

Minnesota's Sensitive Lakeshore Identification Manual: A Conservation Strategy for Minnesota's Lakeshores

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**STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ECOLOGICAL AND WATER RESOURCES**



Minnesota's Sensitive Lakeshore Identification Manual: A Conservation Strategy for Minnesota's Lakeshores

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Metric and English Units

In Minnesota, most of the statewide lake hydrologic data have been recorded in English units. Specifically, lake depth contour data, lake area and shoreline length measurements available from MnDNR are recorded in feet. Where feasible, conversions have been made. However, it would be difficult and time consuming to convert these data to metric, particularly for GIS data. As an example, standard lake depth data is available in five or ten feet increments and these data would not convert cleanly to metric (5, 10, 15, 20, 25 feet would be converted to 1.5, 3.0, 4.6, 6.1, 7.6 meters). Conversely, establishment of survey site locations in GIS and in-field navigation with GPS is primarily done using UTM (universal transverse mercator) coordinates (meters).



Note:

All maps in this document depict Ten Mile Lake, DOW 11-0413-00, Cass County, MN

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**SENSITIVE LAKESHORE IDENTIFICATION
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ECOLOGICAL AND WATER RESOURCES**

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Chapter 1. An Introduction to Sensitive Lakeshores

This manual explains the survey protocol used to identify and map sensitive fish and wildlife shoreline habitat for Minnesota lakes. Sensitive areas are places that contain unique or critical ecological habitat, and they provide important habitat for a variety of species, including species of greatest conservation need. The protocols in this manual are science-based, and were developed to be objective, fair, and commonly repeatable with basic due diligence. The purpose of the survey protocol in this manual is to provide the framework for data collection and analysis so that reliable advice can be given to local and state resource managers, who can use the information to maintain environmental conditions and protect habitat for species in greatest conservation need.

The shoreline and near-shore areas are critical to the health and well-being of fish, wildlife, and native plants. Many fish and wildlife species, including many species of greatest conservation need, are highly dependent on naturally vegetated shorelines as habitat for feeding, resting, and mating and juvenile life stages. Development and land alteration in the immediate shoreland and on the shoreline may have significant negative impacts on these species.

For the purpose of this manual the following definitions are used:

Shoreland is defined as Minnesota Rule 6120, which for lakes is that land located within 1000 feet of the ordinary high water level. Some local governments use a distance of 1320 feet. The methods in this protocol use land located within 1320 feet of the ordinary high water level in order to buffer the state-defined shoreland area.

Shoreline is the edge of a body of water and, alternatively, used here with regard to fish and wildlife habitat to refer to the narrow band around the lake centered on the land-water interface.

Near-shore is the shallow aquatic areas of a lake within 680 feet of the shoreline.

Shore impact zone means land located between the ordinary high water level of a public water and a line parallel to it at a setback of 50 percent of the structure setback, but not less than 50 feet. This area serves as the primary shoreline buffer, and for the General Development lakes surveyed it is the first 50 feet landward.

Lakeshore is the area comprised of the shoreland, shoreline and the near-shore.

Need

Increases in shoreland development are changing lake ecosystems. Development pressure is increasing with more dwellings per lake each year in Minnesota (Kelly and Stinchfield 1998). Human habitation along the shore has a cumulative effect on fish and wildlife habitat, water quality, and biota of lake ecosystems (Engel and Pederson 1998, Ramstack et al. 2004). Christensen et al. (1996) found significantly less submerged woody habitat from fallen trees along developed shorelines in Wisconsin and Michigan, and predicted that recent losses in developed lakes will affect littoral communities for about two centuries. Meyer et al. (1997)

concluded that housing development along shores of northern Wisconsin lakes dramatically altered native vegetation, especially shrubs, and reduced frog populations. Elias and Meyer (2003) found that the mean number of plant species and the percent of native species were both greater at undeveloped sites than along developed Wisconsin lakeshores for upland, shoreline, and shallow water areas. Jennings et al. (1996) noted changes in near-shore substrate composition in Wisconsin lakes due to human activity. In an Iowa lake, Byran and Scarnecchia (1992) found significant reductions in aquatic macrophyte abundance in developed compared with undeveloped shorelines. Jennings et al. (2003) also found that the amount of littoral wood remains and emergent and floating-leaf vegetation was lower at developed sites and lakes with greater development density. By comparing vegetation abundance along undeveloped and developed shorelines for 44 lakes in Minnesota, Radomski and Goeman (2001) estimated that 20 to 28 percent of the near-shore emergent and floating-leaf coverage was lost. Radomski (2006) determined that floating-leaf and emergent vegetative cover was significantly affected by development for the period from 1939 to 2003 for Minnesota lakes.

Alteration of natural littoral zone habitats has negative consequences to fish and wildlife. Littoral zone vegetation is important for amphibians, ducks, herons, and many species of greatest conservation need (Meyer et al. 1997; Lindsay et al. 2002; Woodford and Meyer 2003). Floating-leaf and emergent vegetation provides fish and wildlife with foraging areas and refuge from predators (Killgore et al. 1993; Casselman and Lewis 1996; Valley et al. 2004). Many fish depend on this habitat for some part or most of their life (Becker 1983). Emergent vegetation, such as hardstem bulrush, provides spawning habitat, cover, and colonization sites for aquatic invertebrates and protects shorelines from erosion by dampening wave energy. Numerous fish species use protected embayments and vegetative cover disproportionately to their availability (Wei et al. 2004). Human activities that change vegetative cover can alter ecological processes and energy flow within lakes, thereby reducing their ability to support diverse and healthy fish and wildlife populations (Schindler and Scheuerell 2002).

Lake shorelines often vary greatly with respect to their ecological characteristics and functions. Additional work is needed to identify and protect high priority near-shore habitats. Protection of these areas, either through conservation easements or more restrictive development standards, in protected bays and areas where habitat exists for species of greatest conservation need seems reasonable and warranted given the substantial near-shore habitat losses estimated to date and the projected losses possible with further shoreland development. Greater protection of sensitive shorelands and the valued ecosystem services requires identification, mapping and designation of these places.

The Sensitive Lakeshore project originated in Cass County in 2005 as the Intra-Lake Land Use Reclassification Project. The county led a technical team of federal, state, and local resource managers to develop criteria for determining sensitive areas. The criteria were then incorporated into a GIS (Geographic Information Systems) algorithm to identify sensitive lakeshores. The county proposed specific development standards, including larger lot sizes and greater structure setbacks for new lots, for these areas. The county held public hearings on this approach for protecting significant fish and wildlife habitat. Cass County acknowledged that insufficient resources existed for extensive field verification and validation of county designated sensitive areas, and they asked the DNR for assistance before proceeding with any proposed zoning or

ordinance changes. This manual was the result of this Cass County/State collaboration. Since then, the project has expanded to include Minnesota DNR collaboration with Crow Wing and Itasca Counties as well as non-profit organizations such as the Leech Lake Area Watershed Foundation and the Minnesota Land Trust.

Minnesota's Comprehensive Wildlife Conservation Strategy (CWCS) identifies the "significant loss and degradation of habitat" as one of four major Management Challenges (DNR 2006). Managing emerging issues affecting species of greatest conservation need is listed a Priority Conservation Action, and the loss and degradation of Minnesota's lakeshore is clearly an emerging issue. Species of greatest conservation need are animals whose populations are rare, declining or vulnerable to decline. They are also species whose populations are below levels desirable to ensure their long-term health and stability. Many species of greatest conservation need depend on lakeshores.

The Minnesota State Demographic Center has projected growth in many of the lake-rich counties to exceed 35 percent in the next 25 years. CWCS promotes habitat-based conservation, and there is a need to assess the amount and quality of key near-shore habitats and to map their locations in this subsection (Priority Conservation Actions for Surveys, subsection item 2a). Species of greatest conservation need in this subsection that may benefit from this project include, but are not limited to: American and least bitterns, red-necked grebe, black tern, common tern, common loon, bald eagle, marsh and sedge wrens, swamp sparrow, Virginia and yellow rails, least darter, pugnose shiner, longear sunfish and numerous invertebrate species. Other wildlife species of interest that are associated with shoreline and lake communities include osprey, great blue heron, and green and mink frogs.

Expected Results or Benefits

A sensitive area district concept and the allowance to reclassify isolated bay shorelands to a more restrictive class was incorporated into Minnesota's Alternative Shoreland Management Standards (version 1.0, December 12, 2005; a product of the Governor's Clean Water Initiative). Local governments can now create sensitive area districts along sensitive shores and reclassify bays on recreational development and general development-classed lakes to provide greater protection to near-shore species of greatest conservation need. Assisting local governments on potential districting and reclassification is a valuable service and benefit, and this manual is an aid to provide those services and benefits.

Within the environmental review processes, determining where significant fish and wildlife habitat occurs and delineating sensitive areas would be helpful in regulating shoreland and public waters development including structures, bridges, culverts, water alterations, excavation, and destruction of aquatic plants. Appropriate aquatic plant management and shoreland development rules and regulations for sensitive areas may help promote healthy and balanced near-shore communities and protect habitat for species of greatest conservation need.

In addition, landowners with property within sensitive lakeshore areas may be willing to donate permanent conservation easements. Conservation easements are a long-term strategy to protect critical lands and aquatic habitats, recreational opportunities, and water quality. This voluntary

approach allows for the protection of lakeshore ranging in size from hundreds to thousands of feet. Thus, a program to delineate sensitive lakeshore areas is anticipated to be beneficial to DNR processes, local government decision-making, and conservation-minded lakeshore property owners.

Assessing the amount and quality of key near-shore habitats and mapping their locations provides additional resources to support some of the Priority Conservation Actions outlined in the CWCS for this ecological subsection.

Summary of Approach

The first work in identifying sensitive lakeshores requires the review and compilation of the existing data. Sources of potential existing data on Minnesota lakes and lakeshore plant and animal communities include, but are not limited to:

1. DNR Fisheries lake surveys
2. DNR Wildlife Shallow Lakes Program surveys
3. DNR Natural Heritage Information System
4. DNR Minnesota County Biological Survey Program
5. DNR Ecological and Water Resources lake surveys
6. DNR Invasive Species Program surveys
7. DNR Volunteer Loon Watcher surveys
8. DNR Bald Eagle and Osprey nest surveys
9. University of Minnesota/Bell Museum Herbarium
10. Published literature and agency reports
11. Aerial photography
12. National Wetland Inventory
13. National Cooperative Soil Survey

Available data are incorporated into a geographic information system (GIS), and these data are used in survey design and determination of unique or critical ecological areas.

The sensitive lakeshore protocol consists of three components: field surveying lakeshore habitats and their use by high priority animal species, identifying sensitive lakeshore habitats and developing an ecological model, and compiling and delivering information on sensitive lakeshores to various land and resource managers. This is the same general approach used by the Minnesota County Biological Survey.

The first component involves field surveys of the lake aquatic plant communities and the distribution of high priority animal species. The aquatic plant surveys are conducted lake-wide and occur at a number of different scales. Submerged habitats and near-shore areas are also sampled. High priority animal species include species of greatest conservation need as well as other animals whose habitat use represent a good proxy for species of greatest conservation need.

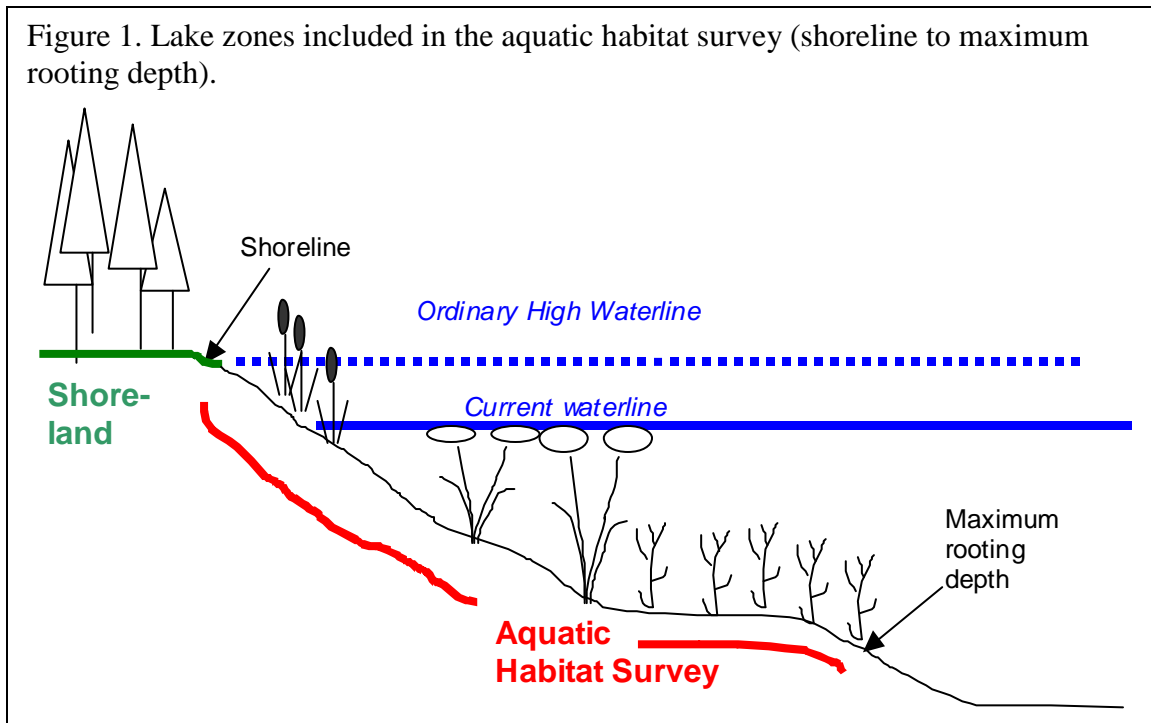
The second component involves the development of ecological models that objectively and consistently rank lakeshores for sensitive area designation. Objective methods deliver repeatable

results that are relatively insensitive to the subjective interpretations of the individuals doing the ranking; in addition, consistent, fair rankings are more likely to stand up to scrutiny and can be used as the basis for regulatory action.

The final component of identifying sensitive lakeshore is to deliver advice to local governments, non-profit organizations, and other groups who could use the information to maintain high quality environmental conditions and to protect habitat for species in greatest conservation need.

Chapter 2. Aquatic Habitat Survey and Mapping

The Aquatic Habitat Survey describes the type, quantity and quality of the existing aquatic habitat, from the shoreline to the maximum depth of aquatic plant growth (Figure 1).



The aquatic habitat surveys are conducted using a tiered survey approach. Survey components include:

1. Assessment of lake-wide vegetation community using the grid point-intercept method.
2. Delineation and description of emergent and floating-leaf plant beds.
3. Delineation and description of other unique aquatic plant areas.

The grid point-intercept method is a useful tool for lake-wide assessment of aquatic plant communities. However, it is not always adequate for assessment of near-shore vegetation, including emergent and floating-leaf beds. One problem with the grid survey methodology is that it may under sample near-shore, shallow sites where the habitat is often quite different from the rest of the lake. To compensate for this shortcoming, sampling protocol includes methods to delineate, map and describe emergent and floating-leaf habitat and other unique aquatic plant communities.

Sampling Timeline

Most vegetation sampling is conducted during peak growth and before plants senesce – July through early September. Lake-wide aquatic plant surveys are the first component and are

conducted after significant plant growth is noted in early summer through July. In lakes with extensive wild rice (*Zizania palustris*) stands, surveys may be conducted earlier (June) to minimize damage to wild rice. If curly-leaf pondweed (*Potamogeton crispus*) is an important part of a lake plant community, surveys may be conducted in May or June, before this species senesces. Surveys to delineate and describe emergent and floating-leaf plant stands and other unique plant areas are conducted in August and early September, and they may be conducted the year after the initial lake-wide aquatic plant assessment. Data management and analysis, which will rely on GIS, are conducted during non-field survey times.

A. Lake-wide vegetation and near-shore substrate survey (grid point-intercept survey)

The goal of the lake-wide vegetation survey is to quantitatively assess the major plant species within the lake basin. Objectives include:

1. Record the aquatic plant species that occur in the lake
2. Estimate frequencies of occurrence of individual species
3. Estimate the percent of the lake occupied by rooted vegetation
4. Develop GIS-based, lake-wide distribution maps for the common species
5. Estimate the maximum depth of rooted vegetation
6. Describe the shoal water substrate types

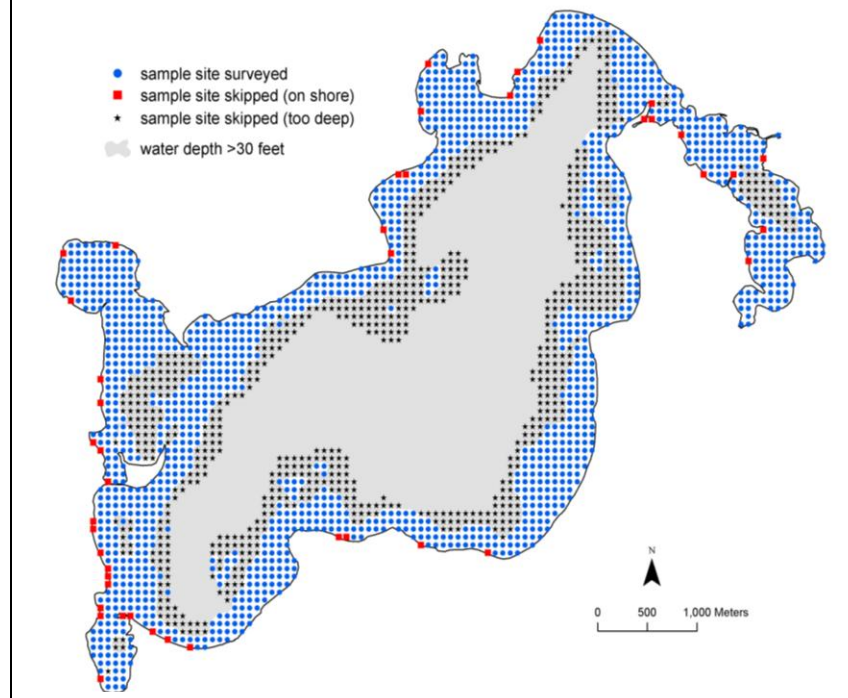
The grid point-intercept method used here records frequency of occurrence (presence/absence) as the measure to estimate plant abundance and individual species abundance. The grid point-intercept vegetation survey method estimates plant frequency by determining the proportion of survey points that “hit” or intercept vegetation. Frequencies of individual species can also be estimated by recording the plant species when intercepted by a point.

The grid point-intercept vegetation survey methodology follows that of Madsen (1999), and the technique has been extensively used in Minnesota by the lead aquatic plant ecologist (Donna Perleberg), the Minnesota DNR Wildlife Shallow Lakes Program, and has been adopted by the Wisconsin DNR as their standard lake vegetation survey method (Jennifer Hauxwell, personal communication). In comparisons of several boat-based aquatic vegetation survey methods, the grid point-intercept method was found to provide the most rapid, repeatable, GIS-based method to assess lake-wide plant species abundance and associated depth data (Perleberg 2001a, Perleberg 2001b). Williams et al. (2008) recommended the point-intercept survey for whole-lake assessments where statistical comparisons are needed. Other boat-based methods (Jesson and Lound 1962, Yin et al. 2000) provide more site-specific detail, but require the boat to be anchored at each sample site, thus reducing the total number of sites that can be sampled per hour. Furthermore, because the grid point-intercept method collects frequency data only, other advantages include consistency in data collection between different surveyors, ability to monitor a variety of plant growth forms, opportunity to monitor at flexible times throughout the growing season, and uncomplicated data analysis (Nichols 1984, Elzinga et al. 2001). In addition, frequency data are recommended as an appropriate abundance estimate when studying long-term changes in communities (Nichols 1999). It may not be appropriate to estimate aerial coverage from these data because accuracy would be dependent on the resolution (spacing of points) of the survey (Williams et al. 2008).

In the grid point-intercept method, survey points are established throughout the littoral (or the vegetated) zone on a grid using GIS. While other aquatic vegetation survey methods may randomly assign survey points within a stratified area (Yin et al. 2000), a random systematic placement of survey points is more appropriate because lake-wide mapping is a primary objective. If a current depth contour map of the lake is available, points may be established within the littoral zone only. However, on many lakes, the exact area of the littoral zone is unknown and it is easier to establish

sample points across the entire basin and once in the field skip points that occur in deep water. Once sampling has begun, surveyors may determine that little or no vegetation occurs beyond a certain depth, and skip survey points that occur beyond that depth (Figure 2). In most Minnesota lakes, it is recommended that surveyors sample to at least a depth of 20 feet (6 meters). If depth contour lines are well documented, a stratified sampling approach may be appropriate where a predetermined number of sample points are placed within a specific depth zone (ex. 200 points in the shore to 5 feet zone, 200 points in the 6 to 15 feet zone). However, for most Minnesota lakes, mapped depth contours only approximate the actual depths and a simple grid spacing of points is easier. It is important that the maximum depth sampled and the total number of surveyed sites be stated along with survey results.

Figure 2. Grid point-intercept survey. Example of sample site locations, Ten Mile Lake, Cass County.



Required sample size

The size of the littoral zone, the shape of the lake, and existing information about the plant community will determine the number of points and the grid resolution (see Appendix 1 for more information on the number of points necessary for appropriate sampling).

