Note: Methodology, explanation of analysis and biological background on Rest Lake studies are contained within the Manitowish Waters Chain-wide Management Plan document.

DRAFT

8.1 Rest Lake

An Introduction to Rest Lake

Rest Lake, Vilas County, is a deep, lowland drainage lake with a maximum depth of 53 feet, a mean depth of 18 feet, and a surface area of approximately 664 acres. It is fed via Papoose Creek from the north and the Manitowish River from the southeast. The Rest Lake Reservoir Dam is located on the west side of the lake, and maintains/controls water levels for upstream lakes in the Manitowish Waters Chain. The lake is currently in a mesotrophic state, and its watershed encompasses approximately 146,515 acres. In 2012, 37 native aquatic plant species were located in the lake, of which common waterweed (*Elodea canadensis*) was the most common. Three non-native plants, pale yellow iris, purple loosestrife, and reed canary grass, were observed growing along areas of Rest Lake's shoreline in 2012.

Field Survey Notes

Primarily sandy substrate observed during point-intercept survey. Great habitat diversity, with sand, rock and shallow wetlands being found around the lake's perimeter.

Photo 8.1 Rest Lake, Vilas County

Lake at a Glance* – Rest Lake

Morphology	
Acreage	664
Maximum Depth (ft)	53
Mean Depth (ft)	18
Volume (acre-feet)	14,544
Shoreline Complexity	6.4
Vegetation	
Curly-leaf Survey Date	May 29, 2012
Comprehensive Survey Date	July 24-25, 2012
Number of Native Species	37
Threatened/Special Concern Species	0
Exotic Plant Species	Pale yellow iris; Purple loosestrife; Reed canary grass
Simpson's Diversity	0.90
Average Conservatism	6.7
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	223:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.1.1 Rest Lake Water Quality

Water quality data was collected from Rest Lake on six occasions in 2012/2013. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. In addition to sampling efforts completed in 2012/2013, any historical data was researched and are included within this report as available.

Unfortunately, very limited data exists for two water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations. In 2012, average summer phosphorus concentrations (14.3 μg/L) were less than the median value (23.0 μg/L) for other deep, lowland drainage lakes in the state (Figure 8.1.1-1) The values measured through this management planning process are similar to several data points which were collected in years past. A weighted value from all available data ranks as *Excellent* for a deep, lowland drainage lake.

Total phosphorus surface values from 2012 are compared with bottom-lake samples collected during this same time frame in Figure 8.1.1-2. As displayed in this figure, on several occasions surface and bottom total phosphorus concentrations were similar. However on some occasions, namely during July and August of 2012, the bottom phosphorus concentrations were much greater than the relatively low surface concentrations. During these periods, anoxic conditions were recorded near the bottom of the lake through measurement of dissolved oxygen (refer to Figure 8.1.1-6 and associated text). This is an indication of hypolimnetic nutrient recycling, or internal nutrient loading, which is a process discussed further in the Manitowish Waters Chain-wide document. While this process may be contributing some phosphorus to Rest Lake's water column, the impacts of nutrient loading are not apparent in the lake's overall water quality; as previously mentioned, Rest Lake's surface water total phosphorus values are slightly lower than the median value for comparable lakes in Wisconsin.

Similar to what has been observed with the total phosphorus dataset, summer average chlorophyll-*a* concentrations (2.3 μg/L) were less than the median value (7.0 μg/L) for other lakes of this type (Figure 8.1.1-3). These values are comparable to several historical values that have been collected on Rest Lake.

Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *Excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2012 visits to the lake, Onterra ecologists recorded field notes describing very good water conditions.

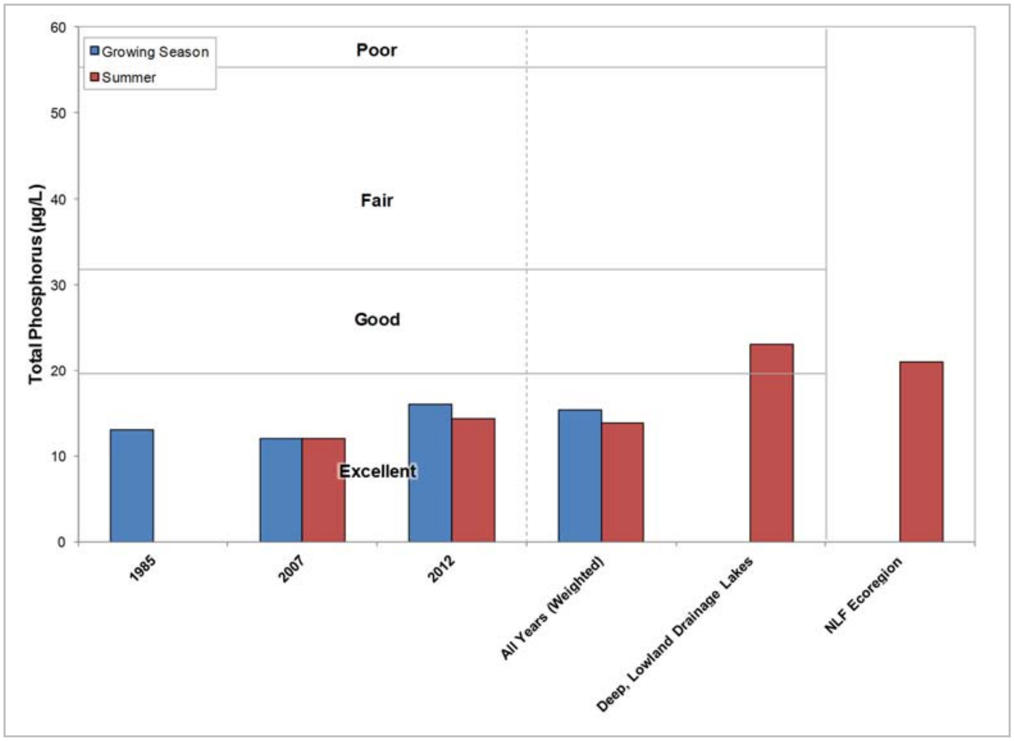

Figure 8.1.1-1. Rest Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

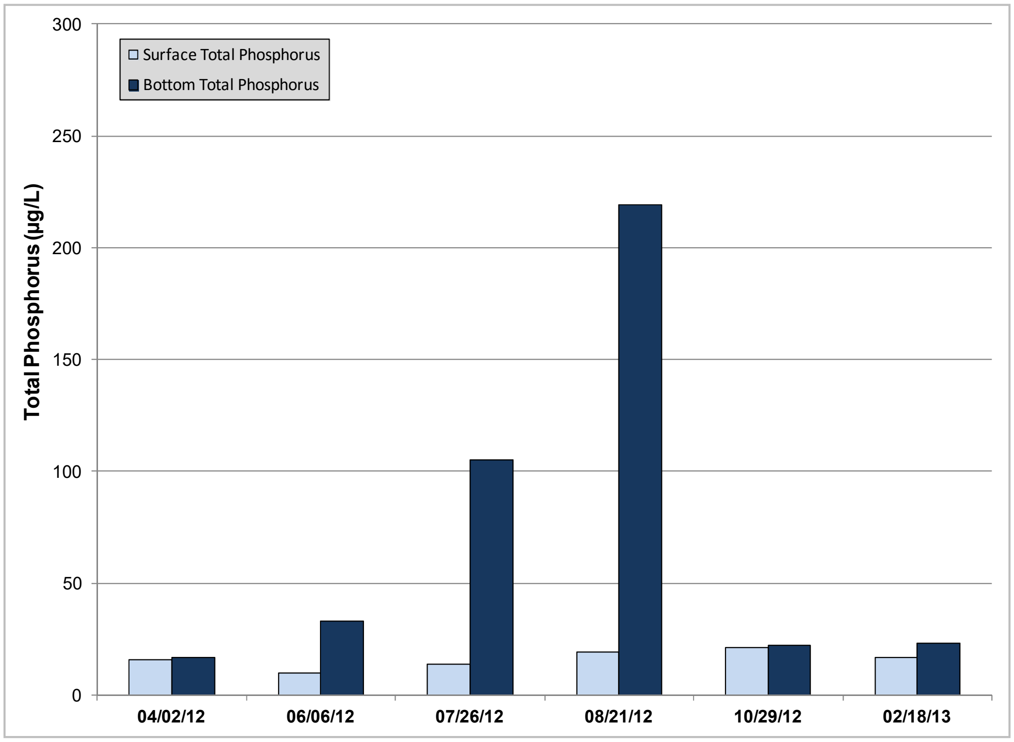

Figure 8.1.1-2. Rest Lake surface and bottom total phosphorus values, 2012-2013. Anoxia was observed in the hypolimnion of the lake during July and August sampling visits.

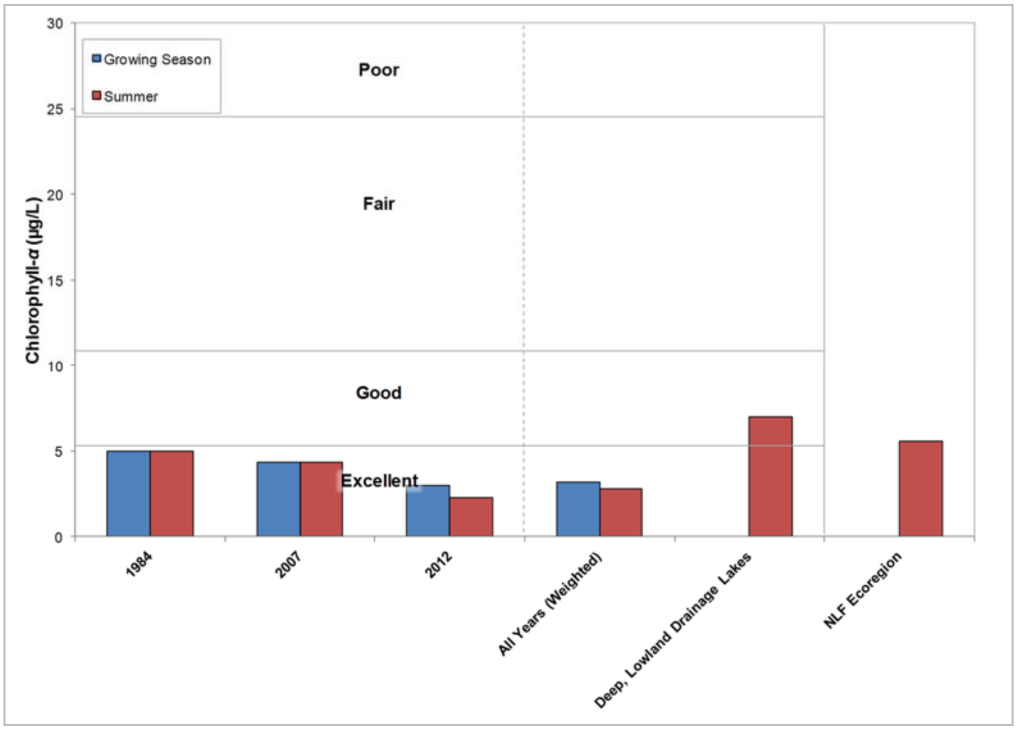

Figure 8.1.1-3. Rest Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

From the examination of nearly two decades worth of intermittent Secchi disk clarity data, several conclusions can be drawn. First, the clarity of Rest Lake's water can be described as *Excellent* in most years (Figure 8.1.1-4). A weighted average over this timeframe is greater than the median value for other deep, lowland drainage lakes in the state as well as all lakes within the ecoregion. Secondly, there is very little variation seen in this data set indicating there is little reason to believe the water clarity has improved, or more importantly, gotten worse over this time period..

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Rest Lake as well as the other lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Rest Lake contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake.

"True color" measures the dissolved organic materials in water. Water samples collected in April and July of 2012 were measured for this parameter, and were found to be at 10 Platinum-cobalt units (Pt-co units, or PCU). Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color.

