

Winter Haven Lakes Report

Presented by the Lakes Advisory Committee

2023

CITY OF WINTER HAVEN
Public Works Department
Natural Resources Division

City of Winter Haven Natural Resources

Mission:

Maintain and improve local natural resources through management based on a sound understanding of social, economic, and ecological systems.

Vision:

To be the premier knowledge base for local natural resources, with an engaged public, supporting natural systems through a community ethic.

Purpose:

Balance the needs of diverse user groups to sustain natural resources the community can be proud of.

Values:

Courteous, Cognizant, Cooperative, Resourceful, Responsive, Accurate, Adaptive

Executive Summary

As the Chain of Lakes City, Winter Haven's economic, cultural, and ecologic identity is inextricably tied to the health of its more than 50 area lakes. Proper management of these resources is absolutely necessary to ensure that Winter Haven remains a place of enriched lifestyle for residents and visitors alike.

Effective lake management requires an understanding of the factors that impact lake health. Starting in the 2018 report, the Winter Haven Natural Resources Division (NRD) developed an evaluation methodology based on water quality, hydrologic, and biological metrics to track comprehensive health of our lakes over time. This integrated, data-driven approach provided a means for objective prioritization and implementation of best management practices for the 37 public lakes in the study area. The purpose of this report is to provide background information on these metrics, an analysis of the most recent data, and to highlight the management strategies utilized to maintain and improve lake health. It is our hope that by sharing this information with the public, we can increase community understanding and support to protect these natural resources.

An overview of the primary lake health metrics and their annual changes can be found on pages 259 - 261. The average lake health score for all lakes has increased from a score of 1.8 in 2018 to an all-time high of 2.0 in 2022 and remains the same in 2023. A review of the 2023 Lake Health Index values showed that 60% (or 22) of the lakes met or exceeded their score from the previous year; while 40% (or 15) of the lakes exhibited decreasing scores. This indicates overall improvement in lake health for Winter Haven's waterbodies.

Water Quality: In 2023, 54% of lakes met all regulatory water quality targets—an increase from 51% in 2022. Of the 17 lakes that are currently impaired, 70% are exhibiting statistically significant improving trends in at least one of the regulatory metrics (i.e. chlorophyll-a, total nitrogen, and/or total phosphorus).

Hydrology: Winter Haven received approximately 47 inches of rainfall in 2023 which is below the 51.6 inch average. As a result, many lakes dropped to lower levels compared with previous years. For nearly 60% of these lakes, an increase in level correlates directly with an improvement in at least one primary water quality parameter. While this decline in water level should result in poorer overall water quality many lakes exhibited the same or better water quality during 2023. It is likely that lake levels have not declined low enough or for a long enough duration to have a negative impact on water quality.

Aquatic Biology: Aquatic vegetation monitoring remains a critical management strategy in order to maintain robust, healthy, and native ecological communities. Comparing biological criteria scores from 2018 to 2023 indicates that vegetation abundance and diversity are at an all-time high. While the average percentage of invasive plant species was slightly lower in 2022, the invasive presence is still better than it has been from 2018

to 2021. This indicates that management efforts have been successful at promoting the growth of healthy, native aquatic plant communities.

The City employs various management practices aimed at improving lake health. These efforts are detailed extensively in the Management Strategies section of the report. However, there are some notable highlights from 2023 that are listed in this summary.

Hydrologic monitoring is critical for understanding how changes in precipitation can impact surface level, water quality, and ecologic functions in our lakes (pp. 48-49). In 2022, the NRD budgeted for the purchase of several surface level sensors. By 2023, staff were able to order and acquire the equipment. Staff are currently in the process of programming and installing the sensors—to be completed in 2024.

Implementation of green stormwater infrastructure helps to capture and treat urban runoff and increase groundwater recharge (pp. 42-43). Construction on several raingardens in the downtown area began in late 2023 and are scheduled to be completed by the middle of 2024. Additionally, staff have initiated efforts to work with private volunteer organizations to help refurbish and maintain existing downtown raingardens.

Natural Resources staff continue to develop its outreach and education programming in 2023 (pp. 44-45, 55-56, 66-67). Staff not only provided guided kayaking tours and summer camp activities like in previous years, but also hosted an increased number of outreach events—reaching over 1500 individuals in 2023. Efforts have also been made to gather participant survey data to help refine outreach programming for the future.

Like in previous report years, an interactive Story Map version of this report can be found online via the following web address: www.tinyurl.com/wh-fl-lakesreport-app

Lastly, it is important to recognize the Lakes Advisory Committee for their valuable input on the report. Completing this document would not be possible without the guidance, advice, and support of local citizens with the passion to protect our natural resources. Additionally, we'd like to thank you, the reader. We hope the information contained herein allows for a deeper, more meaningful understanding of the factors that affect the health of our lakes. Please don't hesitate to contact the City Natural Resources Division if you have questions, suggestions, or wish to support lake management efforts in the Winter Haven area.

Sincerely,

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ANNUAL LAKES REPORT

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- What lakes are being studied?
- How are the lakes being evaluated?



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- What are the goals and success criteria?

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- What specific management efforts are used for each lake?
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#1 | Introduction



1.1 Purpose

The lakes of the greater Winter Haven area are considered some of its most important natural assets. The use of these waterbodies by visitors and residents alike has cemented their role as economic and cultural resources. Our lakes also impart environmental benefits such as fish and wildlife habitat, water storage, aquifer recharge, and flood protection. By virtue of this, one of the primary objectives of the City's Natural Resources Division is to monitor their overall wellness and to implement best management practices that will ensure the continued enjoyment of their benefits by our diverse user groups.

This report is compiled based on the data gathered from the Natural Resources Division's ongoing monitoring efforts. It presents a comprehensive outlook on the characteristics that comprise lake health as well as provides a detailed list of management strategies aimed at improving water quality. In using this holistic assessment approach, the City can prioritize waterbodies based on measurable conditions and implement specific management practices geared toward each lake's characteristics and issues. Using methods and techniques that are technically sound but presented in a manner that is accessible ensures that the information contained within this report can be understood and applied by the scientific community as well as the general public.

The work the City does to monitor and maintain the health of its lakes is also incredibly beneficial outside City limits. Winter Haven's lakes form part of the headwaters for the Peace River via the Peace Creek. The Peace River flows toward the Gulf of Mexico, eventually emptying into Charlotte Harbor—an economically and ecologically vital estuary along Florida's southwest coast. Since our lakes flow into such a major waterway, the health of both are intrinsically tied with far-reaching consequences for many people, businesses, and ecosystems.

Lastly, this annual report serves to document the City's evolving approach to environmental stewardship. As we continue to gain a better understanding of our natural systems, we hope to use that knowledge to refine our analytical methods and management practices. The principles we learn today will certainly drive how we preserve our lakes for the future.

1.2 Background on the Waterbodies

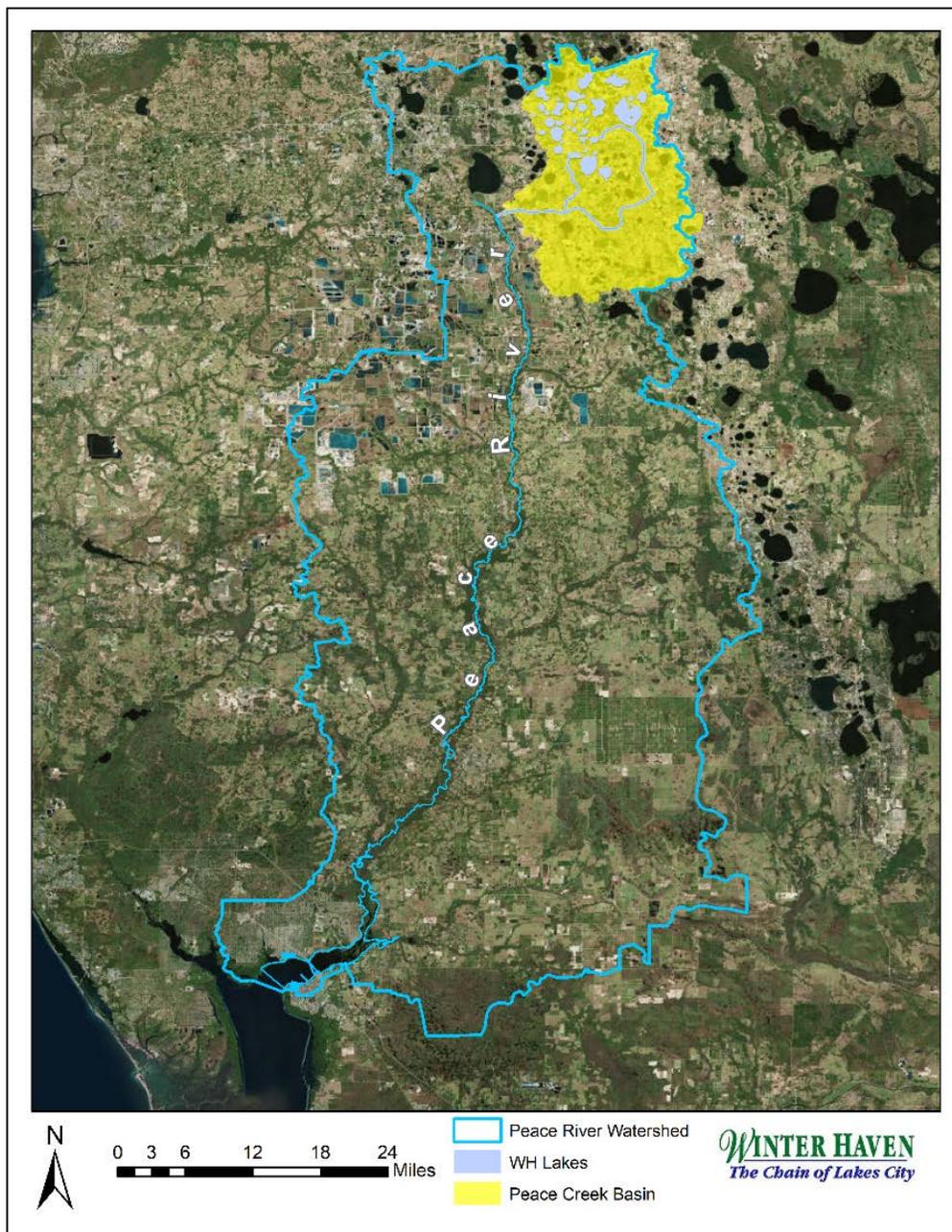


Figure 1-1. Map of Peace River & Peace Creek Watersheds

The lakes of the Winter Haven area are located within the Winter Haven Ridge and Polk Uplands geographic regions of Central Florida. The regional topography means that the Winter Haven lakes are at the top of the Peace River watershed in what is known as the Peace Creek sub-basin. As such, these waterbodies are a major contributor of surface and groundwater flow to the Peace River which flows to the Gulf of Mexico at Charlotte Harbor (Figure 1-1). The lakes chosen for this evaluation discharge directly or indirectly

to the Peace Creek Canal—a major tributary that flows south of the Winter Haven area from Lake Hamilton and then west to join with Saddle Creek to become the Peace River (Figure 1-2).

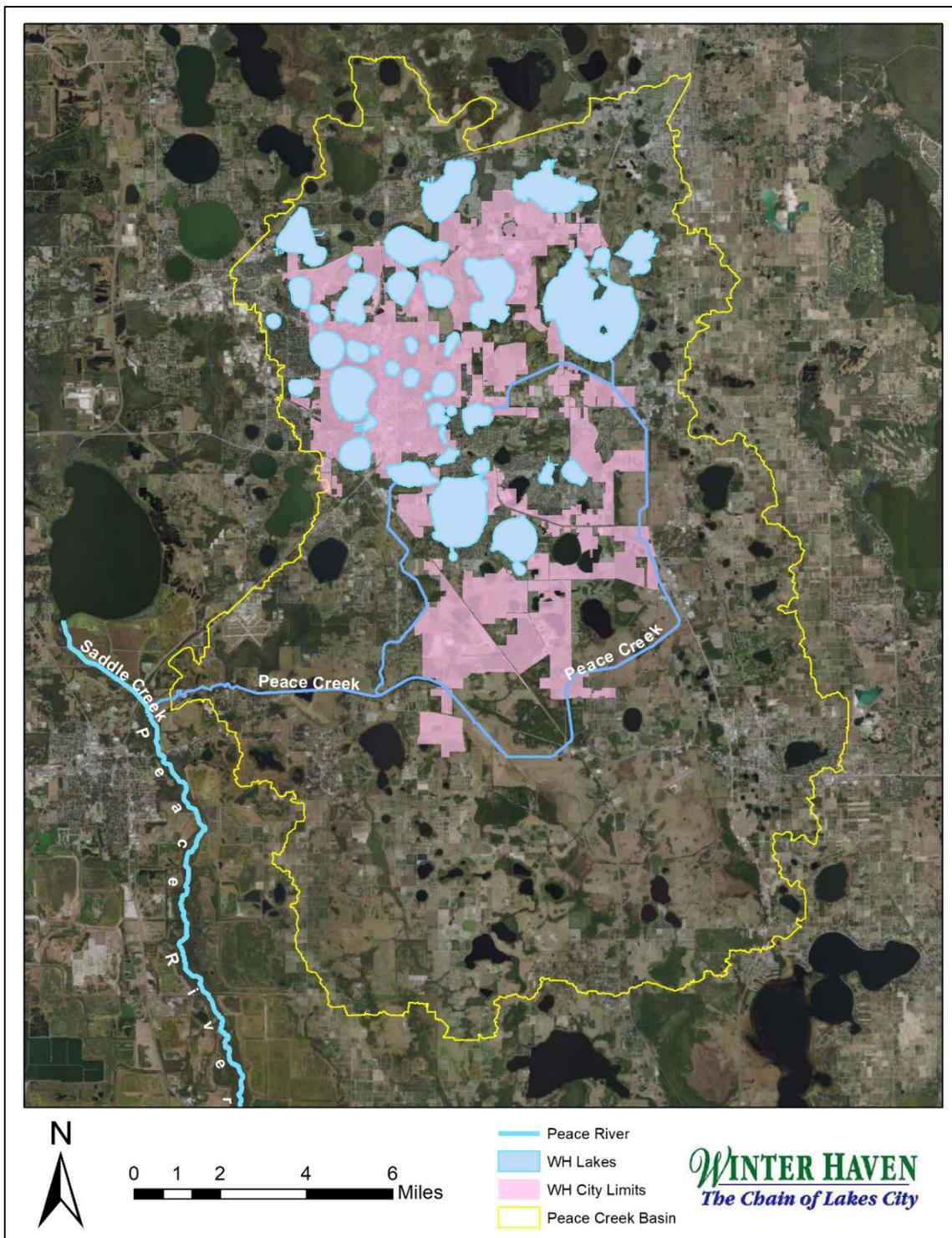


Figure 1-2. Map of the Peace Creek sub-basin, City of Winter Haven limits, contributing lakes and flow-ways.

Winter Haven Lakes

This report focuses on the 37 primary lakes that the Winter Haven Natural Resources Division monitors for lake health. These lakes were selected for monitoring based on several criteria:

- The lake must have some form of public access (e.g. public park, boat ramp, or navigable canal from another publicly accessible lake).
- The lake must be located within or adjacent to Winter Haven city limits, or it must discharge directly to a public lake within city limits.
- The lake must discharge, either directly or indirectly, to the Peace Creek.
- The lake must have a sufficient period of record water quality and hydrologic data set (approximately 20 years) in order to evaluate.

The lakes included in this report were previously categorized into five groups: *North Chain of Lakes, North Central Lakes, South Chain of Lakes, South Central Lakes, and Outlying Lakes*, based on their geographic location and where they discharge water to. This was done in order to summarize the water quality, hydrologic, and ecological data by group. Recent iterations of this report evaluate each lake individually, meaning the lake groupings are no longer necessary. The following are the 37 lakes listed in alphabetical order:

- | | | |
|----------------------|---------------------|----------------------|
| 1. Blue | 14. Idyl | 27. Pansy |
| 2. Buckeye | 15. Idylwild | 28. Rochelle |
| 3. Cannon | 16. Jessie | 29. Roy |
| 4. Conine | 17. Link | 30. Shipp |
| 5. Daisy | 18. Lulu | 31. Silver |
| 6. Deer | 19. Mariam | 32. Smart |
| 7. Elbert | 20. Mariana | 33. Spring |
| 8. Eloise | 21. Martha | 34. Summit |
| 9. Fannie | 22. Maude | 35. Winterset |
| 10. Haines | 23. May | 36. Little Hamilton |
| 11. Hamilton | 24. Mirror | 37. Middle Hamilton |
| 12. Hartridge | 25. Ned | |
| 13. Howard | 26. Otis | |

The series of waterways connected by navigable canals is colloquially referred to as the Winter Haven Chain of Lakes (highlighted in **bold** in the list above). Many of these canals were constructed in the early 1900's, in part as a means to transport citrus through the region [Cavitt, 2015; Gernert, 2016]. With the advent of the automobile, the canals never got to serve this purpose—instead their primary role became recreational transportation. Winter Haven's Chain of Lakes are a paramount piece of the City's culture and economy. The Lakes are used year-round for recreation and many businesses rely on their presence to keep their doors open. Similarly, residents and visitors enjoy the lakes for everything from

water skiing to landing seaplanes. Not only is Winter Haven the Water Skiing Capital of the world, but pilots looking to learn how to fly seaplanes come from around the world to train on the Winter Haven Chain of Lakes. Whether it’s fishing, boating, water skiing, kayaking, or flying a seaplane, Winter Haven has built its day-to-day life around our lakes, which means caring for them is a critical responsibility.

The Winter Haven Chain of Lakes can be differentiated into a ‘North Chain’ and ‘South Chain’; managed at different levels and separated by a lock system which allows boats to navigate from one to the other. The lock system is controlled by the Lakes Region Lakes Management District (LRLMD) and is located between Lakes Hartridge and Conine. The Southwest Florida Water Management District (SWFWMD) manages the surface level of the Northern Chain of Lakes via a series of active water control structures. For the purposes of water conservation and flood control, the SWFWMD sets the maximum desired levels at each of these structures—discharging water to the Peace Creek Canal when surface levels exceed the upper limits [SWFWMD, 2019]. In this system, water flows from west to east toward the terminal discharge point at Lake Hamilton. The South Chain of Lakes is comprised of 14 waterbodies connected via navigable canals and held at roughly the same surface elevation. A passive control structure located on the southern shore of Lake Lulu and managed by the LRLMD maintains the surface level of this chain.

The remaining (Interior) lakes have non-navigable connections (i.e. pipes and ditches) that allow them to flow either directly to the Peace Creek or indirectly via one of the lake chains. The movement of water through many of these connections is determined by water control structures put in place primarily to maintain the lakes at desirable levels. The control structures can be grouped into active or passive categories. Active structures rely on the deliberate opening/closing of a gating mechanism to allow water to pass through the flow-way at an adjustable level. Whereas passive structures include weirs or pipes set at the lake’s maximum desired water level. Passive structures only allow for the overflow of water above that set level. The SWFWMD and LRLMD maintain the majority of structures in the Winter Haven area, however, a couple of passive structures are managed by Polk County (Table 1-1). The canals and connections for these lakes are shown in Figure 1-3.

Control Structure ID	Contributing Waterbody	Managing Organization	Control Type	Maximum Desired Elevation (NGVD29)
P-5	Lake Henry	SWFWMD	Active	126.00
P-6	Lake Smart	SWFWMD	Active	128.50
P-7	Lake Fannie	SWFWMD	Active	125.50
P-8	Lake Hamilton	SWFWMD	Active	121.25
Lulu-CS	Lake Lulu	LRLMD	Passive	132.00
Silver-CS	Lake Silver	LRLMD	Passive	146.50
Martha-CS	Lake Martha	LRLMD	Passive	142.00
Maude-CS	Lake Maude	LRLMD	Passive	140.50
Idyl-CS	Lake Idyl	LRLMD	Passive	132.00
Link-CS	Lake Link	LRLMD	Passive	128.00
Mariam-CS	Lake Mariam	LRLMD	Passive	124.75
Mariana-CS	Lake Mariana	LRLMD	Passive	137.50
Blue-CS	Lake Blue	Polk County	Passive	148.86
Deer-CS	Lake Deer	Polk County	Passive	138.61

Table 1-1. Control structure elevations, contributing waterbodies, and managing agencies of study area lakes.

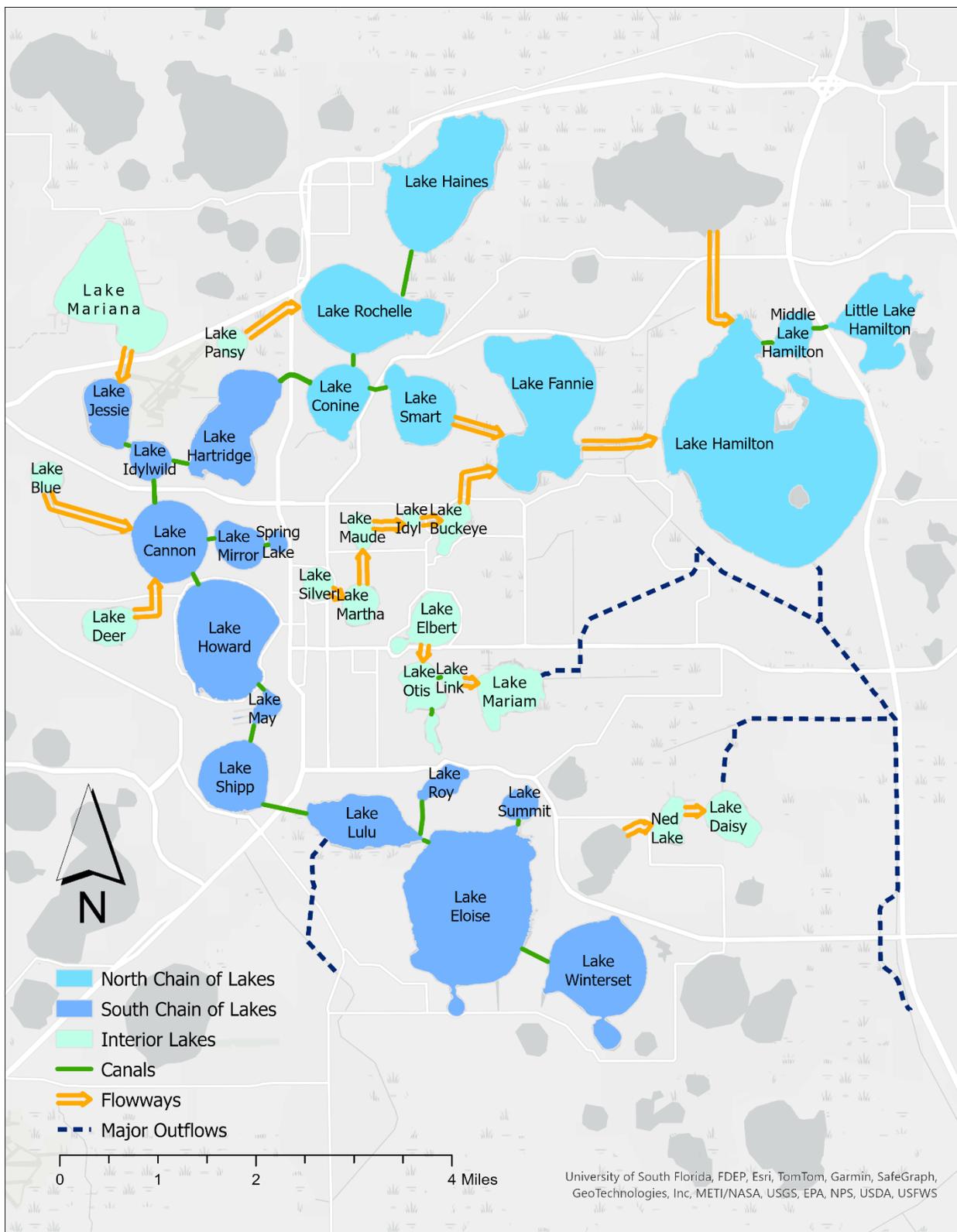


Figure 1-3. Map of Winter Haven Lakes, navigable canals, non-navigable flow-ways, and major outflows.

1.3 Background on the Metrics

Just as a person’s physical health relies on multiple factors, so are the facets of lake health built upon complex interactions amongst various components. While significant insights can be gained by studying the individual metrics, a more comprehensive approach is needed to identify systemic issues and prescribe effective solutions. For the purposes of managing the previously mentioned lakes, the focus will be placed on understanding the interactions amongst water quality, hydrology, and ecology.

Water Quality

The term “water quality” refers to the relative perceived condition of a water source based on a selection of its physical and chemical characteristics. Different user groups may often evaluate a lake based on what they consider good or bad qualities. Attributes like water clarity or color can conjure different connotations to swimmers than to anglers or ecologists. Managing waterbodies in a way that strikes a balance between usability and environmental health ensures that the greatest number of people can take advantage of the benefits our lakes provide.

In the context used by the scientific community and regulatory agencies, water quality refers to specific chemical characteristics of a waterbody and how they affect its intended use. The following are some of the parameters utilized by the Federal and State governments that the City also considers as objective water quality indicators. Throughout the following sections, these core water quality metrics will be used in the City’s analysis in the context of overall lake health.

Primary Water Quality Metrics

Chlorophyll-a (Chl-a): *Measured as the concentration of photosynthetic pigment of plants and algae in the water column, Chl-a is used to estimate algal abundance and can represent the trophic state or biological productivity of a waterbody.*

Nutrient Concentrations: *Measured as the concentration of total nitrogen (TN) and total phosphorus (TP) in the water column, TN and TP are the primary nutrients that contribute to anthropogenic eutrophication and negative impacts like algae blooms and fish kills.*

Water Clarity: *Measured as Secchi depth, or the maximum depth in the water column that a Secchi disk remains visible to the naked eye. Clarity can be used to measure both suspended and dissolved matter in the water column. Turbidity and true color are separate parameters that impact overall water clarity.*

Regulatory Impairment Evaluation

A major effort by State and Federal environmental agencies in recent decades was the development of an objective set of standards to measure anthropogenic (human) impacts to waterbodies. These impacts primarily come from the discharge of pollutants such as bacteria, heavy metals, and nutrients. For the purposes of this report, the focus will be placed on nutrient pollution as these are the primary catalysts of lake eutrophication and

the reason for impairment of Winter Haven’s waterbodies. Eutrophication is an increase in productivity (i.e. plant and algal growth) that is the result of the lake receiving sediment and other inputs over time. This process occurs naturally over thousands of years. However, many anthropogenic sources of pollution can expedite this process until lakes become hypereutrophic—a productive state that facilitates harmful algal blooms (HABs), fish kills, and increased growth of nuisance or invasive plants.

In 2011, under section 303(d) of the Clean Water Act, the US Environmental Protection Agency (EPA) and the Florida Department of Environmental Protection (FDEP) established sets of Numeric Nutrient Criteria (NNC) for all of Florida’s surface waters. These criteria are based on a waterbody’s intended use classification, estimated natural conditions, and the human-related influences that contribute to eutrophication.

FDEP Intended Use Classifications

- **Class I:** *Potable Water Supply*
- **Class II:** *Shellfish Propagation & Harvesting*
- **Class III:** *Recreation; Propagation, & Maintenance of a Healthy, Well-Balanced Population of Fish & Wildlife*
- **Class IV:** *Agricultural Water Supply*
- **Class V:** *Navigation, Utility, & Industrial Use*

The NNC are specific chemical concentration targets that waterbodies must meet for their intended use classification. All of the Winter Haven lakes fall under Class III. Chlorophyll-a (Chl-a), a measure of algal abundance, is generally used as a response metric for a waterbody’s trophic state. High Chl-a concentrations indicate an increased trophic state and vice versa. The EPA and FDEP have established that the two main drivers of eutrophication in freshwater systems are TN and TP. These nutrients are often the limiting component for Chl-a increase as illustrated by their correlative relationships (Figure 1-4). This figure shows that an increase in either TN or TP will generally lead to an increase in Chl-a. As a result, NNC thresholds were established to help determine if a waterbody is impaired. Once impairment has been established, action is taken to reduce water quality back to target concentrations.

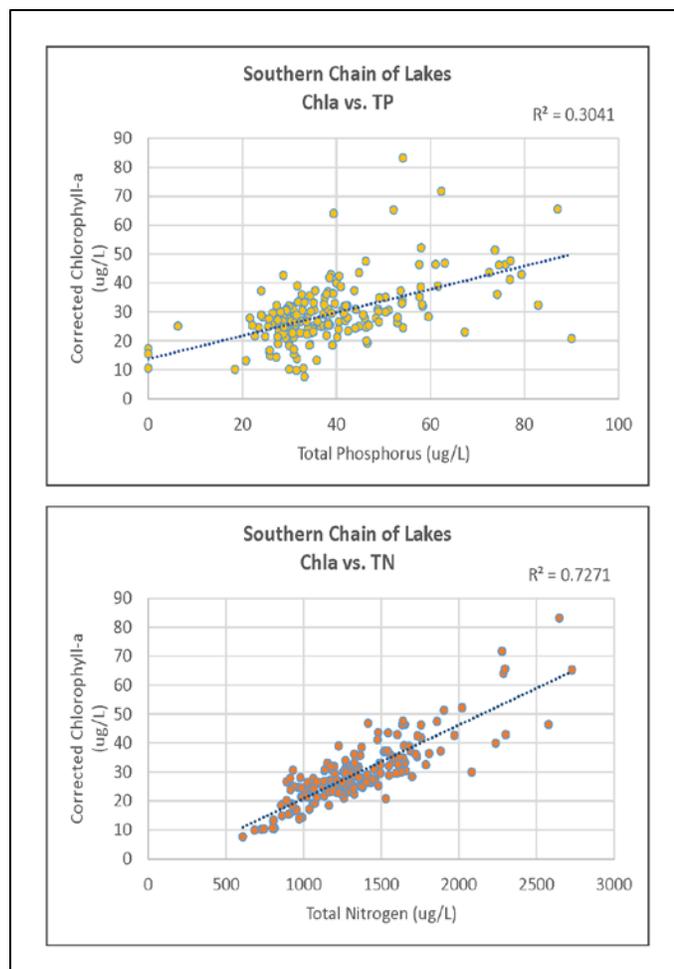


Figure 1-4. Linear Regression of Chlorophyll-a vs. Total Phosphorus & Total Nitrogen

In addition to the parameters mentioned above, other chemical characteristics can impact how a lake responds to increased nutrient concentrations. FDEP further categorizes freshwater lakes based on long-term concentrations of True Color and Total Alkalinity.

True Color: *Measured in Platinum-Cobalt Units (PCU), is indicative of the amount of dissolved organic compounds present in the water column.*

Color partly affects the depth light can reach in the water column, impacting the growth of aquatic plants and algae. Color is often imparted by the breakdown of tannins found in wetland plant matter. Therefore, lakes with large connecting wetlands typically have higher color concentrations.

Total Alkalinity: *or water hardness, measured in milligrams per liter of Calcium Carbonate (mg/L CaCO₃), indicates a waterbody's ability to neutralize acids and buffer against changes in pH.*

Generally, lakes with more alkalinity can support more productivity which is why this metric is used to classify lakes [Lakewatch 101, 2000]. Due to the increased presence of underlying carbonate rock (limestone) in this region of Florida, the majority of Winter Haven's lakes possess relatively high natural alkalinity.

To simplify the NNC impairment determination process, a flow chart was developed by City staff as a step-by-step guide (Figure 1-5) [FDEP, 2013]. The initial step of the assessment process involves categorization of lakes based on the long-term geometric mean true color and total alkalinity concentrations. Winter Haven's lakes generally fall into two categories: colored lakes (>40 PCU) and clear/alkaline lakes (<40 PCU & >20 mg/l CaCO₃).

These categories are subject to individual thresholds for the annual geometric mean (AGM) concentrations of Chl-a, TN, & TP. The first NNC parameter assessed is Chl-a concentration. If the AGM Chl-a exceeds the NNC threshold, or if there is insufficient data to determine Chl-a impairment, the AGM TN & TP concentrations are subject to the minimum impairment limit for that year. If there is no Chl-a exceedance, AGM TN & TP concentrations are subject to the maximum limit. To assess long-term water quality trends, 7.5 years of AGM concentrations are evaluated. If the Chl-a, TN, or TP threshold is exceeded more than once in any consecutive 3 year period, then the waterbody is placed on the verified impaired or study list. By this process, a lake can be considered impaired for nutrients in response to exceedances by Chl-a, TN, and/or TP.

Regulatory Response

After a waterbody is determined to have a nutrient impairment, the FDEP develops pollutant reduction goals for stakeholders that contribute surface water or groundwater to that waterbody. Referred to as a Total Maximum Daily Load (TMDL), the reduction goals represent the total allowable amount of pollutants that can be discharged to a waterbody per day and still meet the intended use. TMDLs are established for the pollutant of concern which is typically the nutrient of impairment, but can also be the limiting nutrient(s). A nutrient is considered limiting if present in lower relative concentrations than other nutrients or if it would be the first to be used up through natural processes. When a

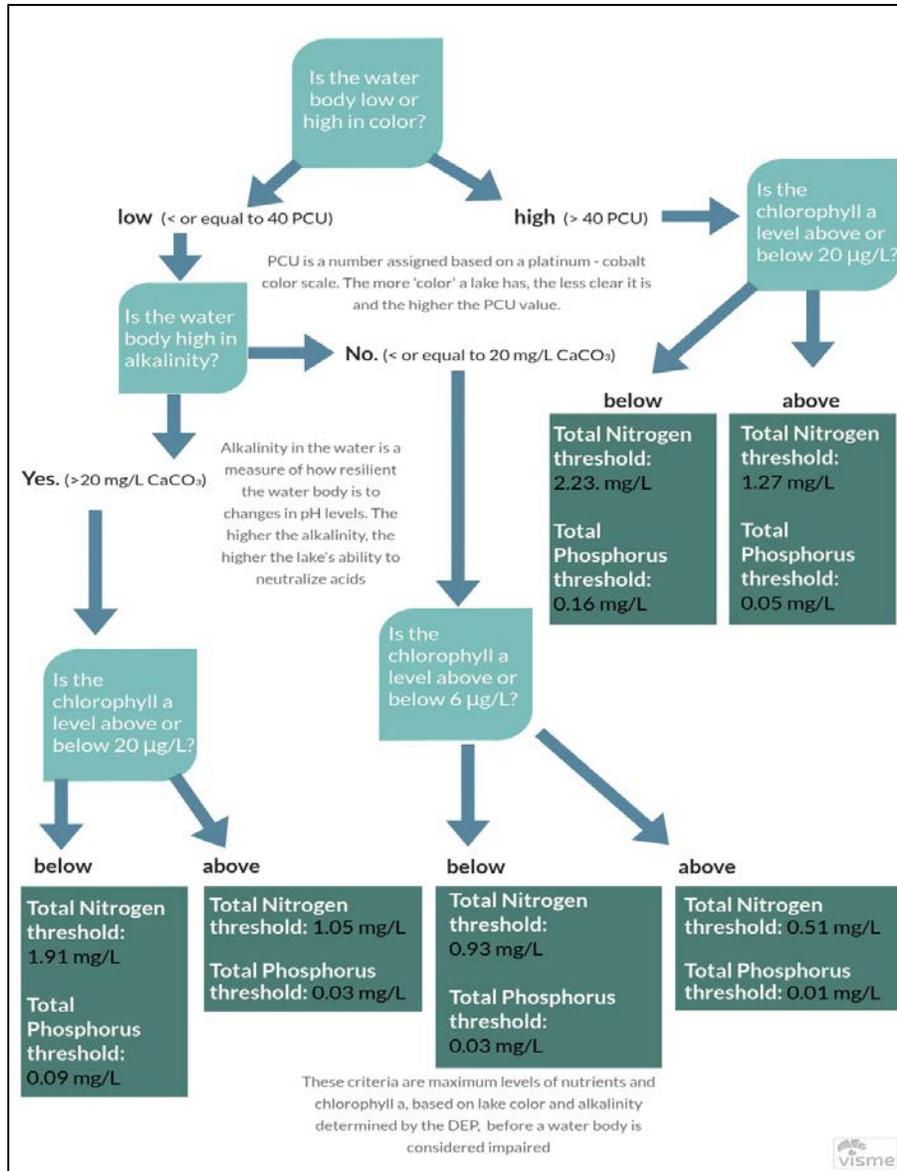


Figure 1-5. NNC Impairment Determination Flowchart

limiting nutrient is depleted, plant and algal growth cannot continue regardless of the presence of other nutrients. Depending on the ratio of nitrogen to phosphorus, a lake may be considered phosphorus-limited, nitrogen-limited, or co-limited. According to UF/IFAS, the majority of Florida lakes are phosphorus limited or co-limited (by both nitrogen and phosphorus) [Lakewatch 102, 2000]. Knowledge of the limiting nutrient can assist lake managers in determining what management practices to focus on to improve water quality.

In order to establish appropriate nutrient reduction goals that will lead to water quality improvement, the FDEP must estimate the current pollutant loading rate from potential sources (e.g. lbs/year of TP). Point sources refer to discharge from wastewater treatment plants and **Municipal Separate Storm Sewer Systems (MS4s)**. Nonpoint sources refer to the introduction of pollutants through surface runoff, atmospheric deposition, groundwater, sediments, and any other sources that don't possess a discrete entry point.

Calculating the current loading rate for each stormwater outfall is accomplished by incorporating estimated annual runoff volumes, size of the contributing drainage areas, land uses, and their respective average loading rates for each pollutant per storm event—referred to as event mean concentrations (EMCs).

With a developed TMDL clearly outlining reduction goals for all relevant loading sources, the next step is the creation of a Basin Management Action Plan (BMAP) or Water Quality Management Plan that mandates stakeholder compliance with the TMDL through the implementation of best management practices (BMPs). BMP is a blanket term that refers to any structural or non-structural practice or initiative that contributes to water quality improvement. The same BMPs aren't applicable for every scenario, therefore the development of BMAPs requires a thorough understanding of the unique challenges associated with individual waterbodies. Successful reduction of pollutant concentrations below the impairment thresholds for an extended period will allow FDEP to remove waterbodies from the verified impaired list to a study list to be monitored for long-term compliance. Once deemed stable in an unimpaired status, waterbodies can then be delisted until such a time they exceed NNC thresholds again.

The FDEP evaluates nutrient impairment of State waterbodies via a cyclical assessment schedule. Impairment determination incorporates the most recent 7.5 years of quality-controlled data. Due to the large number of waterbodies in the State and FDEP staffing limitations, statewide annual re-evaluations of impairment aren't feasible. Using the FDEP methodology, the City of Winter Haven has begun evaluating NNC exceedances of local lakes annually. The ability to evaluate individual lake exceedances annually is beneficial in that it provides insights into the incremental changes in water quality. While impairment doesn't typically change from year to year, extrapolation of the water quality trends can allow for predictions of when NNC goals will be met or exceeded in the future.

Nutrient Cycles

Nitrogen (N) and Phosphorus (P) have been established as the primary pollutants of concern from an anthropogenic standpoint, but each is involved in a complex natural cycle within lake ecosystems. Both nitrogen and phosphorus enter aquatic systems through similar external pathways: surface runoff, groundwater infiltration, and atmospheric deposition (i.e. air and precipitation). Nitrogen is typically present in three forms: organic N, inorganic N, and atmospheric N. Typically, only the inorganic, mineral form of N is biologically available for plants and algae to uptake. Most inorganic N is derived from a microbial process called mineralization that converts it from organic forms. Bioavailable N can also be introduced via anthropogenic sources such as fertilizers and wastewater. One of the more important aspects of the nitrogen cycle is denitrification—a process by which soil bacteria in anoxic conditions can convert inorganic N to atmospheric N; effectively removing it from the aquatic environment.

Similar to nitrogen, phosphorus also cycles in and out of inorganic (bioavailable) and organic (unavailable) forms. Plants and algae uptake inorganic P from the water column and sediments and convert it into organic P as it's incorporated into their cellular structure.

When plant and algal cells die or are eaten, the remains are left to decompose on lake bottoms. Bacteria convert the organic P to inorganic P which can return to the water column depending on the current TP gradient in the lake. This process, called phosphorus flux, can allow large amounts of P to be stored and released over long periods of time—facilitating a continual source of TP. Unlike the nitrogen cycle, phosphorus doesn't undergo a bacterial transformation to an atmospheric form; meaning the only effective means to reduce TP in aquatic environments is through the physical removal of plants, animals, or sediments (muck removal). Due to the large costs associated with these strategies, it's often more economically feasible to develop methods to lock phosphorus in the sediments or prevent it from entering aquatic environments altogether.

Underscoring the concepts of phosphorus flux and nitrogen mineralization is the concern regarding internal nutrient loading. The presence of legacy nutrients originating from historic wastewater or industrial discharges and deposits of phosphatic soils can exacerbate eutrophication. These legacy nutrients require special consideration in planning BMPs as even a significant reduction of stormwater input may not have much effect on water quality if the majority of loading originates from the underlying sediments.

Additional Parameters & Considerations

Trophic state was mentioned previously as a concept describing a waterbody's level of primary productivity. Productivity is a term that relates to the amount of plants, algae, and wildlife a waterbody can support. Trophic status is broken down into several classes (Figure 1-6) [USGS, 1998]:

Trophic States

- **Oligotrophic:** *Low productivity*
- **Mesotrophic:** *Moderate productivity*
- **Eutrophic:** *High productivity*
- **Hypereutrophic:** *Very high productivity*

As stated above, lakes naturally increase in productivity as they age due to the deposition of sediments over time. Generally, oligotrophic lakes are relatively clear, deeper, and possess smaller populations of plants and fish. Eutrophic lakes, on the other hand, are often highly colored or turbid due to increased amounts of organic sediments. These lakes are typically shallower and have higher natural nutrient concentrations—as such they

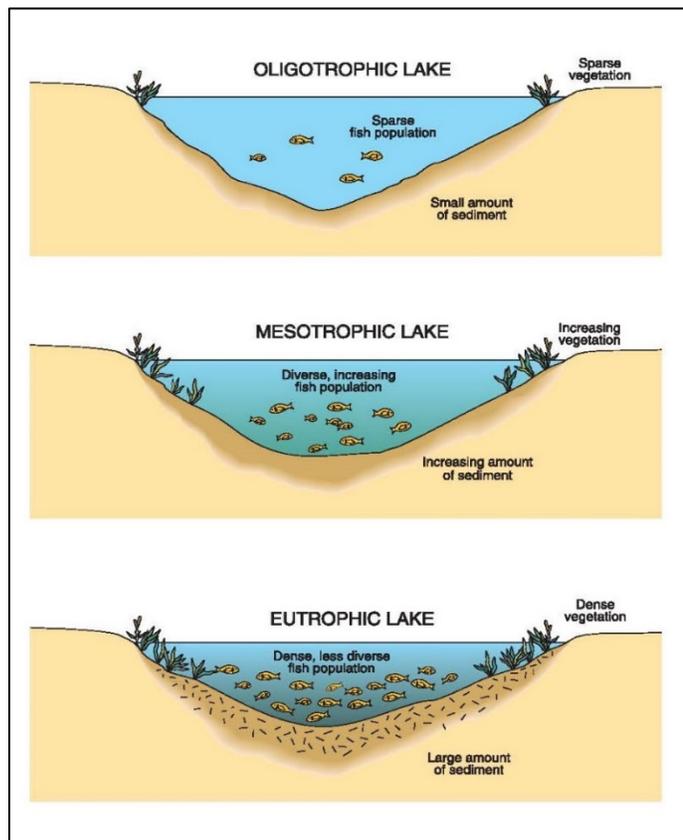


Figure 1-6. Diagram of Lake Trophic States [USGS, 1998].

can support more plants, algae, and wildlife. Mesotrophic waterbodies fit the middle ground between these two while hypereutrophic waterbodies fall on the extreme side of eutrophic. Due to an overabundance of nutrients in hypereutrophic lakes, they are often associated with harmful algal blooms, fish kills, and the unrestricted growth of invasive or nuisance plants. Impairment regulations attempt to set achievable nutrient targets to reduce lake trophic state or prevent further anthropogenic eutrophication. Most of Winter Haven's lakes are considered eutrophic to hypereutrophic.

Prior to the use of the current NNC system, FDEP relied on a ranked system known as the Trophic State Index (TSI) to determine impairment ^[FDEP, 2013]. The index ranks trophic state from low to high productivity on a scale from 1 – 100; calculated using concentrations of TN, TP, total chlorophyll, and Secchi depth. It was determined that a combined trophic state metric cannot always accurately represent the overall quality of a lake. A waterbody with high average TSI values may not be preferable for swimming or skiing, but it could still easily meet the intended use for other forms of recreation such as fishing or kayaking ^[Lakewatch, 2000].

Paleolimnology, or the ecological study of historic lake conditions, can provide insights into the pre-disturbance trophic state of inland waterbodies. By testing the layers of sediment that have accumulated on the lake floor, inferences regarding historic phosphorus and chlorophyll concentrations can be made. Several studies performed on Winter Haven area lakes have shown that several of these waterbodies were naturally eutrophic before human development in the region ^[Whitmore et al., 1996; Whitmore & Brenner, 2002].

Water clarity is a metric that indicates the depth that light can penetrate in the water column. This parameter is measured by lowering a Secchi disk into the water column until it is no longer visible. Unlike true color, clarity is impacted by the dissolved *and* suspended particulate matter in the water column. This includes algae, turbidity, and color imparted by dissolved solids. Turbidity or total suspended solids (TSS) is the component of water clarity associated with particulate matter. Often, recreational user groups misconstrue clarity as a mark of water cleanliness. Since many components factor into the overall clarity metric, an unclear lake may not always suffer from water quality issues. Due to this, Secchi depth is no longer used as an impairment determination parameter. Nevertheless, clarity can still provide insights into a lake's response to changes in water quality.

Hydrology

Hydrology is the study of the pathways that water takes through our environment. Water's journey is long and varied and each molecule travels the Earth through different paths. The way water enters, leaves, and interacts with our lakes plays a large part in their overall health. The following metrics are the primary hydrologic response variables and characteristics that are assessed by the City and other environmental agencies. While the metrics listed below are not direct indicators of lake health, they are useful for determining underlying causes of poor water quality and/or biological health. In addition, management practices can be tailored to specific waterbodies based on their unique hydrologic characteristics. In the health and wellness analogy, hydrology is akin to a patient's medical history and genealogy—things that cannot be changed, but can point to underlying issues that can be managed.

Primary Hydrologic Metrics

Surface Level: *The elevation of a waterbody's surface measured in feet above sea level. Also known as lake stage, surface level changes over time in response to environmental stimuli such as precipitation and groundwater influence.*

Aquifer Level: *The elevation of groundwater surface measured in feet above sea level. There are two major types of groundwater in peninsular Florida. The surficial aquifer or water table and the confined aquifer.*

Pollutant Loading: *The amount of pollution that can enter a waterbody via stormwater flow, pollutant load is typically estimated based on precipitation, land use, and surface runoff potential (imperviousness).*

Rainfall

Precipitation in all its forms (rain, snow, sleet, hail) is one of the main drivers of the hydrologic cycle. Winter Haven is a great example of the importance of precipitation as our local hydrologic system is completely rainfall-driven. The topography of the Winter Haven Ridge and Polk Uplands regions essentially places these lakes on a hilltop that causes surface water to naturally migrate downstream toward the Peace River. The amount of rainfall received in this area is responsible for fluctuations in lake levels as well as the recharge of groundwater reservoirs.

Precipitation can reach a lake directly or via surface runoff from the surrounding land. The total area that contributes stormwater runoff to a waterbody is referred to as that lake's drainage basin. In a natural system the effective drainage basin of a lake is relatively small. An abundance of vegetation and a lack of impervious surfaces cause much of that stormwater to infiltrate into the groundwater system before it reaches the lake. Installation of "gray" infrastructure such as stormwater pipes or concrete ditches that direct runoff to a waterbody effectively increase that waterbody's drainage basin. This can cause issues such as more extreme surface level fluctuations as well as increased nutrient loading. Restoring some of the natural drainage pathways can be accomplished through the

implementation of “green” infrastructure that reduces runoff and increases stormwater storage and infiltration.

Groundwater

There are two primary tiers of groundwater in Florida: the upper layer known as the surficial aquifer, and the deeper Floridan aquifer that is confined under a layer of impermeable clay. Measurement of the elevation above sea level of the upper surface of each aquifer is the accepted method for determining their current water quantity. The surficial aquifer level, referred to as the water table, generally fluctuates readily based on rainfall, soil saturation, temperature, and humidity. The Upper Floridan Aquifer is confined under pressure. As a result, its level is measured as the potentiometric surface, or the level at which water will rise in a well pipe due to the pressure exerted on it. Where there are breaks or perforations in this confining layer, water can be exchanged with the surface. Fluctuations of both the surficial and Upper Floridan levels can significantly impact lake surface levels (Figure 1-7). During periods of time or locations where the aquifer surfaces are high, water may flow to the surface via the bottom of lakes. Naturally, the opposite occurs when the water table and potentiometric surface are low.

The Upper Floridan Aquifer is the sole municipal water source for the City of Winter Haven. As one of the fastest growing metropolitan regions in the Country [US Census Bureau, 2018], the potential hydrologic impacts of water use must be considered for both the ecological outlook of our lakes and the future of our drinking water supply. The primary hydrologic strategies for this area include promoting rapid recharge of the Upper Floridan and the long-term storage, treatment, and slow infiltration of stormwater in areas where fast recharge isn't feasible.

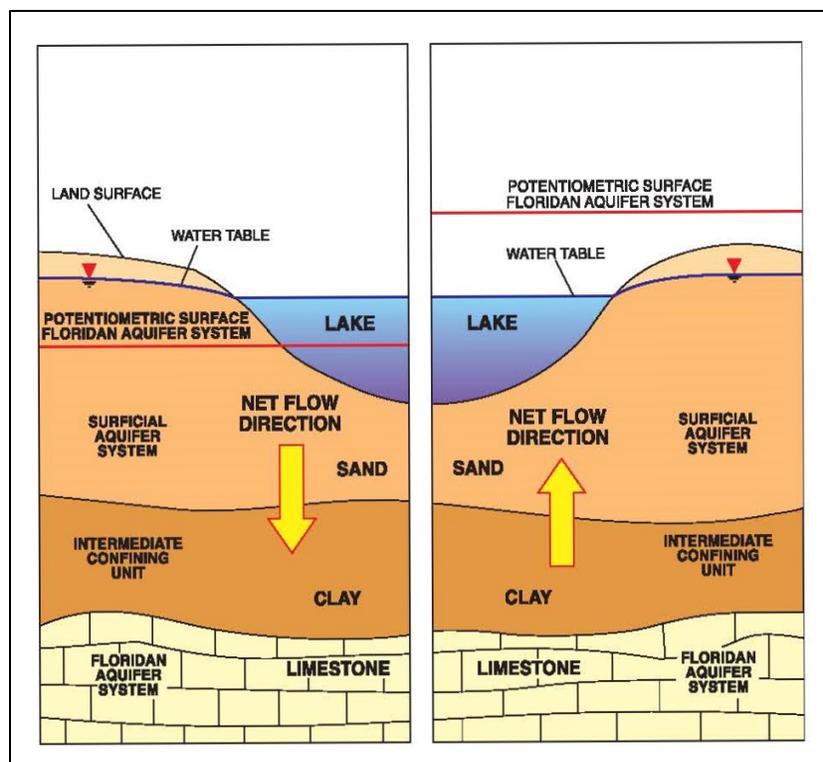


Figure 1-7. Diagram of Groundwater Interactions.

Soil Type

The types of soils found in lake drainage basins can significantly impact hydrology. The United States Department of Agriculture (USDA) has classified soils on public and private

lands into several hydrologic groups based on sediment types (e.g. sand, clay, loam) and their respective water infiltration rates. This information has been used in site development planning/engineering across the country since the early 1900s. Environmental scientists can also utilize soil data to determine how quickly water can percolate into the groundwater system.

USDA Hydrologic Soil Groups

- **Group A:** Soils consisting mostly of excessively drained sands or gravel with a high infiltration rate when thoroughly wet.
- **Group B:** Soils consisting of moderately well-drained coarse or fine texture sediments with a moderate infiltration rate when thoroughly wet.
- **Group C:** Soils consisting of fine textures having a layer that impedes the downward movement of water with a slow infiltration rate when thoroughly wet.
- **Group D:** Soils consisting chiefly of clays or clay layers near the surface or over nearly impervious material with a very slow infiltration rate.
- **Dual Groups: (A/D, B/D, C/D)** Mixed soils with no dominant type where the designation applies to their status when 'drained'/'saturated'.

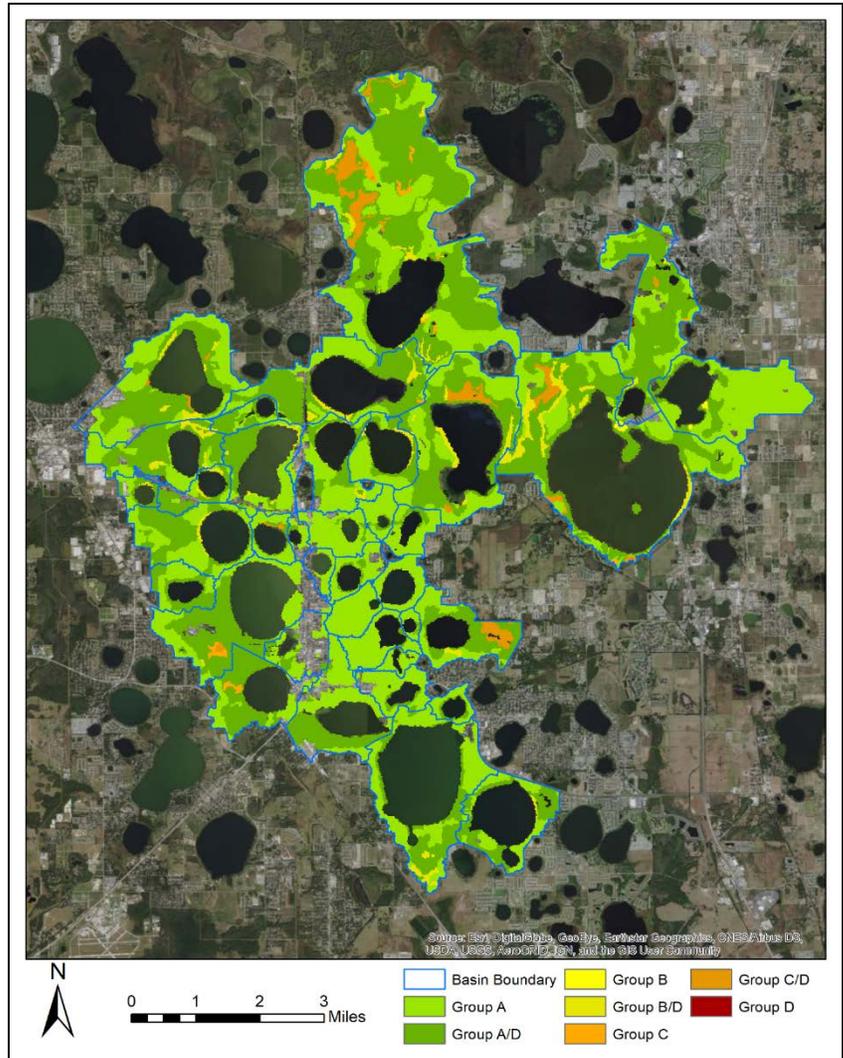


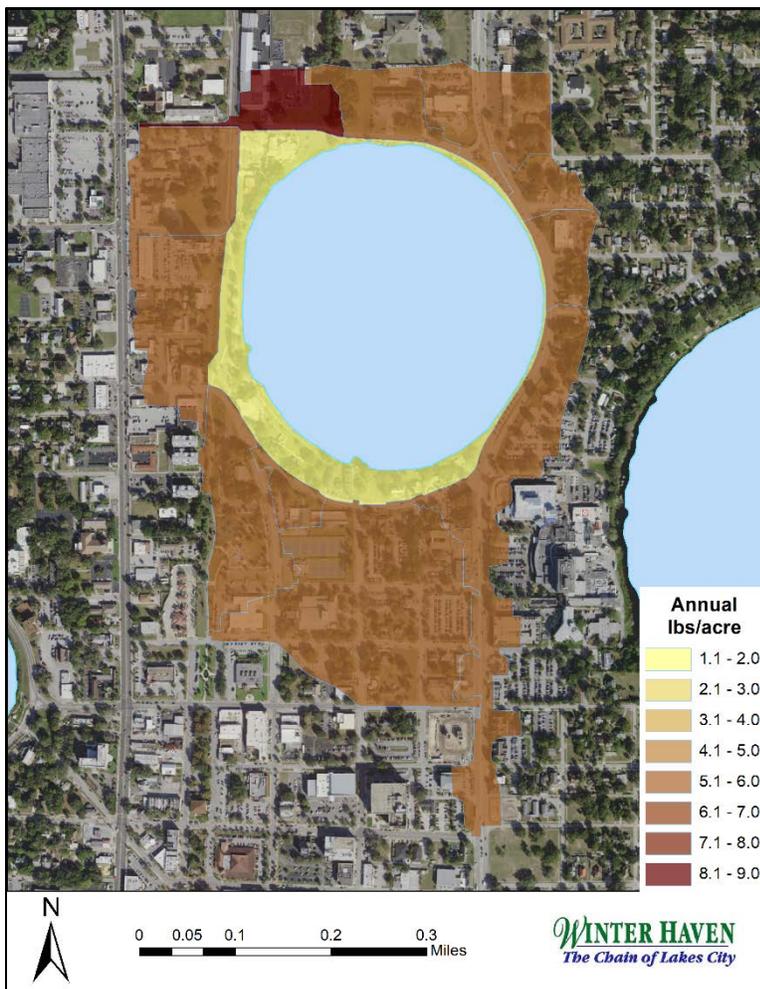
Figure 1-8. Hydrologic Soil Groups of the Winter Haven Lakes.