Within the littoral zone, a minimum of 250 points will be sampled on most lakes, to ensure that commonly occurring species (species occurring at frequencies of at least 40%) are adequately sampled with an error of 15% with 95% confidence. A two-person crew can generally survey between 100 and 300 points per day (fewer points with high plant density or species richness).

Equipment

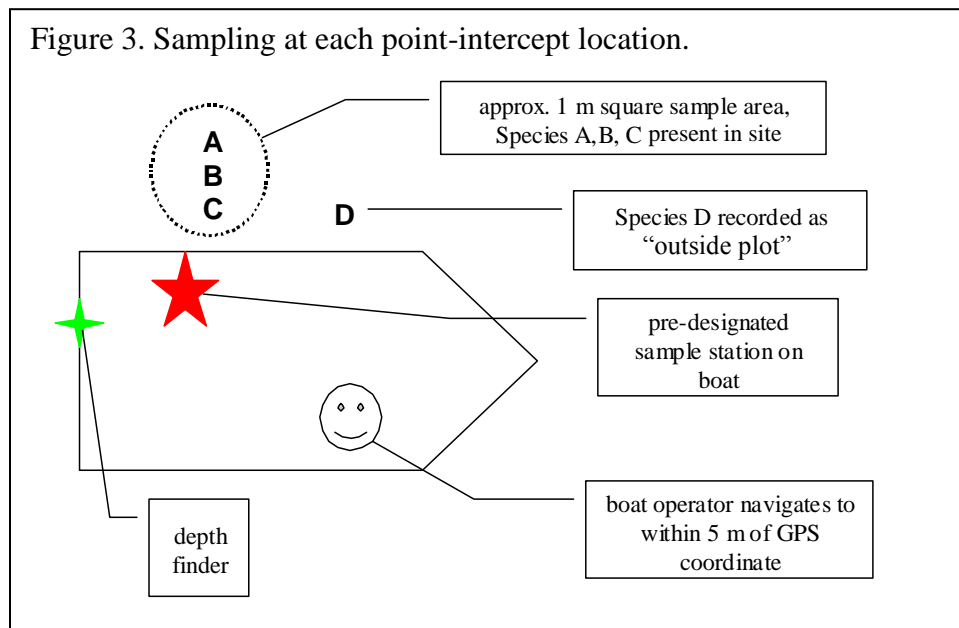
A checklist of required and recommended equipment is provided in Appendix 2, and the field data collection form is given in Appendix 3. Survey point waypoints are uploaded to handheld GPS units.

Field sampling

Sampling is conducted primarily from a boat (Figure 3) and GPS units are used to navigate to each sample point. The survey points are not intended to be permanent sampling locations and are not marked with permanent markers. Rather, the goal is to navigate to the approximate location of each sample point. Given the inherent inaccuracy of field-model GPS units, and the shifting movement of the boat due to wave action, surveyors are not always able to stop precisely on the survey point location. Surveyors are directed to navigate to within five meters of survey point coordinates shown on the GPS unit. The boat operator maintains the position of the boat without anchoring and sampling is conducted from a pre-designated side of the boat.

Survey points may be skipped under the following conditions:

1. Site location is on shore (sample station is permanently removed from database)
2. Site location is within a dense and/or shallow bed of emergent or floating-leaf vegetation and motoring into the site would likely destroy vegetation (surveyors record general observations about the site but do not include data in calculations)
3. Site location occurs in water depths greater than maximum rooting depth of vegetation
4. Access to site is prevented by dock, swim area, other boats



Water depth

At each sampling point, water depth is recorded in one-foot increments using an electronic depth finder mounted at the stern of the boat or, in water depths less than eight feet (2.5 meters), with a measured stick at the pre-designated sample side on the boat (Figure 3).

Vegetation sampling – presence/absence

Plant species abundance is estimated by presence/absence, or frequency of individual species within the survey sites. All plant taxa found within an approximate one square meter sample site are identified and recorded. In shallow water, where vegetation is visible, it may be useful to use a plastic hoop to delineate the sample area (Figure 4). A double-headed, weighted garden rake attached to a rope is used to survey vegetation not visible from the surface (Figure 5). In depths where the lake bottom is not visible, surveyors drag the rake across an approximate one-meter square area.

Plants are identified to the species level when feasible. Plant taxonomy follows Crow and Hellquist (2000) and nomenclature follows MNTaxa (2011). Voucher specimens are collected for most plant species (Hellquist 1993) and are stored at the University of Minnesota Bell Museum Herbarium or at the Minnesota Department of Natural Resources office in Brainerd. Any additional plant species found outside of the survey area (“D” in Figure 3) are recorded as present in the lake but are not included in estimates of species frequency.

Frequency of occurrence is calculated for each species as the number of sites in which a species occurred divided by the total number of sample sites. Frequency is calculated for the entire sampled area and also by water depth intervals.

Vegetation sampling – cover estimate

In addition to vegetation presence/absence data collected with the grid point-intercept method, lake managers are also often interested in “plant cover” as it relates to fish and wildlife habitat and recreational lake use. Plant cover can be defined as the vertical projection of vegetation from the ground as viewed from above and can be distinguished as basal cover and aerial or canopy cover (Elzinga et al. 2001). Surveyors also have the option of recording a coarse description of plant cover at each site but this is a qualitative estimation and is not used in statistical analyses. Recording cover can be difficult because:

Figure 4. Plastic hoop measuring 1 meter square in area (1.13 m diameter) used to delineate sample area in shallow water.

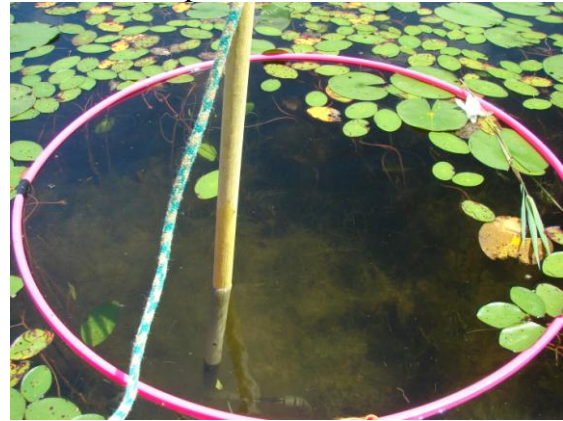


Figure 5. Double-headed, weighted rake for submerged plant sampling.



1. The boat is not anchored and it can be difficult to maintain position long enough to record cover
2. In low clarity and/or deep water, plant cover cannot easily be viewed from the boat surface (Newman et al. 1998)
3. Cover estimations will vary between surveyors (Newman et al. 1998)
4. Cover may change throughout the time period of the survey (Nichols 1984)

Nevertheless, it may sometimes be useful to have a general estimate of cover, for example, in lakes where non-native species management is a priority. In such cases, surveyors may elect to estimate cover for only the non-native species. If surveyors decide to include a cover estimate, it is recommended that they select only two or three categories for cover descriptions such as:

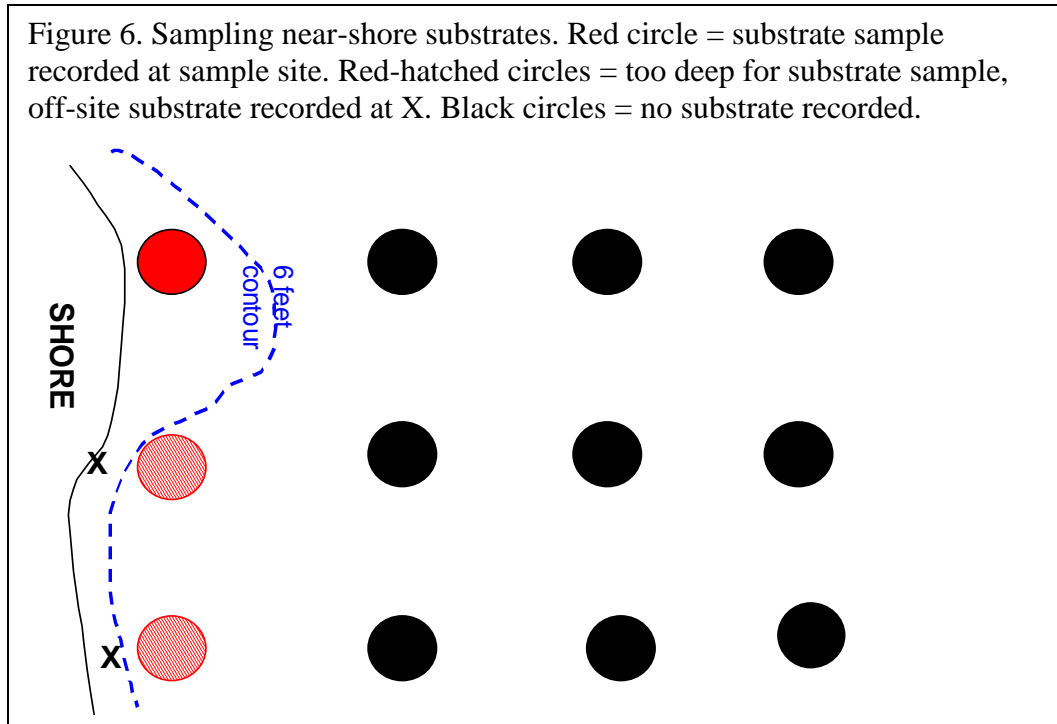
1. Plant species matted at or near water surface vs. not matted
2. Few plants collected on rake vs. rake full of vegetation

Substrate sampling

In water depths of seven feet (two meters) and less, surveyors evaluate lake bottom substrate from the pre-designated sample station (Figure 3) by tapping a pole into the lake bottom; soft substrate can usually be brought to the surface on the pole or sampling rake for evaluation. Standard lake substrate classes are recorded following the Minnesota DNR Lake Survey Manual (MN DNR 1993). If several substrate types occur at a site, surveyors record the most common type.

Substrate Group	Type	Code	Description
Hard Bottom	Boulder	BO	Diameter over 10 inches
	Rubble	RU	Diameter 3 to 10 inches
	Gravel	GR	Diameter 1/8 to 3 inches
	Sand	SA	Diameter less than 1/8 inch
	Sand/Silt	SS	Sand bottom overlaid with thin layer of silt
Soft Bottom	Silt	SI	Fine material with little grittiness
	Marl	MR	Calcareous material
	Muck	MU	Decomposed organic material

Surveyors attempt to record a substrate description at the shore side of each row of points. If a sample site occurs near shore but in water depth greater than seven feet, surveyors collect depth and vegetation data and then motor into shallower water and record the substrate type adjacent to the actual survey point (Figure 6).



B. Delineate and describe emergent and floating-leaf plant beds

Protocols are based on the procedures documented in the DNR draft Aquatic Vegetation Mapping Guidelines (DNR 2005) and may include a combination of aerial photo delineation and interpretation, field delineation, ground-truthing and site specific surveys. Large stands of emergent and floating-leaf vegetation are mapped. Mapping of small beds is resource intensive and imprecise using available GIS tools. Plant beds are characterized by the dominant genera or species and plant community descriptions may continue to be refined as more data are collected:

Survey Method	Plant community	Dominant plants
Field delineation	Bulrush	<i>Schoenoplectus</i> spp.
	Spikerush	<i>Eleocharis</i> spp.
Aerial photos with field verification; descriptive detail will vary with survey effort	Giant cane	<i>Phragmites australis</i>
	Cattail	<i>Typha</i> spp.
	Wild rice	<i>Zizania palustris</i>
	Mixed emergent	Various – <i>Equisetum</i> spp., <i>Eleocharis</i> spp., <i>Sagittaria</i> spp., <i>Sparganium</i> spp.
	Waterlily	<i>Nymphaea odorata</i>
		<i>Nuphar variegata</i>
		<i>Brasenia schreberi</i>

Aerial Photo Delineation

Existing aerial photographs are used to map floating-leaf vegetation. The photo source, scale, and date are documented. Some issues associated with this method include difficulties in identifying vegetation beds from photos. This may result in missing small or floating-leaf vegetation beds altogether. Several photo sources are used, if possible, because different types of vegetation may appear different on separate photos. The locations on the photo are only as accurate as the photo rectification.

Aerial photo delineated maps are field-checked. Using field surveys, species compositions of stands are verified. Changes in vegetation observed between different photo dates can also be confirmed.

Field Delineation

Field mapping focuses on bulrush (*Schoenoplectus* spp.) beds, which are difficult to see on aerial photos. Existing data are used along with a reconnaissance survey to identify extensive bulrush stands for further quantification. Bulrush habitat is mapped and digitized using GPS (see Appendix 4 for equipment checklist).

Stem density is an important factor in assessing the overall habitat quality of an emergent plant stand. Emergent vegetation stem density in general, and bulrush stem density in particular, has been used to describe several types of waterfowl and shorebird nesting habitat (Custer 1993, Spautz and Nur 2002). Waterfowl studies may focus specifically on optimal ranges of bulrush stem densities for a particular bird species (Custer 1993). Bulrush also serves as habitat for many fish species (Becker 1983). Numerous factors may affect bulrush stem density including the species of bulrush present, competition from other plant species, water depth (Hunter et al. 2000), substrate type, substrate nutrient levels, herbivory (Lentz and Cipollini 1998), and disturbance by humans. Stem density varies within and among bulrush stands and the number of stems per square meter may range from less than one to more than 800 (Hall and Freeman 1994).

Estimating bulrush stem density can be difficult and surveyors often rely on visual estimates to describe stand density (MN DNR 2005). Bulrush stands have been described as “sparse”, “moderately dense”, or “dense” (MN DNR 2005) with no association to stem density counts, or with stem density counts that overlap (same mean count for sparse and moderate categories) (Morris 1999). Kantrud (1996) suggests that a “healthy” stand of soft-stem bulrush (*Schoenoplectus tabernaemontani*) would have a stem density range of 50 to 500. Field trials were conducted in 2006 to determine the feasibility of estimating bulrush stem density using plotless methods (Engeman et al. 1994). Survey methods were found to be labor intensive and difficult to reliably repeat. Therefore, stem density estimates of bulrush is not included as a standard method in this protocol.

C. Identify areas of unique and rare aquatic plant species

Surveyors use information collected during the grid point-intercept survey and emergent plant bed mapping to locate unique aquatic plant species. These species may include:

1. Rare (endangered, threatened, special concern) plant species
2. Plant species that are not listed as rare but are uncommon in the state or locally. These may include species that are proposed for rare listing.
3. Plants species with high coefficient of conservatism values. A coefficient of conservatism value, or C value, may range from 0 to 10 and represents an estimated probability that a plant is likely to occur in a landscape relatively unaltered from what is believed to be a pre-settlement condition (Nichols 1999, Bourdaghs et al. 2006.). Because the amount of information for each species differs, C values are subjectively assigned by biologists based on existing information and professional judgment. Nichols (1999) developed tentative C values for 128 Wisconsin lake plants based on their substrate preference, turbidity tolerance, rooting strength, primary reproductive means, and tolerance to water drawdowns. C values have now been established for most aquatic and wetland plant species native to Wisconsin (WDNR 2011) and Minnesota (Milburn et al. 2007). C values may vary from region to region (Swink and Wilhelm 1994, Herman et al. 1996) and values developed by Wisconsin are mostly applicable in Minnesota. Plant species with assigned C values of 9 and 10 will be included as “unique species.” C values could vary regionally within the state (Nichols 1999), and it may be necessary to regionalize the selection process within Minnesota (e.g., for southern Minnesota lakes, species with C values of 7 or higher will be included as “unique species”). Terrestrial species are not included in the unique plant survey.

Partial list of rare (special concern, threatened, or endangered) and unique plant species most likely to be found in Minnesota lakes or along lakeshores can be found in Appendix 5.

Chapter 3. Aquatic Frog Calling Survey

An aquatic frog survey is conducted from mid June to mid July. The methodology follows the Minnesota Frog and Toad Calling Survey (MFTCS) protocol, which was an outgrowth of the North American Amphibian Monitoring Program. Information on MFTCS can be found at:

http://www.dnr.state.mn.us/volunteering/frogtoad_survey/index.html



Several life-cycle characteristics make mink frogs (*Rana septentrionalis*) and green frogs (*Rana clamitans*) ideal indicator species of lakeshore habitats. First, mink and green frogs are shoreline-dependent species that inhabit nearly all types of permanent water in this region. Adult male frogs are easily surveyed by auditory detection. They establish and defend distinct territories, and tend to remain along the periphery of lakes and ponds throughout the summer breeding season or in areas of shallow water with emergent vegetation. Green frogs breed from late May to mid-August and mink frogs begin their calling in late May with the breeding season extending from late June to early August (Breckenridge 1944), so a summer calling survey is an effective technique to determine presence and abundance.

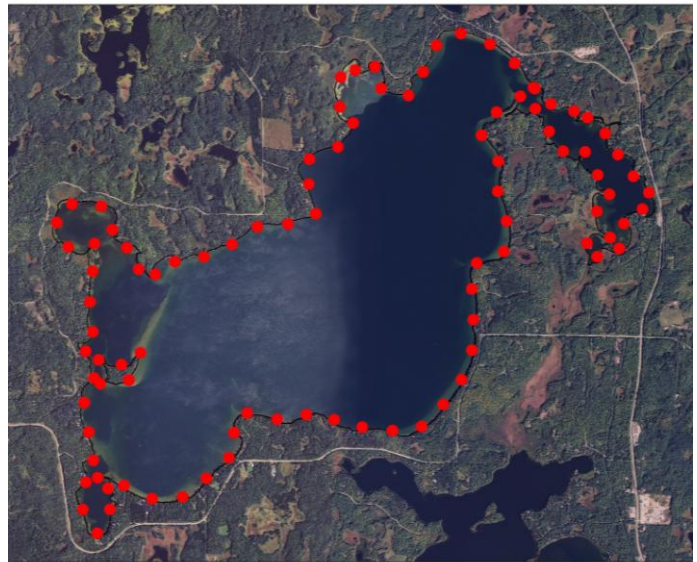
Objectives of the aquatic frog calling survey include:

1. Determine index of abundance for all frogs and toads
2. Estimate actual abundance of mink frogs and green frogs
3. Develop distribution maps for mink frogs and green frogs

The entire shoreline of each lake is surveyed. Listening stations are established using GIS to generate evenly spaced points every 400 meters around the lake (Figure 11). Shoreline length determines the total number of stations, and a minimum of 100 stations will be established on each large lake.

Surveys are conducted between sunset and 1:00 AM, and if conditions deteriorate such that rain showers or breezy conditions substantially affect hearing ability, a survey is stopped. At each listening station, a biologist listens for several minutes for frog and toad calls. An estimate of the

Figure 11. Sampling stations every 400 meters along shore (Ten Mile Lake, DOW 11-0413-00).



abundance of frogs and a calling index is recorded for both mink and green frogs. The calling intensity of all other amphibian species heard is also recorded. The field datasheet used for the survey is provided in Appendix 6.

The abundance of green and mink frogs at each station is classed as:

1. 1 – 9 individuals
2. 10 – 20 individuals
3. 20 – 100 individuals
4. >100 individuals

The call index value for each amphibian species heard is recorded according to the following:

1. Individuals can be counted (silence between calls)
2. Calls of individuals can be distinguished, but some overlap of calls
3. Full chorus (calls constant, continuous, and overlapping)

Chapter 4. Near-shore Fish and Other Aquatic Animals Survey

The purpose of this survey is to identify critical areas for aquatic animals and map locations where sensitive indicator species are present. Specific objectives include:

1. Record presence and abundance of fish species of greatest conservation need
2. Record presence and abundance of fish proxy species
3. Develop distribution maps for species of greatest conservation need and proxy species
4. Identify habitat (substrate and aquatic vegetation biovolume) associated with presence of species of greatest conservation need and proxy species
5. Identify near-shore fish assemblages
6. Document presence of other aquatic vertebrate species (frogs, turtles)



Near-shore fish species of greatest conservation need in central Minnesota lakes include pugnose shiner (*Notropis anogenus*), least darter (*Etheostoma microperca*), and longear sunfish (*Lepomis megalotis*). These fish are associated with large, near-shore stands of muskgrass or aquatic macrophytes, as are the proxy species for these sensitive indicator species, which include blackchin shiner (*Notropis heterodon*), blacknose shiner (*Notropis heterolepis*), and banded killifish (*Fundulus diaphanus*). These fish species are intolerant to disturbance and may require large undisturbed patches of near-shore vegetation. They are often only present in undisturbed lakes, and they have been extirpated from lakes where watershed and lakeshore development has occurred (Clady 1976, Lyons 1989).

Near-shore aquatic animal surveys are conducted in the summer using a systematic random or stratified random sampling design with fish collection methods that generally follow Minnesota's lake near-shore fish sampling protocol (Drake and Pereira 2002, Drake and Valley 2006). For each lake, points used during the aquatic frog calling survey are also used for near-shore aquatic vertebrate sampling stations. Sampling is conducted within a 50 foot (15 meter) radius of the sampling station. The number of stations will be dependent on the size of the lake and whether any stratification is used.

Near-shore fish assemblages are sampled using shoreline seining, backpack electrofishing, and trapnets. Within each near-shore sampling area, all sampling gear will be used, if possible. Trap nets have a 12.2 m lead approximately 1.1 m deep with two 1.5 m by 0.8 m frames and six 0.76 m hoops with an 18 cm square throat; all mesh is 6.4 mm nylon. The nets are oriented perpendicular to shore with the leader on or near the shore. Nets are set overnight and pulled the next day. For seining and electrofishing effort at sampling stations, the survey crew alternates gear used first. Two shocking passes are conducted at each station, one near the shoreline and

one at a depth of approximately 30 to 40 inches (75 – 100 cm). Electrofishing crews consist of two members, one to carry and operate the backpack electroshocker and one to collect fish. The seine used is 15.2 m long with a bag, and all mesh is 3.2 mm nylon. The seine is set at the shoreline and perpendicular out to the length of the seine or the maximum wadable depth, and the offshore end of the seine is arced back to shore. For each gear, species are identified and counted. In places with excessive vegetation, depth, or extremely soft bottom, seining or trapnetting may not be conducted. However, in these situations, electrofishing is conducted, often from a boat.