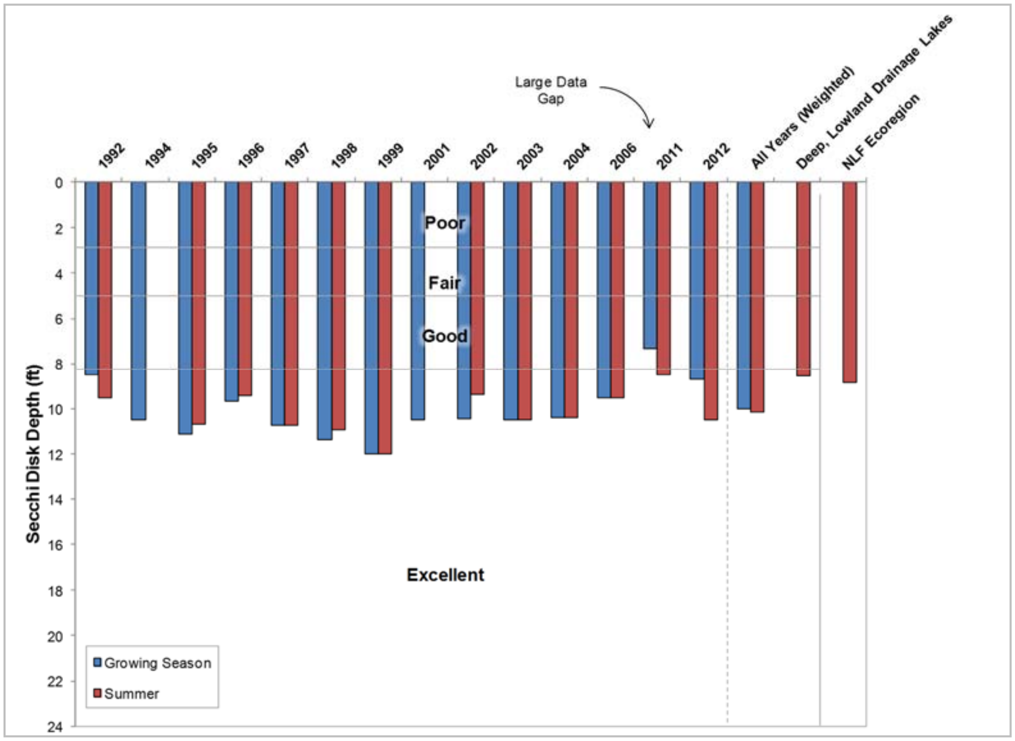

Figure 8.1.1-4. Rest Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Rest Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.1.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Rest Lake is in a mesotrophic state.

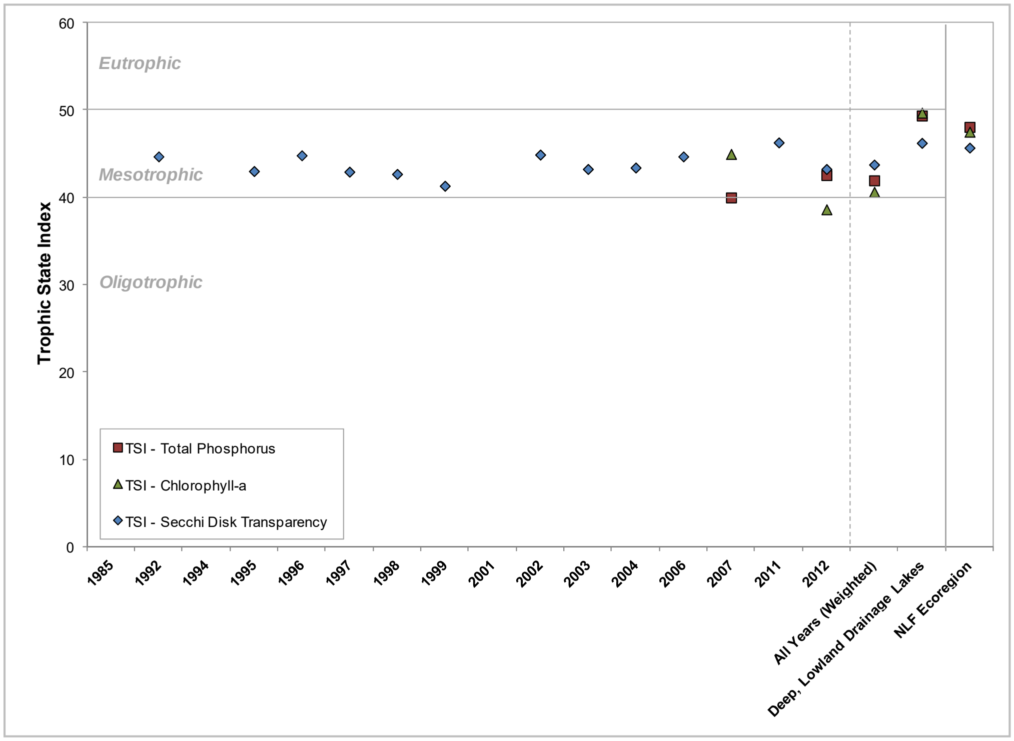

Figure 8.1.1-5. Rest Lake, state-wide deep, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Rest Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Rest Lake by Onterra staff. Graphs of those data are displayed in Figure 8.1.1-6 for all sampling events.

Rest Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the bottom of the lake becomes void of oxygen and temperatures remain fairly cool as they were in the spring months. This occurrence is not uncommon in deep Wisconsin lakes, where wind energy is not sufficient during the summer to mix the entire water column – only the upper portion. During this time, bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2013, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

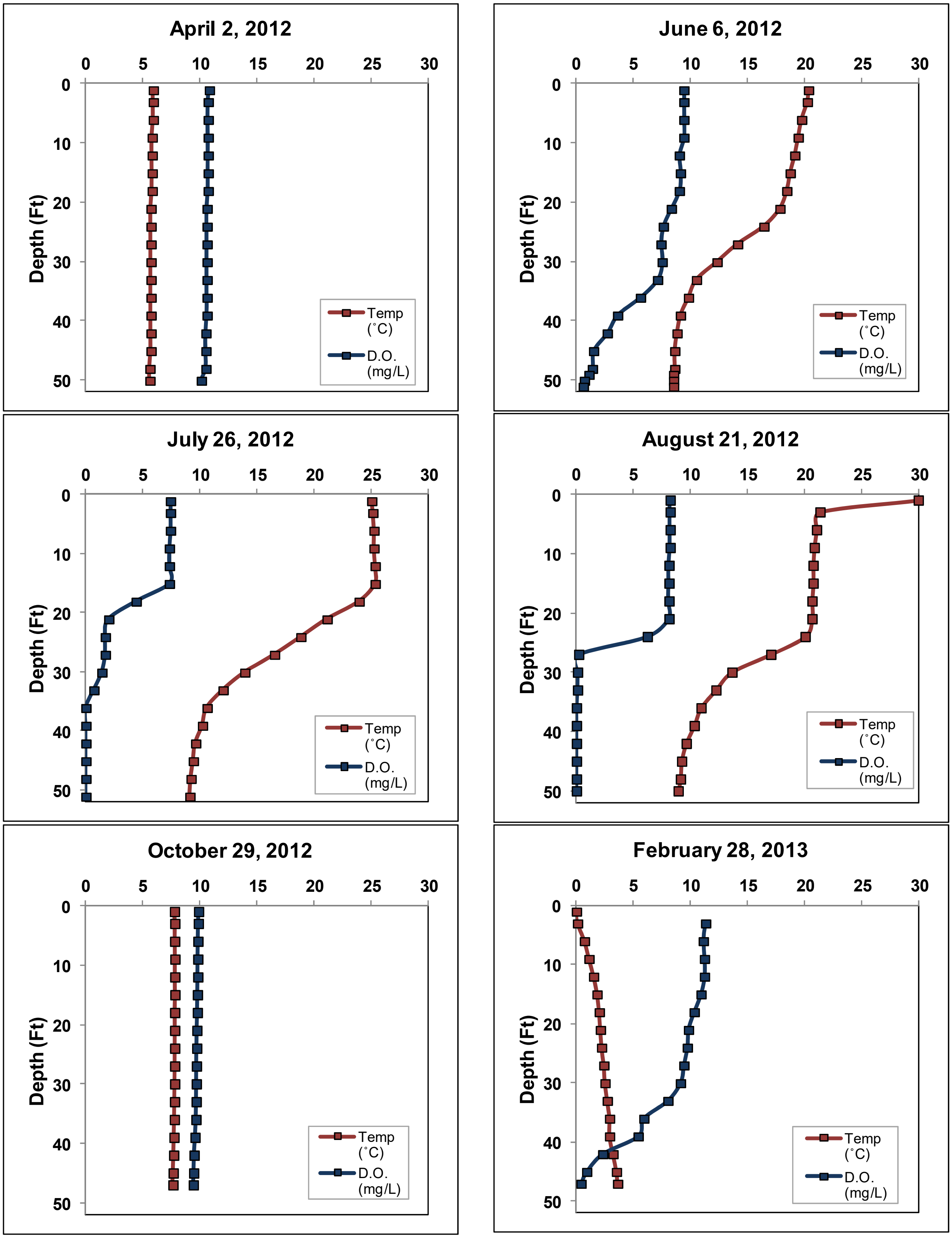

Figure 8.1.1-6. Rest Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Rest Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Rest Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

As the Chain-wide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Rest Lake's surface water pH was measured at roughly 8.5 during April and 7.2 during July of 2012. These values are near or slightly above neutral and fall within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality is common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter add carbon dioxide to water, thereby increasing acidity.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Rest Lake was measured at 47 mg/L as $CaCO_3$ in April and July of 2012. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Rest Lake during 2012. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Rest Lake's pH of 7.2 – 8.5 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Rest Lake was found to be 14.2 mg/L in April and 12.7 mg/L in July of 2012, which is at the bottom end of the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2012 and these samples were processed by the WDNR for larval zebra mussels. *Results to be included within the next draft.*

8.1.2 Rest Lake Watershed Assessment

Rest Lake's watershed is 146,515 acres in size. Compared to Rest Lake's size of 664 acres, this makes for an incredibly large watershed to lake area ratio of 223:1.

Exact land cover calculation and modeling of nutrient input to Rest Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.1.3 Rest Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2012, Rest Lake's immediate shoreline was assessed in terms of its development. Rest Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 4.5 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.1.3-1). This constitutes about 50% of Rest Lake's shoreline. These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 2.5 miles of urbanized and developed–unnatural shoreline (28%) was observed. If restoration of the Rest Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Rest Lake Map 1 displays the location of these shoreline lengths around the entire lake.

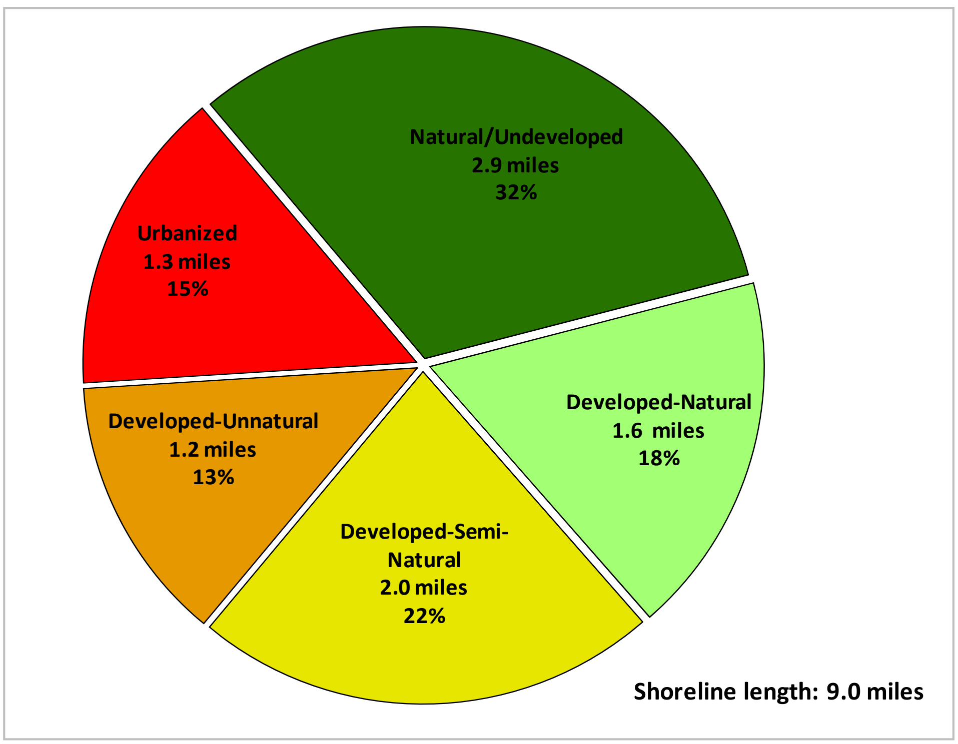

Figure 8.1.3-1. Rest Lake shoreland categories and total lengths. Based upon a late summer 2012 survey. Locations of these categorized shorelands can be found on Rest Lake Map 1.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Manitowish Waters Chain-wide document, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 59 total pieces of coarse woody habitat were observed along 9.0 miles of shoreline, which gives Rest Lake a coarse woody habitat to shoreline mile ratio of 7:1 (Figure 8.1.3-2). Locations of coarse woody habitat are displayed on Rest Lake Map 2. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