The proportion of each soil group making up a given lake drainage basin can indicate the pre-development infiltration potential in that basin. This information can also be used to determine adequate locations for BMPs that promote groundwater recharge or treatment of stormwater. The majority of the Winter Haven area consists of Class A or A/D soils. However, notice that the proportion of poorly-drained soil types increases further from the downtown area (Figure 1-8). It can be inferred that stormwater infiltration BMPs will be more effective in the City center with surface water storage/treatment being relegated to the less well-drained lower elevations at the periphery of the downtown area.

Pollutant Loading

Identifying pollution hotspots in our waterbodies is the primary purpose of pollutant load determination. Focusing management efforts on areas with relatively high pollutant loads can only be done through quantification. Nonpoint pollutant loads such as septic leaching into groundwater are difficult to estimate, however it is still useful to identify areas of high septic density to develop management plans around them. For point sources or stormwater drainage basins with few discharge points, it may be more feasible to sample during storm events and calculate an average pollutant load during a typical year. Larger or more complex watersheds may require hydrologic modeling to estimate loading. Due to the number of lakes and individual drainage sub-basins in the Winter Haven area, the City has elected to model stormwater pollutant loads for the 37 lakes under consideration.

In the realm of stormwater pollutant load modelling, there are several methods that take into account various factors that can influence loading rates. The ‘Simple Method’, developed by Thomas Schueler in 1987, is an EPA approved model that utilizes rainfall volume, soil type, impervious area, and land use to estimate the annual load of various pollutants such as TN, TP, suspended solids, and heavy metals [Schueler, 1987]. Tied to each



land use are average impervious percentages to determine runoff rates as well as event mean concentrations (EMCs) which denote average loading rates for each pollutant per storm event. The result of this modeling work is the ability to estimate annual loads of nutrients from each sub-basin to prioritize the implementation of BMPs in high-loading hotspots. For example, differences in land use can drastically impact pollutant loading even amongst a small urban area (Figure 1-9).

The calculated loading rates displayed here are raw values that exclude nutrient load reductions from stormwater best management practices. There are numerous privately owned BMPs within each drainage basin, however the estimated load reduction they confer is not always documented. The City’s

Figure 1-9. Annual Total Nitrogen Loads to Lake Silver in lbs/acre.

Unified Land Development Code requires a match of pre and post-development runoff rates and volumes [City Code § 21-161]. By design, these BMPs capture the majority of runoff. However, many parcels that were developed before the initiation of these ordinances have no stormwater management BMPs implemented. By identifying where raw pollutant loads are highest and where there are no documented BMPs, staff can pinpoint specific areas where new stormwater practices will have the greatest effect. This strategy is most effective in Winter Haven's residential urban center where aging stormwater infrastructure and high density of impervious surfaces funnel untreated stormwater directly to lakes. Redevelopment of urban residential areas is often slow or nonexistent and so construction/retrofitting projects that implement green infrastructure are some of the City's viable means to reduce pollutant loading.

As previously mentioned, groundwater can also be a contributor of pollutants if there are potential sources within a lake's drainage basin. Leaky Onsite Sewage Treatment & Disposal (OSTD), aka septic systems, near a lake could be contributing to water quality issues. While the density of OSTDs within a basin doesn't provide concrete evidence of this, considering septic as a potential nutrient source can lead to exploratory studies as confirmation. This is just one component to consider when developing a water quality improvement plan.

Morphology

One less frequently discussed component of hydrology is lake morphology or the size and shape of a waterbody. The depth and slope of a lake's benthos (bed) can provide insights into how a waterbody may react to various environmental stimuli. For example, a deep, steeply sloping lake may be affected more strongly by aquifer fluctuations, will usually have a smaller zone where aquatic plants can grow, and will usually be less susceptible to sediment suspension through wind and wave action when compared to a more shallow and gradually sloping counterpart. As a result, morphology is useful to consider alongside other factors when developing a lake-specific management strategy.

Ecology

Ecology is a subsection of biology that focuses on the study of living organisms and their interactions with one another and their environment. An understanding of these biological communities is necessary to meet the intended use requirements for Class III waterbodies, referenced earlier in this document.

Class III: *Recreation; Propagation, & Maintenance of a Healthy, Well-Balanced Population of Fish & Wildlife*

One of the main components of any ecosystem is the presence of primary producers (i.e. plants and algae). These photosynthetic organisms provide multiple benefits for the aquatic environment. Management of non-algal plants, or macrophytes, ensures that their populations remain healthy and well-balanced. The quantity and quality of vegetation in a waterbody can respond to and impact the response of both hydrologic and water quality metrics. In addition, a healthy plant community will also provide habitat and food sources for fish and wildlife. It is for this reason that the City decided to focus on aquatic vegetation as a vital component of lake health.

Primary Ecological Metrics

Biological Abundance: *The quantity of vegetation growing in a waterbody can be estimated through the use of remote monitoring methods. Percent area coverage (PAC) and biological volume (BV) represent the respective 2-dimensional and 3-dimensional quantification of plant matter relative to a waterbody's size.*

Species Composition: *Ecological surveys are performed to estimate the overall population of aquatic plants in each lake. A count of each species present during a survey allows for the evaluation of diversity, dominant taxa, and the presence of harmful invasive species.*

Species Diversity: *Species diversity is a measure of the overall richness (number of unique species) and evenness (relative species proportion) of a lake's biological community. Multiple indices are used to evaluate overall diversity.*

Aquatic Plant Types

Of the different types of primary producers in aquatic environments, both microscopic algae and macrophytes (large aquatic plants) fill a similar ecological role as producers of oxygen and a food source for organisms higher on the food chain. A healthy balance of each is necessary for a functioning, diverse aquatic community. However, macrophytes provide additional ecological benefits such as their role as habitat for aquatic fauna. Based on their various fundamental growth strategies, aquatic macrophytes are separated into several categories: submerged aquatic vegetation (SAV), emergent aquatic vegetation (EAV), floating leaf vegetation (FLV), and free-floating vegetation (FV) (Figure 1-10). A full list of commonly occurring plant species in the area, with links to images, is provided in Table 4-8 (in the appendix).

Submerged plants grow completely under the water's surface and are usually rooted in the benthic sediments. Since the main body of the plant is supported by water, SAV isn't

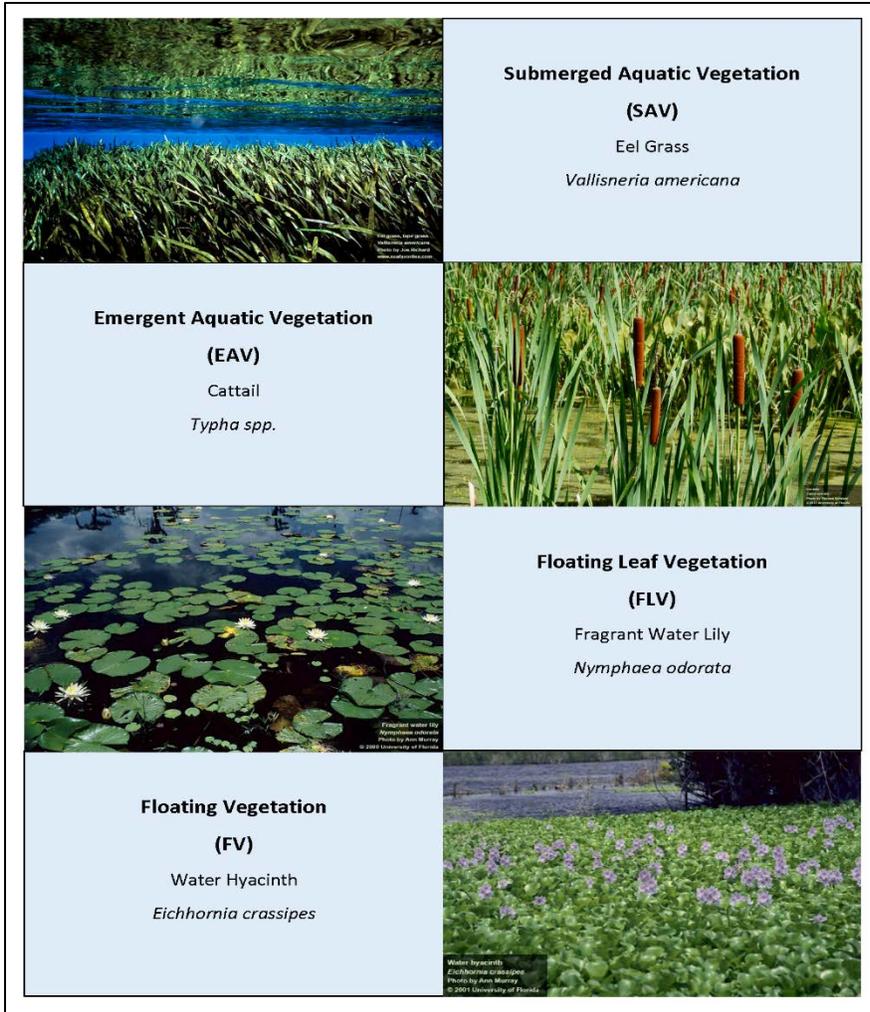


Figure 1-10. Examples of Aquatic Vegetation Categories.

hampered by the energy requirements needed to develop rigid support structures to keep them upright. Due to this, SAV species typically grow relatively quickly. However, this evolutionary strategy ties the growth of submerged plants to the availability of sunlight—meaning that water clarity, bathymetry, and surface level can significantly impact available real estate where SAV can grow. Common examples of SAV in our lakes include eelgrass (*Vallisneria americana*) and the invasive species hydrilla (*Hydrilla verticillata*).

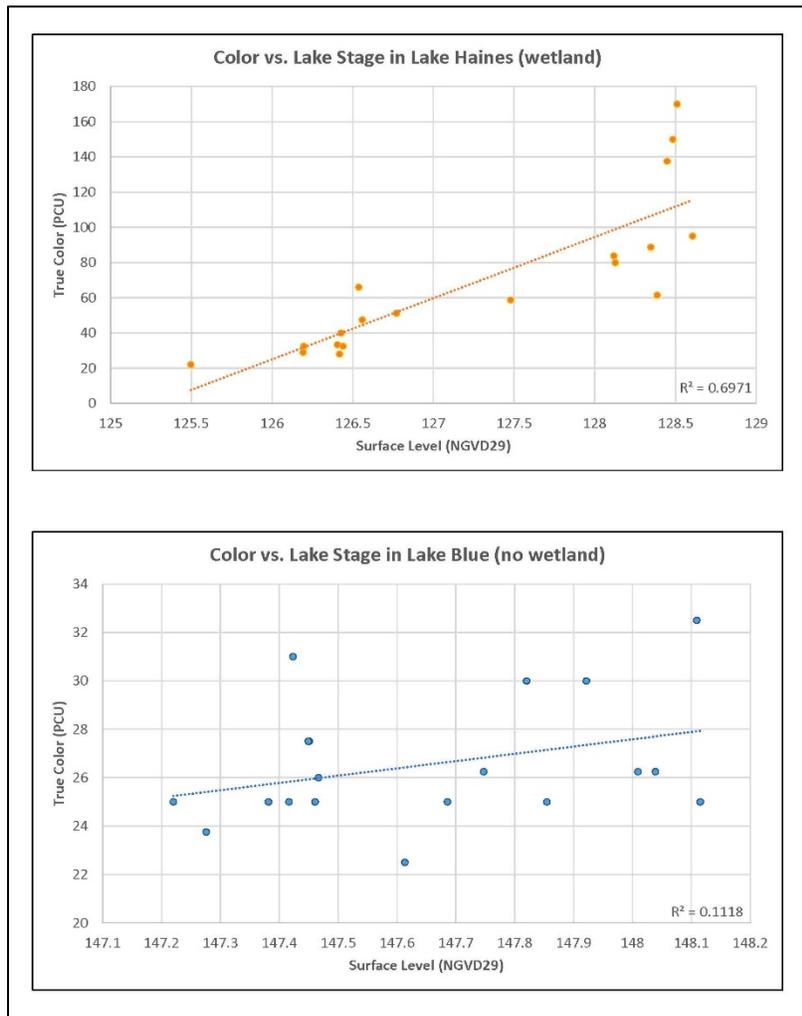
Emergent plants are similar to SAV in that they are rooted in the

benthic substrate, however, the main photosynthetic body of the plant grows above or floats on the water’s surface. This adaptation negates some of the issues associated with light availability, but these plants must put more energy into structural components that allow them to rise above the surface. In addition, the growing depth of EAV is limited by the capacity to transport air and nutrients to their root systems—meaning that most species are relegated to the shallow margins of lakes. Duck potato (*Sagittaria lancifolia*) and cattail (*Typhus spp.*) are a couple examples. Floating leaf plants (FLV) are a subcategory of emergent vegetation that behave very similarly to EAV, but present a unique habitat type for fish and wildlife. Like other rooted plants, they are restricted to the shallower margins of lakes. However, their floating leaves provide cover from sunlight which restricts the growth of SAV below them. Often, floating leaf plants will form dense stands that can be an impediment to navigation in shallow waterbodies. Common species of FLV include fragrant water lily (*Nymphaea odorata*) and Spatterdock (*Nuphar advena*). Floating plants are unique in that they have evolved beyond the need to root into the underlying substrate. To prevent them from sinking, most are small in size while some species possess adaptations that create buoyancy. The ability to float negates many of

the challenges that SAV and EAV must contend with. Because of this, some of the most prolific invasive plant species in Florida are floating plants. Examples of FV species are water hyacinths (*Eichhornia crassipes*) and duckweeds (*Lemnoideae spp.*). A list of all species identified in Winter Haven lakes can be found in Table 4-8 in the appendix.

Vegetation Quantity

The areas of saturated or inundated ground along the peripheries of some lakes can support emergent vegetation. These areas, known as wetlands, are a unique habitat area that many species of wildlife rely on. Wetlands can act as a pollutant sink and a source of beneficial chemical components [USEPA, 2015]. Surface water that comes into contact with wetland areas deposits sediments, nutrients, and other contaminants. Also, most forested



wetlands provide a source of dissolved organic compounds that impart color to the water column. Figure 1-11 illustrates the correlation between surface level and true color in a system with a surrounding wooded wetland area and one without significant wetlands. Lake Haines, with its surrounding wetlands, elicits a much stronger relationship between surface level and color than Lake Blue which lacks any substantial forested wetland area. Reductions in wetland connectivity through land development or surface level alteration can diminish these benefits. Identification and restoration of historic wetland connections is one management strategy that can be employed to improve water quality.

Figure 1-11. Correlation between Wetlands and True Color in Lake Haines & Lake Blue.

For submerged vegetation, the area within a lake that can support the growth of SAV is referred to as the littoral zone. This area, measured as the percent of area covered (PAC), is limited by the depth that light can penetrate in the water column. As such, the size of the littoral zone is determined by lake morphology, water clarity, and the unique requirements of the species of plants

that inhabit it. Since most SAV species are rooted, they contribute to the stabilization of the benthic sediments [Barko & James, 1998]. Therefore, it can be inferred that greater PAC generally equates to lower potential suspended sediment concentrations. Unofficial sources state that a range of 15 – 30 PAC is generally considered a conservative target for beneficial wildlife habitat.

One additional benefit of SAV in lakes is their increased capacity to uptake nutrients directly from the water column compared to most emergent species [Denny, 1980]. Monitoring the total quantity of SAV can help determine a lake's ability to buffer against changes in nutrient concentrations. The use of SONAR mapping technology allows for the 3-dimensional quantification of SAV. By finding the difference between depth to bottom and depth to vegetation, the volume of water inhabited by plants can be calculated. This metric, known as biological volume, or biovolume (BV), is often recorded as a percentage in relation to total lake volume. The City has been recording the annual changes in BV in most study area lakes since 2016.

Vegetation Diversity

Species diversity is a complex metric that takes into account the number of species present (richness) as well as the relative proportion of each species (evenness). Since each individual plant can't feasibly be counted, scientists can use a variety of survey methods to identify what a representative sample of the overall population looks like. Using a point-intercept method to sample regularly spaced points across a lake's area, the City can record not only the estimated number (frequency) of each species but also their relative spatial distribution.

Species frequency can be used to identify a waterbody's dominant taxa as well as to calculate species richness and evenness (Figure 1-12). The resulting scores, referred to as diversity index values can be used to evaluate the health of vegetation communities. Ecologically, a healthy population is a diverse and evenly distributed one. As an example, a lake that is dominated by one or two species is at a substantially greater risk of collapse than one with numerous, equally abundant species. Common sources of collapse include climatic changes, pests, diseases, as well as competition from invasive species. Since species diversity is such a complex metric, no single index can adequately represent diversity in all cases. Moreover, some indices make assumptions regarding the population being studied and are applicable only in specific scenarios. For the intents and purposes of this study, these indices are only used to compare the changes in vegetation communities over time and not for comparing the diversity of one lake to another:

Primary Species Diversity Indices [Ludwig & Reynolds, 1988]

- **R2:** known as *Menhinick's richness index*, represents the number of unique species sampled in a given site or area. This index is reliant upon sampling effort, therefore it is useful only for comparing richness of the same site over time (assuming sample size remains constant).

- **E3:** One of many popular indices that represent how evenly the species in a population are distributed. E3 ranks a sample from 0 – 1 where the index approaches 1 when all species are present in equal proportions.
- **H:** Referred to as Shannon’s Diversity Index, this metric incorporates concepts of richness and evenness. H represents the uncertainty of sampling the same species multiple times in a row; as such, this value increases as a population becomes more diverse.

In the realm of vegetation management, knowing where a given species is located is equally as important as understanding the community dynamics of the local population. Where a particular plant species is commonly found can provide information about its optimal growing conditions (e.g. light, depth, or substrate). It can also be used as a handy method for tracking invasive species such as hydrilla and water hyacinth. These plants have few natural checks that would limit their growth in this region and can outcompete most natives; often to the detriment of navigation and ecological diversity.

The City of Winter Haven manages invasive aquatic plants along City-owned shorelines and provides support to the organizations that manage the lakes. The Florida Fish and Wildlife Commission (FWC) is the governing body with jurisdiction over the treatment of waters of the State. Through funding from FWC, Polk County assists in the treatment of invasive plants in this area using various methods including herbicide, mechanical removal, and biological controls. Excluding physical removal methods, the treatment of invasive species can facilitate the reintroduction of nutrients as the treated plants decompose. Fortunately, the release of nutrients can be mitigated by limiting treatment area and intensity. The City’s monitoring efforts allow for the early detection of invasives so that they may be managed before their populations expand and require large scale treatment. This concept of early detection and rapid response is critical to the maintenance of species diversity and overall ecological health. Since complete eradication of invasives is often not a feasible goal, reduction of invasive presence to a maintenance state is the general target. These targets are typically based on percent of lake surface area covered and are species specific. Since the point-intercept survey methods aren’t the most applicable means of measuring species area, the City considers reduction in invasive frequency an adequate indicator of improvement.

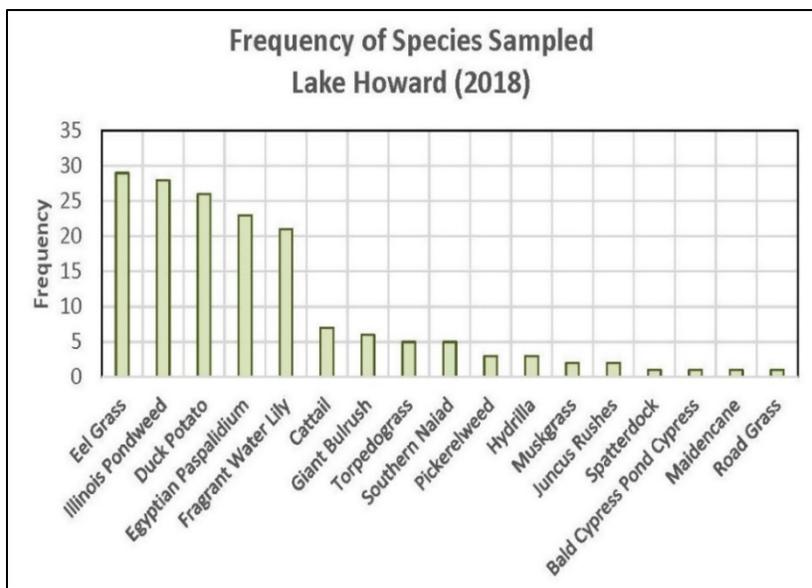


Figure 1-12. Species Frequency Chart of Aquatic Vegetation in Lake Howard.

#2 | Management Strategies



Summary

One of the primary challenges of managing dozens of lakes spanning both urban and rural areas involves balancing the diverse needs of the various lake user groups while also maintaining the health of the waterbodies being used. No one management strategy will be effective in all scenarios. By virtue of this, an objective approach is necessary to ensure that any proposed management practices will address a given lake's unique challenges and that they aren't biased towards any particular user group. A thorough understanding of the management practices that are available is the first step to an effective lake management program.

The following is a list of the City of Winter Haven's commonly utilized management practices. Each management strategy listed includes a general description of the practice, justification for how it supports the Natural Resources mission, vision, and purpose, an explanation of the types of benefits it provides, and details on future implementation goals.

Management actions should support the organizational Mission, Vision, and Purpose (MVP). This ensures that strategies fit within the City's ideals and adds a level of accountability so that stakeholders can be confident that their tax dollars are being utilized effectively. The Natural Resources MVP (listed below) was developed, in part, by the Lakes Advisory Committee:

Mission:

Maintain and improve local natural resources through management based on a sound understanding of social, economic, and ecological systems.

Vision:

To be the premier knowledge base for local natural resources, with an engaged public, supporting natural systems through a community ethic.

Purpose:

Balance the needs of diverse user groups to sustain natural resources the community can be proud of.

In order for lake management programs to be successful, effective practices should be selected based on a sound understanding of the factors that influence lake health. Many management practices help to improve more than one aspect of lake health. For example, the creation of nature parks improves water quality while also providing wildlife habitat and a recreational space for residents to enjoy nature. In keeping with the concepts laid out in the introductory section, each management strategy will denote the types of benefits they provide in one or more of the four focus areas:



Water Quality

Management strategies focused on improving water quality through reduction of pollutants like nitrogen, phosphorus, and other solid debris.



Hydrology

Management strategies focused on improving hydrologic functions like increasing surface water storage and promoting aquifer recharge.



Ecology

Management strategies focused on improving ecological functions like creating wildlife habitat and promoting healthy, native plant communities.



Public Engagement

Management strategies focused on improving public awareness of environmental issues and promoting community stewardship actions.

319 Gray to Green

Summary:

The use of low impact development (LID) and green stormwater infrastructure (GSI) can provide benefits over traditional “pipe and pond” (gray) infrastructure by slowing, spreading, and soaking stormwater runoff---thereby promoting groundwater recharge and reducing pollutant loading from urban areas. The City of Winter Haven has become a forerunner in the process of prioritizing the design and implementation of green stormwater infrastructure. It was determined, however, that the adoption of the gray to green mindset by the local community would be necessary to protect our surface water and groundwater resources. By virtue of this, the City has initialized a plan to develop and implement a public education program targeting local engineers, developers, and City staff to provide the tools and information required for this shift in stormwater management focus.

In 2018, the City held public meetings with the local development community in an effort to create guidelines for the design and implementation of LID/GSI in the private sector. Funding for this effort was sourced from a United States Environmental Protection Agency (EPA) 319 Education Grant administered by the Florida Department of Environmental Protection (FDEP) through “DEP AGREEMENT NO. NF015”. Based on feedback from these meetings, the community identified several barriers to the utilization of green infrastructure including lack of incentives and lack of credit for infiltration and treatment by the permitting agencies. Working with knowledgeable consultants, the Natural Resources Division drafted a Development Guide to educate the development community about the benefits of LID/GSI. An additional phase of this project, funded through a second 319 Education Grant “DEP AGREEMENT NO. NF050”, saw development of a stormwater permit design manual and streamlining of the City’s ordinances to remove some of the roadblocks to LID/GSI implementation. Natural Resources staff currently sit on the City’s Development Review Committee—providing information and feedback to developers on their upcoming projects.

Support of Mission, Vision, and Purpose:

This is an effort driven by the “sound understanding of the social, economic, and ecological systems” identified in the Mission. Development has economic and social benefits to the area and can also have ecological benefits if planned properly, this approach strives to “Balance the need of diverse user groups” as identified in the Purpose. By providing tools and education to the development community and internal staff the hope is to further perpetuate the “community ethic” therefore realizing the Vision.

Benefits:

Developing tools and methods that incentivize the use of LID/GSI supports hydrologic restoration and water quality improvement in Winter Haven’s lakes. This forward-thinking,

educational effort will ensure that the community as a whole is aware of environmental issues and engaged in practices that enhance our natural resources.



Strategic Goals:

- Continue to promote the Gray to Green Development Guide and Permit Design Manual towards the development community during Development Review Committee meetings.
- Seek funding to continue developing educational programming in future grant submission cycles.
- Plan to update City Ordinances to promote green stormwater infrastructure and low impact development principles in the 2024 calendar year.

Alum Treatment

Summary:

Aluminum sulfate (Al_2SO_4), also known as alum, has been a popular treatment option for surface waters in order to reduce concentrations of phosphorus, total suspended solids (TSS), algae, and nitrogen originating from stormwater inputs. Alum injection is a stormwater management solution that can be useful in locations where the area for large settling ponds does not exist or as an alternative to less stable chemical coagulants. On contact with water, alum forms a precipitate or gelatinous floc in the water column. Nutrients and sediments adsorb to the alum floc which eventually falls out of solution and can be collected in settling reservoirs or allowed to settle in the treated waterbody (Figure 2-1). This alum floc is stable in a pH range of 5.5 – 7.5 [Harper, 2007]. Since Winter Haven's lakes are generally alkaline with stable pH levels, they make adequate candidates for alum treatment as there is little risk of the precipitate re-dissolving into the water column. Alum may be broadcast across an entire lake surface in order to create a barrier over nutrient-rich sediments, thereby reducing the influx of pollutants such as phosphorus. This capping process is one solution for lakes that have received historic point-source discharge.

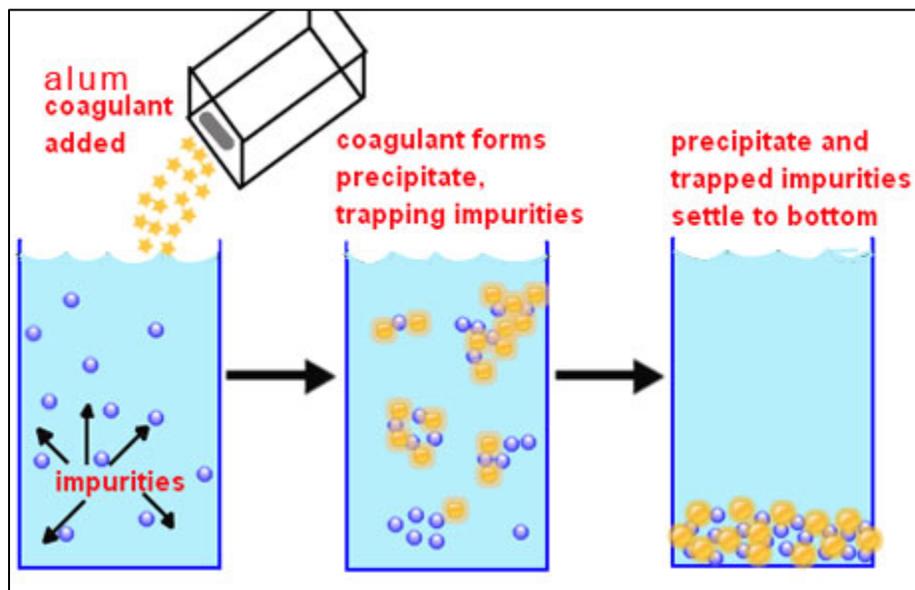


Figure 2-1 Diagram of alum floc adsorption properties. [Bionics, 2013]

The City currently maintains three alum injection sites at points on Lakes Howard, Lulu, and May. Additionally, a broadcast alum treatment was contracted by Polk County in the mid-1990's to cap internal phosphorus loading from historic point-source discharges in Lake Conine [ERD, 2018]. The City's management goals

for the three alum injection sites on the South Chain of Lakes involve updating the outdated equipment and developing an internal maintenance plan. Additionally, the City is interested in developing a study to determine the current nutrient reduction efficiency of alum in these lake systems. The operation and maintenance costs to run these systems can be substantial, so future efforts will seek to determine if the benefits are worth the price.

Support of Mission, Vision, and Purpose:

Alum Injection is a management strategy that strives to “Maintain...local natural resources” as stated in the Mission. Alum injection alone will not cause improvements in lakes, but it does help to limit further impacts from being realized. By reducing stormwater impacts, lake systems become more predictable making it is easier to manage systems to “the needs of diverse user groups” as outlined in the Purpose. Alum injection is an interesting process and it provides an opportunity to talk with residents about it and other management tools and the effectiveness of different management strategies. This helps to create the “engaged public” identified in the Vision.

Benefits:

Alum’s ability to make nutrients biologically unavailable is a viable option to reduce pollutant loads from stormwater. While alum does not intrinsically reduce ambient TN or TP concentrations in a waterbody, it actively works to prevent further decline in water quality.

**Strategic Goals:**

- Repairs to the Lakes Howard, Lulu and May alum systems were completed in 2022.
- Contracted regular monthly inspections & maintenance in 2023.
- Evaluate effectiveness of updates through stormwater quality monitoring.
- Continue to conduct cost-benefit analysis to explore if alum could be implemented in new drainage basins.

Aquatic Vegetation Monitoring

Summary:

Aquatic vegetation monitoring (AVM) is a methodology employed by the Winter Haven Natural Resources Division to regularly assess plant abundance and diversity in City lakes. This protocol is based on a survey process developed by the Florida Fish and Wildlife Commission (FWC). Utilizing sound navigation and ranging (SONAR) technology, the Division is capable of measuring the amount of vegetation in the water column. Percent area cover and biological volume make up the vegetation abundance metrics obtained through SONAR mapping (Figure 2-2). In addition, the Division performs point-intercept sampling; identifying the species present at regularly spaced points across a lake to provide a representative sample of plant diversity.

This information is then analyzed, allowing the City to incorporate vegetation data into the overall lake health evaluation. Information regarding invasive species is shared with Polk County and FWC for use in planning treatment. As this monitoring program continues, the City plans to collect multiple years of aquatic plant data to better understand the nuances of each lake’s vegetative community. In addition, the Division works closely with the environmental departments of other agencies including the Cities of Lakeland and Haines City, FWC, and Polk County to coordinate monitoring strategies. The development of this Polk Regional Aquatic Vegetation Working Group has fostered beneficial relationships and a support chain useful for representing the needs and interests of all parties in the region.

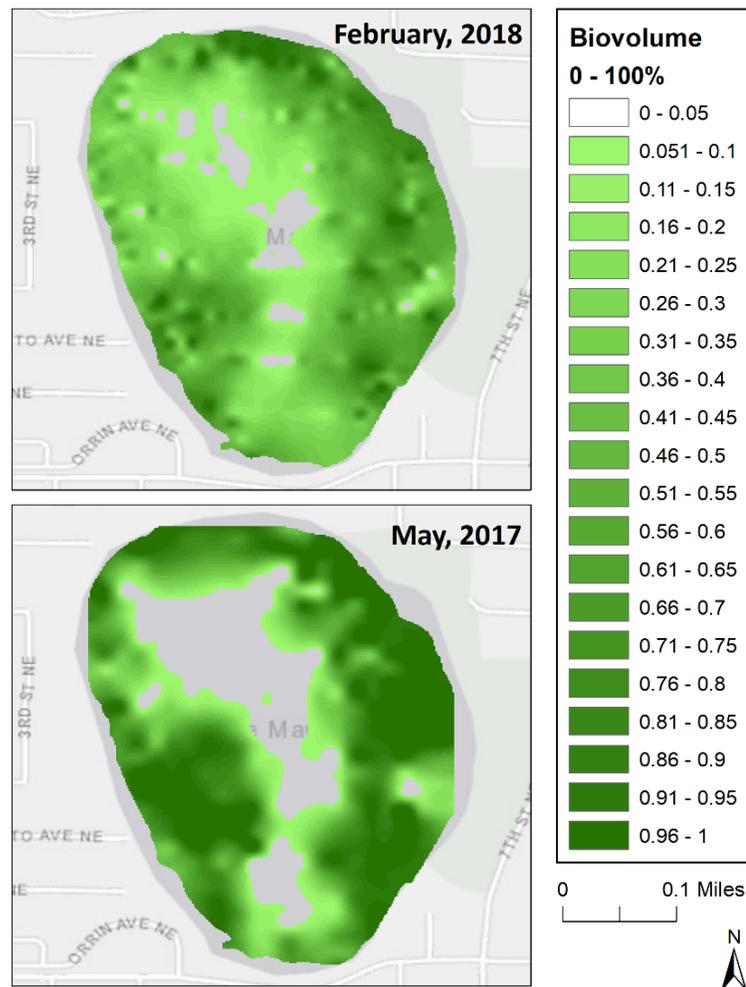


Figure 2-2. Biovolume heat map of Lake Maude. Color scale represents percent of water column occupied by plants.

Future applications of the vegetation monitoring data will likely be in the realm of nutrient budgeting. By calculating the nitrogen and phosphorus content of the common plant species found in Winter Haven's lakes, it would be possible to estimate the quantity of nutrients released or removed through various management practices. City staff are exploring collaborations with academic institutions to realize this goal.

Support of Mission, Vision, and Purpose:

This effort supports the Mission by developing a "sound understanding of social, economic, and ecological systems" which enables the Division to serve its Purpose and "Balance the need of diverse user groups while sustaining natural resources". This is also in fulfillment of the Vision by establishing the City as "the premier knowledge base for local natural resources" and ensuring the community is represented in discussions about management aquatic plants.

Benefits:

The early detection and rapid treatment response to invasive species ensures that waterbodies are navigable for all user groups. More importantly, maintaining a robust, native plant community provides fish and wildlife habitat and is a crucial component of lake health. By closely monitoring these plant communities, the City is better prepared to answer difficult questions and respond with data-driven management strategies.



Strategic Goals:

- Aquatic vegetation surveys were conducted for 37 area lakes in 2023.
- Continue to coordinate with other local vegetation management professionals in the Polk Regional Aquatic Vegetation Working Group.
- Continue to stay up-to-date regarding the latest vegetation monitoring and management strategies and techniques (e.g. drone/satellite imagery).
- Explore plant tissue analysis to conduct nutrient budgeting studies. This will allow for nutrient reduction quantification in the future.

Green Stormwater Infrastructure

Summary:

Green stormwater infrastructure (GSI) is a term referring to practices that incorporate natural processes in the development of stormwater systems. Traditional, or “gray”, stormwater infrastructure relies on impervious materials, gutters, and pipes to transfer runoff from one area to another. Typically, these systems are implemented in urban areas to prevent flooding by directing stormwater to a nearby catchment or basin. In the Winter Haven area, gray infrastructure diverts runoff, as well as any pollutants, directly to lakes or stormwater ponds. In contrast, green infrastructure and LIDs utilize plants and soil characteristics to promote stormwater treatment and groundwater infiltration; resulting in cleaner and/or less runoff entering local waterbodies. Examples of green infrastructure and LIDs include raingardens (Figure 2-3), bioswales, pervious pavement, and exfiltration structures (French drains).

If designed properly and placed in appropriate areas, GSI are able to capture sediments, heavy metals, and other solid debris during the first flush of a rainfall event, preventing it from entering waterbodies at the “end of the pipe”. Employing well-drained soils to promote percolation, flooding along roadways can be reduced during 1-year to 10-year storm events. Planting of appropriate vegetation can also allow for nutrient uptake while also beautifying the urban landscape. In many cases, GSI can be utilized in lieu of traditional stormwater ponds in city planning; often occupying smaller footprints than traditional stormwater ponds while mitigating similar volumes of stormwater. Green infrastructure can benefit developers by reducing the area devoted to stormwater mitigation and can often be more aesthetically pleasing.



Figure 2-3. Photo of a raingarden capturing runoff and road debris in downtown Winter Haven.

Currently, the City has constructed over 60 raingardens and exfiltration systems in and around Winter Haven’s urban center. Lakes receiving stormwater benefits from these systems include: Lakes Elbert, Howard, Martha, Maude, May, Otis, Roy, and Silver. Nutrient removal capabilities are minimal on an individual basis, however, GSI can collectively have a greater impact in larger numbers as more stormwater is treated.

Moreover, relatively low construction costs in addition to the aforementioned benefits make low impact projects an elegant solution for future stormwater treatment in the urban cityscape.

Support of Mission, Vision, and Purpose:

LID implementation directly supports the Mission by using “a sound understanding of social, economic, and ecological systems.” To “Maintain and Improve local natural resources”. Improving hydrology and water quality help to “balance the needs” identified in the Purpose. LID construction is a realization of the Vision, in that the City has received outside support because other agencies recognized the City is the “premier knowledge base for local natural resources”.

Benefits:

Low impact development and green infrastructure projects provide multiple benefits including stormwater pollutant load reduction, groundwater recharge, aesthetic improvements, and a reduction in street ponding—thereby increasing roadway lifespans. These social, economic, and environmental benefits make GSI implementation an efficient and effective management strategy for the City.



Strategic Goals:

- Implementation of a couple raingardens as part of the Ave C Complete Streets project in 2023.
- Complete construction of raingardens along MLK Blvd, Ave O NE, and south of Polk State College in 2024. This project was made possible through a Southwest Florida Water Management District cooperative funding agreement.
- Explore software options to assist with planning maintenance of existing green stormwater infrastructure.
- Continue developing relationships with non-profit organizations to rehab existing raingardens (i.e. Adopt-a-Raingarden Program).

Guided Kayak Tours

Summary:

For the Winter Haven Natural Resources Division, increasing awareness of environmental issues is crucial in building public support for the various management activities in which we are engaged. Those who can physically interact with the resources we manage may be more likely to take action to protect them. Kayaking is an excellent outreach opportunity to introduce residents to some of our prominent water resources and the plants and animals that reside in them. Time spent on the water also provides an excellent setting to discuss concepts like water quality, hydrology, ecology, and what efforts residents can make to improve them.

Since the early 2000's, the Natural Resources Division has offered free guided kayaking tours for various clubs, community groups, and the general public. The City maintains a fleet of 12 kayaks with the capability to guide groups of up to 16 guests (Figure 2-4). Tours are typically held on local lakes, but Peace River trips have been offered in the past. In recent years, guided tours for the general public have been advertised via the City's social media accounts. Topics discussed include the City's lake management efforts, monitoring techniques, water quality and pollution control, lake ecology (i.e. fish, plants, and wildlife), and what personal actions residents can take to improve lake health. Of note are recommendations for lakeshore vegetation management, pollution prevention tips, and landscaping to reduce watering needs and fertilizer use.

Attendees are polled before and after each trip in an evaluate knowledge gained by participants and to gauge level of satisfaction in the experience.

Responses have been overwhelmingly positive so far. The Division plans to expand the number of kayaking tours and locations offered in the future.



Figure 2-4. Photo of 2022 guided kayak tour on Lakes Conine and Hartridge.

Support of Mission, Vision, and Purpose:

Educational and recreational activities like this support the “sound understanding of social, economic, and ecological functions” described in the Natural Resources Mission. Attendees learn how each of these aspects function simultaneously and why the lakes

are such integral components of the community. Staff dialogue with attendees from various backgrounds, supporting the ideal of “balancing the needs of diverse user groups” outlined in the Purpose. Additionally, the Vision is supported through staff sharing their knowledge (being “the premier knowledge source”) and striving to achieve an “engaged public”.

Benefits:

The primary objective of these tours is to benefit public engagement by increasing appreciation of water resources and understanding of environmental issues.



Strategic Goals:

- Conducted 5 kayak tours, hosting at least 40 guests in 2023.
- Continue to offer guided kayak tours of City lakes and other waterbodies in 2024.
- Adapted user surveys to a pre/post format in order to better assess knowledge gain and retention before and after each tour.
- Develop relationships with various community groups (e.g. Scout Troops, Non-profits, and Clubs) to offer outreach opportunities to new audiences.
- Budget for kayak, trailer, and equipment upkeep and replacement at regular intervals to ensure quality experiences for participants.

Habitat Restoration

Summary:

Fostering adequate fish and wildlife habitat is one of the core objectives for managing healthy lakes. In the absence of more structural features like coral and rock outcroppings not typically found in Florida’s fresh waterbodies, the majority of habitat is comprised of aquatic vegetation. Proper management of this habitat involves actions that promote the proper abundance and diversity of plants. Some circumstances may require removal of vegetation, such as overgrowth of nuisance plants. The formation of tussocks, or floating vegetation islands, can cause both ecological and economic issues. Areas underneath tussocks are deprived of oxygen—creating dead zones. Also, as tussocks drift around lakes, they can become navigational hazards by blocking canals and stormwater outflows. Other circumstances require the introduction of new plants in areas that have become denuded. Additional habitat restoration methods include deployment of natural or artificial fish attractors which provide structure at lake bottoms around which multiple fish species can congregate.



Figure 2-5. Photos of Lake Martha diesel spill remediation planting (top) and Lake Idyl tussock removal (bottom).

Natural Resources staff have conducted shoreline vegetation plantings in Lake Martha in 2013 and Lake Silver in 2017. City staff also assisted FDEP and the Winter Haven Hospital with remediation efforts in Lake Martha after a diesel spill in 2020 (Figure 2-5). More recently, staff have coordinated with residents and the Lakes Region Lakes Management District to remove tussocks from Lakes May and Idyl (Figure 2-5). In 2022, staff entered into discussions with the FWC’s Aquatic Habitat Restoration and Enhancement Subsection (AHRES) to deploy fish attractors in Lake Martha as well.

Support of Mission, Vision, and Purpose:

Understanding where habitat restoration is needed and what tools are applicable demonstrates the Mission through “a sound understanding of social, economic, and ecological systems”. Habitat restoration efforts also support the Purpose of “balancing the needs of diverse user groups” by addressing both ecological and recreational needs. Understanding where and how to improve habitat supports the Vision by making the City the “premier knowledge base” and by “maintaining natural resources the community can be proud of”.

Benefits:

Planting native vegetation, installing fish attractors, and removing nuisance plants certainly provide ecological benefits through the improvement of fish and wildlife habitat. These efforts also positively affect public-facing aspects through improving aesthetics of parks and public lakeshores, waterway navigation, and recreational fishing opportunities. Pairing public outreach and education components with these projects can provide public engagement benefits as well.



Strategic Goals:

- Planning partnership with FWC to plan Illinois pondweed in Lake Martha in 2024.
- Seek funding to conduct additional habitat restoration efforts in other lakes.
- Request mechanical harvesting equipment in future NRD budget.
- Continue to monitor lakes for drainage, navigation, and habitat issues.

Hydrologic Monitoring

Summary:

Hydrologic monitoring is a practice that provides information on the quantities and movement of water in an area. Collection and analysis of rainfall, surface water, and groundwater data allows the City to build a better understanding of the relationships amongst these parameters as well as their impacts on lake health and municipal water supply. The Natural Resources Division and Utilities Department work together to obtain this data through a network of weather stations, monitoring wells, and surface level gauges located throughout the City. Additional data, collected by the Southwest Florida Water Management District (SWFWMD) and the Lake Region Lakes Management District (LRLMD), is also incorporated to better understanding the local hydrology.

Since the Winter Haven area is rainfall driven, hydrologic functions are not always directly controllable. That said, hydrologic fluctuations can significantly impact aspects like pollutant loading, wetland connectivity, and the future growth of the City. Many lakes possess strong relationships between water level and quality. In times of drought, the recreational uses of the lakes also suffers as docks, boat ramps, and canals can become unusable or un-navigable. However, these low water times also allow for natural breakdown of organic matter that can help rid the lakes of excess nutrients. Connected to the lakes are the aquifers, which provide the City with its potable water supply. By closely monitoring these hydrologic fluctuations, staff gain a better understanding of these complex dynamics.

With regards to the monitoring efforts, the Natural Resources Division currently maintains continuous surface level monitors in eight lake systems. However, the City has planned to expand its hydrologic monitoring network via the installation of additional rainfall, groundwater, and surface level sensors. This hydrologic information, which is updated monthly, is presented on the City's Hydrology webpage. This data is also incorporated into hydrologic models that can help identify areas of potential flooding and/or higher pollutant loading due to differences in soils and land use.

Support of Mission, Vision, and Purpose:

This activity directly supports the Mission by developing “a sound understanding of social, economic, and ecological systems”. Due to the unique nature of the local system, water levels are critical not just for water quality, but also for navigation through the Chain of Lakes. Navigability is of significant importance to the “diverse user groups” described in the Purpose, and by understanding how the local hydrology works the City is able to be the “premier knowledge base”, mentioned in the Vision, that can drive decision making about management of the resource.

Benefits:

The City utilizes the data collected through hydrologic monitoring to gain a stronger understanding of how various hydrologic factors impact aspects like water quality, habitat, and navigation. These factors are incredibly important in selecting and prioritizing management efforts. In addition to guiding our own lake management efforts, this data is shared with the public via this report as well as the City website. Spreading this knowledge also benefits public understanding and engagement.



Strategic Goals:

- Purchased and acquired 14 additional surface level sensors in 2023. Installation of sensors will be completed in 2024.
- Budget for purchase of additional hydrologic sensors (i.e. surface level, rainfall, and groundwater) to expand network.

Invasive Plant Control

Summary:

Since invasive species have fewer natural checks and balances, their presence can cause issues for both native organisms and people. For non-native plants this includes out-competing native species, thus reducing diversity and wildlife habitat, and clogging up waterways—making navigation and recreational activities more difficult. Controlling the introduction and spread of invasive plants is critical to preserving the health of our lakes.

One of the primary results of the aquatic vegetation monitoring practice is the development of invasive management plans. While the City has traditionally not engaged directly in invasive plant control efforts within State waterbodies, staff does provide data and insights to collaborating agencies like the FWC and Polk County. However, in 2022 Natural Resources staff initiated efforts to manage for invasives on City-owned lakeshores and rights-of-way; and with the capacity to assist other agencies with in-lake management efforts. With the proper equipment and certifications, the City is better prepared to maintain healthy vegetation communities on public lands adjacent to our lakes.

Support of Mission, Vision, and Purpose:

This effort supports the Mission by allowing City staff to actively “maintain and improve local natural resources” using the knowledge and understanding that we already have. Managing invasive species enhances lake navigation, accessibility, and aesthetics. Therefore, this effort also supports the Division’s Purpose of maintaining resources “the community can be proud of”. Finally, expanding staff expertise to be able to actively manage for invasives supports the ideal of “a premier knowledge base” described in the Vision.

Benefits:

The management of invasives on City-owned properties improves wildlife habitat by reducing their negative impact on native plants and animals. The ability for Natural Resources staff to more actively manage these properties increases the efficiency of these management efforts. Additionally, controlling invasive plants often provides aesthetic and recreational benefits to residents who utilize these public areas—thus improving public engagement with nature. Finally, the ability to engage in plant management efforts strengthens the City’s relationships with partner organizations like FWC and Polk County.



Strategic Goals:

- Continue to maintain aquatic herbicide applicator certifications through training and education credits.
- Continue to monitor, prioritize, and manage for invasive plants on City parks, shorelines, and rights-of-way.
- Continue to work with FWC and Polk County in order to develop invasive management plans on local waterbodies.

National Pollutant Discharge Elimination System

Summary:

As a directive of the United States Environmental Protection Agency (EPA), the National Pollutant Discharge Elimination System (NPDES) was created in 1972 under the Federal Clean Water Act. The NPDES is a permit system designed to regulate point source discharge into U.S. waters in an effort to improve water quality. The EPA works closely with the Florida Department of Environmental Protection (FDEP) to administer this program within the State of Florida.

Polk County is a primary permit holder in the region with the City of Winter Haven as a co-permittee under it. The permit requires each co-permittee to list all Municipal Separate Storm Sewer Systems (MS4s) maintained in their jurisdiction, document the functional maintenance of all infrastructure, track any public education initiatives that support pollutant load reduction, and monitor lake health to determine any measurable impacts.

Support of Mission, Vision, and Purpose:

By requiring the City to continually improve on its stormwater infrastructure, it drives the Division to improve their “understanding of the social, economic, and ecological systems” directly supporting the Mission. “Sustaining natural resources” is a central focus of the Division’s Purpose and the tracking associated with the permit has the same focus. The transparency created by the permit and the assurance to the residents that impactful activities are appropriately tracked supports the “engaged public” and “community ethic” outlined in the Vision.

Benefits:

The NPDES permit provides accountability and transparency to residents that every precaution is being taken by the permittee organization to protect water quality. The permit also requires the City to constantly improve its understanding of the potential local impacts and create plans for addressing those impacts.



Strategic Goals:

- Submitted Cycle 4 Year 6 Permit by deadline in 2023; hosted FDEP staff for a local inspection.
- Submit Cycle 4 Year 7 Permit in 2024.
- Continue to refine data collection process for future reports.

One Water

www.OneWaterWH.com



Summary:

One Water is an organizational planning effort which was borne out of the 2010 Sustainable Water Resource Plan and seeks to preserve the quality of life afforded by Winter Haven’s water resources. The impetus for this effort is the identified threat of hydrologic decline that is driven by several factors: population growth, limited fresh water supply, climate change, aging infrastructure, funding needs, and increased regulatory pressure [Black & Veatch, 2021]. The goals of the plan are to ensure the future of the region’s potable water supply and natural water resources. This is accomplished by improving utility planning, water conservation, wastewater treatment processes, reuse water infrastructure, watershed optimization, land use planning, and many other practices.

One of the signature recommendations evaluated and accepted as part of the One Water Master Plan is the Sapphire Necklace—a conceptual design of Winter Haven ringed by approximately 5000 acres of restored wetlands and nature parks (Figure 2-6). These sites would provide water storage, groundwater infiltration, wildlife habitat, and the backdrop for recreational amenities such as an expanded trail network—all of which benefit Winter Haven’s lakes and the residents that utilize them.

Support of Mission, Vision, and Purpose:

One of the first steps of the One Water plan includes modeling the impacts of various water use regimes on natural resources like the lakes and groundwater. This effort supports the Mission by improving the organization’s “understanding of social, economic, and ecological systems” as well as the Vision of being “the premier knowledge base for natural resources”. Since everyone uses water, this effort also supports the Purpose of “balancing the needs of diverse user groups”.

Benefits:

Smarter water use, surface water storage, and groundwater recharge all benefit local hydrology. Water quality, ecology, and public engagement benefits are also realized through stormwater treatment and the creation of nature parks that double as wildlife habitat and recreational areas.



Strategic Goals:

- Complete watershed optimization model in 2024.
- Develop plan for the purchase of properties to improve watershed storage and recharge.

Public Outreach Events

Summary:

Outreach encompasses most of the Division’s efforts that spread information to the public, with the aim of increasing engagement to solve specific issues. Some believe that the role of government agencies is to solve issues through regulation, compliance, and enforcement. However, studies have shown that many environmental issues cannot be solved through regulatory compliance alone—mostly due to a lack of staff and funding to meaningfully enforce regulations everywhere [Paddock, 2004]. Increasing residents’ understanding of local environmental issues is shown to result in voluntary public participation and stewardship efforts. Therefore, informal education efforts are a vital public service that help to protect natural resources.

The types of environmental issues the City seeks to address are those that benefit from public participation; such as pollution and litter control, reducing fertilizer usage, water conservation, proper lakeshore management, and living harmoniously with wildlife. The majority of the Natural Resources Division’s active, adult-focused outreach occurs during sponsored events like the 7 Rivers Water Festival, Community Fest, and Project Eagle (Figure 2-7). These provide opportunities to hear from individual residents and respond with personalized information and guidance in a relaxed setting. Staff are able to interact with several dozen to several hundred participants per event.



Figure 2-7. Photo of Arbor Day Tree Giveaway booth during the 2023 Community Fest event.

Recently, City staff piloted a new outreach program that tailors educational information to specific communities. These outreach events target neighborhoods and community groups/HOAs within individual lake watersheds. The goal is to increase public “ownership” of these shared resources by informing residents how they can proactively solve issues specific to their lake. The first of these Watershed Seminars was held in 2021 for residents around Lakes Otis and Link. While the total number of participants is smaller than the sponsored events, these seminars provide a more intimate forum for

communities to share their specific issues and gain insights into how they can be solved through cooperation. Due to the success of this first venture, the City has plans to expand the program to other neighborhoods and communities.

Support of Mission, Vision, and Purpose

The educational component of outreach seeks to increase public understanding of environmental issues while also giving City staff insight into how these issues are impacting citizens. Outreach efforts support the Mission by building residents' "understanding of social, economic, and ecological systems". The Vision of the City with "an engaged public" is also supported. Lastly, increasing public stewardship supports the Purpose of maintaining "natural resources the community can be proud of".

Benefits:

Outreach efforts directly improve public engagement by providing understanding and guidance to residents. The anticipated result is a better informed public who is more willing to engage in stewardship efforts that will improve overall lake health.



Strategic Goals:

- Over 180 participants in Winter Haven's National Arbor Day Tree Giveaway.
- Participated in several events (e.g. Hands on Haven, 7 Rivers Water Festival, Project Eagle, etc.) with a total outreach impact of over 1677 people in 2023. Staff plan to expand outreach efforts to additional events in 2024.
- Develop plan to collect participant survey data to improve educational programming.
- Work with community groups to schedule watershed seminars and other outreach events.
- Expand the variety of public outreach events to reach a broader community in 2024.

