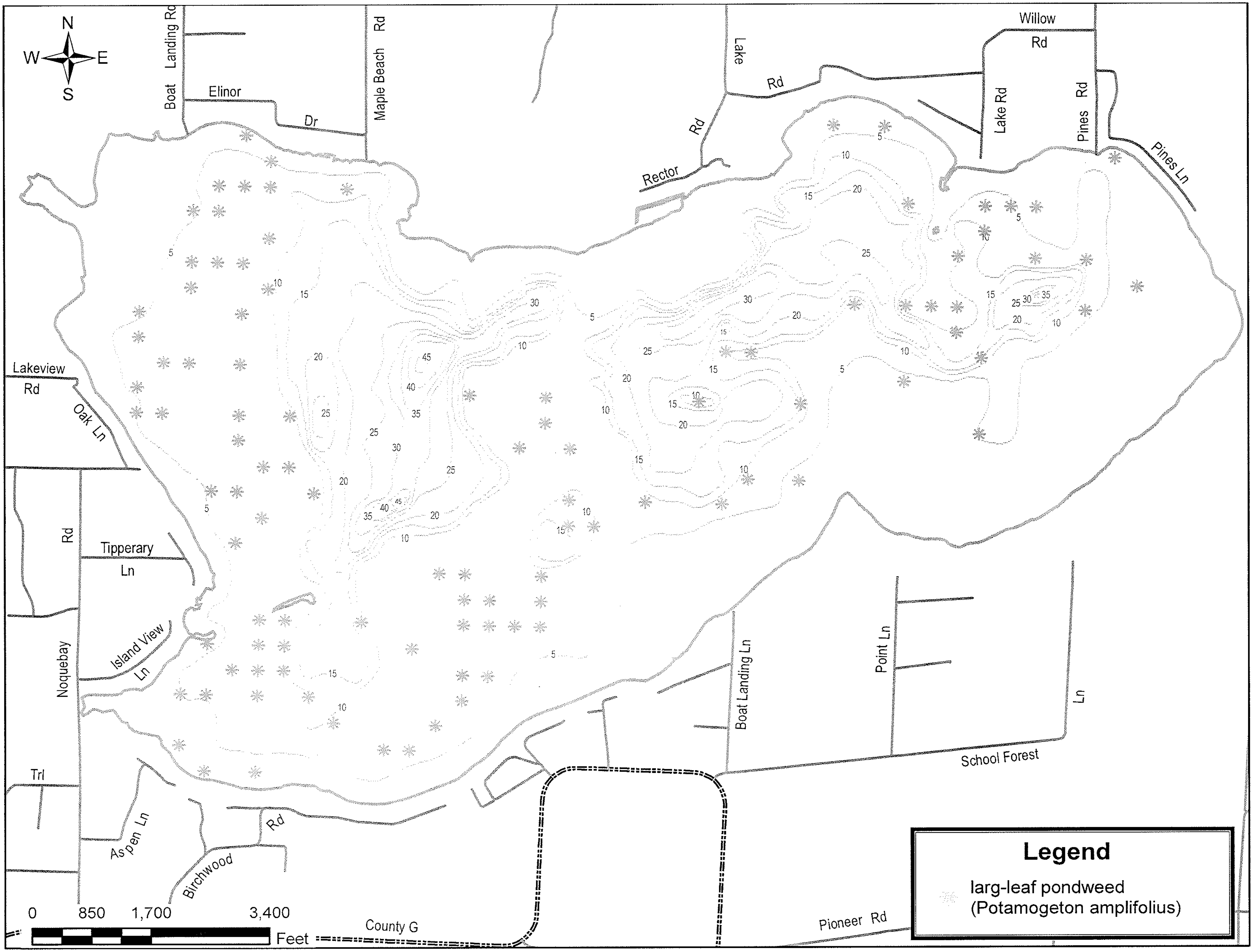
850
1,700
3,400
Feet
Legend
Illinois pondweed
(Potamogeton illinoensis)