Figure 12. Surveyors use backpack electroshocker to conduct near-shore aquatic vertebrate surveys.



Standard near-shore lake substrate classes are recorded for each sampling station following DNR Fisheries Lake Manual (DNR 1993) (see Chapter 2). In addition, an estimate of aquatic vegetation biovolume is recorded for the sampling area (i.e., 15 m² area abutting the shore). This estimate represents the volume of a sampling area that contains submerged aquatic vegetation. Seining, electrofishing and trapnet data are pooled by station, each station representing one unit of sampling effort.

Chapter 5. Bird Surveys

Birds use a wide variety of lakeshore habitats. Many birds use specific habitat types or require a combination of habitats for their life cycles; some of these habitats are rare or limited in size and distribution, thus limiting the range of the bird species. Lakeshore habitats used by birds include trees and forested areas, shrub swamps, aquatic emergent vegetation such as bulrush and cattail marshes, rocky reefs and islands, mud flats, the water/land interface of the shoreline, the water surface and under the water.



Information on birds is collected in two phases. The first phase is to search existing databases for historical records of nesting and for occurrences of rare species. This data collection takes place before the field season begins. Special efforts are made to search during the field season for species that had historical records. The second phase of the project is field surveys for all bird species utilizing lake shorelines. Field surveys take place during the breeding season, when birds are most vocal. Methods include point-counts, call-playback surveys for secretive marsh species, and general observations of rare species observed.

Although all bird species are noted and recorded, surveyors focus on bird species of greatest conservation need (SGCN). A second list of species is also given special note. These species are dependent on specific aquatic habitats, represent SGCN proxy species, or are suffering declines in Minnesota.

Bird Species of Greatest Conservation Need

These species have been found near north-central Minnesota lakeshores. Species are listed in AOU order.

American Black Duck (*Anas rubripes*)
 Common Loon (*Gavia immer*)
 Red-necked Grebe (*Podiceps grisegena*)
 American White Pelican (*Pelecanus erythrorhynchos*)
 American Bittern (*Botaurus lentiginosus*)
 Least Bittern (*Ixobrychus exilis*)
 Bald Eagle (*Haliaeetus leucocephalus*)
 Red-shouldered Hawk (*Buteo lineatus*)
 Yellow Rail (*Coturnicops noveboracensis*)
 Virginia Rail (*Rallus limicola*)
 Common Tern (*Sterna hirundo*)
 Forster's Tern (*Sterna forsteri*)
 Black Tern (*Chlidonias niger*)

Common Nighthawk (*Chordeiles minor*)
Red-headed Woodpecker (*Melanerpes erythrocephalus*)
Yellow-bellied Sapsucker (*Sphyrapicus varius*)
Eastern Wood-Pewee (*Contopus virens*)
Least Flycatcher (*Empidonax minimus*)
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)
Sedge Wren (*Cistothorus platensis*)
Marsh Wren (*Cistothorus palustris*)
Veery (*Catharus fuscescens*)
Golden-winged Warbler (*Vermivora chrysoptera*)
Ovenbird (*Seiurus aurocapilla*)
Swamp Sparrow (*Melospiza georgiana*)
White-throated Sparrow (*Zonotrichia albicollis*)
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)

Other Bird Species of Interest

Great Blue Heron (*Ardea herodias*)
Green Heron (*Butorides virescens*)
Osprey (*Pandion haliaetus*)
Sora (*Porzana carolina*)
Spotted Sandpiper (*Actitis macularia*)
Caspian Tern (*Sterna caspia*)
Alder Flycatcher (*Empidonax alnorum*)
Purple Martin (*Progne subis*)

Database Searches for Historical Information

This information search focuses on past records of species that have been entered in DNR databases such as the DNR Natural Heritage Database Information System, DNR Volunteer Loon Watcher Surveys, DNR Eagle Nest Records, and DNR Osprey Nest Records. Bird species of focus include the common loon, red-necked grebe, bald eagle, osprey, black tern and other colonial nesting waterbird species.

Field Surveys

Three methods are used to collect data on lakeshore birds – point counts, call-playback surveys targeting marsh birds, and general field observations. All birds heard or seen while conducting the surveys or while working on the lake or along the shoreline during the nesting season, defined as the last week of May through the first week of July, are recorded.

Morning point counts for birds are conducted between sunrise and 10:00 AM at the same sample stations used for frog surveys (see Chapter 5). The entire shoreline is surveyed by boat with points at 400 m intervals. The boat is stopped when the GPS point is reached and the boat is positioned 20 –50 m from shore (depending on water depth). A timer is set for 5 minutes and all birds heard or seen are recorded. Relatively calm conditions are required in order to hear the birds along the shoreline, so surveys require positioning the boat out of the wind (protected side of lake or sheltered bay) or conducting surveys only when wind speeds are less than 6 mph. If

noise from sources such as waves along the shoreline, wind, or road construction negatively affects the ability to hear birdsong, the survey is cancelled for that day. Birds seen or heard within a 200 m radius of the sample point are recorded for that point. Birds seen or heard in the distance are recorded as present at the lake but not associated with a specific sample point. Bird flyovers (birds seen overhead but not utilizing any lake habitat) are not recorded.

Marsh birds are notoriously secretive and are not often recorded on passive-listening point counts. Call-playback surveys done in the evening, before sunset, are a better method to discover the presence of birds such as rails. The survey methodology used is modified from “Standardized North American Marsh Bird Monitoring Protocols” (Conway 2005), and uses calls from species expected to be found in the local lakeshore/marsh habitats. Surveys are not conducted from pre-determined sampling stations, but at locations where there is significant marsh habitat. The surveys are done from a boat and begin two hours before sunset. The survey begins with five minutes of passive listening, which is followed by 30 seconds of call-playback, then a shorter period of listening. This call-playback sequence is repeated three times. Species targeted with this method include American bittern, least bittern, Virginia rail and sora. If suitable habitat for yellow rails is found, surveys are conducted after dark using their distinctive call.

General field observations are also recorded while surveyors are in transit between points or conducting other work on the lake. These observations include notes on feeding areas, roosting/resting sites, and nest areas, especially for birds that are SGCN or other species of interest. A bird checklist is kept to record all species observed on the lakeshore or in the water for each study lake so that a species list can be compiled at the end of the field season. A sample field data collection form is provided in Appendix 7.

Loon Nesting Areas

Data on loon nesting areas is obtained in several ways. The volunteer LoonWatcher survey began in 1979 as a way for the DNR to obtain information on loon nesting locations and success in Minnesota. Volunteers are often lake residents, or spend a significant amount of time on a particular lake during the summer. Each year, volunteer loon watchers observe the loons on a selected lake and fill out a report, noting information such as number of loons, number of nests, and number of chicks. Locations of loon nests, if known, are also documented in the report. LoonWatchers who report on lakes targeted for Sensitive Lakeshore assessment are asked to pay special attention to locations of loon nesting areas. Lake maps are included with the volunteer survey packet, and LoonWatchers are asked to map the locations of natural loon nests or active artificial nest platforms.



If LoonWatchers are unavailable on a particular lake, targeted loon nest surveys may be conducted. These surveys are best conducted from the water by boating (by motorboat, canoe or kayak) slowly along the shoreline and searching for incubating birds. Single adult birds foraging

near shore may also indicate a nearby nest. Protected bays and areas of shoreline with abundant emergent vegetation should be surveyed with particular care. Nest surveys should be conducted during May and early June, when adults are still incubating eggs. Extreme care should be taken not to disturb incubating loons. Disturbance can interfere with nesting and cause distractions that make eggs more vulnerable to predators or extreme temperatures. Observation should be done with binoculars when possible. If loons exhibit any threatened or defensive behavior, the surveyor should quickly and quietly leave the area. Crews conducting bird and aquatic plant surveys also record locations of loon nesting areas.

Chapter 6. Wetlands, Hydric Soils, Rare Features, and Size and Shape of Natural Areas

Wetlands

Wetlands supply a multitude of critical services to the environment, including filtering pollutants, preventing erosion, and providing habitat for many wildlife species. The technical definition of wetlands (adapted from Cowardin et al. 1979) includes three criteria:

1. Hydrology – the substrate is saturated with water or covered by shallow water at some time during the growing season of each year
2. Hydrophytes – at least periodically, the land supports predominantly hydrophytes (plants adapted to life in flooded or saturated soils)
3. Hydric soils – the substrate is predominantly undrained hydric soil (flooded or saturated soils)



Wetland data are obtained from the National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service. Only wetlands occurring within the extended state-defined shoreland area (i.e., within 1320 feet of the shoreline) are considered for analysis. In addition, wetlands classified as lacustrine or occurring lakeward of the study lake ordinary high water mark are excluded.

Hydric Soils

Hydric soils are those soils formed under conditions of saturation, flooding, or ponding. The saturation of these soils, combined with microbial activity, causes oxygen depletion; hydric soils are characterized by anaerobic conditions during the growing season. These conditions often result in the reduction of iron or other elements, and the accumulation of a thick layer of organic matter. Identification of hydric soils may indicate the presence of wetlands, and provide information on where to focus conservation efforts.

Hydric soil data are obtained from the National Cooperative Soil Survey. Digital hydric soil data are available for nearly all Minnesota counties; if data are unavailable, this attribute is eliminated from the ecological model. As with wetlands, only hydric soils occurring within 1320 feet of the shoreline are used in analysis.

Rare Features

The Minnesota Natural Heritage Information System provides information on Minnesota's rare animals, plants, native plant communities, and other features. The database Biotics includes locational records, both historical and current, of all Federal and State-listed endangered and threatened species and state species of special concern. Information obtained from the Rare



Heritage program has many uses, including in environmental review, land conservation, management decisions, and education.

Locations of rare features within 1320 feet of the shoreline were obtained from the Biotics database. Only listed plant and animal species (Federal or State endangered, threatened, or special concern) were considered in the analysis. New rare feature locations recorded during field surveys were submitted to the Natural Heritage program for inclusion in the database.

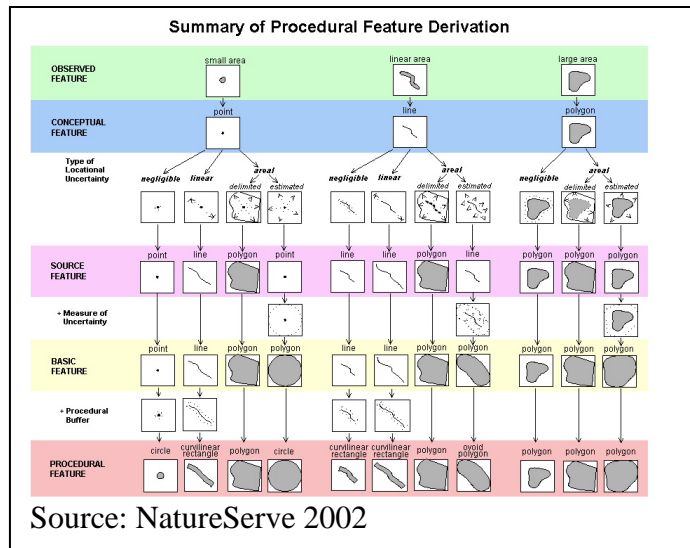
Size and shape of natural areas (i.e., bays)

Bays are defined as bodies of water partially enclosed by land. They offer some degree of protection from the wind and waves, and therefore are frequently characterized by abundant vegetation and wildlife. Protection of these areas will be beneficial to a variety of plant and animal species.

Bays are delineated using lake maps and aerial photographs. Obvious bays (e.g., significant indentations of shoreline, bodies of water set off from main body or nearly enclosed by land) are mapped based on inspection of lake maps. Additional bays are identified using aerial photographs. Underwater shoals or reefs that offset a body of water from the main body are often visible only in these photographs. Bays are defined as either non-isolated or isolated. Non-isolated bays are open to the main water body by a wide mouth (generally > 200 m). Isolated bays have a narrower connection to the main water body (generally < 200 m) or are offshoots of non-isolated bays. Maximum and minimum bay sizes are loosely set for each lake; these are dependent upon the size of the lake. In general, separate lake basins are not defined as bays. Very small indentations in the shoreline (i.e., coves) are also not classified as bays.

Chapter 7. Ecological Models to Delineate Sensitive Lakeshore

Ecological models are used to assist in the determination of sensitive areas. This approach is based on ecologically based guidelines for land use (Dale et al. 2000) and is consistent with research on identifying important green infrastructure (Benedict and McMahon 2006). Two modeling approaches are used. First, an ecological model based on documented lakeshore plant and animal communities and hydrological conditions is used to identify sensitive lakeshore. Examples of such an approach on a coarser scale include the Regionally Significant Ecological Area Assessment by the DNR for the seven-county metropolitan area completed in 2003 and the sensitive natural area assessment for the 17-county central region (AMEREGIS & DNR 2006). The benefit of this approach is that criteria come from the science-based surveys (variables include species presence, biological diversity, and habitat size and quality), and the value (or model score) of the shoreline with regard to fish and wildlife habitat is objectively assessed. Second, predictive models are used to identify lakeshore in need of restoration where sensitive indicator species are not present or are in very low abundance. These statistical models use logistic regressions or spatial analyses on hydrological, morphological and aquatic vegetation variables.



A. Models based on habitat, plant and animal occurrences

The following 15 attributes, based on the major conservation principles listed below, were used to identify sensitive lakeshores:

1. Hydric soils
2. Near-shore substrate
3. Wetlands
4. Near-shore plant frequency
5. Near-shore aquatic plant community richness
6. Presence of rare and unique plant species in the near-shore area
7. Presence of emergent and floating-leaf vegetation beds
8. Presence of aquatic frogs
9. Loon nesting areas
10. Bird species richness
11. Presence of bird species of greatest conservation need (exclusive of loon and bald eagle nests)

12. Near-shore aquatic vertebrate richness (fish, frogs, turtles)
13. Presence of fish species of greatest conservation need or their proxy species
14. Natural rare features as documented in the DNR's Natural Heritage Information System
15. Size and shape of natural areas (i.e., bays)

Conservation principles

The ecological models are based on the following conservation principles:

1. Wetlands and littoral areas provide important habitat and services

Shallow water areas, wetlands, bogs and fens often provide critical habitat. Near-shore areas, which are rich in aquatic plant diversity and abundance, represent prime habitat for a variety of fish and wildlife. Aquatic plants in these near-shore areas tend to serve a variety of functions, such as absorbing nutrients that reduce water quality, reducing erosion from waves, and providing food and habitat for fish and wildlife. Wetlands are especially critical habitats for wildlife. Many wildlife species in Minnesota inhabit or are attracted to wetlands, and wetlands are the principal habitat for many waterfowl and waterbird species. The loss of natural wetlands around lakes and in their drainage basins is a causal factor in the deterioration of many lakes. Wetlands filter nutrients and runoff sediments that may impair water quality, recharge groundwater, and reduce runoff discharge that could cause erosion and flooding.

2. Wetlands and productive littoral areas are vulnerable to development

Shallow bays are particularly vulnerable to water surface use. Boat traffic on shallow lakes can result in an increase in phosphorus concentrations due to sediment resuspension. This phosphorus can then stimulate growth of attached or planktonic algae, thereby degrading or eliminating important aquatic plant communities. In addition, boat traffic on shallow lakes and in littoral areas can damage or destroy aquatic macrophytes.

3. Shoreland and shorelines are often heterogeneous with critical habitat clustered

Shorelines are often comprised of a mix of windswept open areas and protected bays. Bays, because they are protected to some degree from wind and waves, often contain abundant vegetation. For example, they may contain a large portion of the valuable floating-leaf and emergent plant stands for a lake. Numerous fish species use these protected bays, wetland fringes, and the associated vegetative cover disproportionately to their availability. Fish prefer wetland embayment areas because they generally warm up faster in the spring, the presence of emergent and floating-leaf vegetation provides cover, and productivity is higher in these areas. In addition, such areas are often used for fish spawning and nursery grounds. Loons also prefer to nest in specific areas, such as on vegetated hummocks, small islands, or masses of emergent vegetation.

Conservation of these shoreland areas containing critical habitat may maintain regional and lake-specific diversity of plants and wildlife.

4. The size and shape of an area is important

Fragmentation of habitat is the leading threat to biodiversity. Wildlife dispersal and travel generally occurs across wide swaths of land, not narrow corridors. To allow the flow of species

across wide areas, large natural areas are needed. When natural areas are fragmented into numerous small and irregular shaped pieces (patches), the plants and animals found on the site, and the interactions that take place between plants and animals (e.g., predator and prey relationships) change. Habitat islands are vulnerable to loss of species.

The larger a natural area is, the more likely it will support populations of native plants and animals. Fish species of greatest conservation need (pugnose shiner, least darter, and longear sunfish) are intolerant to disturbance and may require large undisturbed patches of near-shore vegetation. Fragmentation of vegetation often results in a reduction in the nest success of some bird species. Small, irregularly shaped areas have a greater proportion of edge area than interior area. Birds forced to nest in the edges may have a greater risk of losing offspring to predators (crows, grackles, brown-headed cowbirds).

Edges do provide important habitat for many plants and animals and often have a high number of species. This is in part because anthropogenic fragmentation of vegetation often increases the occurrence of invasive, non-native plants and animals that inhabit edge habitats. Natural edges, however, provide a mosaic of habitats that native plant and animal species utilize. Lakeshores themselves are edges, as they represent the boundary between the lake habitat and the upland habitat. Edges enable animals to access various habitats for nesting, foraging, or escape cover. Several species of greatest conservation need, including the golden-winged warbler, are frequently found within edge habitat.

5. Adjacent land use affects natural areas

Strategic conservation requires an integrated landscape approach that considers the influence of neighboring areas. Local changes can have broad-scale impacts on lake and river ecosystems. The introduction of non-native plant species into forests and lakeshores from urban gardens, trampling of vegetation from heavy pedestrian or recreational use, and increased salinity of wetlands from road salts are several ways that adjacent urban, suburban, and agricultural land uses adversely impact natural areas.

Extensive development introduces new predators and may increase predator populations. Wildlife impacts include increased mortality from cat predation, car kills, killing of wildlife (snakes and bats) by landowners due to misperceptions/fear, and reduced reproductive success if breeding is disrupted by human activities.

6. The connectivity of habitats and vegetation is important

Linkage is essential for natural systems to function properly. The loss of connectivity through the addition of impervious surfaces such as roads and buildings often fragments landscapes. Fragmentation changes how plants, animals, wind and water move across the landscape.

Habitat connectivity may allow an animal to relocate when habitat is lost or degraded due to natural or human disturbance. Movement allows individuals from different populations to breed, which maintains genetic diversity in the population. Some animals have different vegetation requirements during different stages of their life cycle. For example, Blanding's turtles require large wetland complexes for over-wintering and dry, sandy soil grasslands for breeding. An animal's risk of being killed (increased predation, road strikes) during movement increases in

fragmented landscapes. Lake, stream and wetland habitat quality is dependent on maintaining vegetated riparian and lakeshore zones, and connectivity to upland vegetation.

7. Species diversity is important

Diversity of both plant and animal species is critical to maintaining the health of an ecosystem. Diversity allows an ecosystem to adapt to varying conditions. Recent ecological research shows that a plot of land with many plant species is more productive and resistant to drought, pests, and other stresses than a plot with only a few species. Diverse habitats are fundamental in allowing an area to have high plant and animal diversity.

Many human activities cause changes in the environment that lead to lower species diversity and decreased ecological resiliency. Examples include excess nitrogen from pollutants, the introduction of invasive non-native species, and the disruption of natural processes such as natural water flow. These disruptions often lead to the elimination of many native species and the promotion of just a few species. These disturbed areas then are less able to tolerate outbreaks of pests and diseases and large-scale changes such as climate change.

Ecological Model Details

A GIS ecological model is used to identify sensitive lakeshore. The goal is to recognize potential shoreland and near-shore areas that contain important environmental features. The ability to identify sensitive areas is dependent on field surveys, which provide reliable information on the elements of biodiversity, how natural resource elements are connected, and their condition. There are several shortcomings with this general approach to identify sensitive lakeshore. For example, the minimum required size of a habitat patch needed for a given organism is quite variable. In addition, habitat variation exists over a range of spatial scales, and the size of the sampling unit used in the various surveys may not be optimal for ecological considerations. However, spatial dependence of neighboring points or nearby sample points is often a reasonable assumption in lakes, and the shoreland development policies necessitate that GIS analytical units constitute groupings of adjacent sampling points.

Environmental decision-making is complex and often based on multiple lines of evidence. Integrating the information from these multiple lines of evidence is rarely a simple process. The identification of sensitive lakeshore used here is an objective, repeatable and quantitative approach to the combination of multiple lines of evidence through calculation of weight of evidence (*weight of evidence* as used in this manual relates to an interpretative methodology).