Sediment Management

Summary:

As a result of natural deposition, biological cycles, and pollution, sediment (aka muck) accumulates in Florida's waterbodies over time. Sediment deposited from historic point-sources, often referred to as legacy sediments, can be a significant contributor of nitrogen and phosphorus. This internal loading occurs through natural groundwater seepage and can be exacerbated by low water levels and wind/wave action; sometimes negating external pollutant reduction efforts [PBS&J, 2010]. In response to initial studies in the late 1990s and early 2000s that explored external pollutant sources in local lakes, the City of Winter Haven contracted Environmental Research & Design, Inc. (ERD) to conduct sediment analysis in several muck-heavy waterbodies. This investigation, conducted in Lakes Lulu, May, and Shipp from 2005 to 2009, included bathymetric evaluation to determine water and muck volumes as well as seepage monitoring and chemical analysis of surface water and sediments to estimate internal nutrient loading.

The volume of muck in Lakes Lulu, May, and Shipp was estimated to be 1.3M yd³, 1.0M yd³, and 487K yd³, respectively. To put these volumes in perspective, if equally distributed over the lake's surface area, the depth of muck in Lakes Lulu, May, and Shipp would be 2.25 ft, 2.75 ft, and 6 ft, respectively. The estimated annual nitrogen and phosphorus loading from these sediments is provided in the following table [PBS&J, 2010]:

Lake	TN Influx (kg)	TP Influx (kg)	TN Areal Loading (kg/ac)	TP Areal Loading (kg/ac)
May	641	14.3	12.7	0.28
Shipp	2814	80.5	10.2	0.29
Lulu	1668	91.7	5.43	0.3

Table 2-1. Annual TN & TP mass loading & areal loading values for Lakes May, Shipp, and Lulu determined through the sediment analysis performed by ERD.

Dredging is a viable management strategy to remove muck from lakes, thereby reducing the internal nutrient load. However, this practice is often prohibitively expensive—exceeding multi-million dollar figures for even small areas of muck removal. Nonetheless, the City has explored outside funding opportunities and other means to reduce these costs. Recently, staff are seeking legislative funding to develop a pilot project that would remove a considerable volume of sediment from Lake May. A significant cost-cutting aspect of this project is the utilization of a City-owned parcel on the southwest shore of Lake May to temporarily store and dewater the removed muck. The expected outcome includes improvements to water quality, navigability, and fish habitat in the lake.

Support of Mission, Vision, and Purpose:

Identifying and mitigating the sources of internal pollutant loading in Winter Haven's lakes supports the Division's Mission of "understanding...ecological systems" as well as the

Vision of being “the premier knowledge base for natural resources”. The Purpose is also supported through sustaining “natural resources the community can be proud of”.

Benefits:

The removal of internal pollutant sources from our lakes certainly seeks to benefit water quality and there are ecological benefits through the restoration of the natural hard lake bottom which is a preferred substrate for more native aquatic plant species.



Strategic Goals:

- Seeking innovative grant funding in 2024-2025 for Lake May sediment removal pilot project.

Stormwater Assessment and Improvement Project

Summary:

Winter Haven's stormwater system is a network of drainage pipes, ditches, and other conveyances that capture surface water runoff and move it to storage ponds or, more often, directly into lakes. The Stormwater Assessment and Improvement Project (SAIP) was drafted by the City, in conjunction with various agencies and organizations, employing a holistic approach to planning maintenance and improvements to the stormwater infrastructure. This project was 100% funded by a legislative appropriation administered by the Florida Department of Environmental Protection (FDEP) and involved contracted work through the consulting firm Chastain-Skillman. The SAIP is a four-pronged approach that includes:

- 1. Refining the current geospatial database of stormwater infrastructure:** The City utilizes ArcGIS—a geographic information system (GIS) program that allows users to create, analyze, and manipulate geospatial data—to store information on the network of stormwater pipes and outfalls.
- 2. Ground-truthing existing and previously unidentified stormwater infrastructure.** Factors such as pipe and drain size, material type (e.g. concrete, steel, etc.), and flow capacity. This evaluation allows the City to more efficiently prioritize management and repairs to the existing stormwater infrastructure.
- 3. Hydrologic modeling, which incorporates accurate topographic, surface water, and groundwater information to identify surface water flow to the lakes and estimate pollutant loading.** Results from this model can be used to identify areas within the City that experience the greatest potential for flooding during storm events as well as drainage basins with high nutrient loading potential. Cooperation with the Southwest Florida Water Management District (SWFWMD) has allowed for the collection of Light Detection and Ranging (LiDAR) data used in the development of a highly detailed topographic map of the City.
- 4. Identification and prioritization of targets for improvement by incorporating all of the previously mentioned methods.** This suite of information allows City employees to pinpoint problem areas and make informed decisions when prioritizing improvements. Understanding where resources should be focused is paramount when time and funds are limited. Moreover, the City has implemented asset management software called Cartegraph that has greatly enhanced the speed and efficiency of repairs, maintenance, and improvements to Winter Haven's stormwater systems. Figure 2-8 displays the locations of high-priority target areas within the City as identified by initial evaluation by the SAIP.

Benefits:

Using this data to drive decisions related to stormwater maintenance and improvement allows the staff to make efficient and informed decisions about projects with the highest return on investment.

The proposed stormwater infrastructure improvements are designed to reduce pollutant loading to area lakes and also increase groundwater infiltration. Therefore, this project fulfills the water quality and hydrology improvement functions.



Strategic Goals:

- Utilize concept plans for Priority Area 1 from SAIP to implement stormwater improvements for Lake Idyl. These improvements are being incorporated into a Pollutant Reduction Plan to be submitted to FDEP in 2024.
- Submit grant applications for Lake Idyl stormwater improvements during the 2024 cycle.

Stormwater Treatment Parks

Summary:

Stormwater treatment parks, or nature parks, are engineered wetlands that perform similar functions as other forms of green stormwater infrastructure. The primary focus of nature parks is to reduce the impact of nonpoint source pollution on target waterbodies by treating surface runoff and stormwater effluent. Comprised of one or more reservoirs, designed with long retention times, and seeded with communities of natural wetland vegetation, nature parks receive redirected stormwater discharge and allow it to slowly pass through the reservoirs before releasing the treated water to an adjacent lake. The multiple aspects of this treatment process include: nutrient reduction via plant uptake, reductions to turbidity and suspended solids via sedimentation, capture of solid debris, and an increase in water color through the introduction of dissolved tannins (organic matter). Secondary goals for these treatment parks are to create wetland habitat, increase biodiversity of wetland flora and fauna, introduce opportunities for public education, and provide recreational areas and green spaces. Maintenance of stormwater treatment parks involves ensuring all flow-ways are clear and free of dense vegetation or debris, removal of invasive species, and occasionally removing excess sediment that builds up over time.



Figure 2-9. Map depicting the Winter Haven nature parks and their drainage basins.

The City of Winter Haven maintains four nature parks adjacent to Lakes Conine, Howard, Hartridge, and Maude (Figure 2-9). The South Lake Howard Nature Park is a roughly 16-acre park that treats a sizable 394-acre drainage area. The 9.4-acre Lake Hartridge Nature Park receives and treats runoff from a 56-acre basin. Lake Maude Nature Park, the smallest of the three at 6.4-acres, treats an approximately 18-acre contributing drainage basin. A fourth park was recently constructed on the southern shore of Lake Conine. This constructed wetland is designed to treat a drainage area greater than 300 acres. Future work will involve implementation of recreational amenities.

Support of Mission, Vision, and Purpose:

Nature Parks are similar to GSI in that they directly support the Mission by using “a sound understanding of social, economic, and ecological systems.” To “maintain and improve local natural resources”. Improving hydrology and water quality help to “balance the needs” identified in the Purpose. Their Construction is a realization of the Vision, in that the City has received outside support because other agencies recognized the City as the “premier knowledge base for local natural resources”.

Benefits:

Stormwater treatment parks improve lake water quality and hydrology. The uptake of nutrients via aquatic plants, sediment settling in ponds, and capture of solid waste are pollution reduction and water storage mechanisms. The construction of wetland ponds and the planting and maintenance of native vegetation provides valuable wildlife habitat. In addition, each park benefits the community by providing a recreational space where residents can interact with nature.



Strategic Goals:

- State funding approved for recreational amenities at Lake Conine Nature Park. Construction is anticipated to begin in 2024.
- Conducted invasive species maintenance treatments of Lake Howard, Maude, and Hartridge nature parks in 2023. Of note was the mechanical removal of nuisance aquatic plants in Lake Howard Nature Park.
- Continuing to work on expansion of stormwater treatment areas at South Lake Howard Nature Park in 2024.

Street Sweeping

Summary:

One significant source of pollutant loading comes from sediment and debris accumulation in streets which drain to waterbodies via stormwater. Street sweeping is what is referred to as a non-structural best management practice (BMP) that helps to reduce pollutant loading by removing debris before it can enter the stormwater infrastructure and the lakes. In 2013, the City entered into a contract with USA Services to sweep curbed streets in specified areas to mitigate this pollutant loading source. Areas swept include downtown and much of Winter Haven's residential areas. Department of Transportation (DOT) roads were prioritized for sweeping on a bi-weekly basis, owing to the larger concentration of nutrient runoff. The remaining residential areas were covered on a semi-annual basis. Many of the roads included in the sweeping plan fall within a major outfall basin. Since 2016, the City began examining the effectiveness of the contracted sweeping service and whether these activities could be accomplished in-house. In 2020, the City created a new position within the Drainage division and purchased a sweeper. This has led to an increase in sweeping quality, efficiency, route control, and total area swept (Figure 2-10).

Support of Mission, Vision, and Purpose:

Street sweeping is a preventative maintenance activity that is managed based on the understanding of the "social, economic, and ecological systems" identified in the Mission. Debris coming out of a stormwater pipe is one of the most visible forms of pollution and street sweeping helps to alleviate this issue in an effort to "sustain natural resources the community can be proud of" as identified in the Purpose. The location and efficiency of street sweeping activities are closely monitored to understand the effectiveness of the program making the City "the premier knowledge base", as outlined in the Vision, for understanding pollutant loading of local water bodies which is beneficial in addressing State and Federal mandates.

Benefits:

This non-structural BMP provides water quality improvement through sediment and debris removal. It also limits debris from blocking the stormwater conveyance system which can lead to flooding, thereby extending street lifespans while also improving the cleanliness and overall aesthetic of City roadways. This is a true preventative maintenance approach that strives to reduce pollutant loading issues at the source which is exponentially more efficient and cost-effective than in-lake nutrient reduction practices.



Strategic Goals:

- Expanded street sweeping to 2298 centerline miles of public streets in 2023; equating to 2303 lbs of TN reduction and 4300 lbs of TP reduction.
- Continue to refine street sweeping services to further reduce pollutant loading to the lakes.

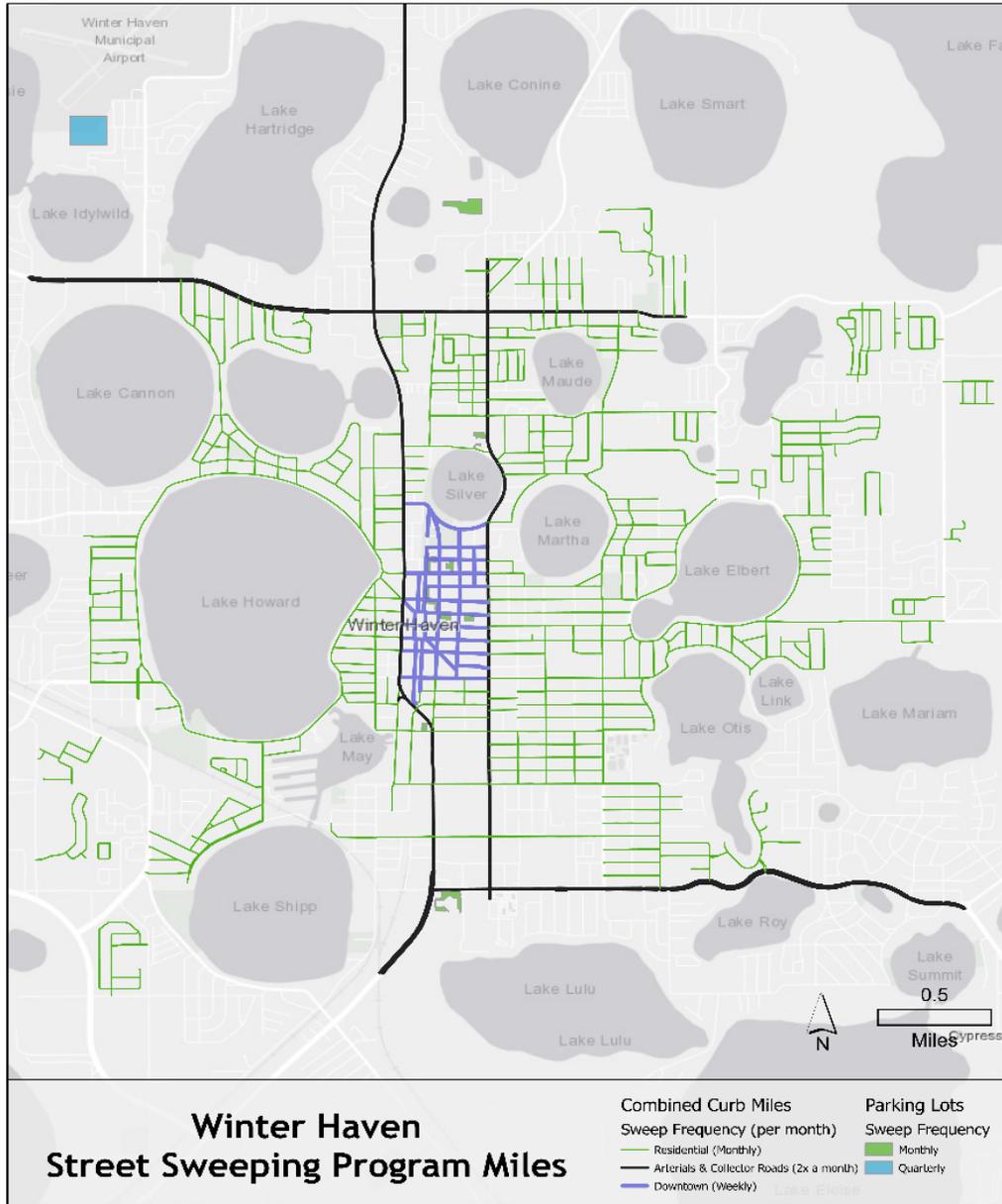


Figure 2-10. Map depicting roadways undergoing street sweeping. Legend indicates sweeping frequency of each street category.

Youth Outreach

Summary:

Youth outreach involves introducing younger members of the community to natural resources and inspiring the next generation of environmental stewards. While these efforts are part of the City’s overall outreach program, the goals and methods are distinct from outreach oriented toward adult residents. The primary objective is the creation of positive experiences that instill an appreciation for water, wildlife, and outdoor recreational activities. Children that are able to build stronger connections with nature are increasingly likely to engage in stewardship or other activities that protect natural resources later in life [Andrejewski, 2011]. Outreach also supports STEM education by reinforcing concepts learned in school while providing guidance to students interested in pursuing careers in environmental sciences.

City staff engage in a variety of youth outreach efforts that target multiple grade levels, City regions, and demographics. Through all of the Division’s outreach efforts, staff interact with approximately 500 children in a given year. Outreach programs include City Summer Camps at the Winter Haven Field House, Recreation and Cultural Center, and Rotary Club. These camps are experience-driven with activities like kayaking, exhibitions of our animal ambassadors, and games emphasizing water and ecology. Staff also participate annually in the Great American Teach-In where students learn about what STEM careers are available and how to pursue them. The City hosts a booth at Water, Wings, and Wild Things—an annual event held at Circle B Bar Reserve where over 2000 2nd grade students from Central Florida schools are introduced to various environmental concepts.



Figure 2-11. Photo of animal ambassador demonstration for the Cypress Junction Montessori School.

Beginning in 2019, staff have worked with the local Cypress Junction Montessori School to develop a natural resources themed curriculum. This is the first time in recent history that the City has partnered with an individual school to provide multiple lessons and activities throughout the school year. Topics include the scientific method, the water cycle, and local wildlife (Figure 2-11). Continued success of this program may result in lesson plan development for additional schools in the area.

Support of Mission, Vision, and Purpose:

Youth outreach seeks to support the Mission of “sound understanding of social, economic, and ecological systems” in the next generation by providing natural resources education and experiences specific to the local area. This effort also supports the Vision by creating an “engaged public” as well as the Purpose of appealing to “diverse user groups” by targeting outreach to multiple age ranges and demographics.

Benefits:

Youth outreach certainly benefits the public engagement aspect of lake management. The children that can gain some appreciation for the lakes and other local amenities may be inspired to help protect and preserve them for generations to come.



Strategic Goals:

- Hosted 22 youth outreach events in 2023, providing education to over 1000 participants.
- Established a full curriculum for the Cypress Junction Montessori School for the '23-'24 school year. This curriculum provided youth education to over 70 students.
- Participated in Great American Teach-in, educating over 120 students about local natural resources.
- Explore lesson plan development for other local schools in the Winter Haven area.

#3 | Data Presentation & Analysis



Introduction

(Please read before continuing)

Information on the study area lakes has been compiled and analyzed in this section of the report. The primary objective of this data presentation and analysis is an evaluation of lake health based on the metrics and criteria described in the introduction. Using these assessments, the report identifies potential challenges impacting lake health and prioritizes areas for improvement. Taking into account these issues and challenges, current and planned management efforts that aim to improve lake health are documented.

This section has been organized so that lake-specific information is presented separately for each waterbody. The data is organized in alphabetic order by lake name to make it easier to locate. Hydrologic information common to all study area lakes (i.e. rainfall, aquifer level, etc.) is presented at the beginning of this section in order to reduce redundancy. Finally, this section concludes with a summary of lake health index scores and management considerations for the Winter Haven area as a whole.

Lake Health Evaluation Methodology

The primary feature in this section is the Lake Health Index—an evaluation methodology that provides an objective annual score for each lake based on a series of water quality and biological criteria. ***The eight individual criteria are scored based on a scale of 0 to 3. The higher the score, the better the lake is doing in that particular criterion.*** The mean (average) of individual criterion values is calculated to derive the Lake Health Index value for each lake during the current report year. These lake-specific index values can be used to track changes in lake health over time as well as rank the area lakes to prioritize management action. The following are descriptions of the individual lake health criteria:

Water Quality Criteria

- *Water Quality Impairments*
- *Chlorophyll-a Trends*
- *Total Nitrogen Trends*
- *Total Phosphorus Trends*
- *Clarity Trends*

Biological Criteria

- *Vegetation Abundance*
- *Invasive Species Percentage*
- *Species Diversity*

Water Quality Impairments: This criterion indicates a lake’s level of impairment in the three primary water quality parameters—chlorophyll-a (Chl-a), total nitrogen (TN), and total phosphorus (TP). Impairment is based on exceedance of the Numeric Nutrient Criteria thresholds. A score of **3** is awarded for lakes that don’t exhibit impairment in any of the three parameters, whereas a point is deducted for each parameter that exceeds

the impairment threshold. For example, a lake impaired for Chl-a and TN would receive a score of 1.

Water Quality Trends: The water quality trend criteria explores long-term changes in the four primary water quality metrics (i.e. Chl-a, TN, TP, and Clarity). Trend evaluation is critical for identifying potential water quality issues before impairment sets in while also highlighting successes in the management of currently impaired lakes. The evaluation considers the 20-year trend direction and statistical significance ($p\text{-value} \leq 0.05$) based on annual levels of Chl-a, TN, TP, and water clarity from 2003 to 2023 to determine if water quality is improving or deteriorating. Significant improving trends are assigned a score of **3**; non-significant improving trends are given a score of **2**; non-significant deteriorating trends are scored as a **1**; and significant deteriorating trends are scored as a **0**.

Vegetation Abundance: The abundance of aquatic vegetation is a critical ecological factor that impacts fish and wildlife habitat as well as a lake's ability to buffer against changes in water quality. The evaluation of abundance is based on annual percent area coverage (PAC) or the total area of the lake bed occupied by vegetation as determined by SONAR mapping. A score of **3** is given to lakes with PAC exceeding 30%; a score of **2** is given for PAC between 30% and 15%; a score of **1** is assigned to PAC between 15% and 2.5%; and a score of **0** is given to lakes with less than 2.5% PAC.

Invasive Species Percentage: The presence of invasive aquatic plants can have negative impacts on lake ecology and navigation. Evaluation of this criterion is based on the proportion of each lake's managed invasive plant species in relation to all species present during the annual survey. A score of **3** is assigned if a lake has no managed invasive species present; a **2** is given if the invasive percentage is less than 2.5% of the total population; invasive presence between 2.5% and 10% is given a score of **1**; while **0** scores are given if invasive species make up greater than 10% of a lake's total population.

Species Diversity: The diversity of aquatic vegetation often parallels the ecological health of a waterbody. Evaluation of the species diversity criterion is based on the measurement of annual diversity index values in relation to that lake's long-term median value. The indexes measure species richness (Menhinick), species evenness (E3), and overall diversity (H). The long-term median index values are calculated based on at least 3 years of species data for each lake. A point is awarded for each diversity index that meets or exceeds its respective long-term median value; for a total possible score of 3.

Lake Health Index: The individual lake health criterion scores for the study year are averaged for each waterbody. ***The resulting value represents the lake's health score on a scale from 0 to 3. Higher scores are indicative of a healthier lake.*** The Lake Health Index was developed to be an unofficial evaluation metric used track changes in the Winter Haven area lakes over time and prioritize management action.

Winter Haven Regional Hydrology

Winter Haven’s regional hydrology is completely driven by precipitation. An abundance or lack of rainfall can significantly impact water resources such as lake levels, stream flows to the Peace Creek, and groundwater supply. Changes in lake surface elevation influence not only recreation, such as usability of boat ramps and navigation through canals, but can also have drastic effects on water quality and wetland ecology. Rainfall on the Winter Haven Ridge recharges the Floridan Aquifer—the underground source of the State’s drinking water supply. Just as important as rainfall, the amount of water in the Upper Floridan Aquifer (UFA) also affects the levels and overall health of the lakes.

On average, the City of Winter Haven receives 51.62 inches of rainfall annually. This is typically distributed throughout the year in distinct wet and dry seasons. The wet season is concentrated from June through September evidenced by the higher average monthly rainfall around 7-8 inches, shown as the orange dotted lines (Figure 3-1). Whereas the dry season, which ranges from October to May, usually receives much less monthly rainfall; between 2-4 inches. The light blue shaded areas on the graph represent the normal range, or one standard deviation from the median, of rainfall during a given month.

In 2023, the City of Winter Haven received 46.84 inches of rainfall which was almost 5 inches below the annual average. This rainfall deficit can mostly be explained by well below-average rainfall totals during January, February, March, July, August, and October. The totals for February, March, and July were below their respective monthly normal ranges, whereas April was the only month with rainfall above its normal range. This lack

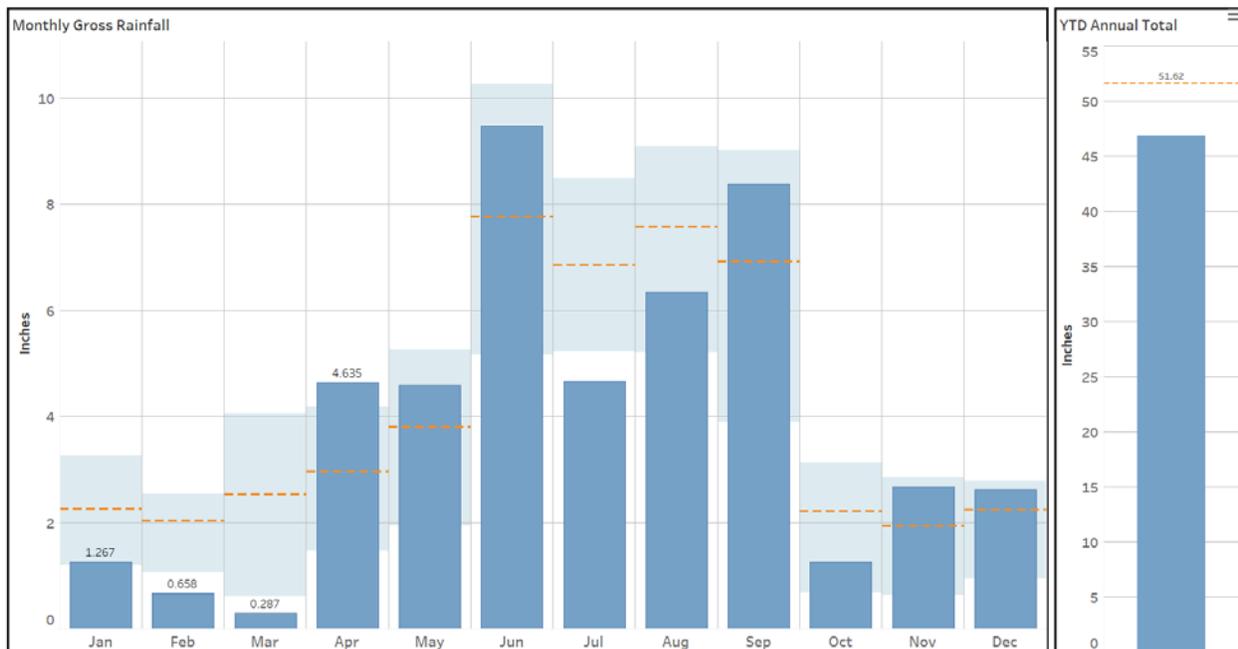


Figure 3-1. 2023 monthly and annual rainfall totals in relation to the long-term average.

of rainfall had impacts on the City’s water resources, described in more detail in the individual lake assessments.

Figure 3-2 depicts the upper surface elevation of the UFA and monthly rainfall totals from 2013 until 2023. The dotted line represents the long-term average UFA level, while the shaded area represents the normal range of one standard deviation above and below the median level. For reference, the ground elevation of the monitoring station is approximately 170 ft above sea level.

The Upper Floridan Aquifer undergoes both seasonal and long-term fluctuations based on annual rainfall patterns and climatic cycles like El Niño/La Niña Oscillations. 2014 marked the end of one of these longer-term fluctuations where the local hydrology began to recover from an extended drought period. The UFA has remained relatively high since then—consistently exceeding the long-term average and even the upper normal range most years. Below-average rainfall during 2021 resulted in the lowest dry season UFA levels since 2017 as well as a lower wet season peak. However, increased rainfall during 2022 resulted in wet season peak UFA levels at nearly the highest in the last 10 years.

The below-average rainfall in 2023 resulted in a much narrower annual fluctuation of the UFA than normal. The UFA level dropped to its lowest point in April near the lower limit of the normal range. Wet season rainfall raised the UFA to a September peak; eventually ending 2023 at a slightly above-average level.

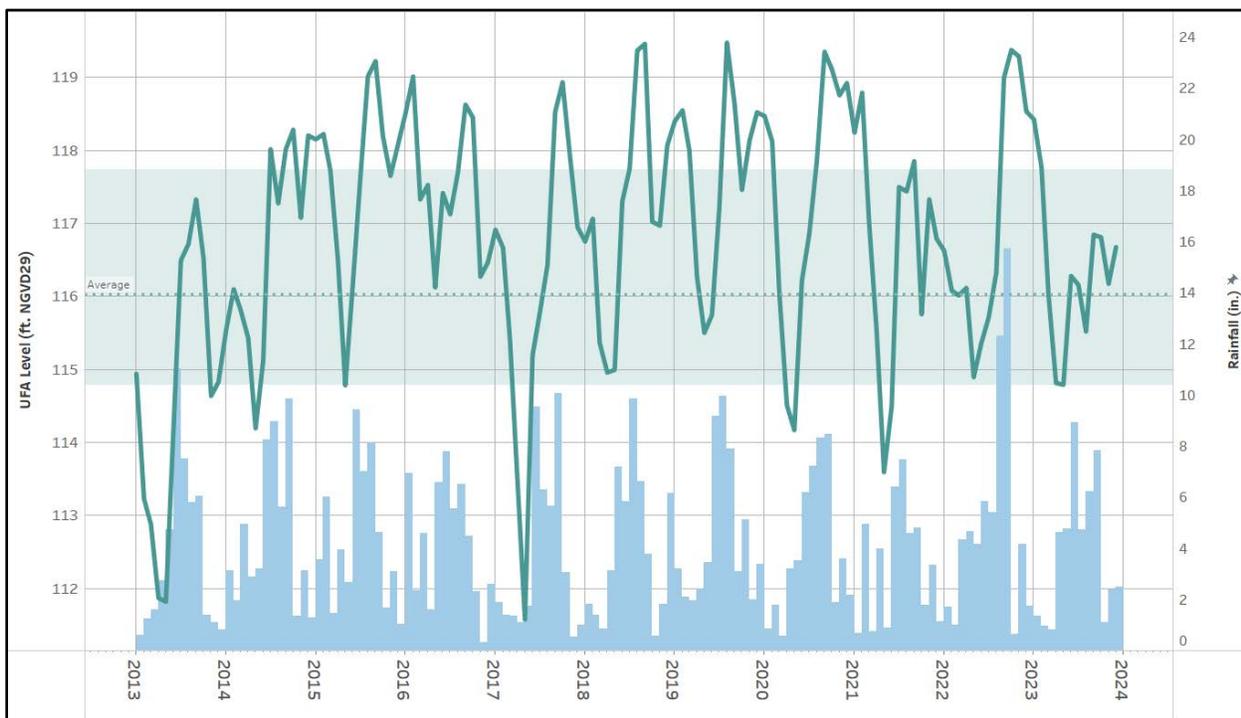


Figure 3-2. Monthly Upper Floridan Aquifer levels and monthly rainfall totals from 2013 to 2023. UFA levels graphed in relation to long-term mean and normal range.

Lake Blue

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
0	2	2	3	1	3	3	2	2.0

Location, Characteristics, & Hydrology:

Lake Blue is located northwest of central Winter Haven, just outside City limits. The lake discharges excess water to Lake Cannon of the South Chain of Lakes via a passive overflow structure and a series of pipes and ditches. Lake Blue is a relatively small and shallow waterbody at just 54 acres, an average depth of 4.6 feet, and a maximum depth of just under 10 feet (Figure 3-3).

Stormwater is conveyed to this waterbody from a 128-acre urbanized drainage basin (Figure 3-4). The top five land use types in this basin, ranked by area, are industrial, commercial, open land, medium-density residential, and institutional. Based on modeling, stormwater from this basin contributes 871.5 lbs of TN and 154.2 lbs of TP to the lake annually. There are no known Onsite Sewage Treatment & Disposal (OSTD/septic) systems within the Lake Blue basin. However, there are OSTDs within the general vicinity. Lake Blue is outside municipal limits; therefore the City has no stormwater infrastructure contributing to the lake and does not conduct street sweeping services within its basin.

Throughout the period of record, the surface level of Lake Blue has fluctuated between 146.4 and 149.8 feet above sea level. The normal range of seasonal fluctuations is between 147.3 to 148.1 feet; with more extreme peaks and troughs occurring during particularly wet and dry years, respectively (Figure 3-5). During 2023, Lake Blue reached a wet season peak of 148.18 ft and a dry season low of 146.78 ft, but ended the year at 147.3 ft

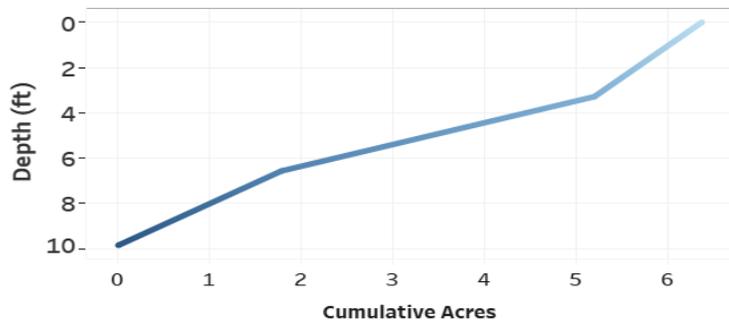


Figure 3-3. Hypsograph of Lake Blue depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

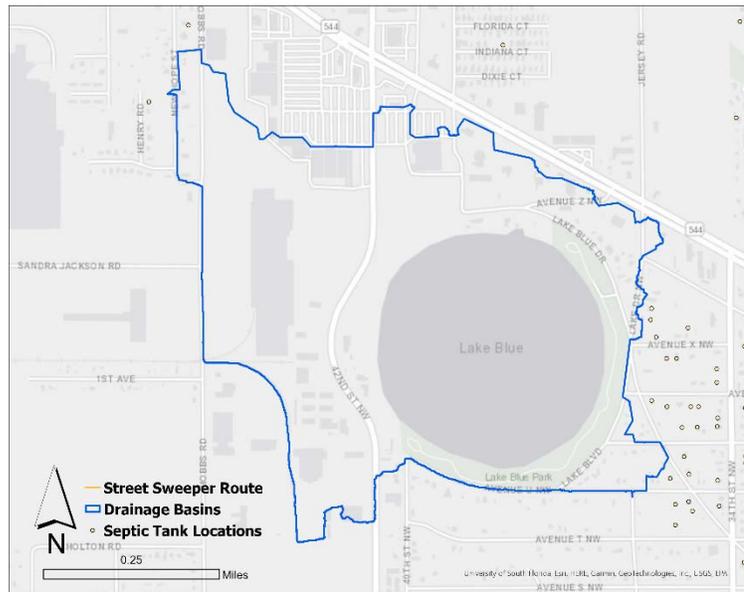


Figure 3-4. Map of Lake Blue's drainage basin, City street sweeper routes, and nearby septic systems.

which is right at the lower end of the normal range. Changes in Lake Blue’s surface level are not correlated with Chl-a, TN, TP, or clarity (see appendix).

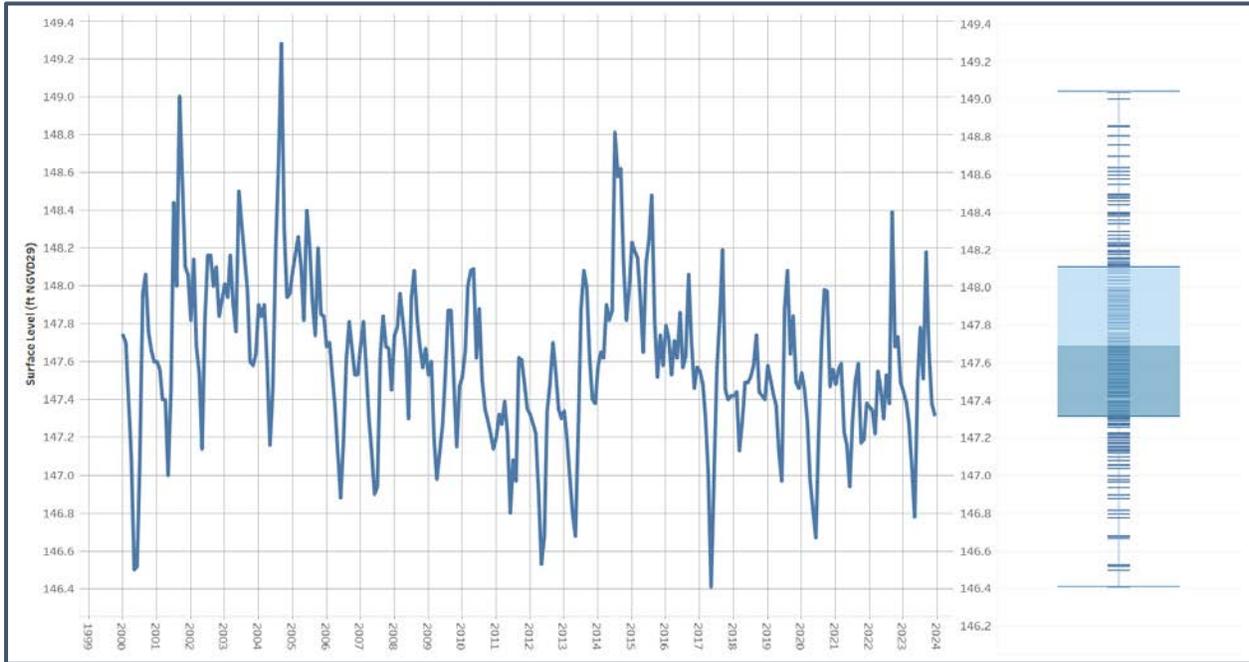


Figure 3-5. Hydrograph of Lake Blue depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details the total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For purposes of determining water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Blue is categorized as a clear, alkaline waterbody. The lake is considered impaired for Chl-a, TN, and TP due to exceedances of the impairment thresholds during the assessment period (Figure 3-6). This equates to an impairment criterion score of 0. In 2018, the FDEP established a total maximum daily load (TMDL) for Lake Blue. The TMDL stipulates a 66% reduction in TN and a 67% reduction in TP to meet NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of annual Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Total phosphorus exhibited a statistically significant improving trend; Chl-a and TN exhibited non-significant improving trends; and Secchi depth exhibited a non-significant declining trend. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing	Not Significant	2
TN	Decreasing	Not Significant	2
TP	Decreasing (Improving)	Significant	3
Secchi	Decreasing	Not Significant	1

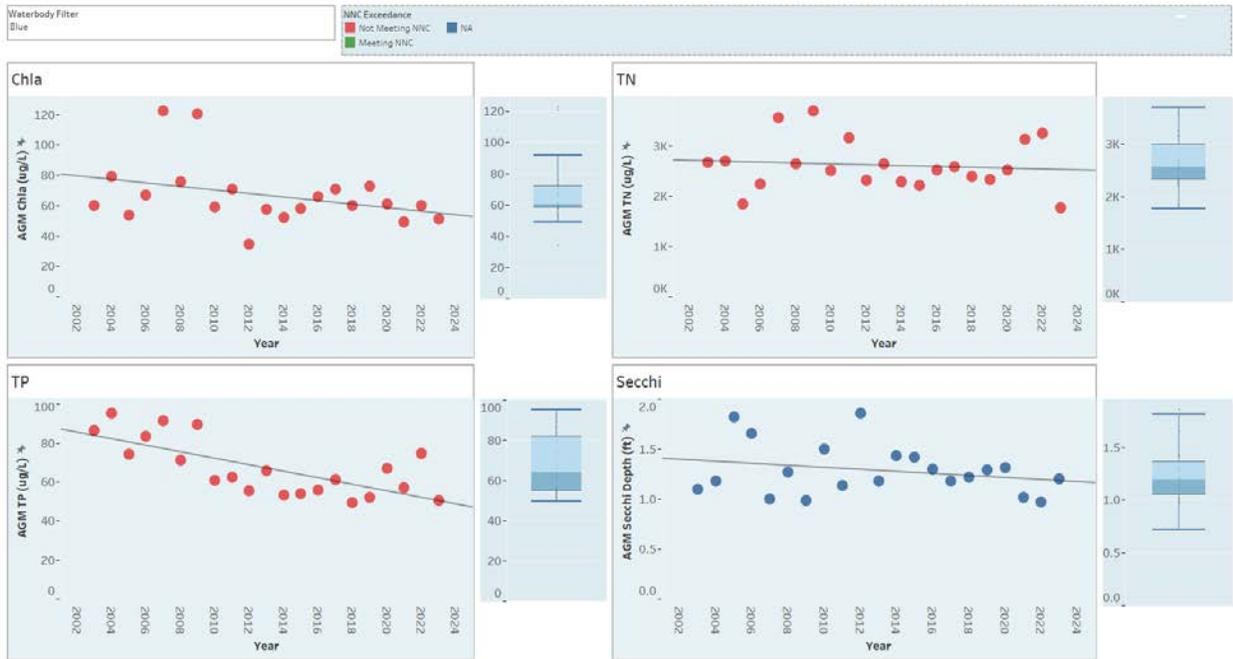


Figure 3-6. Lake Blue AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Blue on 1/27/2023. The PAC during this survey as 78.9% and the total BV was 12.7% (Figure 3-7). While the vegetation coverage has been increasing the last couple of years, this may have been an error in the SONAR’s ability to distinguish between decaying organic matter and living vegetation as shown by the light green areas in the center of the lake. That said, there was a marked increase in shoreline vegetation in 2023. The result is the Lake Blue receives a score of 3 for this criterion.

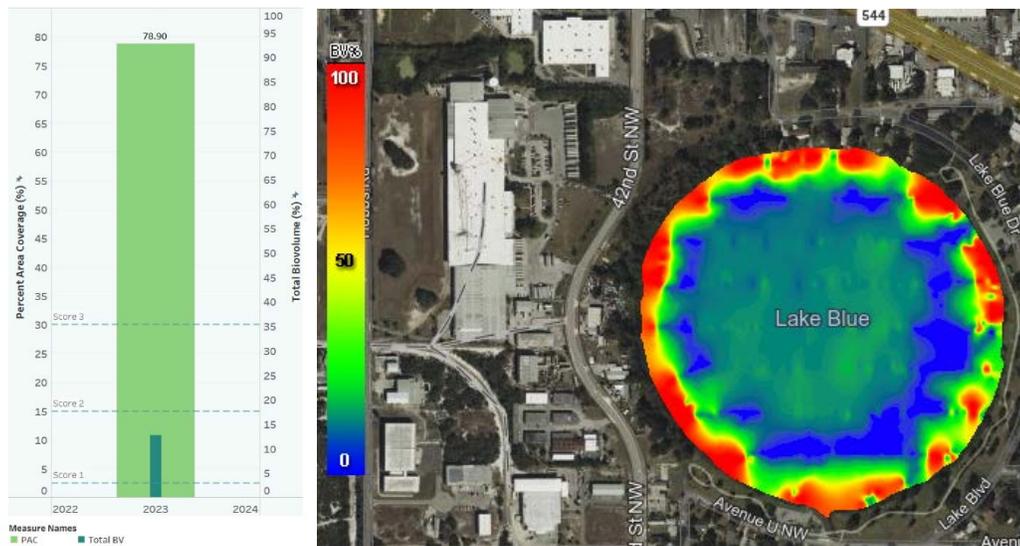


Figure 3-7. Graph depicting 2023 PAC/BV and biovolume heatmap; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Based on data from the 2023 vegetation survey, Lake Blue’s vegetation community was primarily made up of emergent vegetation, with less than 2% submerged (Figure 3-9). The most abundant species was pickerelweed—a native emergent. While exotic species were present during the survey (e.g. primrose willow and torpedograss), these often do not require management action to control. Therefore, Lake Blue possessed no appreciable presence of managed invasive species—earning a score of 3 for this criterion.

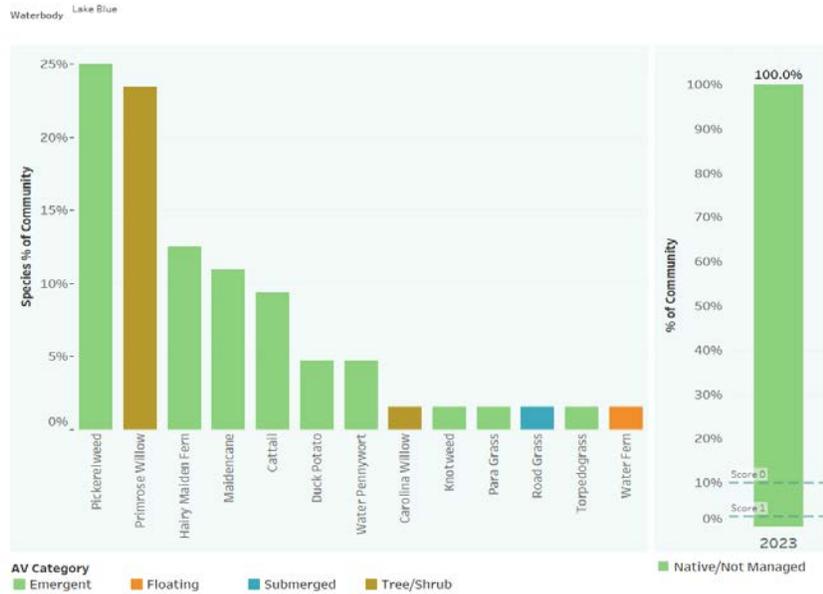


Figure 3-8. Chart depicting species frequency and invasive species percentage of Lake Blue during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H) and compares them with long-term values. During 2023, Lake Blue’s richness and diversity indices exceeded there long-term medians. Evenness was slightly below the median resulting in a criterion score of 2 (Figure 3-9). Compared with previous years, richness and overall diversity remain high, but species evenness has dropped considerably.

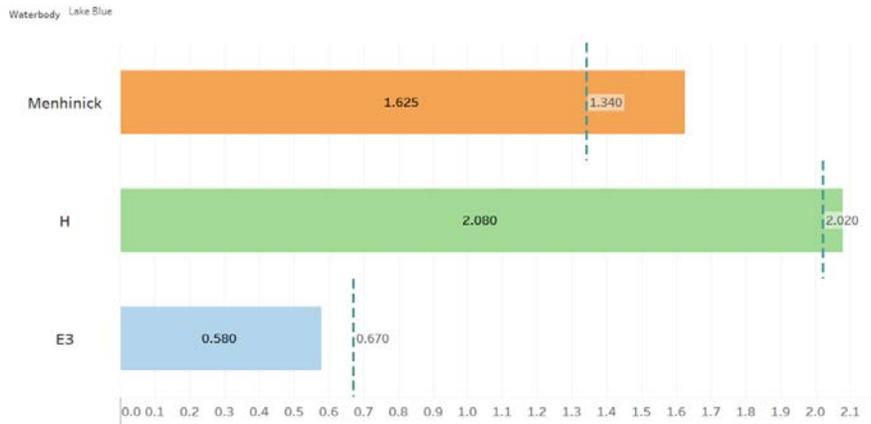


Figure 3-9. Chart depicting 2023 diversity index values for Lake Blue.

Lake Health Tracking:

A comparison of Lake Blue’s health index scores from 2018 to 2023 shows a gradual decline and sudden improvement in overall lake health (Figure 3-10). During this six year span, there were no observed changes in water quality impairment or trend scores. Though the trends show some general movement toward better water quality, Lake Blue is still far from meeting the impairment thresholds. The major differences occurred in the aquatic vegetation scores, with increases in abundance and diversity contributing to an all time high lake health score of 2.3.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	2	3	2	2	3	3	2.1
2019	0	2	2	3	2	1	3	3	2.0
2020	0	2	2	3	2	NA	3	0	1.7
2021	0	2	2	3	2	2	3	1	1.9
2022	0	2	2	3	2	3	3	3	2.3
2023	0	2	2	3	1	3	3	2	2.0

Figure 3-10. Chart depicting a comparison of Lake Blue’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Blue currently exhibits poor water quality with impairments in each of the NNC metrics. With high intensity industrial and commercial land uses dominating the drainage basin, the stormwater pollutant load is likely the primary driver of these water quality issues.
- Despite the 2023 PAC values, Lake Blue distinctly lacks vegetation beyond the very edge of the lake. The low clarity likely prevents the growth of vegetation in water deeper than a few feet, resulting a very narrow littoral zone. Fish and wildlife habitat is limited by the lack of submerged vegetation.
- The morphology of Lake Blue likely exacerbates its water quality issues. At an average depth of 4.6 feet, wind and wave action have greater potential to suspend sediments from the lake bed—leading to poor water clarity.

Lake Management Strategy:

- The City currently conducts annual aquatic vegetation monitoring and shares this information with partnering agencies for use in management efforts. Staff will continue to support Polk County and FWC in these efforts.
- City staff may work with Polk County and other agencies to explore the potential for aquatic vegetation planting. However, the poor water clarity may hinder the planting of submerged vegetation.
- Polk County has plans to implement an algal neutralization device in the lake to help filter the water column and increase clarity. This is scheduled to be deployed in 2024.

Lake Buckeye

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	3	3	2	3	2	2	3	2.6

Location, Characteristics, & Hydrology:

Lake Buckeye is located to the northeast of central Winter Haven. It receives excess water flows from Lake Idyl and discharges downstream to Lake Fannie of the North Chain of Lakes via a passive overflow structure. Lake Buckeye is a moderately sized waterbody at 72.4 acres and an average depth of 9 feet, but with deeper holes reaching over 26 feet (Figure 3-11).

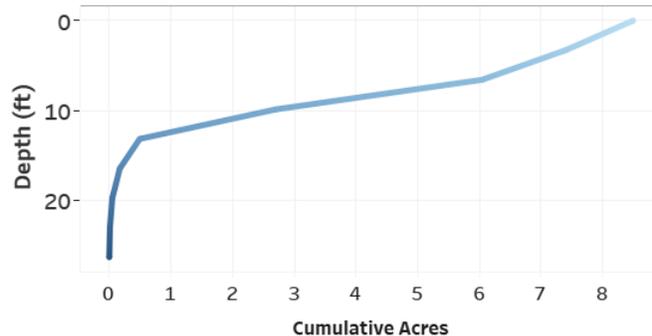


Figure 3-11. Hypsograph of Lake Buckeye depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 305 acre drainage basin made up of eight separate sub-basins (Figure 3-12). Land use is mixed in this basin, with the top five uses comprised of medium density residential, open land, high density residential, tree crops, and lake swamps, respectively. Based on stormwater modeling, these land uses contribute 867 lbs of TN and 155 lbs of TP annually. There are 42 Onsite Sewage Treatment & Disposal (OSTD/septic) systems located within this basin that could also be contributing to internal pollutant loading via groundwater seepage. The City conducts monthly street sweeping services up to 5.6 miles within this basin.

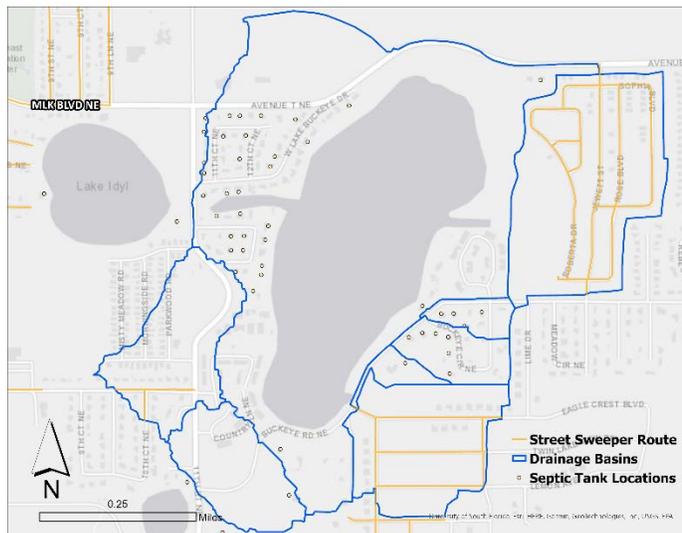


Figure 3-12. Map of Lake Buckeye's drainage basin, City street sweeper routes, and nearby septic systems.

Over its period of record, Lake Buckeye's surface level has fluctuated between 125 and 129.8 feet above sea level. The normal level range fluctuates less than half a foot, between 127.6 and 128 feet (Figure 3-13). During 2023, Lake Buckeye reached a wet season peak of 128.2 in June and a dry season low of 127.6 in April. The surface level ended the year slightly above average at 127.9 ft. Changes in Lake Buckeye's surface level is not correlated with Chl-a, TN, TP, or clarity (see appendix).

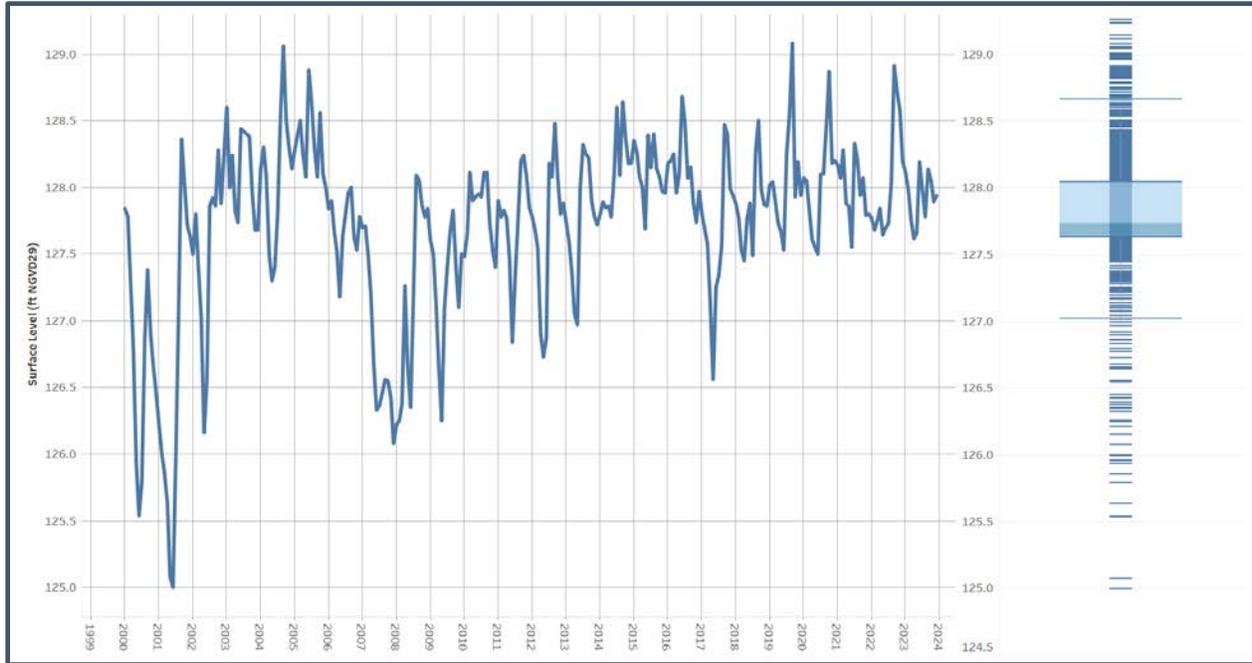


Figure 3-13. Hydrograph of Lake Buckeye depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Buckeye is categorized as a clear, alkaline waterbody. Since 2000, there has only been one year in which Buckeye exceeded NNC thresholds in Chl-a and TP—2005 (Figure 3-14). As of 2023, Lake Buckeye is not impaired for any of the NNC parameters. It should be noted that the 2023 mean water quality values were the poorest since 2005. This may be due to changes in the lake’s vegetation community; to be discussed in greater detail below.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. The Chl-a, TN, and Secchi depth parameters continue to exhibit significant improving trends. However, the TP trend, while still moving in a downward trajectory, is no longer statistically significant. This tracks with the relatively poorer water quality exhibited in 2023. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing	Not Significant	2
Secchi	Increasing (Improving)	Significant	3

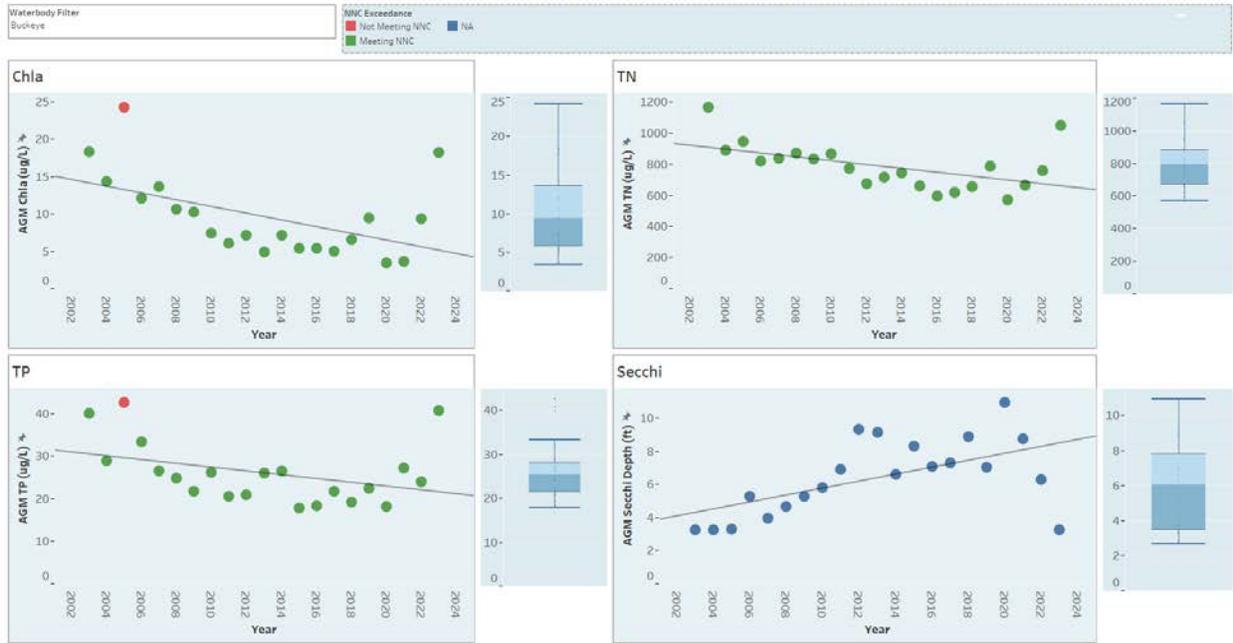


Figure 3-14. Lake Buckeye AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Buckeye on 3/31/2023. The PAC during this survey was 20.1% and the total BV was 1.5%—equating to an abundance criterion score of 2 (Figure 3-15). This constituted a significant decline in vegetation abundance compared to previous years. It is unclear what caused this massive decline.