Legend
Coontial
(Ceratophyllum demersum)
N
S
W
E
0
850
1,700
3,400
Feet
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Noquebay Rd
Island View Ln
Trl
Aspen Ln
Birchwood Rd
County G
Boat Landing Ln
Point Ln
School Forest Ln
Pioneer Rd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Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Rd
Tipperary Ln
Island View Ln
Noquebay
Trl
Aspen Ln
Birchwood Rd
Boat Landing Ln
Point Ln
School Forest Ln
County G
Pioneer Rd
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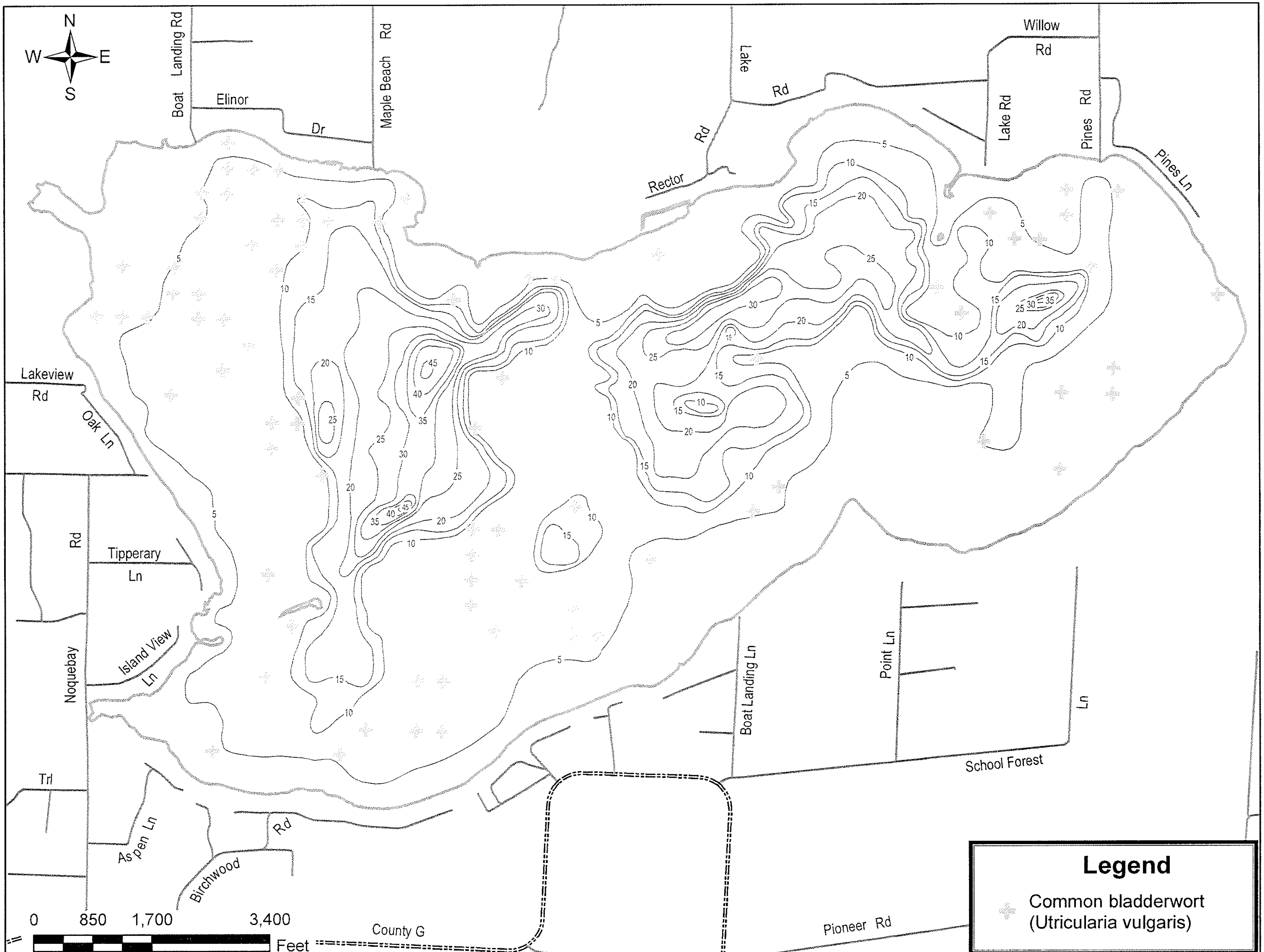
1,700
3,400
Feet
Legend
larg-leaf pondweed
(Potamogeton amplifolius)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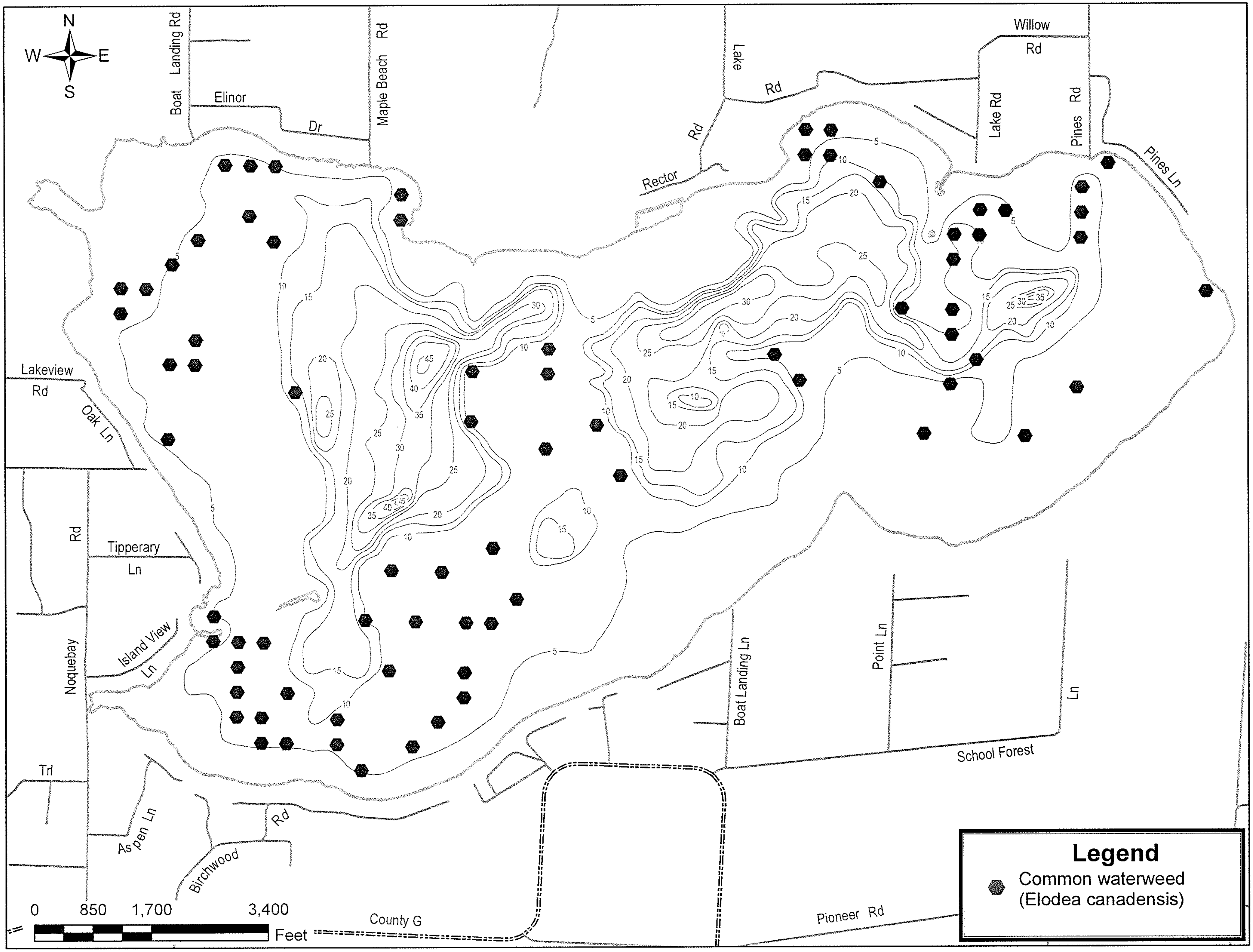
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Noquebay Rd
Island View Ln
Trl
Aspen Ln
Birchwood Rd
County G
Boat Landing Ln
Point Ln
School Forest Ln
Pioneer Rd
0
850
1,700
3,400
Feet
Legend
Common bladderwort
(Utricularia vulgaris)