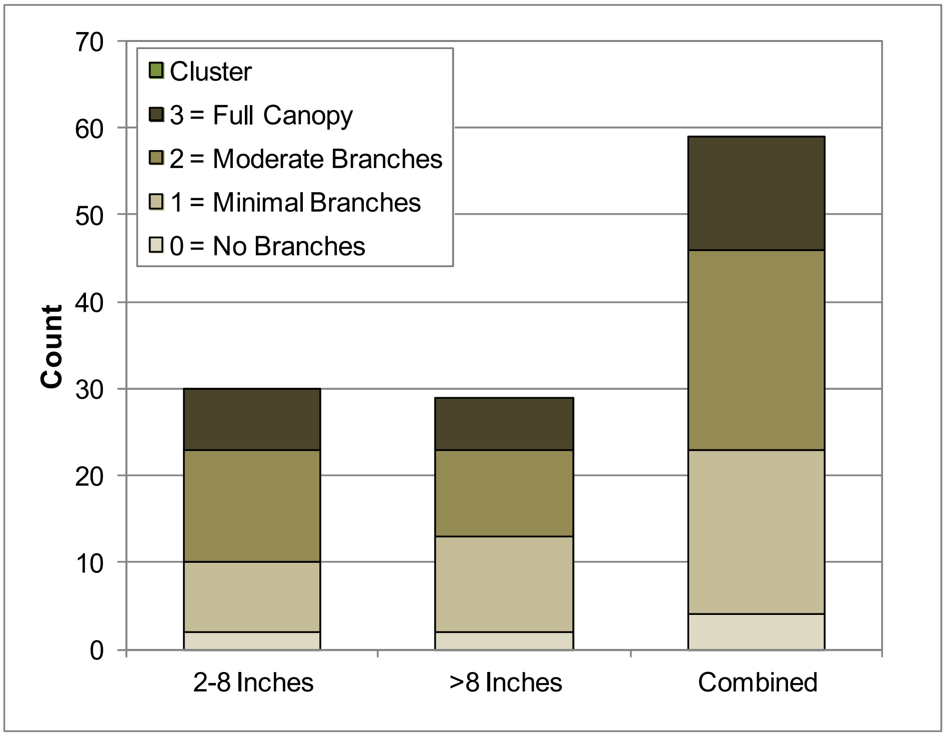

Figure 8.1.3-2. Rest Lake coarse woody habitat survey results. Based upon a late summer 2012 survey. Locations of Rest Lake coarse woody habitat can be found on Rest Lake Map 2.

8.1.4 Rest Lake Aquatic Vegetation

Note: Rest Lake consists of what some consider two waterbodies – Rest Lake and a bay at the north end called Papoose Bay. Papoose Bay and Rest Lake were surveyed in a similar manner with regards to the aquatic plant community; however, some aspects of the aquatic plant community are analyzed separately as discussed below.

An early season aquatic invasive species survey was conducted on Rest Lake and Papoose Bay on May 29, 2012. While the intent of this survey is to locate *any* potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species.

The aquatic plant point-intercept survey was conducted on Rest Lake and Papoose Bay on July 24, 2012 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on July 25, 2012 to map these community types. During all surveys, 37 species of native aquatic plants were located in Rest Lake (Table 8.1.4-1). Twenty-one of these species were sampled directly on the rake during the point-intercept survey and are used in the analysis that follows, while the remaining 16 species were observed incidentally. Three exotic species, pale yellow iris (*Iris speudacorus*), purple loosestrife (*Lythrum salicaria*), and reed canary grass (*Phalaris arundinacea*) were observed along the shores of Rest Lake also. Exotic species inventories and management actions are discussed within the Chain-wide plan document. A total of 24 native aquatic plant species were located in Papoose Bay in 2012, 17 of which were sampled directly during the point-intercept survey (Table 8.1.4-2). No exotic species were located in Papoose Bay in 2012. Table 8.1.4-1 and Table 8.1.4-2 also include a list of aquatic plant species located in Rest Lake and Papoose Bay during whole-lake point-intercept surveys conducted by members of WDNR in 2008.

Aquatic plants were found growing to a depth of 15 feet in Rest Lake and to the maximum depth of Papoose Bay, 7 feet, in 2012. A WDNR 2008 survey found aquatic plants growing to a depth of 11.5 feet in Rest Lake and 6.5 feet in Papoose Bay. Of the 415 point-intercept sampling locations that fell at or below the maximum depth of plant growth (littoral zone) in Rest Lake in 2012, 18% contained aquatic vegetation, indicating Rest Lake's littoral zone is not highly vegetated. As illustrated on Rest Lake-Map 3, aquatic vegetation was most abundant in shallow areas within the northern and southwestern areas of the lake. Papoose Bay, being relatively shallow, was highly vegetated with 84% of the point-intercept sampling locations sampled containing aquatic vegetation in 2012. Papoose Bay-Map 1 displays the point-intercept locations that contained aquatic vegetation in 2012, and that many of the point-intercept sampling locations were not sampled and were listed as "non-navigable" due to dense emergent vegetation.

On Rest Lake, approximately 60% of the point-intercept sampling locations where sediment data were collected (<14 feet) were sand, 35% consisted of a fine, soft sediments (muck) and 5% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5). Most (76%) of the point-intercept sampling locations in Papoose Bay held fine, soft sediments, while 21% contained sand and 3% contained a rocky substrate.

Table 8.1.4-1. Aquatic plant species located in Rest Lake during Onterra 2012 surveys and WDNR 2008 point-intercept survey.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatsim (C)	WDNR (2008)	Onterra (2012)
Emergent	*Carex crinita*	Fringed sedge	6		I
	Carex lacustris	Lake sedge	6		I
	Carex retrorsa	Retrorse sedge	6		I
	Eleocharis palustris	Creeping spikerush	6		I
	Equisetum fluviatile	Water horsetail	7	X	I
	Glyceria canadensis	Rattlesnake grass	7		I
	Iris pseudacorus	Pale yellow iris	Exotic		I
	Iris versicolor	Northern blue flag	5		I
	Juncus effusus	Soft rush	4		I
	Lythrum alatum	Winged loosestrife	6		I
	Lythrum salicaria	Purple loosestrife	Exotic		I
	Phalaris arundinacea	Reed canary grass	Exotic		I
	Sagittaria latifolia	Common arrowhead	3		I
	Schoenoplectus pungens	Three-square rush	5		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4		I
	Scirpus cyperinus	Wool grass	4		I
	Sium suave	Water parsnip	5	X	I
	Typha sp.	Cattail sp.	1	X	I
	Zizania palustris	Northern wild rice	8	X	X
FL	*Nymphaea odorata*	White water lily	6		I
	Nuphar variegata	Spatterdock	6		X
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10	X	X
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Ceratophyllum demersum	Coontail	3	X	X
	Chara sp.	Muskgrasses	7		X
	Elodea canadensis	Common waterweed	3	X	X
	Elodea nuttallii	Slender waterweed	7	X	
	Heteranthera dubia	Water stargrass	6	X	X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Najas flexilis	Slender naiad	6	X	X
	Najas guadalupensis	Southern naiad	7		X
	Nitella sp.	Stoneworts	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton foliosus	Leafy pondweed	6	X	X
	Potamogeton friesii	Fries' pondweed	8	X	X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X	X
	Potamogeton strictifolius	Stiff pondweed	9	X	
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Utricularia intermedia	Flat-leaf bladderwort	9	X	
	Utricularia vulgaris	Common bladderwort	7		X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Sagittaria cristata*	Crested arrowhead	9	X	
	Schoenoplectus subterminalis	Water bulrush	9	X	

FL = Floating-leaf; FL/E = Floating-leaf/Emergent; S/E = Submergent/Emergent
X = Located on rake during point-intercept survey; I = Incidentally located

Table 8.1.4-2. Aquatic plant species located in Papoose Bay during Onterra 2012 surveys and WDNR 2008 point-intercept survey.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatsim (C)	WDNR (2008)	Onterra (2012)
Emergent	*Carex sp.*	Sedge sp.	N/A	X	
	Cicuta maculata	Water hemlock	6	X	
	Equisetum fluviatile	Water horsetail	7	X	I
	Juncus effusus	Soft rush	4	X	
	Leersia sp.	Sawgrass sp.	N/A	X	
	Sagittaria rigida	Stiff arrowhead	8	X	
	Sagittaria sp.	Arrowhead sp.	N/A	X	
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I
	Scirpus cyperinus	Wool grass	4		I
	Sium suave	Water parsnip	5		I
	Typha spp.	Cattail spp.	1		I
	Zizania palustris	Northern wild rice	8		X
FL	*Nuphar variegata*	Spatterdock	6		I
	Nymphaea odorata	White water lily	6	X	
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10		I
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Callitriche sp.	Water starwort sp.	N/A	X	
	Ceratophyllum demersum	Coontail	3	X	X
	Chara sp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6	X	
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella sp.	Stoneworts	7		X
	Potamogeton foliosus	Leafy pondweed	6	X	
	Potamogeton friesii	Fries' pondweed	8	X	
	Potamogeton gramineus	Variable pondweed	7	X	X
	Potamogeton gramineus	Variable pondweed	7	X	
	Potamogeton obtusifolius	Blunt-leaf pondweed	9		X
	Potamogeton pusillus	Small pondweed	7	X	
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Ranunculus aquatilis	White water-crowfoot	8	X	
	Utricularia vulgaris	Common bladderwort	7		X
	Vallisneria americana	Wild celery	6		X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	
	Sagittaria cuneata	Arum-leaved arrowhead	7	X	X
FF	*Lemna trisulca*	Forked duckweed	6	X	X

FL = Floating-leaf; FL/E = Floating-leaf/Emergent; S/E = Submergent/Emergent; FF = Free-floating
X = Located on rake during point-intercept survey; I = Incidentally located

Figure 8.1.4-1 displays the littoral frequency of occurrence of aquatic plant species in Rest Lake from the 2012 point-intercept survey. Common waterweed, fern pondweed, and slender naiad were the three-most frequently encountered species in 2012. Common waterweed can be found in lakes throughout Wisconsin and North America. It is usually found growing in soft substrates, and possesses long stems with whorls of three, slender leaves. This species can tolerate and thrive in lakes with lower water clarity, and can often grow to nuisance levels forming large mats on the water's surface. Common waterweed provides excellent structural habitat for aquatic organisms and is an important food source for animals such as muskrats.

