Please note that study methods and explanations of analyses for Big Saint Germain Lake can be found within the Town of St. Germain Town-wide Management Plan document.

8.2 Big Saint Germain Lake

An Introduction to Big Saint Germain Lake

Big Saint Germain Lake, Vilas County, is a 1,622-acre deep lowland drainage lake with a maximum depth of 42 feet and a mean depth of 21 feet (Big Saint Germain Lake – Map 1). Its watershed encompasses approximately 41,283 acres, and the lake is fed by Plum and Lost creeks from the north and Mud Creek from the west. Lake Content is connected to Big Saint Germain Lake to the south via a manmade channel constructed over a naturally-occurring waterway. Big Saint Germain is drained via the Saint Germain River to south which flows into downstream Fawn Lake. In 2019, 41 native aquatic plant species were located within the lake, of which wild celery (*Vallisneria americana*) was the most common. One non-native plant, narrow-leaved cattail (*Typha angustifolia)*, was found during the surveys.

Lake at a Glance - Big Saint Germain Lake

Morphology	
LakeType	Two-Story - Deep Lowland Drainage Lake
Surface Area (Acres)	1,622
Max Depth (feet)	42
Mean Depth (feet)	21
Perimeter (Miles)	8.2
Shoreline Complexity	2.1
Watershed Area (Acres)	41,283
Watershed to Lake Area Ratio	24:1
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	27.9
Avg Summer Chl-α (µg/L)	11.0
Avg Summer Secchi Depth (ft)	10.1
Summer pH	8.5
Alkalinity (mg/L as $CaCO_3$)	36.9

Vegetation (2019)	
Number of Native Species	41
NHI-Listed Species	None
Exotic Species	Narrow-leaved cattail (*Typha angustifolia*)
Average Conservatism	6.7
Floristic Quality	37.4
Simpson's Diversity (1-D)	0.90

Descriptions of these parameters can be found within the Town-Wide portion of the management plan

8.2.1 Big Saint Germain Lake Water Quality

It is often difficult to determine the status of a lake's water quality purely through observation. Anecdotal accounts of a lake "getting better" or "getting worse" can be difficult to judge because a) a lake's water quality may fluctuate from year to year based upon environmental conditions such as precipitation, and b) differences in observation and perception of water quality can differ greatly from person to person. It is best to analyze the water quality of a lake through scientific data as this gives a concrete indication as to the health of the lake, and whether its health has deteriorated or improved. Further, by looking at data for similar lakes regionally and statewide, the status of a lake's water quality can be made by comparison.

As is discussed in the Town-Wide Report Section, two-story lakes like Little Saint Germain Lake are deep lakes which thermally stratify during the summer and have the potential to support a cold, oxygenated hypolimnion (bottom waters) and coldwater fish populations (e.g., cisco). Maintaining sufficient oxygen within the deep, cold waters of the hypolimnion in summer is essential if coldwater fish populations are to survive. Higher levels of nutrients and therefore biological production/decomposition can result in an increased rate of oxygen demand and a loss of oxygen from bottom waters in summer. Because of this, two-story lakes have the most protective phosphorus thresholds of Wisconsin's lakes to ensure that this coldwater habitat is preserved.

Cisco have been documented in Big Saint Germain Lake. However, the most recent survey by the WDNR in 2014 found them in low abundance (Lyons et al. 2015). As is discussed later in this section, available temperature and dissolved oxygen data indicate that the cold, oxygenated habitat cisco require for survival is minimal in Big Saint Germain Lake during the summer. While near-bottom water temperatures in summer are ideal for cisco, these waters are completely devoid of oxygen. In 2019, there was a very narrow zone of water at around 20 feet where temperature and dissolved oxygen were within tolerable ranges for cisco. Despite suboptimal conditions, as of 2014 Big Saint Germain Lake supports at least a small cisco population, and is therefore classified as a two-story lake.

Water quality data were collected from Big Saint Germain Lake on six occasions in 2019. Data were collected by Onterra staff and citizen lake volunteers. The lake was sampled for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk depth, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October) and summer months (June-August). Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. In addition to sampling efforts completed in 2019, any historical data was researched and are included within this report as available.

Near-surface total phosphorus data from Big Saint Germain Lake are available from 2000-2002, and 2010-2012, and 2014-2019 (Figure 8.2.1-1). Average annual summer phosphorus concentrations in Big Saint Germain Lake are variable, ranging 20.3 µg/L in 2018 and 2019 to 46.7 µg/L in 2012. The weighted summer average total phosphorus concentration is 27.9 µg/L and straddles the threshold between *fair* and *poor* for Wisconsin's two-story lakes. Big Saint Germain Lake's summer average total phosphorus concentrations are higher than the median values for both deep lowland drainage lakes in the state and all lake types in the Northern Lakes and Forests (NLF) ecoregion. However, phosphorus concentrations in 2018 and 2019 were below average, straddling the threshold between *good* and *fair*.

While annual phosphorus concentrations are variable in Big Saint Germain Lake, data are limited and it is not clear if any trends are occurring over time. To investigate why phosphorus concentrations may vary from year to year, phosphorus concentrations were examined against annual weather data. Increases in phosphorus concentrations have been associated with increased precipitation in other Wisconsin lakes (Carpenter et al. 2014), and precipitation data were obtained from the nearby Eagle River Airport. Surprisingly, these data show that phosphorus concentrations in Big Saint Germain Lake were highest in years with the lower precipitation (e.g., 2012). Phosphorus concentrations were also compared against average monthly temperatures. This analysis found that phosphorus concentrations in Big Saint Germain Lake were positively correlated with average air temperatures in May and June.

The correlation of phosphorus concentrations in Big Saint Germain and air temperature suggest that the variability in annual phosphorus concentrations is likely being influenced by differences in thermal stratification and internal nutrient loading. Internal nutrient loading involves the release of phosphorus (and other nutrients) from lake bottom sediments into the overlying water. In general, lakes tend to act as phosphorus sinks, meaning they accumulate phosphorus over time within lake sediments. In most lakes, there is a net movement of phosphorus from the water to bottom sediments where it accumulates. The retention of this phosphorus within bottom sediments depends on a number of physical, chemical, and biological factors (Wetzel 2001). If this phosphorus remains bound within bottom sediments, it is largely unavailable for biological use. However, under certain conditions, this phosphorus can be released from bottom sediments into the overlying water where it may become biologically available.

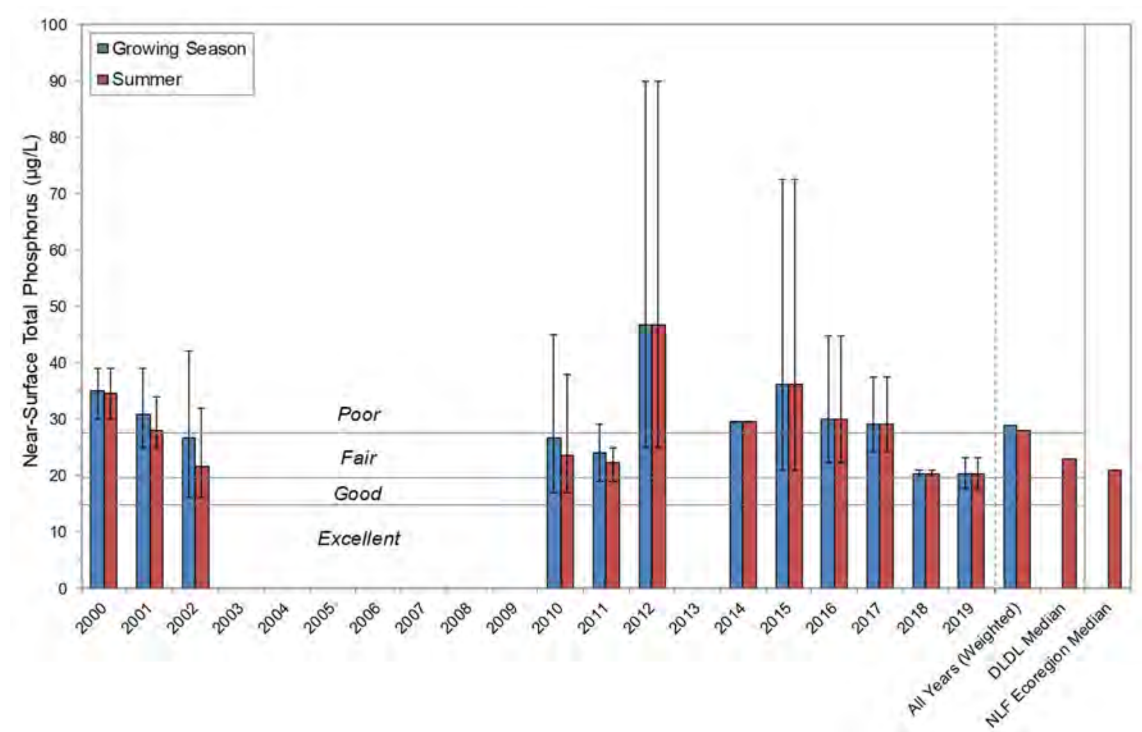


Figure 8.2.1-1. Big Saint Germain Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Index thresholds apply to Wisconsin two-story lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

When water at the sediment-water interface contains oxygen, phosphorus largely remains bound to ferric iron within the sediment. When the water at the sediment-water interface becomes anoxic, or devoid of oxygen, ferric iron is reduced to ferrous iron and the bond between iron and phosphorus is broken. Under these conditions, iron and phosphorus are now soluble in water and are released from the sediments into the overlying water (Pettersson 1998).

Anoxia at the sediment-water interface typically first develops following thermal stratification, or the formation of distinct layers of water based on temperature and density. As surface waters warm in late-spring/early summer, they become less dense and float atop a colder, denser layer of water below. The large density gradient between the upper, warm layer of water (epilimnion) and lower, cold layer of water (hypolimnion) prevents these layers from mixing together and eliminates atmospheric diffusion of oxygen into bottom waters. If there is a high rate of biological decomposition of organic matter in the bottom sediments, anoxic conditions within the hypolimnion can develop as oxygen is consumed and is not replaced through mixing. The loss of oxygen then results in the release of phosphorus from bottom sediments into the water of the hypolimnion.

The development of an anoxic hypolimnion and subsequent release of phosphorus from bottom sediments occurs in many lakes in Wisconsin. However, in deeper lakes which remain stratified during the summer, internal nutrient loading is often not problematic as the majority of the phosphorus released from bottom sediments is confined within the hypolimnion where it is largely inaccessible to phytoplankton. These deep lakes remain stratified throughout the summer (and winter) and experience only two complete mixing events (turnover) per year, one in spring and one in fall (dimictic lakes). In deep lakes, phosphorus released from bottom sediments into the hypolimnion during stratification only becomes available to phytoplankton in surface waters during the spring and fall mixing events. While these spring and fall mixing events can stimulate diatom and golden-brown phytoplankton blooms, these mixing events generally to not stimulate nuisance algal blooms because water temperatures are cooler.

Internal nutrient loading can become problematic in lakes when sediment-released phosphorus becomes accessible to phytoplankton during the summer months when surface temperatures are at their warmest. Sediment-released phosphorus can be mobilized to surface waters during the summer in shallow, polymictic lakes, or moderately shallow lakes which have the capacity to experience multiple stratification and mixing events over the course of the growing season. Some polymictic lakes tend to straddle the boundary between deep and shallow lakes and have the capacity to break stratification in summer when sufficient wind energy is generated. Consequently, phosphorus which has accumulated in the anoxic hypolimnion during periods of stratification is mobilized to the surface during partial or full mixing events where it then can spur nuisance phytoplankton blooms.

Although summer average concentrations are informative, in Big Saint Germain Lake there are seasonal changes that are important. The higher summer mean values in 2012 and 2015 are due to unusually high concentrations in August of those years. These higher phosphorus values also corresponded to high chlorophyll-*a* concentrations, indicating visible algal blooms were likely occurring. While phosphorus concentrations in August of 2012 and 2015 were unusually high, concentrations in August of most years are higher when compared to June and July (Figure 8.2.1-2), suggesting the lake receives a ‘pulse’ of phosphorus in late summer in most years.

While phosphorus can be mobilized to the surface from anoxic bottom waters during a complete mixing event, phosphorus can also be mobilized to the surface in polymictic places through entrainment, or the continual deepening of the epilimnion and erosion of the metalimnion (transition zone or thermocline) and hypolimnion (Wetzel 2001). Wind-driven water generates turbulence across the thermal barrier between the epilimnion and the metalimnion and the metalimnion is eroded, mixing sediment-released nutrients into the epilimnion above. Both periodic mixing and entrainment act as “nutrient pumps” in polymictic lakes, delivering sediment-released nutrients in bottom waters to surface waters (Orihel et al. 2015). While a continuum exists between dimictic and polymictic lakes, the Osgood Index (Osgood 1988) is used to determine the probability that a lake will remain stratified during the summer. This probability is estimated using the ratio of the lake’s mean depth to its surface area. Lakes with an Osgood Index of less than 4.0

are deemed polymictic. Big Saint Germain Lake has an Osgood Index value of 2.5, indicating it is a polymictic system.

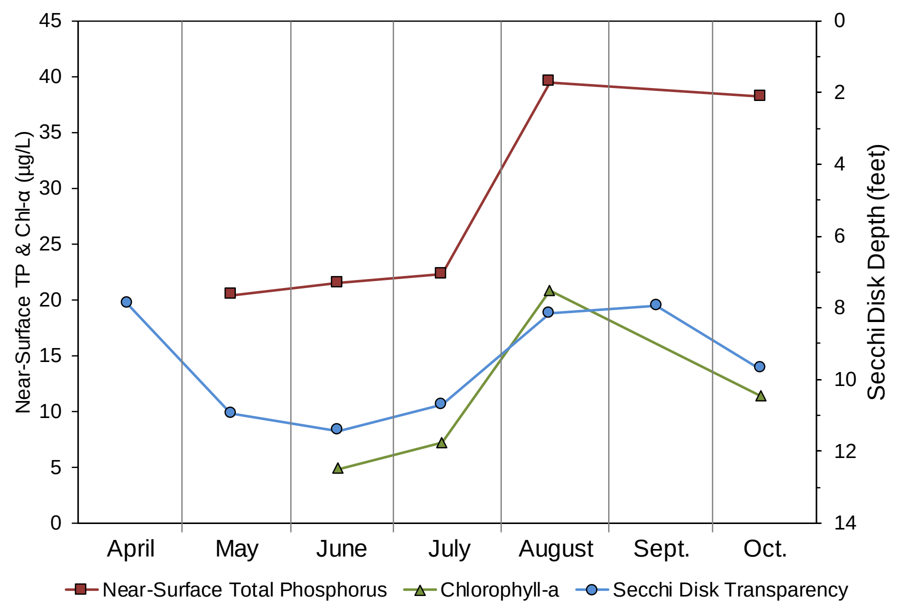


Figure 8.2.1-2. Average monthly near-surface total phosphorus, chlorophyll-α, and Secchi disk depth in Big Saint Germain Lake. Calculated using available data from 2000-2019. Data show phosphorus concentrations tend to increase in August, likely the result of entrainment of sediment-released phosphorus from bottom waters to the surface.