N
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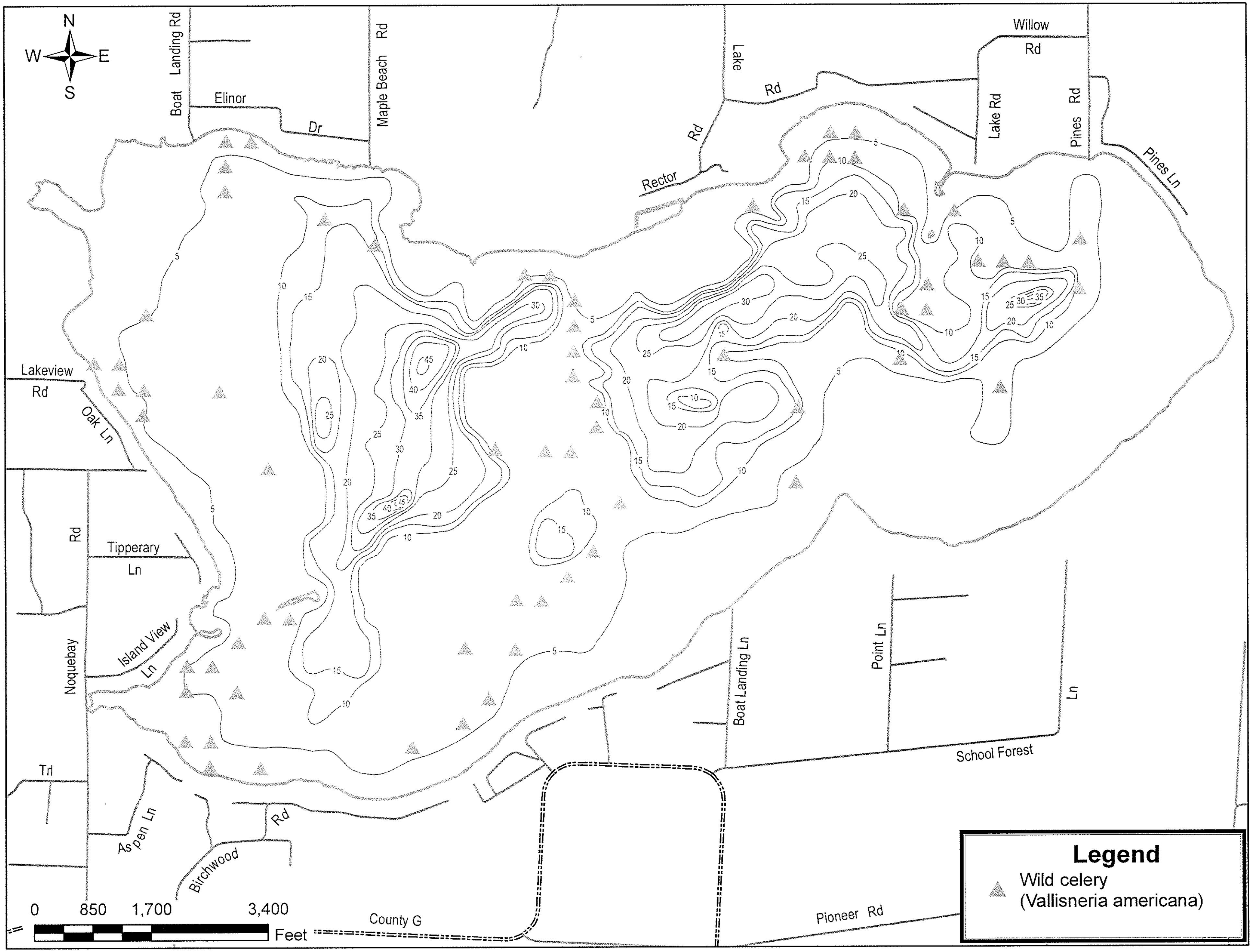
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Noquebay Rd
Island View Ln
Trl
Aspen Ln
Birchwood Rd
Boat Landing Ln
Point Ln
School Forest Ln
County G
Pioneer Rd
0
850
1,700
3,400
Feet
Legend
Common waterweed
(Elodea canadensis)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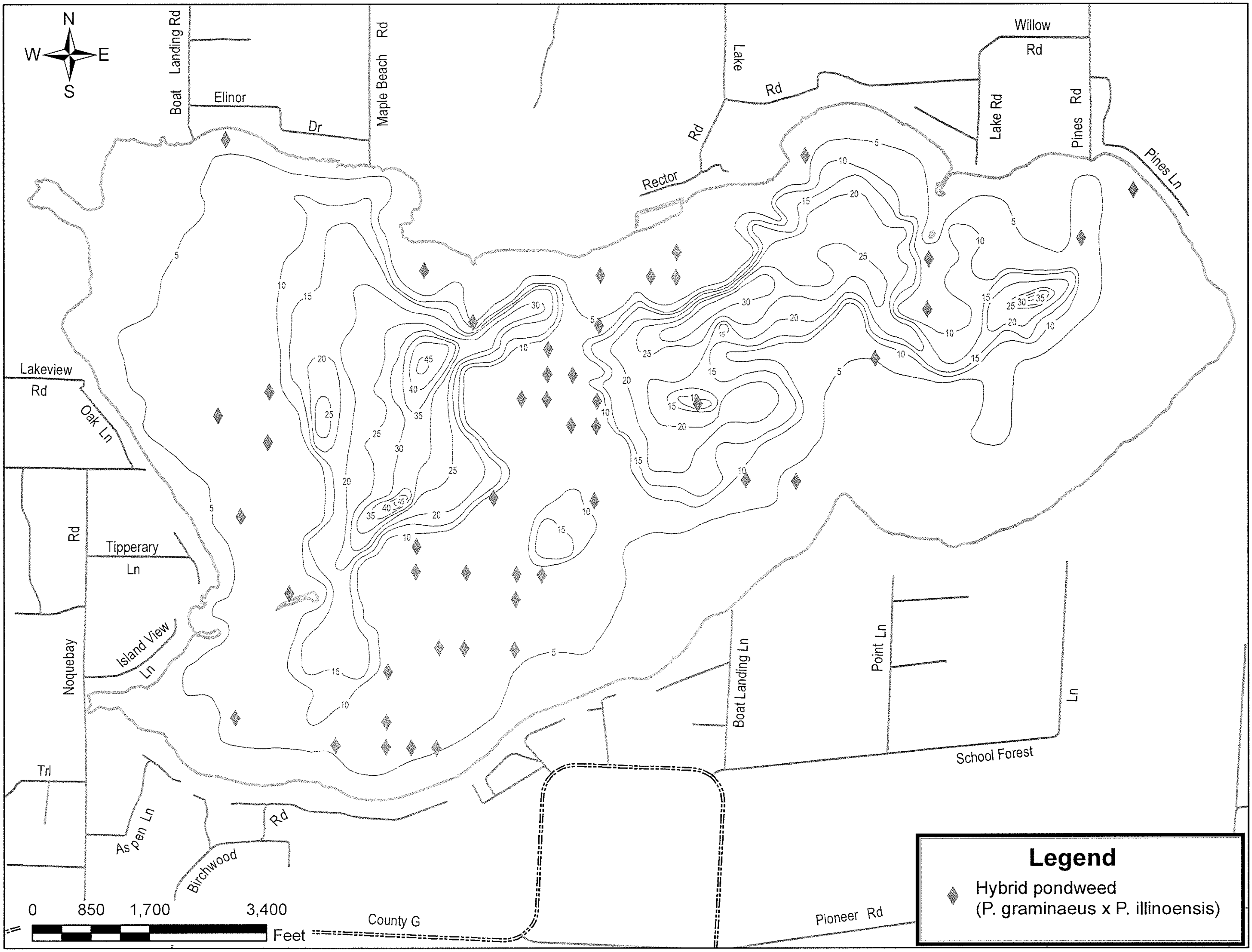
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Island View Ln
Noquebay Rd
Trl
Aspen Ln
Birchwood Rd
Boat Landing Ln
Point Ln
School Forest Ln
County G
Pioneer Rd
0
850
1,700
3,400
Feet
Legend
Wild celery
(Vallisneria americana)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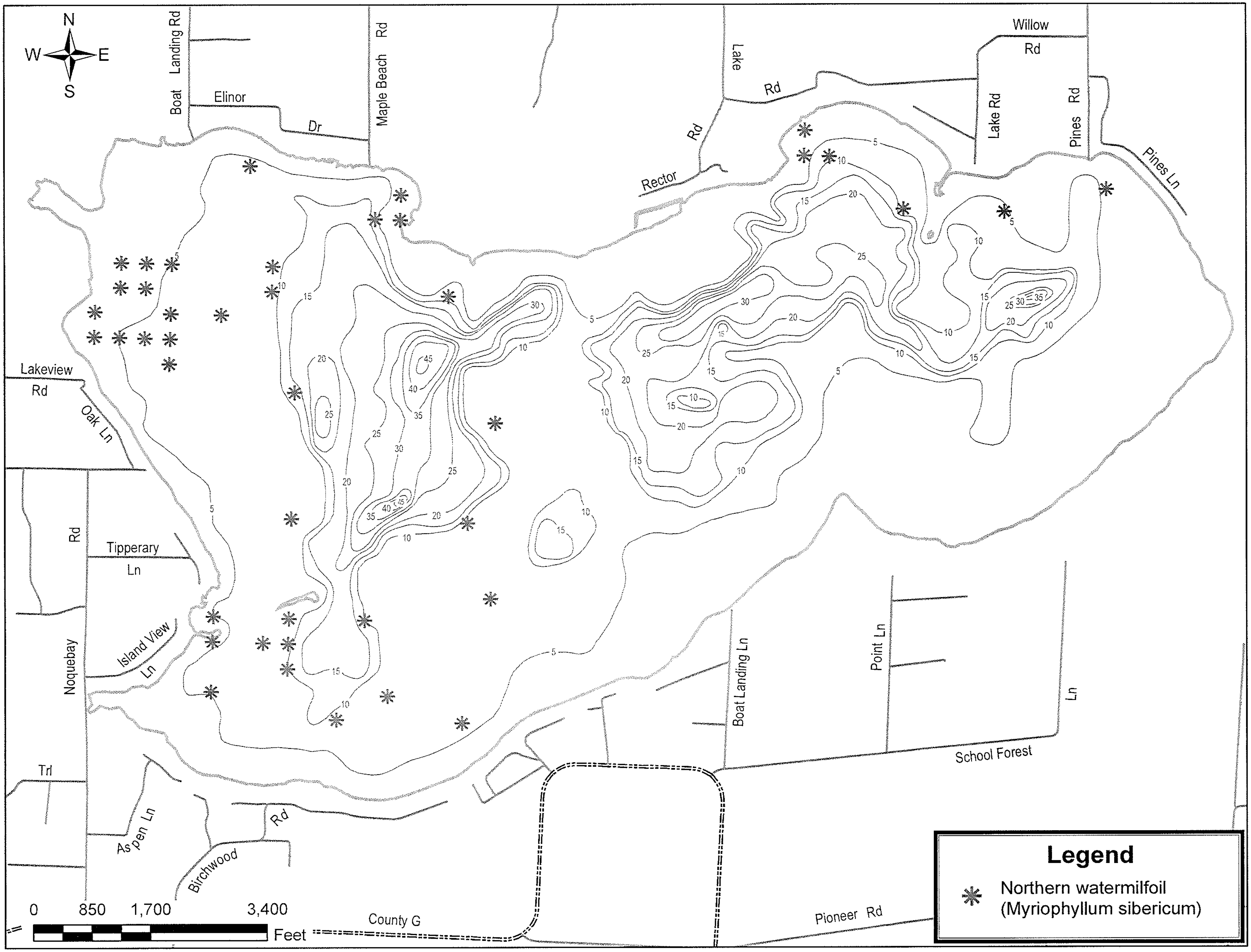
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Noquebay Rd
Island View Ln
Trl
Aspen Ln
Birchwood Rd
County G
Boat Landing Ln
Point Ln
School Forest Ln
Pioneer Rd
0
850
1,700
3,400
Feet
Legend
Hybrid pondweed
(P. graminaeus x P. illinoensis)