Fern pondweed, a common plant of lakes in northern Wisconsin, was the second-most abundant plant in Rest Lake in 2012. This plant generally grows in dense beds which creep along the bottom of the lake, where they provide excellent structural habitat for aquatic invertebrates and fish. The third-most abundant plant in 2012, slender naiad, is a common annual species in Wisconsin, and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). Their numerous seeds, leaves, and stems all provide sources of food, while the small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

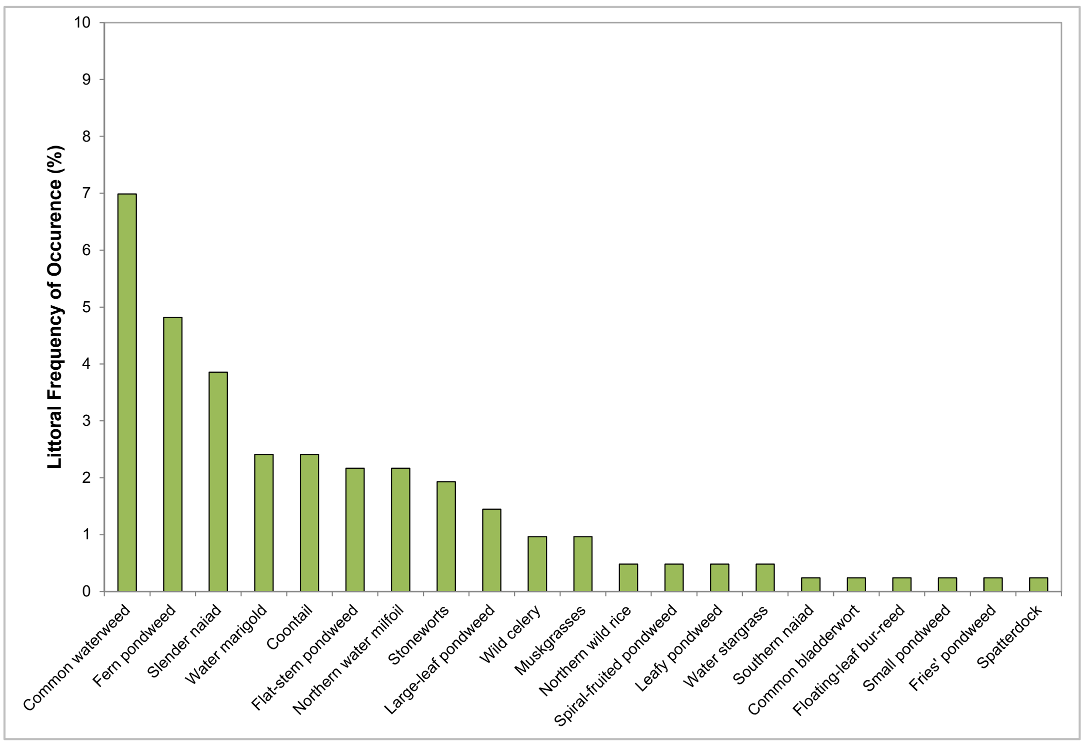

Figure 8.1.4-1. Rest Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2012 point-intercept survey.

Figure 8.1.4-2 displays the littoral frequency of occurrence of select aquatic plant species from both the Onterra 2012 and WDNR 2008 point-intercept surveys. Like in 2012, common waterweed and fern pondweed were the most frequently encountered aquatic plants. As indicated on Figure 8.1.4-2, northern wild rice was the only aquatic plant species to exhibit a statistically valid reduction in its littoral occurrence from 2008 to 2012 (Chi-square $\alpha = 0.05$). However, this is due to additional point-intercept sampling locations that were sampled in 2008 within the northwest bay of Rest Lake that were non-navigable due to dense northern wild rice in 2012. No other aquatic plant species exhibited statistically valid changes in their occurrence over this time period.

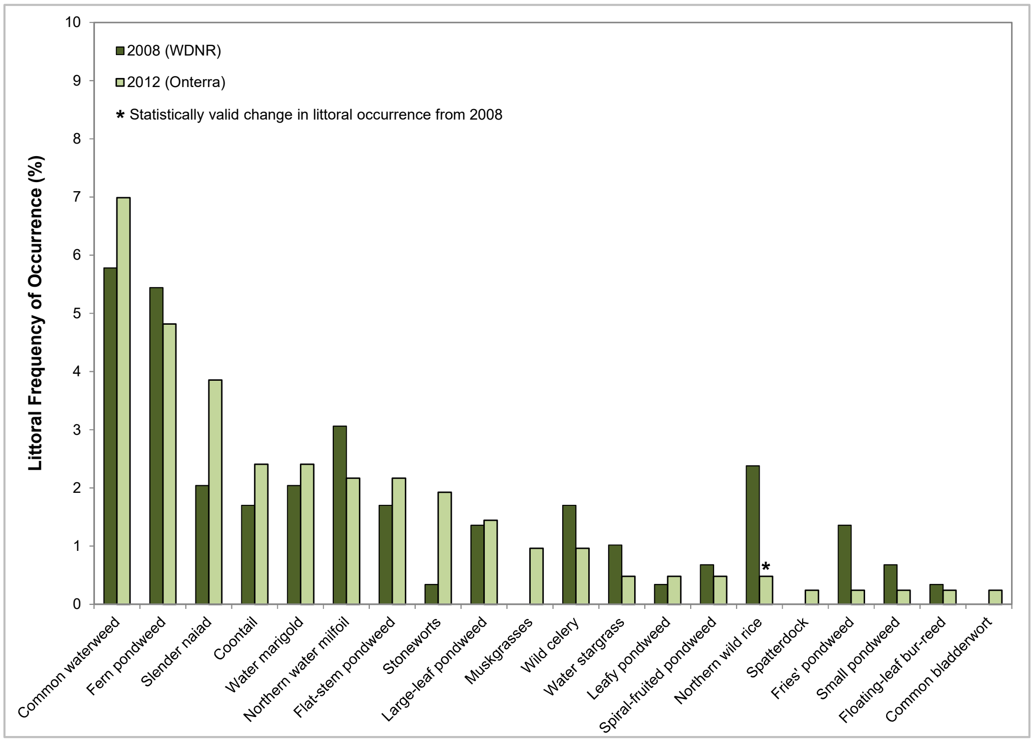

Figure 8.1.4-2. Rest Lake select aquatic plant littoral frequency of occurrence analysis. Created using data from WDNR 2008 and Onterra 2012 point-intercept surveys.

The 2012 littoral frequency chart for Papoose Bay (Figure 8.1.4-3) illustrates that coontail, common waterweed, and flat-stem pondweed were the three-most frequently encountered aquatic plant species during the 2012 point-intercept survey. However, only about half of the point-intercept sampling locations were able to be sampled, the remaining were located in dense, emergent vegetation, mostly comprised of northern wild rice. Had these points been able to be sampled, these data would likely show that northern wild rice is the most dominant plant within Papoose Bay.

Coontail, like common waterweed, is found throughout lakes in Wisconsin and North America. It produces long stems that contain whorls of stiff leaves, lacks true roots, and obtains the majority of its essential nutrients directly from the water. Coontail is usually found in lakes of higher productivity where there are sufficient nutrients within the water to support it. Its dense growth removes excess nutrients from the water, and provides aquatic wildlife with excellent structural habitat. Flat-stem pondweed, as its name indicates, possesses a conspicuously flattened stem. Like coontail, flat-stem pondweed is usually found in more productive lakes, and provides valuable structural habitat and sources of food for wildlife.

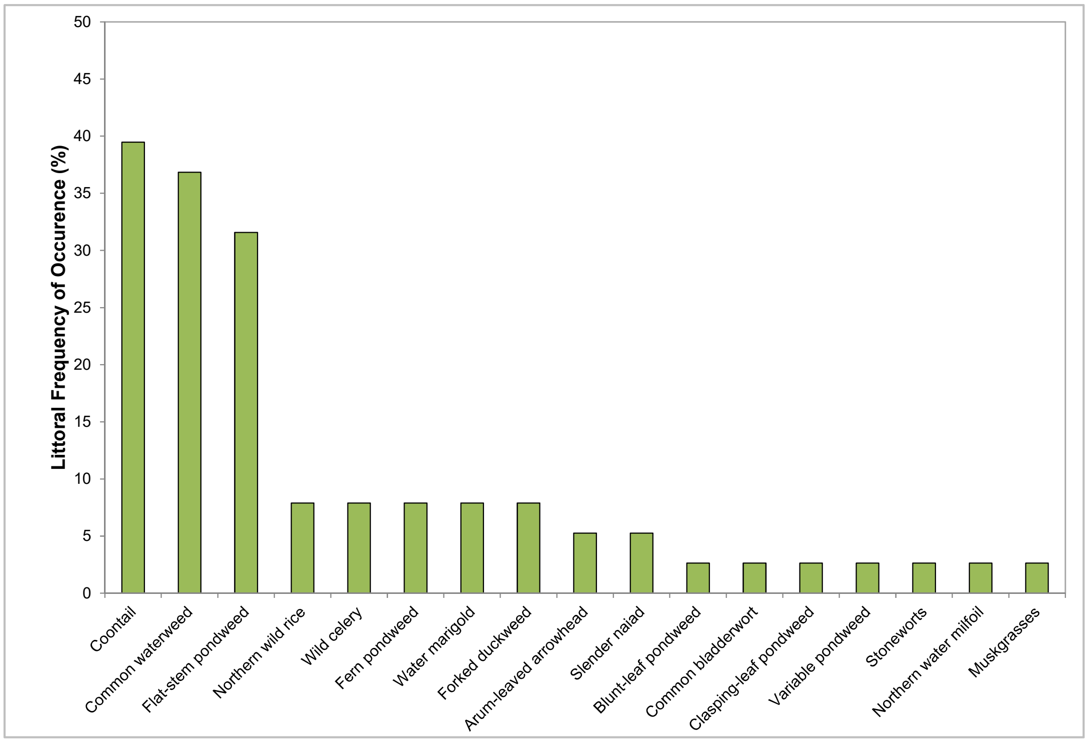

Figure 8.1.4-3. Papoose Bay aquatic plant littoral frequency of occurrence analysis. Created using data from a 2012 point-intercept survey.

Figure 8.1.4-4 displays the littoral frequency of occurrence of aquatic plants from the 2012 and WDNR 2008 point-intercept surveys in Papoose Bay. As illustrate, a number of aquatic plants, including muskgrasses, northern water milfoil, Fries' pondweed, arrowhead sp., small pondweed, coontail, and flat-stem pondweed, saw statistically valid changes in occurrence from 2008 to 2012. While some of these may reflect natural community dynamics of Papoose Bay over time, these changes are likely due to the difference in the number of point-intercept locations sampled between 2008 and 2012. Nearly all the points (83) were able to be sampled in 2008, while less than half (38) were able to be sampled in 2012. As discussed in the chain-wide section, northern wild rice populations tend fluctuate naturally on an annual basis. It is likely that the northern wild rice in Papoose Bay was less dense in 2008 allowing surveyors to access areas that were non-navigable in 2012.

As discussed in the chain-wide section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. These species encountered on the rake and their conservatism values were used to calculate the FQI of Rest Lake's and Papoose Bay's aquatic plant communities in 2008 and 2012 (Figure 8.1.4-5). The number of native species encountered on the rake declined from 2008 to 2012 in both Rest Lake and Papoose Bay. The large reduction in the number of species encountered in Papoose Bay in 2012 is likely due to the previously discussed reduced sampling effort. The number of native species for both Rest Lake and Papoose Bay falls above the median value for both lakes in the Northern Lakes and Forests Lakes (NLFL) Ecoregion and for lakes throughout Wisconsin.