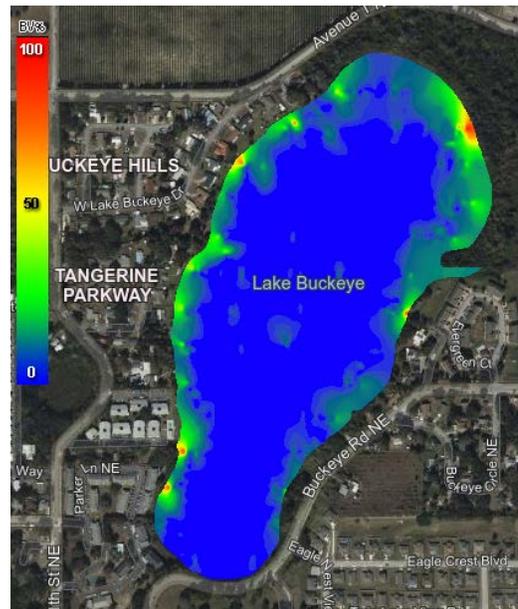
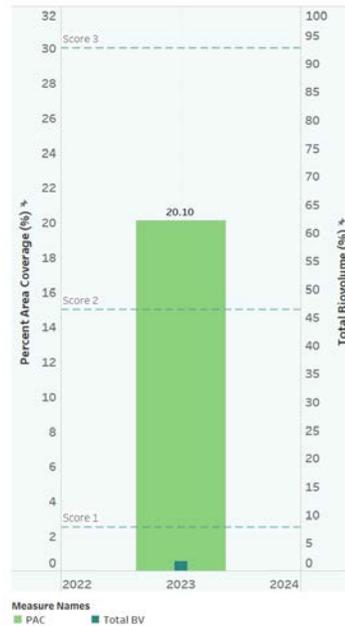


Figure 3-15. Graph depicting 2023 PAC/BV and biovolume heatmap; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Lake Buckeye was previously dominated by the submerged plant coontail. Due to the impacts of the invasive treatment, spatterdock became the dominant species, followed by cattail, coontail, and primrose willow. Invasive species like burhead sedge and parrotfeather made up just 2.22% of the community in 2023—earning an invasive criterion score of 2. In previous years, hydrilla has been the main competition of coontail for submerged species dominance, but recent management

efforts has reduced its population to undetectable quantities. It is unlikely that spot treatment of invasives led to the decline in vegetation abundance.

Species Diversity:

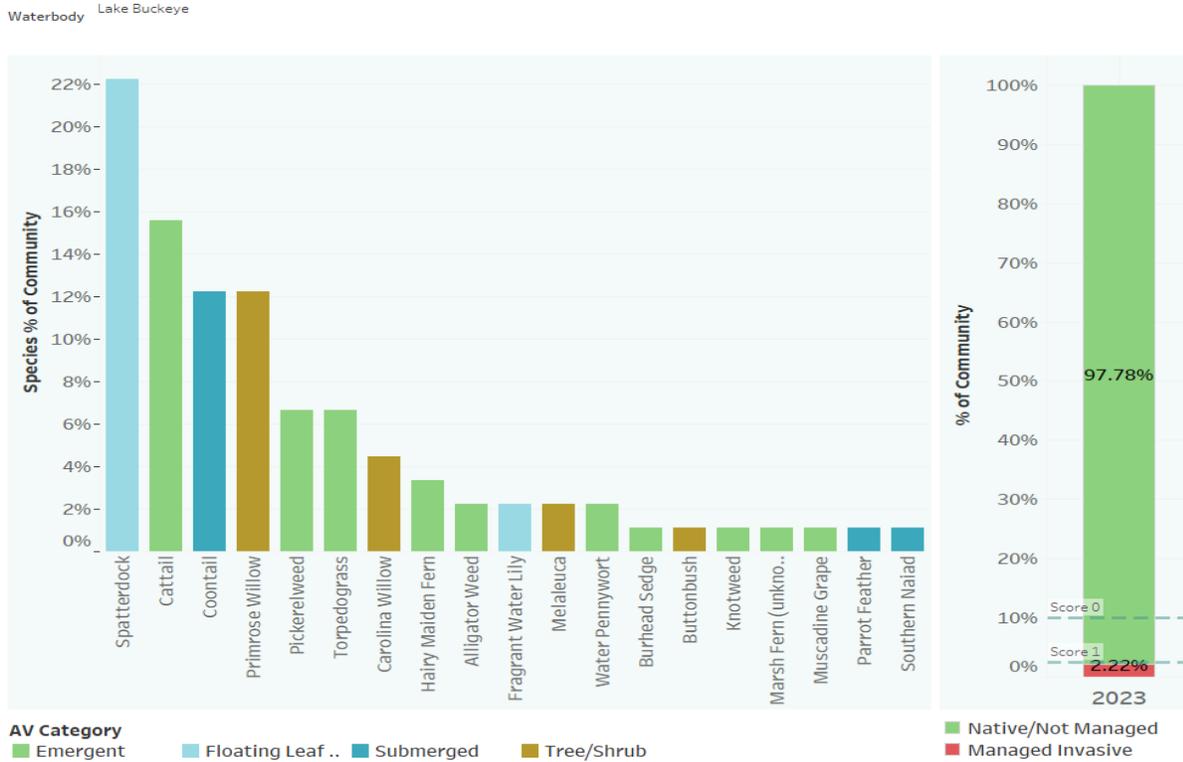


Figure 3-16. Chart depicting species frequency and invasive species percentage of Lake Buckeye during 2023.

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Due to the massive shift in the vegetation community in 2023, Lake Buckeye’s diversity indices all exceeded median values—earning a diversity criterion score of 3 (Figure 3-17). While the coontail is a native species, its dominance prevented other plants from expanding their habitat zones. While the drop in vegetation abundance is unfortunate, this shift should allow other species the opportunity to expand in numbers and improve the lake’s overall ecological community.

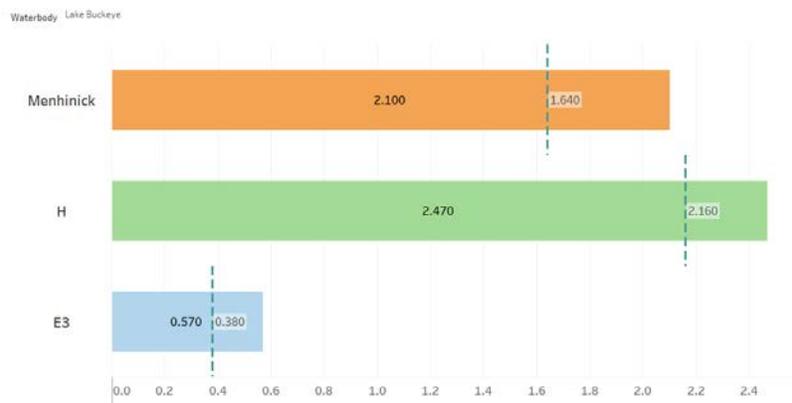


Figure 3-17. Chart depicting 2023 diversity indices for Lake Buckeye. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Buckeye’s health index scores from 2018 to 2022 shows relative consistency. Since the City began documenting lake health, the only variability in Lake Buckeye’s scores has come from changes in the biological criteria (Figure 3-18). The discovery, treatment, and subsequent resurgence of invasive plants like hydrilla likely contribute to these scores; which underscores the necessity for regular vegetation monitoring to prevent a takeover of invasive species. Such a robust abundance of vegetation is thought to contribute to Lake Buckeye’s impressive water quality, so maintaining a healthy vegetation community is critical.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	3	3	3	0	1	2.4
2019	3	3	3	3	3	3	0	3	2.6
2020	3	3	3	3	3	3	0	2	2.5
2021	3	3	3	3	3	3	1	1	2.5
2022	3	3	3	3	3	3	1	0	2.4
2023	3	3	3	2	3	2	2	3	2.6

Figure 3-18. Chart depicting a comparison of Lake Buckeye’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Buckeye currently exhibits excellent water quality. However, stormwater pollutant loading is a potential concern if water quality trends ever change for the worse.
- The presence of OSTDs (septic) systems in the drainage basin may not currently be an issue assuming they are functioning properly. However, as these systems age, they may begin to leach nutrients into the water table—leading to water quality declines.
- The management of invasive species like hydrilla and burhead sedge are a constant concern. It can only take a single season for even a small population to take over large areas of a waterbody. Large-scale invasive treatments can sometimes result in the sharp declines in vegetation abundance as seen in 2023.

Lake Management Strategy:

- With the majority of the drainage basin comprised of residential housing, future management of stormwater will likely consist of public education and outreach. Education aims to increase residents’ knowledge of best stormwater practices and ways they can collectively reduce their pollutant load.
- If water quality becomes a future issue, City staff may explore source analysis to determine if OSTD leachate is a potential contributor to nutrient pollutant loading. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large scale herbicide treatments and potential water quality issues that follow.

Lake Cannon

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2	2	2	3	2	3	1	3	2.3

Location, Characteristics, & Hydrology:

Lake Cannon is located northwest of central Winter Haven, at the edge of City limits. As part of the South Chain of Lakes, Cannon is connected to Lakes Howard, Idylwild, and Mirror via navigable canals. Excess water from the South Chain of Lakes discharges to the Wahneta Farms drainage canal via a passive overflow structure at the south shore of Lake Lulu; eventually connecting with the Peace Creek near Bartow. Lake Cannon is a moderately sized waterbody at 340 acres, an average depth of 10.9 feet, and a maximum depth in deeper holes approaching 20 feet (Figure 3-19).

Stormwater is conveyed to this waterbody from a 1039 acre urbanized drainage basin made up of five separate sub-basins (Figure 3-20). The top five land use types in this basin, ranked by area, are medium density residential, commercial, institutional, and high density residential. Based on modelling, stormwater from this basin contributes 2,836 lbs of TN and 638 lbs of TP to the lake annually. There are 338 Onsite Sewage Treatment & Disposal (OSTD/septic) systems within the Lake Cannon drainage basin. This high density of OSTDs may pose a greater risk of groundwater pollutant loading via septic leachate. The City provides monthly street sweeping services up to 9.58 miles in the eastern half of the basin that is within Winter Haven limits.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs,

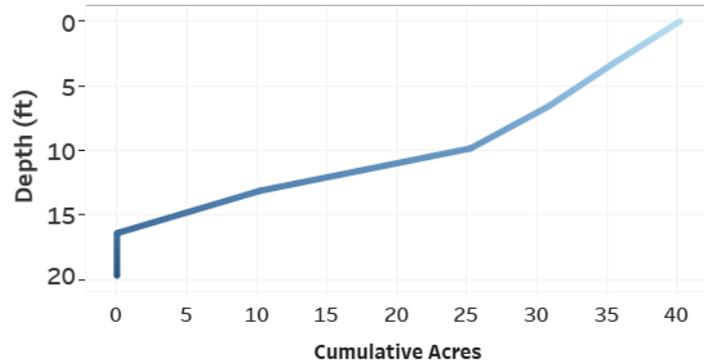


Figure 3-19. Hypsograph of Lake Cannon depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

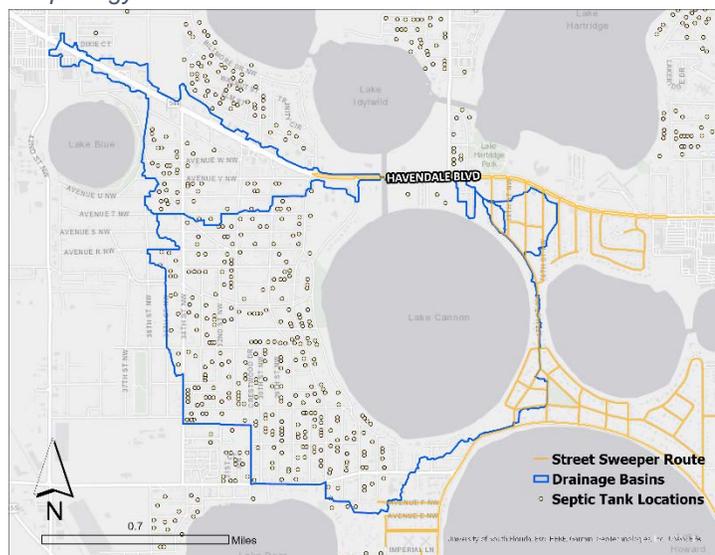


Figure 3-20. Map of Lake Cannon's drainage basin, City street sweeper routes, and nearby septic systems.

respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake Cannon’s surface level directly correlate with water clarity and indirectly correlate with Chl-a and TN (see appendix). This carries management implications as a higher surface level should result in water quality improvements.

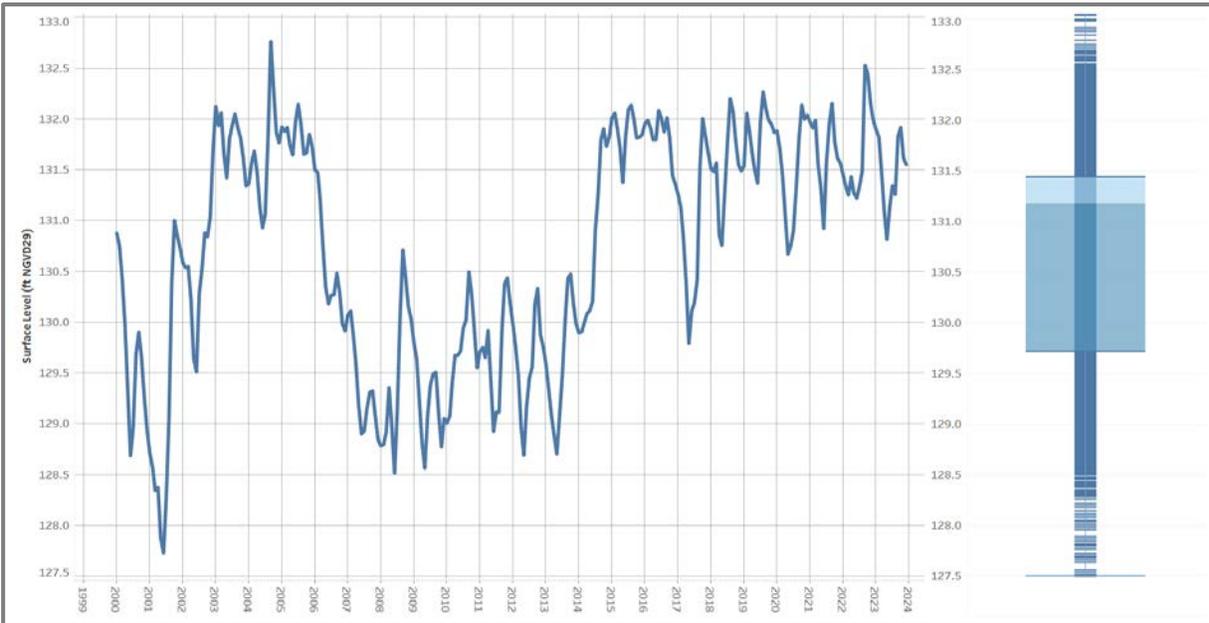


Figure 3-21. Hydrograph of the South Chain of Lakes depicting monthly surface level readings from 2000 to 2023. A box & whisker plot details the total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Cannon is categorized as a clear, alkaline waterbody. Based on exceedances in 2018, 2019, and 2020, it is considered impaired for Chl-a (Figure 3-22). In 2019, the FDEP established a total maximum daily load (TMDL) for Lake Cannon which stipulates a 20% reduction in TN concentration to meet the Chl-a guidelines. None of the NNC parameters exceeded impairment thresholds in 2023. This indicates that the higher than normal concentrations in 2022 were outliers.

Parameter	Impaired	Index Score
Chla	Y	2
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Only TP exhibited a significant improving trend; Chl-a, TN, and Secchi depth exhibited non-significant improving trends during this period. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing	Not Significant	2
TN	Decreasing	Not Significant	2
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing	Not Significant	2

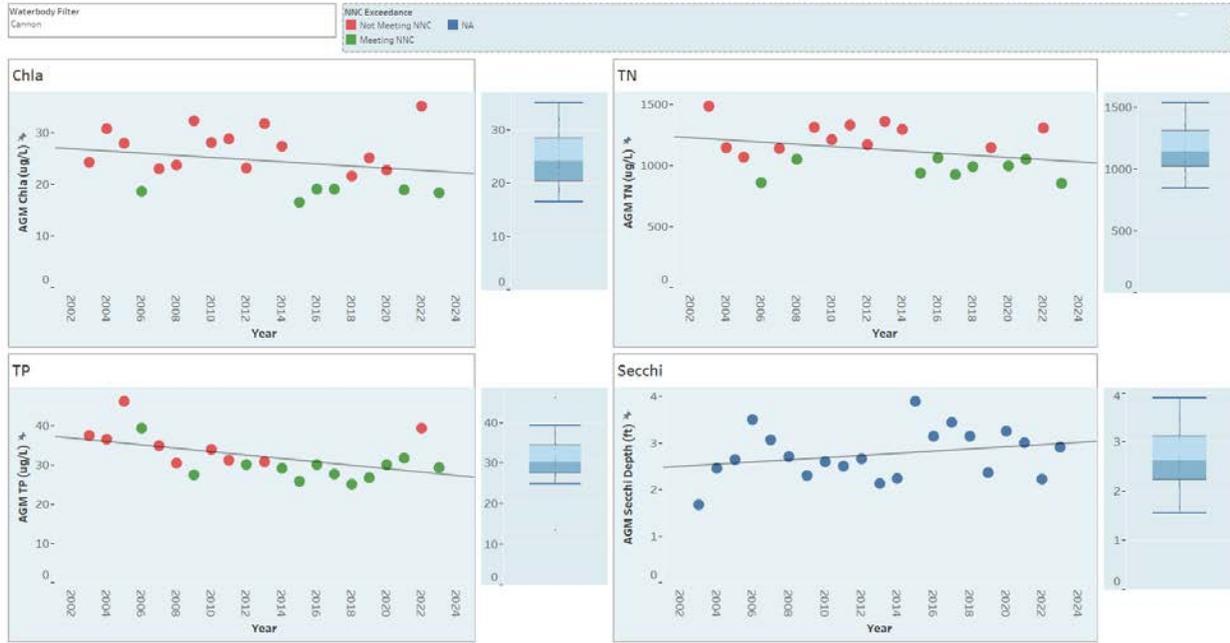


Figure 3-22. Lake Cannon AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted on Lake Cannon on 5/4/2023. The PAC during this survey was 30.5% and the total BV was 4.78% (Figure 3-23). Due to the slope of Lake Cannon’s bed, the littoral zone is limited to around 10-12 feet in depth. Over the years, Lake Cannon has not exhibited much variability in its vegetation abundance. While the coverage of aquatic plants slightly decreased from 2022 to 2023, the overall biovolume increased. Despite the slight decrease in PAC, Lake Cannon still achieves a score of 3 for the biological abundance criterion.

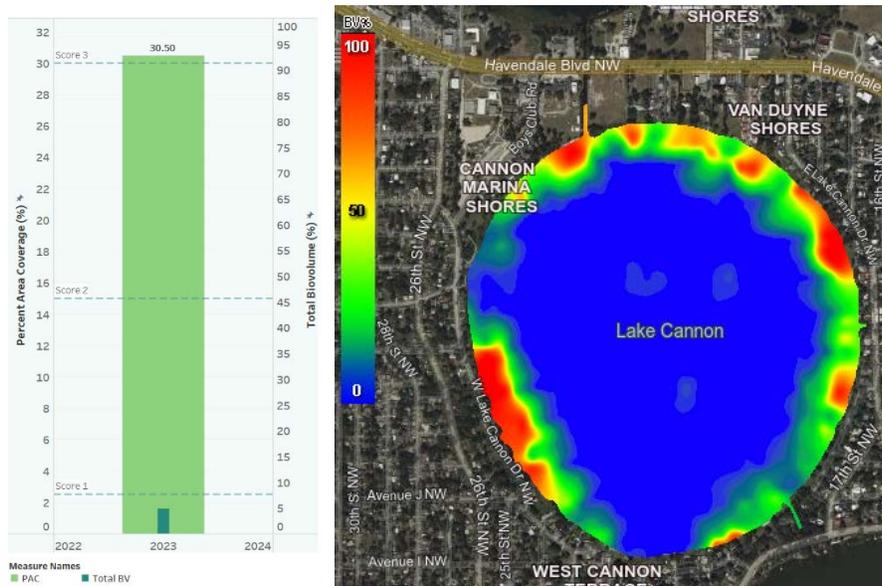


Figure 3-23. Graph depicting 2023 PAC/BV and biovolume heatmap; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of annual vegetation surveys using point-intercept sampling methodology. Based on data from the 2022 survey, Lake Cannon’s vegetation community was comprised of a good mix of submerged and emergent species. The most abundant species were natives like eelgrass, Kissimmee grass, and southern naiad (Figure 3-24). There was a significant increase in the presence of the invasive species as the percentage of hydrilla totaled almost 7%. As a result, Lake Cannon scored a 1 in the invasive species presence criterion. This also indicates a need to work with partner agencies to treat the hydrilla before it becomes a larger issue.

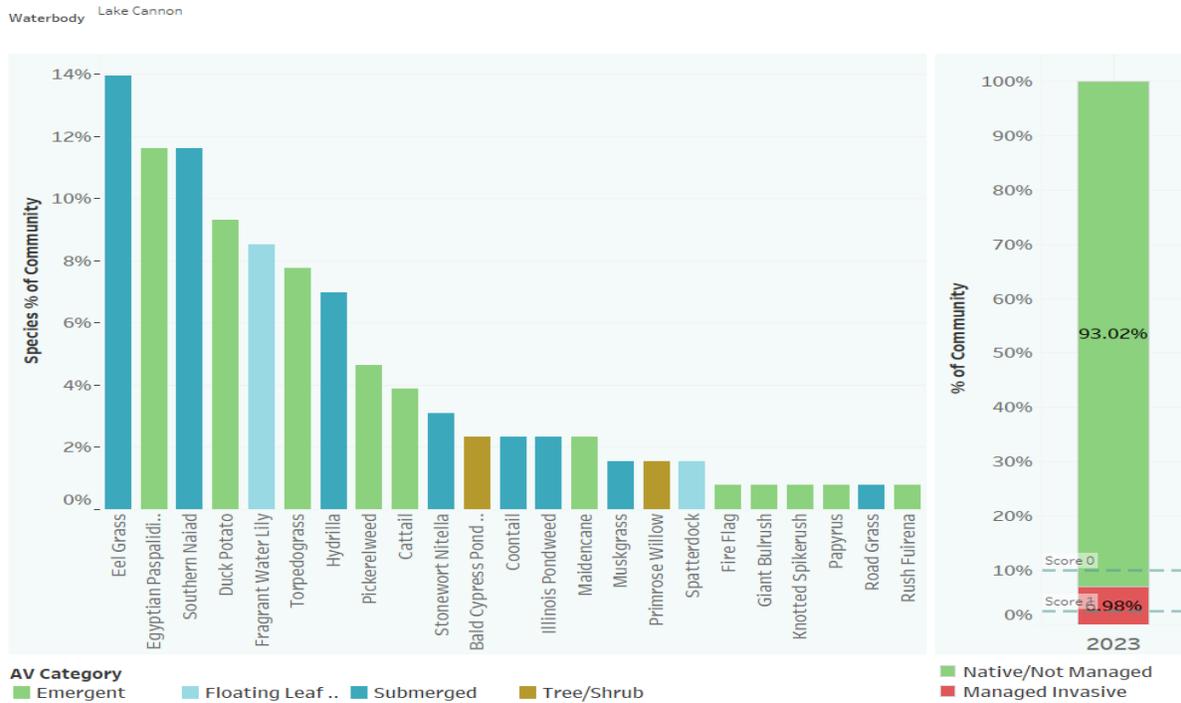


Figure 3-24. Chart depicting species frequency and invasive species percentage of Lake Cannon during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to 2023 values, all three of Lake Cannon’s diversity indices met or exceeded their respective medians; resulting in a diversity criterion score of 3. Lake Cannon generally has a very diverse vegetation community, but the overall number and distribution of unique species increased dramatically since 2021. Since there has been little management of invasives in this waterbody, these shifts in the community dynamics are most likely natural.

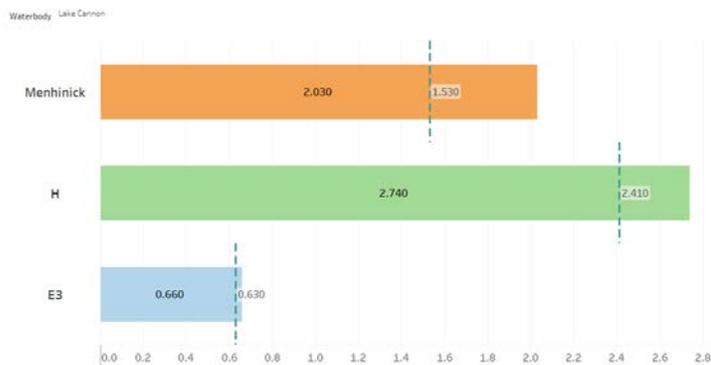


Figure 3-25. Chart depicting 2023 diversity index values for Lake Cannon. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Cannon’s health index scores from 2018 to 2023 shows a gradual increase in overall lake health (Figure 3-26). In the six years since lake health monitoring began, the impairment criterion has shown steady improvement. There have been minor fluctuations in the trend significance, but water quality appears to be trending in a positive direction. Vegetation abundance has remained high, with some fluctuation in the invasive and diversity criteria.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	3	2	3	3	2	NA	2.1
2019	1	2	3	2	3	3	2	1	2.1
2020	1	2	3	2	3	3	1	2	2.1
2021	2	3	3	2	3	3	1	1	2.3
2022	2	2	2	2	3	3	2	3	2.4
2023	2	2	2	3	2	3	1	3	2.3

Figure 3-26. Chart depicting a comparison of Lake Cannon’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Cannon’s chlorophyll-a concentrations still exceed the impairment threshold. Stormwater is a primary concern as a leading contributor of nutrient pollutant loading.
- The presence of OSTDs (septic) systems in the drainage basin may not currently be an issue assuming they are functioning properly. However, as these systems age, they may begin to leach nutrients into the water table—leading to water quality declines.
- The management of invasive species like hydrilla is a constant concern. It can only take a single season for even a small population to take over large areas of a waterbody. The subsequent treatment can result in impacts to native vegetation and water quality.
- Several water quality metrics are significantly correlated with Lake Cannon’s surface level; likely due to increased flushing during wetter periods. The means that drought conditions could result in water quality declines.

Lake Management Strategy:

- City staff can explore implementation of green stormwater infrastructure and increased street sweeping in high-pollutant loading areas.
- City staff may explore source analysis to determine if OSTD leachate is a potential contributor to nutrient pollutant loading. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Conine

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	3	3	2	3	2	1	3	2.5

Location, Characteristics, & Hydrology:

Lake Conine is located to the north of central Winter Haven, bordering City limits. Connected via navigable canals to Lakes Rochelle and Smart, as well as a lock system to Lake Hartridge, Conine is grouped into the North Chain of Lakes. Excess water from the North Chain eventually drains via the SWFWMD-managed P-8 control structure to the south of Lake Hamilton and enters the Peace Creek. Lake Conine is a moderately sized waterbody at 233 acres, an average depth of 9 feet, and a maximum depth approaching 18 feet (Figure 3-27).

Stormwater is conveyed to this waterbody from a 796 acre drainage basin made up of seven separate sub-basins (Figure 3-28). Land use varies in this basin, with the top five uses comprised of medium density residential, commercial, institutional, forested wetlands, and utilities. Based on stormwater modelling, these land uses contribute 2,836 lbs of TN and 474 lbs of TP annually. There are 39 Onsite Sewage Treatment & Disposal (OSTD/septic) systems within this drainage basin at a relatively low density. The City conducts monthly streets sweeping services up to 0.77 miles within this basin.

Over the period of record, surface levels in this section of the North Chain (Lakes Conine, Haines, Rochelle, and Smart) have fluctuated between 122 and 129.5 feet above sea level. The normal range fluctuates much less between 126.1 and 128.2 feet (Figure 3-29). During 2023, Lake Conine reached a wet season peak of 128.6 feet in September and a dry season low of 127.8 feet in May. The surface level ended the year above the high end of the normal range at 128.6 feet. Changes in Lake Conine’s surface level are directly correlated with water clarity and indirectly correlated with Chla and TN (see appendix). This carries management implications as maintaining a higher surface level should result in improved water quality.

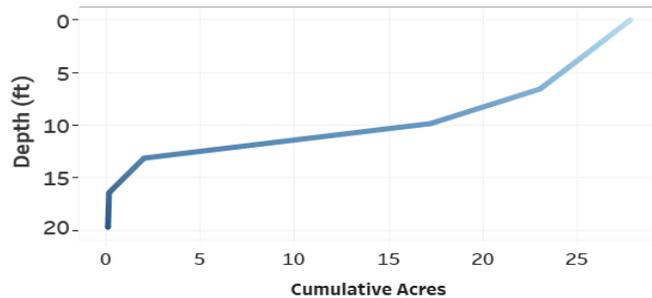


Figure 3-27. Hypsograph of Lake Conine depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

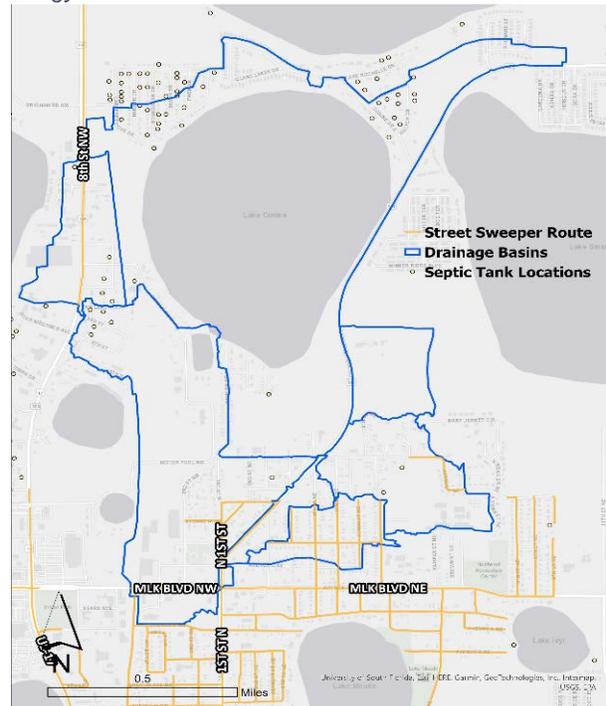


Figure 3-28. Map of Lake Conine’s drainage basin, City street sweeper routes, and nearby septic systems.

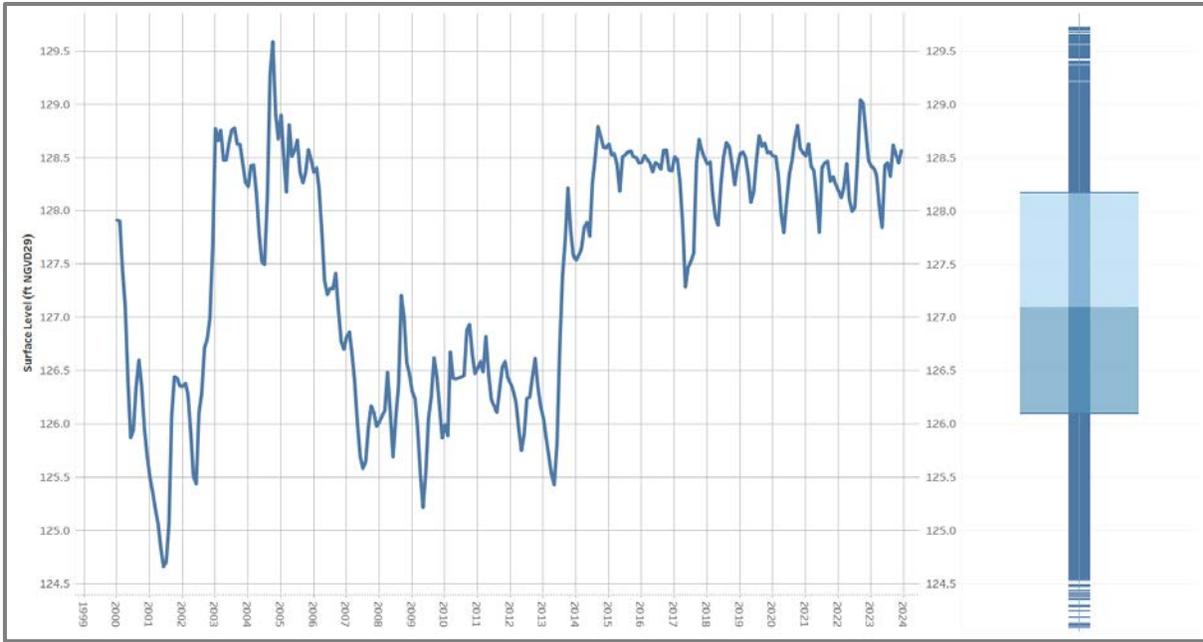


Figure 3-29. Hydrograph of Lake Conine depicting monthly surface level readings from 2000 to 2023. A box & whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Conine is categorized as a clear, alkaline waterbody. Based on a lack of multiple consecutive exceedances in the last 7.5 years, Lake Cannon is no longer exhibiting impaired status (Figure 3-30). While now meeting standards, the lake will need to continue exhibiting good water quality in the future in order to be removed from the official impaired list. In 2018, the FDEP established a total maximum daily load for Lake Conine stipulating a 36% reduction in TN and a 57% reduction in TP in order to meet NNC guidelines. The City will continue to work towards meeting these guidelines through its management activities.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Lake Conine exhibits significant improving trends in Chl-a and Secchi depth and non-significant improving trends in TN and TP. This equates to water quality trend criteria scores listed in the table below. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing	Not Significant	2
TP	Decreasing	Not Significant	2
Secchi	Increasing (Improving)	Significant	3

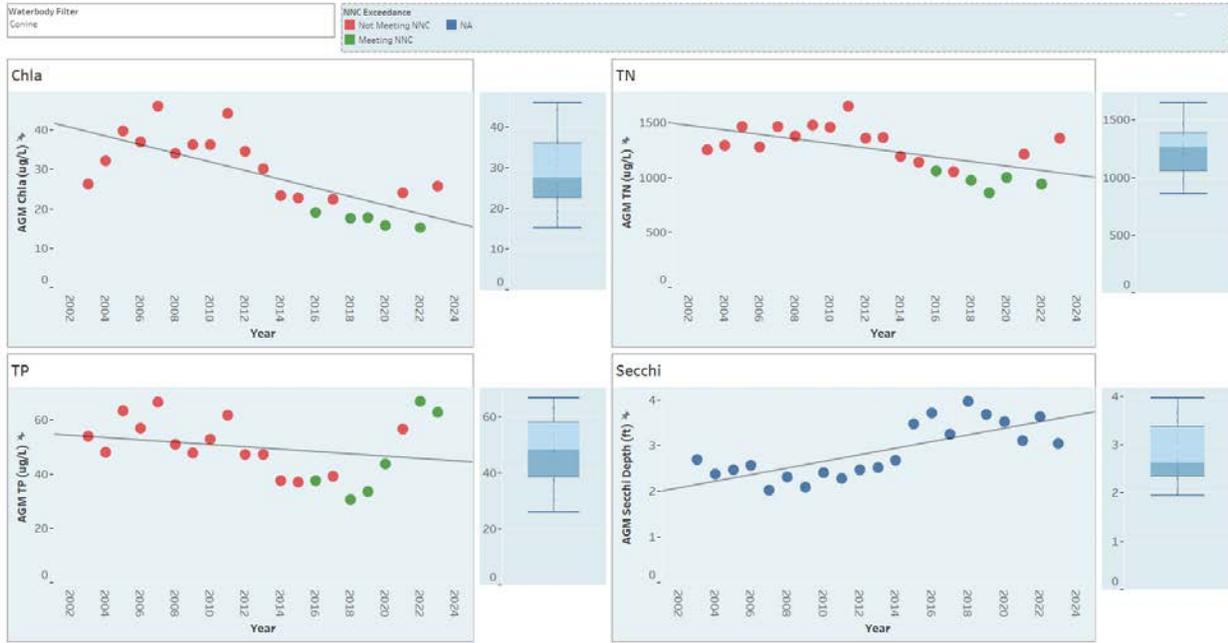


Figure 3-30. Lake Conine AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Conine on 8/11/2023. The PAC during this survey was 23.1% and the total BV was 5.06% (Figure 3-31). Lake Conine saw a dramatic drop in abundance in 2021 has continued to exhibit similar vegetation abundance since. This was likely due to treatment of invasive species like hydrilla. One positive was a nearly doubling of the overall biovolume from 2022 to 2023—indicating that there is growth of aquatic plants without expansion into new areas. The 2023 PAC value earns Lake Conine an abundance criterion score of 2 for this year.

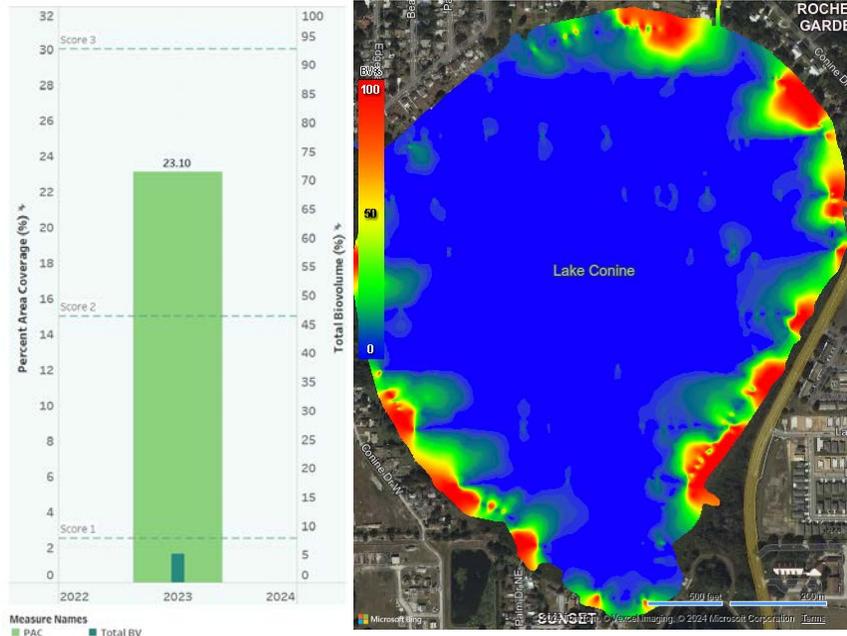


Figure 3-31. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Conine; biovolume values range from green (lowest) to red (highest).

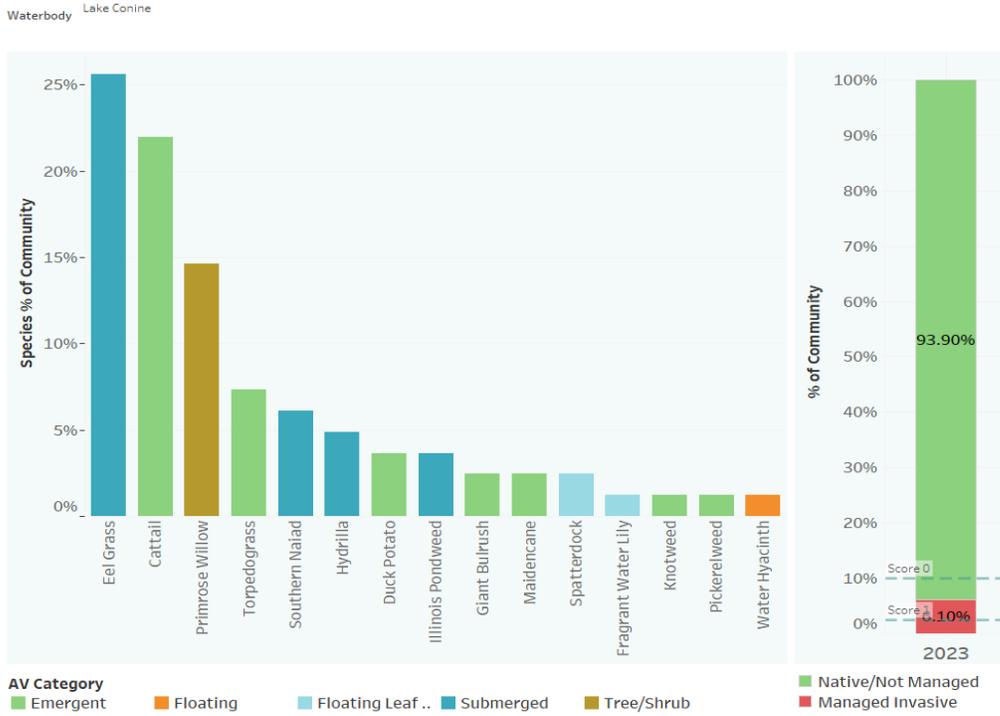


Figure 3-32. Chart depicting species frequency and invasive species percentage of Lake Conine during 2023.

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. During the 2023 survey, there was a relatively even mix of submerged and emergent plant types present. The most abundant species was the native eelgrass at 25% (Figure 3-32). The population percentage for hydrilla and water hyacinth totaled 6.1% which relates to an invasive presence criterion score of 1. Hydrilla has historically been the primary invasive species present in Lake Conine. Fortunately, there has been little change in the overall invasive percentage since 2022

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, all three of Lake Conine’s diversity indices met or exceeded median values (Figure 3-33). Species richness and overall diversity increased from the previous year while evenness declined slightly.

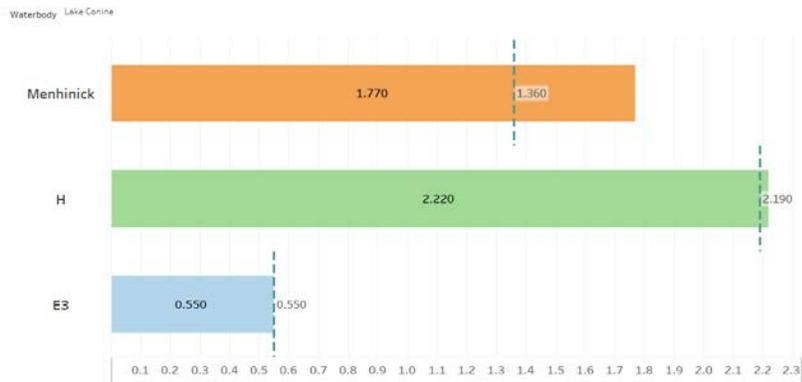


Figure 3-33. Chart depicting 2023 diversity indices for Lake Conine. Dashed line represent median values.

Lake Health Tracking:

A comparison of Lake Conine’s health index scores from 2018 to 2022 shows general fluctuation between scores of 1.6 and 2.1. However, the recent change to impairment status has significantly increased Conine’s score in 2023 (Figure 3-34). The trend criteria scores improved somewhat since 2018 and also indicate that the water quality impairment score should continue to improve in the future. One of the primary areas for improvement will be addressing invasive species presence.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	2	2	3	2	0	2	1.6
2019	0	3	2	3	3	3	0	2	2.0
2020	0	3	2	3	3	3	0	0	1.8
2021	0	3	2	2	3	2	0	3	1.9
2022	0	3	2	2	3	2	1	1	1.8
2023	3	3	3	2	3	2	1	3	2.5

Figure 3-34. Chart depicting a comparison of Lake Buckeye’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- In addition to stormwater influx to Lake Conine, the wastewater treatment plant near this lake was a historic contributor of point-source pollutants. These legacy nutrients in the lake bed are a potential source of nitrogen and phosphorus.
- The management of invasive species like hydrilla and burhead sedge are a constant concern. It can only take a single season for even a small population to take over large areas of a waterbody.
- Several water quality metrics are significantly correlated with Lake Conine’s surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- The City is addressing stormwater pollutant loading through the recent construction of the Lake Conine Nature Park—a constructed wetland designed to treat runoff from the largest southern sub-basins contributing to Lake Conine.
- City staff continue to monitor aquatic vegetation and share the information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- Previous efforts by Polk County have used alum to “cap” historic legacy sediments in Lake Conine. Future efforts may evaluate the longevity of this project and the potential for future nutrient flux from the lake bed.

Lake Daisy

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	3	3	3	3	2	1	3	2.6

Location, Characteristics, & Hydrology:

Lake Daisy is located to the southeast of central Winter Haven, bordering City limits on its eastern shore. It receives excess water from neighboring Lakes Dexter and Ned and likely discharges east toward the Peace Creek during periods of high water. Lake Daisy is a small and shallow waterbody at just 135 acres, an average depth of 8.5 feet, and a maximum depth of 13 feet (Figure 3-35).

Stormwater is conveyed to this waterbody from a 356 acre, suburban drainage basin (Figure 3-36). The five top land uses in this basin, ranked by area, are high-density residential, medium-density residential, institutional, pasture, and upland hardwood. These uses contribute up to 1,717 lbs of TN and 382 lbs of TP to the lake annually. There are 33 Onsite Sewage Treatment and Disposal (OSTD/septic) systems in the basin which constitutes a relatively low density. Lacking any City-owned public roads in the area, Winter Haven does not conduct street sweeping services within this basin.

Over its period of record, Lake Daisy's surface level has fluctuated between 125.75 and 129.9 feet above sea level. The normal range is much narrower; between 127.9 and 128.9 feet (Figure 3-37). During 2023, Lake Daisy reached a wet season peak of 128.7 feet in October and a dry season low of 127.8 feet in August. The surface level ended the year slightly below the median at 128.4 feet. It should be noted that Lake Daisy's surface level reached a high not observed in the last 20 years due to increased rainfall from Hurricane Ian. This excess water quickly dissipated afterwards. Changes in Lake Daisy's surface level are not correlated with Chl-a, TN, TP, or clarity (see appendix).

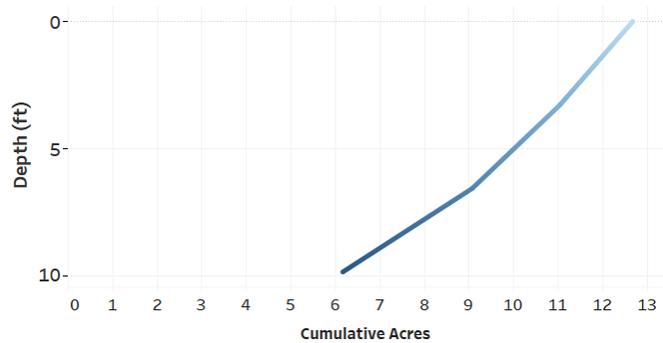


Figure 3-35. Hypsograph of Lake Daisy depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

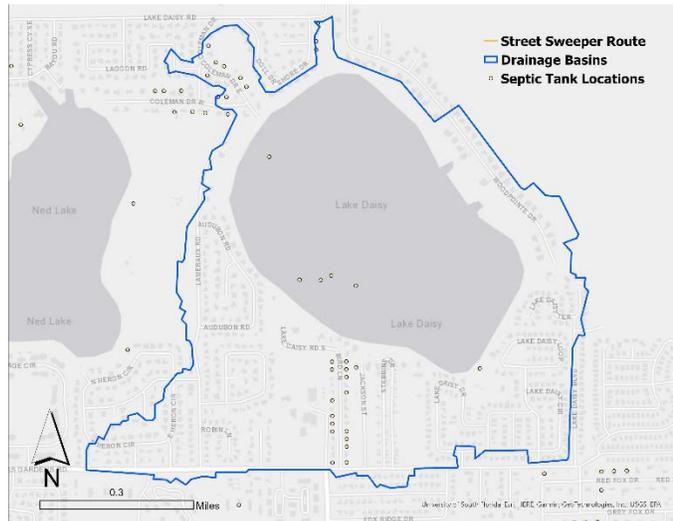


Figure 3-36. Map of Lake Daisy's drainage basin, City street sweeper routes, and nearby septic systems.

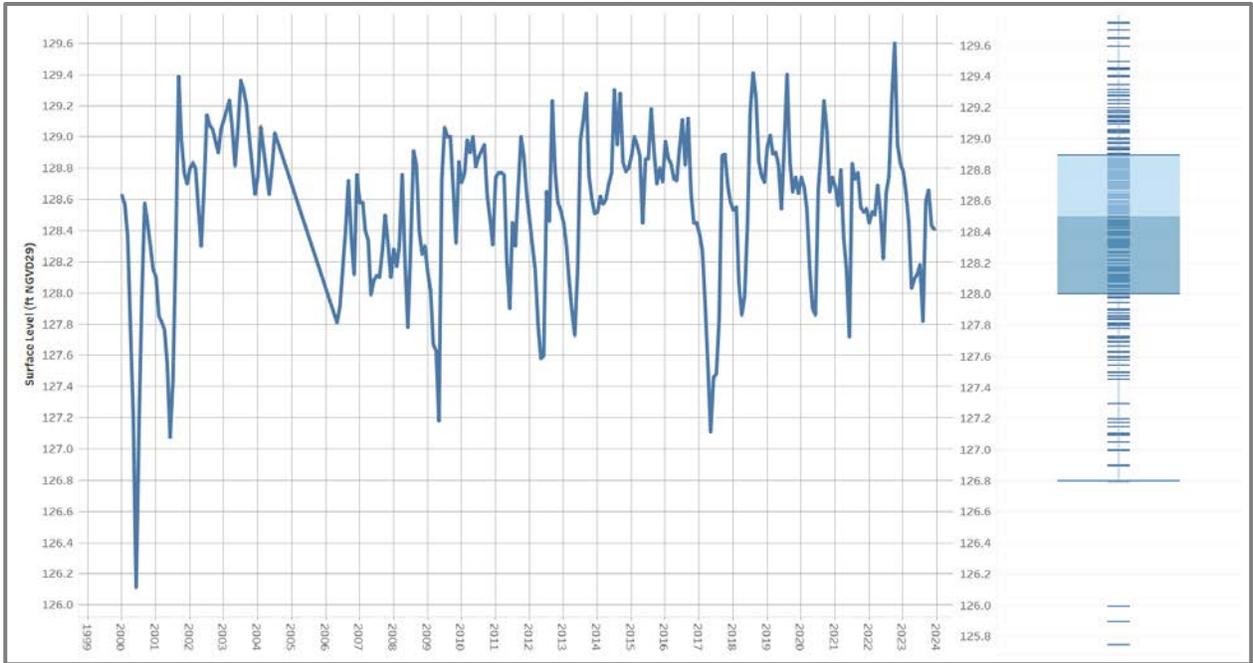


Figure 3-37. Hydrograph of Lake Daisy depicting monthly surface level readings from 2000 to 2023. A box and whisker plot detail total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Daisy is categorized as a clear, softwater waterbody. Lake Daisy has not exhibited exceedances of any of its NNC parameters within the 7.5 year assessment period (Figure 3-38). The most recent exceedance occurred for TP in 2009. As a result, Lake Daisy is not considered impaired—earning an impairment criterion score of 3.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on the trend analysis, all four of the primary water quality parameters exhibit significant improving trends. This equates to trend criteria scores of 3 for each of these parameters. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	2
TP	Decreasing (Improving)	Significant	2
Secchi	Increasing (Improving)	Significant	2

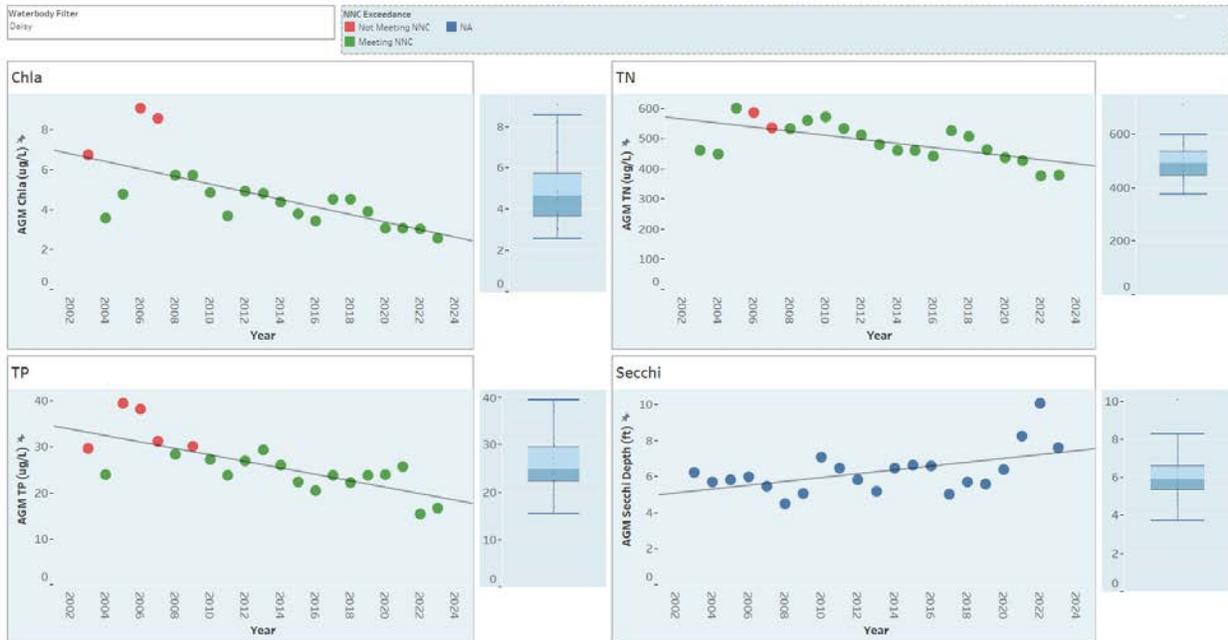


Figure 3-38. Lake Daisy AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Daisy on 9/1/2023. The PAC during this survey was 18.7% and the total BV was 2.4% (Figure 3-39). Lake Daisy has traditionally lacked submerged vegetation. In 2022 there was a significant increase in the presence of native SAV. However, the introduction of hydrilla in late 2022 required immediate treatment which ultimately reduced the overall abundance. Future management goals should involve maintaining the beneficial vegetation while systematically treating the invasives in small batches.