The amount of phosphorus released from bottom sediments in Big Saint Germain Lake is going to depend on the strength and duration of thermal stratification. The strength and duration of thermal stratification is going to depend largely on temperature and wind. In years with warmer temperatures, the duration of stratification will likely be longer. These longer periods of stratification can result in longer periods of anoxia and release of nutrients from bottom sediments (Battarbee et al. 2012). In Big Saint Germain Lake, the lake was likely stratified for longer in 2012 and 2015, allowing more phosphorus to accumulate in bottom waters. As the summer progressed, the epilimnion was likely driven deeper, cutting into anoxic bottom waters and mobilizing this phosphorus to the surface.

While this likely happens to some extent each year, the amount of phosphorus in bottom waters is going to depend on the duration of stratification. In 2019, August phosphorus concentrations were only slightly higher when compared to June and July, suggesting internal phosphorus loading was not as significant. Bottom waters were devoid of oxygen in July 2019 in Big Saint Germain Lake, and phosphorus concentrations in the near bottom waters was 171 µg/L, approximately nine times higher than at the surface and indicating the release of phosphorus from bottom sediments was occurring. A concentration of 171 µg/L is not a high concentration compared to other lakes which experience internal nutrient loading. However, Big Saint Germain Lake has a large hypolimnion, which in 2019 had a volume of approximately 12,500 acre-feet or nearly 40% of the lake's volume. Using the July 2019 phosphorus concentrations and the lake's volume, it is estimated that if the lake experienced a complete mixing event, near-surface phosphorus concentrations would have increased to 75 µg/L. These estimated concentrations are similar to those measured in the late summers of 2012 and 2015.

A more detailed study of Big Saint Germain Lake would have to be completed to accurately quantify the amount of phosphorus originating from internal nutrient loading. However, the available data indicate the significance of internal nutrient loading on the lake's water quality will vary from year to year depending on climatic conditions. Ongoing monitoring of the lake's water quality through the CLMN program will allow for a greater understanding of phosphorus dynamics in this system and the significance of internal nutrient loading on algal blooms. If phosphorus concentrations increase and algal blooms become more frequent, additional studies should be completed to determine if there are any applicable management strategies that could be implemented to reduce the internal release of phosphorus from deep-water bottom sediments.

Chlorophyll-*a* data from Big Saint Germain Lake are available from 1979, 2000-2002, and from 2010-2012, and 2014-2019 (Figure 8.2.1-3). Average summer chlorophyll-*a* concentrations ranged from 4.7 µg/L in 2011 to 26.1 µg/L in 2012. Big Saint Germain Lake's summer average chlorophyll-*a* concentration is 11.0 µg/L, falling into the *poor* category for two-story and the *good* category for deep lowland drainage lakes. Big Saint Germain Lake's summer average chlorophyll-*a* concentration is higher than the median values for deep lowland drainage lakes in the state and double the median for all lake types in the NLF ecoregion. Given the variability in phosphorus concentrations from year to year, chlorophyll-*a* concentrations are also variable. Chlorophyll-*a* concentrations are highly correlated with phosphorus – years with the highest phosphorus concentrations also have the highest chlorophyll-*a* concentrations (Figure 8.2.1-4).

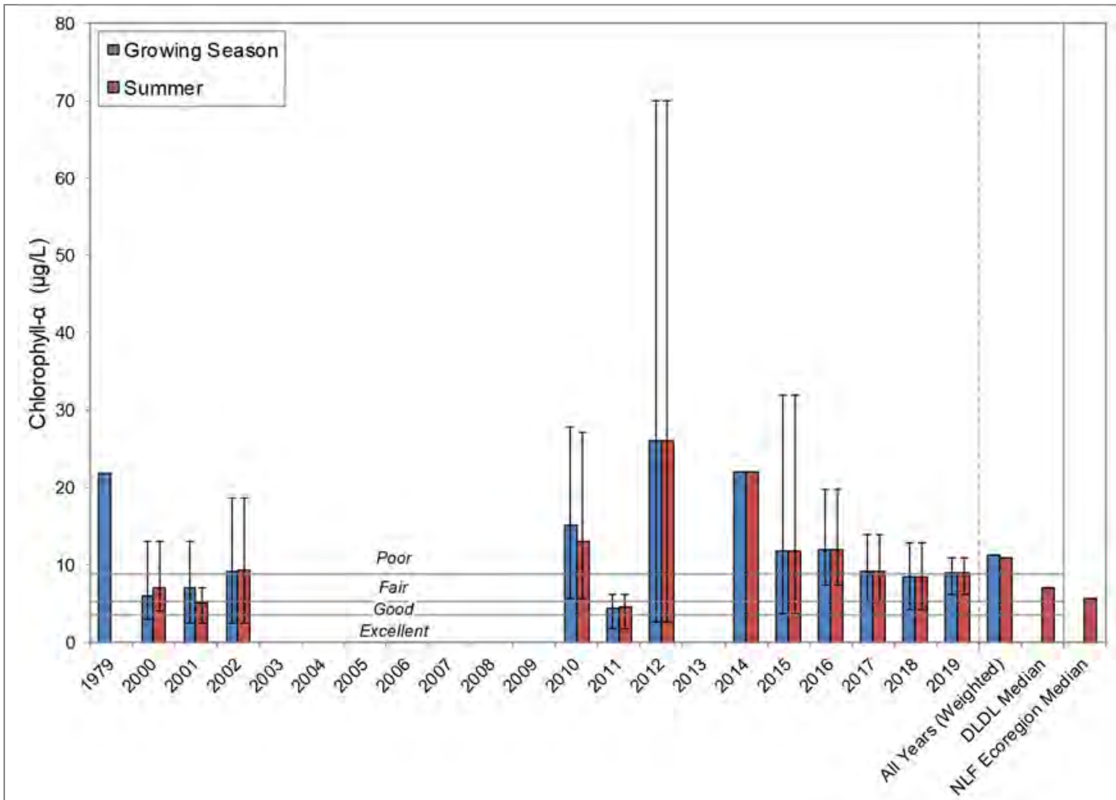


Figure 8.2.1-3. Big Saint Germain Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Index thresholds apply to Wisconsin two-story lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

There is a much more complete record of Secchi disk depth data from Big Saint Germain Lake available than there is for total phosphorus or chlorophyll-*a*. Data are available from 1979, 1989-1998 and 2000-2019 (Figure 8.2.1-5). Average summer Secchi disk depths ranged from 7.2 feet in 2000 to 12.0 feet in 2007, 2011, and 2012. The weighted summer average Secchi disk depth is 10.1 feet and falls into the *good* category for two-story lakes and the *excellent* category for deep lowland drainage lakes in Wisconsin. Big Saint Germain Lake's weighted summer average Secchi disk depth exceeds the median values for both deep lowland drainage lakes in the state and for all lake types in the NLF ecoregion. Water clarity in Big Saint Germain Lake is higher than expected based on chlorophyll-*a* concentrations. This may indicate that the phytoplankton community is dominated by larger particulates, such as *Aphanizomenon* or *Gloeotrichia*.

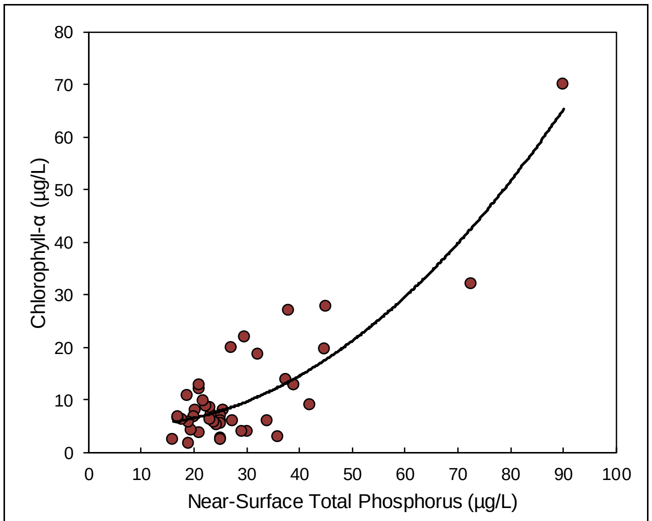


Figure 8.2.1-4. Big Saint Germain Lake chlorophyll-α plotted against near-surface total phosphorus.

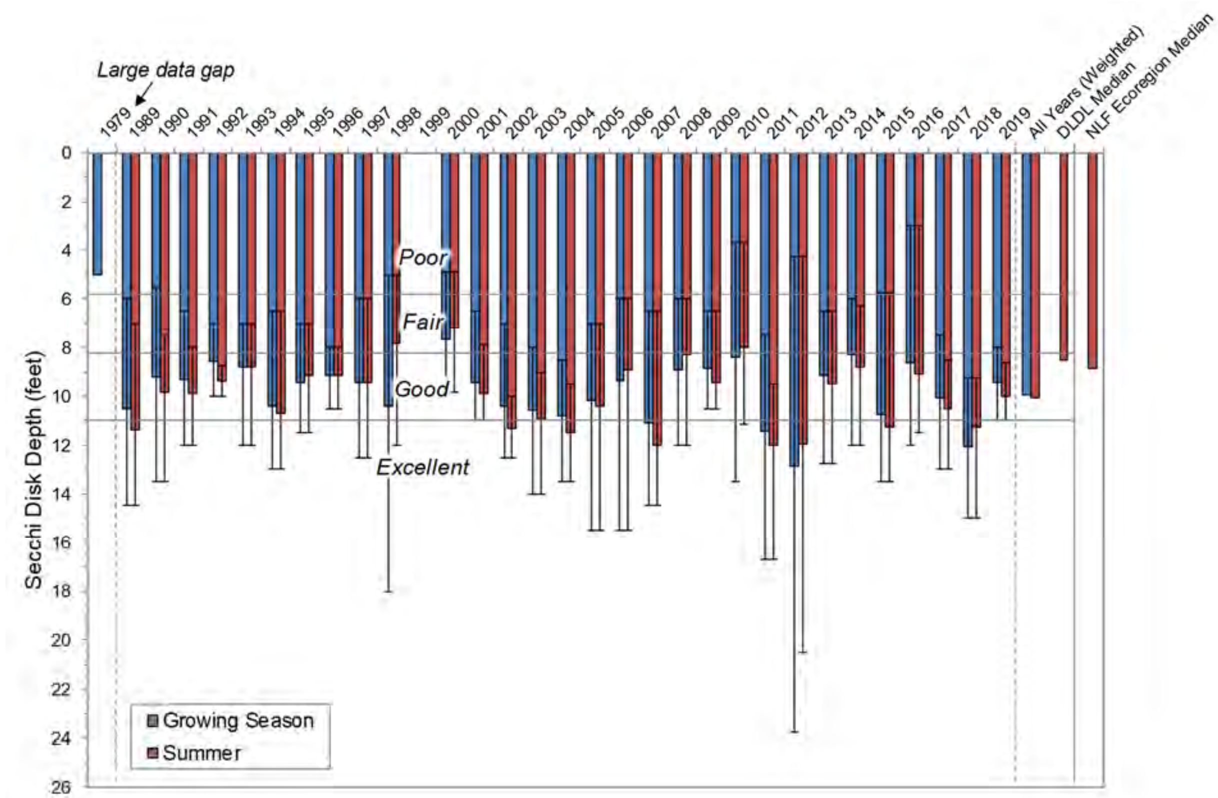


Figure 8.2.1-5. Big Saint Germain Lake average annual Secchi disk depths and median Secchi disk depths for state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Index thresholds apply to Wisconsin two-story lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Secchi disk depth in Big Saint Germain Lake is highly correlated with chlorophyll-*a* concentrations (Figure 8.2.1-6), indicating like most Wisconsin lakes, algae are the primary factor influencing water clarity. While water clarity varies from year to year in Big Saint Germain Lake, water clarity also has the capacity to vary widely within a given season. For example, in 2012, Secchi disk depths collected in May and June were around 20 feet before steadily declining to 4 feet by August as algal production increased. Water clarity can be expected to be lower in years when more phosphorus is mobilized to surface waters fueling agal production.

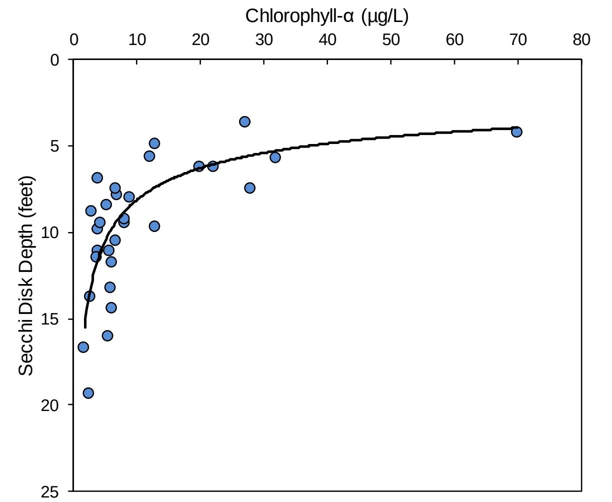


Figure 8.2.1-6. Big Saint Germain Lake Secchi disk depths plotted against chlorophyll-α.