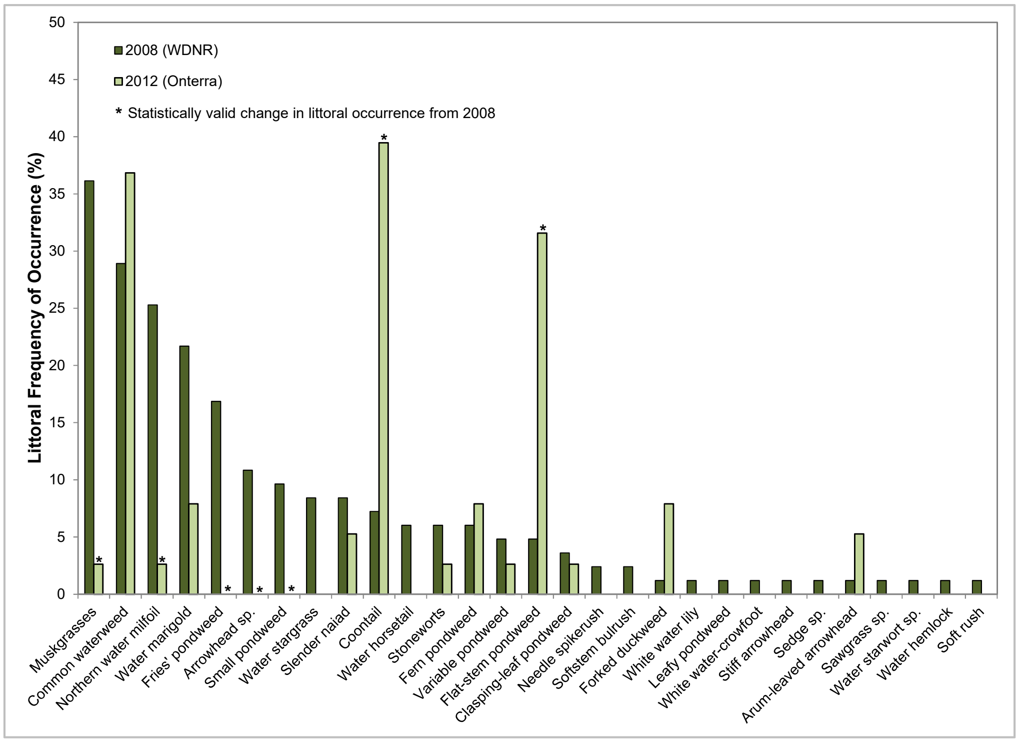

Figure 8.1.4-4. Papoose Bay aquatic plant littoral frequency of occurrence analysis. Created using data from WDNR 2008 and Onterra 2012 point-intercept surveys.

The average conservatism values decreased slightly in Rest Lake from 2008 to 2012, and increased slightly in Papoose Bay (Figure 8.1-4-5). The average conservatism values for Rest Lake and Papoose Bay in 2012 fall below the median value for lakes in the NLFL Ecoregion, but above the median for lakes throughout Wisconsin. The Floristic Quality Index values for both Rest Lake and Papoose Bay declined from 2008 to 2012, but both waterbodies were higher than the median values for lakes in NLFL Ecoregion and lakes in Wisconsin in 2012. These data indicate that the aquatic plant community of Rest Lake is of comparable quality to other lakes in NLFL Ecoregion and of higher quality than the majority of lakes in Wisconsin, and the plant community has changed little since 2008. The plant community of Papoose Bay is of comparable to slightly lower quality than other lakes in the NLFL Ecoregion but of higher quality than most of the lakes in Wisconsin.

As explained earlier in the Manitowish Waters chain-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while common waterweed was found at 7% of the littoral sampling locations in Rest Lake in 2012, its relative frequency of occurrence is 21%. Explained another way, if 100 plants were randomly sampled from Rest Lake, 21 of them would be common waterweed. This distribution can be observed in Figures 8.1.4-6 and 8.1.4-7.

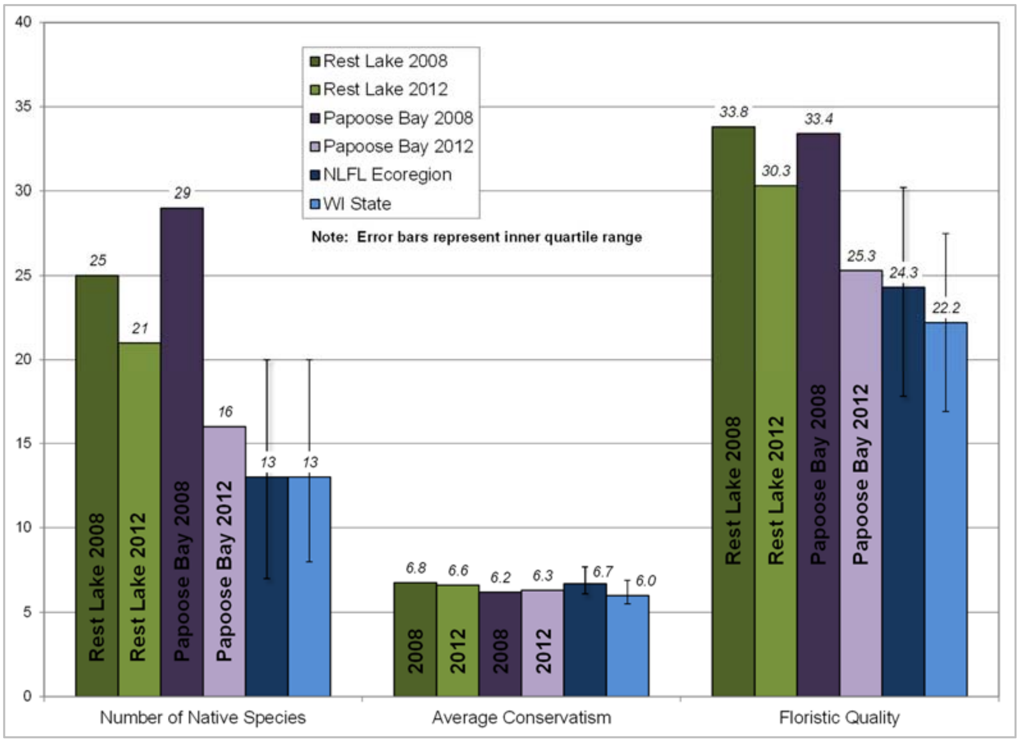

Figure 8.1.4-5. Rest Lake and Papoose Bay 2008 and 2012 Floristic Quality Analysis. Created using data from WDNR 2008 and Onterra 2012 point-intercept surveys. Analysis following Nichols (1999).

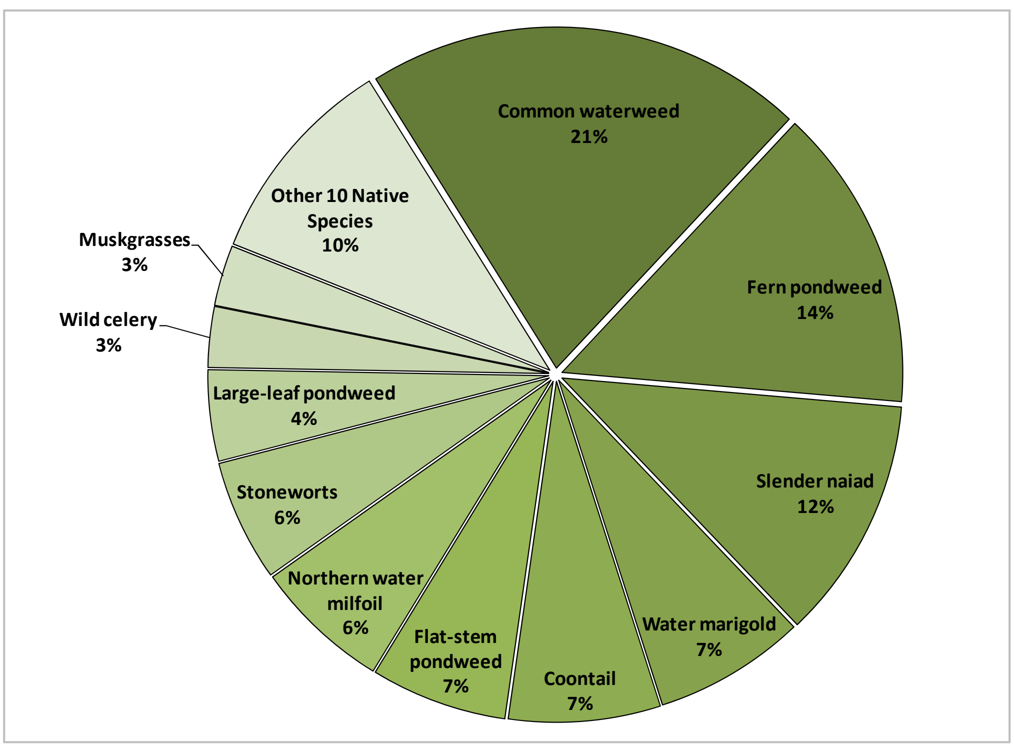

Figure 8.1.4-6. Rest Lake 2012 aquatic plant relative frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

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Lake Management Planning

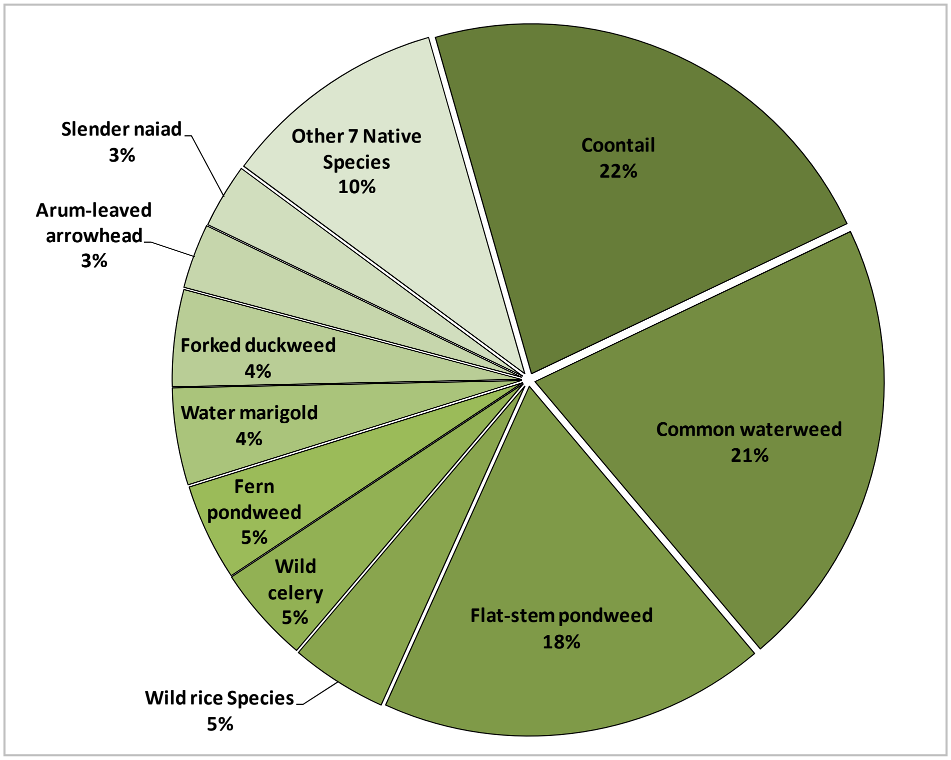


Figure 8.1.4-7. Papoose Bay 2012 aquatic plant relative frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

The quality of Rest Lake and Papoose Bay are also indicated by the presence of emergent and floating-leaf plant communities that occur in many areas. The 2012 community map indicates that approximately 11.1 acres of Rest Lake and 9.1 acres of Papoose Bay contain these types of plant communities (Rest Lake-Map 4, Papoose Bay-Map 2, Table 8.1.4-3). Fourteen native floating-leaf and emergent species were located on Rest Lake and Papoose Bay (Table 8.1.4-1, 8.1.4-2), all of which provide valuable wildlife habitat.

Table 8.1.4-3. Rest Lake and Papoose Bay acres of emergent and floating-leaf plant communities from the 2012 community mapping survey.

Plant Community	Rest Lake Acres	Papoose Bay Acres
Emergent	10.3	9.0
Floating-leaf	0.1	0.1
Mixed Emergent & Floating-leaf	0.7	0.0
Total	11.1	9.1
Grand Total	**20.2**	

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Rest Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Papoose Bay

Papoose Bay consists of a tributary stream and a small bay at the north end of Rest Lake. Some consider the bay a separate waterbody from Rest Lake and the remaining Manitowish Waters Chain. The Papoose Bay Association (PBA) is heavily involved with the Manitowish Waters Lake Association, North Lakeland Discovery Center and other stakeholders in management of this waterbody. Specifically, the PBA is involved with management of abundant aquatic plant populations, which bring about navigational issues in this bay.

Mechanical Harvesting in Papoose Bay

Papoose Bay riparian property owners, many who are members of the Papoose Bay Association, experience navigational issues brought about by abundant aquatic plant populations within the bay. The association has sponsored mechanical harvesting to maintain navigational lanes to increase navigability annually since 2002. In 2012, approximately 2 acres of aquatic plants were mechanically harvested. Papoose Bay-Map 3 shows that a 30-foot wide navigational lane was harvested down the center of the bay, while 15-foot wide riparian access lanes were harvested to maintain access to the main navigational channel. Within the Rest Lake Implementation Plan, Management Goal 7 addresses future harvesting permitting and activities.