Legend
Northern watermilfoil
(Myriophyllum sibericum)
N
W
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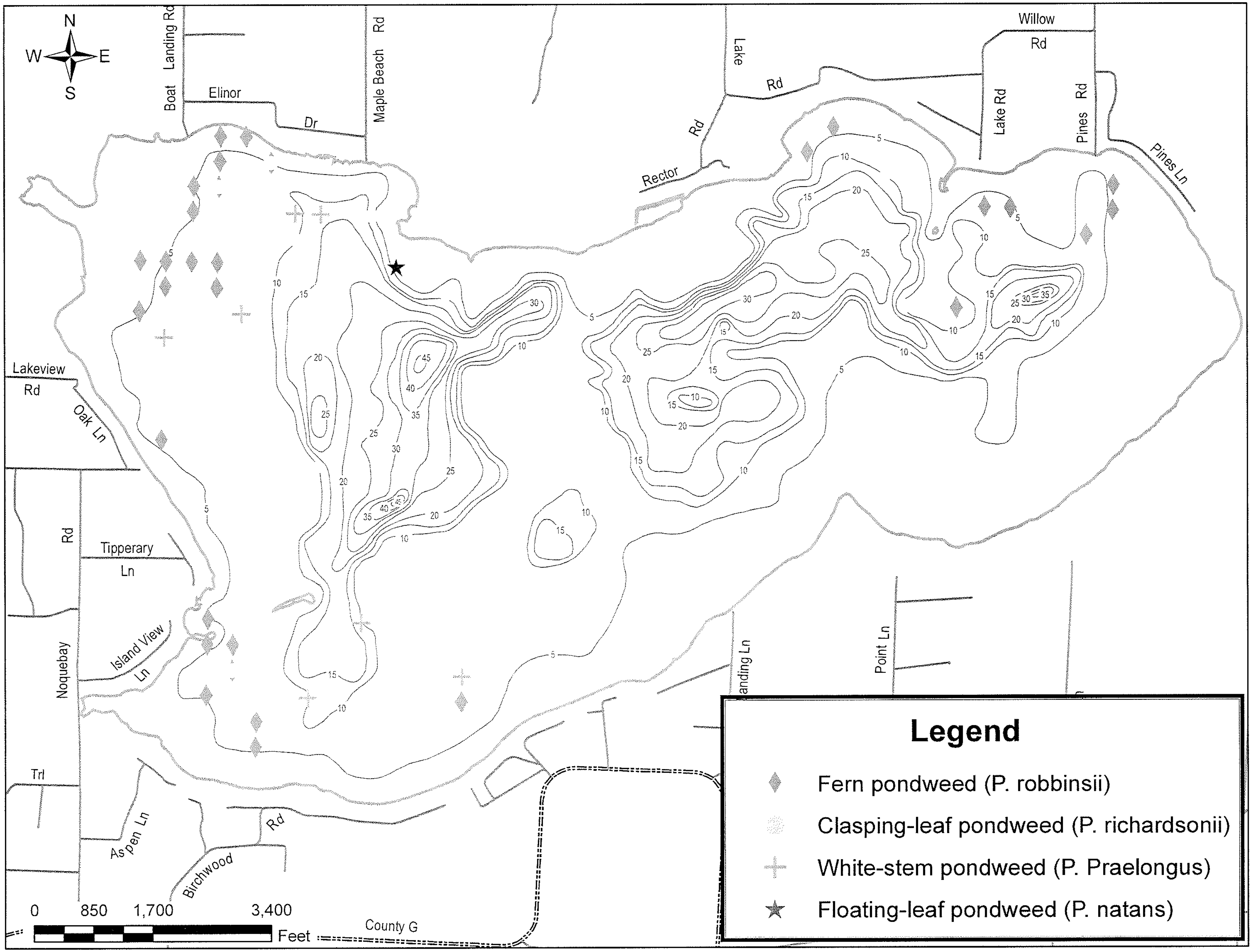
S
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Noquebay Rd
Island View Ln
Trl
Aspen Ln
Birchwood Rd
Boat Landing Ln
Point Ln
School Forest Ln
Pioneer Rd
County G
0
850
1,700
3,400
Feet