A measure of water clarity once all of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color was measured in Big Saint Germain Lake in 2019 at 10 SU (standard units), indicating the lake's water was *slightly tea-colored*. This true color value is low, but indicates that these dissolved humic substances influence Big Saint Germain Lake's water clarity to some extent.

Limiting Plant Nutrient of Big Saint Germain Lake

Using midsummer nitrogen and phosphorus concentrations from Big Saint Germain Lake, a nitrogen:phosphorus ratio of 20:1 was calculated. This finding indicates that Big Saint Germain Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that phosphorus is the primary nutrient regulating algal growth.

Big Saint Germain Lake Trophic State

Figure 8.2.1-7 contains the Trophic State Index (TSI) values for Big Saint Germain Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk depth data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values are for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* in Big Saint Germain Lake indicate the lake is at present in a eutrophic state. Based upon just the Secchi disk depth, the lake would be classified as mesotrophic. As mentioned above, the water clarity in this lake is better than would be expected with the phosphorus and chlorophyll-*a* concentrations. Phosphorus and chlorophyll-a are the best parameters to measure a lake's trophic status as these are the parameters used by the WDNR to determine if a lake is impaired. Big Saint Germain Lake's productivity based upon phosphorus and chlorophyll-*a* is higher than other deep lowland drainage lakes in Wisconsin and all lake types within the NLF ecoregion.

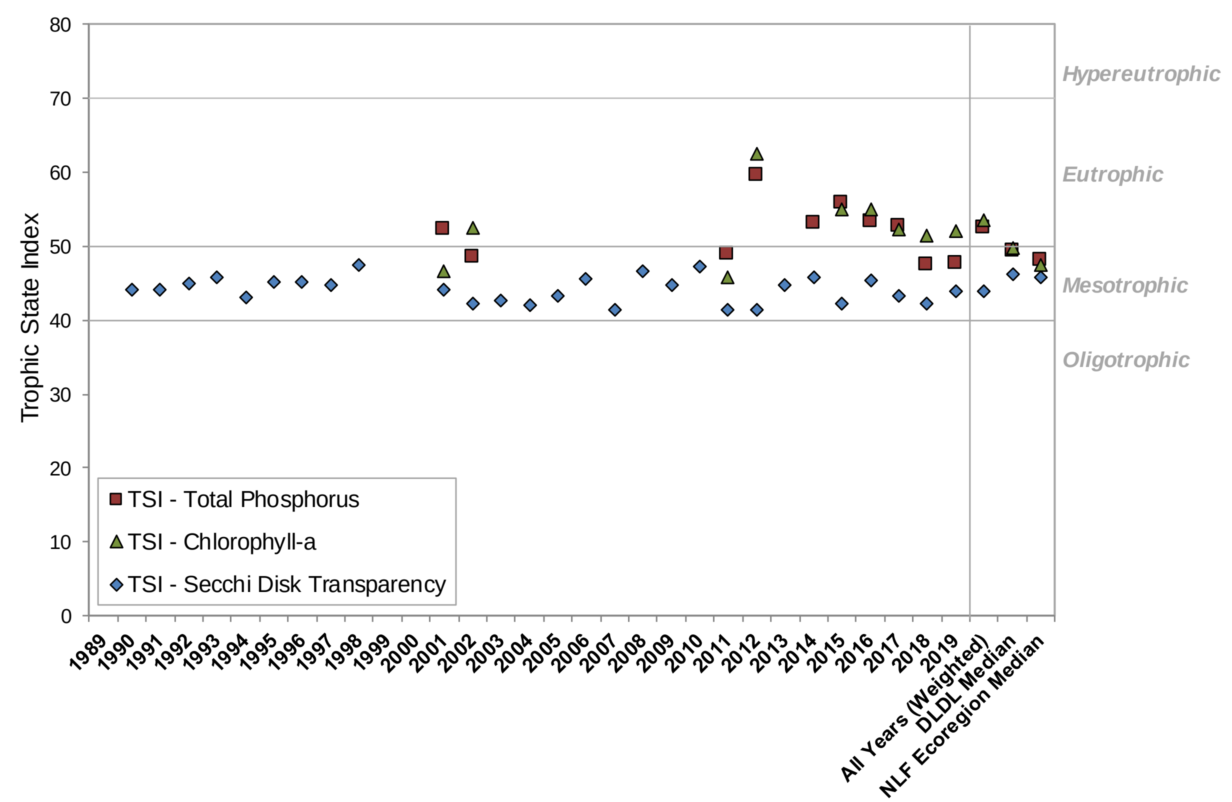


Figure 8.2.1-7. Big Saint Germain Lake, statewide deep lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Big Saint Germain Lake

Dissolved oxygen and temperature profiles were collected in June, July, and August 2019. Figures depicting these data are displayed in Figure 8.2.1-8. Big Saint Germain Lake straddles the threshold between being a *dimictic* lake, a lake which remains stratified during the summer, and a *polymictic* lake, a lake which can periodically mix during the summer. The temperature and dissolved oxygen data that are available suggest that the lake likely remains stratified in most years, but as discussed previously, there is also evidence to indicate the mobilization of phosphorus from bottom waters to the surface in late summer. This is likely through a process called entrainment, where warmer surface waters are gradually driven deeper, eroding into the cooler waters below.

During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. Given Big Saint Germain Lake's deeper nature, wind and water movement are not sufficient during the summer to completely mix these layers together, only the warmer upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen and decomposition of organic matter within this layer depletes available oxygen. Without oxygen, sediment-bound phosphorus is released into the overlying water. As wind continues to mix surface waters, this layer is driven deeper, and turbulence is generated at the boundary between warm and cold layers. Phosphorus from bottom waters is entrained across this barrier and mobilized to surface waters later in the summer. In fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion.

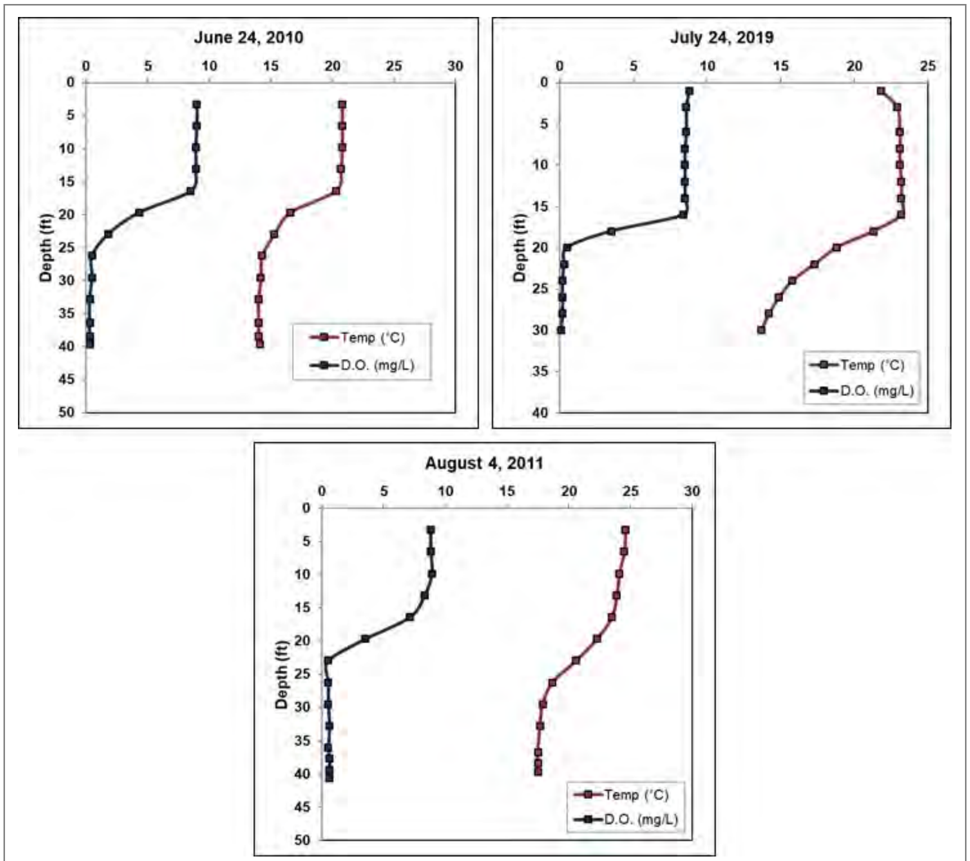


Figure 8.2.1-8. Big Saint Germain Lake 2019 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Big Saint Germain 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 Big Saint Germain 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.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-) and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The mid-summer pH of the water in Big Saint Germain Lake was found to be alkaline with a value of 8.5 and falls at the high end of the normal range for Wisconsin Lakes.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Big Saint Germain Lake was 36.9 mg/L (mg/L as $CaCO_3$), indicating that the lake is not sensitive to lower pH values from acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Big Saint Germain Lake's pH of 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 Big Saint Germain Lake was found to be 11.1 mg/L, meaning it is unlikely to support the growth of zebra mussels.

8.2.2 Big Saint Germain Lake Watershed Assessment

Two aspects of a lake's watershed are the key factors in determining the amount of phosphorus the watershed exports to the lake: 1) the land cover (land use) within the watershed and 2) the size of the watershed. The type of land cover and the amount of that land cover that exists in the watershed is largely going to determine the amount of phosphorus (and sediment) that runs off the land and eventually makes its way to the lake. The actual amount of pollutants (nutrients, sediment, toxins, etc.) depends greatly on how the land within the watershed is used. Areas within a lake's watershed that are naturally vegetated (e.g., forests, grasslands, and wetlands) strongly influence the way water behaves on the land surface after it falls as precipitation or is released by the melting of snow (Silk and Ciruna 2005).

Runoff is slowed down in areas with denser vegetation and increases the time it takes for precipitation from a storm event to reach the lake. This allows more water to soak into the soil and reduces the potential for flooding. Intact wetlands within a lake's watershed have been likened to the "kidneys of the landscape" as they filter out nutrients, sediments, and other pollutants from water which passes through them (Silk and Ciruna 2005). The water quality within a lake is largely a reflection of the health of its watershed, and maintaining natural land cover within a lake's watershed is essential for maintaining good water quality.

Among the largest threats to a lake's water quality is the conversion of natural areas to agriculture and urban development. Conversion of natural areas to agriculture disrupts the hydrologic regime and increases surface runoff due to increased soil compaction and reduced water infiltration. Wetlands which were drained and converted to farmland were shown to increase runoff by 200-400% (Silk and Ciruna 2005). Agriculture accounts for 60% of the pollutants in lakes and rivers in the United States due to increased runoff in combination with the application of fertilizers, pesticides, and manure.

Similar to agriculture, urban development can significantly alter the hydrologic regime within a watershed, primarily through the installation of impervious surfaces (e.g., roads, driveways, roof-tops) which decrease water infiltration and increase runoff. As impervious surface cover increases, the time it takes water from a storm event to reach the lake decreases. With the increase in water velocity and volume entering the water body, nutrient and sediment input also increase, degrading water quality. Nutrient input can also increase from urban areas as the result of fertilizer application, wastewater treatment facilities, and other industrial activities.

As is discussed further in this section, Big Saint Germain Lake's watershed is largely comprised of intact upland forests and wetlands with some smaller areas of rural and urban development. In the forested watersheds of northern Wisconsin where soils and climate are not as conducive for farming, apart from shoreland development (discussed in the next section) forestry or timber harvest likely represents the largest man-made disturbance occurring in these watersheds. While timber harvest has the potential to increase sediment erosion through the removal of vegetation and construction of access roads and bridges, the impacts of timber harvest to a lake's water quality are going to be highly dependent upon harvest rates and methods, vegetation management, and the location and size of these activities within the watershed (Silk and Ciruna 2005).

Wisconsin is required by federal law to develop and implement a program of best management practices (BMPs) to reduce nonpoint source pollution, including from timber harvesting activities

(WDNR PUB FR-093 2010). In summary, any forestry activities that occur within Big Saint Germain Lake's watershed must be implemented under this framework and should not impart significant impacts to the lake's water quality.

In addition to land cover within the watershed, the size of the watershed relative to the water volume within the lake also influences water quality. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drain to each surface-acre of the lake. Larger ratios result in the watershed having a greater role in the lake's annual water budget and phosphorus load. In systems with lower WS:LA ratios, land cover type plays a very important role in how much phosphorus is loaded to the lake from the watershed. In these systems, the occurrence of agriculture or urban development in even a small percentage of the watershed (less than 10%) can unnaturally elevate phosphorus inputs to the lake. If these land cover types are converted to a cover that does not export as much phosphorus, such as converting row crop areas to grasslands or forested areas, the phosphorus load and its impacts to the lake may be decreased. In fact, if the phosphorus load is reduced greatly, changes in lake water quality may be noticeable, (e.g., reduced algal abundance and better water clarity) and may even be enough to cause a shift in the lake's trophic state.

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

Regardless of the size of the watershed or the makeup of its land cover, it must be remembered that every lake is different and other factors, such as flushing rate, lake volume, sediment type, and many others, also influence how the lake will react to what is flowing into it. For instance, a deeper lake with a greater volume can dilute more phosphorus within its waters than a less voluminous lake and as a result, the production of a lake is kept low. However, in that same lake, because of its low flushing rate (a residence time of years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time and lead to a problem such as internal nutrient loading. On the contrary, a lake with a higher flushing rate (low residence time of days or weeks) may be more productive early on, but the constant flushing of its waters may prevent a buildup of phosphorus and internal nutrient loading may never reach significant levels.

Watershed Modeling

A reliable and cost-efficient method of creating a general picture of a watershed's effect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface.

WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the impact of shoreland septic systems.

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

Big Saint Germain Lake Watershed Assessment

Big Saint Germain Lake's watershed encompasses approximately 41,283 acres (65 square miles) across Vilas County, yielding a watershed to lake area ratio of 24:1 (Figure 8.2.2-1 and Big Saint Germain – Map 2). In other words, approximately 24 acres of land drains to every one acre of Big Saint Germain Lake's surface area. WiLMS modeling estimates that Big Saint Germain Lake's water residence time is approximately 0.7 years, meaning the water within the lake is completely replaced (flushing rate) on average once every 256 days or 1.4 times per year.