8.1.5 Rest Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Rest Lake stakeholders, the MWLA, the NLDC, the Towns of Manitowish Waters and Boulder Junction, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Rest Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Manitowish Waters Chain of Lakes are geographically similar, they are certainly ecologically diverse, as evidenced by the studies described within this report. This diversity leads to the need for individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Manitowish Waters Chain have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Rest Lake's Implementation Plan illustrates how Rest Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Rest Lake

Chain-wide Management Goal 1: Strengthen Association Relationships, Effectiveness and Lake Management Capability

Management Action: **Enhance involvement with other entities that have a hand in managing the Manitowish Waters Chain of Lakes.**

Description: While the MWLA and NLDC are primarily responsible for facilitating partnerships with many defined management units, Rest Lake property owners may participate in this management goal by keeping the lines of communication open with the MWLA and NLDC, as well as members from other Manitowish Waters Chain lakes. This may be done through representation on the MWLA Board of Directors, active participation in the Lake Captain and Deckhand Program, involvement in MWLA and NLDC sponsored events, attending meetings, etc.

Management Action: **Increase the Manitowish Waters Chain of Lakes' volunteer base**

Description: Rest Lake property owners may assist in this management action by simply donating several hours of their time a year towards MWLA and NLDC activities including active participation in the Lake Captain and Deckhand program. While it is beneficial to volunteer on their own lake, the entire chain would benefit by having Rest Lake individuals assist with activities occurring on other lakes within the chain.

Chain-wide Management Goal 2: Maintain Current Water Quality Conditions

Management Action: **Continue and expand monitoring of the Manitowish Waters Chain of Lakes' water quality through the WDNR Citizen Lake Monitoring Network.**

Description: Currently, Rest Lake is enrolled in the CLMN's water clarity monitoring program. Although this is a great accomplishment, it must be continued in order to ensure the quality of Rest Lake is protected; the SWIMS database indicates volunteers have not collected information since 2012. Additionally, a better understanding of the lake's water quality would be obtained from volunteers enrolling in the CLMN's advanced water quality monitoring program. In this program, phosphorus and chlorophyll-*a* data is collected from the lake as well.

A volunteer should be identified to continue water quality collection on Rest Lake. Volunteers from Rest Lake must also be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: **Restore highly developed shoreland areas on the Manitowish Waters Chain.**

Description: As a part of this project, the entire Rest Lake shoreline was categorized in terms of its development. According to the results from this survey, 28% of the shoreline is in an urbanized or developed-unnatural state, while another 22% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

TAISP is prepared to provide Rest Lake property owners with the necessary informational resources to restore their developed shoreland, should they be interested. Interested property owners may contact the NLDC and Vilas County Land and Conservation office for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: **Protect natural shoreland zones along the Manitowish Waters Chain of Lakes.**

Description: While 28% of the shoreland was found to be highly developed along Rest Lake, about 50% of the shoreland is currently in a very natural or undeveloped state. These areas are extremely important to protect for the environmental and aesthetic benefits they provide.

Rest Lake property owners interested in preserving their shoreland may contact the NLDC and Vilas County Land and Conservation office for information on land trusts, conservation easements, or best management practices. Implementing a number of these options will ensure the integrity of these undeveloped shorelands will remain well into the future.

Management Action: **Investigate algal blooms on the Manitowish Waters Chain.**

Description: While some algae blooms are natural and do not impact a lake ecosystem or human health in a negative manner, some blooms may cause recreational or health impairment. Rest Lake and Papoose Bay residents who observe algae blooms may contact the NLDC with their concerns. The NLDC can take the appropriate response in contacting WDNR officials about the matter. Residents may be asked to provide a sample of the algae for identification purposes.

Chain-wide Management Goal 3: Expand Awareness and Education of Lake Management and Stewardship Matters

Management Action: **Engage stakeholders on priority education items through participation in educational initiatives and efficient communication.**

Description: Rest Lake stakeholders can assist in the implementation of this action by actively participating in the MWLA and NLDC's educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events (including the Winter Rendezvous), participating in committees and the Lake Captain and Deckhand program, or simply notifying the MWLA or NLDC of concerns involving Rest Lake and its stakeholders.

Chain-wide Management Goal 4: Control Existing and Prevent Further Aquatic Invasive Species Establishment within the Manitowish Waters Chain of Lakes

Management Action: **Continue control strategy for curly-leaf pondweed on the Manitowish Waters Chain of Lakes.**

Description: Rest Lake residents may participate in curly-leaf pondweed control actions through a variety of passive means, such as keeping themselves up to date on aquatic invasive species matters through trainings, media releases, or participating in local meetings on the issue. Rest Lake residents can also assist by participating in the Lake Captain and Deckhand program, actively monitoring for curly-leaf pondweed. Additionally, lake users may report sightings of aquatic invasive species to the NLDC and remove floating CLP fragments when they are observed.

Management Action: **Maintain connection and open dialogue with management partners on matters pertaining to wild rice growth on the Manitowish Waters Chain.**

Description: As this is an action designed for a designated individual, there is no action necessary for Rest Lake property owners.

Management Action: **Continue control and monitoring efforts on purple loosestrife, Japanese knotweed, phragmites, and pale yellow iris throughout the Manitowish Waters Chain of Lakes.**

Description: Emergent shoreland plants such as purple loosestrife, Japanese knotweed, phragmites, and pale yellow iris can be easily identified and small infestations addressed through simple control methods. Rest Lake property owners may participate in this action through monitoring their shorelands and wetlands and removing plants in accordance with methods determined by the NLDC, MWLA and Vilas County Invasive Species Coordinator.

Management Action: **Continue locally-based aquatic invasive species monitoring and watercraft inspections.**

Description: Prevention of aquatic invasive species introduction remains the most effective way of minimizing the spread of this threat. Rest Lake property owners may participate in this initiative through volunteering for aquatic invasive species monitoring or Clean Boats Clean Waters inspections.

Management Action: **Investigate feasibility of alternative aquatic invasive species control methodologies for applicability to the Manitowish Waters Chain of Lakes.**

Description: As this is an action designed for a designated individual, there is no action necessary for Rest Lake property owners.

Chain-wide Management Goal 5: Enhance the Available Habitat and General Understanding of the Manitowish Waters Chain of Lakes Fishery

Management Action: **Work with WDNR fisheries managers and other stakeholders to enhance and understand the fishery.**

Description: Angling is often one of the most enjoyed recreational activities that takes place on Wisconsin lakes. A complete understanding of a lake's fishery is needed to base decisions off of, both for the fishery manager and the fisherman. Rest Lake residents can help the fishery of the Manitowish Waters Chain of Lakes by attending events aimed at educating the public about the chain's fishery, as well as volunteering for habitat improvement efforts, including shoreland preservation/remediation and coarse woody habitat projects.

Chain-wide Management Goal 6: Continue to Understand, Protect and Enhance the Ecology of the Manitowish Waters Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Continue the development of comprehensive management plans for the Manitowish Waters Chain waterbodies.

Description: Though studies have been completed on Rest Lake as part of this chain-wide management planning project, it is up to Rest Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the goals described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Rest Lake may wish to revisit their lake management plan in 5-10 years or as necessary. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Individual Rest Lake Management Goal

Management Goal 7: Maintain Reasonable Navigation within Rest Lake

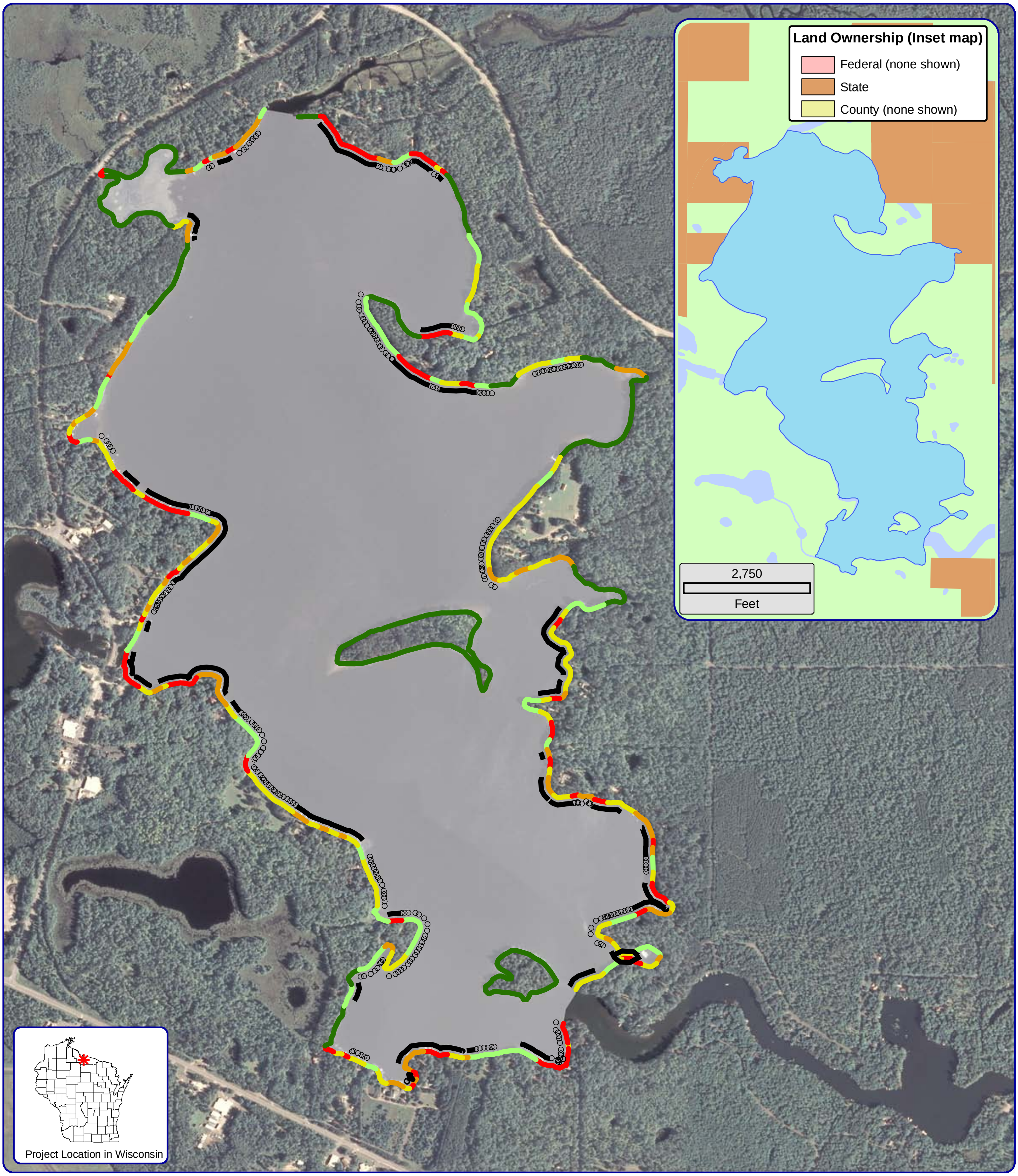
Management Action: **Use mechanical harvesting to maintain reasonable navigation on Rest Lake.**

Description: As Rest Lake stakeholders know, and this project's field studies have confirmed, the Papoose Bay area of Rest Lake is a productive system which includes abundant plant growth. So much growth, in fact, that navigation is impeded in much of this area. Papoose Bay Map 3 displays the mechanical harvesting plan that the Papoose Bay Association (PBA) has followed to ensure navigability for Papoose Bay property owners and others navigating through Rest Lake. This map illustrates two types of harvesting lanes; riparian access lanes, which are 15 feet wide, and common use lanes, which are 30 feet wide. Altogether, the total cutting area depicted consists of 1.7 acres, or 12.5% of the bay's surface area. The PBA has conducted harvesting in these areas since 2008 through annual permits that have been issued by the WDNR. These permits typically includes stipulations for harvesting activity, such as:

1. The permit is valid for one year.
2. The harvesting lanes should not exceed 30 feet (navigation lane) and 15 feet (riparian access lane) in width.
3. Harvesting is permitted for submergent and emergent plants only, no floating-leaf plants may be harvested.
4. Aquatic plant harvesting is strictly for human access concerns – no harvesting shall occur in areas where riparian property owner docks are not located.
5. Harvesting must be done in a manner such that the impacts to the wild rice community are minimized.
6. Harvesting must be done in areas where water depth is great enough to prevent suspension of bottom materials.
7. All aquatic plants that are cut must be removed immediately from the water.
8. Harvesting operations shall not disturb spawning or nesting fish, and must minimize accidental capture of fish.
9. All harvesting equipment shall be de-contaminated for invasive species and viruses prior to and after use.