The model has several components. First, spatial data layers of soils, wetlands, rare features, plant communities, and fish and wildlife habitat are overlaid with a spatial layer of shoreland areas. Priority rankings for shoreland segments or plots are based on an overlapping moving window that follows the shoreline. An overlapping window technique allows the value of connectivity to be automatically included in the rankings. The size of the window used in the analysis is dependent on the lake size since the optimal window size varies by survey designs (e.g., for moderately sized lakes, a 2000 feet long (1320 feet landward, 680 feet lakeward) by 500 feet wide window, with 250 feet overlap is used, whereas for large lakes this window size is

increased). In this framework, shorelands are rated based on the cumulative score of the spatial data layers to provide resource conservation priorities.

Attributes from field surveys are summarized by polygons according to the elements occurrence (EO) data standard (NatureServe 2002). Substrate and aquatic plant data are given a negligible locational uncertainty type (areal estimated type with a 25 m radius). Unique plant communities and emergent and floating-leaf stands are of the areal delimited type (assuming negligible uncertainty). Frog and bird survey locations and loon nesting area polygons are of the areal estimated type with a 200 m radius. Fish and other aquatic vertebrate survey polygons are of the areal estimated type with a 50 m radius. The Natural Heritage Information System also uses this EO data standard.

Model Attributes

The following matrix is used to assign scores for shoreland segments:

Attribute	GIS Data Type	Score	Criteria of Plot
Hydric Soils	Polygons from Natural Resources Conservation Service Soil Survey	3	> 25% of analysis window is hydric soils
		2	12.5 – 25% hydric soils
		1	< 12.5% hydric soils
		0	No hydric soils observed
Near-shore Substrate	Points from surveys (converted to a circle procedural feature based on measure uncertainty)	3	Frequency of occurrence is > 50% soft substrate (muck, marl or silt) (i.e., at least 50% of points within analysis window consist of soft substrate)
		2	Frequency of occurrence is 25 – 50% soft substrate
		1	Frequency of occurrence < 25% soft substrate
		0	No soft substrate observed
Wetlands	Polygons from the National Wetland Inventory	3	> 25% of analysis window is wetlands
		2	12.5 – 25% is wetlands
		1	< 12.5% is wetlands
		0	No wetlands recorded
Near-shore Plant Occurrence	Points from the Aquatic Plant Surveys (converted to a circle procedural feature based on measure uncertainty)	3	Frequency of occurrence is > 75% (>75% of points within the analysis window contain vegetation)
		2	Frequency of occurrence is 25 – 75%
		1	Frequency of occurrence < 25%
		0	No vegetation observed

Attribute	GIS Data Type	Score	Criteria of Plot
Aquatic Plant Richness	Points from the Aquatic Plant Surveys (converted to a circle procedural feature based on measure uncertainty)	3	Total number of plant taxa within analysis window > 10
		2	Total number of plant taxa 5 – 10
		1	Total number of plant taxa 1 – 4
		0	No vegetation observed
Unique and Rare Plant Species	Points determined from the Aquatic Plant Surveys (converted to a circle procedural feature based on measure uncertainty)	3	Presence of 2 or more unique or rare plant species within analysis window
		2	Presence of 1 unique plant species
		0	No unique plant species observed
Emergent and Floating-leaf Plant Beds	Polygons based on stand locations delineated with the Aquatic Plant and Remote Sensing Surveys	3	Emergent and/or floating-leaf plant stands occupy > 25% of the aquatic part of the analysis window
		2	Stands occupy 5 – 25%
		1	Present but occupy < 5%
		0	No emergent or floating-leaf plant beds observed
Frog Areas	Points from the Frog Surveys (converted to a circle procedural feature based on measure uncertainty)	3	Presence of both green and mink frogs within analysis window
		2	Presence of green or mink frogs
		0	Neither species observed
Loon Nesting Areas	Polygons based on Loon Watcher Surveys and Bird Surveys	3	Presence of natural loon nest within analysis window
		2	Presence of loon nest on artificial platform within analysis window
		0	No loon nesting observed
Shoreline Bird Richness	Points from the Bird Surveys (converted to a circle procedural feature based on measure uncertainty)	3	Total number of bird species within analysis window > 25
		2	Total number of bird species within analysis window 11 – 25
		1	Total number of bird species within analysis window 1 – 10
		0	No bird species observed

Attribute	GIS Data Type	Score	Criteria of Plot
Bird Species of Greatest Conservation Need (SGCN)	Points from the Bird Surveys (converted to a circle procedural feature based on measure uncertainty)	3	Presence of 3 or more SGCN within analysis window
		2	Presence of 2 SGCN
		1	Presence of 1 SGCN
		0	No SGCN observed
Aquatic Vertebrate Richness (fish, frogs, turtles)	Points from the Aquatic Vertebrate Surveys (converted to a circle procedural feature based on measure uncertainty)	3	Total number of aquatic vertebrate species within analysis window > 10
		2	Total number of aquatic vertebrate species 5 – 10
		1	Total number of aquatic vertebrate species 1 – 4
		0	No aquatic vertebrates observed
Fish Species of Greatest Conservation Need (SGCN) and their	Points from the Aquatic Vertebrate Surveys (converted to a circle procedural feature based on measure uncertainty)	3	Presence of one or more SGCN within analysis window
		2	Presence of one or more proxy species
		0	SGCN or proxies not present
Natural Heritage Rare Features	Polygons from the Natural Heritage Information System	3	Presence of multiple Natural Heritage Features within analysis window
		2	Presence of one Natural Heritage Feature
		0	No Natural Heritage Feature recorded
Size and Shape of Natural Areas	Polygons based on DNR lake map interpretation	3	Protected or isolated bay within analysis window
		2	Non-protected or non-isolated bay within analysis window
		0	No distinctive bays

The Sensitivity Index is the cumulative score of the 15 attributes. The cumulative Sensitivity Index is lake-specific and a result of that lake's unique characteristics and habitat. These scores are not meant to be compared between lakes (e.g., what is a high score for one lake may not be a high score for another). Once a Sensitivity Index has been developed for a lake, clusters of points with similar values are identified using GIS. Cluster analysis uses ArcMap Hot Spot algorithms with a fixed Euclidean distance search radius of 2000 feet (609 m). The mapped calculated z-scores where Sensitivity Index values are statistically significant (> 1.96) indicate the most probable highly sensitive shoreland. These areas are then buffered by ¼ mile, resulting in discrete potential sensitive shoreland areas or resource protection districts. In occasional cases, data may not be available for one of the attributes (e.g., hydric soils). In these cases, the analyses are conducted with the remaining 14 attributes.

The intentions of the user will help determine which product will be most valuable. Those organizations looking to change zoning ordinances and rezone properties may focus on the potential resource protection districts. Those entities looking to prioritize shorelands for conservation easements may find the Sensitivity Indices provide a more detailed view of lakeshore sensitivity.

It is expected that the conservation principles and this ecological model will have a greater propensity to identify the most highly sensitive lakeshores to be shorelands associated with bays or sheltered areas of the lake characterized by quiet water and abundant vegetation. However, sections of the shoreline with high wind and wave exposure (i.e., high-energy shorelines) may also be sensitive. Although many of the animal species surveyed (e.g., frogs, bird and fish species of greatest conservation need) prefer the protected, vegetation-rich areas such as bays, other species inhabit the windswept shorelines. These high-energy shorelines often have vegetation communities and substrates that differ significantly from the bays. Waves may uproot or fragment plants, or affect plant growth and reproduction (Doyle 2001). Waves can also transport sediments, altering the substrate composition. Silt may be suspended and removed from an area, leaving a sandy or gravelly bottom. Because walleye typically require silt-free substrates for spawning (Newburg 1975), they may inhabit these shores during spawning. There is a positive association between wind-wave power and walleye, and walleye may be also attracted to high-energy areas where smaller prey species are vulnerable due to wave action (Cross and McInerney 2006). Certain shorebirds, such as sandpipers and plovers, use the sandy beaches of high-energy shorelines for feeding and even nesting. Because these high-energy shorelines provide habitat for several animal species, they may have sufficient diversity to receive a high species richness score. The presence of rare features, wetlands, and hydric soils around these sections of shoreline may also enable these areas to obtain high scores in the ecological model.

Habitat Connectivity

In addition to the sensitive lakeshore areas identified through the ecological model, adjacent rivers and streams that provide connectivity should also be considered for protection. Aquatic habitat connectivity allows for the movement of organisms within a watershed. Organisms can move between existing habitats, colonize new areas, or recolonize former habitat in the wake of local extinctions. Aquatic habitat connections, also known as ecological connections, allow movement of animals from various populations, increasing diversity. They also allow animals with different habitat requirements during different life stages to access these habitats. For the purposes of this project, ecological connections are defined by three criteria:

1. The lake is connected, networked, or linked to existing good habitat
 - a. The presence of an impassable dam eliminates a connection
 - b. A stream/river that enters/exits the lake but does not connect up/downstream to another waterbody is not considered an ecological connection
2. The connection itself is good habitat
 - a. Although a ditch or canal may provide connectivity, these channels are not high quality habitat and, as such, are not considered ecological connections
3. Higher land use development standards would benefit the designated ecological connection

Often, lake inlets and outlets are designated ecological connections. Other non-river habitats, such as a wetland that connects two nearby lakes, could also be considered ecological connections.

Depending on the existing classification of rivers and streams, the local government may use the ecological connection recommendation to consider reclassifying to a more protective river class. Shorelands of ecological connections could also be designated as priority conservation acquisitions.

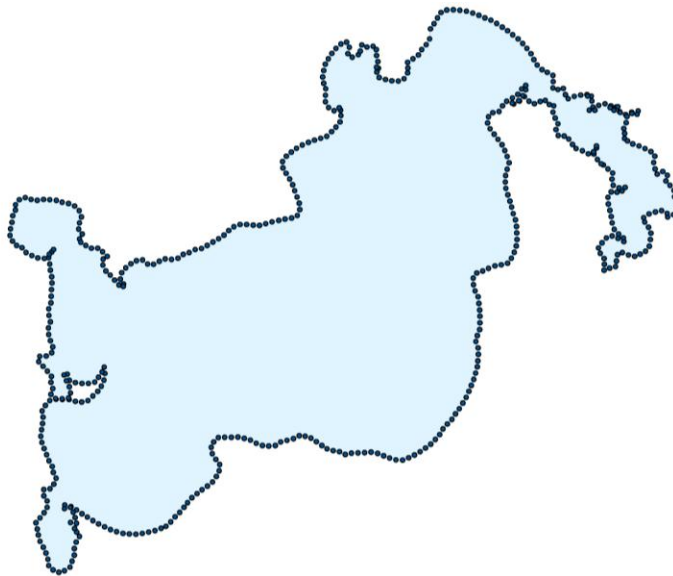
Other Areas of Ecological Significance

Additional areas of ecological significance that are not associated with priority shoreland features may also occur within a lake. These may be sites that are not typically associated with aquatic plants or rare fish because they occur along less protected/high energy shorelines and are dominated by hard substrates. Or, they may be sites that are too small to warrant inclusion as part of a shoreline resource protection district – but the small size of these sites is a defining feature that adds to their importance within the lake. Identifying these sites is important, although exact delineation of their boundaries may be difficult because they occur in the water and can be patchy in distribution.

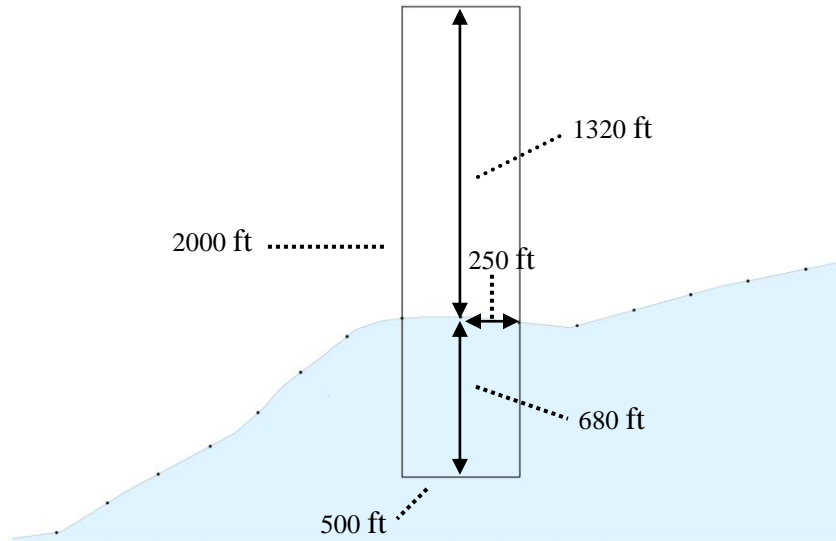
GIS Steps of Ecological Model

The following nine steps are used to create a sensitive lakeshore map (see Appendix 8 for details):

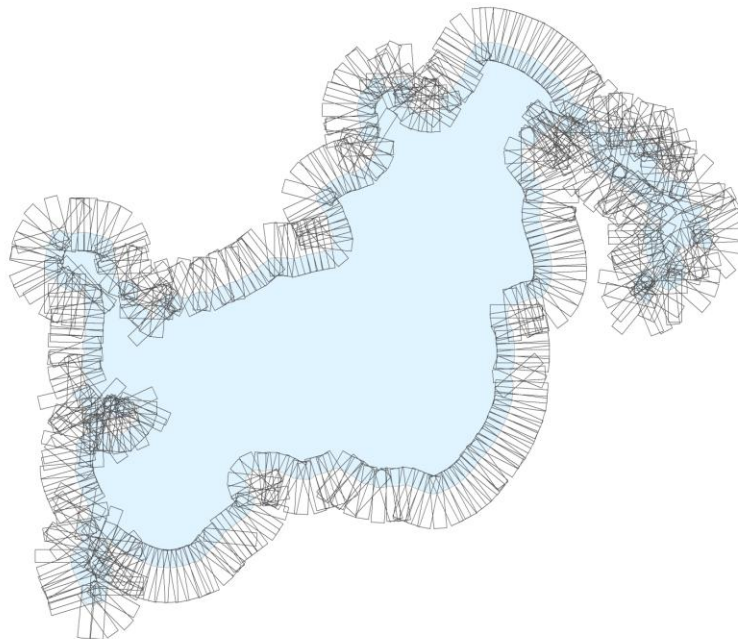
1. Create points every 250 ft along the shoreline.



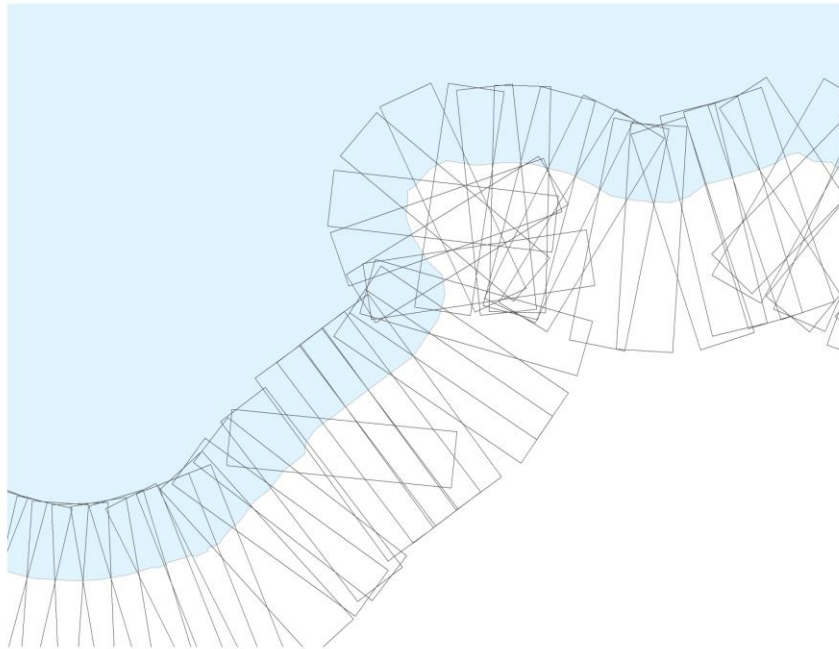
2. Create window around each point with following specifications (this will vary depending on lake size).



All points with windows around points



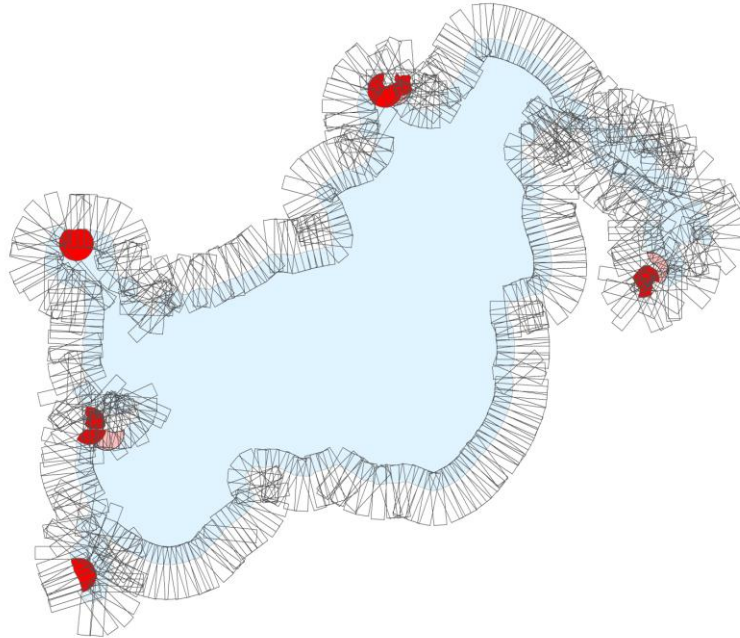
Zoom in of windows on shoreline



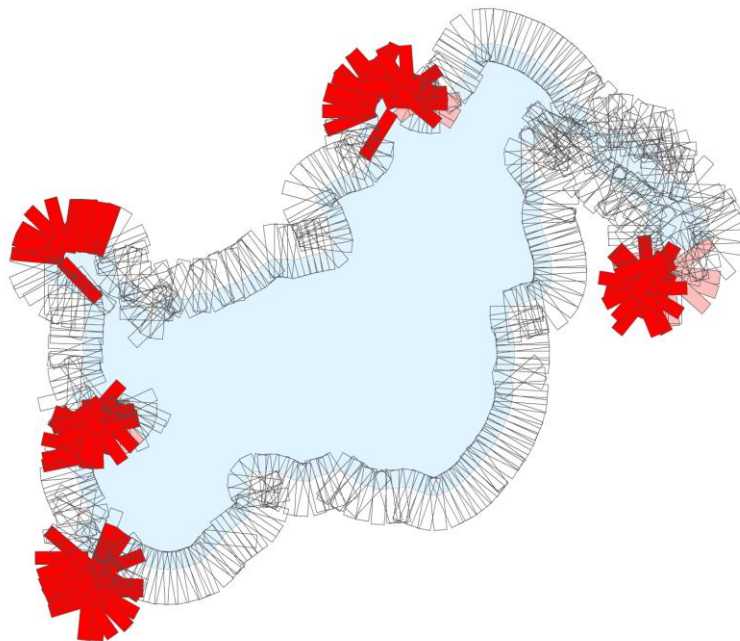
3. Input data layer. Example below is for loon nests where red is a natural nest and pink is a platform nest. The nest sites are buffered by 200 m and limited to the water.



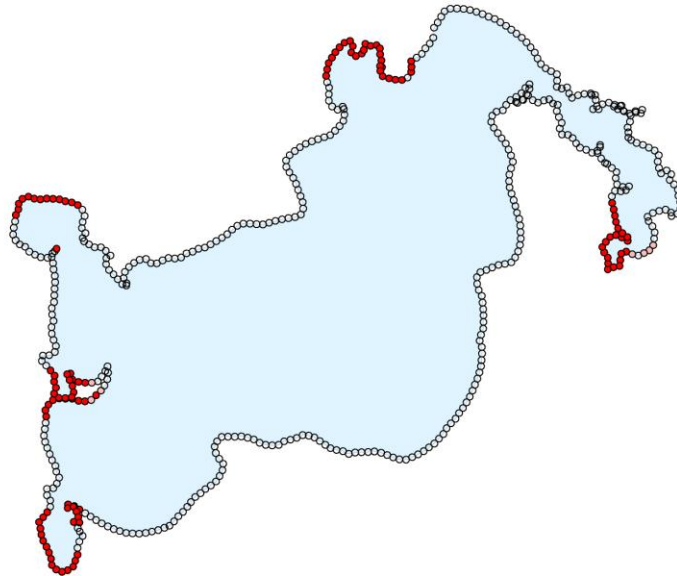
4. Perform a spatial join between the windows and loon nest sites to assign each window a loon nest value. Natural nests are assigned a value of 3 and platform nests are assigned a value of 2 (see Model Attributes matrix). If multiple loon nests occur within one window, the window is assigned the highest score.