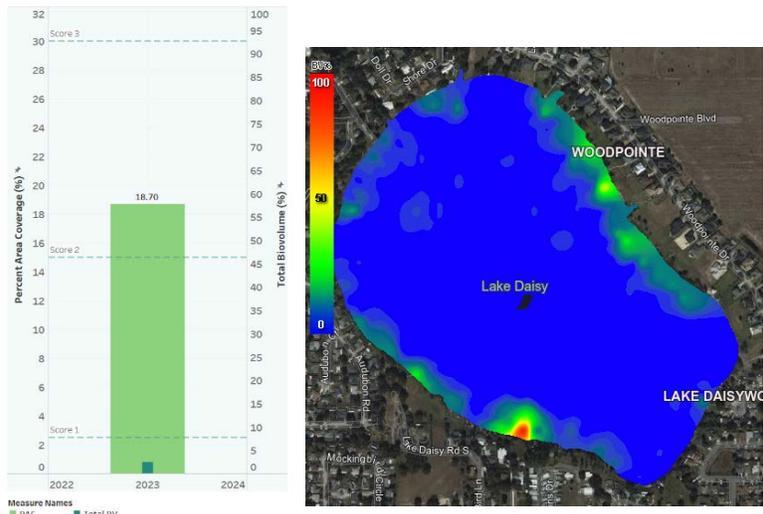


Figure 3-39. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Daisy; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, Lake Daisy remains dominated by emergent species (Figure 3-40). However, there has been a resurgence of submerged species since the invasive treatment. Hydrilla and burhead sedge were the only two invasive species detected in 2023—totalling 5.1% of the population and resulting in an invasives criterion score of 1.

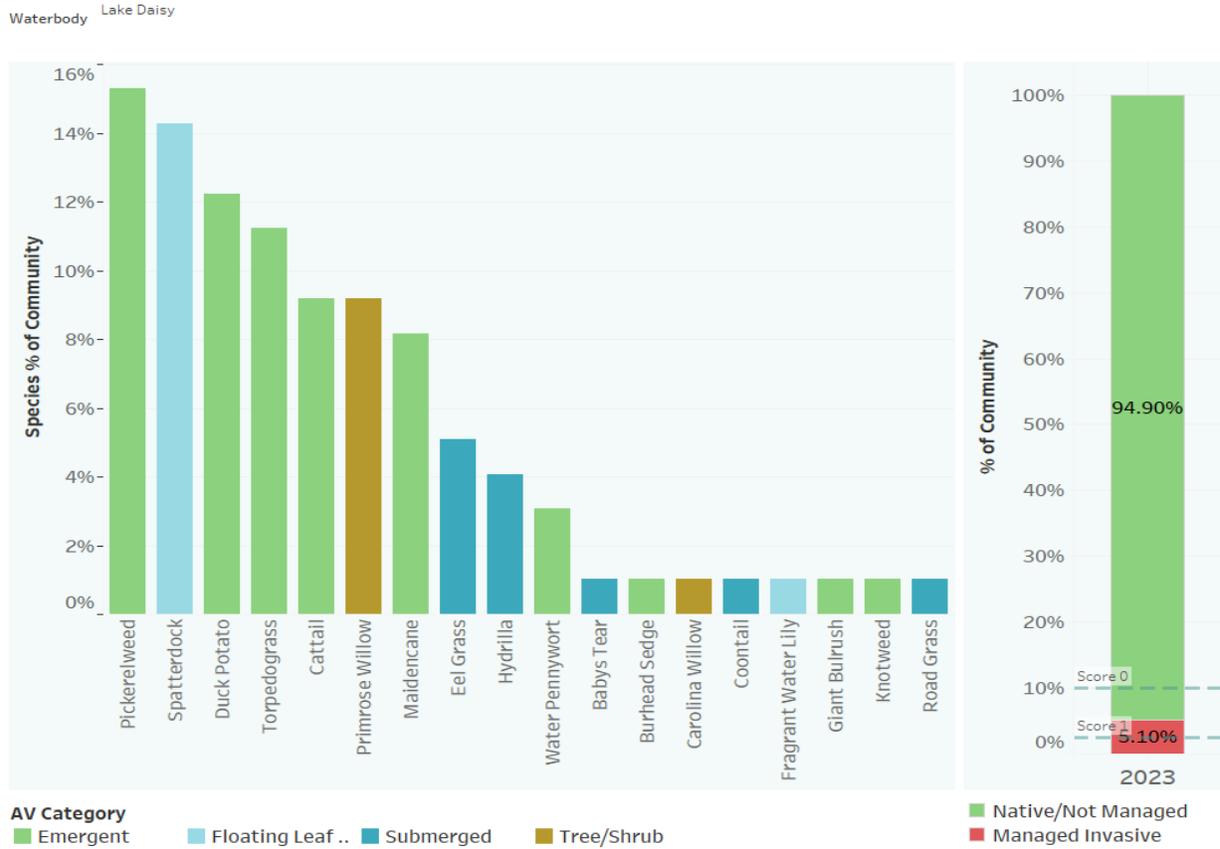


Figure 3-40. Chart depicting species frequency and invasive species percentage of Lake Daisy during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, all three indices met or exceeded their long-term median values (Figure 3-41). Species diversity increased from previous years across the board—coinciding with the discovery of several species not previously detected in Lake Daisy. These increases have resulted in a 2023 diversity criterion score of 3.

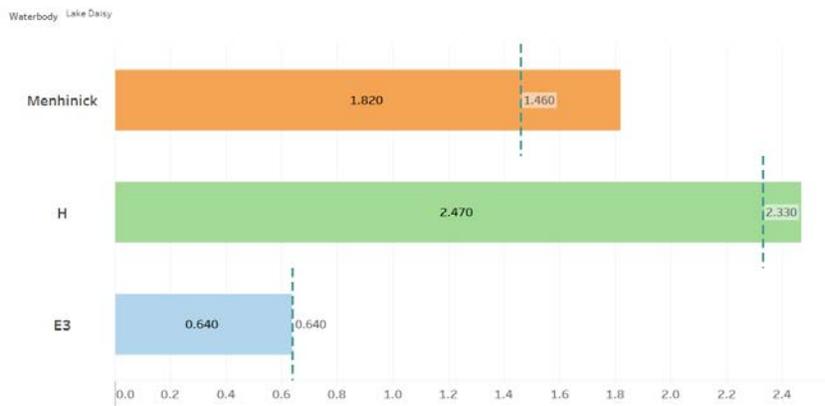


Figure 3-41. Chart depicting 2023 diversity indices for Lake Daisy. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Daisy’s health index scores from 2018 to 2023 shows a substantial increase during the last two years (Figure 3-42). The majority of this increase has come from statistically significant changes in three of the four trend criteria as well as an increase in the vegetation criterion scores. Future management goals should involve maintaining a healthy vegetation community and ensuring that invasive species are under control.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	2	2	2	1	3	1	2.1
2019	3	3	2	2	2	1	3	1	2.1
2020	3	3	2	2	2	1	2	2	2.1
2021	3	3	2	2	2	2	2	2	2.3
2022	3	3	3	3	3	3	2	2	2.8
2023	3	3	3	3	3	2	1	3	2.6

Figure 3-42. Chart depicting a comparison of Lake Daisy’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Daisy currently exhibits acceptable water quality. Lacking stormwater infrastructure, the primary sources of pollutant loading would be from nonpoint sources.
- While the presence of invasive species is currently low, there is potential for these plants to take over large areas of a waterbody in a single season. This requires regular monitoring to keep track of.
- While the OSTD systems within the drainage basin are in low densities, these could be a potential avenue for pollutant loading via groundwater if they begin to fail.

Lake Management Strategy:

- With the majority of the drainage basin comprised of residential housing, future management of stormwater will likely consist of public education and outreach. Education aims to increase residents’ knowledge of best stormwater practices and ways they can collectively reduce their pollutant load.
- If water quality becomes a future issue, City staff may explore source analysis to determine if OSTD leachate is a potential contributor to nutrient pollutant loading. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species remains the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Deer

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	2	2	3	2	3	0	2	2.1

Location, Characteristics, & Hydrology:

Lake Deer is located to the west of central Winter Haven, bordering City limits. It receives no water from other waterbodies, but discharges excess water via a passive control structure and pipe system to Lake Cannon of the South Chain of Lakes. Lake Deer is a smaller waterbody at 119 acres, with an average depth of 7.3 feet, and a maximum depth of 17.5 feet (Figure 3-43).

Stormwater is conveyed to this waterbody from a 377 acre urbanized drainage basin made up of two separate sub-basins (Figure 3-44). Land use within this basin varies, with the top five uses comprised of medium-density residential, high-density residential, institutional, commercial, and industrial. Based on stormwater modelling, these land uses contribute up to 1,451 lbs of TN and 261 lbs of TP annually. There are 41 Onsite Sewage Treatment and Disposal (OSTD/septic) systems located within this basin—a relatively low density. However, factoring in other septic systems in close proximity to the basin reveals a higher density of OSTDs that could impact water quality. The areas of the drainage basin within City limits possess few public roadways. As a result, the City provides no street sweeping services within the basin.

Over its period of record, Lake Deer’s surface level has fluctuated between 136.9 and 141.9 feet above sea level. That said, Deer’s surface level has not exceeded 140.1 feet since before the year 2000 (Figure 3-45). The normal range fluctuates between 136.9 and 139.6 feet. However, since around 2008, Deer’s level has remained at the low end of this range. This is likely the result of an alteration to the lake’s water control structure driving a shift in the overall hydrological regime. In 2023, Deer reached a wet season peak of 138.6 and a dry season low of 137.8. Changes in Lake Deer’s surface level are not correlated with any of the primary water quality metrics (see appendix).

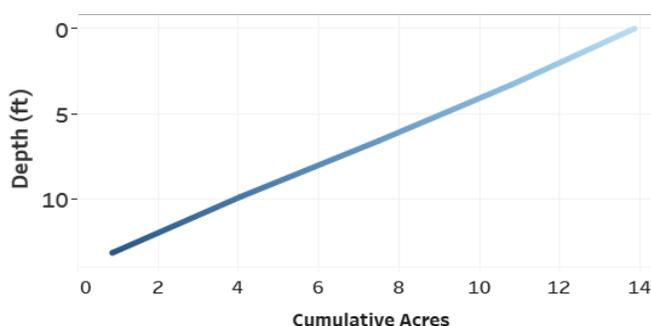


Figure 3-43. Hypsograph of Lake Deer depicting cumulative area at regular depth intervals. Demonstrates the slope and

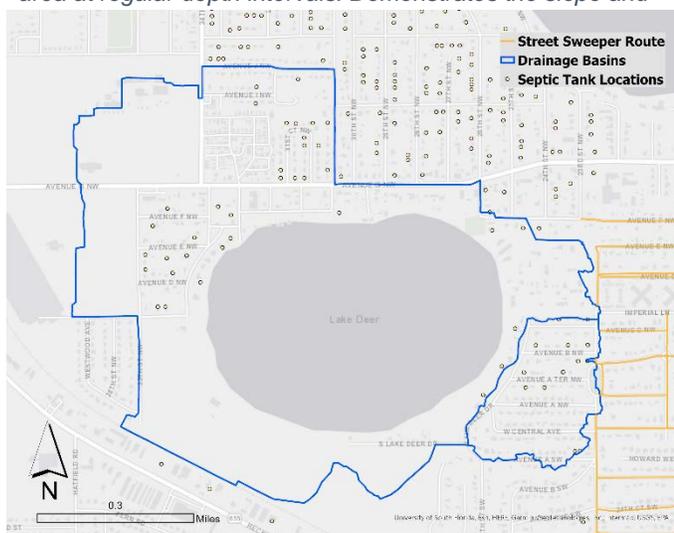


Figure 3-44. Map of Lake Deer’s drainage basin, City street sweeper routes, and nearby septic systems.

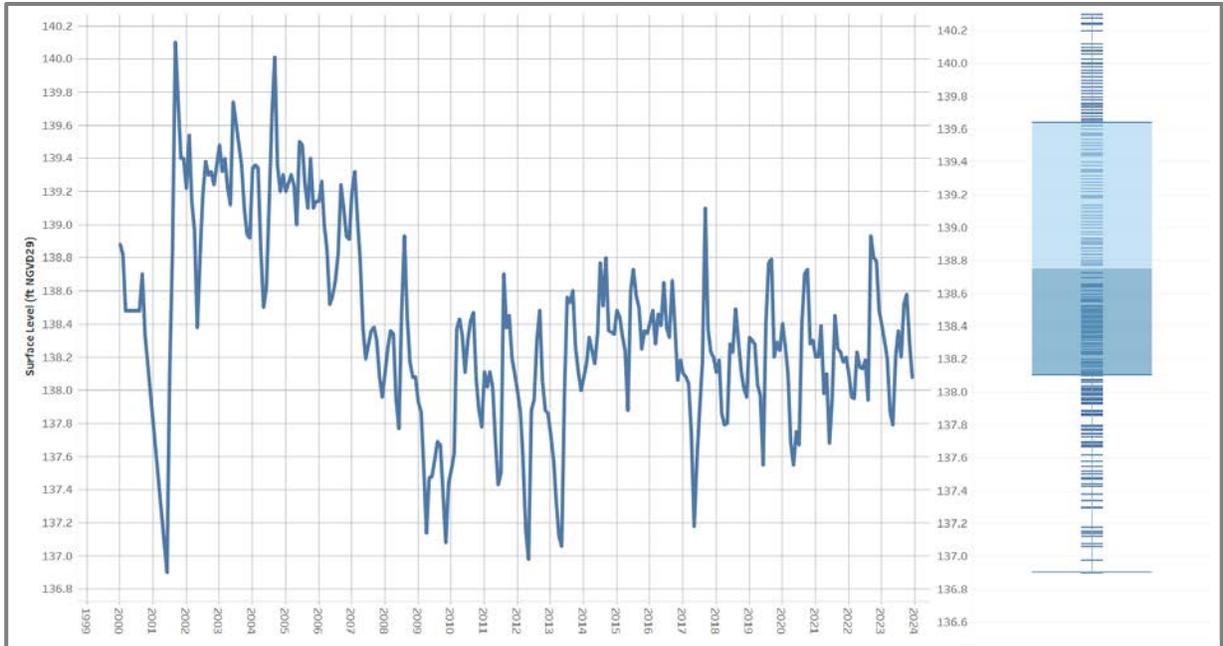


Figure 3-45. Hydrograph of Lake Deer depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface levels during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Deer is categorized as a clear, alkaline waterbody. Lake Deer has not exhibited exceedances of NNC thresholds since 2013 (Figure 3-46). Since there have been no exceedances in the 7.5 year assessment period, Lake Blue is currently considered not impaired—earning an impairment criterion score of 3. Despite this, in 2015, the FDEP established a TMDL for Lake Deer stipulating a 12% reduction in TN in order to meet the NNC guidelines. Lake Deer is currently meeting these guidelines.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Total phosphorus exhibits a significant improving trend; while Chl-a, TN, and Secchi depth exhibit non-significant improving trends. Individual AGM values and trend statistics can be found in the appendix.

Impaired	Parameter	Trend Direction	Significance	Index Score
N	Chla	Decreasing	Not Significant	2
N	TN	Decreasing	Not Significant	2
N	TP	Decreasing (Improving)	Significant	3
NA	Secchi	Increasing	Not Significant	2

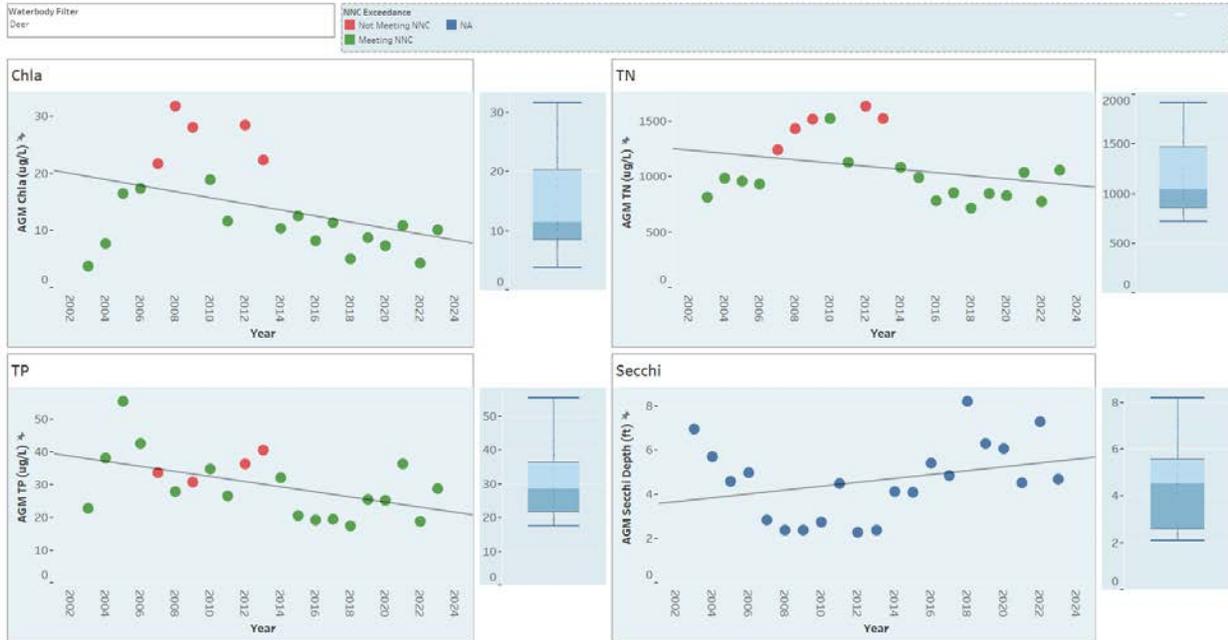


Figure 3-46. Lake Deer AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Deer on 10/31/2023. The PAC during this survey was 86.6% and the total BV was 99% (Figure 3-47). Lake Deer has historically maintained very high abundances of aquatic vegetation due to a high presence of submerged aquatic plants. The water quality improvements observed are likely due, in part, to the nutrient sequestration capacity of this vegetation. That said, while there was a significant increase in abundance from the previous year, the 99% BV value may be due to a processing error.

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, submerged plants make up a large percentage of the total vegetation community at almost 48% (Figure 3-48). The two major species competing for dominance are the native eelgrass and the invasive hydrilla. As of 2023, the total proportion of invasives

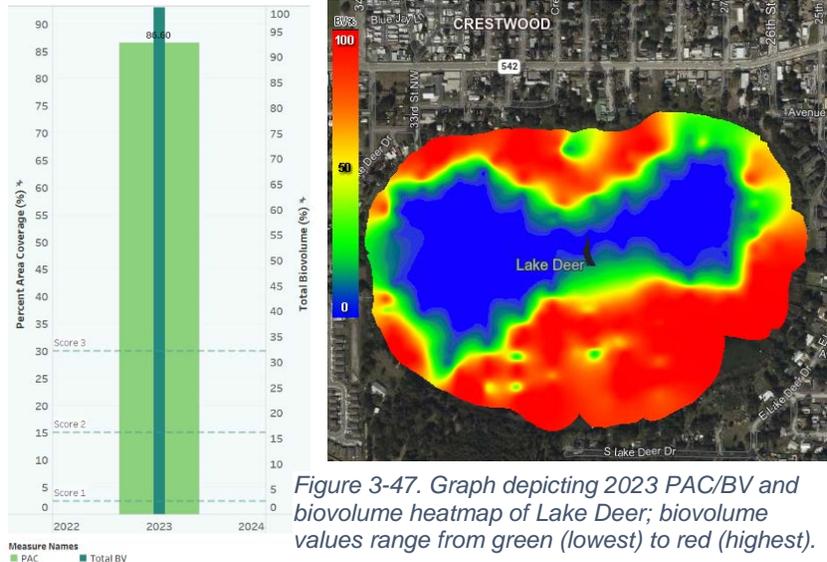


Figure 3-47. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Deer; biovolume values range from green (lowest) to red (highest).

dropped slightly from 19% to 17%. This abundance of invasive species still equates to an invasive criterion score of 0.

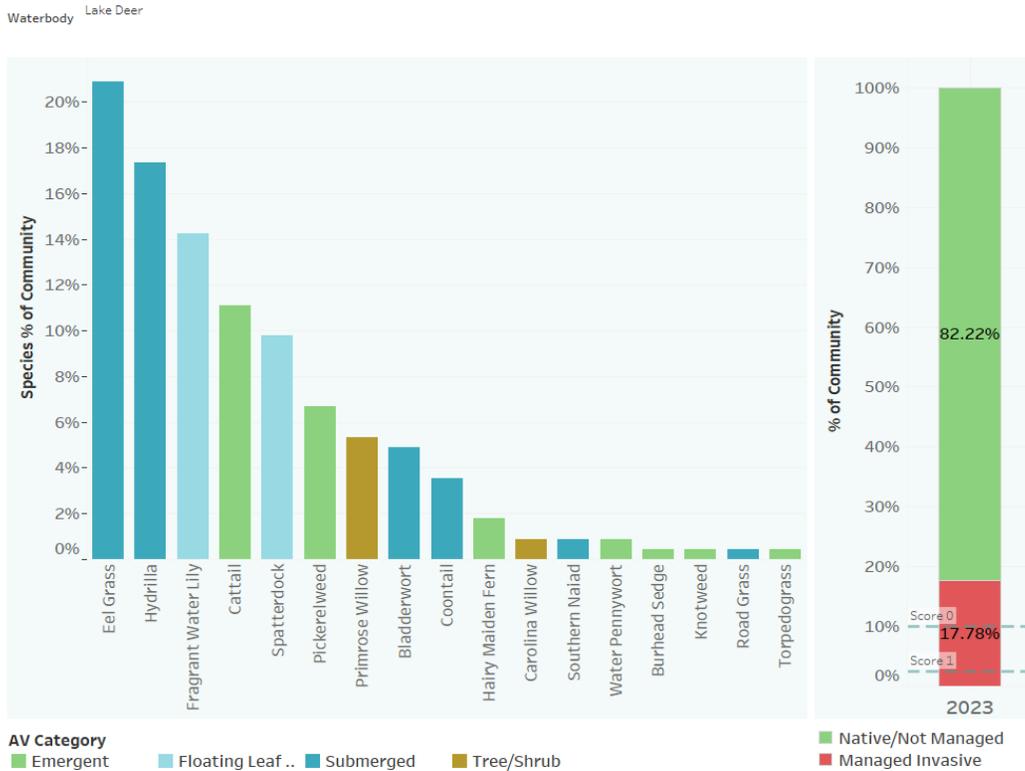


Figure 3-48. Chart depicting species frequency and invasive species percentage of Lake Deer during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, richness and evenness indices met their median values (Figure 3-49). This earns Lake Deer a score of 2 in the diversity criterion. A comparison from the previous years diversity values shows regular variation in all three indices. The evenness and richness values likely change in response to the treatment and subsequent resurgence of invasive species. Plants with lesser presence can fill niches left by invasives and be wiped out in short periods—leading to these fluctuations in diversity.

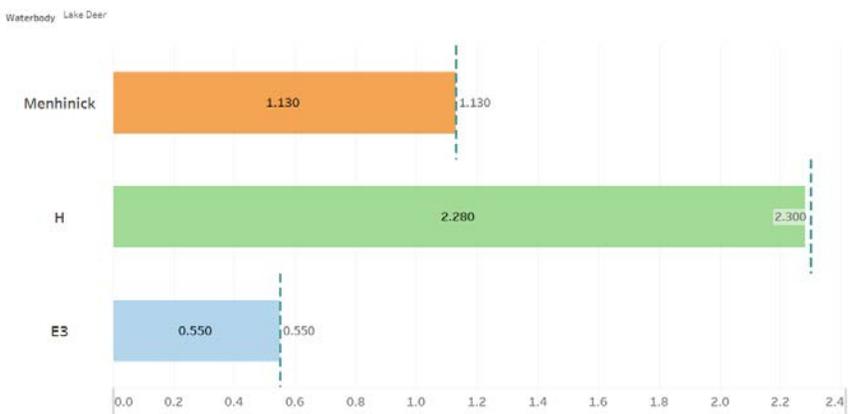


Figure 3-49. Chart depicting 2023 diversity indices for Lake Deer. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Deer’s health index scores from 2018 to 2023 shows a substantial increase since 2021. Most of this improvement has been due to meeting impairment thresholds along with generally stable long-term water quality trends (Figure 3-50). Vegetation abundance remains high, but the main issue plaguing Lake Deer now is management of invasive species.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	2	2	2	3	1	2	1.8
2019	0	2	2	2	2	3	0	2	1.6
2020	0	2	2	2	2	3	0	2	1.6
2021	0	2	3	2	2	3	0	0	1.5
2022	3	2	3	2	3	3	0	1	2.1
2023	3	2	2	3	2	3	0	2	2.1

Figure 3-50. Chart depicting a comparison of Lake Deer’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- While Lake Deer’s water quality is improving, managing the stormwater pollutant loads from its drainage basin is still a priority.
- The presence of OSTDs (septic) systems in the drainage basin may be a potential source of pollutants. As these systems age, they may begin to leach nutrients into the water table—leading to water quality issues.
- The management of invasive species is especially important for Lake Deer. Hydrilla has been a constant issue since monitoring began since it can quickly undo management efforts in a single season.

Lake Management Strategy:

- While the City has little stormwater infrastructure contributing to Lake Deer, efforts can still be made to improve these pollutant loads through implementation of green infrastructure where possible.
- City staff may explore source analysis of septic systems in the vicinity of Lake Deer to determine if they are contributing pollutant loads via groundwater. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Elbert

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	0	0	1	0	2	2	3	1.4

Location, Characteristics, & Hydrology:

Lake Elbert is located to the east of central Winter Haven. At the top of the watershed, Elbert is capable of discharging excess water downstream to Lake Otis via an emergency pump station and pipe system. Based on its physical characteristics, Lake Elbert is a moderately sized and deep waterbody at 177 acres, an average depth of 14 feet, and a maximum depth of almost 26 feet (Figure 3-51).

Stormwater is conveyed to this waterbody from a 439 acre urbanized drainage basin made up of 50 individual sub-basins (Figure 3-52). By far the largest proportion of land use in this basin is comprised of medium-density residential, followed by institutional, commercial, and open land. Based on stormwater modelling, these land uses contribute up to 2,365 lbs of TN and 385 lbs of TP to the lake annually. There are very few known Onsite Sewage Treatment and Disposal (OSTD/septic) systems within the vicinity of Lake Elbert. Completely within City limits, Winter Haven conducts monthly street sweeping services of up to 33.5 miles within this basin.

Over its period of record, Lake Elbert’s surface level has fluctuated between 128.8 and 137.6 feet above sea level (Figure 3-53). As stated, the water level pump station is only activated during extremely high levels—such as after Hurricane Ian in 2022. As a result, Lake Elbert’s level is able to fluctuate more or less naturally. The normal level range is much narrower—between 131.9 and 134.7 feet. During 2023, Elbert mostly lost water with a January peak of 135.4 ft and May low of 134.1 ft. The end-of-year level was 134.15—slightly below the median. Based on 2019 regression analyses, changes in Lake Elbert’s level are significantly correlated with Chl-a, TN, TP, and clarity such that an increase in surface level should result in water quality improvements.

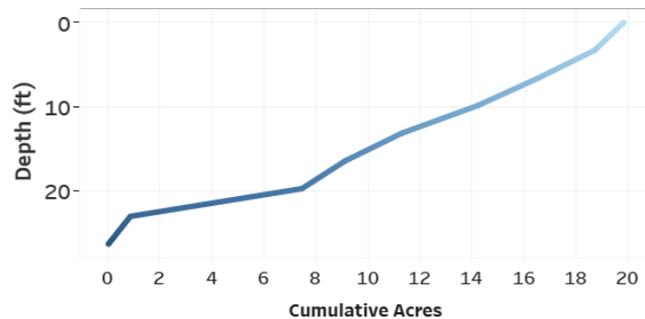


Figure 3-51. Hypsograph of Lake Elbert depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.



Figure 3-52. Map of Lake Elbert’s drainage basin, City street sweeper routes, and nearby septic systems.

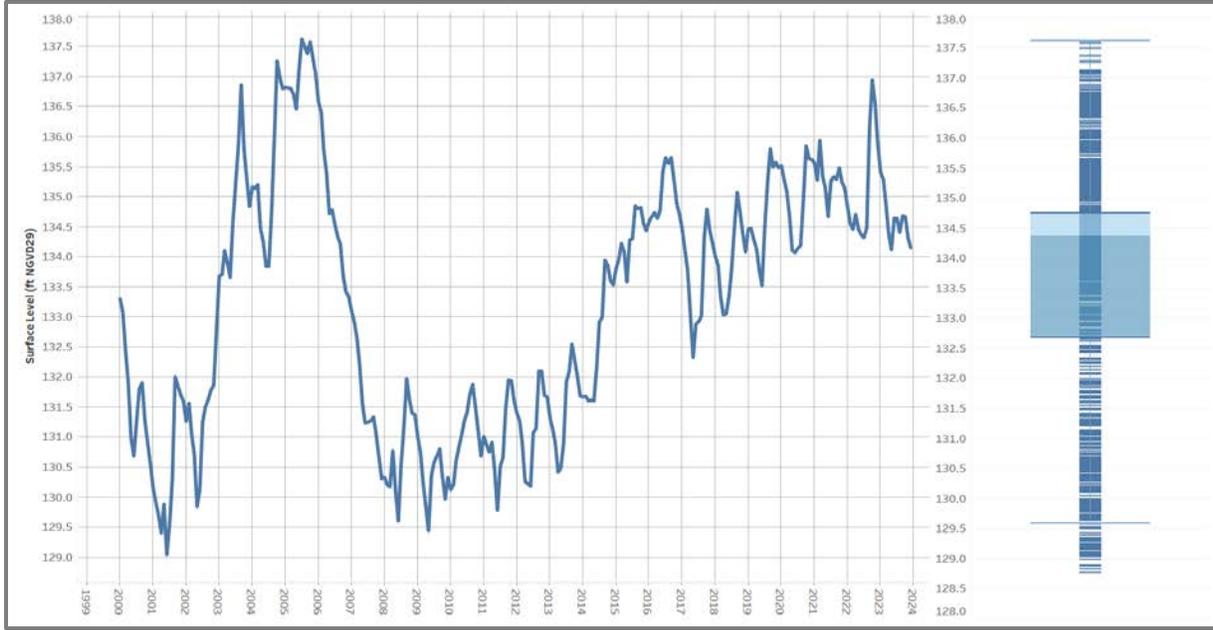


Figure 3-53. Hydrograph of Lake Elbert depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Elbert is categorized as a clear, alkaline waterbody. Since 2000, Lake Elbert has not exhibited any exceedances of NNC thresholds (Figure 3-54). By virtue of this, Lake Elbert is not considered impaired by any metric—earning an impairment criterion score of 3.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Chl-a, TN, and Secchi depth exhibit significant declining trends—earning scores of 0 for their respective trend criteria. That said, there was a recent shift where the increasing TP trend is no longer statistically significant. In fact, the R² and p-values for each of these trends are lessening—indicating some slight turnaround in the downward trajectory. Individual AGM values and trend statistics can be found in the appendix.

Impaired	Parameter	Trend Direction	Significance	Index Score
N	Chla	Increasing (Deteriorating)	Significant	0
N	TN	Increasing (Deteriorating)	Significant	0
N	TP	Increasing	Not Significant	1
NA	Secchi	Decreasing (Deteriorating)	Significant	0

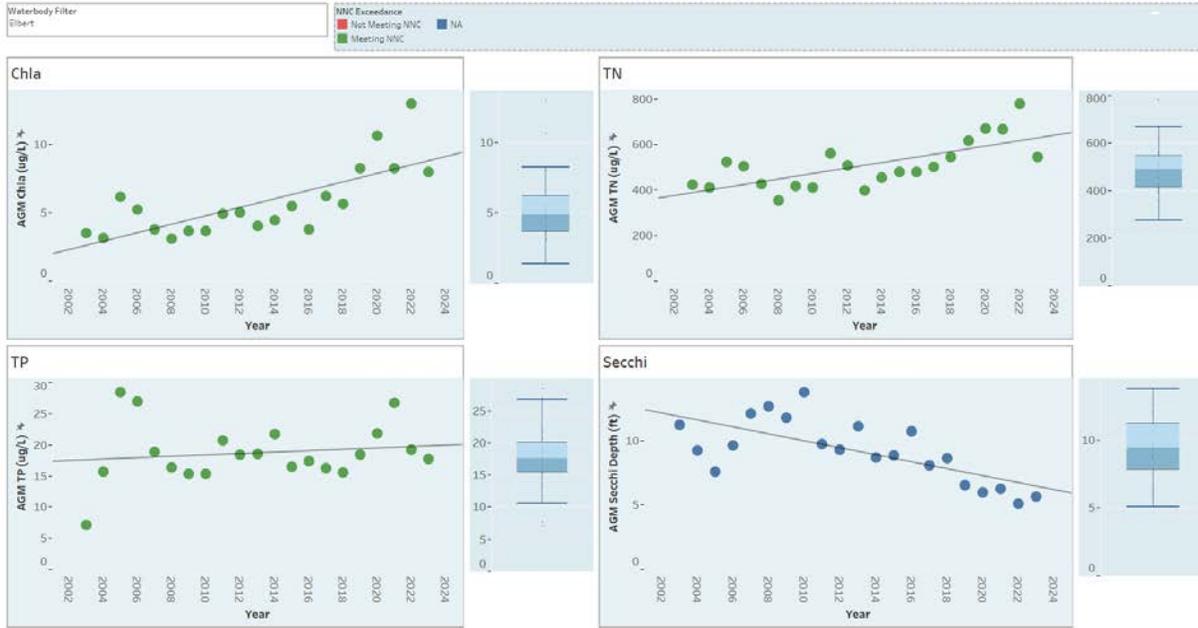


Figure 3-54. Lake Elbert AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Elbert on 7/28/2023. The PAC during this survey was 23.3% and the total BV was 1.3% (Figure 3-55). A comparison of abundance from previous years shows a significant decline in overall abundance in 2023. This is likely due to the continued management of hydrilla, but it may also be an indication of the water clarity decline having an impact on the vegetation community. As a result, Elbert receives an abundance criterion score of 2.

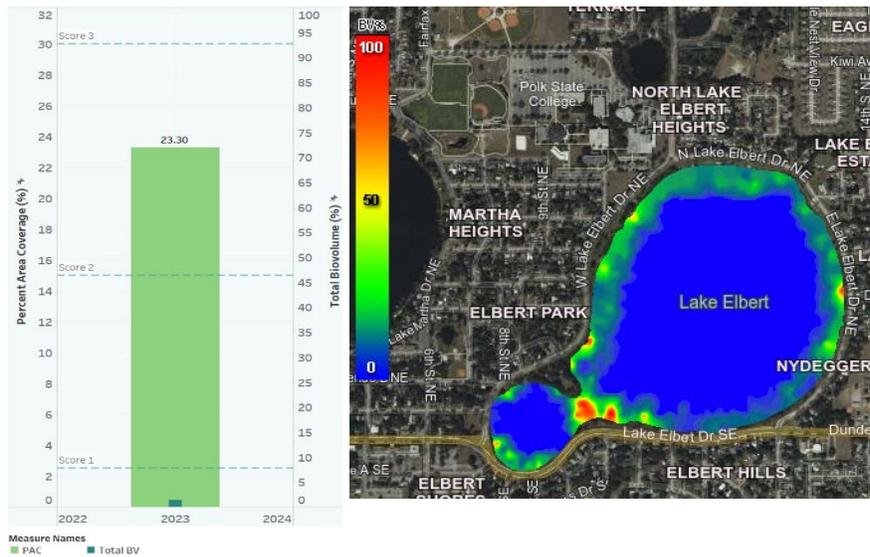


Figure 3-55. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Elbert; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on 2023 data, native submerged plants made up the majority of the vegetation community. Lake Elbert has historically had issues managing invasives and the dominance often shifts between hydrilla and eelgrass on an annual basis. That said, invasive

management efforts effectively reduced hydrilla populations such that the total invasive percentage is 1.75%. This equates to an invasive criterion score of 2.

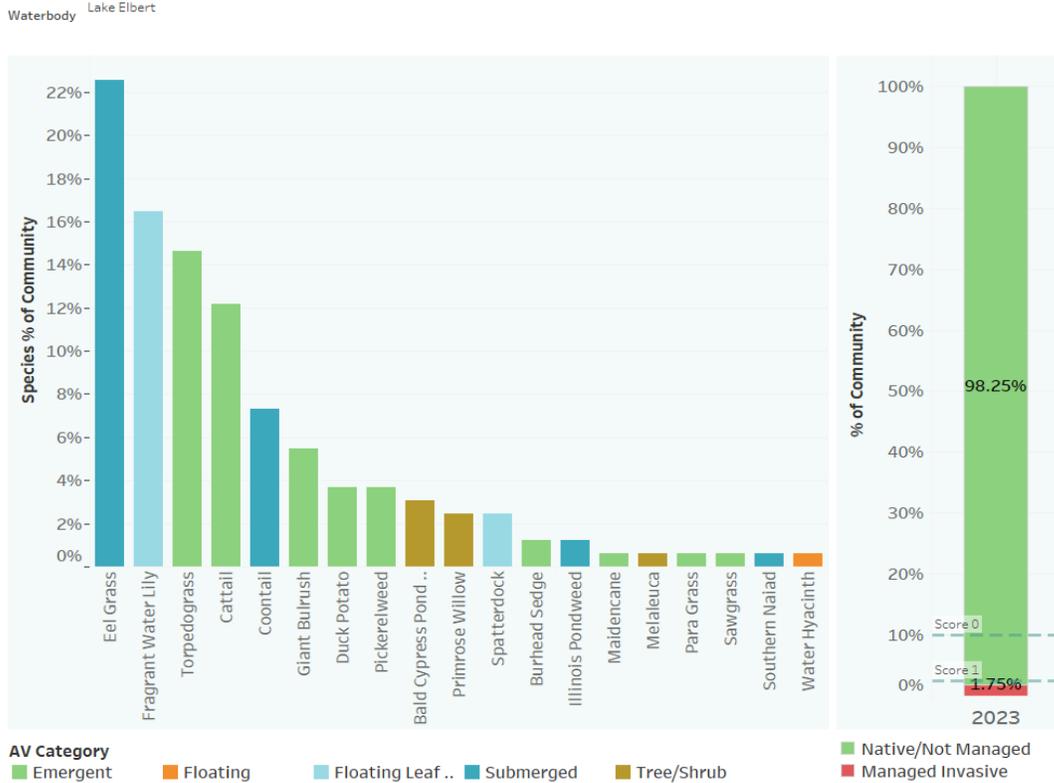


Figure 3-56. Chart depicting species frequency and invasive species percentage of Lake Elbert during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, all three indices exceeded their median values—resulting in a diversity criterion score of 3 (Figure 3-57). Despite the hit to vegetation abundance, the overall vegetation diversity for Elbert has seen a general improvement due to the invasive treatment. Future management should seek to maintain low quantities of hydrilla to keep the ecological community in a good place.

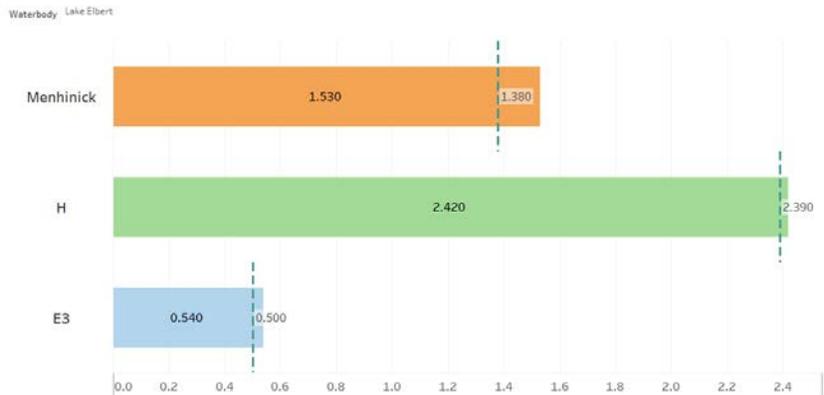


Figure 3-57. Chart depicting 2023 diversity indices for Lake Elbert. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Elbert’s health index scores from 2018 to 2023 shows consistently low values, below 1.5 (Figure 3-58). The trend scores have been the primary contributor to the low lake health scores. However, the abundance of invasive species has been a consistent issue as well. The lake health score of 2023 marks the best Lake Elbert has been on record—mostly due to the improvements in the biological criteria.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	0	1	1	1	3	1	0	1.3
2019	3	0	0	1	1	3	0	2	1.3
2020	3	0	0	1	0	3	0	1	1.0
2021	3	0	0	0	0	3	0	3	1.1
2022	3	0	0	0	0	3	0	2	1.0
2023	3	0	0	1	0	2	2	3	1.4

Figure 3-58. Chart depicting a comparison of Lake Elbert’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- The prevalence of older residential neighborhoods within Lake Elbert’s drainage basin means that stormwater pollutant loading goes largely unmitigated. Managing this stormwater is a high priority.
- The management of invasive species like hydrilla is a constant concern. Recent efforts to reduce invasive presence have only been able to slow the spread. Large-scale herbicide applications are not advised due to the fragility of Lake Elbert’s water quality.
- Lake Elbert’s water quality metrics are significantly correlated with its surface level. This means that drought conditions could result in further declines in water quality.

Lake Management Strategy:

- In addition to conducting street sweeping (annual removal of 378 lbs of TN and 205 lbs of TP), the City has plans to address stormwater pollutant loading through construction of green infrastructure (swales and ponds) as part of a planned trail improvement project. These structural management practices are estimated to remove an additional 125 lbs of TN and 19 lbs of TP annually.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Additionally, staff will advocate for alternative invasive management strategies to limit large-scale herbicide use to reduce further water quality declines.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- With the majority of land use in the drainage basin being residential, public education should be prioritized to increase residents’ knowledge of best stormwater practices and ways they can collectively reduce their pollutant load.

Lake Eloise

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
0	3	2	3	3	2	2	1	2.0

Location, Characteristics, & Hydrology:

Lake Eloise is located to the southeast of central Winter Haven. Connected to Lakes Winterset and Lulu via navigable canals, it is grouped into the South Chain of Lakes. Excess water discharges from the South Chain via a passive overflow structure at the south shore of Lake Lulu. Lake Eloise is one the largest lakes in the area at 1,185 acres, an average depth of about 13 feet, and deeper holes upwards of 20 feet in depth (Figure 3-59).

Stormwater is conveyed to this waterbody from a 1981 acre drainage basin—of which the lake makes up the majority (Figure 3-60). The terrestrial areas of the basin are comprised of medium-density residential, recreational, low-density residential, high-density residential and agricultural; ranked from highest to lowest. These land uses contribute up to 3,875 lbs of TN and 665 lbs of TP to the lake annually. There are 186 Onsite Sewage Treatment and Disposal (OSTD/septic) systems within this basin—mostly congregated in the north and south areas of the basin. There exist few City-owned roadways with stormwater infrastructure that drain to the lake. As a result, the City does not conduct street sweeping services in this basin.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain’s surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the

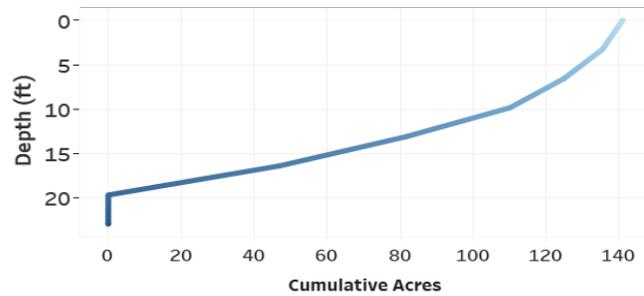


Figure 3-59. Hypsograph of Lake Eloise depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

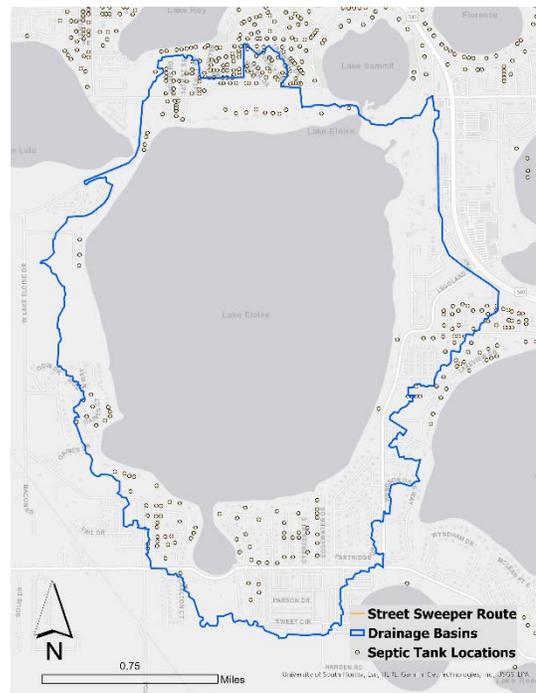


Figure 3-60. Map of Lake Eloise’s drainage basin and nearby septic systems.

year. According to linear regression analysis, changes in Lake Eloise’s surface level do not correlate with water quality.

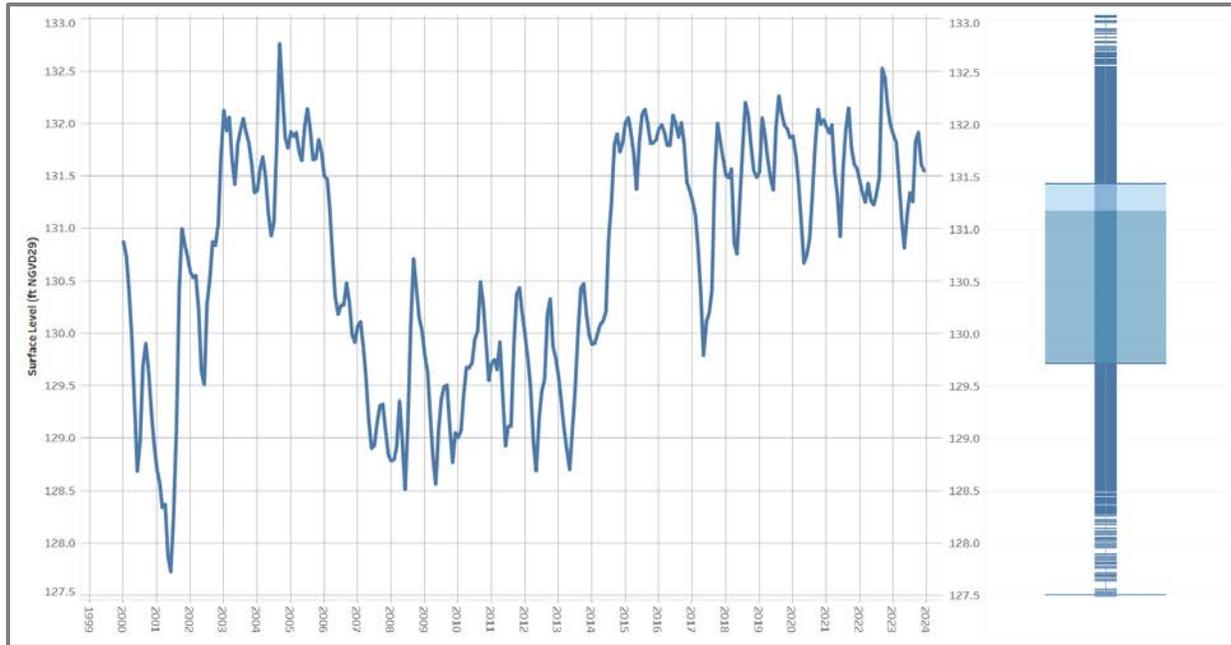


Figure 3-61. Hydrograph of the South Chain of Lakes depicting monthly surface level readings from 2000 to 2023. A box & whisker plot details the total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Eloise is categorized as a clear, alkaline waterbody. Based on NNC exceedances most years during the assessment period, Lake Eloise is considered impaired for Chl-a, TN, and TP—earning it an impairment criterion score of 0 (Figure 3-62). In 2019, the FDEP established a total maximum daily load (TMDL) for Lake Eloise stipulating a 39% reduction in TN in order to meet NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on the trend data, Chl-a, TP, and Secchi depth exhibit significant improving trends. Total nitrogen continues to exhibit a non-significant improving trend. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing	Not Significant	2
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3

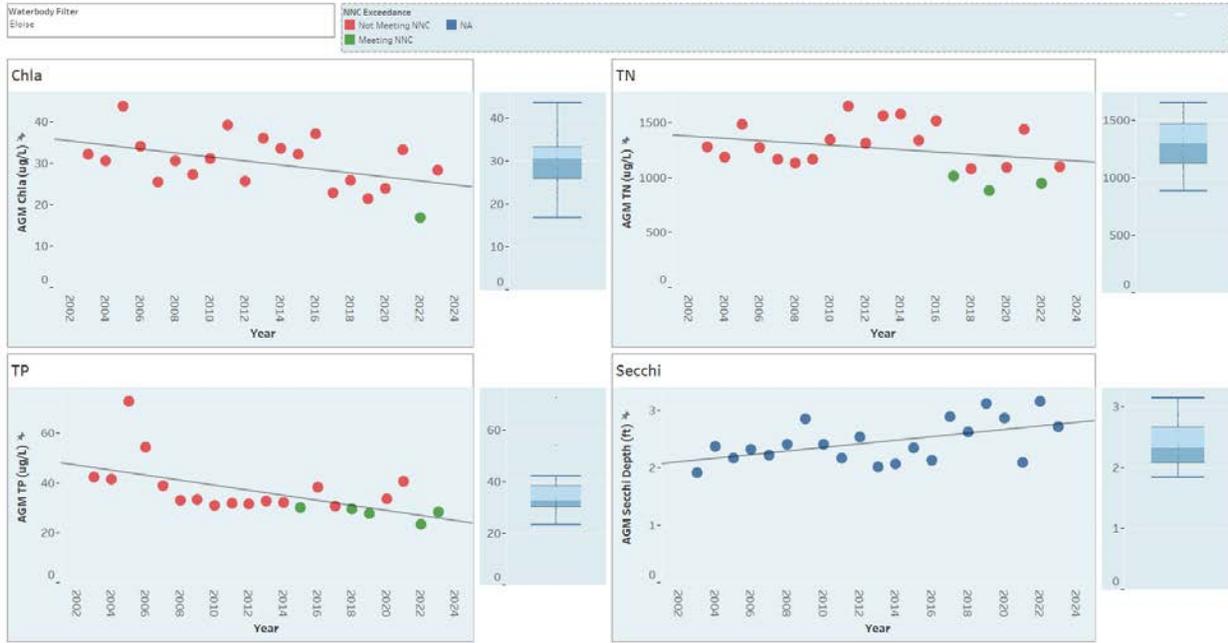


Figure 3-63. Lake Eloise AGM Chl-a, TN, TP, and Secchi depth values from 2002 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative abundance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Eloise on 12/21/2023. The PAC during this survey was 17% and the total BV was 2.7% (Figure 3-63). A comparison of abundance metrics from previous years shows a surge in coverage to 36% in 2020 and then a gradual decline to current levels. That said 2023 abundance is still within the normal range for Lake Eloise.

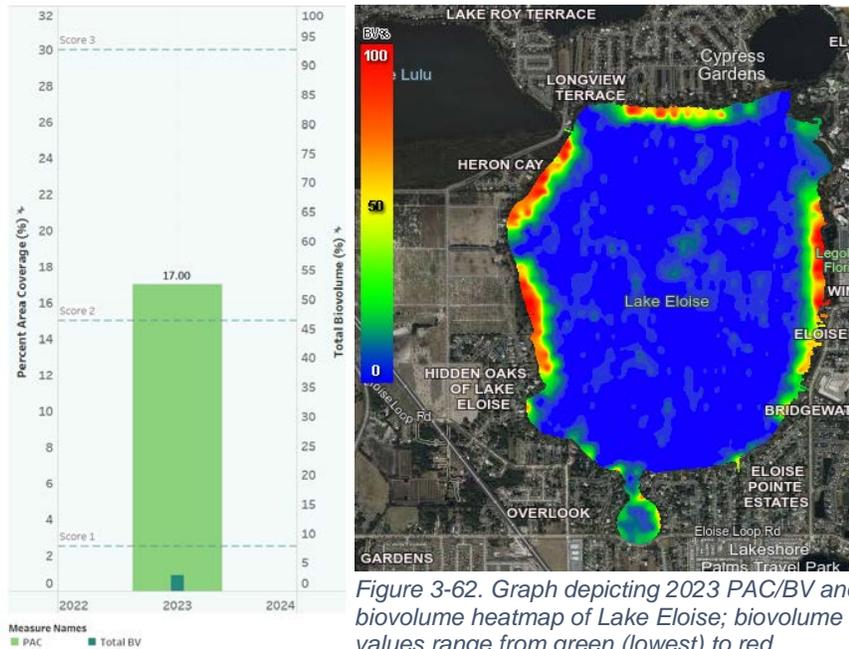


Figure 3-62. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Eloise; biovolume values range from green (lowest) to red

Invasive Species Management:

Species composition is collected as part of the annual vegetation survey using point-intercept sampling methods. Based on 2023 species data, the native eelgrass was the most dominant species at 19% of the community (Figure 3-64). The remaining plants were comprised of a good mix of submerged and emerged species. The only managed invasive species was hydrilla at less than 1%--earning Lake Eloise an invasive presence score of 2. Hydrilla has historically been a very minor issue and is considered controlled in Lake Eloise.

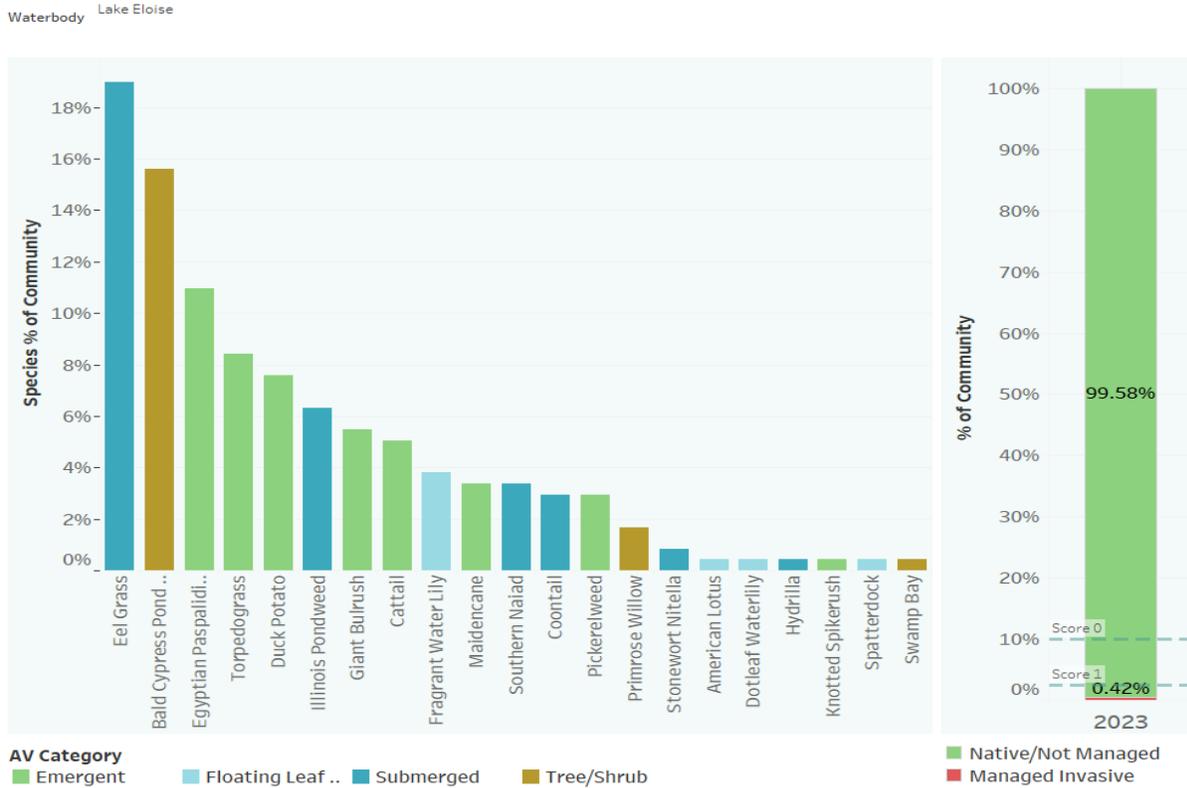


Figure 3-64. Chart depicting species frequency and invasive species percentage of Lake Eloise during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, richness was the only index that met or exceeded its median value—earning Lake Eloise a diversity criterion score of 1. That said, the evenness and overall diversity index values increased from 2022. Eelgrass remains the most dominant species which explains the slightly lower evenness and overall diversity scores. It should be noted that Lake Eloise’s species diversity is not greatly impacted by active management efforts due to a lack of invasive species presence. The vegetation community in this lake largely self-regulates.