These regulations are put in place to protect the natural ecosystem of Papoose Bay. Note that this list serves as a general overview - further stipulations may be viewed within the annual WDNR permit for Papoose Bay.

The plan the PBA has been following is valuable in that it minimizes the area of harvesting while still providing Papoose Bay property owners access to Rest Lake. The PBA will continue this harvesting strategy in accordance with WDNR permits. Should significant changes occur within the bay, such as the introduction of aquatic invasive species, a new harvesting strategy would need to be developed. Specifically, this strategy would include coordination of NLDC and consultant mapping results along with harvesting activities to ensure that aquatic invasive species are not picked up and spread by the harvesting unit. In addition to detailed mapping and effective communication, hand-harvesting of aquatic invasive species may be utilized to remove plants from harvesting areas prior to harvesting use, thereby minimizing the opportunity for spread throughout Papoose Bay.



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Feet

Legend

Natural/Undeveloped
Developed-Natural
Developed-Semi-Natural
Developed-Unnatural
Urbanized

Seawall
Masonary/Wood
Rip-Rap

Rest Lake - Map 1

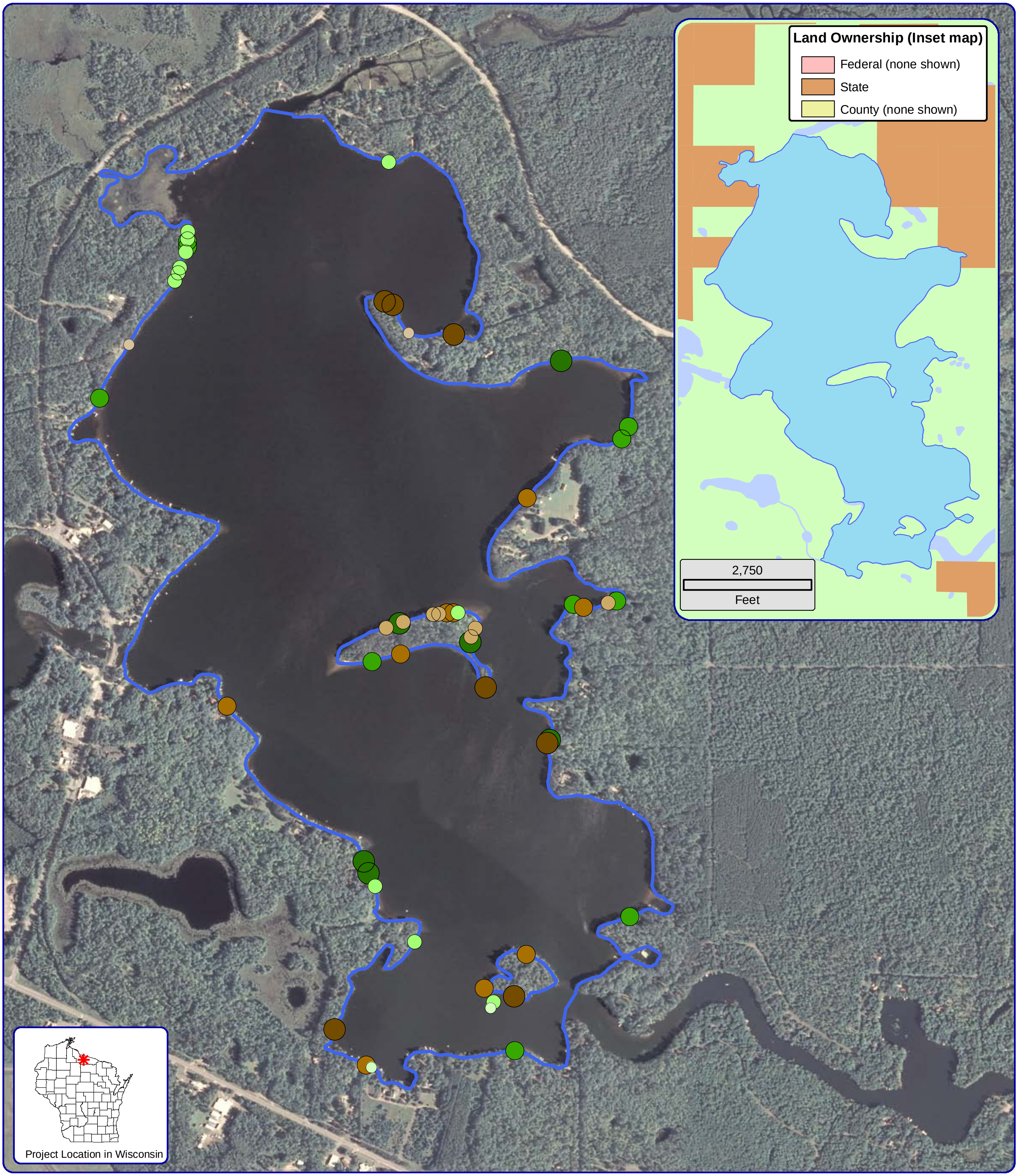
Manitowish Waters Chain of Lakes

Vilas County, Wisconsin

Shoreline Condition

Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Shoreline Assessment: Onterra, 2013
Orthophotgraphy: NAIP, 2010
Map Date: September 24, 2013
Filename: Rest_Map1_SA_2012.mxd



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920.338.8860
www.onterra-eco.com

Sources:
Shoreline Assessment: Onterra, 2013
Orthophotography: NAIP, 2010
Map Date: September 24, 2013
Filename: Rest_Map2_CWH_2012.mxd

Legend

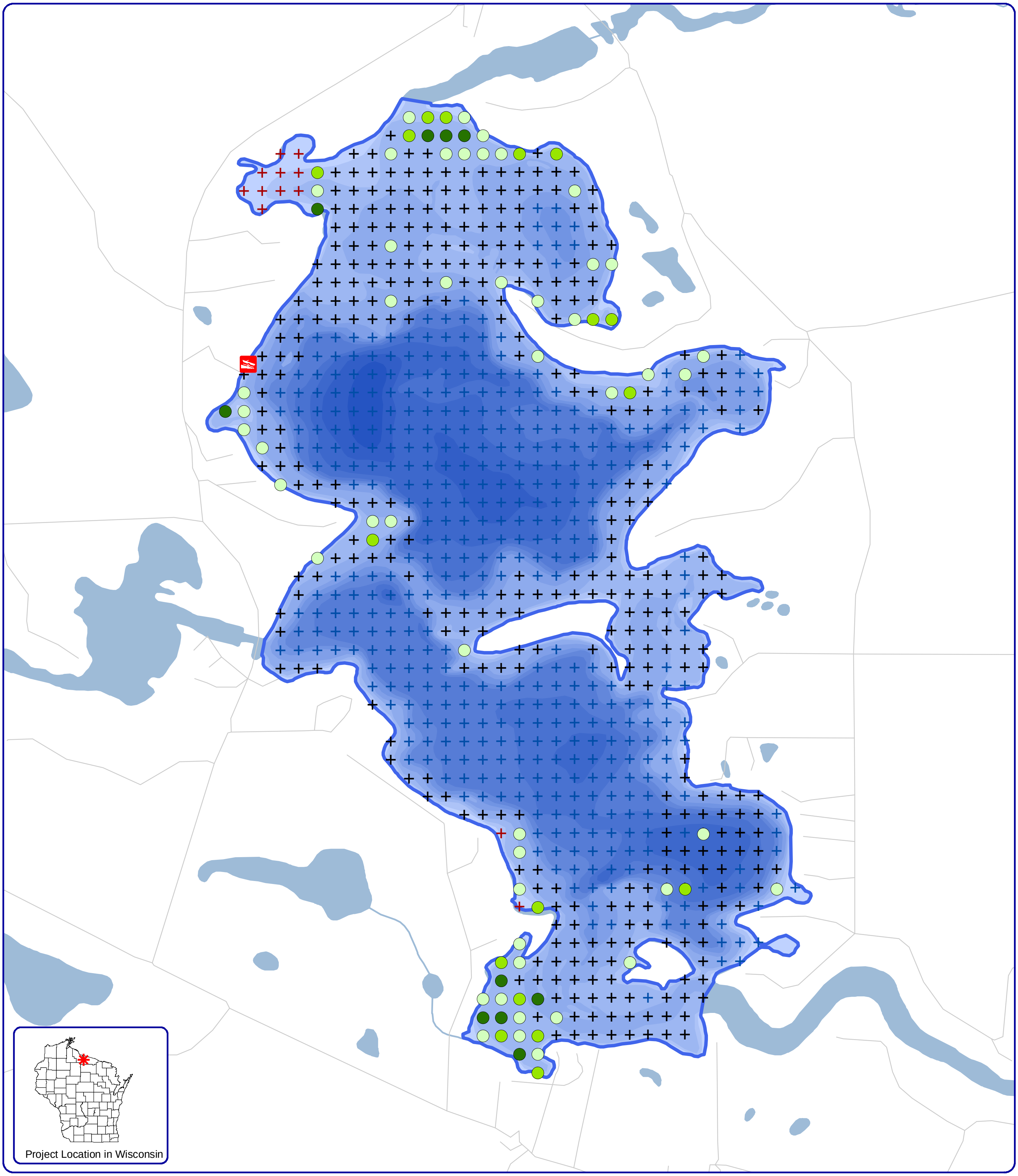
- 2-8 Inches, No Branches
- 2-8 Inches, Minimal Branches
- 2-8 Inches, Moderate Branches
- 2-8 Inches, Full Canopy (none)
- >8 Inches, No Branches
- >8 Inches, Minimal Branches (none)
- >8 Inches, Moderate Branches
- >8 Inches, Full Canopy
- Cluster

Rest Lake - Map 2

Manitowish Waters Chain of Lakes

Vilas County, Wisconsin

Course Woody Habitat



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Feet

Onterra LLC
Lake Management Planning

815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Aquatic Plant Survey: Onterra, 2012
Map Date: September 24, 2013
Filename: Rest_Map3_TRFPI_2012.mxd