N
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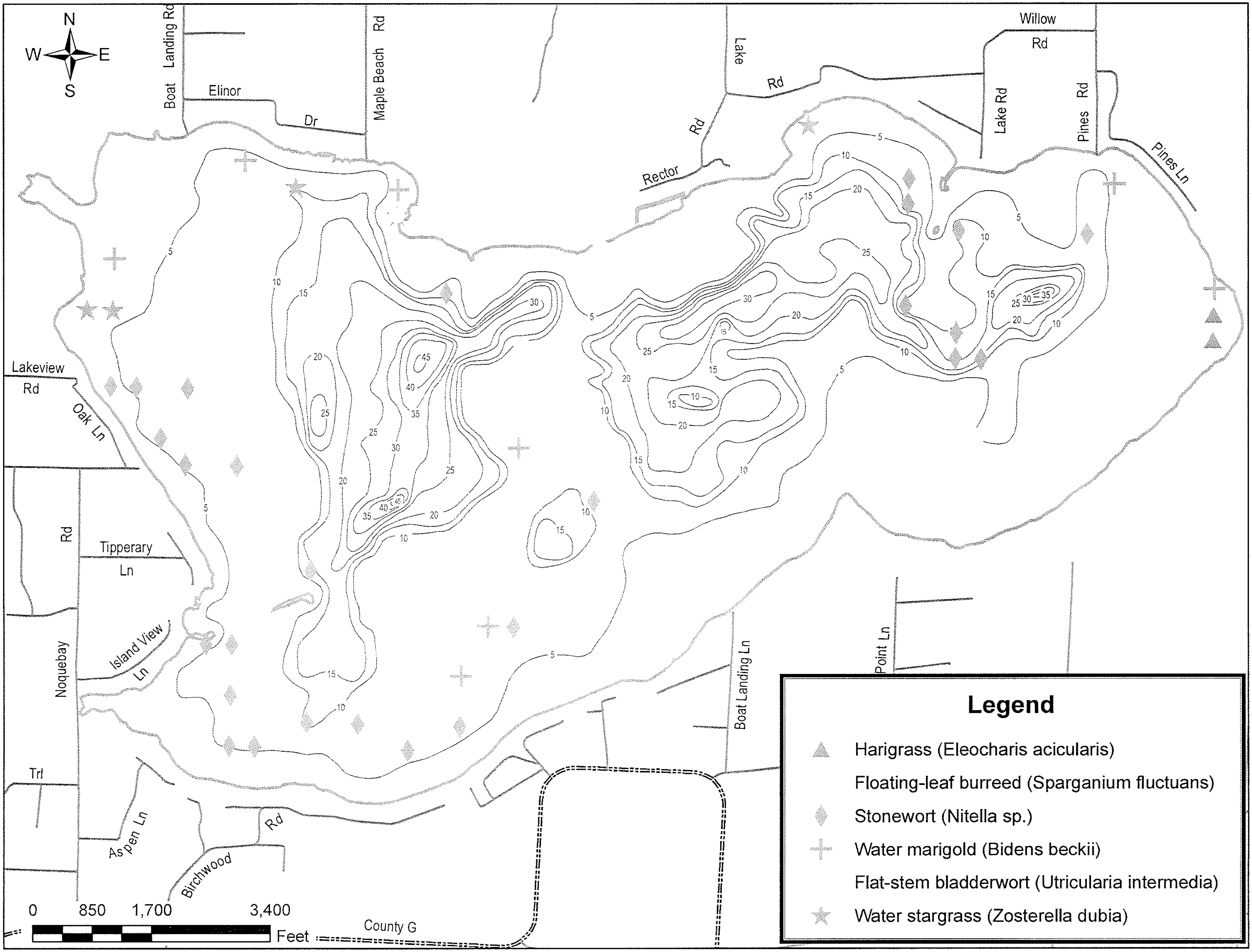
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Noquebay Rd
Island View Ln
Trl
Aspen Ln
Birchwood Rd
County G
Point Ln
Landing Ln
0
850
1,700
3,400
Feet
Legend
Fern pondweed (P. robbinsii)
Clasping-leaf pondweed (P. richardsonii)
White-stem pondweed (P. Praelongus)
Floating-leaf pondweed (P. natans)


N
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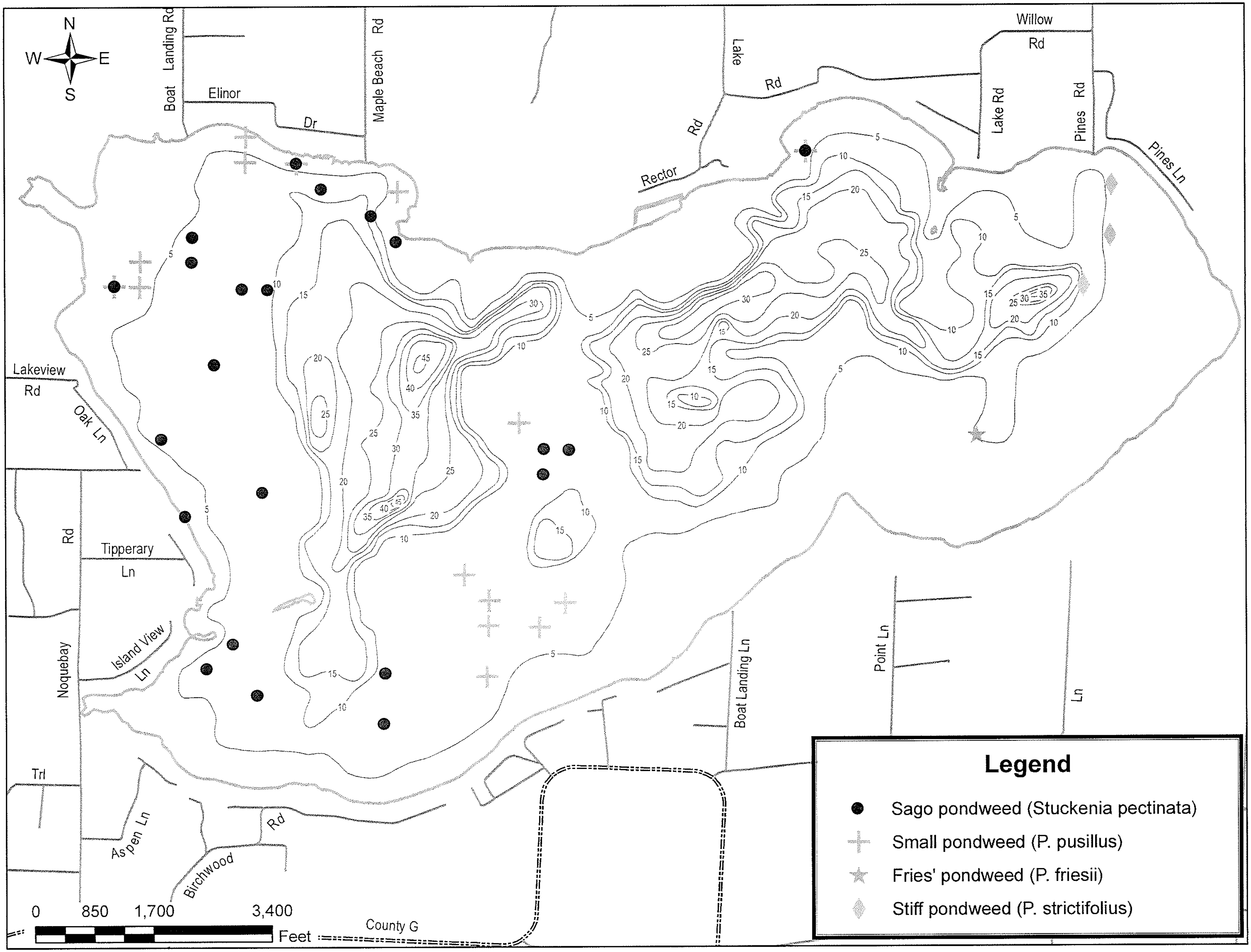
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Noquebay Rd
Island View Ln
Trl
Aspen Ln
Birchwood Rd
Boat Landing Ln
Point Ln
County G
0
850
1,700
3,400
Feet
Legend
Harigrass (Eleocharis acicularis)
Floating-leaf burreed (Sparganium fluctuans)
Stonewort (Nitella sp.)
Water marigold (Bidens beckii)
Flat-stem bladderwort (Utricularia intermedia)
Water stargrass (Zosterella dubia)