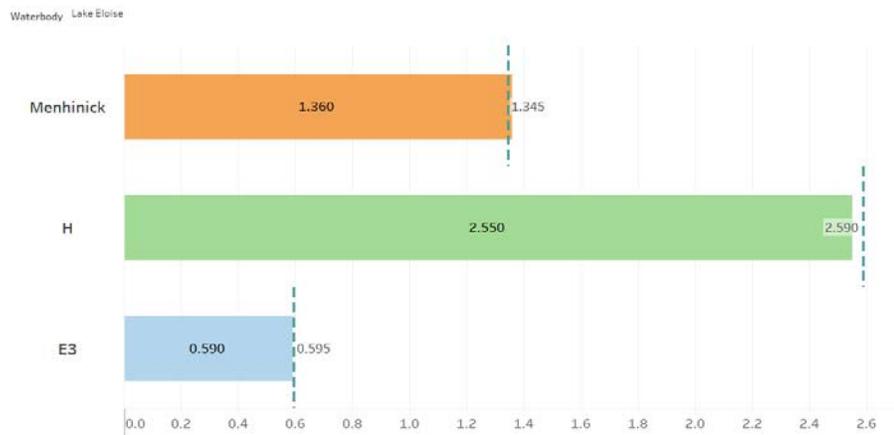


Figure 3-65. Chart depicting 2023 diversity indices for Lake Eloise. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Eloise’s health index scores from 2018 to 2023 shows relative consistency. Since the City began documenting lake health, the only changes to Lake Eloise’s scores have come from the biological criteria. As stated previously, invasive species have not been a large component of the vegetation community and the vegetation community typically fluctuates naturally with minor management input. While the lake has remained impaired, the trends are showing gradual improvement in all water quality metrics.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	2	2	3	1	2	2	1.8
2019	0	2	2	2	3	2	2	2	1.9
2020	0	2	2	2	3	3	2	1	1.9
2021	0	2	2	2	3	2	2	2	1.9
2022	0	2	2	2	3	2	2	1	1.8
2023	0	3	2	3	3	2	2	1	2.0

Figure 3-66. Chart depicting a comparison of Lake Eloise’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- In addition to the stormwater pollutant loads, Lake Eloise has had historic point source loading from the Cypress Gardens Wastewater Treatment Plant as late as 1975. There is potential for these legacy nutrients to be embedded in the lake sediments.
- While invasive species like hydrilla are generally in check, it can only take a single season for even a small population to take over large areas of a waterbody.
- The presence of OSTDs (septic) systems in the drainage basin could have potential impacts if they are leaching into the water table.

Lake Management Strategy:

- With the majority of the drainage basin comprised of residential housing, public education and outreach is a viable strategy for mitigating stormwater pollutant loading. Staff have worked with individual communities and homeowner’s associations within the basin to suggest the use of green infrastructure in their private stormwater systems.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- The City may explore source analysis to determine if septic systems in the drainage basin may be contributing nutrient loads to Lake Eloise. Further management may involve septic-to-sewer conversions.

Lake Fannie

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	3	2	2	3	2	0	3	2.3

Location, Characteristics, & Hydrology:

Lake Fannie is located to the northeast of central Winter Haven. It receives excess water from Lake Smart to the west and discharges its excess water east to Lake Hamilton through a SWFWMD-managed water control structure. While it shares no navigable connections to these other lakes, it is considered part of the North Chain of Lakes. Lake Fannie is a large, but shallow waterbody at 794 acres, with an average depth of 7.6 feet, and a maximum depth of only 10.75 feet (Figure 3-67).

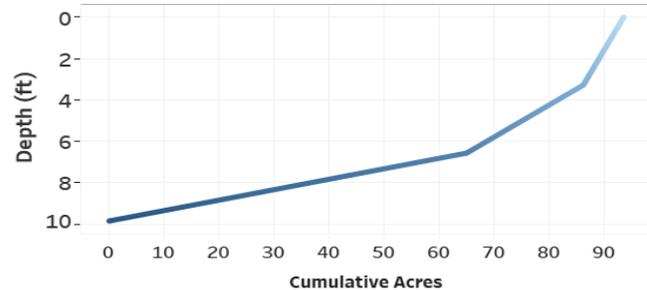


Figure 3-67. Hypsograph of Lake Fannie depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 2,208 acre, mostly rural drainage basin (Figure 3-68). Aside from the lake itself, the primary land uses within this basin are wetlands, agricultural, industrial, and recreational (golf courses). These land uses contribute 4,133 lbs of TN and 717 lbs of TP to the lake annually. There are 33 Onsite Sewage Treatment and Disposal (OSTD/septic) systems within this drainage basin. However, due to their low density, this isn't a major concern from a pollutant loading standpoint. Lacking much stormwater infrastructure in the area, the City sweeps a small section in the southern portion of the watershed.



Figure 3-68. Map of Lake Fannie's drainage basin, City street sweeping services, and nearby septic systems.

Over its period of record, Lake Fannie's surface level has fluctuated between 119.8 and 128 feet above sea level. The normal range is between 121.4 and 125.1 feet (Figure 3-69). During 2023, Lake Fannie reached a wet season peak of 125.4 feet in October and a dry season low of 124.1 feet during May. At the end of 2023, the surface level was 125.3 feet; slightly above the normal high. With District managed control structures on its upstream and downstream flow pathways, Lake Fannie's level is managed quite closely. Often levels are maintained at or near recommended highs until water must be released ahead of

intense storms. According to 2019 regression analyses, changes in Lake Fannie’s surface level significantly correlate with Chl-a, TN, TP, and clarity such that higher levels should result in improved water quality.

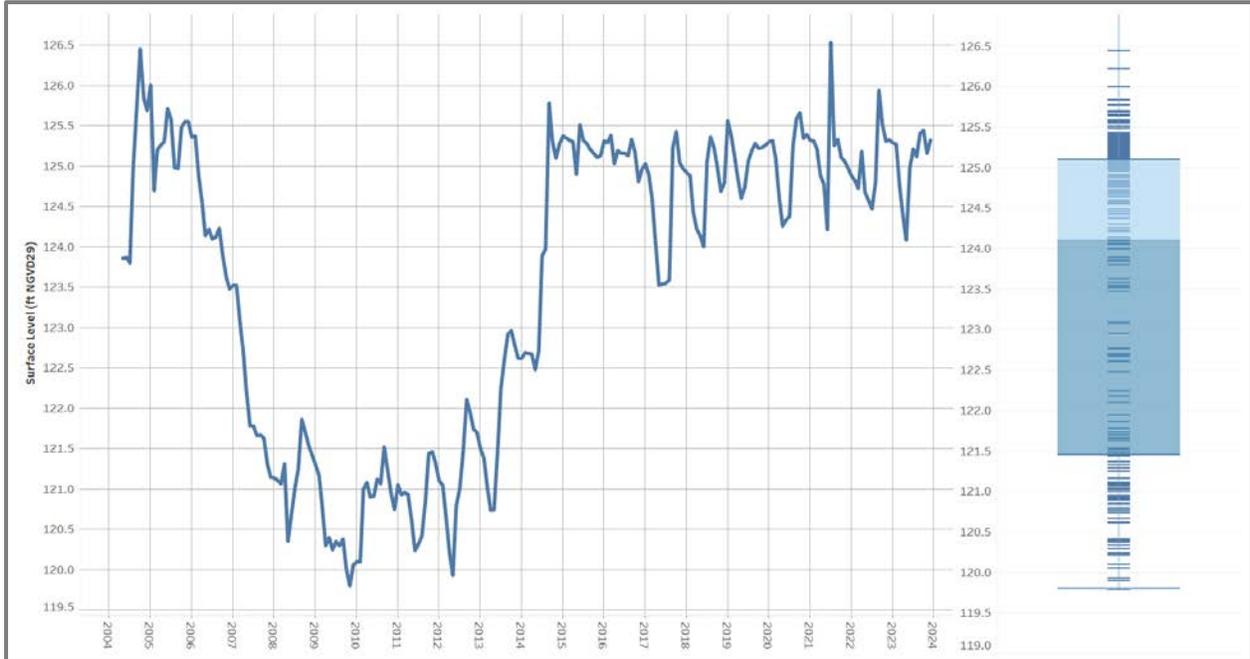


Figure 3-69. Hydrograph of Lake Fannie depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Fannie is categorized as a high color waterbody. Due to a lack of NNC exceedances in Chl-a, TN, and TP during the assessment period, Lake Fannie is considered unimpaired (Figure 3-70). The last exceedances recorded were in 2011; as a result, Lake Fannie has received an impairment criterion score of 3 since 2019.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on the water quality data, Chl-a and Secchi depth exhibit significant improving trends—earning a trend criterion score of 3. The non-significant trends for TN and TP receive trend criteria scores of 2. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing	Not Significant	2
TP	Decreasing	Not Significant	2
Secchi	Increasing (Improving)	Significant	3

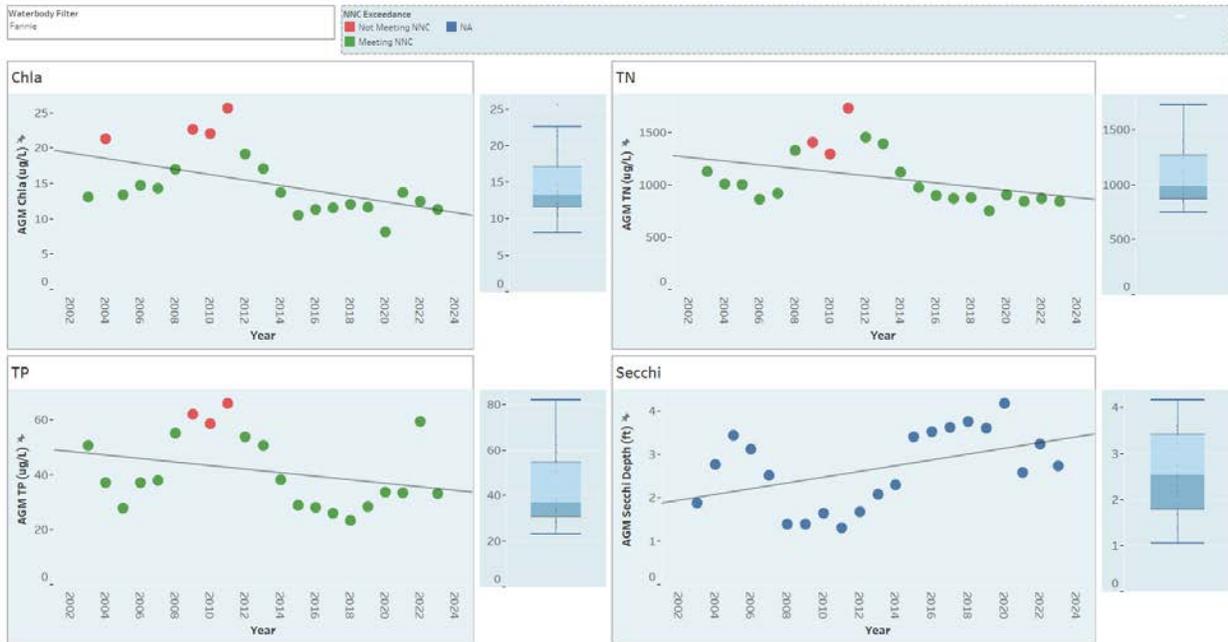


Figure 3-70. Lake Fannie AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Fannie on 11/2/2023. The PAC during this survey was 21% and the total BV was recorded at 87%--though this level may be an error (Figure 3-71). While the vegetation survey places the abundance criterion score at 2, the overall abundance of vegetation is much higher than the data shows. Being so shallow, Lake Fannie hosts a wide and dense littoral zone that the SONAR does not adequately capture. The City is seeking alternate means to capture these dense wetland areas for future surveys.

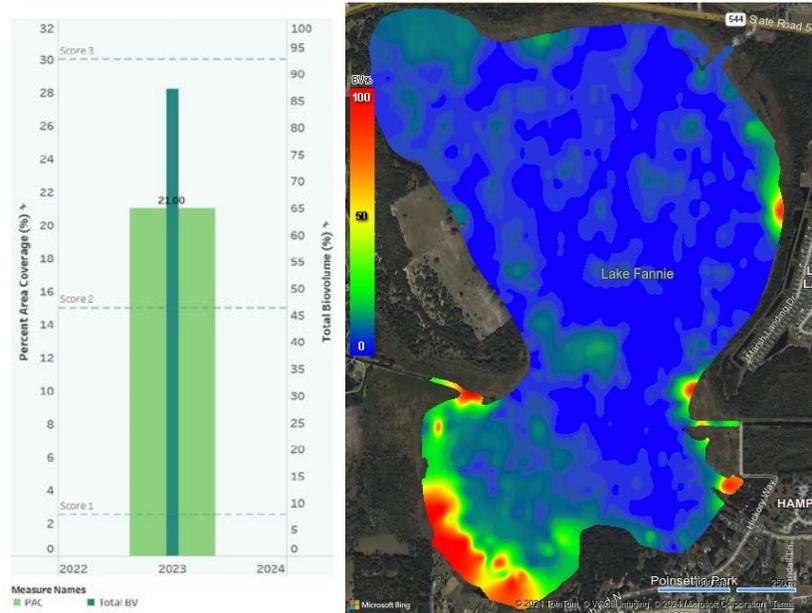


Figure 3-71. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Fannie; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the data, nearly 50% of the dense littoral zone areas are comprised of the native emergent cattail and floating leaf spatterdock (Figure 3-72). The next most abundant

species is spatterdock at 26%. Invasive species like burhead sedge and water hyacinth made up nearly 14% of the population. This places the invasive presence criterion score at 0.

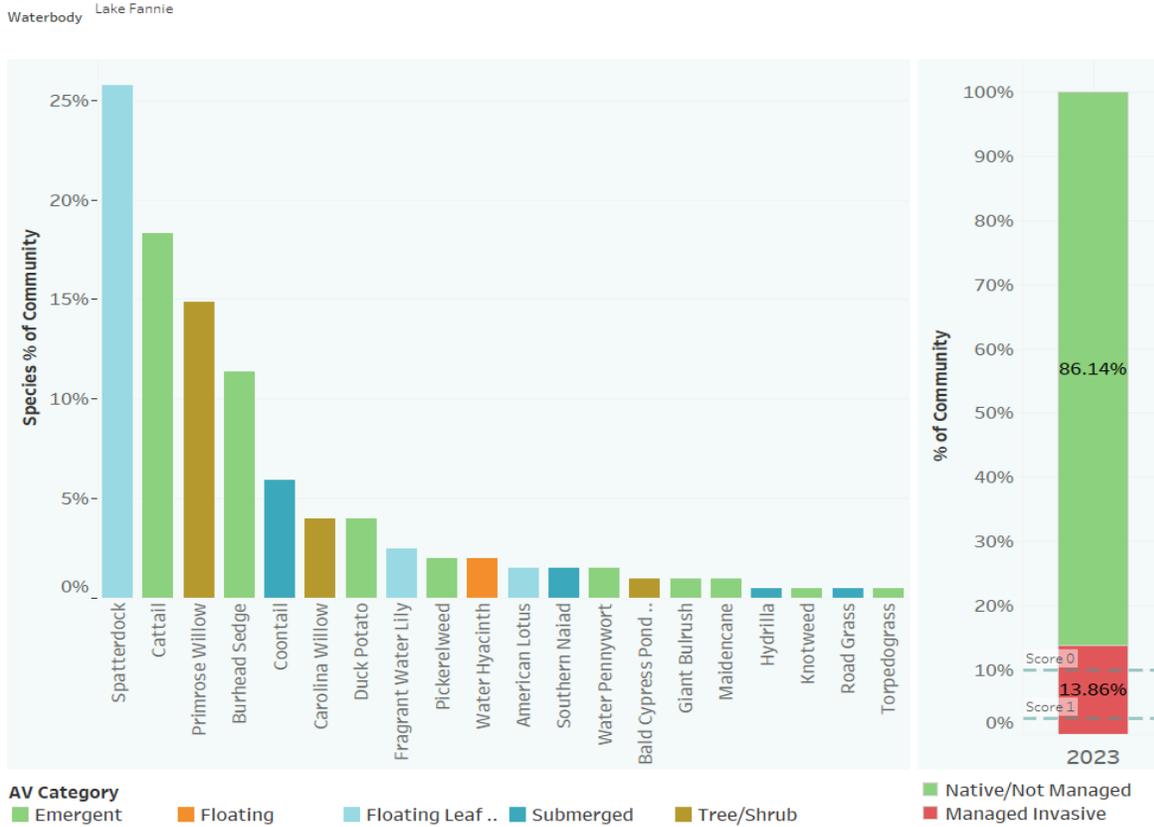


Figure 3-72. Chart depicting species frequency and invasive species percentage of Lake Fannie during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, all three of Lake Fannie’s diversity indices exceeded their respective long-term medians—resulting in a diversity criterion score of 3 (Figure 3-73). This is likely due to the increased prevalence of less abundant species now that the large stands of burhead sedge and hydrilla have been treated. Continued management of invasives should hopefully allow other native species to fill the newly opened ecological niches and improve the overall community in the long term.

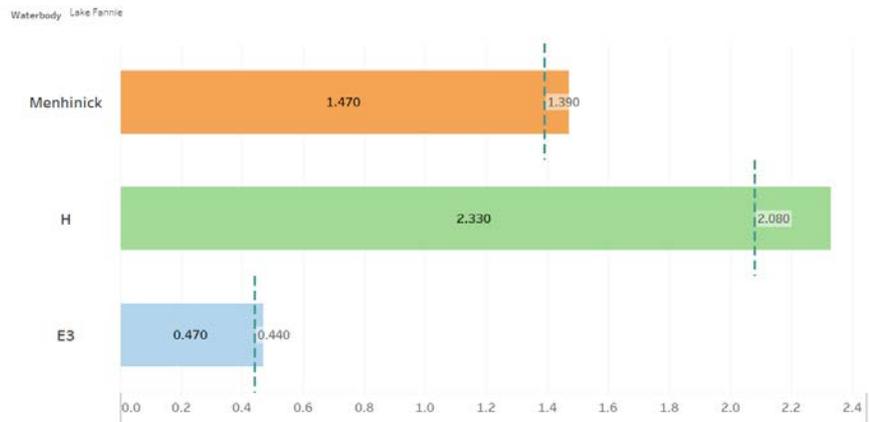


Figure 3-73. Chart depicting 2023 diversity indices for Lake Fannie. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Fannie’s health index scores from 2018 to 2023 shows a significant improvement in 2019, followed by a more gradual improvement (Figure 3-74). The large jump in 2019 was due to water quality meeting NNC guidelines as well as changes in the trend directions and significance in regards to water clarity. The biological parameters are the main source of lake health score fluctuations recently as invasive species control efforts impact the overall vegetation community. On the whole, Lake Fannie is doing much better than it was when monitoring began.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	1	2	2	2	0	2	1.3
2019	3	2	2	2	3	2	0	1	1.9
2020	3	2	2	2	3	1	0	1	1.8
2021	3	2	2	2	3	2	0	2	2.0
2022	3	2	2	2	3	2	0	3	2.1
2023	3	3	2	2	3	2	0	3	2.3

Figure 3-74. Chart depicting a comparison of Lake Fannie’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- While the majority of the drainage basin is undeveloped, new housing in the area carries potential for added stormwater pollutant loading. Fortunately, the majority of these newer developments are required to include stormwater treatment in their site plans.
- The management of invasive species like hydrilla and burhead sedge is a constant concern. Management that foregoes large-scale herbicide treatments is advised in order to prevent water quality decline.
- Lake Fannie’s water quality metrics are significantly correlated with its surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in further water quality decline.

Lake Management Strategy:

- As the Lake Fannie drainage basin continues to develop into residential land uses, public education efforts aimed at improving residents’ knowledge of proper stormwater management practices can help to ensure water quality continues to trend in a positive direction.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- Due to correlation between surface level and water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Haines

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
1	3	3	1	3	3	1	0	1.9

Location, Characteristics, & Hydrology:

Lake Haines is located to the north of central Winter Haven, outside of City limits. It is connected to Lake Rochelle via a navigable canal and discharges excess water to the Peace Creek through Lakes Rochelle, Conine, Smart, Fannie, and Hamilton. Based on these factors, Lake Haines is part of the North Chain of Lakes. Lake Haines is a large and relatively shallow waterbody at 720 acres, an average depth of 9.5 feet, and a maximum depth of just over 15 feet (Figure 3-75).

Stormwater is conveyed to this waterbody from a massive and mostly rural drainage basin with a total area of 2,317 acres (Figure 3-76). The majority of the basin is comprised on wetland land uses. However, high, medium, and low-density residential uses are also present. This basin contributes 5,701 lbs of TN and 1,055 lbs of TP to the lake annually. There are 14 Onsite Sewage Treatment and Disposal (OSTD/septic) systems within the basin; not at a density to cause potential harm via leaching to the water table. Located completely outside Winter Haven limits, the City does not conduct street sweeping services within the basin.

Over the period of record, surface levels in this section of the North Chain (Lakes Conine, Haines, Rochelle, and Smart) have fluctuated between 122 and 129.5 feet above sea level. The normal range fluctuates much less between 126.1 and 128.2 feet (Figure 3-29). During 2023, Lake Conine reached a wet season peak of 128.6 feet in September and a dry season low of 127.8 feet in May. The surface level ended the year above the high end of the normal range at 128.6 feet. Changes in Lake Haines’ surface level are directly correlated with water clarity and indirectly correlated with

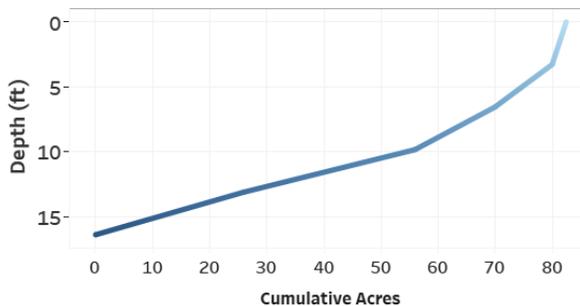


Figure 3-75. Hypsograph of Lake Haines depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

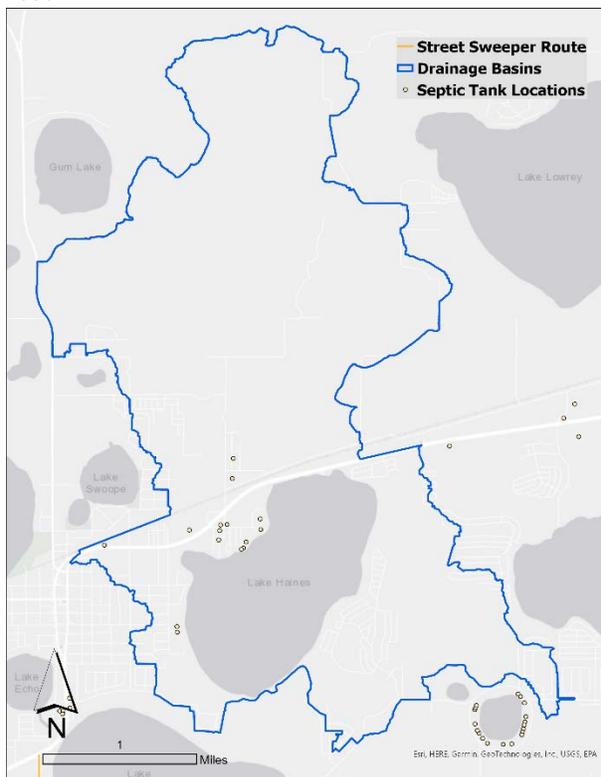


Figure 3-76. Map of Lake Haines’ drainage basin and nearby septic systems.

TN (see appendix). This carries management implications as maintaining a higher surface level should result in improvements in these metrics.

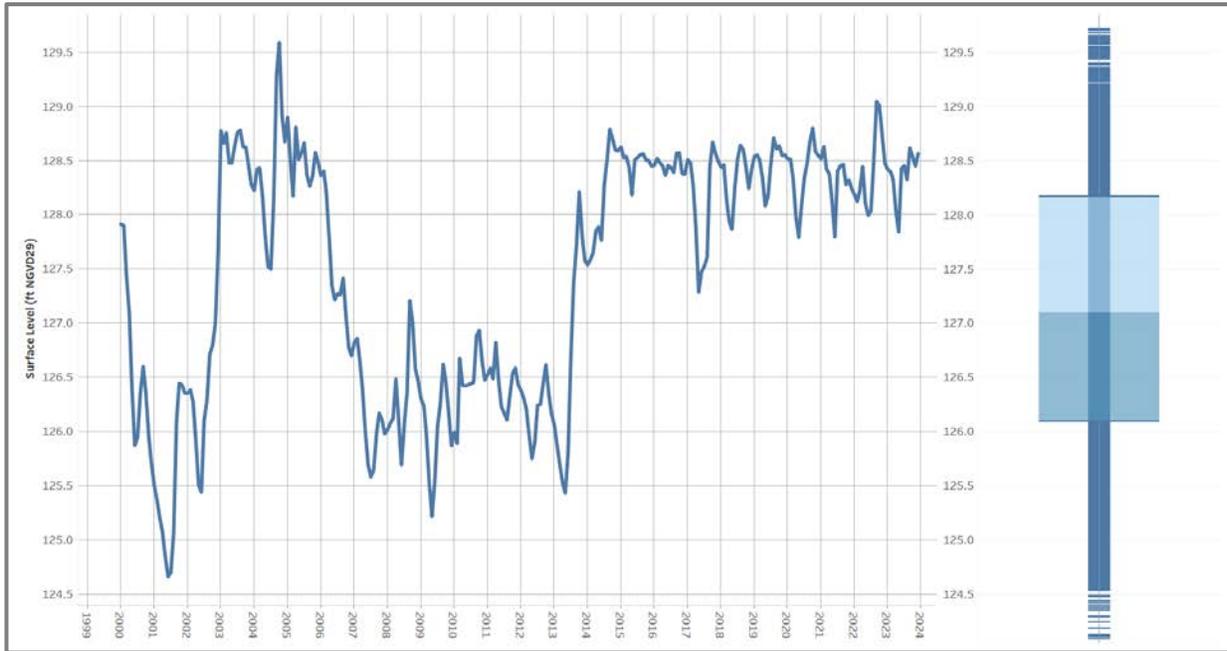


Figure 3-77. Hydrograph of Lake Haines depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairments based on the Numeric Nutrient Criteria (NNC), Lake Haines is categorized as a high-color waterbody. Based on multiple NNC exceedances during the assessment period, Lake Haines is considered impaired for Chl-a and TP. While TN did exceed the NNC threshold in 2021, there have not been multiple consecutive exceedances since 2015 (Figure 3-78). In 2018, the FDEP established a total maximum daily load (TMDL) for Lake Haines stipulating a 33% reduction in TN to achieve NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	1
TN	N	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on the water quality data, Lake Haines exhibits significant improving trends in Chl-a, TN, and Secchi depth—earning trend criteria scores of 3. A non-significant deteriorating trend is exhibited for TP, for a score of 1. Individual AGM values and trend statistics can be found in the appendix. It should be noted that 2023 TN and TP concentrations were some of the highest exhibited in the last 20 years.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Increasing	Not Significant	1
Secchi	Increasing (Improving)	Significant	3

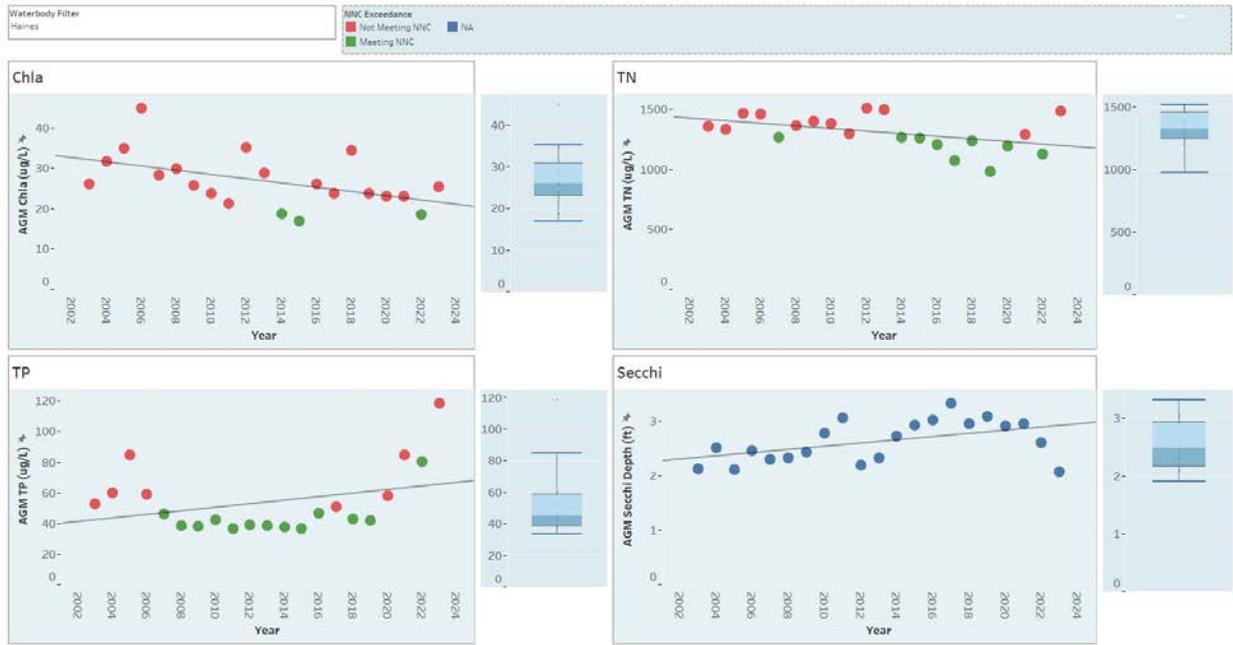


Figure 3-78. Lake Haines' AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Haines on 11/16/2023. The PAC during this survey was 31% and the total BV was 3.7% (Figure 3-79). This was a considerable increase in abundance from previous years. This indicates a substantial improvement in the vegetation community after large-scale invasive species treatment. Fortunately, the majority of this change can be attributed to growth of native plant species.

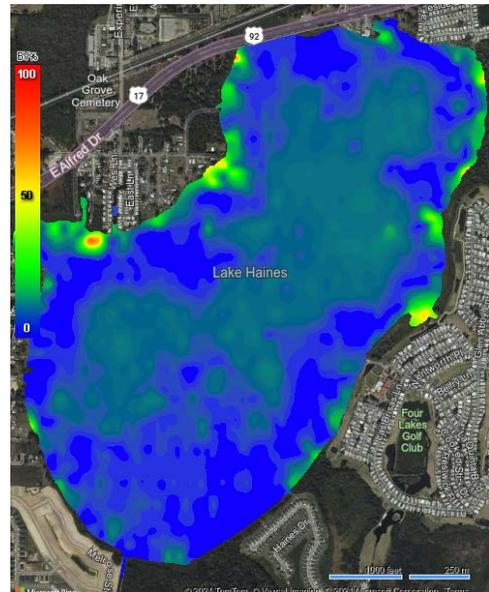
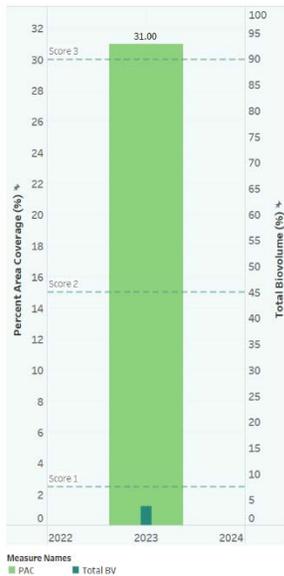


Figure 3-79. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Haines; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on 2023 species data, emergent vegetation remains the most dominant vegetation type in Lake Haines. There were no submerged species detected. Water hyacinth was the only invasive species present in 2023 at 4.76% of the community (Figure 3-80). Unfortunately, it appears the invasive treatment may have had an impact on the native vegetation as evidenced by the disappearance of most SAV. Future

management efforts should focus on maintaining the controlled status of invasives so that native species can return and eventually improve the vegetation community.

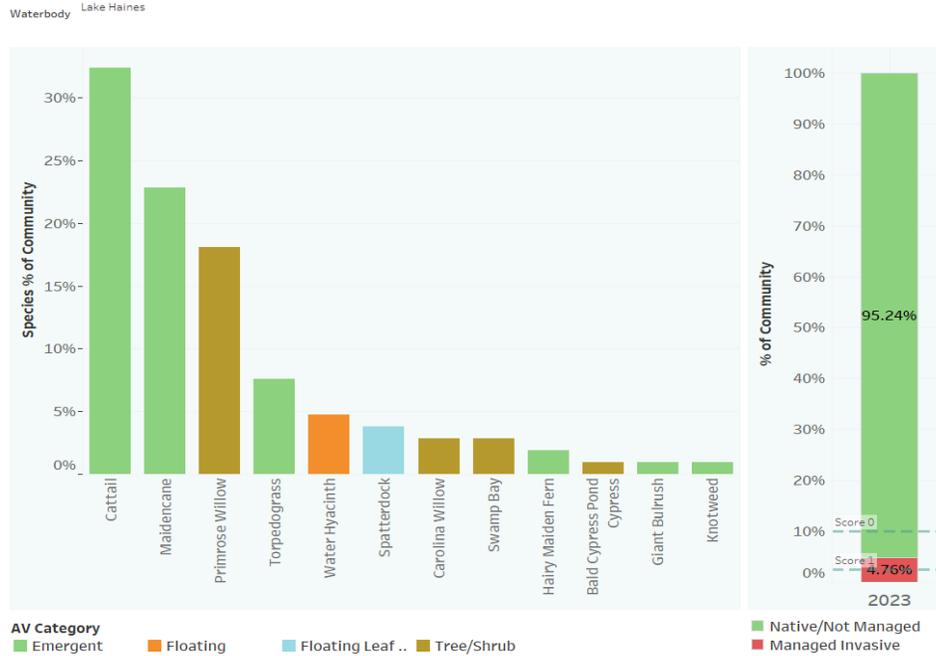


Figure 3-80. Chart depicting species frequency and invasive species percentage of Lake Haines during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, none of the diversity indices met their long-term median values—earning a diversity score of 0 (Figure 3-81). The loss of most submerged vegetation had a large impact on the diversity index values as the number of unique species and species evenness declined considerably. Future surveys should indicate if the effects of the invasive species treatment are long or short term.

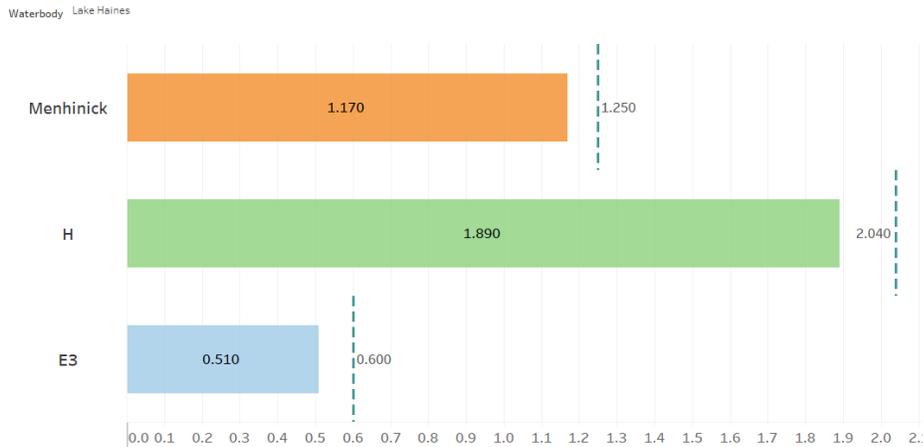


Figure 3-81. Chart depicting 2023 diversity indices for Lake Haines. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Haines’ health index scores from 2018 to 2023 shows some variability over time (Figure 3-82). While the impairment criterion was showing significant improvement by 2022 due to improvements in TN and TP concentrations, back-to-back TP exceedances in 2020 and 2021 resulted in a drop back to an impairment score of 1. The trend criteria have remained relatively static except for a shift in the TP trend direction in 2021 due to some unusually high AGM values. Vegetation abundance declined slightly after hydrilla treatments in 2020 but has shown improvement in 2023. Even with the low diversity score, Lake Haines’ overall health is generally fairly high.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	3	2	3	2	0	1	1.6
2019	1	2	3	2	3	2	0	2	1.9
2020	2	2	3	2	3	3	0	2	2.1
2021	1	2	3	1	3	1	1	2	1.8
2022	1	2	3	1	3	1	1	1	1.6
2023	1	3	3	1	3	3	1	0	1.9

Figure 3-82. Chart depicting a comparison of Lake Haines’ Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Due to the low density of urban development in the drainage basin, the per acre stormwater pollutant loading is relatively low. That said Lake Haines may possess some legacy nutrients from historic point-source loading via the Lake Alfred Wastewater Treatment Facility.
- The correlation between surface level and water quality is likely due in part to Lake Haines’ morphology. As a large, shallow waterbody, it is more susceptible to sediment suspension from wind and wave action. This is exacerbated when lake levels are lower.
- The management of invasive species like hydrilla is a constant concern. Even with regular treatments, the presence of invasives is still not quite under control. Large-scale herbicide treatments may also impact both native vegetation and water quality.

Lake Management Strategy:

- Due to correlations between surface level and water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Additionally, staff will advocate for invasive management actions that limit the large-scale use of herbicides.
- Staff can support Polk County and the City of Lake Alfred in efforts to mitigate pollutant loading. Either through source analysis or guidance on the use of green infrastructure within the drainage basin.

Lake Hamilton

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
0	0	0	3	0	1	3	3	1.3

Location, Characteristics, & Hydrology:

Lake Hamilton is located to the northeast of central Winter Haven, at the very eastern edge of City limits. It receives excess water flows from Lakes Fannie, Henry, and Middle Hamilton, and discharges directly to the Peace Creek via the SWFWMD-managed P-8 control structure. Based on these factors, Lake Hamilton is part of the North Chain of Lakes. Lake Hamilton is the largest area waterbody at 2224 acres, an average depth of 6.3 feet, and a maximum depth greater than 15 feet in deeper holes (Figure 3-83).

Stormwater is conveyed to this waterbody from a 4177 acre drainage basin comprised of medium-density residential, wetlands, low-density residential, agricultural, and high-density residential land uses (Figure 3-84). Based on stormwater modelling, this basin of suburban and rural land uses contributes 6,701 lbs of TN and 1,167 lbs of TP to the lake annually. There are approximately 62 Onsite Sewage Treatment and Disposal (OSTD/septic) systems within this drainage basin—a relatively low density for its size. Lacking City roads and stormwater infrastructure conveying runoff to the lake, Winter Haven does not conduct any street sweeping services within this basin.

Over its period of record, Lake Hamilton’s surface level has fluctuated between 117.5 and 123.6 feet above sea level. The normal range of fluctuation is between 119 and 121 feet (Figure 3-85). In 2017, the SWFWMD enacted new water level management protocols with the intent to restore seasonal level fluctuations within the lake’s normal range. This is accomplished by releasing water downstream during the rainy season and storing water during the dry season. During 2023, Lake Hamilton reached a wet season peak of 121.5 feet in September and a dry season low of 120.4 feet in

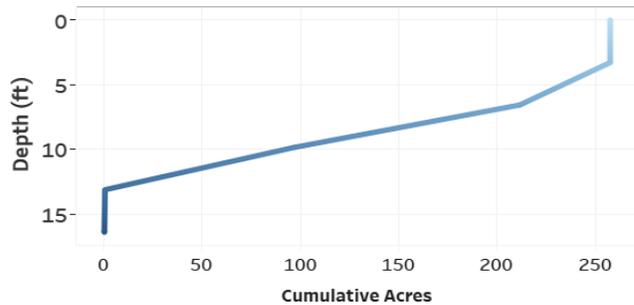


Figure 3-83. Hypsograph of Lake Hamilton depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

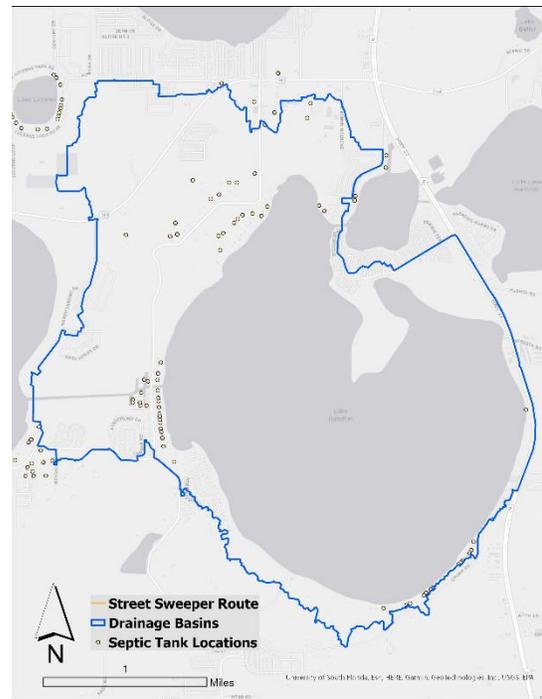


Figure 3-84. Map of Lake Hamilton’s drainage basin and nearby septic systems.

May. Changes in Lake Hamilton’s surface level are not correlated with Chl-a, TN, TP, or clarity (see appendix).

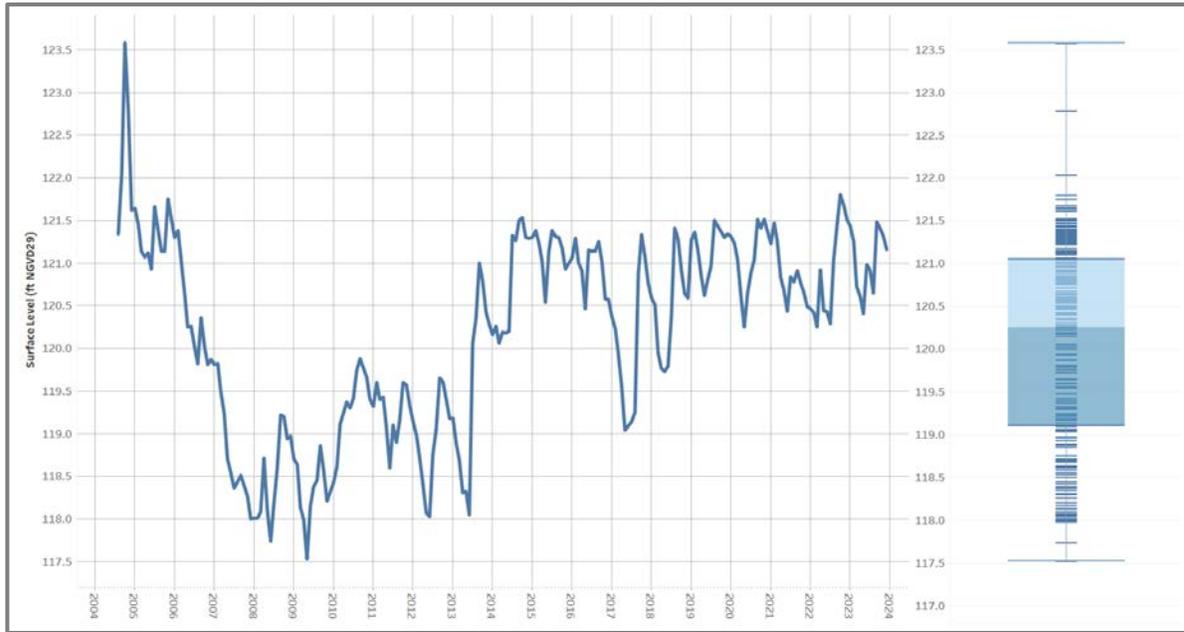


Figure 3-85. Hydrograph of Lake Hamilton depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Hamilton is categorized as a clear, alkaline waterbody. Based on multiple consecutive NNC exceedances during the assessment period, Lake Hamilton is considered impaired for Chl-a, TN, and TP (Figure 3-86). This equates to an impairment criterion score of 0. While the FDEP began developing a total maximum daily load (TMDL) for Lake Hamilton in 2020, the City and Polk County have introduced a pollutant reduction plan to address the water quality issues. This plan has been accepted by the FDEP.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Chl-a, TN, and Secchi depth each exhibit significant deteriorating trends—earning trend criteria scores of 0. Surprisingly, TP exhibits a significant improving trend, for a criterion score of 3. These trends are indicative of a cycle of nitrogen-fixing cyanobacteria blooms occurring in Lake Hamilton—increasing Chl-a and TN concentrations while decreasing TP and clarity. Further study is needed to assess other potential drivers of these trends.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing (Deteriorating)	Significant	0
TN	Increasing (Deteriorating)	Significant	0
TP	Decreasing (Improving)	Significant	3
Secchi	Decreasing (Deteriorating)	Significant	0

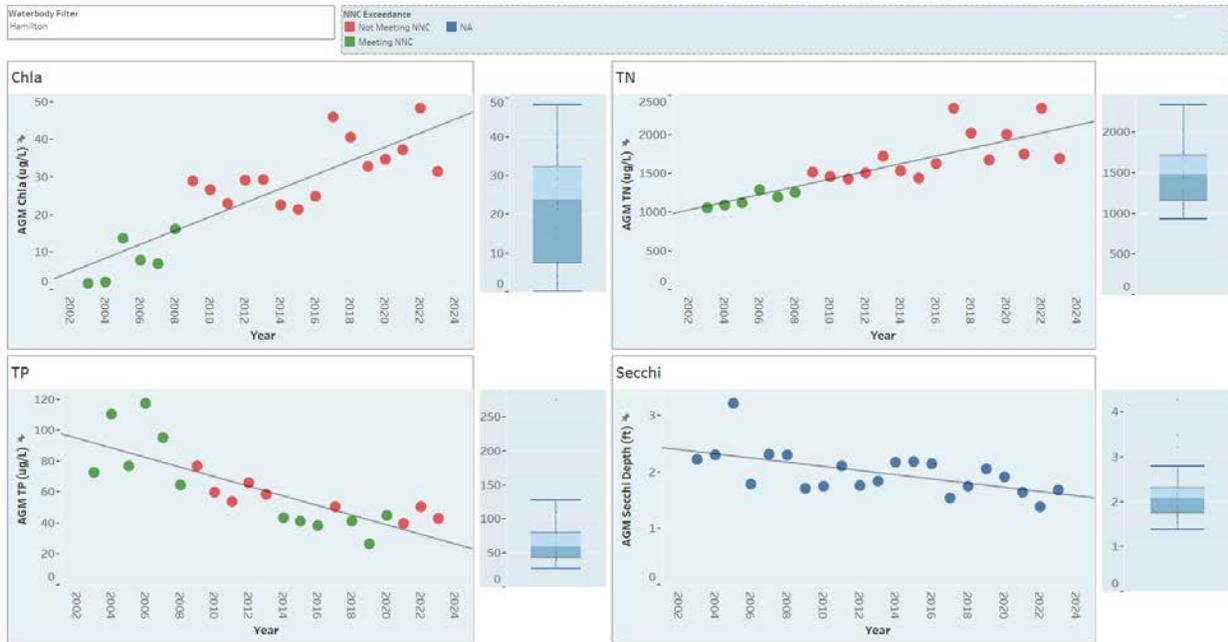


Figure 3-87. Lake Hamilton AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Hamilton on 11/29/2023. The PAC during this survey was 13.5% and the total BV was recorded at 72%--which may be due to an instrument error (Figure 3-87). A comparison of data from previous years shows a slight, but consistent increase in coverage from 7.7% in 2018 to the current percentage. Regardless, the amount of coverage is still within the range for an abundance criterion score of 1. Based on Lake Hamilton’s morphology and water clarity, this amount of coverage is expected.

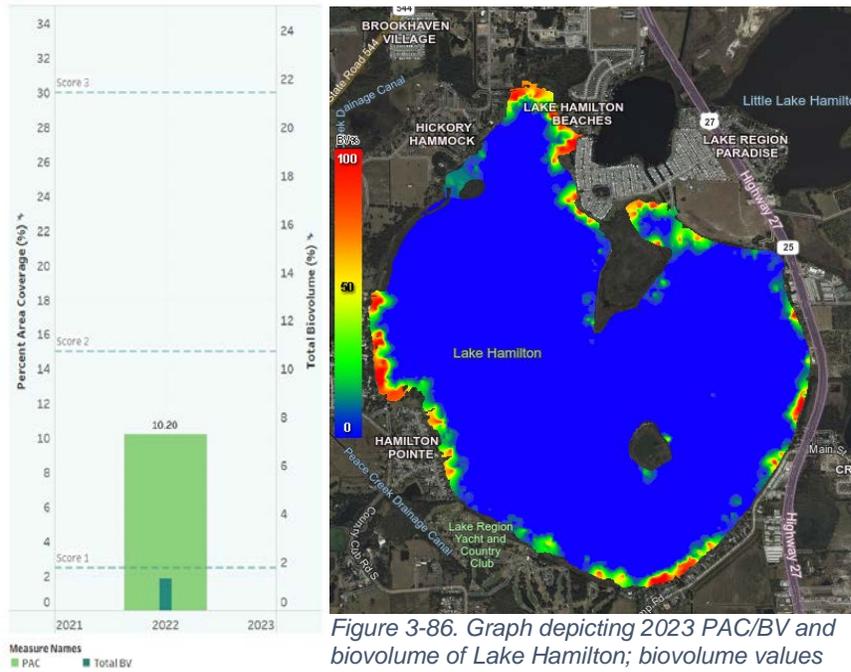


Figure 3-86. Graph depicting 2023 PAC/BV and biovolume of Lake Hamilton; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on 2023 species data, the dominant plant type in the lake was emergent, with giant bulrush and cattail comprising almost 27% of the community (Figure 3-88). This is followed by submerged and floating leaf natives, respectively. While invasive species have

historically been at a minimum, total invasive percentage of 5.8% was discovered—comprised of burhead sedge and other floating species. This was an increase from 2022 and indicates spot treatment efforts need to be implemented to keep these species from expanding.

Waterbody Lake Hamilton

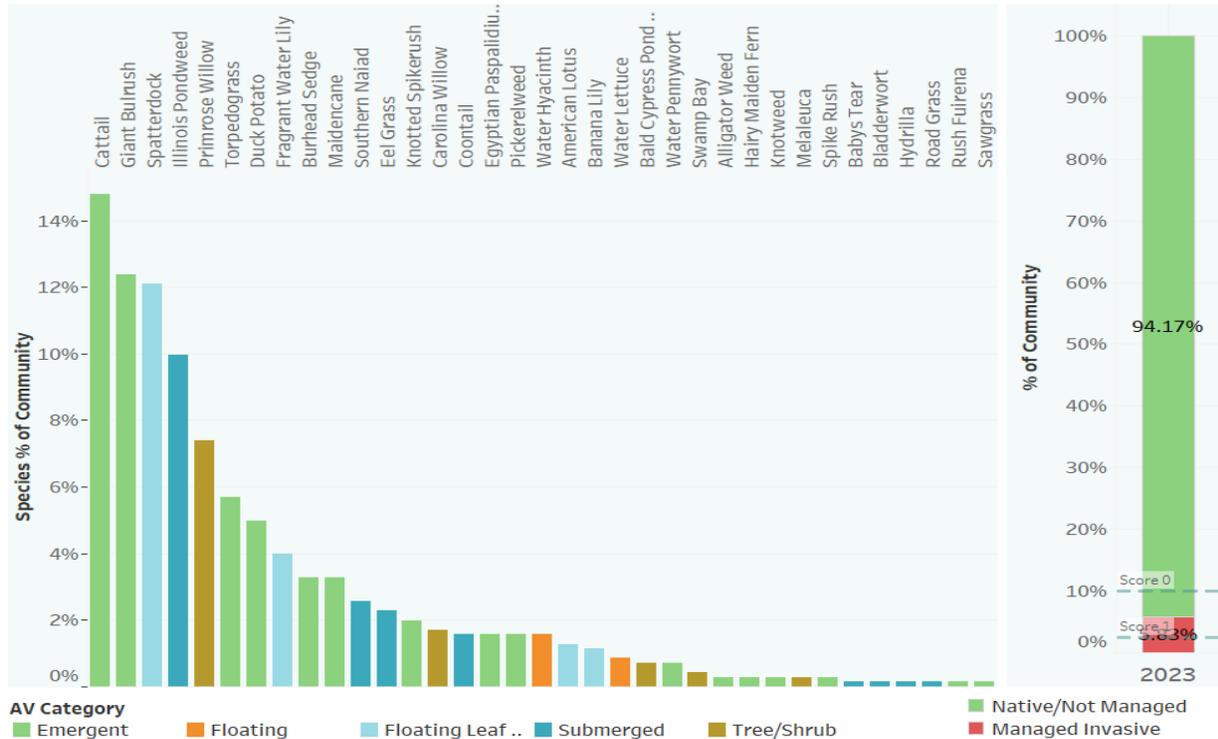


Figure 3-88. Chart depicting species frequency and invasive species percentage of Lake Hamilton during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, all three of Lake Hamilton’s diversity indices met or exceeded their respective median values (Figure 3-89). This was an increase from previous years and is due to a massive increase in the number and distribution of unique species not previously detected. Future management efforts should strive to maintain this level of diversity. This may be accomplished through low-intensity invasive treatments aimed at minimizing impacts to native vegetation.