For modeling purposes, Big Saint Germain Lake's watershed was divided into four main subwatersheds: the Plum Lake subwatershed, Lost Lake subwatershed, Lake Content subwatershed, and the Big Saint Germain direct watershed (Figure 8.2.2-1). Approximately 37% of Big Saint Germain Lake's watershed is comprised of the Plum Lake subwatershed, 28% is comprised of the Lost Lake subwatershed, 2% is comprised of the Lake Content subwatershed, and the remaining 33% is comprised of the Big Saint Germain Lake direct watershed.

Using total phosphorus data measured in these lakes along with outflow estimates from WiLMS, phosphorus loading from these subwatersheds into Big Saint Germain Lake was calculated. WiLMS was also utilized to estimate phosphorus inputs from land cover within the lake's direct watershed. Phosphorus estimates from the subwatersheds and the lake's direct watershed were combined to estimate the total amount of annual phosphorus loading to Big Saint Germain Lake.

The 2016 land cover data indicate that Big Saint Germain Lake's direct watershed is comprised of upland forests (47%), wetlands (32%), the lake's surface itself (12%), pasture/grass/rural open space (8%), rural residential areas (1%), urban-medium density (<1%), row crop agriculture (<1%), and urban-high density (<1%) (Figure 8.2.2-2). The majority of land cover within the subwatersheds is comprised of upland forests and wetlands.

Using the land cover types and their acreages within Big Saint Germain Lake's direct watershed along with the estimated outflow of phosphorus from the four subwatersheds, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Big Saint Germain Lake from its watershed. In addition, using data obtained from the 2019 stakeholder survey, an estimate of phosphorus loading to the lake from septic systems was also incorporated into the model. The model estimated that a total of 3,712 pounds of phosphorus are delivered to Big Saint Germain Lake from its watershed on an annual basis (Figure 8.2.2-3).

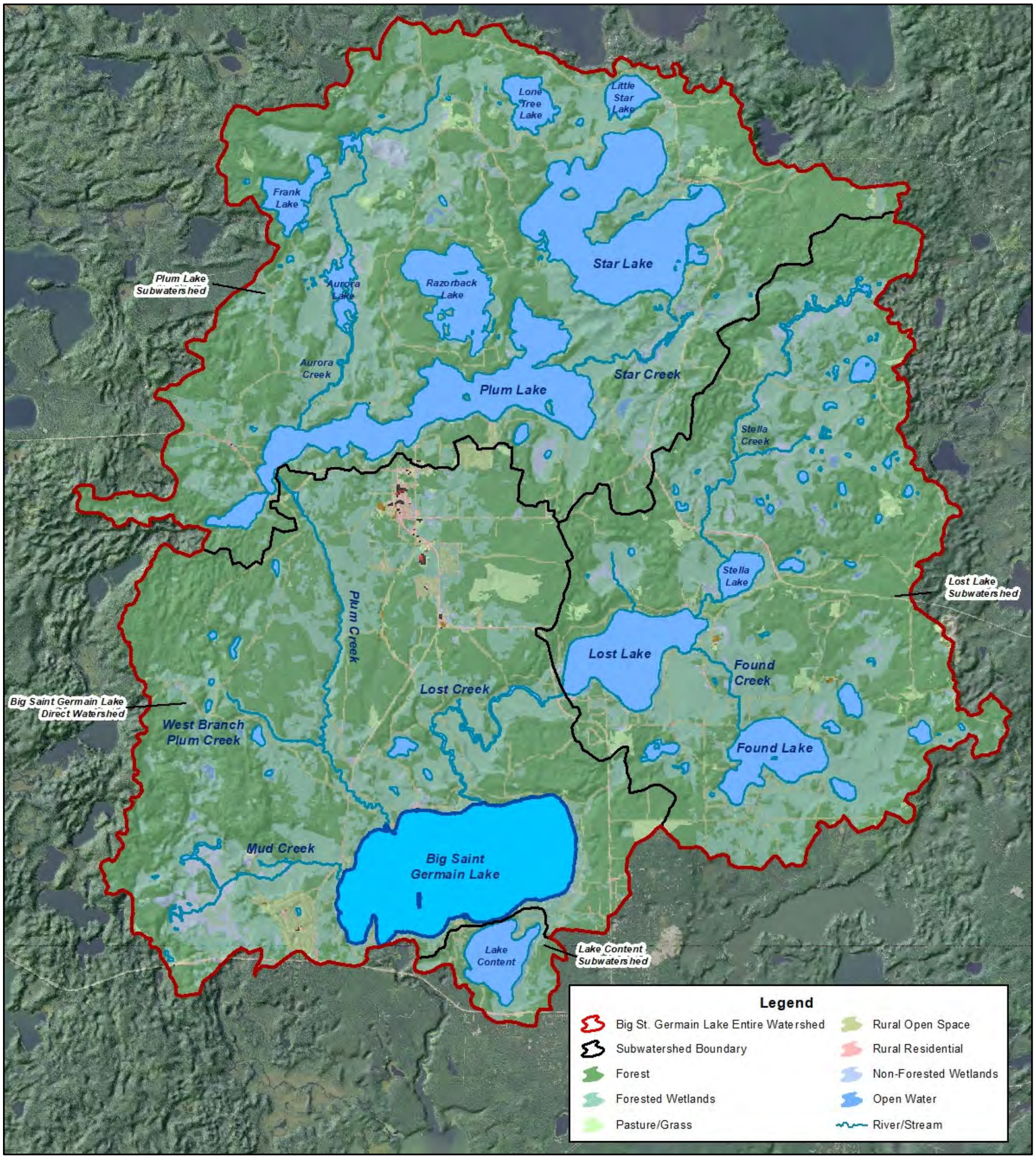


Figure 8.2.2-1. Big Saint Germain Lake watershed and land cover types.

Using the estimated annual potential phosphorus load of 3,712 pounds, WiLMS predicts that Big Saint Germain Lake should have an in-lake growing season mean total phosphorus concentration of 18 µg/L, which is 46% lower than the actual average measured growing season concentration of 28.9 µg/L. The growing season mean total phosphorus concentration in 2018 and 2019 of around 20 µg/L was closer to the WiLMS-predicted concentration. The fact that average measured phosphorus concentrations in Big Saint Germain Lake are higher than model predictions indicates that there is a source of phosphorus being loaded to the lake that was not accounted for in the model.

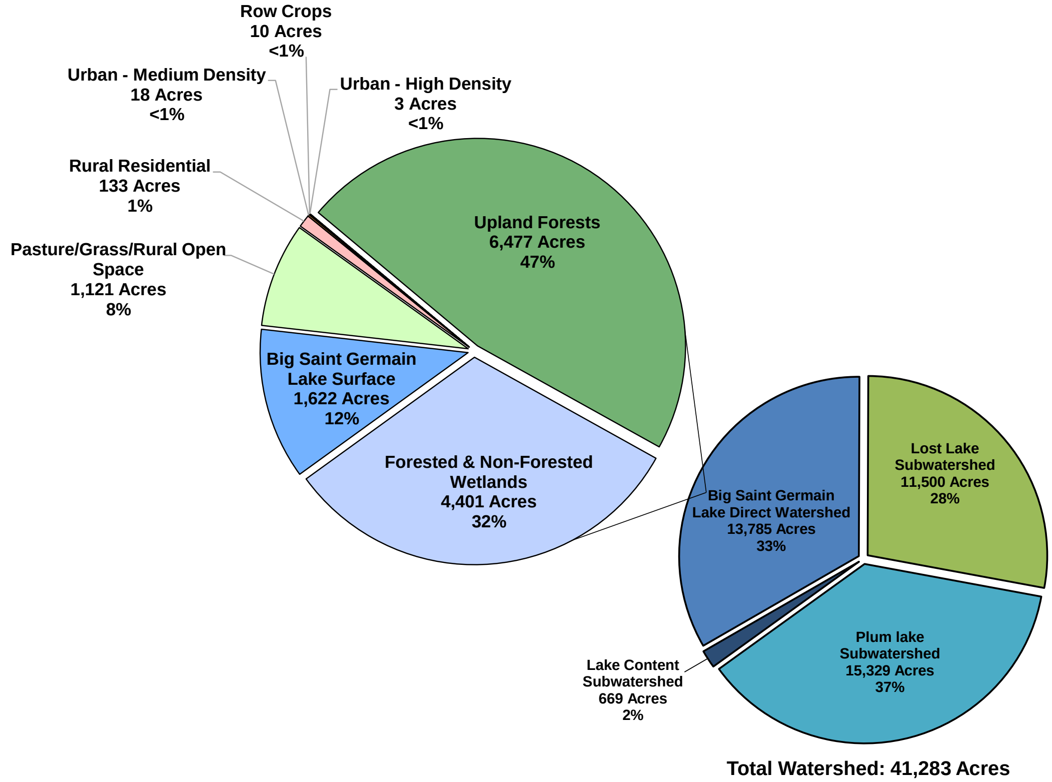


Figure 8.2.2-2. Big Saint Germain Lake watershed land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

This unaccounted source of phosphorus is believed to be internal nutrient loading, or the loading of phosphorus from bottom sediments during summer stratification. As is discussed in the Big Saint Germain Lake Water Quality Section (Section 8.2.1), the data indicate that phosphorus is mobilized from bottom sediments to surface waters in some years, elevating surface phosphorus concentrations. To achieve the measured in-lake growing season phosphorus concentration of 28.9 µg/L, the model indicates Big Saint Germain Lake needs to receive approximately 2,800 pounds of phosphorus annually (Figure 8.2.2-3).

This indicates that the internal nutrient loading of phosphorus is the single largest source of phosphorus for Big Saint Germain Lake, accounting for approximately 44% of the total annual load. However, this amount likely varies from year to year depending on the duration of stratification and hypolimnetic anoxia. While internal nutrient loading was occurring in 2019, it did not have a significant impact on surface concentrations during the summer. However, historical data from 2012 and 2015 indicate that internal nutrient loading has the capacity to significantly affect Big Saint Germain Lake's water quality, particularly in late summer where the mobilization of sediment-released phosphorus fueled large agal blooms.

Of the remaining phosphorus being delivered to Big Saint Germain Lake annually, 22% is estimated to originate from sources within Big Saint Germain Lake's direct watershed, 20% is estimated to originate from the Lost Lake subwatershed, 13% from the Plum Lake subwatershed, and 1% from the Lake Content subwatershed (Figure 8.2.2-3). Within Big Saint Germain Lake's direct watershed, upland forests account for 8% of the phosphorus loading, wetlands 6%, pasture/grass/rural open space 5%, atmospheric deposition on the lake's surface 4%, while septic systems, rural residential, row crop agriculture, urban areas, and shoreland development each account for less than 1% of the total loading.

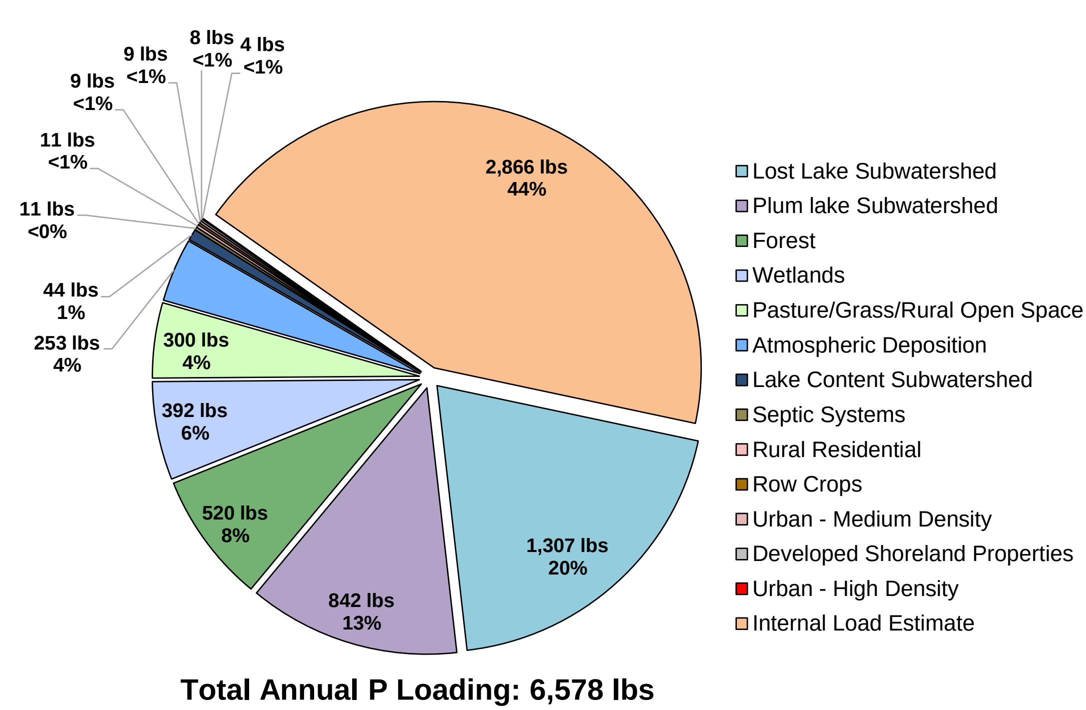


Figure 8.2.2-3. Big Saint Germain Lake estimated annual watershed phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

8.2.3 Big Saint Germain Lake Shoreland Condition

As mentioned previously in the Town-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 fall of 2019, Big Saint Germain Lake's immediate shoreline was assessed in terms of its level of development.

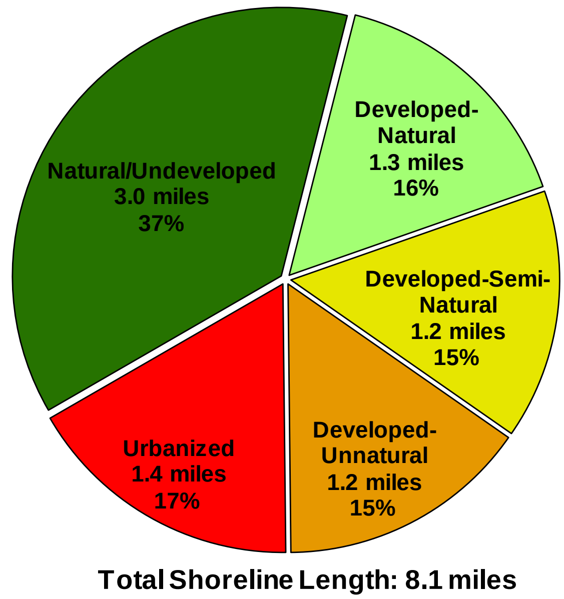


Figure 8.2.3-1. Big Saint Germain Lake shoreland categories and total lengths. Based upon a fall 2019 survey. Locations of these categorized shorelands can be found on Big Saint Germain Lake Map – 3.