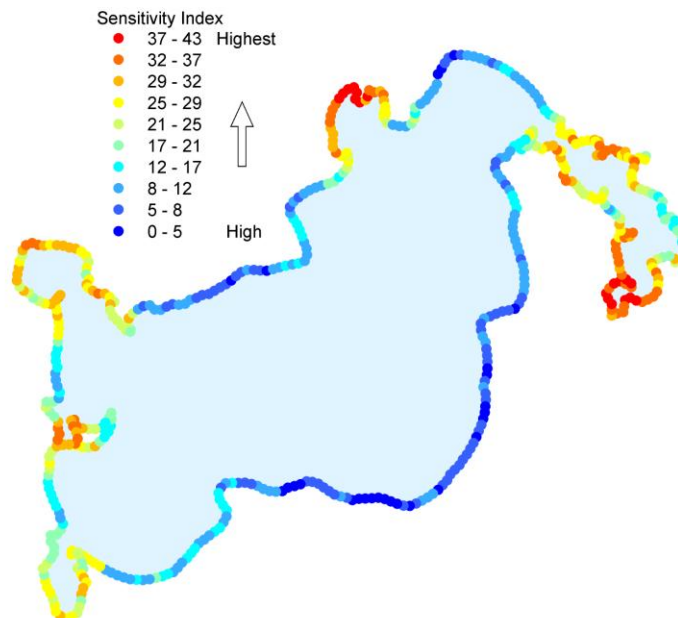
results in:



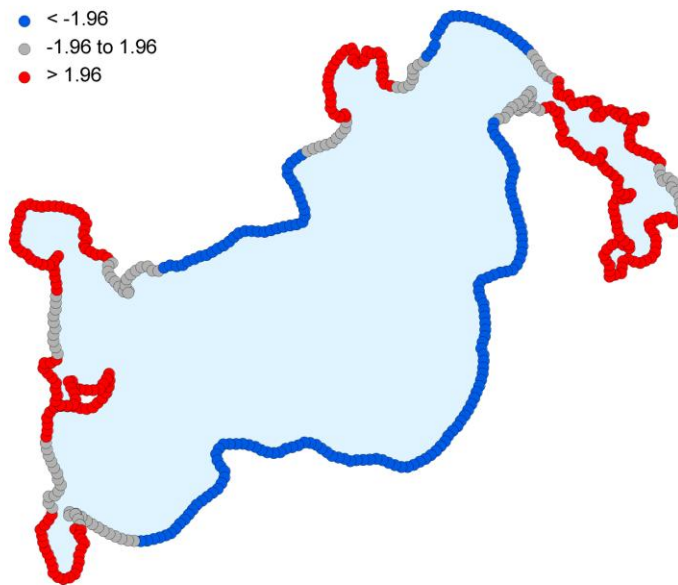
5. Perform a spatial join between the “loon coded” windows and the original 250 ft points. Each point is therefore assigned the same value as its corresponding window.



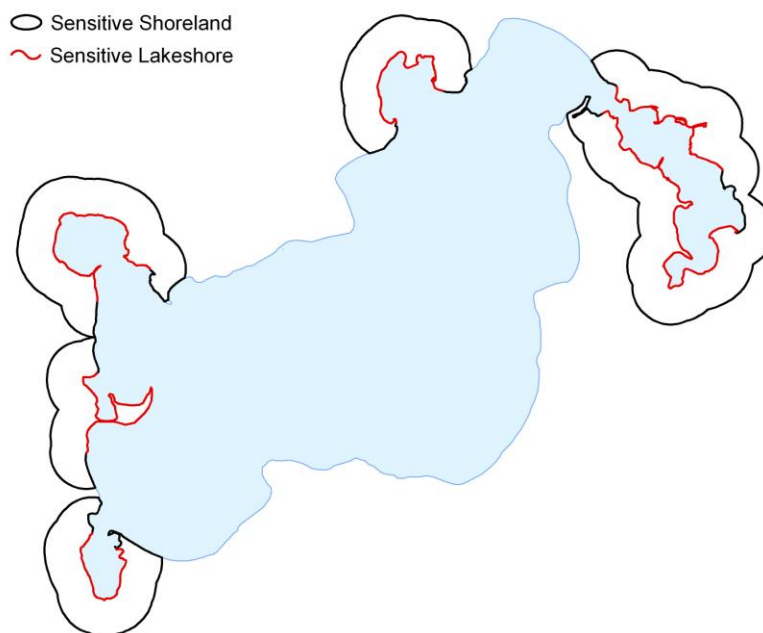
6. Repeat this on all layers. The Sensitivity Index is the cumulative score. Red/orange colors represent points with the highest cumulative scores (highest sensitivity), whereas green/blue scores represent points with lower cumulative scores (high sensitivity).



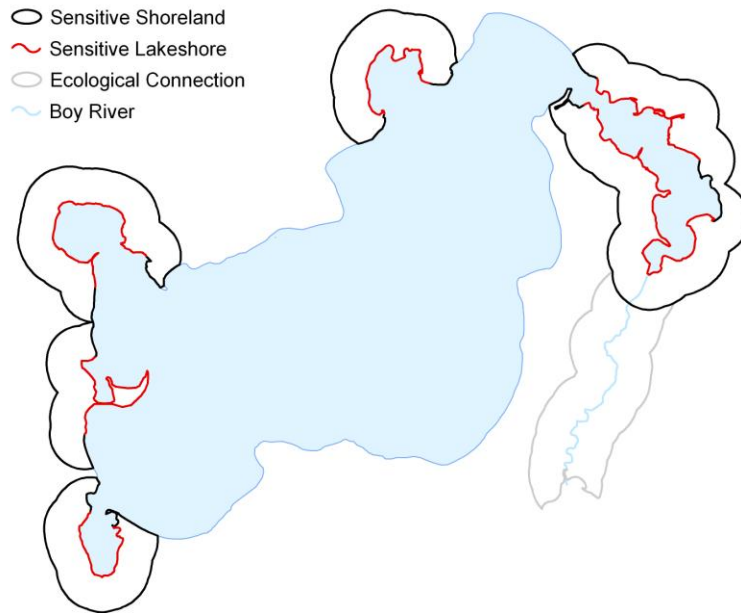
7. Perform cluster analysis on Sensitivity Index layer to obtain distinct segments of sensitive shoreland. Red areas represent highly sensitive shoreland.



8. Create buffers around highly sensitive shoreland to generate potential resource protection areas.



9. Shorelands of inlets or outlets in potential sensitive lakeshore and other ecological connections will also be forwarded to the local government for consideration of sensitive area districting and public water reclassification, as water quality protection and connectivity of these areas for fish and wildlife is important.



A final report is assembled for each lake that summarizes the various surveys and the results of the ecological model. The final step is to provide the locations and maps of sensitive shorelines to the local government and other organizations and individuals who may be interested in lakeshore protection.

B. Predictive models for prompt, timely delineations

Rapid Assessment Model

As development pressure on Minnesota's lakes continues to increase, there is also an increased need to efficiently identify areas of sensitive lakeshore. The current survey protocol, though valuable for the depth and breadth of information it provides, requires large amounts of time for data collection and analysis. This process is not always practical or feasible. A rapid assessment model will provide local governments and other organizations the ability to identify sensitive lakeshore in a much shorter time and at a much lower cost than the original assessment technique.

Rather than develop an entirely new set of criteria to rapidly identify sensitive lakeshore, a subset of the original suite of variables was chosen. Several modifications of the original analysis technique were also tested. The variables selected for potential inclusion in the rapid assessment model were chosen based on several characteristics, including accessibility. Many of the biotic data used in the original model, such as near-shore plant occurrence, bird richness, and aquatic

vertebrate richness, require specialized technical skill to obtain. Many of the abiotic variables, on the other hand, such as wetlands and hydric soils, may be easily attained as digital data. Of the 15 parameters used in the original assessment, five were used to develop the rapid assessment model. These parameters were wetlands, hydric soils, rare features, loon nesting areas, and size and shape of natural areas (i.e., bays). Earlier analyses also indicated that several of these variables were important in determining lakeshore sensitivity (Appendix 9).

Methods

The ecological model was tested using all possible combinations of the five variables, for a total of 31 variable combinations. For each combination, the model was run and a sensitivity index calculated. The subsequent cluster analysis identified every (250 foot) point around the shoreline as either highly sensitive ($z > 1.96$) or not highly sensitive ($z \leq 1.96$) (see steps 1 – 7 above). These results were then compared to the results of the original (15 attribute) model, and the number of points identified correctly (i.e., the same as in the original results) was calculated. The parameter “bays” and all combinations including it were eliminated from contention due to the subjective nature of bay identification. Although guidelines for delineating bays are available within this protocol, they are open to interpretation and bay boundaries may be drawn differently by different observers. Efforts to find a substitute for the bays attribute, including the use of shoreline curvature, were largely unsuccessful. To maintain objectivity in the rapid assessment model, the bay parameter was removed from the list of potential candidate models.

In addition, as part of the rapid assessment model development process, several analysis techniques were tested. They included varying both the shape and size of the overlapping windows along the shoreline, and using actual data values of several parameters (e.g., percent wetland within window, percent hydric soil within window) instead of scoring the parameters. The result of this testing indicated that using the original analysis method to identify sensitive shoreline was equally as or more effective than other methods (Table 2). Therefore, to maintain consistency the original analysis window shape and size are used in the rapid assessment analysis.

The scores of the variable combinations were ranked according to Akaike’s Information Criterion (Table 1).

Results

The top-ranking models based on AIC results were the single-parameter models: wetlands, loon nesting areas, hydric soils, and rare features. However, the parameter combination that correctly classified the greatest number of shoreline points was wetlands + hydric soils + loon nesting areas. Overall, this model correctly classified 81% of the shoreline points. We suggest that when data are available, a model incorporating wetlands + hydric soils + loon nesting areas be used to most accurately identify areas of sensitive lakeshore. If hydric soil or loon nesting data are unavailable, a model including only wetland data will provide a reasonable method to identify sensitive lakeshore.

Table 1. Results of model selection procedure using Akaike's information criterion to examine ability of various attributes to predict sensitive lakeshore.

Parameter(s)	%^a	K^b	AIC_c^c	ΔAIC_c^d	w^e
Soils	0.680	1	10.853	0.202	0.139
Wetlands	0.769	1	10.652	0.000	0.154
Soils, wetlands	0.765	2	12.666	2.014	0.056
Loons	0.757	1	10.685	0.034	0.152
Soils, loons	0.799	2	12.553	1.901	0.060
Wetlands, loons	0.795	2	12.565	1.913	0.059
Soils, wetlands, loons	0.814	3	14.497	3.845	0.023
Rare features	0.590	1	10.960	0.308	0.132
Soils, rare features	0.667	2	12.876	2.225	0.051
Wetlands, rare features	0.680	2	12.855	2.203	0.051
Soils, wetlands, rare features	0.712	3	14.799	4.148	0.019
Loons, rare features	0.741	2	12.729	2.077	0.055
Wetlands, loons, rare features	0.774	3	14.641	3.990	0.021
Soils, loons, rare features	0.760	3	14.681	4.029	0.021
Soils, wetlands, loons, rare features	0.782	4	16.617	5.965	0.008

^a % = Percent of shoreline points classified correctly (i.e., same as in original model) using listed parameters in ecological model

^b K = Number of parameters

^c Akaike's information criterion corrected for small sample size

^d Difference between lowest Akaike score and Akaike score for each model

^e Akaike weight (ratio of ΔAIC_c values for each model to the whole set of models); provides a measure of strength of evidence

Table 2. Percent of shoreline points classified correctly (i.e., same as in original model) using different analysis window shapes and sizes. Analyses were conducted using the top-rated (based on AIC results) parameter, wetlands.

Window shape/size	Score (S)/ Percent (P)	Ada Lake	Birch Lake	Pine Mtn. Lake	Thunder Lake	Woman Lake
Original analysis window	S	72	89	79	64	90
Original analysis window	P	74	87	80	62	84
Circular window (250 ft radius)	S	75	67	89	69	90
Circular window (250 ft radius)	P	75	85	91	69	88
Circular window (500 ft radius)	S	75	93	92	69	87
Circular window (500 ft radius)	P	75	89	91	64	91
Circular window (750 ft radius)	S	75	92	90	66	86
Circular window (750 ft radius)	P	76	89	89	63	88
Circular window (1000 ft radius)	S	75	89	90	64	89
Circular window (1000 ft radius)	P	77	89	84	63	88

Limitations

The sensitive lakeshore assessment project was conducted on a group of lakes that exhibit fairly similar physical characteristics (Table 3) and are located within a defined geographical area (Figure 13). The rapid assessment tool has not been tested outside these boundaries, and its performance in other parts of the state and on different types of lakes is unknown. As data from additional sensitive lakeshore surveys are obtained, they will be used to evaluate the performance of the rapid assessment model.

Table 3. Characteristics of lakes used to develop rapid assessment model.

Lake name	DOW number	Lake area (acres)	Shoreline length (mi)	Max depth (ft)	Lake class*
Ada	11-0250-00	1044	7.5	60	27
Big Portage	11-0308-00	956	7.7	23	39
Birch	11-0412-00	1262	15.7	45	25
Boy	11-0143-00	3404	25.9	45	25
Little Boy	11-0167-00	1396	10.0	74	22
Long	11-0142-00	926	15.6	115	25
Pine Mountain	11-0411-00	1657	9.5	80	22
Pleasant	11-0383-00	1038	9.0	72	27
Roosevelt	11-0043-00	1561	18.4	129	22
Steamboat	11-0504-00	1761	8.2	93	22
Sylvan	11-0304-00	882	11.1	57	25
Ten Mile	11-0413-00	4640	25.2	208	22
Thunder	11-0062-00	1316	15.9	95	25
Wabedo	11-0171-00	1272	11.3	95	22
Washburn	11-0059-00	1768	19.5	111	22
Woman	11-0201-00	5360	30.7	54	22

*Lake class based on Schupp 1992.

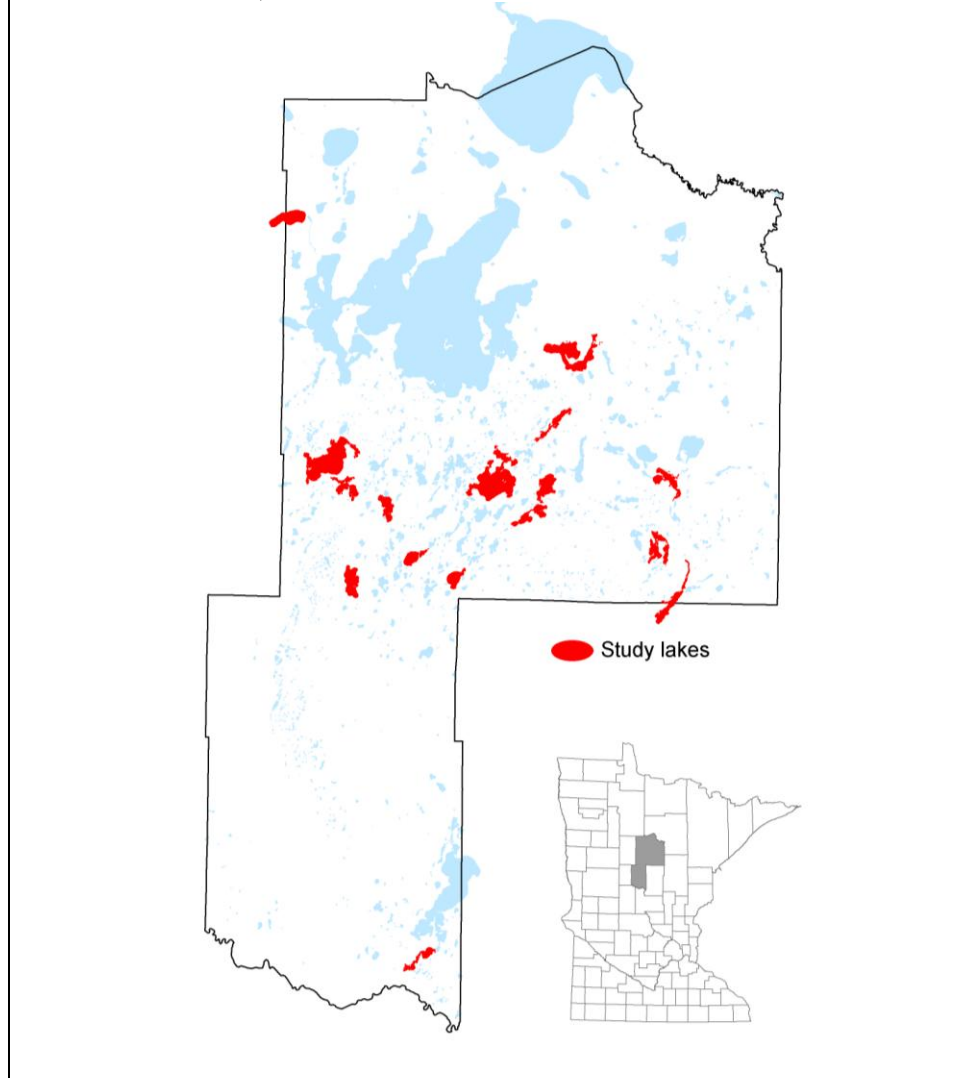
Class 22 - generally clear, very large, very deep, low percent of shallow water, irregular shoreline

Class 25 - deep, clear, hard water, irregular shoreline

Class 27 - generally large, deep, regularly shaped

Class 39 - shallow, regularly shaped

Figure 13. Location of study lakes (lakes used to develop rapid assessment model) in Minnesota.



C. Limitations of ecological model

Geographic Scope

As alluded to in the Rapid Assessment section of this manual, the Sensitive Lakeshore identification protocol was developed for use on north-central Minnesota lakes. Therefore, the attributes that were chosen for inclusion in the ecological model are those that are relevant within this geographical area. This same suite of attributes may not be appropriate in other areas of the state. For example, wetlands are an important indicator of sensitive lakeshore in Cass, Crow Wing, and Aitkin Counties. In areas of the state where wetlands are scarce, such as southern Minnesota, this attribute may not be applicable. Other attributes, such as slope, presence of an inlet or outlet, or presence of additional wildlife species, may provide valuable information in identifying sensitive lakeshore. Modifications to the set of ecological model attributes and the

attribute scoring criteria may be necessary if implementing sensitive lakeshore identification outside of central Minnesota.

Lake Size

The ecological model for sensitive lakeshore delineation is most appropriate for use on lakes 500 acres or larger in size. On smaller lakes, cluster analysis may lead to very small or fragmented sections of shoreline being identified as sensitive; one goal of this protocol is to avoid “spot zoning” of shorelines by local governments. Alternatively, once the 1320 foot buffer is created around sections of sensitive shoreline, nearly the entire lake may fall within the potential resource protection district. Therefore, for smaller lakes, use of other lake classification techniques may be more appropriate. Lakes designated as natural environment lakes, Fisheries cisco lakes, Wildlife special shallow lakes, or MCBS high biological quality lakes would all benefit from additional lakeshore protection.

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Appendices

1. Grid point-intercept vegetation survey – required sample size
2. Grid point-intercept vegetation survey – equipment checklist
3. Grid point-intercept vegetation survey – field data collection form
4. Aquatic plant bed (e.g., bulrush) field delineation – equipment checklist
5. Partial list of rare (SPC-special concern, THR-threatened, END-endangered) and unique plant species most likely to be found in lakes or along lakeshores
6. Aquatic frog calling survey – field data collection form
7. Bird survey – field data collection form
8. Evaluation of GIS ecological model attributes
9. GIS methods for sensitive lakeshore analysis

Appendix 1. Grid point-intercept vegetation survey: required sample size

The number of sample points required to reliably estimate species frequencies is not dependent on lake size (Newman et al. 1998) and required sample size can be calculated using the formula:

$N = (t/D)^2 * (1-p)/p$, where:

N = required sample size

t = appropriate value from t distribution table (1.96 for 95% confidence interval)

P = estimate of frequency of occurrence

D = error as a fraction of p (i.e. 0.1 to estimate p within 10%)

Newman et al. (1998) recommended that for data collected using the Jesson-Lound (1962) method, 40 to 100 samples per lake were adequate and found that sample sizes greater than 100-200 did not yield much additional precision or accuracy for frequencies of “common” species. His analysis was based on data collected using a method in which sample area (and thus resulting frequency estimate) was greater than that used in the point-intercept method. Required sample size may need to be increased for point intercept surveys.

Nichols (1984) agreed that the most common species should be used for calculating the adequacy of the sample and added that it may be appropriate to accept a greater error (for example 15% error instead of 10%) in order to reduce sampling effort. For many Minnesota lakes where point intercept surveys have been conducted, the “common” or most abundant species occurred with frequencies between 15% and 40% (within the zone from shore to 20 feet) (Perleberg, unpublished data).

Binomial distribution occurrence	Required sample size (20% error)	Required sample size (15% error)	Required sample size (10% error)
0.90	11	20	44
0.80	25	45	100
0.70	43	76	171
0.60	67	119	267
0.50	100	178	400
0.40	150	267	600
0.30	233	415	933
0.20	400	712	1600
0.10	900	1602	3600

Newman et al. (1998) found that required sample size is independent of lake size but we consider lake size here because we are also interested in vegetation mapping. For mapping purposes, on most lakes, sample points will be placed 213 feet (65 meters) apart, which will result in approximately one sample point per littoral acre. The minimum distance between survey points is determined by the accuracy of the GPS (Global Position System); with current GPS technology, a minimum distance of 98 feet (30 meters) is recommended to avoid overlap of sampling location.

Littoral zone width will influence sample point spacing and on lakes with narrow littoral zones points will be spaced closer together. For example, Roosevelt Lake in Cass County has a 390-acre littoral zone that, in many areas, is less than 50 meters in width. If lake littoral area alone were used to determine sample number, most points would not occur within the vegetated zone. Therefore, sample points were spaced 40 meters apart on this lake.