N
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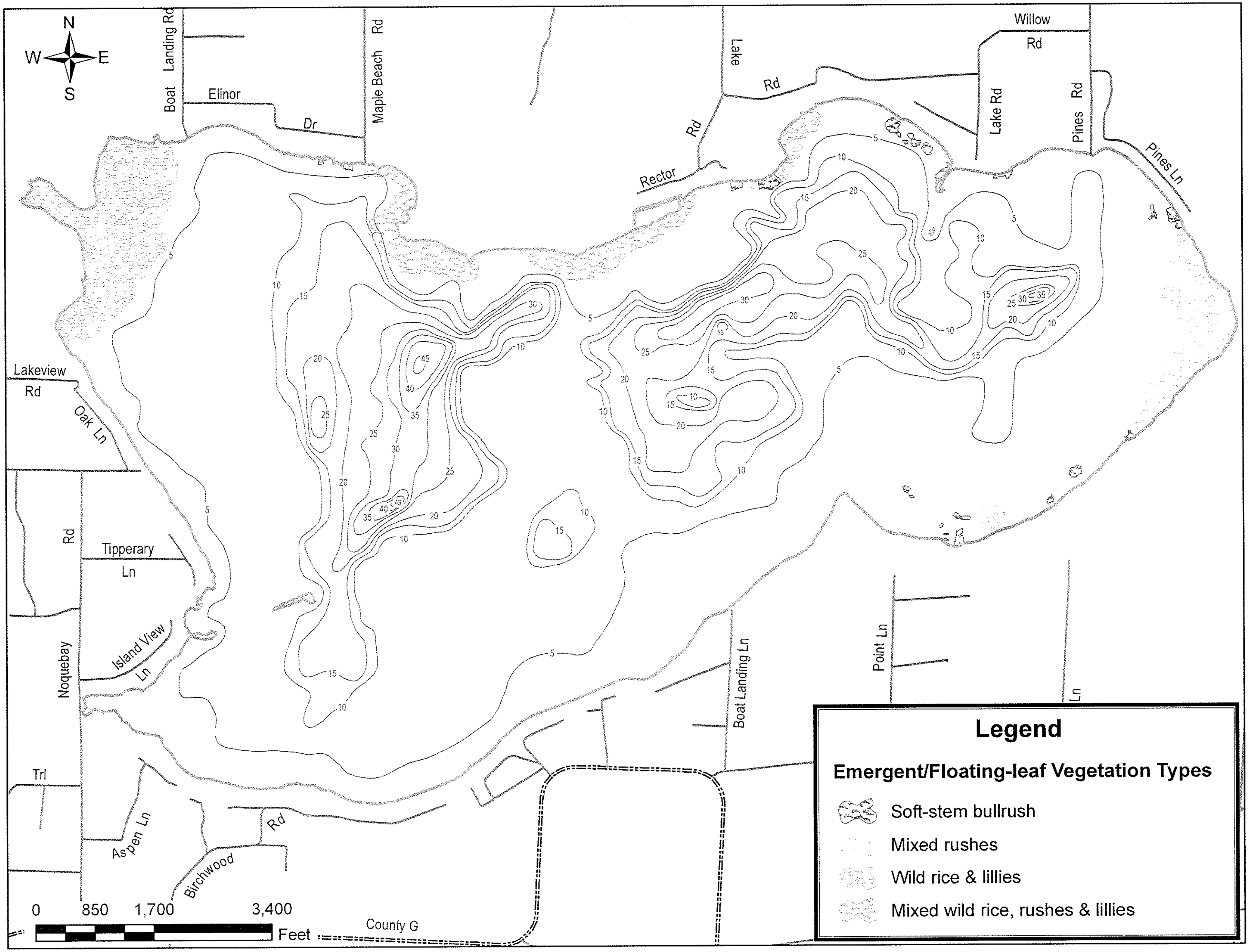
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Noquebay Rd
Tipperary Ln
Island View Ln
Trl
Aspen Ln
Birchwood Rd
County G
Boat Landing Ln
Point Ln
Ln
0
850
1,700
3,400
Feet
Legend
Sago pondweed (Stuckenia pectinata)
Small pondweed (P. pusillus)
Fries' pondweed (P. friesii)
Stiff pondweed (P. strictifolius)