Big Saint Germain Lake has stretches of shoreland that fit all of the five shoreland assessment categories (Figure 8.2.3-1). Approximately 53% (4.3 miles) of the lake's shoreline contains little to no development, categorized as natural/undeveloped or developed-natural. 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, 32% (2.6 miles) of shoreline with a higher degree of development was observed, categorized as either urbanized or developed-unnatural. If restoration of the Big Saint Germain 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.

Coarse Woody Habitat

As part of the shoreland condition assessment, Big Saint Germain Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (cluster of pieces, 2-8 inches in diameter, and 8+ inches in diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. Pictures descriptions of these categories can be found in the Town-Wide Section 3.4. As discussed earlier, 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 (Newbrey et al. 2005).

During this survey, 118 total pieces of coarse woody habitat were observed along 8.1 miles of shoreline (Big Saint Germain Lake Map – 4), which yields a coarse woody habitat to shoreline mile ratio of 15:1 (Figure 8.2.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Sixty pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, 58 pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and zero instances of clusters of coarse woody habitat were found.

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). Please note the methodologies between the surveys done on Big Saint Germain Lake and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat. Onterra has completed coarse woody habitat surveys on 111 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Big Saint Germain Lake falls in the 20th percentile of these 111 lakes.

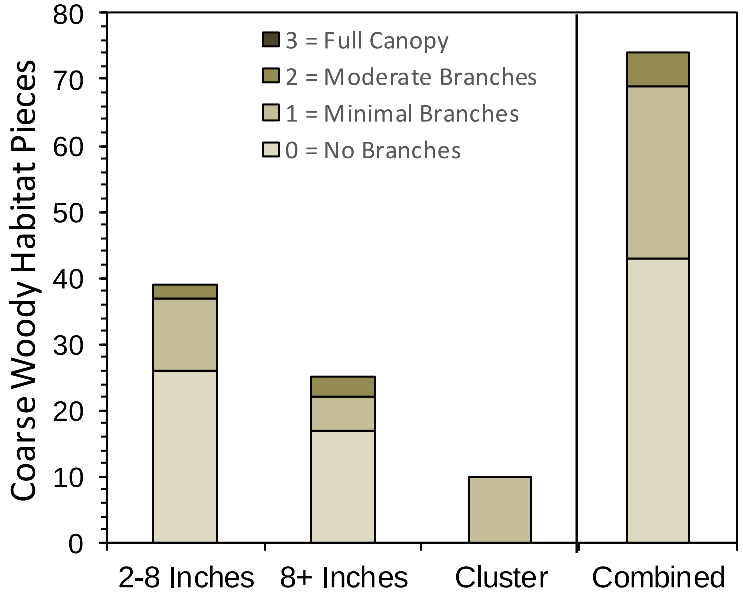


Figure 8.2.3-2. Big Saint Germain Lake coarse woody habitat survey results. Based upon a Fall of 2019 survey. Locations of the Big Saint Germain Lake coarse woody habitat can be found Big Saint Germain Lake – Map 4.

8.2.4 Big Saint Germain Lake Aquatic Vegetation

An Early-Season Aquatic Invasive Species (ESAIS) Survey was conducted by Onterra ecologists on Big Saint Germain Lake on June 20, 21, and 24, 2019. 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 the non-native curly-leaf pondweed, which should be at or near its peak growth at this time. No curly-leaf pondweed was located during this survey. Lost Lake, upstream from Big Saint Germain Lake, has a population of curly-leaf pondweed. Onterra ecologists were able to navigate upstream into Lost Creek for approximately 0.2 miles, and no curly-leaf pondweed was observed.

The whole-lake aquatic plant point-intercept survey was conducted on Big Saint Germain Lake by Onterra ecologists on July 31 and August 1, 2019, while the emergent and floating-leaf aquatic plant community mapping survey was completed on August 19, 2019. During these surveys, a total of 41 native aquatic plant species were located (Table 8.2.4-1). One non-native aquatic plant species, narrow-leaved cattail, was located in one location along Big Saint Germain Lake's shoreline in 2019. Narrow-leaved cattail and possible management actions are discussed in the subsequent Non-Native Aquatic Plants in Big Saint Germain Lake Section. Onterra also completed a whole-lake point-intercept survey on Big Saint Germain Lake in 2010, and the species located during that survey are also included in Table 8.2.4-1.

Lakes in Wisconsin vary in their morphometry, water chemistry, water clarity, substrate composition, management, and recreational use, all factors which influence aquatic plant community composition. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy/rocky areas, and some can be found growing in either. The combination of both soft sediments and areas of harder substrates creates different habitat types for aquatic plants, and generally leads to a higher number of aquatic plant species within the lake.

During the 2019 point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 15 feet). These data indicate that 65% of the point-intercept locations in 15 feet of water or less contained sand, 19% contained soft, organic sediment, and 16% contained rock (Figure 8.2.4-1). The combination of both soft and hard substrates in Big Saint Germain Lake creates habitat types which support different aquatic plant community assemblages.

The maximum depth of plant growth is largely going to be determined by water clarity. In general, aquatic plants grow to a depth of two to three times the average Secchi disk depth. Big Saint Germain Lake's mean Secchi disk depth in 2019 was 9.9 feet, and aquatic plants were recorded growing to a maximum depth of 15 feet, similar to the depth of 16 feet recorded in 2010.

The littoral frequency of occurrence of vegetation in Big Saint Germain Lake in 2019 of 79% was not statistically different (Chi-Square $\alpha = 0.05$) from the littoral frequency of occurrence recorded in 2010 of 84% (Figure 8.2.4-2). The proportion of total rake fullness ratings were relatively similar between the two surveys, indicating that the biomass of aquatic plants was similar. Approximately 76% of the sampling locations that contained aquatic vegetation in 2019 had a total rake fullness rating of 1, 18% a rating of 2, and 6% a rating of 3, indicating that overall biomass of aquatic vegetation in Big Saint Germain Lake is relatively low.

Table 8.2.4-1. Aquatic plant species located in Big Saint Germain Lake during 2010 and 2019 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2010	2019
Emergent	*Calla palustris*	Water arum	Native	9	I	
	Carex comosa	Bristly sedge	Native	5	I	
	Carex crawfordii	Crawford's oval sedge	Native	5	I	
	Carex lacustris	Lake sedge	Native	6	I	
	Eleocharis palustris	Creeping spikerush	Native	6	X	I
	Pontederia cordata	Pickerelweed	Native	9		I
	Sagittaria latifolia	Common arrowhead	Native	3	I	
	Sagittaria rigida	Stiff arrowhead	Native	8	X	I
	Schoenoplectus acutus	Hardstem bulrush	Native	5	X	X
	Scirpus cyperinus	Wool grass	Native	4	I	
	Sparganium eurycarpum	Common bur-reed	Native	5		I
	Typha angustifolia	Narrow-leaved cattail	Non-Native - Invasive	N/A		I
	Typha latifolia	Broad-leaved cattail	Native	1		I
	Zizania palustris	Northern wild rice	Native	8	I	I
FL	*Nuphar variegata*	Spatterdock	Native	6	X	X
	Nymphaea odorata	White water lily	Native	6	X	X
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9		I
Submergent	*Bidens beckii*	Water marigold	Native	8	X	X
	Ceratophyllum demersum	Coontail	Native	3	X	X
	Chara spp.	Muskgrasses	Native	7	X	X
	Elatine minima	Waterwort	Native	9		I
	Elodea canadensis	Common waterweed	Native	3	X	X
	Heteranthera dubia	Water stargrass	Native	6	X	X
	Isoetes spp.	Quillwort spp.	Native	8	X	X
	Lobelia dortmanna	Water lobelia	Native	10	I	I
	Myriophyllum sibiricum	Northern watermilfoil	Native	7	X	X
	Myriophyllum tenellum	Dwarf watermilfoil	Native	10		X
	Najas flexilis	Slender naiad	Native	6	X	X
	Nitella spp.	Stoneworts	Native	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X	X
	Potamogeton amplifolius x *P. praelongus*	Large-leaf x White-stem pondweed hybrid	Native	N/A	X	X
	Potamogeton berchtoldii	Slender pondweed	Native	7		X
	Potamogeton friesii	Fries' pondweed	Native	8	X	X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7	X	X
	Potamogeton illinoensis	Illinois pondweed	Native	6	X	
	Potamogeton praelongus	White-stem pondweed	Native	8	X	X
	Potamogeton pusillus	Small pondweed	Native	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	Native	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	Native	8	X	X
	Potamogeton strictifolius	Stiff pondweed	Native	8		X
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6	X	X
	Ranunculus aquatilis	White water crowfoot	Native	8	X	X
	Ranunculus flammula	Creeping spearwort	Native	9	X	
	Stuckenia pectinata	Sago pondweed	Native	3	X	I
	Utricularia vulgaris	Common bladderwort	Native	7	X	
	Vallisneria americana	Wild celery	Native	6	X	X
SE	*Eleocharis acicularis*	Needle spikerush	Native	5	X	X
	Sagittaria cristata	Crested arrowhead	Native	9	X	X
FF	*Lemna trisulca*	Forked duckweed	Native	6		X
	Lemna turionifera	Turion duckweed	Native	2	X	
	Spirodela polyrhiza	Greater duckweed	Native	5	X	

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
FL = Floating-leaf; SE = Submergent and/or emergent; FF = Free-floating

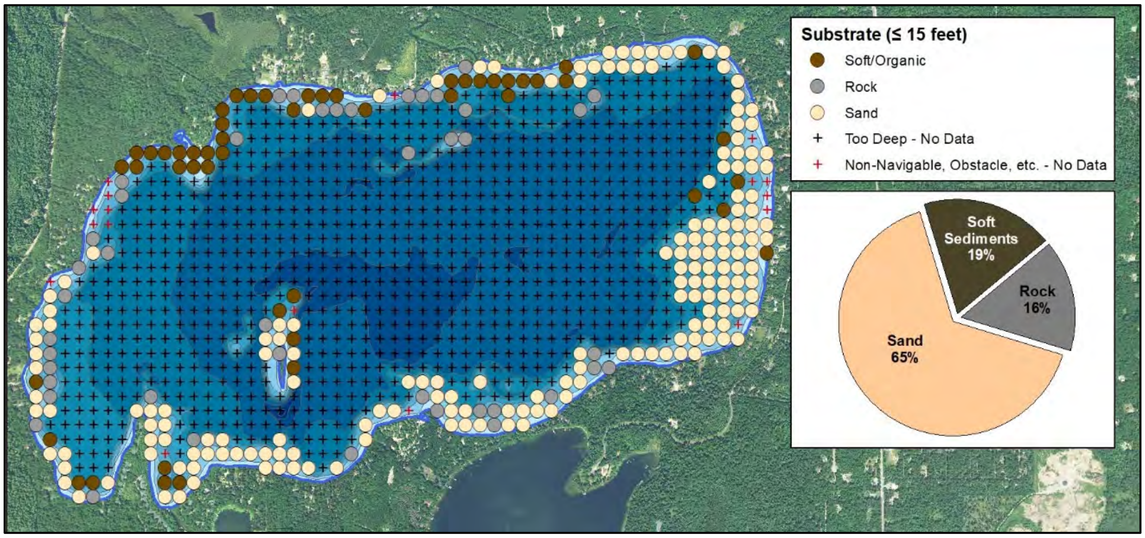


Figure 8.2.4-1. Big Saint Germain Lake substrate types as determined from the 2019 point-intercept survey. Please note substrate types can only be determined at sampling locations in 15 feet of water or less.

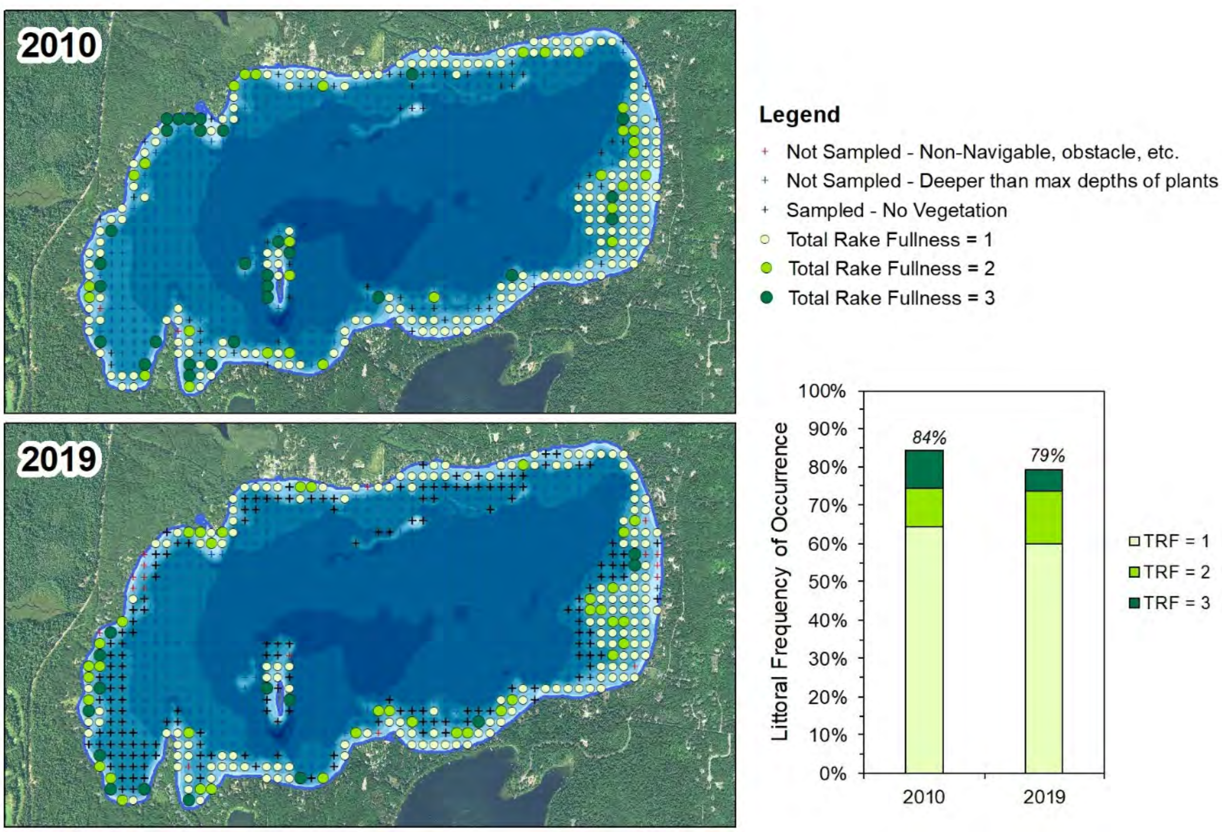


Figure 8.2.4-2. Distribution of aquatic vegetation in Big Saint Germain Lake in 2010 and 2019. Littoral frequency of occurrence of vegetation was not statistically different between 2010 and 2019 (Chi-Square α = 0.05). Created using data from Onterra 2010 and 2019 point-intercept surveys.