Recommended sample size and grid spacing

Lake littoral zone area (acres)	Maximum distance between survey points		Sampling density	Example lakes
	feet	meters		
>5,000	656	200	1 point per 10 acres	Leech
1001-5,000	328 – 492	100 – 150	1 point per 4 – 6 acres	Boy, Woman, Ten Mile, Pelican, Whitefish
250-1000	213	65	1 point per acre	Washburn, Alexander
<250	98-197	30-60	1-5 points per acre	Thunder, Deep Portage

General plant abundance and distribution are also considered when determining sample spacing. While the physical littoral zone may extend to 15 feet and deeper, vegetation on many lakes may be restricted to shallower depths. In these situations, sample points should be concentrated within the actual vegetated zone.

Appendix 2. Grid point-intercept vegetation survey equipment checklist.**Point Intercept Field Equipment Checklist***(Italics indicates optional gear)***BOAT and accessories**

	Motorized boat (or canoe)
	Gas
	Tool Kit
	Fire Extinguisher
	First Aid Kit
	Life Jackets
	Seat Cushion
	<i>Trolling motor</i>
	<i>Push pole</i>
	<i>Anchor</i>

SAMPLING EQUIPMENT

	Telescoping pole marked in feet to measure water depth and test substrate
	Double-headed, weighted rake attached to 30+ feet of rope
	<i>Plastic hoop measuring 1 meter square in area</i>
	<i>View tube</i>
	<i>Secchi disc</i>

ELECTRONICS

	Depth finder
	GPS with survey points downloaded
	12 volt adapter for GPS
	<i>field computer</i>
	Camera
	Cell phone
	Batteries
	Waterproof case for electronics

PLANT SAMPLES

	Cooler
	Ice
	Ziploc bags
	Waterproof markers
	Plant field guides

PAPERWORK

	Clipboard
	Lake Contour Map
	Map of survey points
	Field data sheets
	<i>Aerial photo of lake</i>
	pencils

PERSONAL GEAR

	Polarized sunglasses
	Rain wear
	Chest or hip waders
	Sunscreen
	<i>Bug repellent</i>
	Lunch, water
	Hand towels

Appendix 3. Grid point-intercept vegetation survey field data collection form.

_____ Lake(_____ County) DOW# _____ - _____ - _____ DATE: _____ 2011

SURVEYORS: _____ MNDNR EWR Vegetation Survey

		Site number →																		
	CODE	DEPTH (ft) →																		
NO SURVEY - (SH = on shore, D= too deep)																				
	EMT	No vegetation found																		
<i>Utricularia vulgaris</i>	UV	Greater Bladderwort																		
<i>U. intermedia</i>	UI	Flat-leaf bladderwort																		
<i>U. minor</i>	UM	Minor bladderwort																		
<i>U. gibba</i>	UG	Humped bladderwort																		
<i>Najas flexilis</i>	NF	Bushy pondweed*																		
<i>N. guadalupensis</i>	NG	Southern naiad																		
<i>Ranunculus aquatilis</i>	R	White-water Buttercup																		
<i>Elodea canadensis</i>	EC	Canada waterweed																		
<i>V. americana</i>	VA	Celery																		
<i>Chara</i> sp.	C	Chara																		
<i>P. richardsonii</i>	POR	Clasping leaf																		
<i>C. demersum</i>	CD	Coontail																		
<i>P. crispus</i>	PC	Curly-leaf pondwd																		
<i>P. zosteriformis</i>	PZ	Flat-stem pondwd																		
<i>P. illinoensis</i>	PI	Illinois pondweed																		
<i>P. amplifolius</i>	PA	Large-leaf pondwd																		
<i>M. beckii</i>	MB	Marigold																		
<i>Potamogeton</i> sp.	POSN	Narrow-leaf pondwd																		
<i>M. sibiricum</i>	MS	Northern milfoil																		
<i>P. robbinsii</i>	PR	Robbin's pondweed																		
<i>S. pectinata</i>	PP	Sago pondweed																		
<i>Heteranthera dubia</i>	HD	Star grass																		
<i>P. gramineus</i>	PG	Variable pondweed																		
<i>P. praelongus</i>	POP	White-stem pondwd																		
<i>Lemna trisulca</i>	LT	Star duckweed																		
<i>S. polyhriza</i>	SPP	Greater duckweed																		
<i>Lemna</i> spp.	LS	Lesser duckweeds																		
<i>P. natans</i>	PN	Floating-leaf pondwd																		
<i>Nymphaea odorata</i>	NO	White waterlily																		
<i>Nuphar variegata</i>	NV	Yellow waterlily																		
<i>Brasenia schreberi</i>	BRS	Watershield																		
<i>Sagittaria</i> sp.	SAS	Arrowhead																		
<i>Schoenoplectus</i> sp.	SCS	Bulrush																		
<i>Phragmites australis</i>	PHAU	Cane																		
<i>Typha</i> sp.	TS	Cattail																		
<i>Eleocharis</i> sp.	ELSP	Spikerush																		
<i>Zizania palustris</i>	ZIP	Wild Rice																		
sediment (BO, RB, GR, SA, SI, MR, MU)																				

pg ____ of ____

X = species present in 1m2 sample area / X with circle = matted plants / 0 = found in lake but not in survey point

Appendix 4. Aquatic plant bed delineation equipment checklist

Field Equipment Checklist

Aquatic plant bed GPS delineation

(Italics indicates optional gear)

BOAT and accessories

	Motorized boat (or canoe)
	Gas
	Tool Kit
	Fire Extinguisher
	First Aid Kit
	Life Jackets
	Seat Cushion
	<i>Trolling motor</i>
	<i>Push pole</i>
	<i>Anchor</i>

ELECTRONICS

	Depth finder
	GPS
	12 volt adapter for GPS
	<i>field computer</i>
	<i>Camera</i>
	<i>Cell phone</i>
	Batteries
	Waterproof case for electronics

PLANT SAMPLES

	Cooler
	Ice
	Ziploc bags
	Waterproof markers
	Plant field guides

PAPERWORK

	Clipboard
	Lake Contour Map
	draft map with photo-interpretation notes
	<i>Aerial photo of lake</i>
	pencils

PERSONAL GEAR

	Polarized sunglasses
	Rain wear
	Chest or hip waders
	Sunscreen
	<i>Bug repellent</i>
	Lunch, water
	<i>Hand towels</i>

Appendix 5. Partial list of rare (SPC-special concern, THR-threatened, END-endangered, *- proposed) and unique plant species most likely to be found in lakes or along lakeshores.

	Scientific name	Common Name	C value		MN Rare Status
			WT ¹	MN ²	
Shrub	<i>Andromeda glaucophylla</i>	Bog rosemary	10	9	none
	<i>Cephalanthus occidentalis</i>	Buttonbush	9	7	*SPC
	<i>Chamaedaphne calyculata</i>	Leatherleaf	9	8	none
	<i>Decodon verticillatus</i>	Waterwillow	7	8	THR /*SPC
	<i>Kalmia polifolia</i>	Bog laurel	10	9	none
	<i>Myrica gale</i>	Sweet gale	9	8	none
Wetland emergents	<i>Arethusa bulbosa</i>	Dragon's mouth	10	10	none
	<i>Carex lasiocarpa</i>	Narrow-leaved woolly sedge	9	7	none
	<i>Carex oligosperma</i>	Few-seeded sedge	10	8	none
	<i>Carex rostrata</i>	Beaked sedge	10	8	none
	<i>Cypripedium arietinum</i>	Ram's head lady's slipper	10	9	THR
	<i>Cypripedium candidum</i>	Small white lady's slipper	10	10	SPC
	<i>Cypripedium parviflorum</i>	Yellow lady's slipper	9	8	none
	<i>Cypripedium reginae</i>	Showy lady's slipper	9	8	none
	<i>Drosera anglica</i>	English sundew	10	10	SPC
	<i>Drosera linearis</i>	Slender-leaved sundew	10	10	SPC
	<i>Eriophorum angustifolium</i>	Narrow-leaved cottongrass	9	8	none
	<i>Menyanthes trifoliata</i>	Bog buckbean	10	9	none
	<i>Sarracenia purpurea</i>	Pitcher plant	10	9	none
	<i>Scheuchzeria palustris</i>	Arrowgrass	10	9	none
	<i>Triglochin maritima</i>	Greater arrowgrass	10	10	none
	<i>Xyris montana</i>	Yellow-eyed grass	10	10	SPC
Lakeshore emergents	<i>Calla palustris</i>	Water arum	9	8	none
	<i>Cladium mariscoides</i>	Twig rush	10	10	SPC
	<i>Dulichium arundinaceum</i>	Three-way sedge	9	8	none
	<i>Eleocharis flavescens</i> var. <i>olivacea</i>	Olive-colored spike rush	8	9	THR /*END
	<i>Eleocharis quinquiflora</i>	Few-flowered spike rush	8	9	SPC
	<i>Eleocharis robbinsii</i>	Robbins' spike rush	10	10	*THR
	<i>Fimbristylis autumnalis</i>	Autumn fimbristylis	8	6	SPC
	<i>Heteranthera limosella</i>	Mud plantain	N/A	7	THR
	<i>Lobelia dortmanna</i>	Water lobelia	10	10	none
	<i>Rhynchospora fusca</i>	Sooty-colored beak rush	10	9	SPC
	<i>Sagittaria brevirostra</i>	Midwestern arrowhead	9	9	none
	<i>Sagittaria cristata</i>	Crested arrowhead	9	8	none
	<i>Sagittaria graminea</i>	Grass-leaved arrowhead	9	8	none
	<i>Schoenoplectus heterochaetus</i>	Slender bulrush	10	8	none
	<i>Schoenoplectus torreyi</i>	Torrey's bulrush	9	8	none
	<i>Sparganium glomeratum</i>	Clustered burreed	8	7	SPC

Appendix 5, continued.

	Scientific name	Common Name	C Value		MN Rare Status
			WI ¹	MN ²	
	<i>Callitriche hermaphrodita</i>	Northern water starwort	9	8	none
	<i>Callitriche heterophylla</i>	Large water starwort	9	8	SPC
	<i>Ceratophyllum echinatum</i>	Hornwort	10	10	none
	<i>Crassula aquatica</i>	Pygmy waterweed	N/A	5	THR /*END
	<i>Elatine minima</i>	Small waterwort	9	9	none
	<i>Elatine triandra</i>	Three-stamened waterwort	9	9	*THR
	<i>Eriocaulon aquaticum</i>	Pipewort	9	9	none
	<i>Hippuris vulgaris</i>	Marestail	10	9	none
	<i>Littorella uniflora</i>	American shore plantain	10	10	SPC
	<i>Myriophyllum alterniflorum</i>	Alternate-leaved water milfoil	10	10	none
	<i>Myriophyllum tenellum</i>	Leafless water milfoil	10	9	none
	<i>Najas gracillima</i>	Slender water naiad	7	10	SPC
	<i>Najas guadalupensis</i>	Southern naiad	N/A	8	*SPC
	<i>Najas marina</i>	Sea naiad	N/A	4	SPC
	<i>Potamogeton alpinus</i>	Alpine pondweed	9	9	none
	<i>Potamogeton bicipulatus</i>	Two-cupped pondweed	9	10	END
	<i>Potamogeton confervoides</i>	Algal-leaved pondweed	10	N/A	none
	<i>Potamogeton diversifolius</i>	Diverse-leaved pondweed	9	10	END
	<i>Potamogeton hillii</i>	Hill's pondweed	9	N/A	none
	<i>Potamogeton oakesianus</i>	Oakes' pondweed	10	10	*END
	<i>Potamogeton obtusifolius</i>	Blunt-leaved pondweed	9	8	none
	<i>Potamogeton pulcher</i>	Beautiful pondweed	10	N/A	*END
	<i>Potamogeton vaseyi</i>	Vasey's pondweed	10	10	SPC
	<i>Ranunculus flammula</i>	Creeping water buttercup	9	7	none
	<i>Ranunculus gmelini</i>	Yellow water crowfoot	10	6	*SPC
	<i>Ruppia cirrhosa</i>	Wigeon grass	8	6	SPC
	<i>Schoenoplectus subterminalis</i>	Water bulrush	9	9	none
	<i>Stuckenia vaginata</i>	Large-sheathed pondweed	9	9	SPC
	<i>Subularia aquatica</i>	Awlwort	10	10	THR
	<i>Utricularia gemniscapa</i>	Twin-scaped bladderwort	9	10	*END
	<i>Utricularia gibba</i>	Humped bladderwort	9	9	none
	<i>Utricularia intermedia</i>	Flat-leaved bladderwort	9	8	none
	<i>Utricularia minor</i>	Lesser bladderwort	10	8	none
	<i>Utricularia purpurea</i>	Purple-flowered bladderwort	9	10	SPC /* END
	<i>Utricularia resupinata</i>	Lavender-flowered bladderwort	9	10	SPC /* END

Appendix 5, continued.

	Scientific name	Common Name	C value		MN Rare Status
			WI ¹	MN ²	
<i>Floating-leaved</i>	<i>Caltha natans</i>	Floating-leaf marsh marigold	10	9	END
	<i>Nuphar microphylla</i>	Small yellow waterlily	9	9	none
	<i>Nuphar X rubrodisca</i>	Intermediate yellow waterlily	9	9	none
	<i>Nymphaea leibergii</i>	Very small white waterlily	N/A	10	THR
	<i>Sparganium angustifolium</i>	Narrow-leaved burreed	9	8	none
	<i>Sparganium fluctuans</i>	Floating-leaved burreed	10	8	none
	<i>Sparganium natans</i>	Least burreed	10	9	none

¹ Wisconsin Floristic quality assessment. Wisconsin State Herbarium.

<http://www.botany.wisc.edu/herbarium/wisflora/Assessment.asp>

² Milburn, S.A., M. Bourdaghs, and J.J. Husveth. 2007. Floristic quality assessment for Minnesota wetlands. Minnesota Pollution Control Agency. St. Paul, MN.

Appendix 6. Aquatic frog calling survey field data collection form.

Frog & Toad Calling Survey <small>Run survey after dark until 1:00 a.m., when wind velocity is less than 12 mph. Listen approximately 3-5 minutes at each stop and record the number of mink and green frogs and an <i>Index Value</i> for all species heard.</small>																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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Appendix 6, continued.

Index Values:

- 1=individuals can be counted (silence between calls)
- 2=calls of individuals can be distinguished, but some overlap of calls
- 3=full chorus (calls constant, continuous, and overlapping).

Wind Codes:

- 0 - Calm (less than 1 mph; smoke rises vertically)
- 1 - Light Air (1-3 mph; smoke drifts in direction of wind)
- 2 - Light Breeze (4-7 mph; leaves rustle)
- 3 - Gentle Breeze (8-12 mph; leaves and small twigs in constant motion; extends light flag)
- 4 - Moderate Breeze (13-18 mph; moves thin branches) ---- Do not conduct survey, unless in Great Plains!
- 5 - Fresh Breeze (>18 mph; small trees begin to sway) ---- Do not conduct any survey!

Sky Codes:

- 0 - Clear or only a few clouds
- 1 - Partly cloudy or variable
- 2 - Broken clouds or overcast
- 3 - Fog
- 4 - Drizzle or light rain (not affecting hearing)
- 5 - Snow
- 6 - Showers (affecting hearing ability) ---- Do not conduct survey!

Frogs and Toads of Minnesota

Wood Frog	Duck-like call; hoarse clacking sound, quack of duck
Western Chorus Frog	Clicking sound; thumb on comb; 'prpeep'
Spring Peeper	High pitch peep or ping; high, piping whistle
Northern Leopard Frog	Low snore with grunts and squeaks; long snore with clucking grunts
Pickerel Frog	Low pitch snore; steady, low pitched snore, 1-2 sec.
American Toad	High trill; long, musical trill
Gray Treefrog	Musical trill
Cope's Gray Treefrog	Fast metallic trill
Northern Cricket Frog	Glick, glick; similar to ball bearings; rattle or metal clicker
Mink Frog	Knock, knock, knock; blurred and deep, 'cut-cut-cut...'; rapid hammering
Green Frogs	Plucked banjo string; 'c'tung'
Bull Frog	Deep baritone; 'jug-a-rum'; humming bass notes
Canadian Toad	Similar to American Toad except trill length shorter (2-9 sec)
Great Plains Toad	Harsh pulsating mechanical trill

Count Codes:

- Any number <10
- 10-20 (A)
- 20-100 (B)
- 100+ (C)

Appendix 7. Bird survey field data collection form.

Morning survey: Sunrise-10 a.m. (weather permitting)															
Survey points: 5 minutes per point															
Birds: All heard or seen at point near shoreline (excluding flyovers)															
Marsh bird survey: 2 hours before sunset until dark															
Name of lake: _____															
Date: _____				Start time: _____				End time: _____							
Observers: _____/_____															
Survey Pt. #															
Air temp															
Wind code (0-5)															
Sky code (0-6)															
Distract. noise (Y/N)															
Species															
Canada Goose															
Mallard															
Common Goldeneye															
Hooded Merganser															
Common Merganser															
Red-breasted Merganser															
Common Loon															
Great Blue Heron															
Green Heron															
Bald Eagle															
Spotted Sandpiper															
Ring-billed Gull															
Caspian Tern															
Common Tern															
Forster's Tern															
Black Tern															
Belted Kingfisher															
Red-bellied Woodpecker															
Yellow-bellied Sapsucker															
Downy Woodpecker															
Hairy Woodpecker															
Northern Flicker															
Pileated Woodpecker															
Eastern Wood-Pewee															
Alder Flycatcher															
Least Flycatcher															
Eastern Phoebe															
Great Crested Flycatcher															
Eastern Kingbird															
Red-eyed Vireo															
Blue Jay															
American Crow															

Appendix 7, continued.[illegible]

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Appendix 8. GIS Methods for Sensitive Lakeshore Analysis

Modified MNDNR - 12/7/2011, Version 3.2

A. Data Preparation (Shapefile Creation)

The following shapefiles will be needed to begin sensitive lakeshore analysis:

- [bnd_py.shp](#) – lake boundary (polygon)
- [#dow#_buff_1320ft_py.shp](#) – Buffer lake boundary polygon by 1320 feet. This shapefile will be used to clip wetlands, hydric soils, and rare features polygons.
- [#dow#_buff_neg30m_py.shp](#) – Buffer lake boundary polygon by negative 30 meters. This shapefile will be used to erase frog polygons within this buffer.

Emergent and Floating-leaf Plants

1. Create shapefile for emergent and floating-leaf plant polygons [#dow#_vegbeds_py.shp](#)
2. Create fields
 - a. Acres (DOUBLE) (calculated geometry using Acres)
 - b. Class (TEXT) (see options in Manual)
 - c. Notes (TEXT) (any additional notes from the field data sheets)

Aquatic Plant Occurrence

1. Query the ACCESS AqVegPoint database for the lake and survey year.
 - a. Open AqVegPoint database and use Query “A_Single_GPS_Survey_Results” (note, if multiple surveys have been conducted on this lake, you will need to use Query “B_Multi_GPS_Survey_Results”)
 - b. In the Design View – for field AQPNT_ProjID, Enter the Project ID number for the survey (DOW number followed by a hyphen and a 2 digit number to indicate survey (01 = first survey conducted).
 - c. In Datasheet View – Save results
 - d. Click External Data TAB, select More-dBASE file
 - e. Enter file name where you want to save the export (note you are limited to an 8 digit name that you will need to rename later)
 - f. “OK”
2. Import the Exported dBASE file into ArcMap as a shapefile.
 - a. In ArcMap, open ArcCatalog
 - b. Select the exported dbase file and right click on it
 - c. Select “create feature class” “from XY table”
 - X Field = XCOORD
 - Y Field = YCOORD
 - Coord System = Projected / UTM / NAD 1983 / Zone 15
3. After the new shapefile has been created, rename it as [#dow#_PIveg_#year#_pt.shp](#)
4. Create the following new fields:
 - a. AQVEG (0 = no vegetation found, 1 = vegetation found)
 - If “EMT” field = 0, then AQVEG = 1
 - If “EMT” field = 1, then AQVEG = 0

- b. NUMSPP (sum of each plant code field)
5. If “EMT” field = “1” then TOTAL_OF_A should = “0”.

Aquatic Plant Richness

1. Use newly created shapefile [#dow#_PIveg_#year#_pt.shp](#)
2. Field NUMSPP indicates total number of plant species (or taxa) found at each site.

Unique Aquatic Plants

1. In ArcMap, [#dow#_PIveg_#year#_pt.shp](#) to create a new point shapefile ([#dow#_unique_veg_#year#_pt.shp](#)).
2. Delete all plant code fields except those that are UNIQUE species (see list in Manual). If needed, create new fields for any unique species that were found in the lake, but outside of the grid sampling.
3. Add fields:
 - a. SURVEYTYPE (text) – options include Point Intercept, Nearshore, Fish Survey, MCBS
 - b. PLOT (text) – options include n/a or the nearshore plot number
 - c. NUMUNIQUE (double) – total number of unique species found at this site
4. If needed, add records of any unique species found outside of grid sampling
 - a. Add a new point to the shapefile – Add the information as needed
 - i. AQPNT_PROJ would be DOW number if it was not a Point Intercept survey
 - ii. CNTYNAME – county of lake
 - iii. Timestamp – When the survey was conducted
 - iv. Surveyor – who conducted the survey
 - v. RNAME = Name of lake
 - vi. X and Y coordinates
 - vii. AQPNT_PNTI – what was the survey site name or number if none leave as a “0”
 - viii. The plants that were present should have a “1” and not a “0”
 - ix. NumUnique – Total number of unique plants
 - x. SurveyType – What type of survey was conducted

Aquatic Vertebrate Richness/Fish Species of Greatest Conservation Need (SGCN)

1. Open spreadsheet containing raw data ([#dow#_#lake#_FISH_#year#.xls](#))
2. Add a new column labeled: PRESENT. Enter “1” for each cell.
3. Summarize data using pivot table

Fields: Column label: SPP
Row label: STATION
Values: Max of PRESENT
Value field settings/Number format/Number (0 decimal places)

Options/Format/For empty cells show: 0
4. Copy data into new spreadsheet (paste special: values) and save as [#dow#_#lake#_FISH_#year#_GIS.xls](#)
5. Add a new column (SUBSTRATE). Calculate as the primary substrate type.