N
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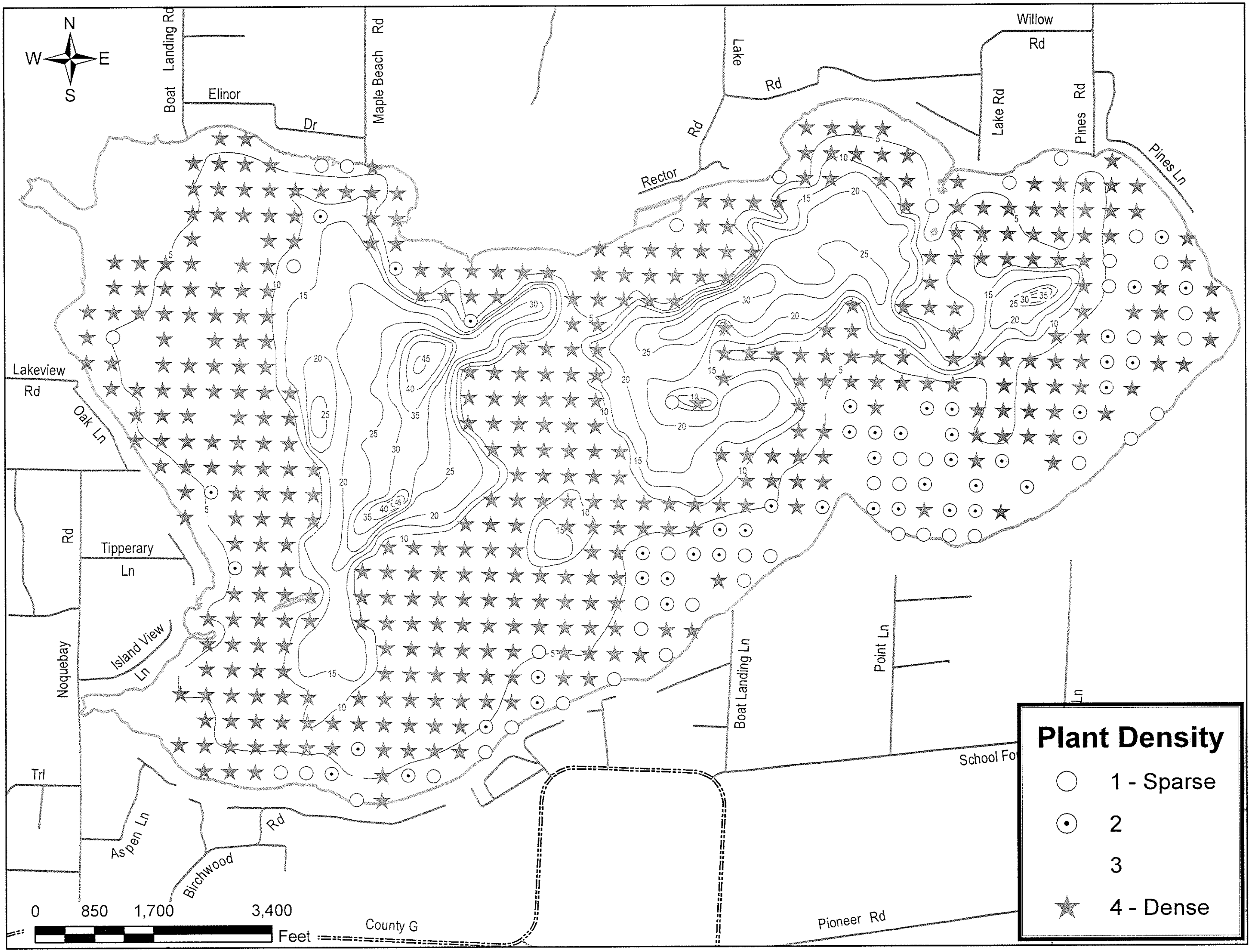
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Island View Ln
Noquebay Rd
Trl
Aspen Ln
Birchwood Rd
Boat Landing Ln
Point Ln
Ln
County G
0
850
1,700
3,400
Feet
Legend
Emergent/Floating-leaf Vegetation Types
Soft-stem bullrush
Mixed rushes
Wild rice & lillies
Mixed wild rice, rushes & lillies


Plant Density
1 - Sparse
2
3
4 - Dense
N
W
E
S
0
850
1,700
3,400
Feet
Boat Landing Rd
Elinor Dr
Maple Beach Rd
Lake Rd
Rector Rd
Willow Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Island View Ln
Noquebay Rd
Trl
Aspen Ln
Birchwood Rd
County G
Boat Landing Ln
Point Ln
School Fo
Pioneer Rd