Unlike some of the other Town of Saint Germain project lakes which have seen significant declines in the occurrence of vegetation between 2010 and 2019 due to either changes in water levels or reductions in water clarity, the occurrence of vegetation in Big Saint Germain Lake has remained stable. Big Saint Germain Lake is a drainage lake with a dam which can regulate water levels and prevent large fluctuations in water level. In fact, the average depth of littoral sampling locations was 6.1 feet in both 2010 and 2019, indicating water levels were the same during both survey years. In contrast, the seepage lakes of Alma and Moon lakes saw water levels increase by over 3.0 feet between 2010 and 2019, causing a significant reduction in overall aquatic plant occurrence.

The data from the two point-intercept surveys completed on Big Saint Germain Lake can be used to compare how the occurrence of individual species have changed between the 2010 and 2019 surveys. Due to their morphologic similarity and often difficulty in identification, the occurrences of slender pondweed (*Potamogeton berchtoldii*) and small pondweed (*P. pusillus*) were combined for this analysis. The littoral frequencies of occurrence of aquatic plant species which had a littoral occurrence of at least 5% in one of the four point-intercept surveys are displayed in Figure 8.2.4-3. In total, six species saw statistically valid increases in their occurrence between 2010 and 2019, six species saw statistically valid declines in their occurrence, and the occurrences of three species were not statistically different.

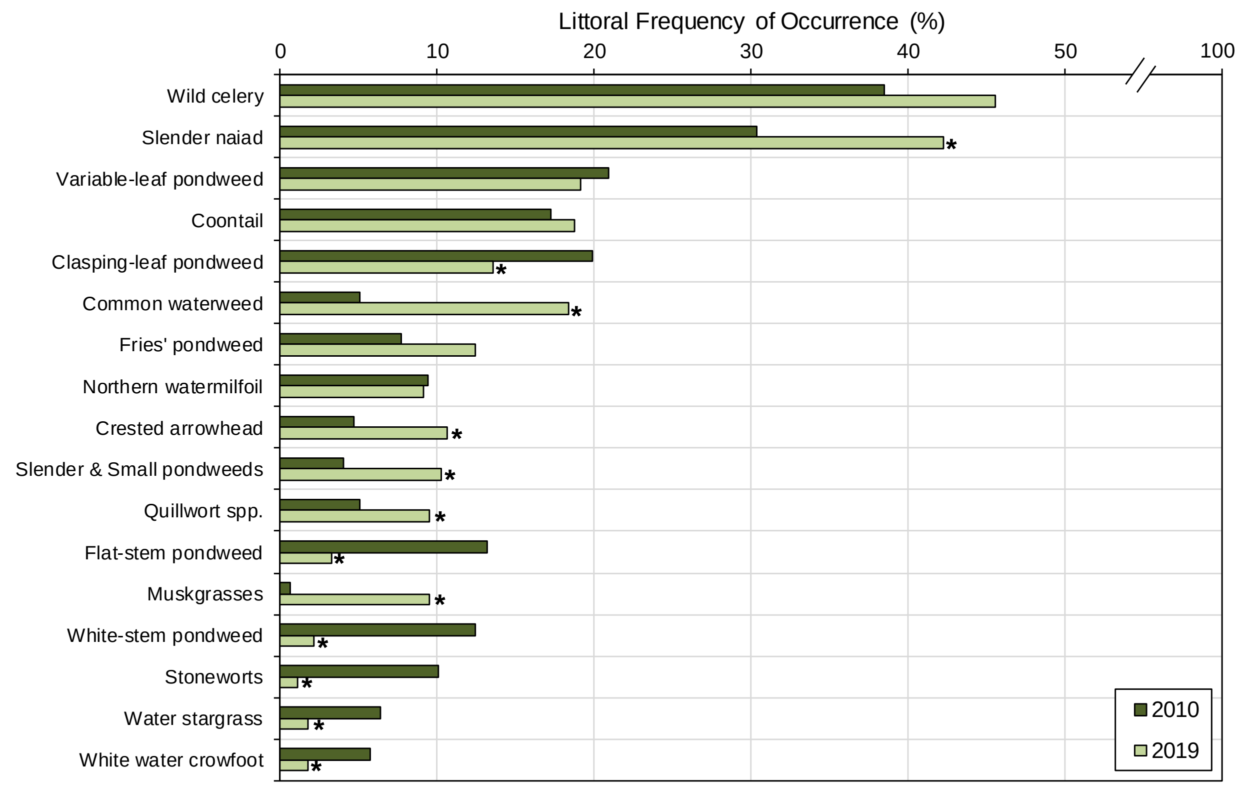


Figure 8.2.4-3. Littoral frequency of occurrence of select aquatic plant species in Big Saint Germain Lake from 2010 and 2019 point-intercept surveys. Species with a littoral frequency of occurrence of at least 5% in one of the two surveys are displayed. Created using data from Onterra 2010 and 2019 point-intercept surveys.

The species which exhibited declines in their occurrence between 2010 and 2019 include: clasping-leaf pondweed (32% decline), flat-stem pondweed (75% decline), white-stem pondweed (82% decline), stoneworts (89% decline), water stargrass (71% decline), and white water crowfoot (68% decline). Species which exhibited a statistically valid increase in occurrence between 2010 and 2019 include slender naiad (39% increase), common waterweed (263% increase), crested arrowhead (125% increase), quillwort species (89% increase), the combined occurrences of slender and small pondweeds (154% increase), and muskgrasses (1,314% increase). The occurrences of wild celery, variable-leaf pondweed, coontail, and northern water milfoil were not statistically different between 2010 and 2019.

The data that continues to be collected from Wisconsin lake's is revealing that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. These fluctuations are driven by a combination of interacting natural factors including variations in water levels, temperature, ice and snow cover (winter light availability), nutrient availability, changes in water flow, water clarity, length of the growing season, herbivory, disease, and competition (Lacoul and Freedman 2006).

Lakes with diverse aquatic plant communities are believed to have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Lakes with a diverse aquatic plant community are thought to be more resilient to environmental fluctuations. In years when conditions are not favorable for some species, others can increase in response and fulfill their ecological role. While the occurrences of a number of species declined in Big Saint Germain Lake between the 2010 and 2019 surveys, the occurrences of others increased, and the overall occurrence of vegetation did not change. One may assume that because a lake has a high number of aquatic plant species that it also has high species diversity. However, species diversity is influenced by both the number of species and how evenly they are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Big Saint Germain Lake's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion. The Simpson's Diversity Index values were calculated for Big Saint Germain Lake using the 2010 and 2019 point-intercept survey data. Big Saint Germain Lake's species diversity decreased slightly from a value of 0.92 in 2010 to 0.90 in 2019 (Figure 8.2.4-4). The diversity value of 0.90 still falls in the 75th percentile for lakes in in the NLFL ecoregion.

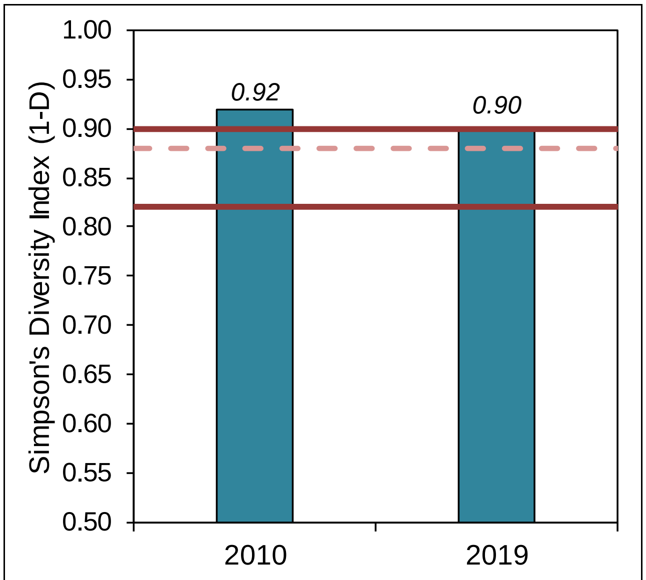


Figure 8.2.4-4. Big Saint Germain Lake Simpson's Diversity Index. Red solid lines represent NLFL upper and lower quartiles; light red dashed line represents NLFL median. Regional and state values calculated with Onterra & WDNR data.

In other words, if plants were randomly sampled from two locations in Big Saint Germain Lake in 2019, there would have been a 90% probability that the plants would be two different species. The slight reduction in species diversity in 2019 is likely due to the increase in occurrence of slender naiad, one of the dominant plant species in the lake. The

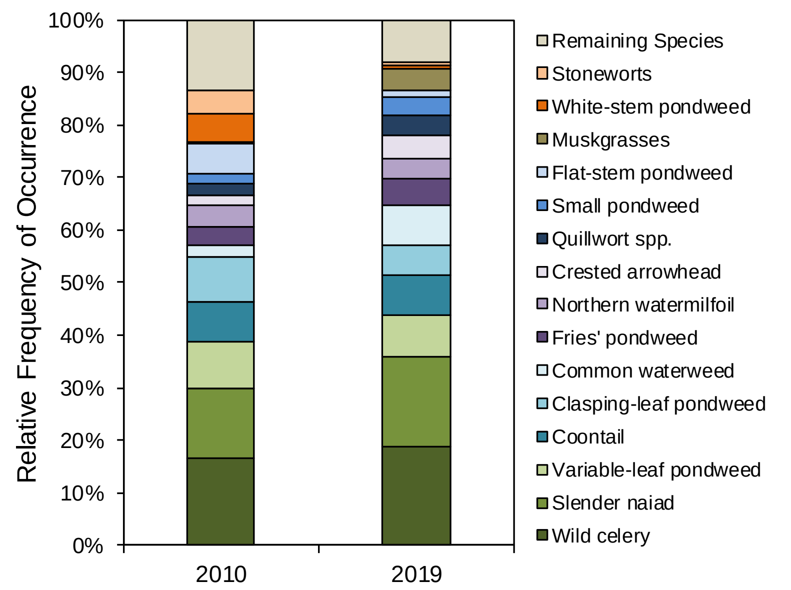


Figure 8.2.4-5. Big Saint Germain Lake aquatic plant relative frequency of occurrence. Created using data from Onterra 2010 and 2019 point-intercept surveys.

increase in occurrence of slender naiad created a more uneven distribution in abundance amongst the plant species within the community.

One way to visualize the diversity of Big Saint Germain Lake's plant community is to examine the relative frequency of occurrence of aquatic plant species. Relative frequency of occurrence is used to evaluate how often each plant species is encountered in relation to all the other species found. For example, while wild celery was found at 46% of the littoral sampling locations in 2019, its relative frequency of occurrence was 19% (Figure 8.2.4-5).

Explained another way, if 100 plants were randomly sampled from Big Saint Germain Lake in 2010, 19 of them would have been wild celery, 17 slender naiad, 8 variable-leaf pondweed, etc. In 2010, the five-most dominant plants in Big Saint Germain Lake accounted for approximately 57% of the total plant community. In 2019, these same five species accounted for 65% of the plant community. This increase, mostly attributable to slender naiad, and decrease in the evenness of the distribution of species is the reason for the small reduction species diversity.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Figure 8.2.4-6). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987) (Vestergaard and Sand-Jensen 2000).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Figure 8.2.4-6). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf watermilfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern watermilfoil (*Myriophyllum sibiricum*) are classified as elodeids.

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

Figure 8.2.4-6. Lake quillwort (Isoetes lacustris) of the isoetid growth form (left) and large-leaf pondweed (Potamogeton amplifolius) of the elodeid growth form (right). Photo credit: Onterra.

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes that have little to no alkalinity (e.g., Alma and Moon lakes) where they can avoid competition from elodeids.