6. In ArcMap, open the fish data ([#dow#_#lake#_FISH_#year#_GIS.xls](#)) and 400m survey points ([#dow#_400m_survpts_pt.shp](#)). Join the fish data (STATION) to the survey points (ID) and export as [#dow#_fish_#year#_pt.shp](#). Delete all fields except FID, SHAPE, STATION, #SPECIES CODES#, and SUBSTRATE

Size and Shape of Natural Areas (Bays)

1. Export lake boundary polygon ([#dow#_bnd_py.shp](#)) and save as [#dow#_bay_delineation_py.shp](#)
2. Create bays by editing the bay delineation polygon shapefile
 - Task: Cut Polygon Features
 - Snap to Edge
 - Save Edits
3. Add new field (TYPE) and label as Isolated, Non-isolated, or Not

Bird Richness/Bird Species of Greatest Conservation Need (SGCN)

1. Open spreadsheet containing raw data ([#dow#_#lake#_BIRDS_#year#.xls](#))
2. Add a new column labeled: PRESENT. Enter “1” for each cell.
3. Summarize data using pivot table
 - Fields: Column label: SPECIES_ID
 - Row label: STATION
 - Values: Max of PRESENT
 - Value field settings/Number format/Number (0 decimal places)
 - Options/Format/For empty cells show: 0
4. Copy data into new spreadsheet (paste special: values) and save as [#dow#_#lake#_BIRDS_#year#_GIS.xls](#)
5. In ArcMap, open the bird data ([#dow#_#lake#_BIRDS_#year#_GIS.xls](#)) and 400m survey points ([#dow#_400m_survpts_pt.shp](#)). Join the bird data (STATION) to the survey points (ID) and export as [#dow#_bird_#year#_pt.shp](#). Delete all fields except FID, SHAPE, STATION, and #SPECIES CODES#

Frog Areas

1. Open FileMaker and query lake of interest. Save records as Excel file ([#dow#_lake_FROG_#year#_GIS.xls](#)).
2. Delete all fields except DOWLKNUM, STATION, MINK_PRES, MINK_ABUND, GREEN_PRES, and GREEN_ABUND
3. In ArcMap, open the frog data ([#dow#_#lake#_FROG_#year#_GIS.xls](#)) and 400m survey points ([#dow#_400m_survpts_pt.shp](#)). Join the frog data to the survey points and export as [#dow#_frog_#year#_pt.shp](#).

Loon Nesting Areas

1. Obtain loon nesting areas shapefile from MN DNR Sensitive Lakeshore project team

Rare Features

1. Obtain rare features polygons
 - a. MN DNR employees may access data through Quick Layers (Events and Sightings/Rare Natural Features Shapefile – polygons)

**MN DNR employees need to have completed Natural Heritage training and have a password to access the Rare Features data.*

- b. Non-DNR employees may request data from the Natural Heritage program
2. Select all features that fall within (or partially within) the 1320 foot shoreland zone; export these data as [#dow#_nhis_1320ft_py.shp](#)

Hydric Soils:

1. Obtain soils shapefile
 - a. Soils data are available at: <http://soildatamart.nrcs.usda.gov/> Select state and county of interest for download.
2. Clip soils layer to within 1320 feet of shoreline and save as [#dow#_soils_1320ft_py.shp](#)

Near-shore Substrate:

2. In ArcMap, open the point-intercept substrate data shapefile ([#dow#_pisub_#year#_pt.shp](#)) and the fish data shapefile ([#dow#_fish_#year#_pt.shp](#)). Make sure that each shapefile has a field named “SUBSTRATE”
3. Merge these two shapefiles and save resulting shapefile as [#dow#_substrate_combined_pt.shp](#)
4. Delete all fields except FID, SHAPE, STATION, and SUBSTRATE. Make sure that the only substrate codes in the field are BO (boulder), GR (gravel), RU (rubble), SA (sand), SI (silt), MU (muck), and MA (marl). If there are additional codes or combined codes, recode to one of the above. Delete records with no substrate recorded.

Wetlands:

1. Obtain wetlands polygons
 - a. MN DNR employees may obtain these data through Quick Layers (National Wetlands Inventory/Cowardin Class or Circular 39 classification-Polygons)
 - b. Non-DNR employees may obtain the data at: <http://107.20.228.18/Wetlands/WetlandsMapper.html#>
2. Clip wetlands layer to within 1320 feet of shoreline. Save final shapefile as [#dow#_nwi_1320ft_py.shp](#)

B. GIS Ecological Model Analysis

The following shapefiles are needed for GIS ecological model sensitive lakeshore analysis (most will have been created with the previous steps):

- [bnd_py.shp](#) – lake boundary (polygon)
- [#dow#_plantbeds_#year#_py.shp](#) – emergent and floating-leaf vegetation beds (polygon)
- [#dow#_PIveg_#year#_pt.shp](#) – point-intercept aquatic vegetation data (point)
- [#dow#_unique_veg_#year#_pt.shp](#) – unique/rare aquatic vegetation locations (point)
- [#dow#_fish_#year#_pt.shp](#) – locations of fish and other aquatic vertebrate species (point)
- [#dow#_bay_delineation_py.shp](#) – bay delineation (both isolated and non-isolated) (polygon)
- [#dow#_bird_#year#_pt.shp](#) – locations of birds (point)

- [#dow#_frog_#year#_pt.shp](#) – locations of frogs (point)
- [#dow#_loon_nest_pt.shp](#) – locations of loon nesting areas (point)
- [#dow#_nhis_1320ft_py.shp/#dow#_new_rare_1320ft_py.shp/#dow#rare_veg_1320ft_py.shp](#) – locations of Natural Heritage rare features (from NHIS database)/locations of newly located rare wildlife features/locations of newly located rare aquatic vegetation features (point)
- [#dow#_soils_1320ft_py.shp](#) – soils clipped to within 1320 feet of shoreline (polygon)
- [#dow#_substrate_combined_pt.shp](#) – substrate (from both aquatic vegetation and fish surveys) (point)
- [#dow#_nwi_1320ft_py.shp](#) – NWI wetlands clipped to within 1320 feet of shoreline (polygon)

Create points along shoreline:

1. Convert lake polygon into polyline
 - a. In ArcMap, add the polygon shapefile ([bnd_py.shp](#))
 - b. Create a new polyline shapefile in ArcCatalog. ([bnd_ln.shp](#))
 - c. Select the Start Editing option in the Editor toolbar.
 - d. Set the Task to Create New Feature and the Target to the polyline shapefile ([bnd_ln.shp](#)).
 - e. Click Select All on the Context menu of the polygon shapefile ([bnd_py.shp](#)).
 - f. Select Copy from the ArcMap Edit menu or type Ctrl+C.
 - g. Select Paste from the ArcMap Edit menu or type Ctrl+V.
 - h. Save your edits.
2. Open the attribute table and select the record that contains the shoreline
3. In ArcCatalog, create a new point shapefile that will contain the points around the lakeshore ([250ft_pt.shp](#))
4. Open Visual basic editor (ALT- F11 or Tool/Macros/Visual Basic Editor)
 - a. Under the normal template; right click on the modules and select new module.
 - b. Paste the code (points_along_curve.doc)
5. Run the macro
6. Enter distance between points (250 feet = 76.2 meters)
7. Add field POINT_ID (double) and calculate as FID

Create perpendicular transects at each point along the shoreline:

1. Buffer shoreline 1000 meters ([bnd_1000m_buff_py.shp](#))
2. In ArcCatalog, create a new polyline shapefile that will contain the transects for each point along the lakeshore with the same coordinate system that is being used in the other files ([transect_ln.shp](#))
3. In the Table of Contents have four shapefiles in this order;
 - a. The Station Layer, which contains the set of regularly occurring points along the centerline - 250 foot points along lakeshore ([250ft_pt.shp](#))
 - b. The Centerline Layer, which contains a single centerline polyline - shoreline as polyline ([bnd_ln.shp](#))
 - c. The Editable Station Line Layer, which will contain the created set of polylines representing the station lines - polyline created in step 2 that will hold the new transects ([transect_ln.shp](#))

- d. The Channel Layer, which contains a single channel polygon - buffered shoreline 1000m either side ([bnd_1000m_buff_py.shp](#))
4. In addition, ArcMap must be in edit mode with the Station Line Layer selected for editing - the polyline file that will hold the transects ([transect_ln.shp](#))
5. Open Visual basic editor (ALT-F11 or Tools/Macros/Visual Basic Editor)
 - a. Under the normal template - right click on the modules and select new module.
 - b. Paste the code ([transect_code.doc](#))
 - c. Select from bottom of code up to, and including, 1st line of code reading: “Private Sub ConstructStationLines_Click()”
 - d. Click the run code button (see step 5 above in creation of points along shoreline)
 - e. Save edits
 - f. Add field LINE_ID and calculate as FID.

Create analysis windows:

1. Open project and create buffer on [transect_ln.shp](#) (arctoolbox: analysis tools/proximity/buffer; specify input as [transects_ln.shp](#); output as [window_py.shp](#); enter distance in linear units (for 250 feet it is 76.2 meters); full style; flat end type; none on dissolve - OK
2. Open attribute table for [window_py.shp](#)
3. Add field POINT_ID and calculate as FID. Delete all fields except FID, SHAPE, and POINT_ID
4. Commence individual layer analysis.

Analyze Distribution of Emergent and Floating-leaf Plants:

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [aquatic_plant_emergent_floating_py.shp](#) (combined emergent and floating-leaf vegetation bed polygons)
1. Make copy of emergent and floating-leaf vegetation shapefile ([#dow#_plantbeds_#year#_py.shp](#)) and save resulting shapefile as [aquatic_plant_emergent_floating_py.shp](#)
 2. Clip all emergent and floating-leaf plant beds to within the lake boundary. Add a new field named TYPE (text, 20). Use the field calculator to calculate TYPE (bulrush, waterlilies, etc...) appropriately for each record
 3. Delete all fields except FID, SHAPE, AREA, and TYPE.
 4. Union [window_py.shp](#) with [aquatic_plant_emergent_floating_py.shp](#); save resulting shapefile as [aquatic_plant_emergent_floating_union.shp](#)
 5. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [aquatic_plant_emergent_floating_union_2.shp](#)
 6. Right-click to recalculate geometry for field AREA (square meters)
 7. Add field ID_ID (text, 15) and calculate as [POINT_ID]&" "& [TYPE]
 8. Select all records with emergent/floating vegetation (TYPE is not null) and summarize by ID_ID; Minimum of POINT_ID, Sum of AREA, First of TYPE (Sum_Output.dbf)
 9. Add new field; PERCENT (double); calculate PERCENT by dividing SUM_AREA by 92812

10. Summarize MIN_POINT_ by Sum of PERCENT (Sum_Output_2.dbf)
11. Add new field; EFLP_IDX (double)
12. Sort by SUM_PERCENT and select records for calculating EFLP_IDX; select all records >0 and <1.7% and calculate as 1; select all records 1.7-8.5% and calculate as 2; select all records >8.5% and calculate as 3
13. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output_2.dbf by MIN_POINT_ and export to new shapefile ([aquatic_plant_emergent_floating_index.shp](#))

Analyze Aquatic Plant Occurrence:

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [aquatic_plant_occurrence_py.shp](#) (buffered vegetation survey point data)
1. Buffer vegetation survey point data ([#dow#_PIveg_#year#_pt.shp](#)) with 25 meter buffer; save resulting shapefile as [aquatic_plant_occurrence_py.shp](#)
 2. Delete all fields except FID, SHAPE, and AQVEG
 3. Union [window_py.shp](#) with [aquatic_plant_occurrence_py.shp](#); save resulting shapefile as [aquatic_plant_occurrence_union.shp](#)
 4. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [aquatic_plant_occurrence_union_2.shp](#)
 5. Add new field ID_ID (text,15); calculate as [POINT_ID]& " "& [FID_AQUATI]
 6. Summarize ID_ID by Minimum of POINT_ID; Minimum of FID_AQUATI and Minimum of AQVEG (Sum_Output.dbf)
 7. Summarize MIN_POINT_ by Sum of MIN_AQVEG (Sum_Output_2.dbf)
 8. Add 3 new fields NUM_PTS ; FREQ_OCC ; and APO_IDX (double)
 9. Calculate NUM_PTS by subtracting 1 from CNT_MIN_PO (to eliminate the -1 records counted as polygons)
 10. Select all records where NUM_PTS equal 0, then switch selection (to avoid VBA error); calculate FREQ_OCC by dividing SUM_MIN_AQ by NUM_PTS
 11. Sort by FREQ_OCC and select records for calculating APO_IDX; select all records >0 and <25% and calculate as 1; select all records 25– 75% and calculate as 2; select all records >75% and calculate as 3
 12. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output_2.dbf by MIN_POINT_ and export to new shapefile ([aquatic_plant_occurrence_index.shp](#))

Analyze Aquatic Plant Richness:

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [aquatic_plant_richness_py.shp](#) (buffered vegetation survey point data)
1. Buffer vegetation survey point data ([#dow#_PIveg_#year#_pt.shp](#)) with 25 meter buffer; save resulting shapefile as [aquatic_plant_richness_py.shp](#)
 2. Delete all fields except FID, SHAPE, and #SPECIES_CODES#; also delete EMT (emergents) and UNK (unknown species) if they are present within species codes.

3. Union [window_py.shp](#) with [aquatic_plant_richness_py.shp](#); save resulting shapefile as [aquatic_plant_richness_union.shp](#)
4. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [aquatic_plant_richness_union_2.shp](#)
5. Summarize POINT_ID by Maximum of #SPECIES_CODES# (Sum_Output.dbf)
6. Add new field; SUM_SPP (double); using field calculator, calculate as Sum of MAX_#SPECIES_CODES#
7. Add new field; APR_IDX (double)
8. Sort by SUM_SPP and select records for calculating APR_IDX; select all records 1-4 and calculate as 1; select all records 5-10 and calculate as 2; select all records >10 and calculate as 3
9. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output.dbf by POINT_ID and export to new shapefile ([aquatic_plant_richness_index.shp](#))

Analyze Unique Aquatic Plants

**This shapefile should not include listed (END, THR, or SPC) plant species. Those are included in the Natural Heritage Rare Features layer.*

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [aquatic_plant_unique_py.shp](#) (buffered unique vegetation point data)
1. Buffer vegetation survey point data ([#dow#_unique_veg_#year#_pt.shp](#)) with 25 meter buffer; save resulting shapefile as [aquatic_plant_unique_py.shp](#)
 2. Delete all fields except FID, SHAPE, and #SPECIES_CODES#
 3. Union [window_py.shp](#) with [aquatic_plant_unique_py.shp](#); save resulting shapefile as [aquatic_plant_unique_union.shp](#)
 4. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [aquatic_plant_unique_union_2.shp](#)
 5. Summarize POINT_ID by Maximum of #SPECIES_CODES# (Sum_Output.dbf)
 6. Add new field; SUM_SPP (double); using field calculator, calculate as Sum of MAX_#SPECIES_CODES#
 7. Add new field; APU_IDX (double)
 8. Sort by SUM_SPP and select records for calculating APU_IDX; select all records equal to 1 and calculate as 2; select all records >1 and calculate as 3
 9. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output.dbf by POINT_ID and export to new shapefile ([aquatic_plant_unique_index.shp](#))

Analyze Aquatic Vertebrate Richness

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [aquatic_vertebrate_richness_py.shp](#) (buffered vertebrate survey point data)
1. Buffer aquatic vertebrate survey point data ([#dow#_fish_#year#_pt.shp](#)) with 50 meter buffer; save resulting shapefile as [aquatic_vertebrate_richness_py.shp](#)

2. Delete all fields except FID, SHAPE, and #SPECIES_CODES#; also delete unknown/undefined species (UNK, YOY, JUV, SUN, BLH), hybrids (HSF), or invertebrates (crayfish) if they are present within species codes.
3. Union [window_py.shp](#) with [aquatic_vertebrate_richness_py.shp](#); save resulting shapefile as [aquatic_vertebrate_richness_union.shp](#)
4. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [aquatic_vertebrate_richness_union_2.shp](#)
5. Summarize POINT_ID by Maximum of #SPECIES_CODES# (Sum_Output.dbf)
6. Add new field; SUM_SPP (double); using field calculator, calculate as Sum of MAX_#SPECIES_CODES#S
7. Add new field; AVR_IDX (double)
8. Sort by SUM_SPP and select records for calculating AVR_IDX; select all records 1-4 and calculate as 1; select all records 5-10 and calculate as 2; select all records >10 and calculate as 3
9. Join 250ft_pt.shp by POINT_ID with Sum_Output.dbf by POINT_ID and export to new shapefile ([aquatic_vertebrate_richness_index.shp](#))

Analyze Size and Shape of Natural Areas (Bays)

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [bays_py.shp](#) (bay delineation polygons)
1. Make copy of bay delineation shapefile and save as [bays_py.shp](#)
 2. Delete all fields except FID, SHAPE, and TYPE
 3. Add new field; SCORE (double); select records and calculate Isolated as 3; Non-isolated as 2; Not as 0
 4. Union [window_py.shp](#) with [bays_py.shp](#); save resulting shapefile as [bays_union.shp](#)
 5. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [bays_union_2.shp](#)
 6. Summarize POINT_ID by Maximum of SCORE (Sum_Output.dbf)
 7. Add new field; BAY_IDX (double); calculate as MAX_SCORE
 8. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output.dbf by POINT_ID and export to new shapefile ([bays_index.shp](#))

Analyze Bird Richness

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [bird_richness_py.shp](#) (buffered bird survey point data)
1. Buffer bird survey point data ([#dow#_bird_#year#_pt.shp](#)) with 200 meter buffer; save resulting shapefile as [bird_richness_py.shp](#)
 2. Delete all fields except FID, SHAPE, and #SPECIES_CODES#; also delete unknown/undefined species if they are present within #SPECIES_CODES#.