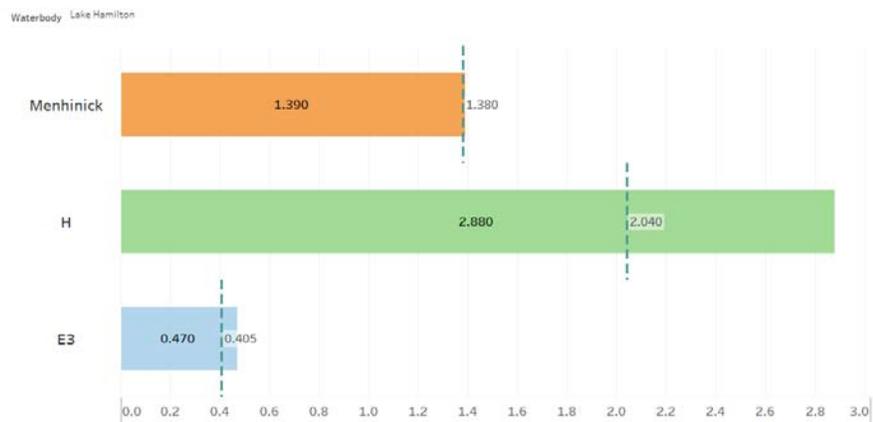


Figure 3-89. Chart depicting 2023 diversity indices for Lake Hamilton. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Hamilton’s health index scores from 2018 to 2023 shows some improvement (Figure 3-90). Besides an instance of TP meeting NNC guidelines for a year in 2021, the water quality scores have not changed. Lake Hamilton’s water quality is still in desperate need of management action to improve. Regarding the biological criteria, vegetation abundance has remained the same. However, invasive species and diversity have both recently improved quite a bit. Continued vegetation management is required to ensure these scores remain high.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	0	0	3	0	1	2	0	0.8
2019	0	0	0	3	0	1	2	2	1.0
2020	0	0	0	3	0	1	1	1	0.8
2021	1	0	0	3	0	1	1	3	1.1
2022	0	0	0	3	0	1	3	3	1.3
2023	0	0	0	3	0	1	3	3	1.3

Figure 3-90. Chart depicting a comparison of Lake Hamilton’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Hamilton’s water quality is continuing to decline. The likely existence of nitrogen-fixing bacteria is a notable result of these issues. It is unclear if this is due to stormwater, OSTDs, or other sources.
- Lake Hamilton continues to lack an abundance of aquatic vegetation. An increase in coverage could improve nutrient sequestration in the future.

Lake Management Strategy:

- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection will help to prevent a resurgence of invasive species.
- As part of the pollutant load reduction plan submitted by the County, there are several projects underway and planned that are intended to reduce the pollutant load to Lake Hamilton. These include:
 - Stormwater treatment BMPs at Lake Eva, Lake Conine (i.e. Lake Conine Nature Park), and a proposed treatment wetland on the west side of Lake Hamilton;
 - Street sweeping in the Haines City area;
 - Seepage study and septic-to-sewer conversion project proposed for the City of Lake Hamilton;
 - Installation of bioactive media along US Hwy 27.

Lake Hartridge

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
1	0	0	2	0	3	3	2	1.4

Location, Characteristics, & Hydrology:

Lake Hartridge is located to the north of central Winter Haven. As part of the South Chain of Lakes, it is connected by a navigable canal to Lake Idylwild and to Lake Conine via a boat lock system. Excess water from the South Chain discharges to the Wahneta Farms Drainage Canal through a passive control structure on the south shore of Lake Lulu. Lake Hartridge is a moderate-to-large waterbody at 451 acres, an average depth of 10 feet, and a maximum depth of over 20 feet in deeper holes (Figure 3-91).

Stormwater is conveyed to this waterbody from a 920 acre drainage basin of which the lake’s surface takes up close to half (Figure 3-92). In order of area, the primary land uses within this basin are medium-density residential, transportation, high-density residential, commercial, and institutional. Based on stormwater modelling, Lake Hartridge receives 2,658 lbs of TN and 458 lbs of TP from this basin annually. There are 65 Onsite Sewage Treatment and Disposal (OSTD/septic) systems in the vicinity of the lake that may constitute a source of pollutant loading through groundwater. The City conducts monthly street sweeping services for over 17 miles along Havendale Blvd and US Hwy 17.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain’s surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the South Chain by the end of the year was slightly above the top of the

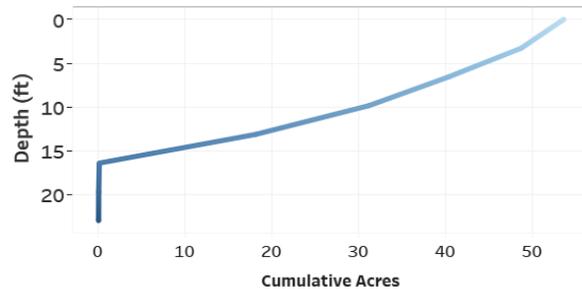


Figure 3-91. Hypsograph of Lake Hartridge depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake

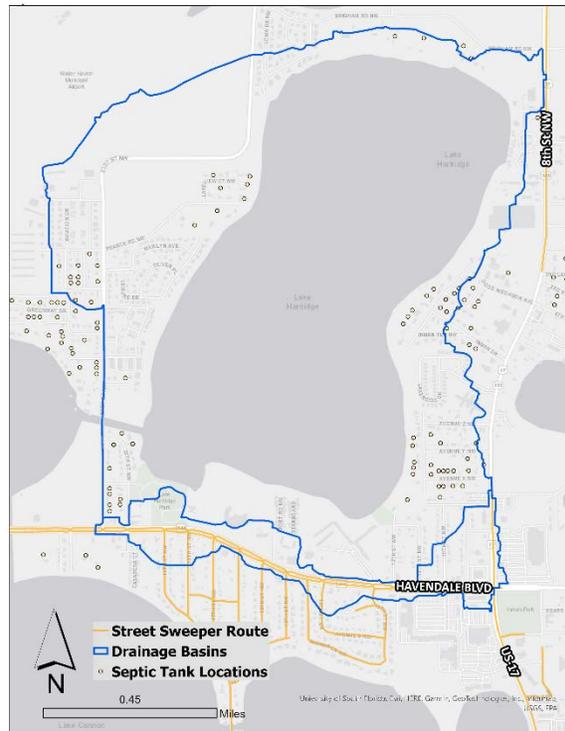


Figure 3-92. Map of Lake Hartridge’s drainage basin, city street sweeper routes, and nearby septic systems.

normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake Hartridge’s surface level correlates indirectly with TP—indicating that higher levels should result in lower TP concentrations (see appendix).

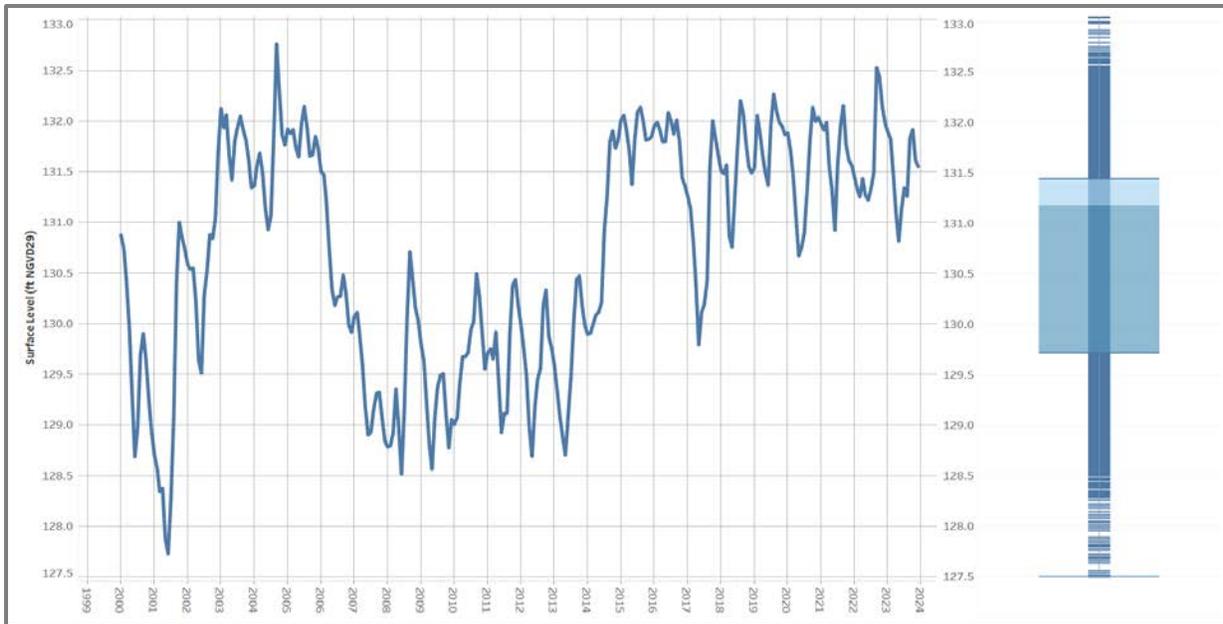


Figure 3-93. Hydrograph of Lake Hartridge depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Hartridge is categorized as a clear, alkaline waterbody. Based on numerous consecutive NNC threshold exceedances during the assessment period, Lake Hartridge is considered impaired for Chl-a and TN (Figure 3-94). Excepting a single exceedance in 2021, AGM TP concentrations have remained below the impairment threshold during the assessment period. Lake Hartridge earns an impairment criterion score of 1.

Parameter	Impaired	Index Score
Chla	Y	1
TN	Y	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. During this period, Chl-a, TN, and Secchi depth exhibit significant deteriorating trends—equating to trend criteria scores of 0. TP exhibits a non-significant improving trend, for a criterion score of 2. This recent shift in the trend direction may point to the presence of nitrogen-fixing bacteria in Lake Hartridge.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing (Deteriorating)	Significant	0
TN	Increasing (Deteriorating)	Significant	0
TP	Decreasing	Not Significant	2
Secchi	Decreasing (Deteriorating)	Significant	0

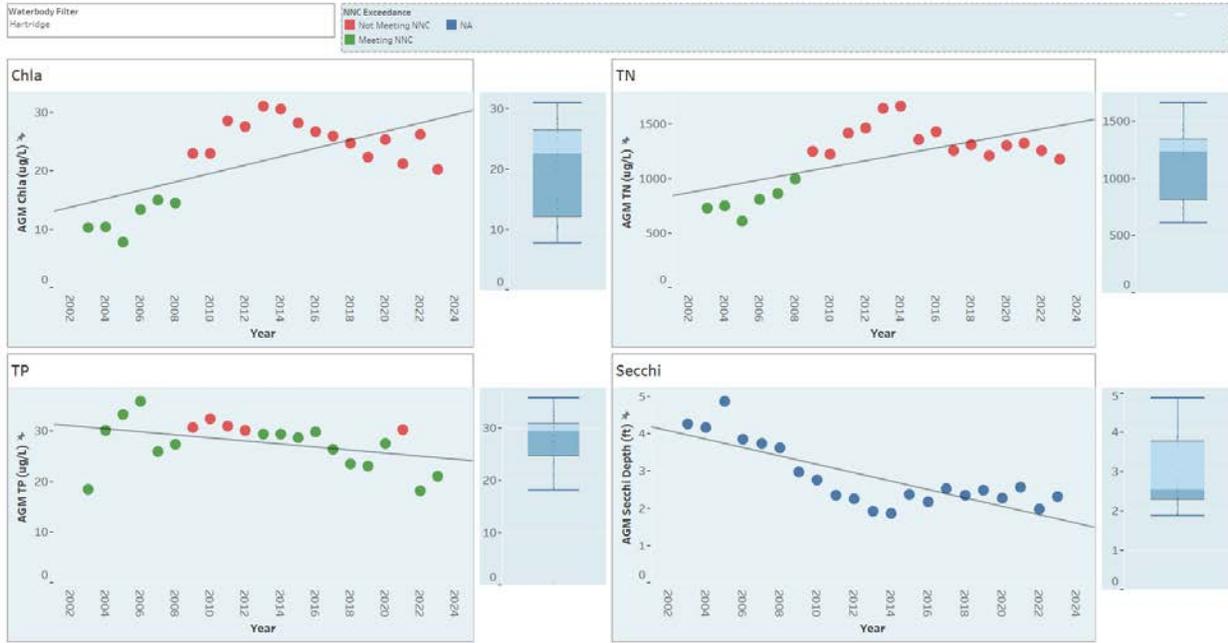


Figure 3-94. Lake Hartridge AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Hartridge on 10/20/2023. The PAC during this survey was 42.4% and the total BV was 9.9% (Figure 3-95). A comparison to previous years shows that vegetation abundance has remained relatively consistent since monitoring began; with PAC values above 35%. Lake Hartridge’s gently sloping morphology likely allows for a wide littoral zone that aquatic plants can occupy. This abundance equates to a lake health criterion score of 3.

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2023 data, the native Illinois pondweed was the most dominant species present, followed by a healthy mix of native emergent and floating leaf plants (Figure 3-96). There were no invasive species detected in 2023; resulting in a score of 3. A comparison to previous years shows that invasives are generally controlled, with total community percentages consistently falling below 2% each year since 2018.

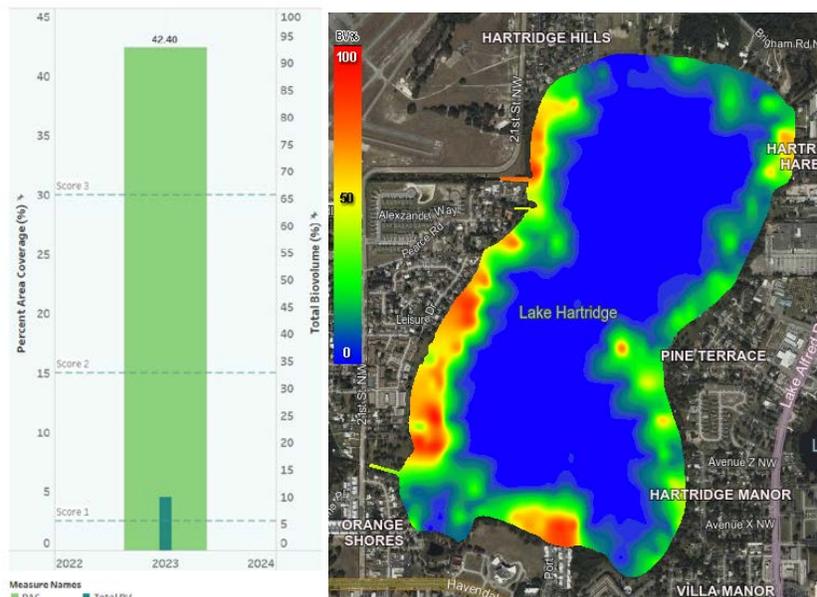


Figure 3-95. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Hartridge; biovolume values range from green (lowest) to red (highest).

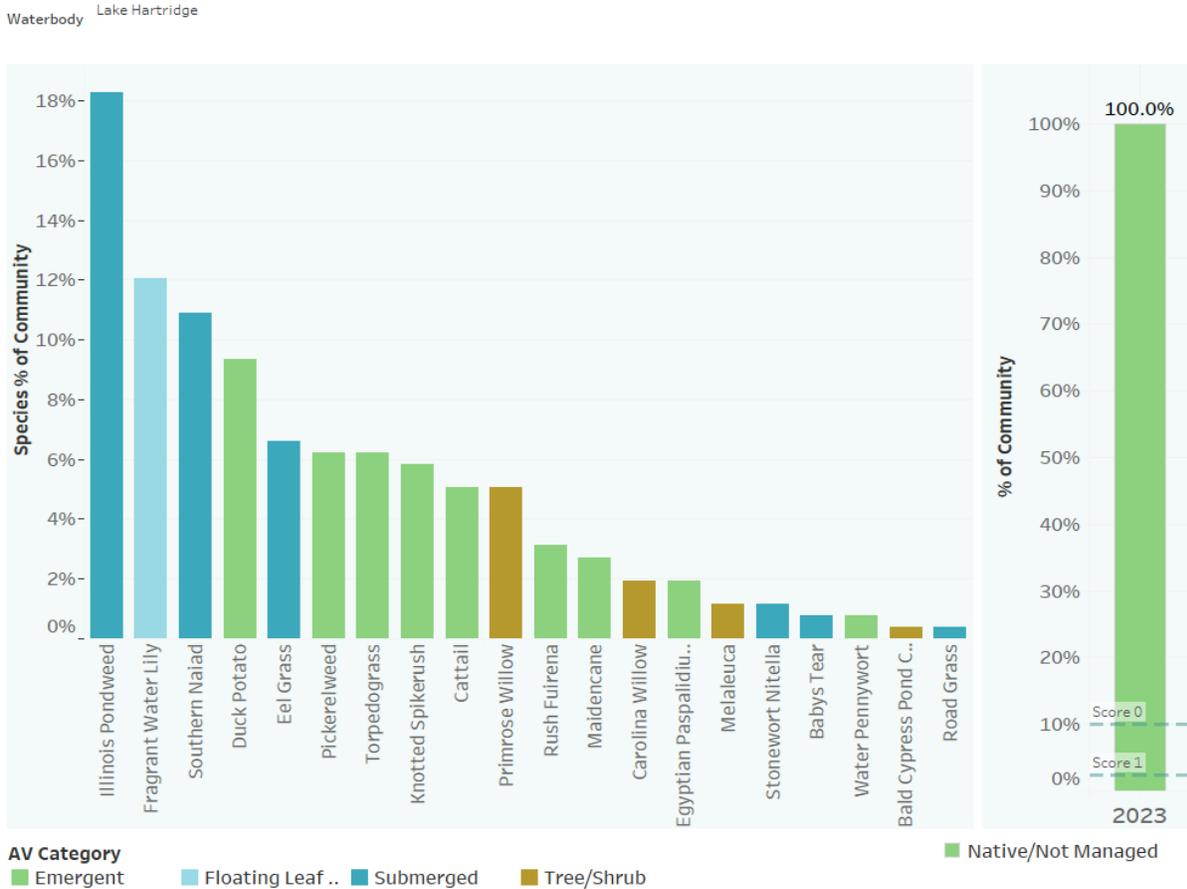


Figure 3-96. Chart depicting species frequency and invasive species percentage of Lake Hartridge during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, Lake Hartridge’s evenness and overall diversity indices met or exceeded their long-term median values (Figure 3-97). The richness index value decreased from previous years due to the lack of invasive species like hydrilla. Otherwise, Lake Hartridge has an adequate number and diversity of aquatic plant species.

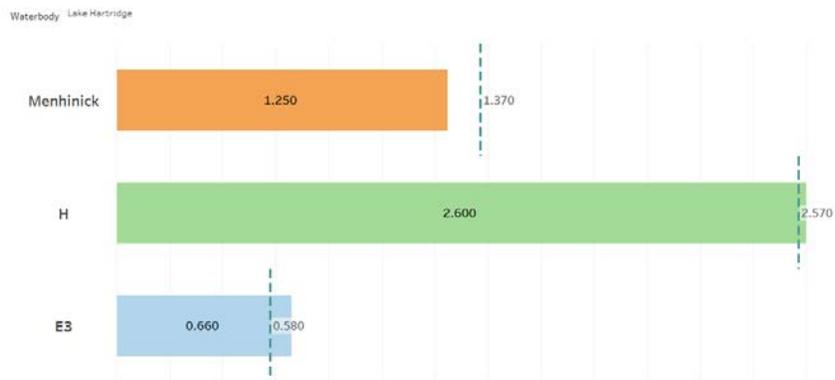


Figure 3-97. Chart depicting 2023 diversity indices for Lake Hartridge. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Hartridge’s health index scores from 2018 to 2023 shows little change (Figure 3-98). The impairment criterion score improved in 2019 due to TP no longer exceeding the NNC thresholds. However, with the exception of TP in the most recent assessment, the trend scores have consistently been pointing to deteriorating water quality. Vegetation abundance has remained high over the last six years, with invasive and diversity scores exhibiting the most variability. This is likely due, in part, to invasive plant management efforts and the changes in the vegetation community that follow. Lake Hartridge’s consistently low score places it high on the City’s priority list for management action.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	0	0	2	0	3	3	2	1.3
2019	1	0	0	1	0	3	2	2	1.1
2020	1	0	0	1	0	3	2	3	1.3
2021	1	0	0	1	0	3	3	3	1.4
2022	1	0	0	1	0	3	2	2	1.1
2023	1	0	0	2	0	3	3	2	1.4

Figure 3-98. Chart depicting a comparison of Lake Hartridge’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- In addition to stormwater, pollutant loading from OSTDs may be a potential contributor to Lake Hartridge’s poor water quality. As these septic systems age, they may begin to leach nutrients into the water table—leading to additional water quality issues.
- The management of invasive species like hydrilla is a consistent concern. It can only take a single season for even a small population to take over large areas of a waterbody.

Lake Management Strategy:

- The City currently conducts street sweeping services in the southern drainage sub-basin that collects water from Havendale Blvd. This is estimated to remove 192 lbs of TN and 104 lbs of TP annually.
- Additionally, a wetland treatment park was constructed in the early 2000s to capture and treat a substantial amount of runoff from this basin. Future studies are required to determine the actual reduction rate.
- The City may explore source analysis to determine if OSTD leachate is a contributor of pollutants to the lake. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.

Lake Howard

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
1	3	3	3	3	2	2	2	2.4

Location, Characteristics, & Hydrology:

Lake Howard is one of the City’s most centrally located lakes, situated just west of downtown Winter Haven. It is part of the South Chain of Lakes with navigable connections to Lakes Cannon and May. The South Chain discharges excess water to the Wahneta Farms Drainage Canal via the passive control structure on the southern shore of Lake Lulu. Lake Howard is a moderately large waterbody at 633 acres, an average depth of 9 feet, and a maximum depth greater than 15 feet in specified areas (Figure 3-99).

Stormwater is conveyed to this waterbody from a mostly urbanized 1869 acre drainage basin that is comprised of 53 separate sub-basins (Figure 3-100). Ranked by area, the primary land uses within this basin are medium-density residential, commercial, high-density residential, and open/natural land. Based on stormwater modelling, these land uses contribute 6,321 lbs of TN and 1,097 lbs of TP to the lake annually. There are fewer than 30 Onsite Sewage Treatment and Disposal (OSTD/septic) systems present within the drainage basin. This is likely too low of a density to contribute meaningful pollutant loads via septic leaching into the groundwater. Much of the stormwater from downtown streets and surrounding neighborhoods is not captured in traditional stormwater treatment ponds. Therefore, the City conducts monthly street sweeping services for more than 50 miles per month.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain’s surface level has fluctuated between 127.5 and 133.7 feet above sea level.

The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During

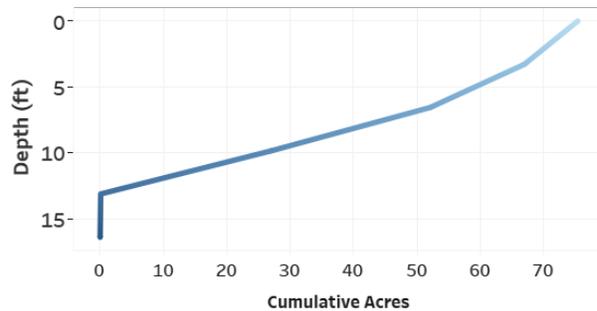


Figure 3-99. Hypsograph of Lake Howard depicting cumulative area a regular depth intervals. Demonstrates the slope and morphology of the lake bed.

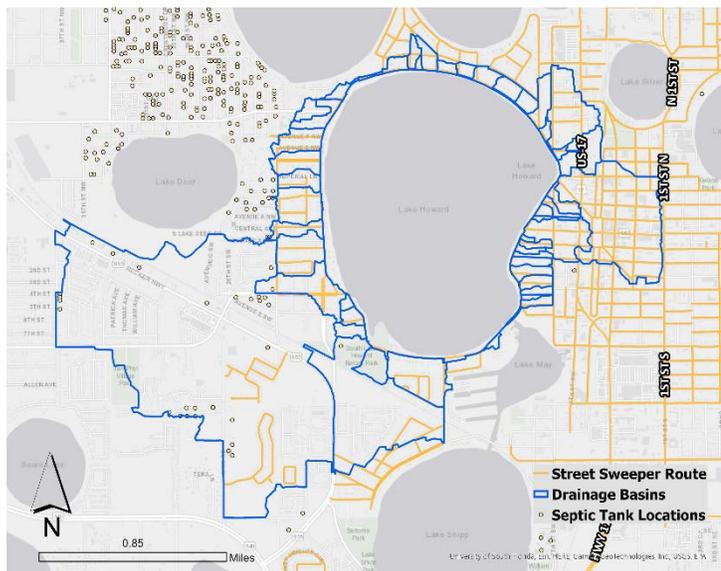


Figure 3-100. Map of Lake Howard’s drainage basin, City street sweeping routes, and nearby septic systems.

2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake Howard’s surface level correlate with Chl-a, TN, and clarity (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.

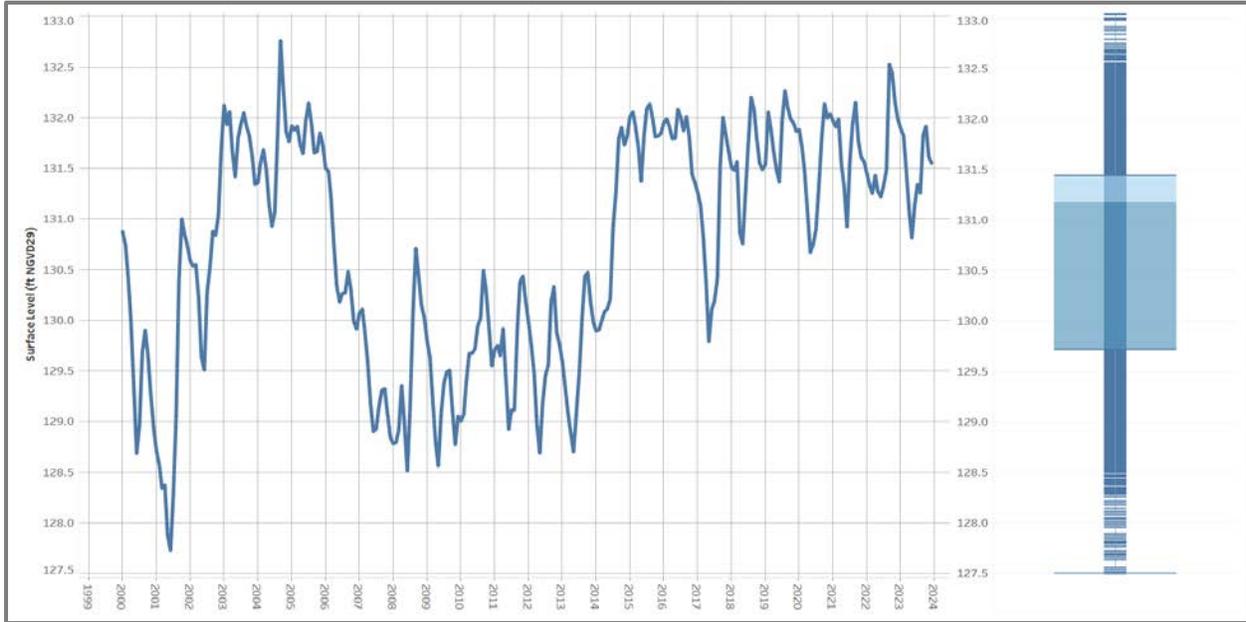


Figure 3-101. Hydrograph of Lake Howard depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Howard is categorized as a clear, alkaline waterbody. Due to numerous consecutive NNC exceedances during the assessment period, Lake Howard is considered impaired for Chl-a and TN (Figure 3-102). There have been no NNC exceedances for TP since 2009. In 2019, the FDEP established a total maximum daily load for Lake Howard, stipulating a 39% reduction in TN to meet NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	1
TN	Y	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on the data, Chl-a, TN, TP, and Secchi depth all exhibit significant improving trends—earning trend criteria scores of 3. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3

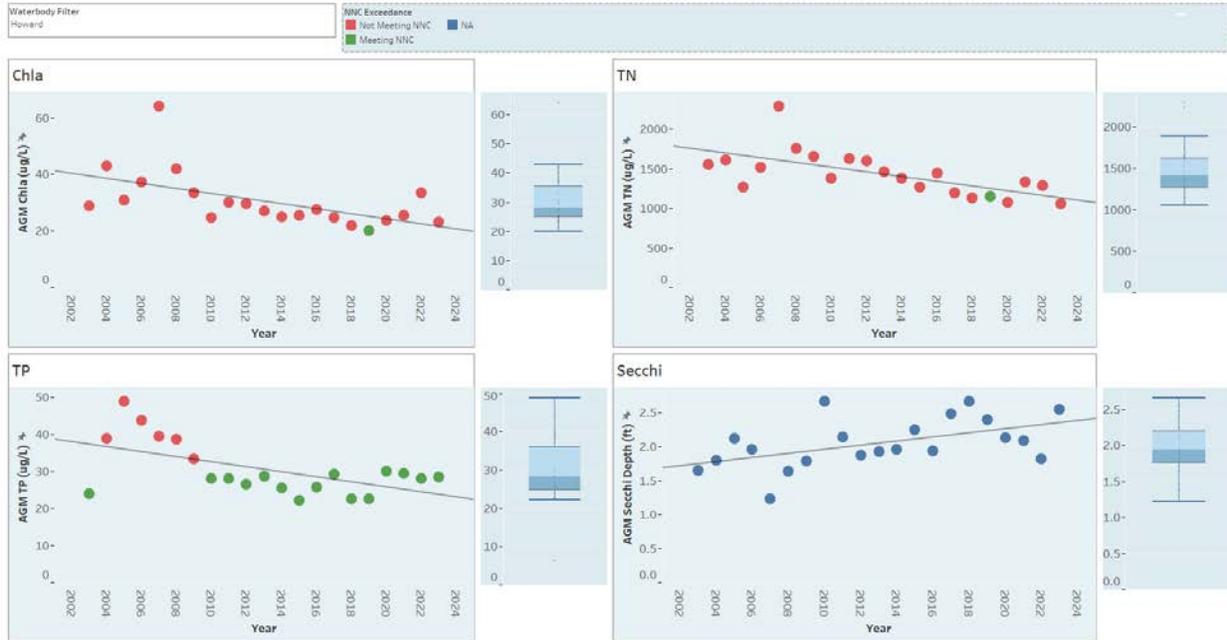


Figure 3-102. Lake Howard AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Howard on 5/11/2023. The PAC during this survey was 27.6% and the total BV was 19.6% (Figure 3-103). A review of abundance values from previous years shows that Lake Howard’s coverage has fluctuated between 27% and 39%. Lacking much of an invasive species presence, the majority of this variance in abundance can be attributed to natural fluctuations. The result of the 2023 values equates to an abundance criterion score of 2.

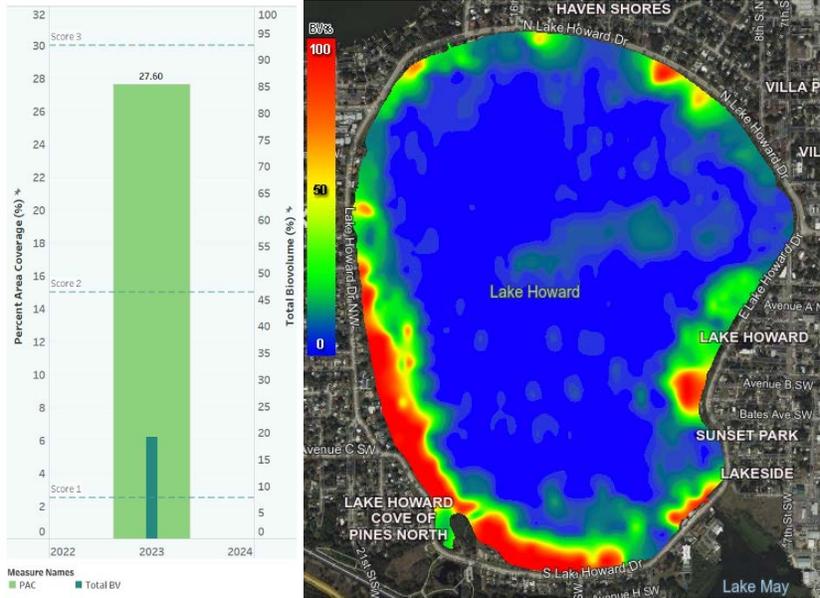


Figure 3-103. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Howard; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, Lake Howard has a healthy mix of native submerged, emergent, and floating leaf plant types. The dominant species was Illinois pondweed at 16%, closely followed by Egyptian paspalidium (Kissimmee grass) and duck potato (Figure 3-104). As stated previously, Lake Howard’s vegetation community lacks a strong presence of

managed invasive species like hydrilla. However, there was a small amount of water hyacinth detected in 2023, resulting in a score of 2 in the invasive percentage criterion.

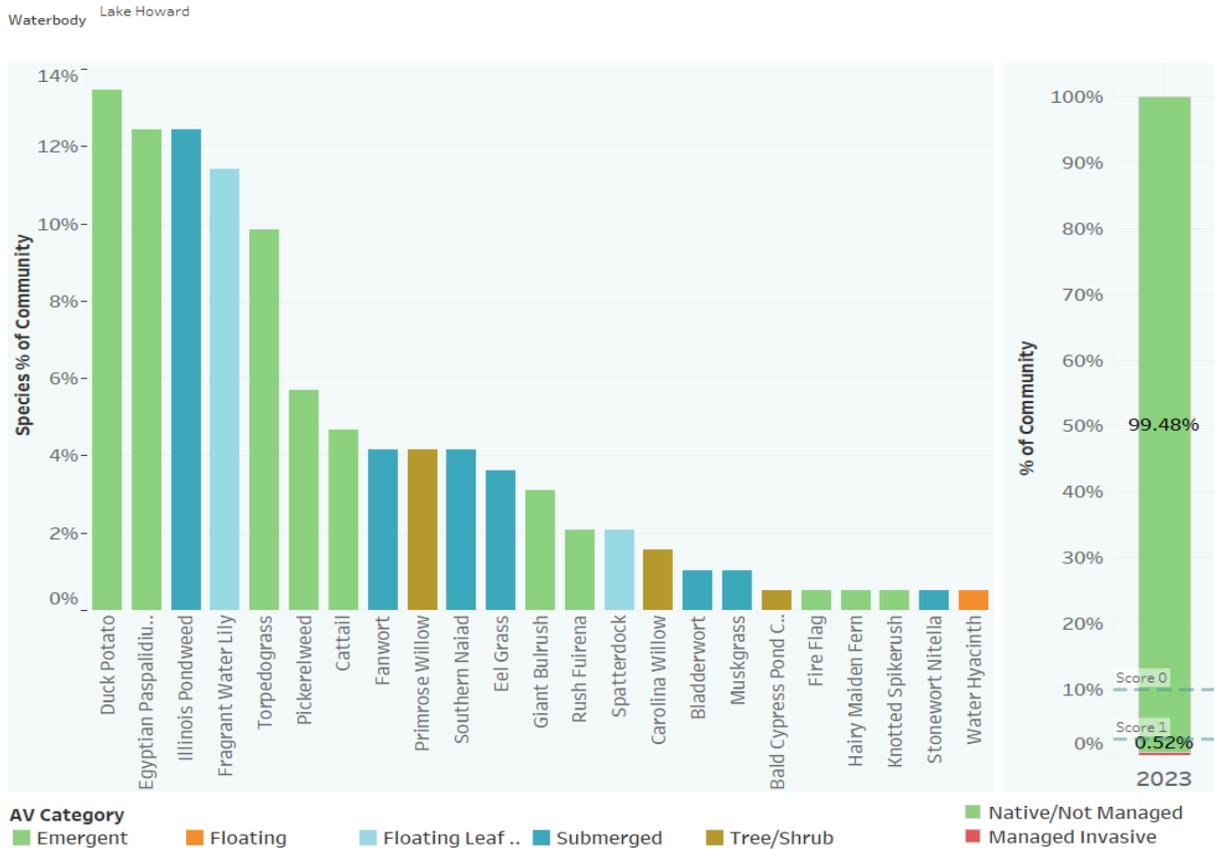


Figure 3-104. Chart depicting species frequency and invasive species percentage of Lake Howard during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, Lake Howard’s richness and overall diversity indices met or exceeded their respective median values (Figure 3-105). These were the highest index values on record for this waterbody for the 2nd year in a row. The richness comes from the detection of some less representative species like road grass and knotted spikerush. That said, overall evenness was lower than the median due to a greater disparity between the top four species and the rest. These results equate to a diversity criterion score of 2.

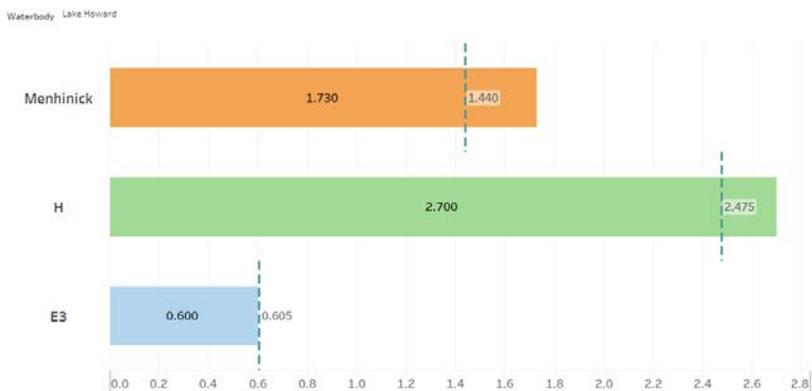


Figure 3-105. Chart depicting 2023 diversity indices for Lake Howard. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Howard’s health index scores from 2018 to 2023 shows consistently good values (Figure 3-106). In the years this monitoring has been conducted, there has been little change to Lake Howard’s water quality criteria scores. While it is impaired, Lake Howard’s water quality is trending in a positive direction. Invasive percentage has remained minimal which indicates that the lake health changes were the result of natural fluctuations in the vegetation community.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	1	3	3	2	3	3	2	NA	2.4
2019	1	3	3	2	3	2	3	3	2.5
2020	1	3	3	2	3	3	3	1	2.4
2021	1	3	3	2	3	3	3	1	2.4
2022	1	3	3	2	3	2	3	2	2.4
2023	1	3	3	3	3	2	2	2	2.4

Figure 3-106. Chart depicting a comparison of Lake Buckeye’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- In addition to stormwater inputs to the lake, the now decommissioned Jan Phyl Village Wastewater Treatment Plant was contributing point-source discharges as late as 1977. These discharges could be a source of legacy nutrients.
- Several water quality metrics are significantly correlated with Lake Howard’s surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- While not currently an issue, the management of invasive species like hydrilla is a potential concern. It can only take a single season for even a small population to take over large areas of a waterbody.

Lake Management Strategy:

- Treating stormwater from the surrounding drainage basin is one of the primary strategies for improving water quality. The City mitigates stormwater through various methods:
 - Street Sweeping over 50 miles per month in the downtown area.
 - Construction of a stormwater treatment/nature park on the south side of Lake Howard in the early 2000s.
 - Construction of an alum injection system in the mid-2000s estimated to reduce Lake Howard’s TN loads by 4% and TP loads by 15% annually.
 - The Stormwater Assessment and Improvement Project: identified priority areas for green infrastructure in southern drainage sub-basins to prevent flooding and improve water quality.
 - Construction and maintenance of other green infrastructure; including over 12 raingardens that capture the first flush of stormwater in the downtown area.

- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- A trash catchment system was installed at Heritage Park in 2020 to capture floating litter and debris from Lake Howard's largest drainage sub-basin.

Lake Idyl

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
0	0	0	0	0	3	0	1	0.5

Location, Characteristics, & Hydrology:

Lake Idyl is located to the northeast of downtown Winter Haven. It receives excess water from Lake Maude and discharges excess water via a passive overflow weir to Lake Buckeye. One of Winter Haven's smallest waterbodies, Lake Idyl is 18 acres, has an average depth of 6.7 feet, and a maximum depth of just under 10 feet (Figure 3-107).

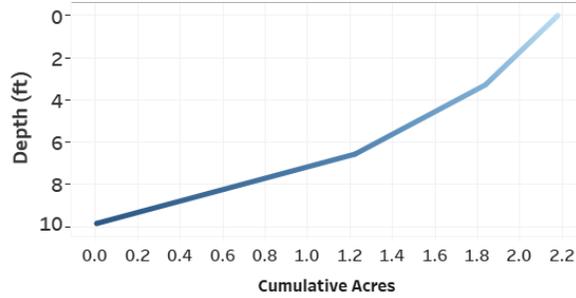


Figure 3-107. Hypsograph of Lake Idyl depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 231 acre drainage basin comprised of three separate sub-basins (Figure 3-108). Ranked by area, the primary land uses within this basin are medium-density residential, institutional, agricultural, and high-density residential. Based on pollutant load modelling, these land uses contribute 935 lbs of TN and 154 lbs of TP to the lake annually. There are six Onsite Sewage Treatment and Disposal (OSTD/septic) systems present in the drainage basin. This low density is likely not a major contributor of pollutants via groundwater leaching. Due to stormwater inputs, the City conducts street sweeping services of up to four miles on a monthly basis.

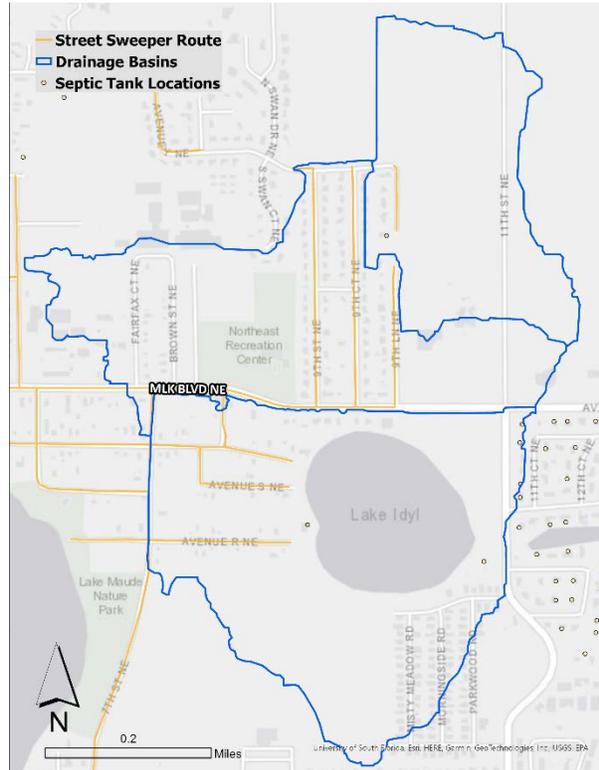


Figure 3-108. Map of Lake Idyl's drainage basin, City street sweeper routes, and nearby septic systems.

Over its period of record, Lake Idyl's surface level has fluctuated between 131.3 and 133.9 feet above sea level. The normal level range fluctuates much more narrowly between 132.3 and 132.5 feet (Figure 3-109). During 2023, Lake Idyl reached a wet season peak of 132.4 feet in September and a dry season low of 132.2 feet in March. Idyl ended the year with a surface level just below the normal range at 132.3 Changes in Lake Idyl's surface level are not significantly correlated with any of the primary water quality metrics (see appendix).

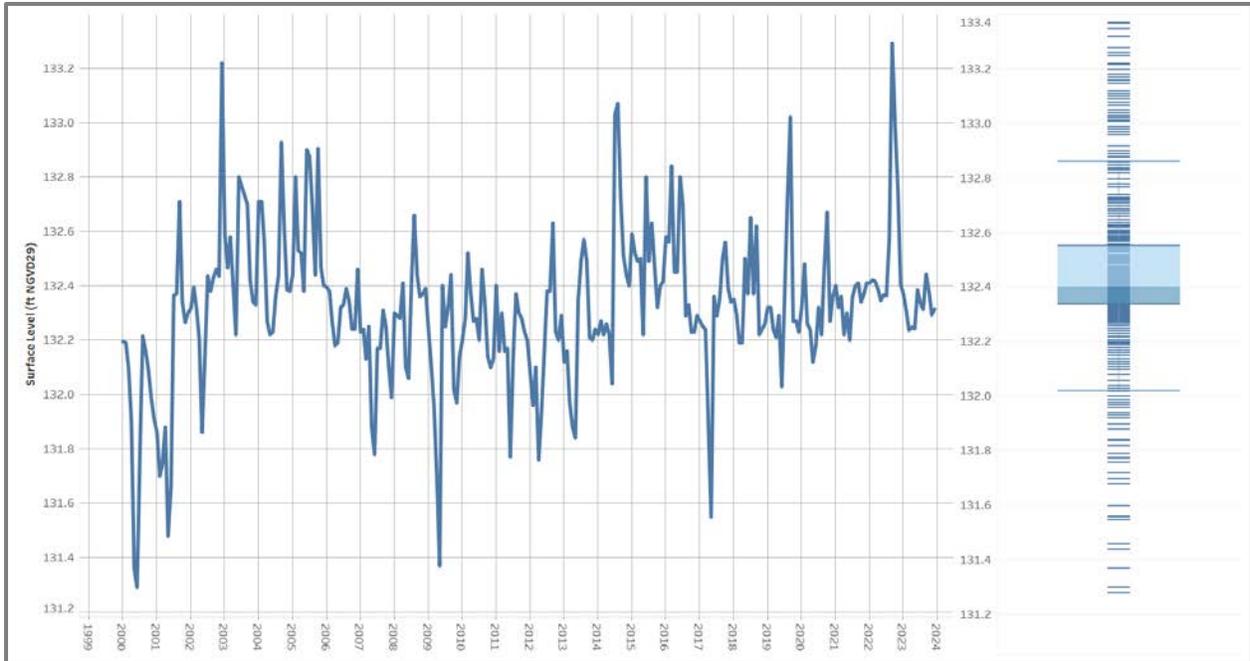


Figure 3-109. Hydrograph of Lake Idyl depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Idyl is categorized as a clear, alkaline waterbody. Due to multiple consecutive NNC exceedances during the assessment period, Lake Idyl is considered impaired for Chl-a, TN, and TP (Figure 3-110). This equates to an impairment criterion score of 0. Fortunately, the 2022 and 2023 AGM values all met their respective NNC thresholds. Water quality must continue to meet NNC guidelines for the next 7 years in order for Lake Idyl to be considered unimpaired.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on the data, all four parameters exhibit significant deteriorating trends. This shift further illustrates the need to address the water quality issues in this lake. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing (Deteriorating)	Significant	0
TN	Increasing (Deteriorating)	Significant	0
TP	Increasing (Deteriorating)	Significant	0
Secchi	Decreasing (Deteriorating)	Significant	0

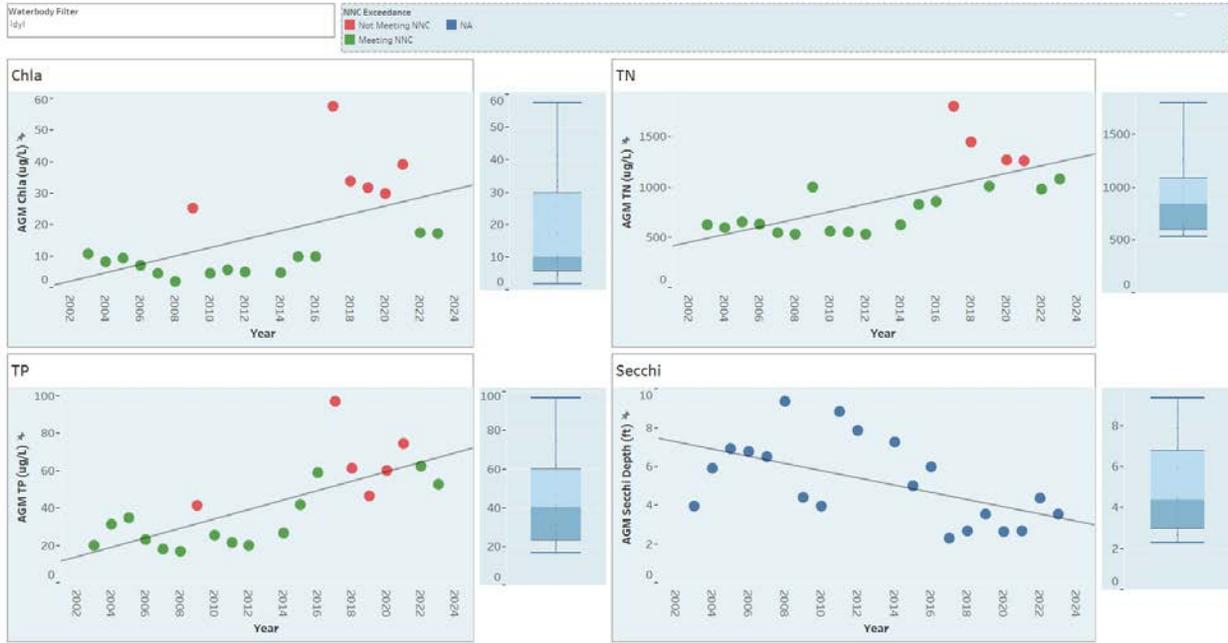


Figure 3-110. Lake Idyl AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Idyl on 1/17/2023. The PAC during this survey was 50.5% and the total BV was 4.5% (Figure 3-111). A comparison of abundance values from previous years shows that Lake Idyl typically exhibits high vegetation coverage in excess of 35%. Much of the lake is covered by spatterdock; a floating leaf plant that is usually found in shallow waters with mucky substrate.

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2023 data, over 40% of the plant community was comprised of spatterdock, followed by mostly emergent species (Figure 3-112). Managed invasive species made up 15% of the community; comprised of burhead sedge and floating water hyacinth. A comparison of data over the last six years shows that invasive presence fluctuates between 4% and 24%. The current percentage earns Lake Idyl an invasive criterion score of 0.

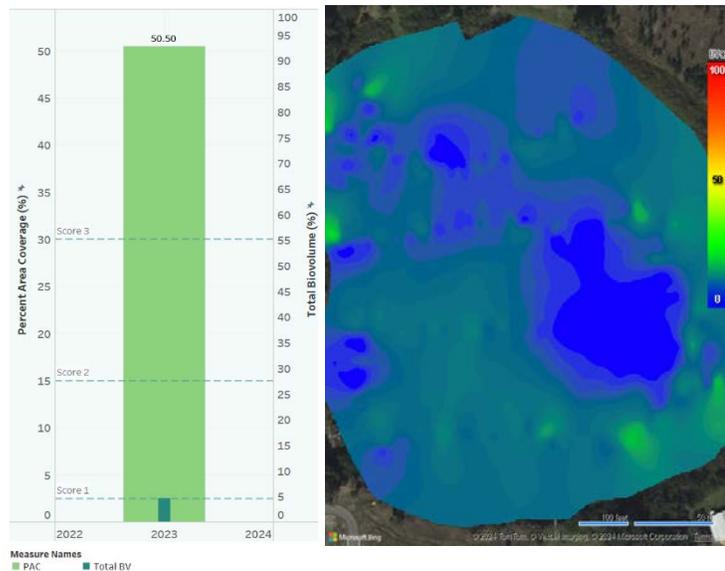


Figure 3-111. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Idyl; biovolume values range from green (lowest) to red (highest).

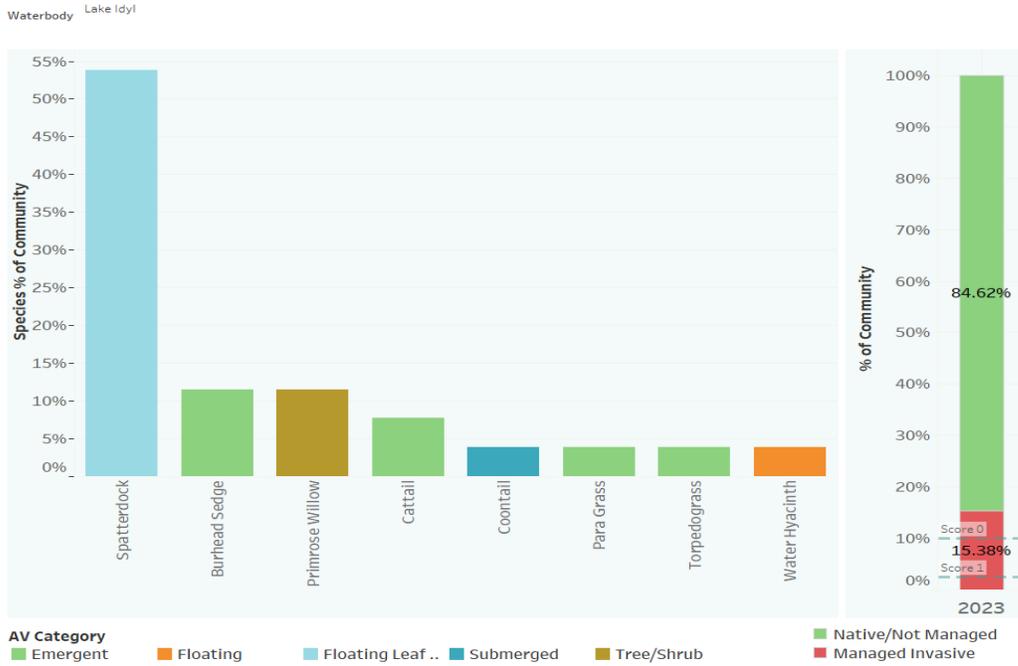


Figure 3-112. Chart depicting species frequency and invasive species percentage of Lake Idyl during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, Lake Idyl’s richness exceeded its median value (Figure 3-113). This equates to a diversity criterion score of 1. A comparison of Lake Idyl’s historic species data shows relatively low richness and diversity. There was an increase in all three diversity index values in 2020. However evenness still remains below its median value for the fourth year running. The dominance of spatterdock and primrose willow are likely the cause of the low diversity scores. That said, the mucky substrate also hinders the growth of most native submerged species.

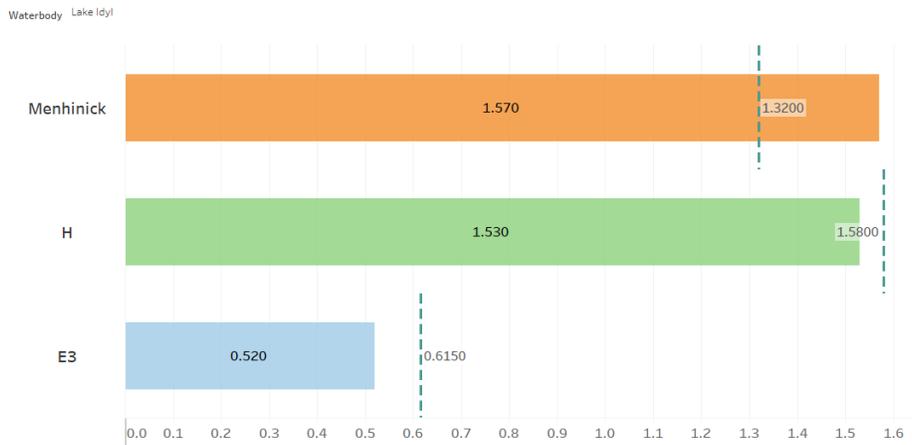


Figure 3-113. Chart depicting 2023 diversity indices for Lake Idyl. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Idyl’s health index scores from 2018 to 2023 illustrates consistently low scores (Figure 3-114). Since monitoring began, Lake Idyl has remained impaired and exhibited a decline all of its water quality trends. The presence of managed invasive species has also been a consistent issue. Species diversity varies considerably—likely due to changes in the vegetation community as a result of increased invasive species presence and subsequent management efforts. On the whole, Lake Idyl is considered a high-priority lake to focus future management efforts on.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	1	1	2	3	1	1	1.3
2019	0	1	1	1	2	1	0	1	0.9
2020	0	1	1	1	1	3	0	2	1.1
2021	0	1	1	0	1	3	0	0	0.8
2022	0	1	1	0	1	3	1	2	1.1
2023	0	0	0	0	0	3	0	1	0.5

Figure 3-114. Chart depicting a comparison of Lake Idyl’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Stormwater pollutant loading is one of the primary factors believed to be driving the decline in water quality.
- The management of invasive species and floating tussocks is a constant concern as these plants can quickly take over large areas of a lake and/or the shoreline in a single growing season.
- The dominance of spatterdock can often result in a higher occurrence of tussocks. These tussocks can present navigation, drainage, and habitat problems.