In the Town of Saint Germain lakes like Big Saint Germain Lake which have more moderate alkalinity levels, isoetids are generally restricted to shallower, wave-swept areas where elodeids are unable to grow, or scattered amongst less dense elodeid communities where light can penetrate to the bottom. In Big Saint Germain Lake, isoetid species were mainly located in shallower areas of sand or rock where taller vegetation was sparser. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders, Lucassen and Roelofs 2002), and a number are listed as special concern or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

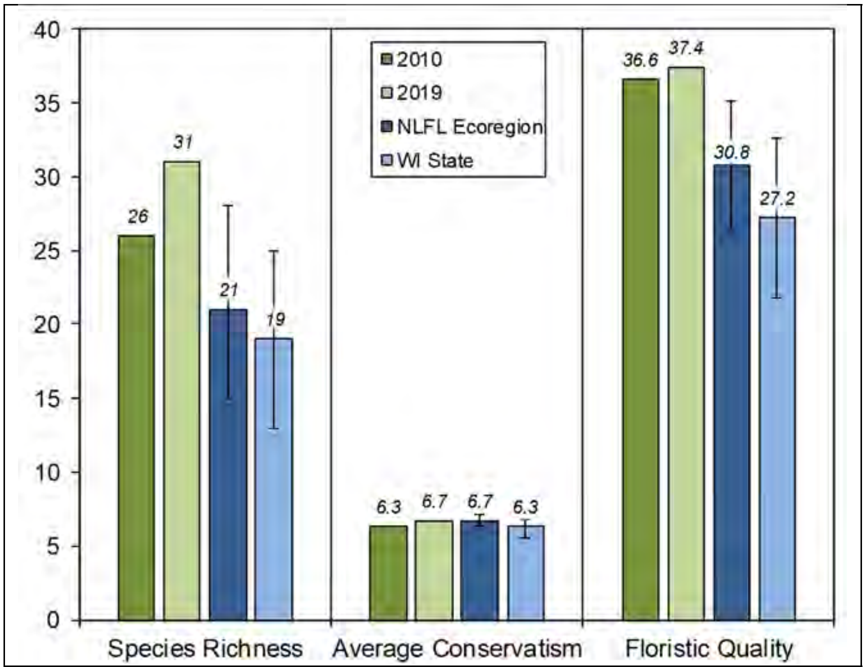


Figure 8.2.4-7. Big Saint Germain Lake Floristic Quality Assessment. Error bars represent interquartile range. Created using data from Onterra 2010 and 2019 point-intercept surveys. Regional and state medians calculated with Onterra and WDNR data. Analysis follows Nichols 1999.

Using the aquatic plant species recorded on the rake during the point-intercept surveys completed on Big Saint Germain Lake, the Floristic Quality Index (FQI) was also calculated for each survey (Figure 8.2.4-7). Native plant species richness, or the number of native species recorded on the rake was 26 in 2010 and 31 in 2019. Average species conservatism was 6.3 in 2010 and 6.7 in 2019, while the FQI was 36.6 in 2010 and 37.4 in 2019. Big Saint Germain Lake's 2019 species richness fell above the 75th percentile for lakes in the NLFL ecoregion (28) and the state (25). Big Saint Germain Lake's 2019 average conservatism value was identical to the median value for both the ecoregion (6.7) and higher than the state median (6.3). Big Saint Germain Lake's FQI values also exceed both the median values for ecoregion lakes (30.8) and the state (27.2).

In 2019, Onterra ecologists also re-mapped emergent and floating-leaf aquatic plant communities in Big Saint Germain Lake (Big Saint Germain Lake – Map 5). Figure 8.2.4-8 illustrates that these communities have increased in size since they were first mapped by NES Ecological Services in 2004. These communities have increased from 12.0 acres in 2004, 15.4 acres in 2010, to 18.2 acres in 2019. These communities often respond to changes in water levels, often expanding in size during periods of lower water levels and contracting again when water levels increase.

The expansion of these communities in Big Saint Germain Lake is a positive sign, as these communities have often been observed to decline over a period of decades following the installation of a water control structure and stabilization of water levels. Many species in these plant communities require periodic water level fluctuations to maintain their populations. In addition, these communities also tend to decline with increasing shoreland development. In Big Saint Germain Lake, these communities are primarily comprised of hardstem bulrush (*Schoenoplectus acutus*), spatterdock (*Nuphar variegata*), creeping spikerush (*Eleocharis palustris*), and white water lily (*Nymphaea odorata*). The full list of species found in these communities can be found in Table 8.2.4-1. These native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake.

The 2019 aquatic plant surveys on Big Saint Germain Lake indicate that the lake continues to support a high-quality native plant community. While some fluctuations in species abundances were observed, overall aquatic plant occurrence was not statistically different from what was recorded in 2010. The relatively small changes in Big Saint Germain Lake's aquatic plant community compared to some of the other project lakes is likely due to the fact that the lake has maintained relatively stable water levels and water clarity over this period. Alma and Moon lakes have seen large fluctuations in water levels while Found Lake has seen a significant reduction in water clarity, disturbances which have caused more significant changes in the plant communities of these lakes.

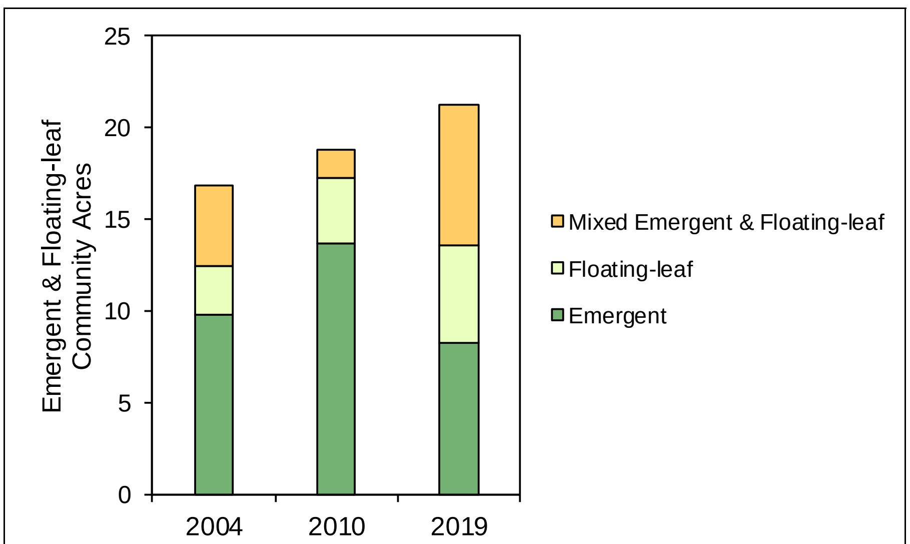


Figure 8.2.4-8. Big Saint Germain Lake emergent and floating-leaf community acres from 2004, 2010, and 2019. Locations of the 2019 communities can be found on Big Saint Germain Lake – Map 5.

Non-Native Aquatic Plants in Big Saint Germain Lake

Narrow-leaved Cattail (Typha angustifolia)

Like purple loosestrife, narrow-leaved cattail is a perennial invasive wetland plant which invades shallow marshes and other wet areas. Like Wisconsin's native broad-leaved cattail (*T. latifolia*), narrow-leaved cattail produces tall, erect, sword-like leaves that can grow nearly 10 feet tall (Photograph 8.2.4-1). The leaves are generally narrower than broad-leaf cattail, typically 0.15-0.5 inches wide. Unlike broad-leaf cattail in which the male and female flowers are typically touching, there is typically a gap of 0.5-4.0 inches between the male and female flowers of narrow-leaved cattail.

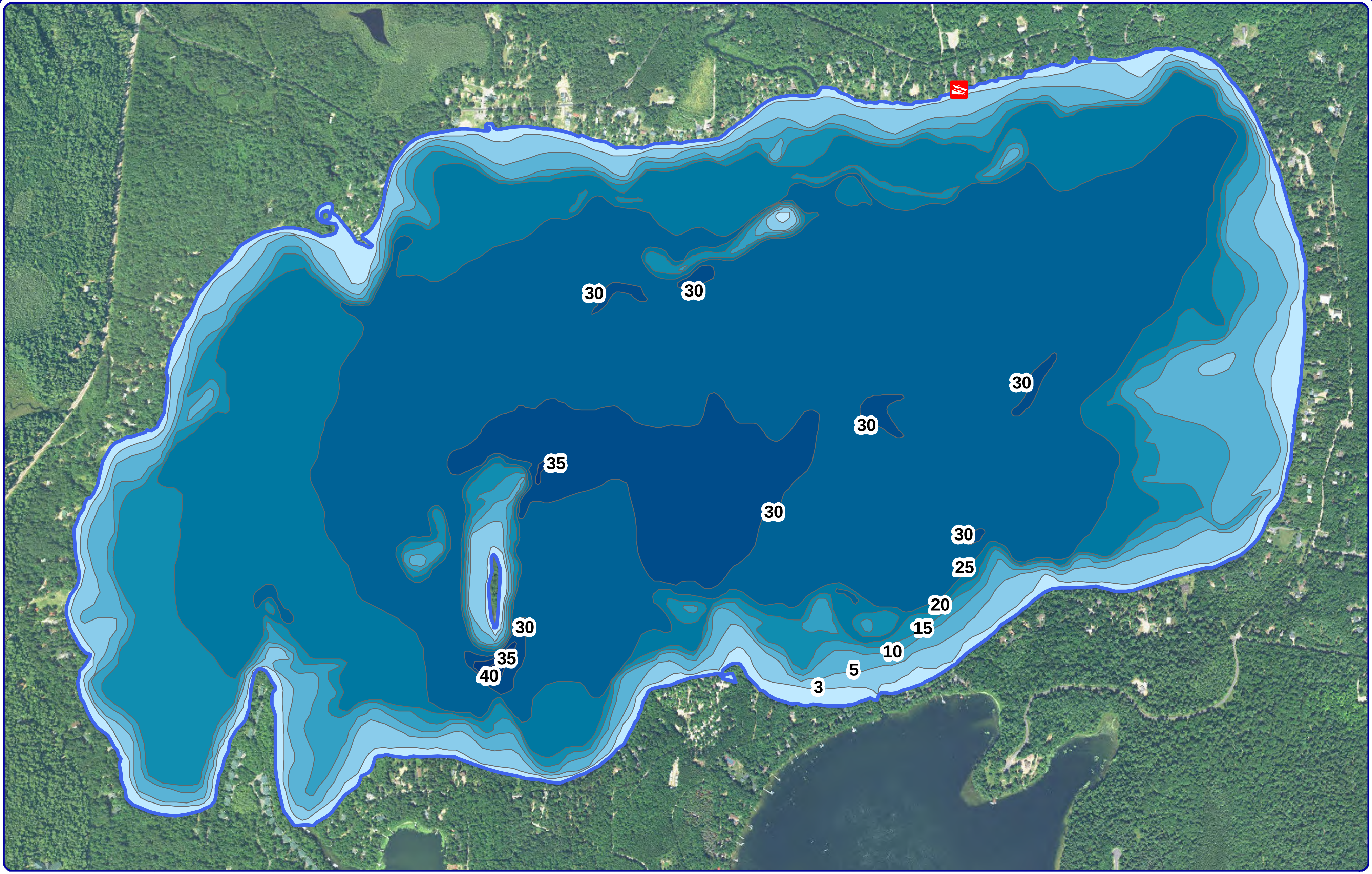
Photograph 8.2.4-1. Onterra ecologist amongst a colony of the invasive narrow-leaved cattail. Photo credit: Onterra.

A small colony of narrow-leaved cattail was located on the southern shore of Big Saint Germain Lake in 2019 (Big Saint Germain Lake – Map 5). Given the isolated nature of this colony, the best method of control is likely the cutting of stems (both green and dead) in mid- to late-summer or early fall to below the water line. The following growing season, continually cut-back emerging stems to maintain them below the water for the remainder of the growing season. This process should be repeated until the plants do not reemerge.

8.2.5 Other Aquatic Invasive Species in Big Saint Germain Lake

In addition to narrow-leaved cattail discussed previously, as of 2019 three non-native, invasive invertebrate species have been documented in Big Saint Germain Lake. These include the rusty crayfish (*Orconectes rusticus*), Chinese mystery snail (*Cipanogopaludina chinensis*), and the banded mystery snail (*Viviparus georgianus*). Rusty crayfish were introduced to Wisconsin from the Ohio River Basin in the 1960's likely via anglers' discarded bait. In addition to displacing native crayfish (*O. virilis* and *O. propinquus*), rusty crayfish also degrade the aquatic habitat by reducing aquatic plant abundance and diversity and have also been shown to consume fish eggs. While there is currently no control method for eradicating rusty crayfish from a waterbody, aggressive trapping and removal has been shown to significantly reduce populations and minimize their ecological impact.

The ecological impacts of the Chinese and banded mystery snails are largely unknown, but one study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009). At this time, there are no approved methods for controlling populations of these invasive snails in Wisconsin's waterbodies.



N
W E
S

1,250

Feet

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

Sources:
Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Orthophotography: 2018 NAIP
Map Date: March 3, 2020 BTB
File Name Map1_BSG_Location.mxd

Project Location in Wisconsin

Legend

Big Saint Germain Lake
(1,622 acres - WDNR definition)