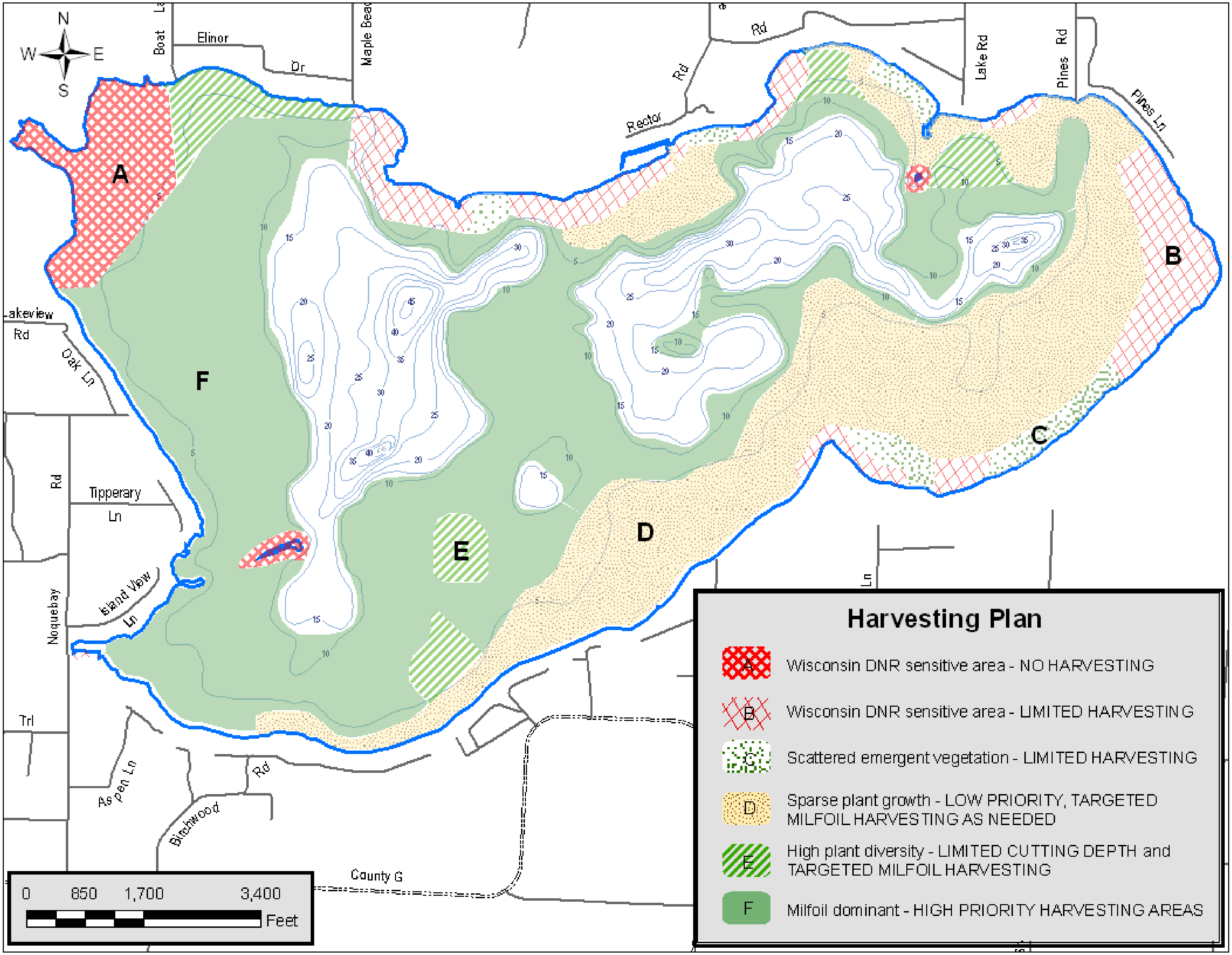
Comprehensive Lake Management Plan

For

Lake Noquebay

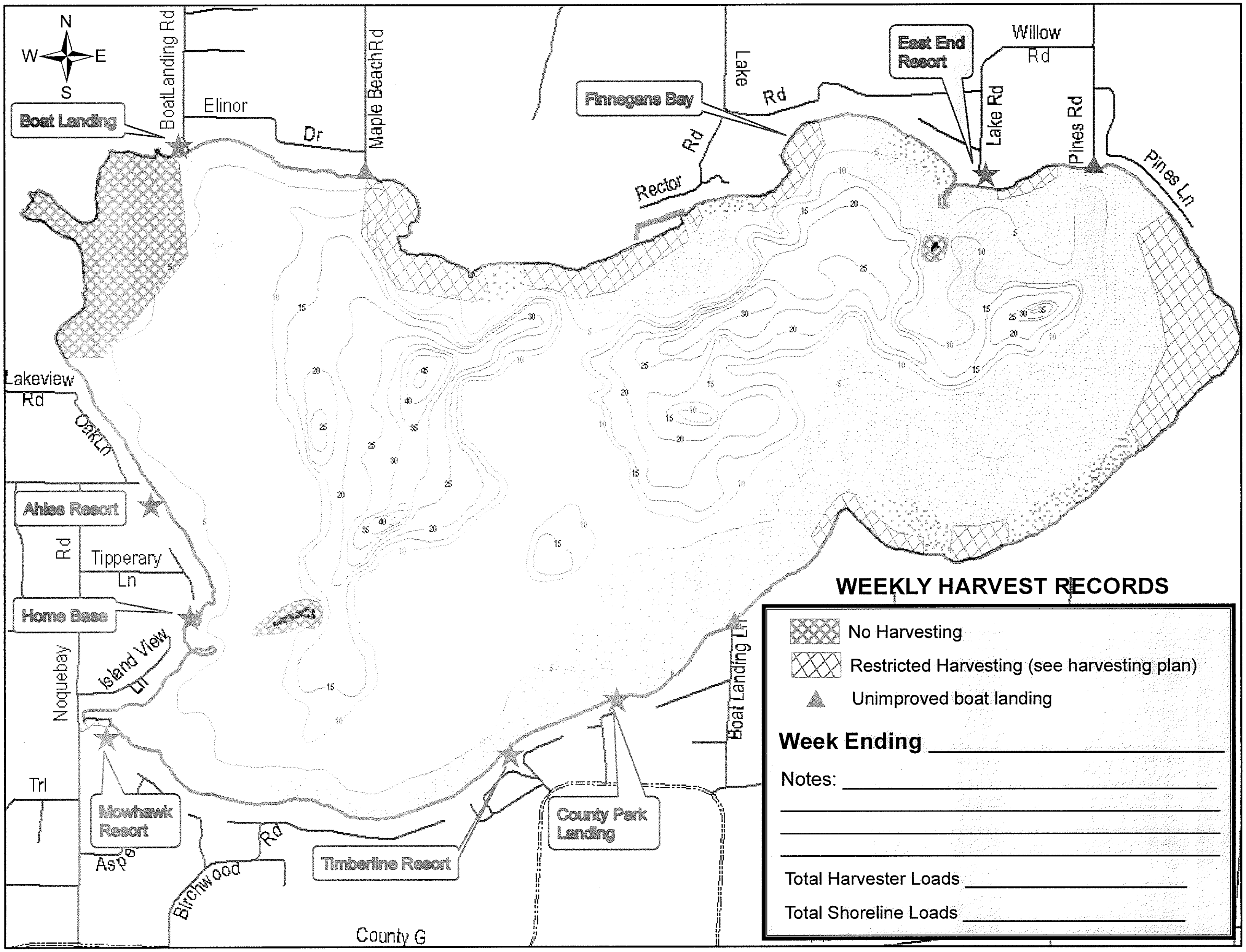
APPENDIX E

Harvesting Plan
&
Record Keeping



Harvesting Plan
A Wisconsin DNR sensitive area - NO HARVESTING
B Wisconsin DNR sensitive area - LIMITED HARVESTING
C Scattered emergent vegetation - LIMITED HARVESTING
D Sparse plant growth - LOW PRIORITY, TARGETED MILFOIL HARVESTING AS NEEDED
E High plant diversity - LIMITED CUTTING DEPTH and TARGETED MILFOIL HARVESTING
F Milfoil dominant - HIGH PRIORITY HARVESTING AREAS
0 850 1,700 3,400 Feet
N
S
E
W
A
B
C
D
E
F
Elinor Dr
Boat
Maple Beach
Rector Rd
Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview Rd
Oak Ln
Tipperary Ln
Rd
Island View Ln
Noquebay
Trl
Aspen Ln
Birchwood Rd
County G
Ln

Area	Zone	Acres	Description & Management Measures
A	Wisconsin DNR identified sensitive areas	96	Selected areas of the lake that contain significant stands of emergent plants (rushes, wild rice etc.) and/or floating-leaf plants (water lilies) that provide important fish & wildlife habitat, or contain other important fish spawning habitat. These areas do not front on developed properties and should be preserved.
			No harvesting of aquatic plants in these areas.
B	Wisconsin DNR identified sensitive areas	152	Selected areas of the lake that contain significant stands of emergent plants (rushes, wild rice etc.) and/or floating-leaf plants (water lilies) that provide important fish and wildlife habitat, or contain uncommon fish habitat. These areas should be preserved.
			Mechanical harvesting of emergent and floating-leaf plants is limited to a 30-foot wide corridor to allow boat access to docks. Boating corridors should be sited and/or combined as needed to minimize the impact on emergent and floating-leaf aquatic plants.
			LNRD shoreline cleanup of dead and dislodged plant material around docks is allowed where practical and the plants can be accessed without destroying emergent and floating-leaf plants.
C	Scattered emergent plants	48	Areas that contain scattered stands of emergent plants providing important fish and wildlife habitat. Submersed aquatic plants are typically sparse in these areas. Emergent vegetation should be preserved.
			No harvesting of emergent aquatic plants.
D	Sparse aquatic plant growth	509	Sandy areas that typically contain sparse aquatic plant growth. Most submersed plants are low growing native varieties.
			Target harvesting efforts on scattered VWM clones as needed.
E	High plant diversity	95	Areas with abundant aquatic plants that also have excellent plant diversity, including both low growing species and native pondweeds. Dense stands of VWM can also be found growing in these areas.
			Reduce harvesting depth to three feet in mixed plant beds.
			Where found, harvest dense stands of VWM at full depth of cut.
F	Milfoil dominant	921	Areas where submersed aquatic plant growth is typically dense and VWM is the dominant species.
			Harvest as needed to maintain navigation and open the plant canopy.


N
S
E
W
Boat Landing
BoatLanding Rd
Elinor
Dr
Maple Beach Rd
Finnegans Bay
Lake
Rd
Rd
Rector
East End Resort
Willow
Rd
Lake Rd
Pines Rd
Pines Ln
Lakeview
Rd
Oak Ln
Ahles Resort
Rd
Tipperary
Ln
Home Base
Island View
Dr
Noquebay
Trl
Mowhawk Resort
Aspe
Birchwood
Rd
Timberline Resort
County Park Landing
Boat Landing Ln
County G
WEEKLY HARVEST RECORDS
No Harvesting
Restricted Harvesting (see harvesting plan)
Unimproved boat landing
Week Ending ____________
Notes: ____________
Total Harvester Loads ____________
Total Shoreline Loads ____________