3. Union [window_py.shp](#) with [bird_richness_py.shp](#); save resulting shapefile as [bird_richness_union.shp](#)
4. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [bird_richness_union_2.shp](#)
5. Summarize POINT_ID by Maximum of #SPECIES_CODES# (Sum_Output.dbf)
6. Add new field; SUM_SPP (double); using field calculator, calculate as Sum of MAX_#SPECIES_CODES#
7. Add new field; BIRD_IDX (double)
8. Sort by SUM_SPP and select records for calculating BIRD_IDX; select all records 1-10 and calculate as 1; select all records 11-25 and calculate as 2; select all records >25 and calculate as 3
9. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output.dbf by POINT_ID and export to new shapefile ([bird_richness_index.shp](#))

Analyze Bird Species of Greatest Conservation Need (SGCN)

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [bird_sgcns_py.shp](#) (buffered bird survey point data)
1. Buffer bird survey point data ([#dow#_bird_#year#_pt.shp](#)) with 200 meter buffer; save resulting shapefile as [bird_sgcns_py.shp](#)
 2. Delete all fields except FID, SHAPE, and #SPECIES_CODES#; also delete all #SPECIES_CODES# fields that are not SGCNs and delete unknown/undefined species if they are present within #SPECIES_CODES#
 3. Union [window_py.shp](#) with [bird_sgcns_py.shp](#); save resulting shapefile as [bird_sgcns_union.shp](#)
 4. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [bird_sgcns_union_2.shp](#)
 5. Summarize POINT_ID by Maximum of #SPECIES_CODES# (Sum_Output.dbf)
 6. Add new field; SUM_SGCN (double); using field calculator, calculate as Sum of MAX_#SPECIES_CODES#
 7. Add new field; BGCN_IDX (double)
 8. Sort by SUM_SGCN and select records for calculating BGCN_IDX; select all records equal to 1 and calculate as 1; select all records equal to 2 and calculate as 2; select all records equal to 3 or more and calculate as 3
 9. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output.dbf by POINT_ID and export to new shapefile ([bird_sgcns_index.shp](#))

Analyze Fish Species of Greatest Conservation Need (SGCN)

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
2. [window_py.shp](#) (analysis window polygons)
3. [fish_sgcns_py.shp](#) (buffered fish survey point data)

1. Buffer fish survey point data ([#dow#_fish_#year#_pt.shp](#)) with 50 meter buffer; save resulting shapefile as [fish_sgcns_py.shp](#)
2. Delete all fields except FID, SHAPE, and #SPECIES_CODES#
3. Add two new fields, SUM_PROXY and SUM_SGCNS (double); using field calculator, calculate each appropriately for nearshore fish species
4. Add new field, SCORE (double); sort by SUM_PROXY, select all records greater than 0 and calculate as 2; sort by SUM_SGCNS, select all records greater than 0 and calculate as 3
5. Union [window_py.shp](#) with [fish_sgcns_py.shp](#); save resulting shapefile as [fish_sgcns_union.shp](#)
6. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [fish_sgcns_union_2.shp](#)
7. Summarize POINT_ID by Maximum of SCORE (Sum_Output.dbf)
8. Add new field FGCN_IDX (double) and calculate as MAX_SCORE
9. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output.dbf by POINT_ID and export to new shapefile ([fish_sgcns_index.shp](#))

Analyze Frog Areas

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [frogs_py.shp](#) (buffered frog survey point data)
1. Buffer frog survey point data ([#dow#_frog_#year#_pt.shp](#)) with 200 meter buffer. Erase lake-side portion of buffered polygons with 30 meter inside buffer around shoreline ([#dow#_buff_neg30m_py.shp](#)).
 2. Delete all fields except FID, SHAPE, MINK_PRES, and GREEN_PRES
 3. Add three new fields, MINK_PA, GREEN_PA, and SCORE (double)
 4. Sort by MINK_PRES, select all Y records and calculate MINK_PA as 1; sort by GREEN_PRES, select all Y records and calculate GREEN_PA as 1; calculate SCORE as sum of MINK_PA and GREEN_PA
 5. Union [window_py.shp](#) with [frogs_py.shp](#); save resulting shapefile as [frogs_union.shp](#)
 6. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [frogs_union_2.shp](#)
 7. Summarize POINT_ID by Maximum of SCORE (Sum_Output.dbf)
 8. Add new field FROG_IDX (double)
 9. Sort by MAX_SCORE and select records for calculating FROG_IDX; select all records equal to 1 and calculate as 2; select records equal to 2 and calculate as 3
 10. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output.dbf by POINT_ID and export to new shapefile ([frog_index.shp](#))

Analyze Loon Nesting Areas

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
2. [window_py.shp](#) (analysis window polygons)
3. [loons_py.shp](#) (buffered loon nest point data)

1. Buffer loon nest point data ([#dow#_loon_nest_pt.shp](#)) with 200 meter buffer. Erase non-lake portion of polygons. Save resulting shapefile as [loons_py.shp](#)
2. Delete all fields except FID, SHAPE, and NATURAL
3. Add new field SCORE (double); sort by NATURAL; select all N records and calculate as 2; select all Y records and calculate as 3
4. Union [window_py.shp](#) with [loons_py.shp](#); save resulting shapefile as [loons_union.shp](#)
5. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [loons_union_2.shp](#)
6. Summarize POINT_ID by Maximum of SCORE (Sum_Output.dbf)
7. Add new field LOON_IDX (double) and calculate as MAX_SCORE
8. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output.dbf by POINT_ID and export to new shapefile ([loon_index.shp](#))

Analyze Rare Features

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [rare_features_py.shp](#) (rare features polygons from the Natural Heritage Information System combined with new rare features [excluding fish] found during field surveys)
1. Import rare vegetation shapefile ([#dow#rare_veg_#year#_pt.shp](#)), if it exists. Buffer point files by appropriate distance using NHIS guidelines and save resulting shapefile as [#dow#rare_veg_1320ft_py.shp](#)
 2. Merge NHIS rare features polygons ([#dow#_nhis_1320ft_py.shp](#)) with new [excluding fish] rare feature polygons found during field surveys ([#dow#_new_rare_1320ft_py.shp](#) and [#dow#rare_veg_1320ft_py.shp](#)) and save resulting shapefile as [rare_features_py.shp](#)
 3. Delete all fields except FID, SHAPE, SCI_NAME, and S_PROTSTAT; also delete all records except those with S_PROTSTAT equal to END, THR, or SPC
 4. Add new field SCORE (double) and calculate as 1
 5. Union [window_py.shp](#) with [rare_features_py.shp](#); save resulting shapefile as [rare_features_union.shp](#)
 6. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [rare_features_union_2.shp](#)
 7. Add new field ID_ID (text,15); calculate as [POINT_ID]& " "& [FID_RARE_F]
 8. Summarize ID_ID by Minimum of POINT_ID and Minimum of SCORE (Sum_Output.dbf)
 9. Summarize MIN_POINT_ by Sum of MIN_SCORE (Sum_Output_2.dbf)
 10. Add new field RARE_IDX (double)
 11. Sort by SUM_MIN_SCORE and select records for calculating RARE_IDX; select all records equal to 1 and calculate as 2; select all records >1 and calculate as 3
 12. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output_2.dbf by MIN_POINT_ and export to new shapefile ([rare_feature_index.shp](#))

Analyze Distribution of Hydric Soils:

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [soils_py.shp](#) (soil survey polygons)
1. Make a copy of the soil survey polygon shapefile ([#dow#_soils_1320ft_py.shp](#)) and save as [soils_py.shp](#)
 2. Delete all fields except FID, SHAPE, AREA, and SOIL_SYM
 3. Open attribute table and sort by SOIL_SYM; delete all records where SOIL_SYM is not hydric (you may have to consult additional sources to determine which soil symbols represent hydric soils)
 4. Union [window_py.shp](#) with [soils_py.shp](#); save resulting shapefile as [soils_union.shp](#)
 5. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [soils_union_2.shp](#)
 6. Right-click to recalculate geometry for field AREA (square meters)
 7. Add field ID_ID (text, 15) and calculate as [POINT_ID]&" "& [SOIL_SYM]
 8. Select all records with hydric soils (SOIL_SYM is not null) and summarize by ID_ID; Minimum of POINT_ID, Sum of AREA, First of SOIL_SYM (Sum_Output.dbf)
 9. Add new field; PERCENT (double); calculate PERCENT by dividing SUM_AREA by 92812
 10. Summarize MIN_POINT_ by Sum of PERCENT (Sum_Output_2.dbf)
 11. Add new field SOIL_IDX (double)
 12. Sort by SUM_PERCENT and select records for calculating SOIL_IDX; select all records >0 and <12.5% and calculate as 1; select all records 12.5-25% and calculate as 2; select all records >25% and calculate as 3
 13. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output_2 by MIN_POINT_ and export to new shapefile ([soil_index.shp](#))

Analyze Near-shore Substrate:

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [substrate_py.shp](#) (buffered substrate survey point data)
1. Buffer substrate survey point data ([#dow#_substrate_combined_pt.shp](#)) with 25 meter buffer; save resulting shapefile as [substrate_py](#)
 2. Delete all fields except FID, SHAPE, and SUBSTRATE
 3. Add new field P_A (double) for presence/absence of soft sediments; sort by SUBSTRATE and select all records equal to MU (muck), MA (marl), or SI (silt) and calculate as 1 (all other records as 0)
 4. Union [window_py.shp](#) with [substrate_py.shp](#); save resulting shapefile as [substrate_union.shp](#)
 5. Select all records that have a FID_WINDOW value of -1; switch selection and export records as [substrate_union_2.shp](#)
 6. Add field ID_ID (text, 15) and calculate as [POINT_ID]&" "& [FID_SUBSTR]
 7. Summarize ID_ID by Minimum of POINT_ID and Minimum of P_A (Sum_Output.dbf)
 8. Summarize MIN_POINT_ by Sum of MIN_P_A (Sum_Output_2.dbf)

9. Add new field NUM_PTS (double); calculate NUM_PTS by subtracting 1 from CNT_MIN_PO (to remove the –1 records counted as polygons)
10. Add new field FREQ_OCC (double); select all records where NUM_PTS equal 0, then switch selection (to avoid VBA error); calculate FREQ_OCC by dividing SUM_MIN_P_ by NUM_PTS
11. Add new field SUB_IDX (double)
12. Sort by FREQ_OCC and select records for calculating SUB_IDX; select all records >0 and <25% and calculate as 1; select all records 25-50% and calculate as 2; select all records >50% and calculate as 3
13. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output_2 by MIN_POINT_ and export to new shapefile ([substrate_index.shp](#))

Analyze Distribution of Wetlands:

Use following files:

1. [250ft_pt.shp](#) (250ft shoreline points)
 2. [window_py.shp](#) (analysis window polygons)
 3. [wetlands_py.shp](#) (national wetlands inventory polygons)
1. Make a copy of the national wetlands inventory (nwi) polygon shapefile ([#dow#_nwi_1320ft_py.shp](#)) and save as [wetlands_py.shp](#)
 2. Delete all fields except FID, SHAPE, AREA, and SYSTEM
 3. Open the attribute table and sort by SYSTEM; delete all records where SYSTEM = L or R.
 4. Union [window_py.shp](#) with [wetlands_py.shp](#); save resulting shapefile as [wetlands_union.shp](#)
 5. Select all records that have a FID_WINDOW value of –1; switch selection and export records as [wetlands_union_2.shp](#)
 6. Right-click to recalculate geometry for field AREA (square meters)
 7. Add field ID_ID (text, 15) and calculate as [POINT_ID]&" "& [SYSTEM]
 8. Select all records with wetlands (SYSTEM is not null) and summarize by ID_ID; Minimum of POINT_ID, Sum of AREA, First of SYSTEM (Sum_Output.dbf)
 9. Add new field; PERCENT (double); calculate PERCENT by dividing SUM_AREA by 92812
 10. Summarize MIN_POINT_ by Sum of PERCENT (Sum_Output_2.dbf)
 11. Add new field WET_IDX (double)
 12. Sort by SUM_PERCENT and select records for calculating WET_IDX; select all records >0 and <12.5% and calculate as 1; select all records 12.5-25% and calculate as 2; select all records >25% and calculate as 3
 13. Join [250ft_pt.shp](#) by POINT_ID with Sum_Output_2 by MIN_POINT_ and export to new shapefile ([wetland_index.shp](#))

Combine individual analysis layers for final shoreline point scores:

Use following files:

1. [#layer#_index.shp](#) (individual layer index points)

1. Join individual layers ([#layer#_index.shp](#)) by POINT_ID and export to new shapefile ([#dow#_sensitivity_index.shp](#))
2. Delete all fields except POINT_ID and individual #LAYER_IDX# fields
3. Add new field SUM_IDX (double)
4. Calculate SUM_IDX as Sum of individual #LAYER_IDX# fields

Determine ecological connections:

1. These may include connecting rivers, streams, public lands, easements, refuges, and other significant ecological connections.
2. Save linear connections as [#dow#_ecological_connections_ln.shp](#) and polygon connections as [#dow#_ecological_connections_py.shp](#)
3. Determine if buffers are appropriate, and if so, save resulting shapefile as [#dow#_ecological_connections_buffer_py.shp](#)

Apply hotspot analysis to determine final sensitive shoreline areas:

1. Apply ArcGIS Hotspot Analysis with a fixed Euclidean distance search radius of 2000 feet (609 meters) to determine sensitive shoreline areas; save resulting shapefile as [hotspot_analysis_2000ft_pt.shp](#)
2. Select points with a z-score greater than 1.96 and save as [#dow#_hotspots_pt.shp](#)
3. Convert [#dow#_hotspots_pt.shp](#) to a polyline and save as [#dow#_sensitive_shoreline_ln.shp](#)
4. Buffer [#dow#_sensitive_shoreline_ln.shp](#) a distance of 1320 feet (402 meters), specify dissolve type ALL, and save as [#dow#_sensitive_shoreline_buffer_py.shp](#)
5. Merge [#dow#_sensitive_shoreline_buffer_py.shp](#) with [#dow#_ecological_connections_buffer_py.shp](#) and save resulting shapefile as [#dow#_preliminary_resource_protection_district_py.shp](#)
6. Use ArcInfo to erase the lake portion of [#dow#_preliminary_resource_protection_district_py.shp](#) and save resulting shapefile as [#dow#_potential_resource_protection_district_py.shp](#)

Appendix 9. Evaluation of GIS ecological model attributes

As of June 2010, the Sensitive Lakeshore Identification Project completed surveys on 18 Cass County lakes. With intensive surveys completed on numerous lakes, the project was able to address several questions: 1) Do GIS Ecological Model attributes have high agreement? For example, do lakeshore plots with high scores for frog areas correspond to high scores for loon nesting areas? To evaluate this question, a Kappa statistic was applied to the frequency tables of paired attributes. When the kappa coefficient is positive, the observed agreement exceeds that of chance, with its magnitude reflecting the strength of the agreement. Below are the results, with those in bold having the highest agreement:

Kappa coefficient from frequency tables														
	EFLP	APO	APR	APU	AVR	BAY	BIRD	BGCN	FGCN	FROG	LOON	RARE	SOIL	SUB
EFLP	1													
APO	0.13	1												
APR	0.10	0.19	1											
APU	0.07	0.02	0.03	1										
AVR	0.08	0.01	0.03	0.04	1									
BAY	0.02	0.02	0.03	0.16	-0.02	1								
BIRD	0.05	0.03	0.07	0.01	0.02	0.03	1							
BGCN	0.18	0.10	0.10	0.05	0.06	0.03	0.17	1						
FGCN	0.06	2E-04	0.03	0.07	0.24	-0.02	0.01	0.04	1					
FROG	0.20	0.06	0.04	0.14	0.05	0.19	0.05	0.09	0.09	1				
LOON	0.10	0.06	0.06	0.13	0.04	0.14	0.05	0.11	0.02	0.19	1			
RARE	0.01	-0.01	-0	0.02	0.02	-0.05	0.01	0.03	-0.02	0.04	0.03	1		
SOIL	0.06	0.02	-0.01	0.04	-0	0.04	-0	0.03	-0.01	0.08	0.06	-0.01	1	
SUB	0.26	0.18	0.12	0.11	0.07	0.14	0.05	0.18	0.08	0.23	0.14	-0	0.08	1
WET	0.06	0.02	0.003	0.03	-0	0.01	0.01	0.05	-0.01	0.05	0.03	-0	0.38	0.05

As expected, there was strong agreement between the hydric soils (SOIL) attribute and the wetlands (WET) attribute; fish SGCN (FGCN) attribute and the aquatic vertebrate richness (AVR) attribute; and the near-shore aquatic plant occurrence (APO) and the aquatic plant richness (APR) attribute. Other high agreements included near-shore substrate (SUB) – presence of emergent and floating-leaf plant beds (EFLP); near-shore substrate – frog areas (FROG); presence of emergent and floating-leaf plant beds – frog areas; frog areas – loon nesting areas (LOON); and frog areas – size and shape of natural features (BAY).

2) Which GIS ecological model attributes contribute most to the highly sensitive lakeshore designation? Several approaches were used to determine the importance of each of the 15 attributes used in the GIS ecological model.

The first approach was a Contingency Table Analysis. This is a simple analysis using lakeshore plots that were classed as highly sensitive or not highly sensitive (see Chapter 7, GIS Steps of Ecological Model, step #7; hotspot analysis; two classes; nominal data) and the each of the 15 attributes (ordinal data). For example: Ten Mile had over 500 ‘window plots,’ some of which were classed as highly sensitive and the rest as non-highly sensitive. Each window plot had a score for each attribute.

So the question is: are the frequencies of the score for an attribute the same (or different) for the two sensitivity classes (highly sensitive, non-highly sensitive)? For example, was the frequency of plots with a score of 3 for loon nesting areas the same between those areas that were identified as highly sensitive or not?

The test for this is based on the negative log-likelihood (which measures uncertainty in the same manner that sum of squares does in continuous response situations). So the higher the value of the negative log-likelihood, the more significant is the difference between the two frequency scores. Here are those results:

Contingency analysis		
Attribute	-log-likelihood	Rank
EFLP	390.84408	5
APO	167.72469	11
APR	131.18528	12
APU	192.15178	10
AVR	44.607283	14
BAY	493.64489	3
BIRD	303.23336	7
BGCN	381.68377	6
FGCN	94.222037	13
FROG	671.86012	1
LOON	390.84566	4
RARE	19.720278	15
SOIL	224.38549	9
SUB	561.96184	2
WET	285.07577	8

Frog areas, near-shore substrate, size and shape of natural areas, and loon nesting areas were the attributes with the highest values of the negative log-likelihood, suggesting that these attributes can be considered most important.

Second, the importance of all the attributes was assessed for each lake by removing a single attribute, recalculating a sensitivity index (see Chapter 7, GIS Steps of Ecological Model, step #6; continuous data; 0 - 45), calculating the difference between the reduced and original sensitivity index, and then determining the variability of the difference. A high standard deviation indicates that the attribute had a substantial contribution to the original sensitivity index. To gauge attribute importance across all the lakes, the median of the standard deviations of the differences in sensitivity index was calculated. The rank of medians were:

Attribute	Median of SD of differences	Rank
EFLP	0.92	10
APO	0.51	15
APR	0.67	13
APU	0.73	12
AVR	1.11	3
BAY	1.02	7
BIRD	0.53	14
BGCN	1.00	8
FGCN	1.09	6
FROG	1.10	5
LOON	1.25	1
RARE	0.86	11
SOIL	1.10	4
SUB	1.21	2
WET	0.93	9

Loon nesting areas, near-shore substrate, aquatic vertebrate richness, and hydric soils were the attributes with the highest median of the standard deviations of the differences between the reduced and original sensitivity index.

When looking at the standard deviation of differences between the reduced and original sensitivity index without regard to lake (i.e., the standard deviation of differences for all window plots), the results are similar:

Attribute	SD of Differences	Rank
EFLP	1.12	7
APO	0.76	14
APR	0.83	13
APU	0.93	11
AVR	1.24	4
BAY	1.25	3
BIRD	0.59	15
BGCN	1.09	9
FGCN	1.13	6
FROG	1.19	5
LOON	1.33	1
RARE	0.89	12
SOIL	1.11	8
SUB	1.29	2
WET	0.95	10

Loon nesting areas, near-shore substrate, size and shape of natural areas, and aquatic vertebrate richness were the attributes with the highest standard deviations of the differences between the reduced and original sensitivity index.

Caution should be applied to this analysis, as the importance of a particular attribute varied by lake. For example, unique and rare plant species (APU) and presence of emergent and floating leaf plant beds attributes were very important in contributing to identifying sites as highly sensitive on Ada and Sylvan lakes. Below are the rankings by lake for this statistic (standard deviations of the difference between the reduced and original sensitivity index; and given that each attribute has the same weight in the sensitivity index, this is also the standard deviation of the score for each attribute):

	Ranks by Lake														
	EFLP	APO	APR	APU	AVR	BAY	BIRD	BGCN	FGCN	FROG	LOON	RARE	SOIL	SUB	WET
Roosevelt 11004300	9	11	10	14	2	6	13	8	1	7	5	4	14	3	12
Lawrence 11005300	9	12	13	7	4	14	11	5	2	8	14	1	3	6	10
Washburn 11005900	7	14	12	13	2	6	15	8	10	4	1	5	9	3	11
Thunder 11006200	8	13	12	15	5	3	14	7	2	6	1	9	10	4	11
Long 11014200	5	14	15	2	6	1	13	8	12	4	3	10	9	7	11
Boy 11014300	11	10	12	13	4	15	14	8	5	2	6	7	1	3	9
Little Boy 11016700	10	12	11	15	6	3	13	4	7	8	1	14	5	2	9
Wabedo 11017100	9	13	12	14	1	2	11	4	3	7	10	14	5	8	6
Woman 11020100	8	7	9	12	10	4	14	5	15	3	2	13	6	1	11
Deep Portage 11023700	8	11	7	4	1	12	9	12	2	10	12	12	5	3	6
Ada 11025000	3	15	12	2	9	5	14	7	11	8	1	13	6	4	10
Sylvan 11030400	3	14	12	2	8	15	13	5	7	6	1	9	10	4	11
Big Portage 11030800	12	14	11	2	6	15	13	9	5	3	1	7	4	10	8
Pleasant 11038300	6	15	13	12	10	8	14	11	3	4	1	9	5	2	7
Pine Mountain 11041100	11	13	10	14	1	15	12	6	7	4	3	9	2	8	5
Birch 11041200	11	14	13	12	7	1	15	6	8	2	4	9	5	3	10
Ten Mile 11041300	10	13	12	7	4	2	14	8	5	3	6	15	9	1	11
Steamboat 11050400	7	11	8	12	3	13	10	6	5	13	13	9	1	2	4

The attribute scores for shoreline bird richness (BIRD) and aquatic plant richness were the least variable attributes for these lakes, which resulted in these attributes contributing less to the determination of the sensitivity index for a given lake and across all the lakes.

Finally, to measure the degree of congruence the Jaccard similarity coefficient between the reduced and original lakeshore classification (see Chapter 7, GIS Steps of Ecological Model, step #7; Hotspot analysis; two classes; nominal data; highly sensitive and non-highly sensitive) was calculated as:

$$J(A, B) = |A \cap B| / |A \cup B|$$

where $A \cap B$ is the number of plots where both the reduced and the original classification were classed as highly sensitive and $A \cup B$ is the number of plots that where the reduced or the original classification were classed as highly sensitive. The index approaches one as the reduced and original classification match; those most different from one are attributes that have more influence on the lakeshore classification. Below are the results:

Attribute	Jaccard Index	Rank
EFLP	0.96	12
APO	0.97	15
APR	0.96	13
APU	0.97	14
AVR	0.95	10
BAY	0.91	2
BIRD	0.96	11
BGCN	0.94	8
FGCN	0.93	7
FROG	0.95	9
LOON	0.89	1
RARE	0.92	4
SOIL	0.93	6
SUB	0.92	5
WET	0.92	3

Overall, the removal of an attribute had only minor influence on the lakeshore classification (i.e., most window plots had very similar results with the elimination of an attribute). Loon nesting areas, size and shape of natural areas, wetlands, and other rare features (RARE) were the attributes with the highest deviations from a Jaccard similarity coefficient of one with the reduced classification from the original.

In conclusion, the following attributes appear to be the most important (and sensitive) variables in determining highly sensitive shorelands across the range of lakes that were completed as of June 2010: loon nesting areas, near-shore substrate, size and shape of natural areas, frog areas, hydric soils, and wetlands.