Legend

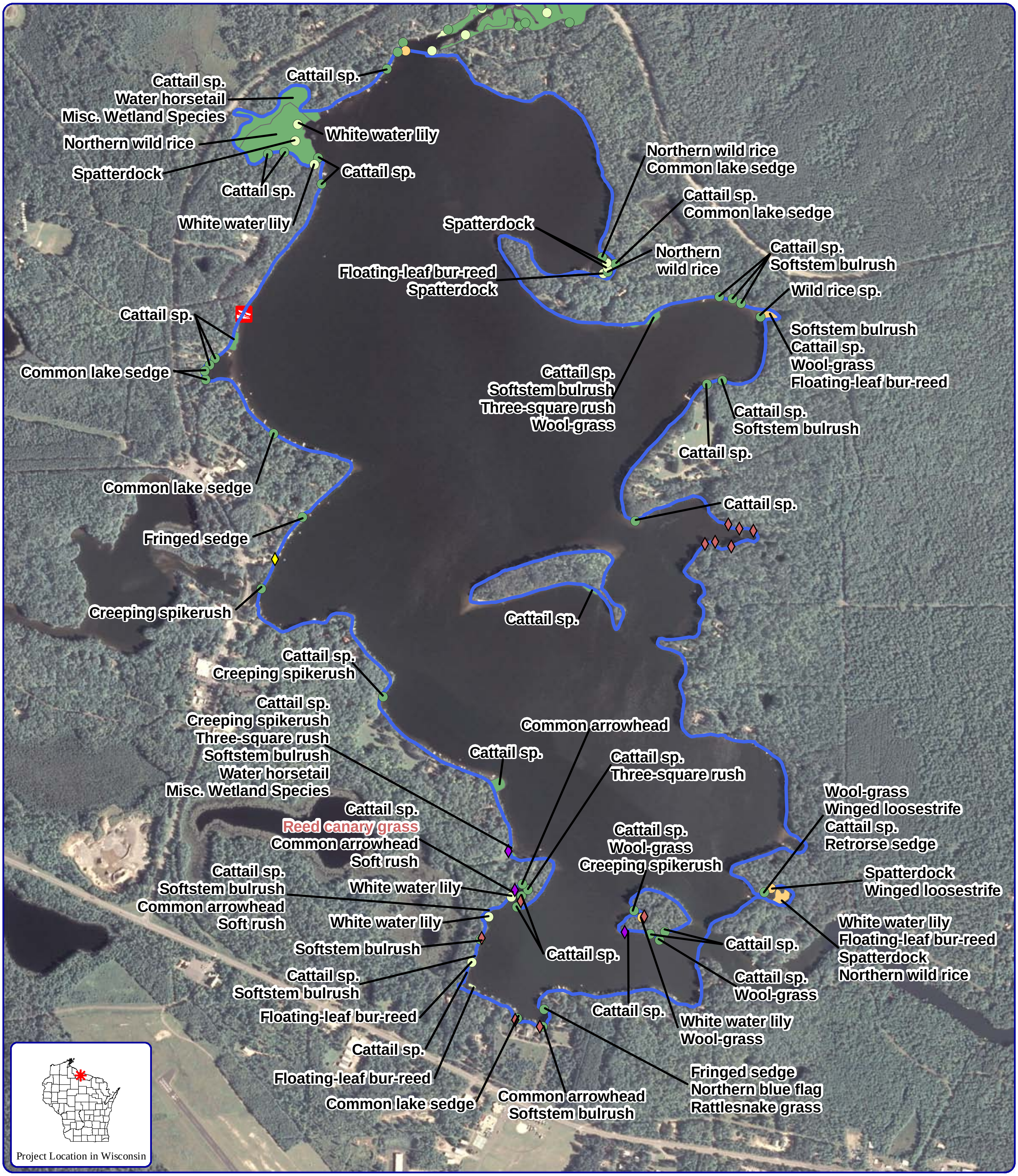
2012 Point-intercept Survey

- No Vegetation
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- Too Deep (Below Max Depth of Plants)
- Non-navigable

Rest Lake - Map 3

Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin

Aquatic Vegetation Distribution



N W E S

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Feet

Legend

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

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

Exotic Plant Communities
- Purple Loosestrife
- Pale Yellow Iris
- Reed Canary Grass

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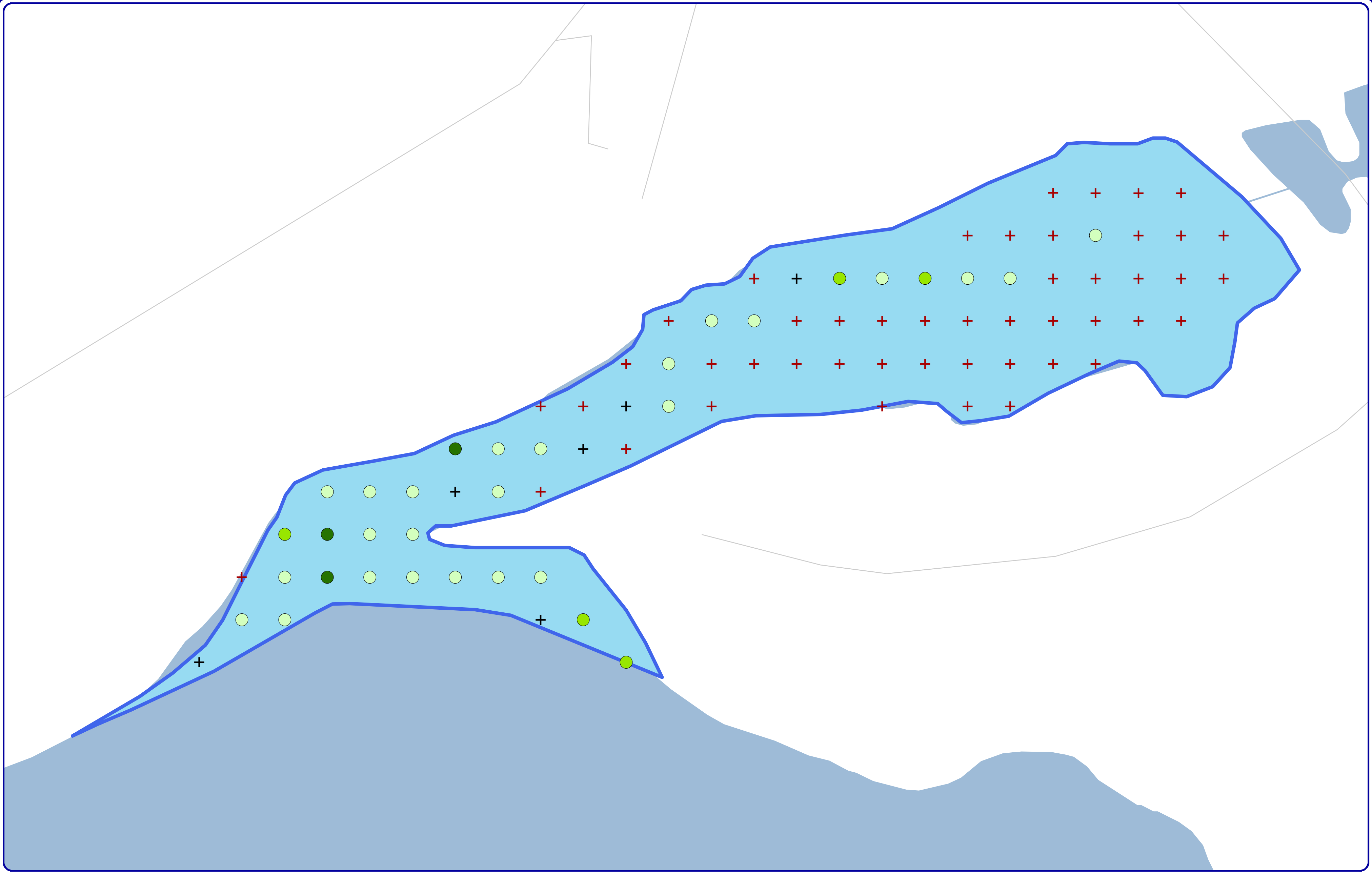
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
Map date: December 11, 2012
Filename: Rest_Comm_2012.mxd

Rest Lake - Map 4
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Emergent & Floating-leaf Aquatic Plant Communities

Papoose Bay - Map 1
Manitowish Waters Chain of Lakes
Vilas County, Wisconsin
Aquatic Plant Distribution



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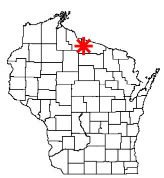
Project Location in Wisconsin

Legend

2012 Point-intercept Survey

- No Vegetation
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- Too Deep (Below Max Depth of Plants)
- Non-navigable

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www.onterra-eco.com

Sources:
Aquatic Plant Surveyt: Onterra, 2012
Roads and Hydro: WDNR
Map Date: September 24, 2013
Filename: PapooseBay_Map1_TRFPI_2012.mxd

N
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325
Feet

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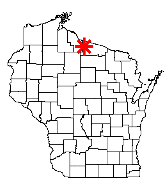
920.338.8860
www.onterra-eco.com

Sources:
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
Map date: December 11, 2012
Filename: PapooseBay_Map2_Comm_2012.mxd



Project Location in Wisconsin

Legend

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

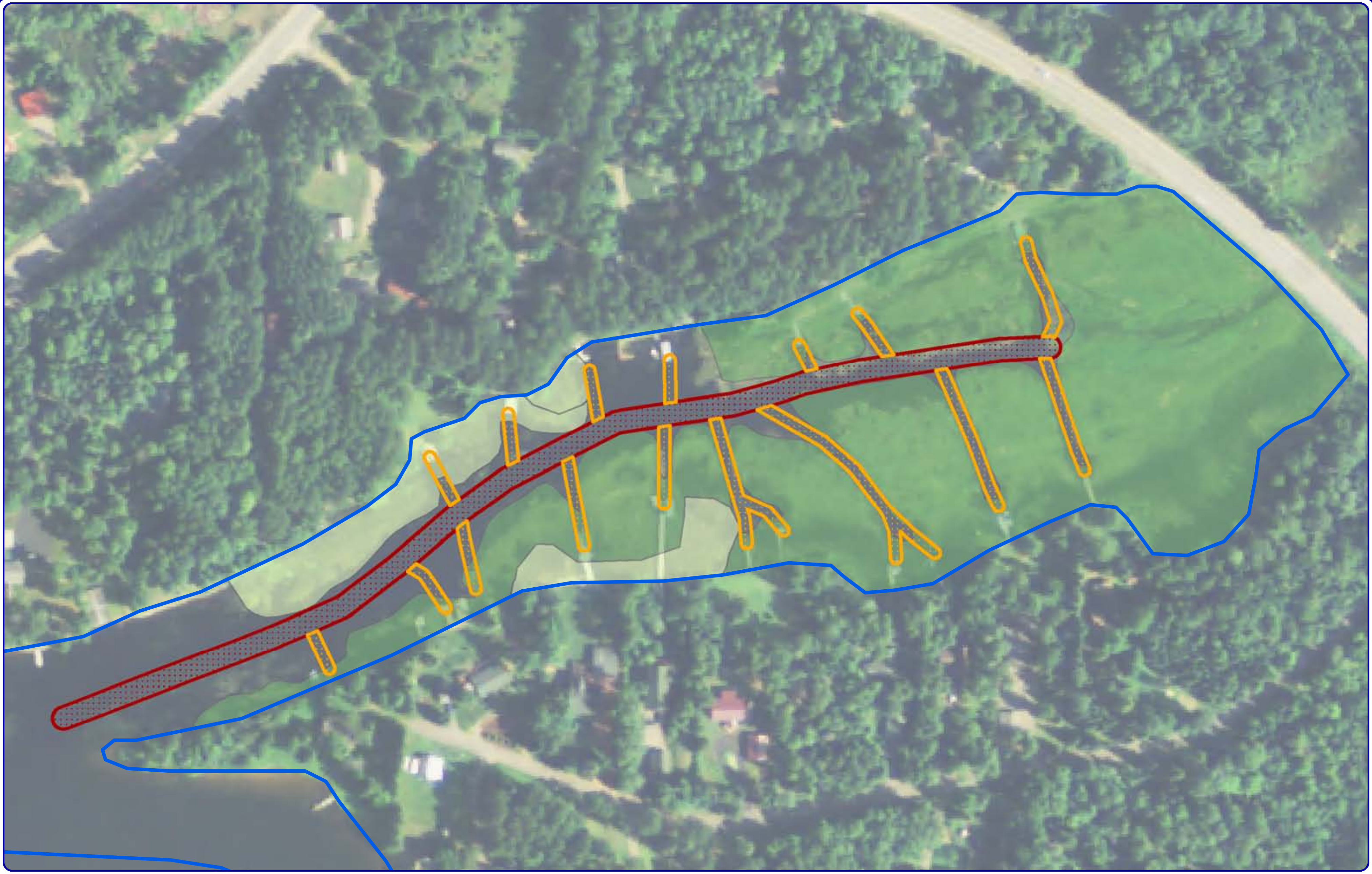
Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Papoose Bay - Map 2
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Emergent & Floating-leaf Aquatic Plant Communities

Papoose Bay - Map 3

Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin

Current Mechanical Harvest Plan



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175
Feet

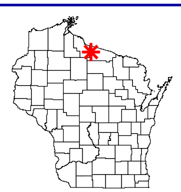
Legend

Mechanical Harvest Plan

- Common Use Lane *(30-ft width, 1.0 total acres)*
- Riparian Acess Lane *(15-ft width, 0.7 total acres)*

Northern Wild Rice

- Dense Plant Community
- Sparse Plant Community



Project Location in Wisconsin

Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
Map date: October 8, 2013
Filename: Rest_Map5_MechanicalHarvestPlan.mxd