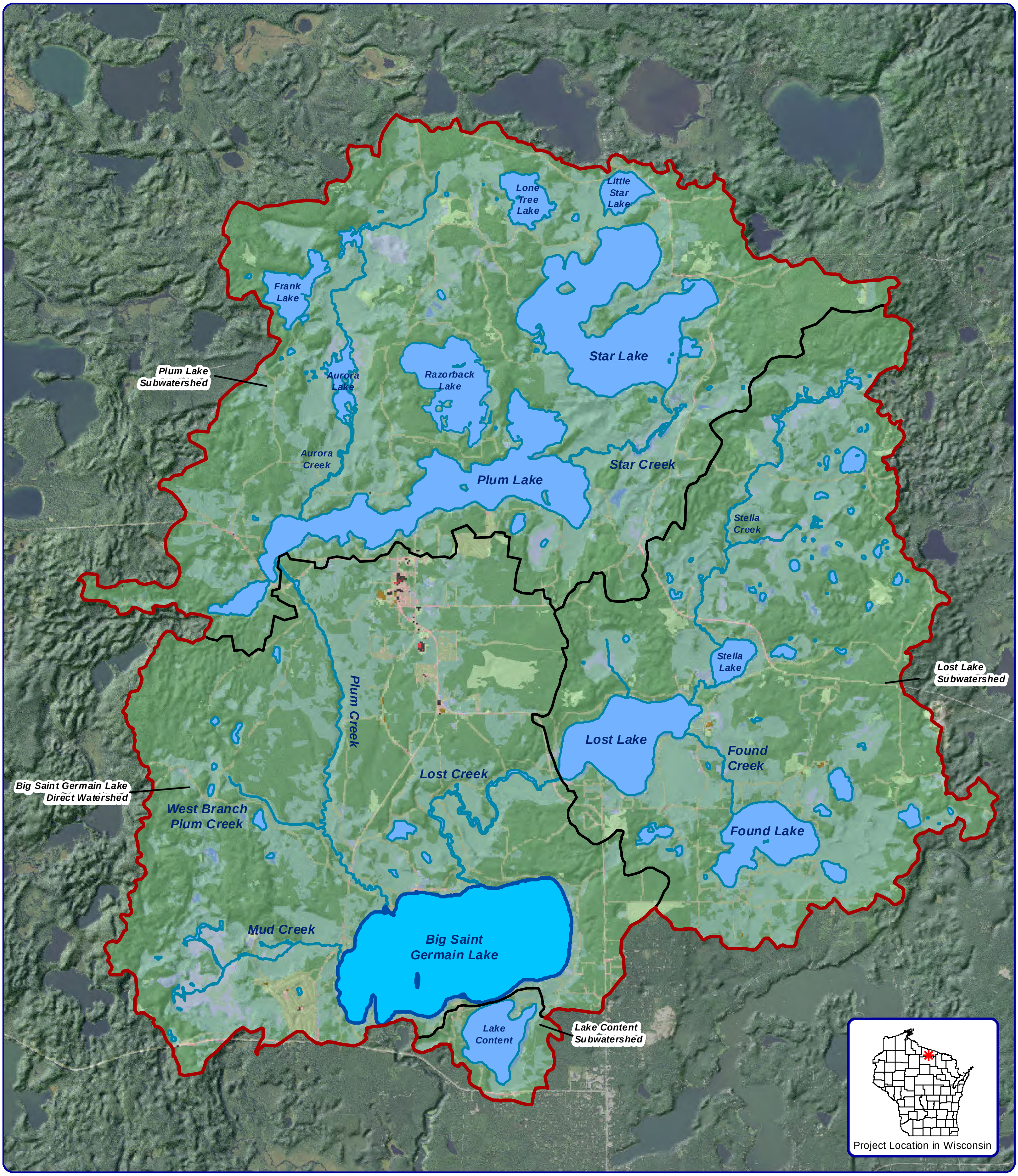
Public Boat Launch

Big Saint Germain Lake - Map 1

Town of Saint Germain

Vilas County, Wisconsin

Project Location & Lake Boundaries



N
W E
S

6,900

Feet

Onterra LLC
Lake Management Planning

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

Sources:
Hydro: WDNR
Watershed: Onterra 2019
Orthophotography: 2018 NAIP
Map Date: March 3, 2020 BTB
File Name Map2_BSG_WS.mxd

Legend

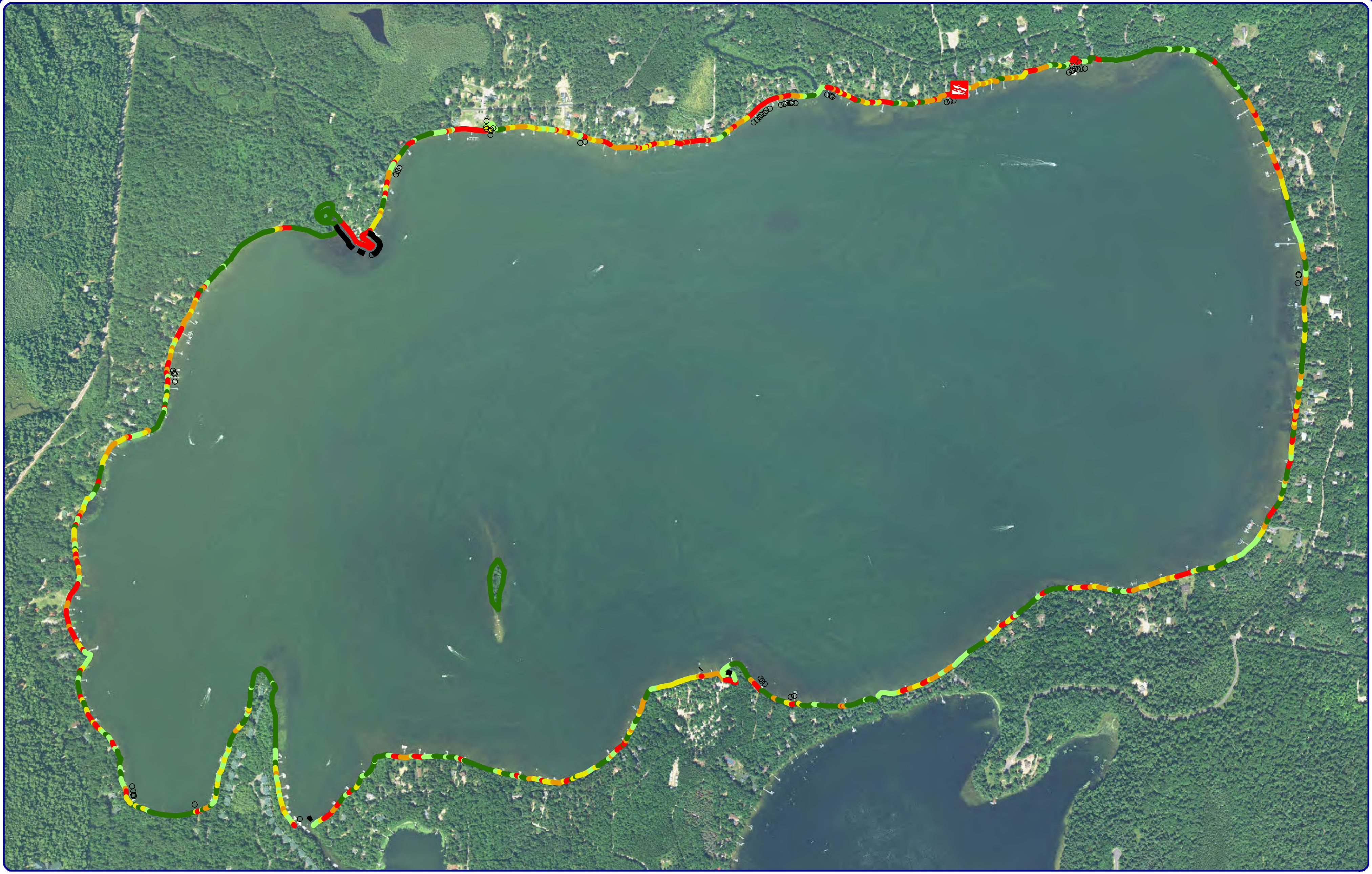
- Big St. Germain Lake Entire Watershed
- Subwatershed Boundary
- Forest
- Forested Wetlands
- Pasture/Grass
- Rural Open Space
- Rural Residential
- Non-Forested Wetlands
- Open Water
- River/Stream

Big Saint Germain Lake - Map 2

Town of Saint Germain

Vilas County, Wisconsin

Watershed Boundaries & Land Cover Types



N
W E
S

1,250
Feet

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

Sources:
Hydro: WDNR
Shoreland: Onterra 2019
Orthophotography: 2018 NAIP
Map Date: March 3, 2020 BTB
File Name Map3_BSG_SCA.mxd

Project Location in Wisconsin

Legend

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

Seawall

- Masonry/Wood/Metal
- Rip-Rap

Big Saint Germain Lake - Map 3

Town of Saint Germain

Vilas County, Wisconsin

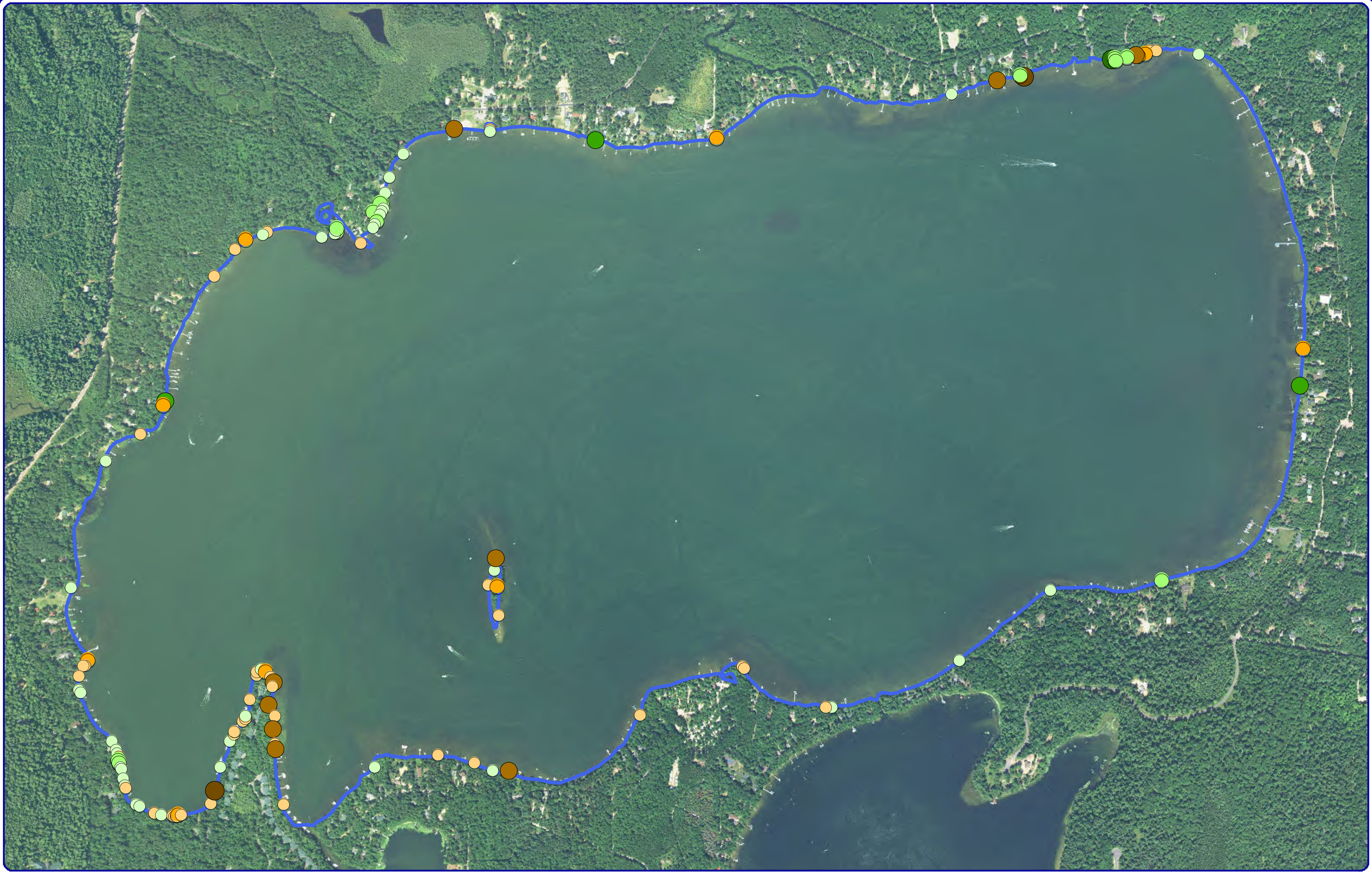
2019 Shoreland Condition Assessment

Big Saint Germain Lake - Map 4

Town of Saint Germain

Vilas County, Wisconsin

2019 Coarse Woody Habitat Assessment



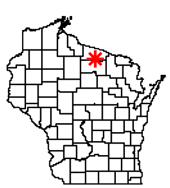
N W E S

1,250

Feet

Legend

2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches
Minimal Branches	Minimal Branches	Minimal Branches
Moderate Branches	Moderate Branches	Moderate Branches
Full Canopy	Full Canopy	Full Canopy



Project Location in Wisconsin

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

Sources:
Hydro: WDNR
Shoreland: Onterra 2019
Orthophotography: 2018 NAIP
Map Date: March 3, 2020 BTB
File Name Map4_BSG_CWH.mxd

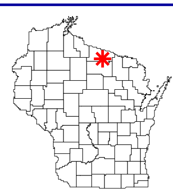
N
W E
S

1,300

Feet

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

Sources:
Hydro: WDNR
Plants: Onterra 2019
Orthophotography: 2018 NAIP
Map Date: March 3, 2020 BTB
File Name Map5_BSG_CM.mxd



Project Location in Wisconsin

Large Plant Community
- Native - Emergent
- Native - Floating-leaf
- Native - Mixed Floating-leaf & Emergent

Small Plant Community
- Native - Emergent
- Native - Floating-leaf
- Native - Mixed Floating-leaf & Emergent
- Non-Native - Narrow-leaved Cattail

Big Saint Germain Lake - Map 5
Town of Saint Germain
Vilas County, Wisconsin
2019 Emergent & Floating-leaf Aquatic Plant Communities

Big Saint Germain Lake Emergent & Floating-Leaf Plant Species

Corresponding Community Polygons and Points are displayed on Big Saint Germain - Map 5

Large Plant Community (Polygons)

Emergent	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8	Acres
A	Hardstem bulrush	Creeping spikerush							0.35
B	Hardstem bulrush	Creeping spikerush	Stiff arrowhead						2.53
C	Creeping spikerush								0.41
D	Hardstem bulrush	Creeping spikerush	White water lily						2.86
E	Hardstem bulrush	Creeping spikerush	Pickerelweed						0.47
F	Hardstem bulrush	Creeping spikerush							1.49
G	Common bur-reed								0.20
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
H	White water lily								0.14
I	Spatterdock								1.31
J	Spatterdock	White water lily							3.52
K	White water lily	Spatterdock							0.33
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
L	Spatterdock	Northern wild rice							0.34
M	Hardstem bulrush	Creeping spikerush	Spatterdock	Common bur-reed	Cattail sp.				2.67
N	Hardstem bulrush	Creeping spikerush	Spatterdock	White water lily					3.73
O	Creeping spikerush	White water lily	Spatterdock						0.31
P	Spatterdock	Hardstem bulrush	Creeping spikerush						0.55

Small Plant Community (Points)

Emergent	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8
1	Hardstem bulrush							
2	Stiff arrowhead							
3	Narrow-leaved cattail	Broad-leaved cattail						
4	Iris sp							
5	Hardstem bulrush	Cattail sp.						
6	Common bur-reed							
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
7	Narrow-leaf bur-reed							
8	White water lily							
9	White water lily	Spatterdock						
10	Spatterdock							
11	Spatterdock	White water lily						

Species are listed in order of dominance within the community; Scientifc names can be found in the species list in the Big Saint Germain Lake Aquatic Vegetation Section 8.2.4