Lake Management Strategy:

- In addition to street sweeping (annual removal of 45 lbs of TN and 25 lbs of TP), the City has plans to implement a water quality restoration plan in 2024. This plan includes:
 - A raingarden at the Recreation & Cultural Center is estimated to remove 17.6 lbs of TN and 0.76 lbs of TP annually.
 - Stormwater improvements in the drainage basin which are estimated to remove 386 lbs of TN and 60 lbs of TP annually.
 - Sediment inactivation treatment designed to neutralize 1,113 lbs of bioavailable phosphorus from the lake’s sediment and water column.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Idylwild

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2	3	2	3	3	3	1	3	2.5

Location, Characteristics, & Hydrology:

Lake Idylwild is located northwest of downtown Winter Haven. As part of the South Chain of Lakes, it is connected to Lakes Cannon, Hartridge, and Jessie via navigable canals. Excess water from the South Chain discharges to the Wahneta Farms Drainage canal via a passive water control structure on the south shore of Lake Lulu. Lake Idylwild is one of the City’s smaller lakes at 95 acres, an average depth of 8.5 feet, and a maximum depth of almost 15 feet in deeper holes (Figure 3-115).

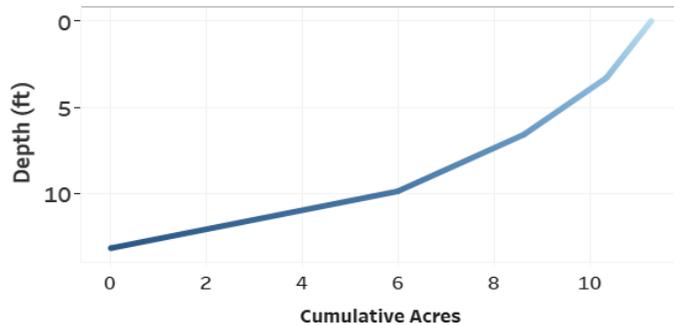


Figure 3-115. Hypsograph of Lake Idylwild depicting cumulative area a regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 225-acre drainage basin (Figure 3-116). Ranked by area, the primary land uses within this basin are medium-density residential, high-density residential, open land, commercial, and transportation. Based on pollutant load modelling, these land uses contribute 669 lbs of TN and 121 lbs of TP to Lake Idylwild annually. There are 33 known Onsite Sewage Treatment and Disposal (OSTD/septic) systems in this drainage basin. This a relatively low density, but septic systems can pose a potential pollutant loading issue. To manage stormwater from the main arterial roads to the south of the lake, the City conducts street sweeping services of up to 6 miles twice per month.

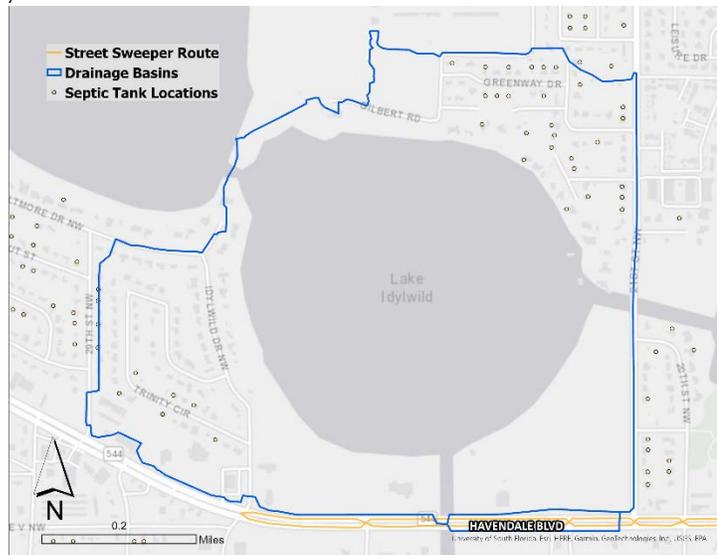


Figure 3-116. Map of Lake Idylwild’s drainage basin, City street sweeper routes, and nearby septic systems.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain’s surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the South Chain by the end of the year was slightly above the

top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake Idylwild’s surface level correlate with Chl-a, TN, and clarity (see appendix). This carries management implications as maintaining higher levels should correlate with improved water quality.

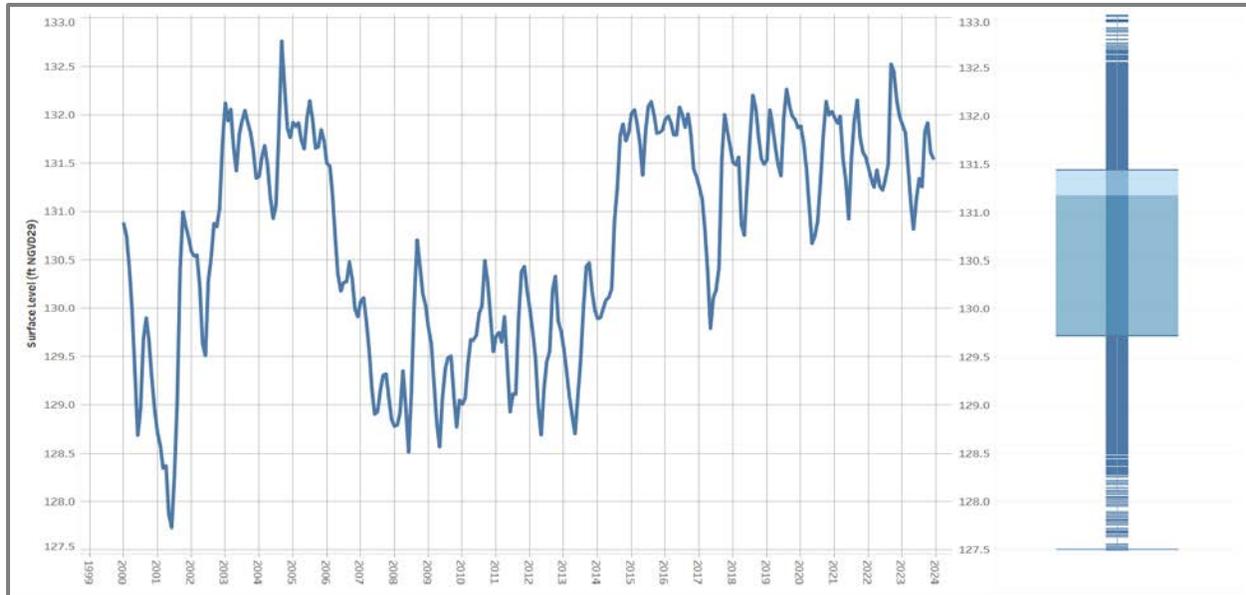


Figure 3-117. Hydrograph of Lake Idylwild depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Idylwild is categorized as a clear, alkaline waterbody. Due to consecutive NNC exceedances in 2017 and 2018, Lake Idylwild is considered impaired for Chl-a (Figure 3-118). This equates to an impairment criterion score of 2. In 2019, the FDEP established a total maximum daily load for Lake Idylwild, stipulating a 31% reduction in TN to meeting NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	2
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on the data, Chl-a, TP, and Secchi depth exhibit significant improving trends; which equate to trend criterion scores of 3. While also improving, the TN trend is not statistically significant; which results in a trend score of 2. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing	Not Significant	2
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3

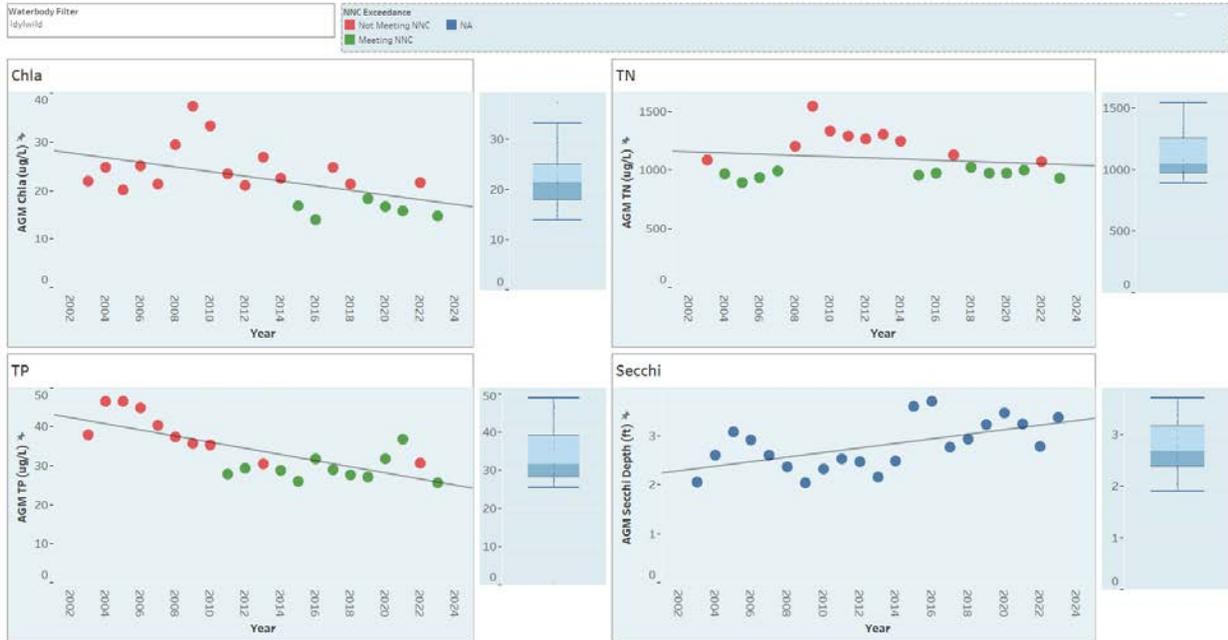


Figure 3-119. Lake Idylwild AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Idylwild on 4/28/2023. The PAC during this survey was 60.4% and the total BV was 15.7% (Figure 3-119). The 2023 coverage value was the second highest on record and equates to a vegetation abundance criterion score of 3. A comparison of abundance data since 2018 shows that Lake Idylwild consistently maintains high vegetation coverage and biovolume.

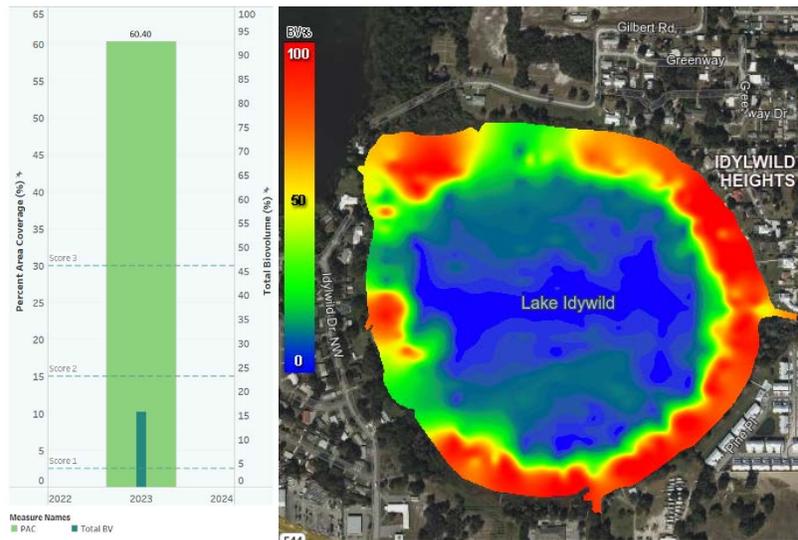


Figure 3-118. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Idylwild; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2023 survey data, native species dominated the vegetation community. The most dominant species was eelgrass at 18% (Figure 3-120). The remaining plants are a healthy mix of submerged and emergent vegetation types. Managed invasive species present were hydrilla, burhead sedge, and water hyacinth. Combined, these made up 7.4% of the community; resulting in an invasive criterion score of 1. Based on data from 2018 to 2023, the invasive percentage has consistently been between 1.75% and 7%. This indicates that invasive populations are in a relatively controlled state.

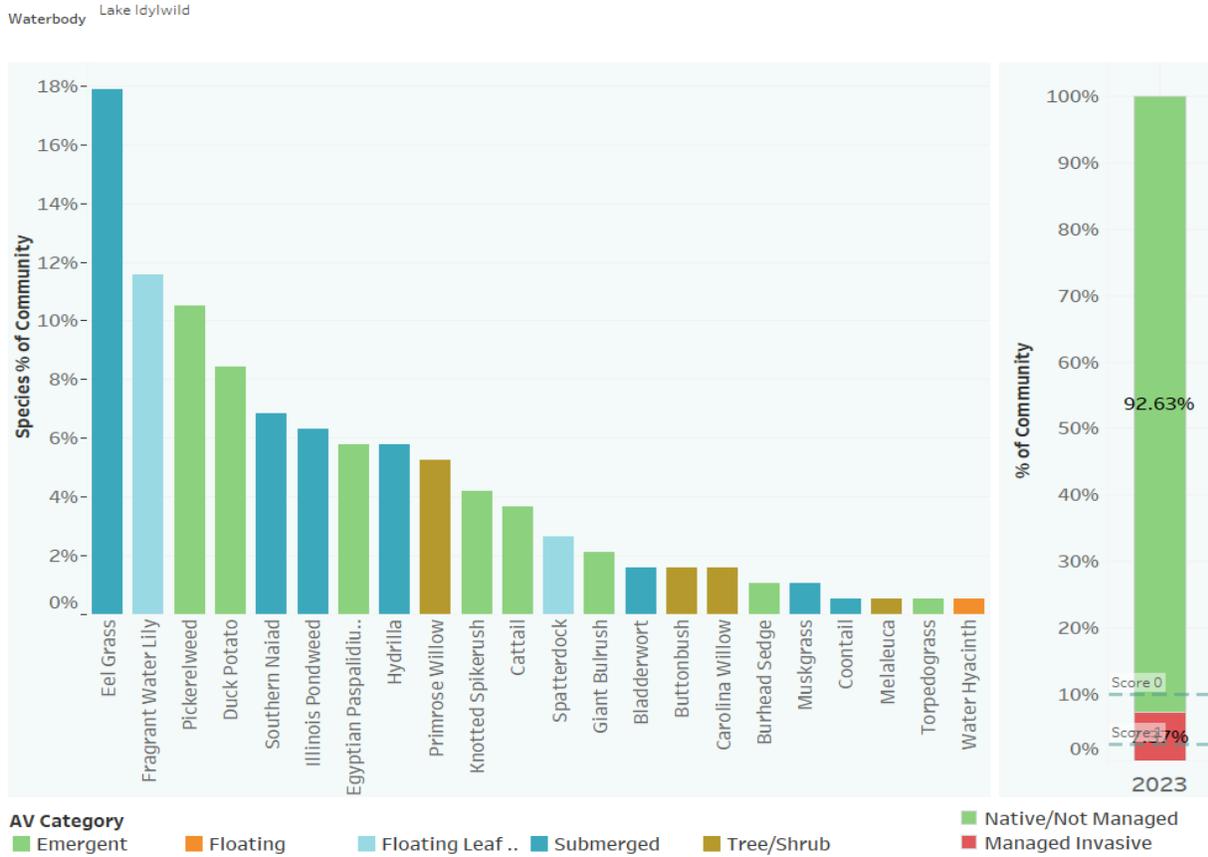


Figure 3-120. Chart depicting species frequency and invasive species percentage of Lake Idylwild during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, all three of Lake Idylwild’s diversity indices met or exceeded their respective median values (Figure 3-121). This equates to a diversity criterion score of 3. In general, the shifts in the vegetation community are the result of natural processes

since invasive species management is minimal. Continued monitoring should be prioritized to prevent the dominance of invasive species in the future.

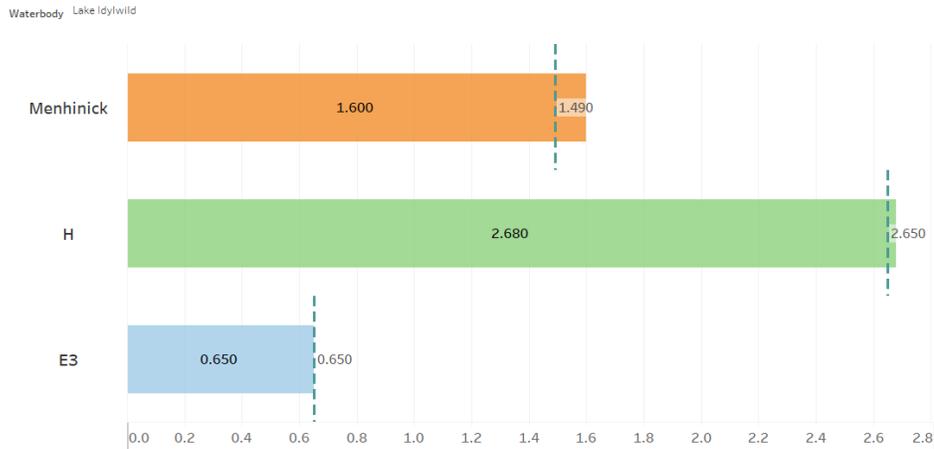


Figure 3-121. Chart depicting 2023 diversity indices for Lake Idylwild. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Idylwild’s health index scores from 2018 to 2023 shows general improvement (Figure 3-122). The majority of this has come from water quality improvements. TN began meeting the NNC guidelines in 2020—resulting in impairment score increases. The trend scores in all parameters have also improved since monitoring began. Lake Idylwild consistently maintains excellent vegetation abundance. The continual cycle of invasive species resurgence and treatment creates the annual fluctuations in the invasive and diversity scores. Ultimately, Lake Idylwild’s lake health scores have been somewhat higher than average—placing it lower on the priority ranking.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	1	2	1	3	2	3	2	1	1.9
2019	1	2	1	2	3	3	1	3	2.0
2020	1	2	2	2	3	3	1	0	1.8
2021	2	2	2	2	3	3	1	2	2.1
2022	2	2	2	2	3	3	1	2	2.1
2023	2	3	2	3	3	3	1	3	2.5

Figure 3-122. Chart depicting a comparison of Lake Idylwild’s Lake Health Index scores from 2018 to 2022.

Lake Health Impacts/Challenges:

- Several water quality metrics are significantly correlated with Lake Idylwild’s surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- The management of invasive species like hydrilla is a constant concern. It can only take a single season for even a small population to take over large areas of a waterbody.

Lake Management Strategy:

- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.
- The City currently conducts street sweeping in the basin to combat stormwater pollutant loads. Recent residential and commercial developments in the area have allowed staff opportunities to promote the Gray to Green initiative. Developers that adopt this mindset are better prepared to utilize green infrastructure in their on-site stormwater treatment.

Lake Jessie

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health Score
0	2	1	3	2	3	1	2	1.8

Location, Characteristics, & Hydrology:

Lake Jessie is located to the northwest of downtown Winter Haven. The east side of the lake is within City limits, while the west side is part of unincorporated Polk County. As part of the South Chain of Lakes, it is connected to Lake Idylwild via a navigable canal. The South Chain discharges excess water to the Wahneta Farms Drainage Canal via a passive control structure on the south shore of Lake Lulu. Lake Jessie is a moderately sized, but shallow waterbody at 192 acres, an average depth of 8 feet, and a maximum depth of around 10 feet (Figure 3-123).

Stormwater is conveyed to this waterbody from a 973-acre drainage basin (Figure 3-124). Ranked by area, the primary land uses within this basin are medium-density residential, transportation, commercial, high-density residential, and agricultural. Based on pollutant load modelling, these land uses contribute 3,871 lbs of TN and 652 lbs of TP to Lake Jessie annually. There are 111 Onsite Sewage Treatment and Disposal (OSTD/septic) systems present within the unincorporated Polk County side of the drainage basin. This constitutes a relatively high density and a potential nutrient source via septic leaching into groundwater. Lacking City-owned roadways or stormwater infrastructure on the east side of the lake, the City does not conduct any street sweeping services within this basin.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft.

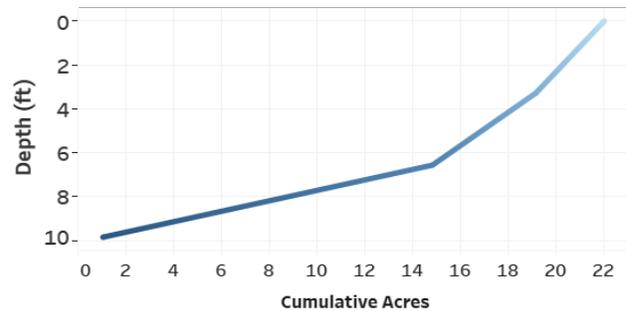


Figure 3-123. Hypsograph of Lake Jessie depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

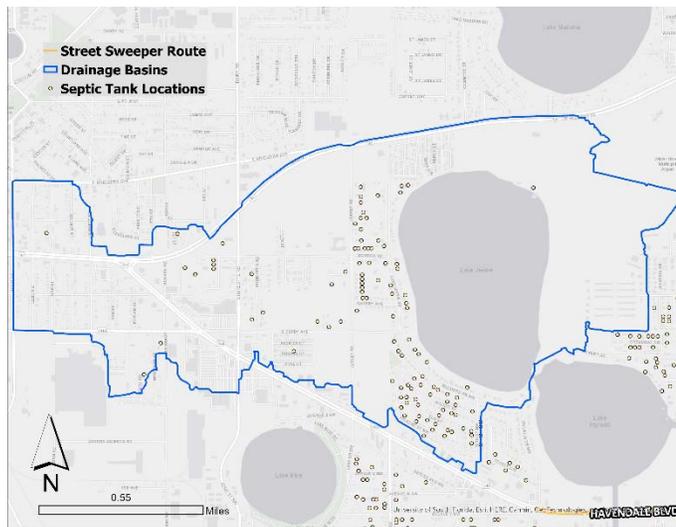


Figure 3-124. Map of Lake Jessie's drainage basin, City street sweeper routes, and nearby septic systems.

The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake Jessie’s surface level correlate with Chl-a, TN, and clarity (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.

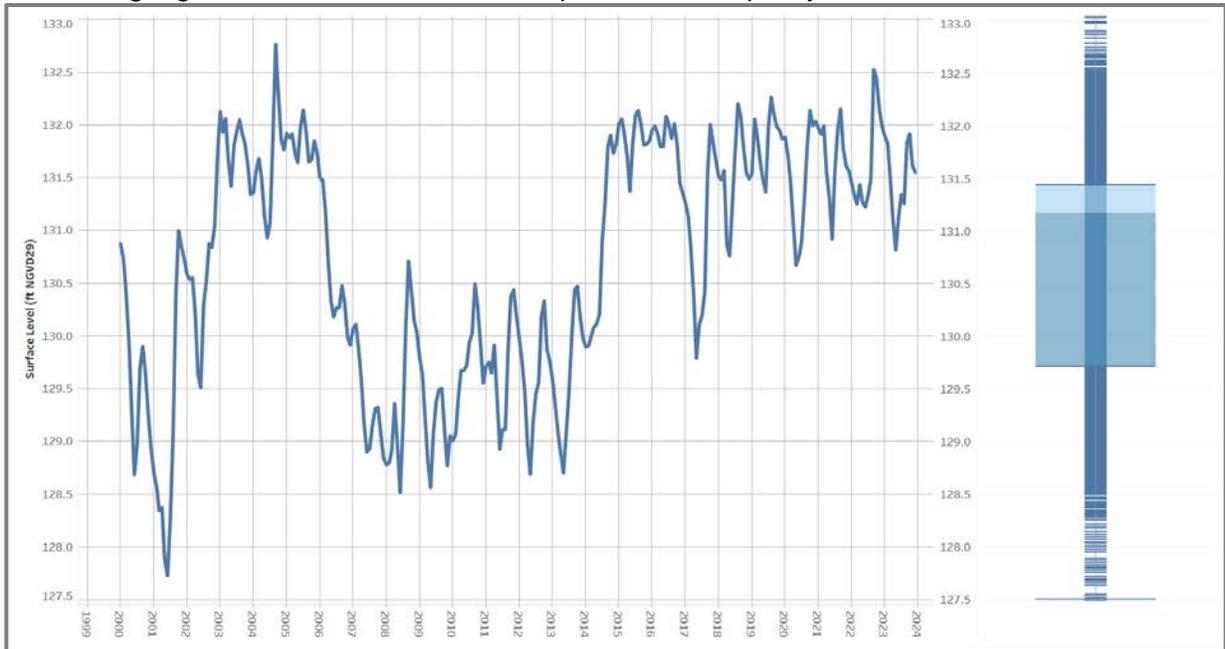


Figure 3-125. Hydrograph of Lake Jessie depicting monthly surface level readings from 2003 to 2023. A box and whisker plot details total range, median, and normal range of surface levels during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Jessie is categorized as a clear, alkaline waterbody. Due to multiple consecutive NNC exceedances during the assessment period, Lake Jessie is considered impaired for Chl-a, TN, and TP. This results in an impairment criterion score of 0. In 2019, the FDEP established a total maximum daily load for Lake Jessie, stipulating a 12% reduction in TN to meet NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Total phosphorus exhibits a significant improving trend; equating to a trend score of 3. Whereas, Chl-a and TN earn a trend criteria score of 1 for their non-significant deteriorating trends and Secchi depth receives a criteria score of 2 for improving trend (Figure 3-126). Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing	Not Significant	2
TN	Increasing	Not Significant	1
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing	Not Significant	2

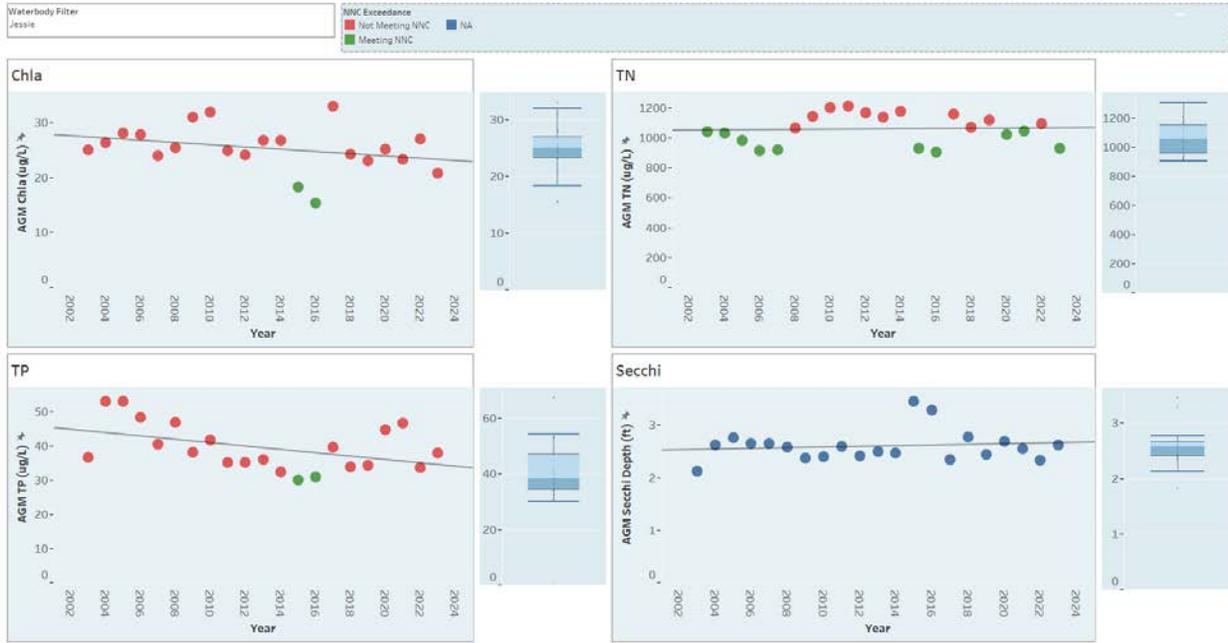


Figure 3-127. Lake Jessie AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Jessie on 2/13/2023. The PAC during this survey was 86.5% and the total BV was 47.7%; a substantial increase from previous years (Figure 3-127). A comparison of abundance data from 2018 to 2022 indicates that Lake Jessie consistently maintains coverage above 30%. This is unsurprising due to the gradual slope of the lake bed allowing for a wide littoral zone. The result is a vegetation abundance criterion score of 3.

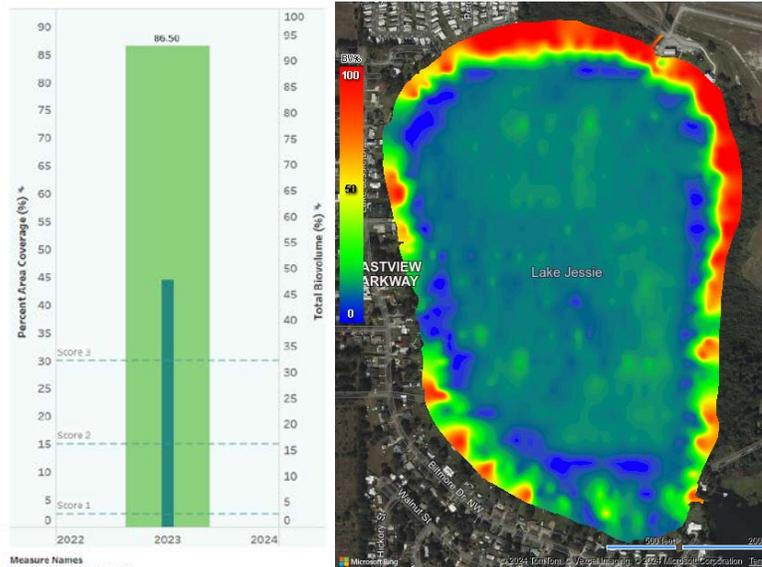


Figure 3-126. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Jessie; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, Lake Jessie is clearly dominated by eelgrass, making up 24% of species (Figure 3-128). The remaining plants are comprised of a mix of emergent, submerged, and floating leaf. With regards to managed invasive species, burhead sedge and hydrilla make up 6.8% of the community. This has resulted in an invasive criterion score of 1.

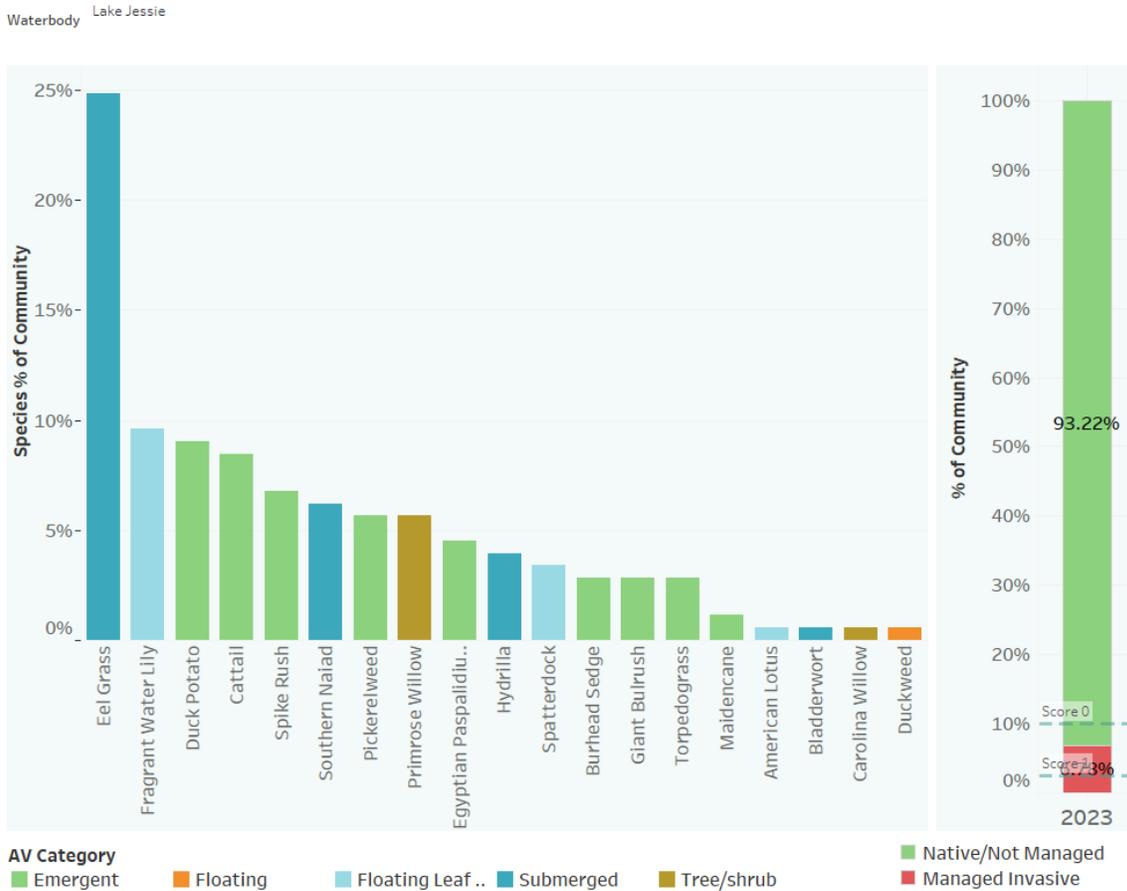


Figure 3-128. Chart depicting species frequency and invasive species percentage of Lake Jessie during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, the species evenness and overall diversity indices met or exceeded their long-term median values (Figure 3-129). While species richness is relatively high compared to other lakes, the number of unique species was not over the median value. Due to this, the 2023 diversity criterion score for Lake Jessie is 2.

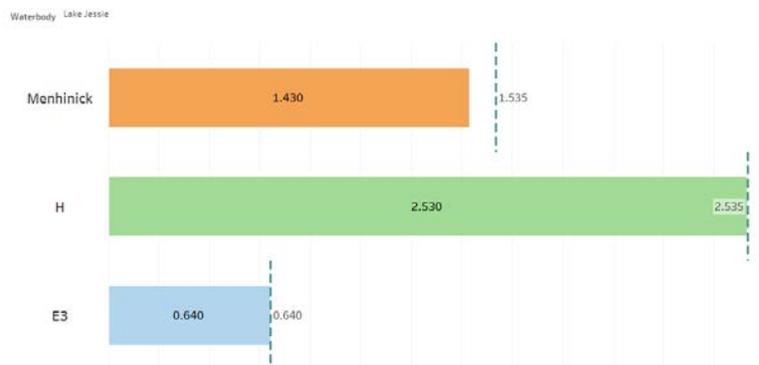


Figure 3-129. Chart depicting 2023 diversity indices for Lake Jessie. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Jessie’s health index scores from 2018 to 2023 some variability (Figure 3-130). While impairment criterion scores have not changed in this five year span, there have been some changes in trend scores. Most notable are the improvements to the Chl-a and TP trend statistics. The majority of the score variance has come from invasive species presence and species diversity. This is likely a reflection of changes in the vegetation community, due in part to the invasive species management efforts. Despite its 2023 lake health score being the highest on record, Lake Jessie’s water quality and invasive management issues place it higher on the City’s priority list for management action.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	1	3	2	3	2	1	1.6
2019	0	1	1	2	2	3	1	3	1.6
2020	0	1	1	2	2	3	1	0	1.3
2021	0	2	1	2	2	3	0	1	1.4
2022	0	1	1	2	2	3	1	1	1.4
2023	0	2	1	3	2	3	1	2	1.8

Figure 3-130. Chart depicting a comparison of Lake Jessie’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- In addition to stormwater pollutant loading, there are reports of historic wastewater treatment plant discharges for this waterbody. The volume and time frame for these discharges is unconfirmed, however. Regardless, these historic point-source pollutants could be impacting water quality now.
- The density of OSTDs within this basin could be a source for nutrient pollutant loading if they are leaching into the nearby water table.
- Several water quality metrics are significantly correlated with Lake Jessie’s surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- The management of invasive species is a constant concern for this waterbody. While invasive presence is low this year, it can take a single growing season for many of these species to take over large areas of the lake.

Lake Management Strategy:

- City staff may explore source analysis of both the historic point source and OSTD pollutant loading. Future management actions may involve sediment removal/inactivation and/or septic-to-sewer conversion.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response is the best management strategy to prevent large-scale herbicide treatments and the water quality issues that can follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Link

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	1	2	1	1	3	2	1	1.8

Location, Characteristics, & Hydrology:

Lake Link is located to the east of downtown Winter Haven. The north side of the lake is within City limits, but the south, east, and west sides are located in unincorporated Polk County. Excess water flows to Lake Link from Lake Otis through a navigable canal. It then discharges excess water downstream to Lake Mariam via a passive control structure. Based on these factors, Lake Link is considered part of the South Central Lakes group. Link is a small but deep waterbody at 29 acres, an average depth of 8.8 feet, and a maximum depth in some deeper holes at 24 feet (Figure 3-131). This is representative of a classic sinkhole lake.

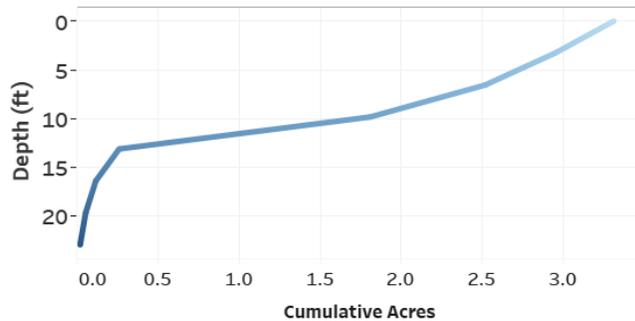


Figure 3-131. Hypsograph of Lake Link depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 63-acre drainage basin comprised of four separate sub-basins (Figure 3-132). Ranked by area, the land uses within this drainage area are medium-density residential, wetlands, and institutional. Based on pollutant load modelling, the drainage basin contributes 197 lbs of TN and 32 lbs of TP to Lake Link annually. There are 15 Onsite Sewage Treatment and Disposal (OSTD/septic) systems present within Link’s drainage basin. This constitutes a low density and likely doesn’t contribute much pollutant loading. To combat stormwater loading, the City conducts street sweeping services of 2.9 miles per month along the north side of the drainage basin.

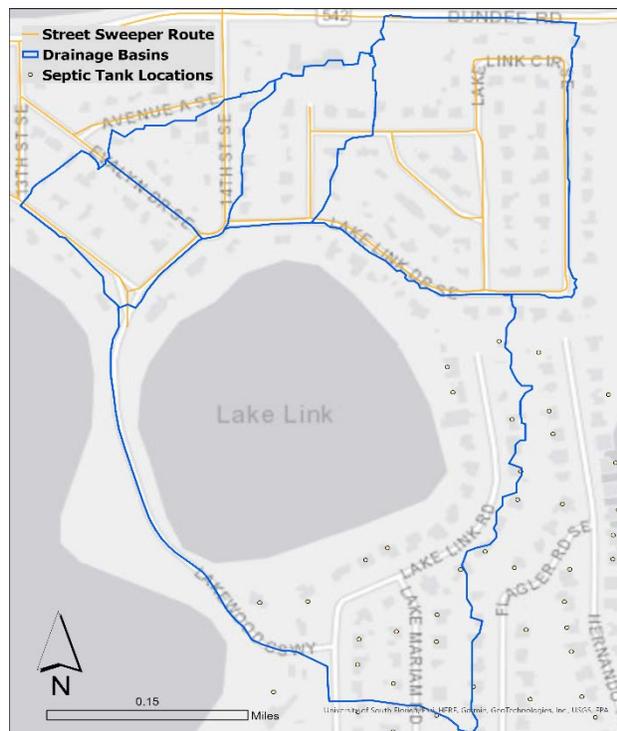


Figure 3-132. Map of Lake Link’s drainage basin, City street sweeper routes, and nearby septic systems.

Over its period of record, the shared surface level of Lakes Link and Otis has fluctuated between 120.3 and 128.8 feet above sea level. The wide range of fluctuation (without flooding the nearby residents) is possible because of the steep-sloped morphology of these lakes. The normal range of fluctuation is much narrower—between 124.9 and 127.2 feet (Figure 3-133). During 2023, Lake Link reached a wet

season peak of 126.9 feet in June and a dry season low of 126.2 feet in May. The surface level ended the year below the median at 126.4 feet. According to linear regression analysis, changes in Lake Link’s surface level are inversely correlated with TN and TP concentrations (see appendix). This carries management implications as an increase in level should result in improved water quality.

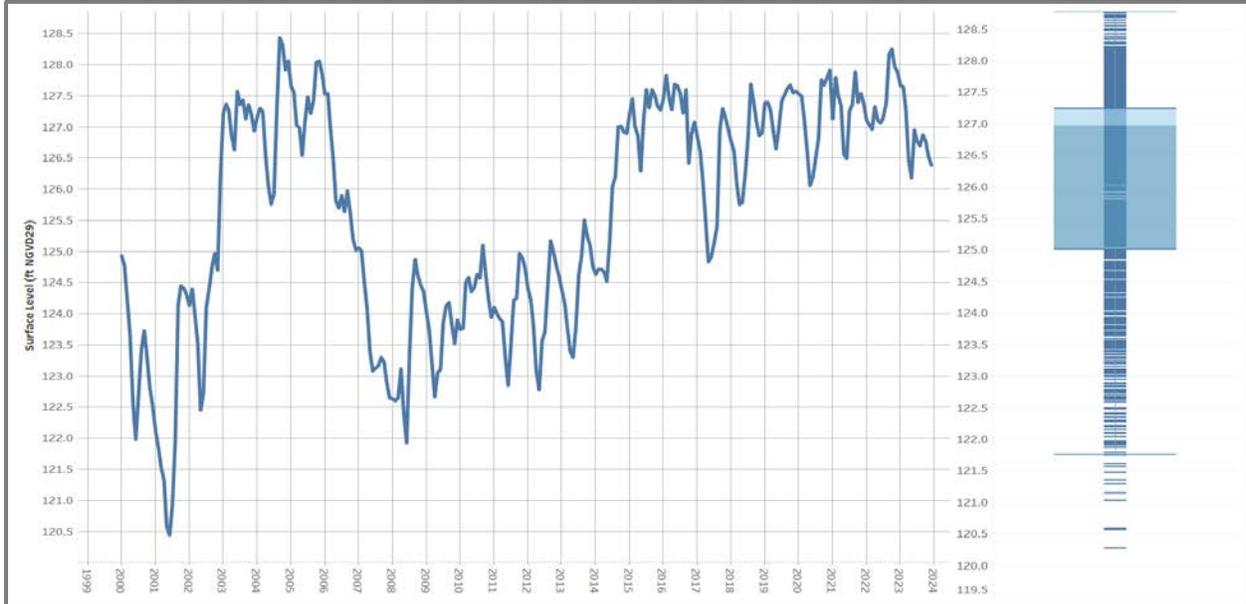


Figure 3-133. Hydrograph of Lake Link depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria, Lake Link is categorized as a clear, alkaline waterbody. Based on the water quality data, Lake Link has not exhibited NNC exceedances in any of the primary water quality parameters during the assessment period (Figure 3-134). This equates to an impairment criterion score of 3. The only NNC exceedances on record took place in 2001. Since then, Lake Link has exhibited excellent water quality.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on the data, TN exhibits a non-significant improving trend; resulting in a trend criterion score of 2. Chl-a, TP, and Secchi depth all exhibit non-significant deteriorating trends which equate with criteria scores of 1. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing	Not Significant	1
TN	Decreasing	Not Significant	2
TP	Increasing	Not Significant	1
Secchi	Decreasing	Not Significant	1

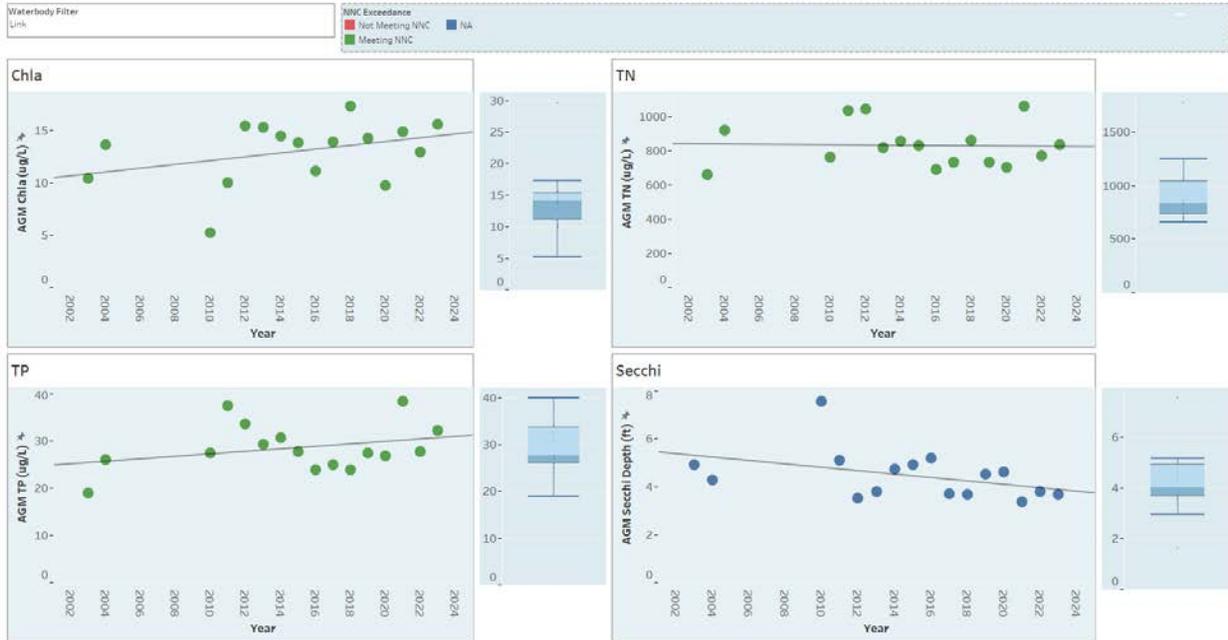


Figure 3-134. Lake Link AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Link on 9/15/2023. The PAC during this survey was 34.9% and the total BV was 4.6% (Figure 3-135). This equates to an abundance criterion score of 3. Over the period of record, Lake Link has had generally high abundance values. Management of invasive species like hydrilla is the primary driver behind changes in coverage and biovolume.

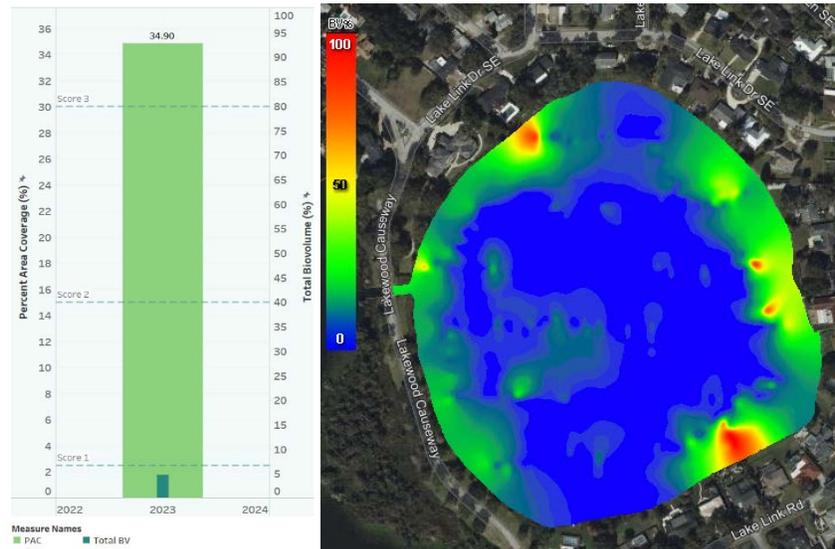


Figure 3-135. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Link; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2023 survey, Lake Link exhibited a more even mix of floating-leaf, emergent, and submerged species compared to previous years. Coontail saw a large increase and is now the second most dominant species in the lake at 16% of the community (Figure 3-136). Burhead sedge was the only managed invasive species detected, making up just 2% of the community. Hydrilla had been prevalent in Lake Link in previous years, but small-scale treatments have functionally eradicated it for now. Lake Link scores a 2 for its 2023 invasive species management criterion score.

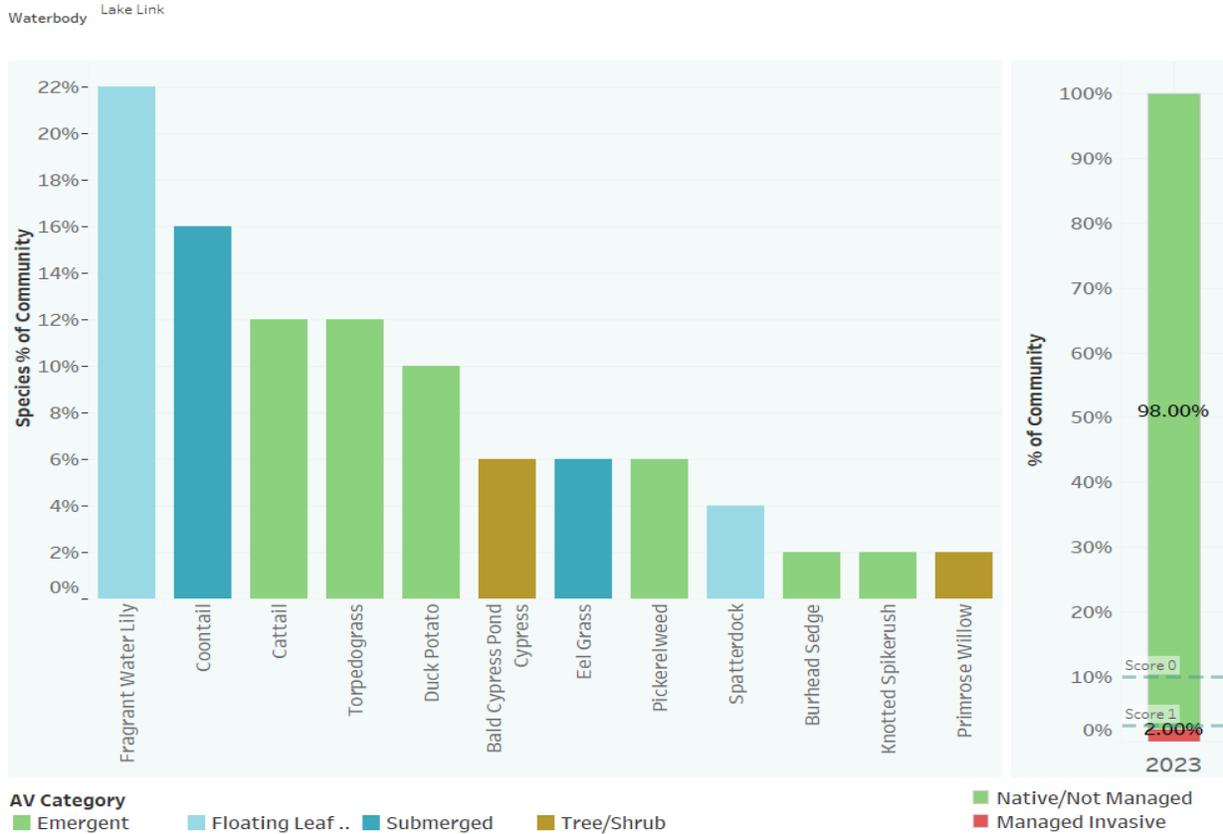


Figure 3-136. Chart depicting species frequency and invasive species percentage of Lake Link during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, only Lake Link’s richness index met its long-term median value; for a diversity criterion score of 1 (Figure 3-137). There was only a slight decrease in the evenness and overall diversity index values from 2022 to 2023. This is likely due to minor changes in the vegetation community. It should be noted that these swings are more pronounced due to a lack of species data from 2019 and 2020. Further monitoring is necessary to gain a better picture of the natural changes in the vegetation community.

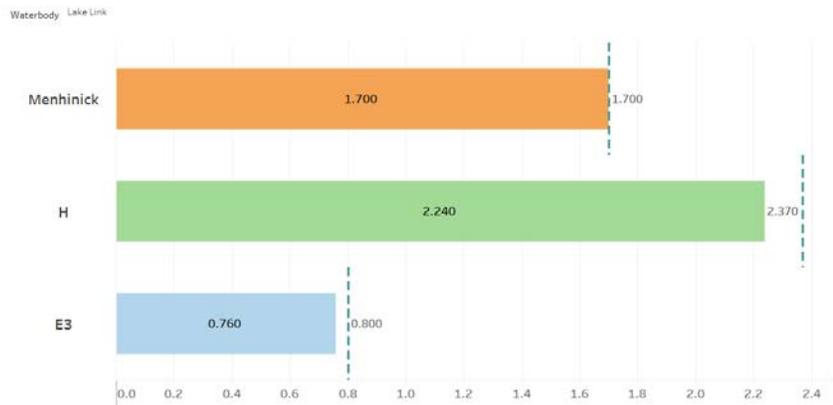


Figure 3-137. Chart depicting 2023 diversity indices for Lake Link. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Link’s health index scores from 2018 to 2023 shows some decline from the middle to lower 2’s (Figure 3-138). While this is a decrease in overall lake health, it should be noted that the 2019 and 2020 scores were artificially higher due to a lack of biological data to balance the water quality scores. Based on the 2018 score, it appears that invasive species management has been a constant issue. The treatment of invasive species has likely caused the declines in abundance and diversity. It remains to be seen if these effects will continue into subsequent years. Overall, Lake Link is lower on the priority list due to its excellent water quality, but the shift in trend scores in 2023 should be monitored closely to ensure that water quality does not decline in the future.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	2	3	2	2	3	0	2	2.1
2019	3	2	3	2	2	NA	NA	NA	2.4
2020	3	2	3	2	2	3	NA	NA	2.5
2021	3	2	3	2	2	2	1	1	2.0
2022	3	2	3	2	2	2	1	1	2.0
2023	3	1	2	1	1	3	2	1	1.8

Figure 3-138. Chart depicting a comparison of Lake Link’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Link currently exhibits healthy water quality. However, pollutant loading via stormwater and other sources is a potential concern if water quality trends begin deteriorating.
- The management of invasive species like hydrilla has been a consistent concern. It can only take a single growing season for even a small population to take over large areas of a waterbody.
- Several water quality metrics are significantly correlated with Lake Link’s surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- The City currently conducts street sweeping in the northern drainage sub-basins. Since much of the zoning in this basin is residential, public outreach and education are ideal management strategies. Education aims to increase residents’ knowledge of best stormwater practices and ways they can collectively reduce their pollutant load.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Lulu

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
0	3	3	3	3	3	1	3	2.4

Location, Characteristics, & Hydrology:

Lake Lulu is located south of downtown Winter Haven. Its northwest and southeast shores are bordered by City limits while the northeast and southwest shores are in unincorporated Polk County. As part of the South Chain of Lakes, Lulu connects with Lake Eloise and Shipp via navigable canals. The South Chain discharges excess water to the Wahnetta Farms Drainage Canal via a passive control structure on the south shore of Lake Lulu. One of Winter Haven’s larger waterbodies, it has a total area of 320 acres, an average depth of 6 feet, and a maximum depth of 9.6 feet (Figure 3-139).

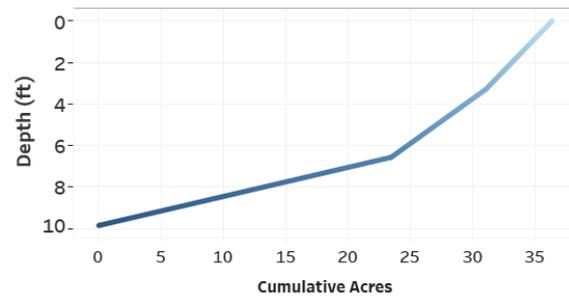


Figure 3-139. Hypsograph of Lake Lulu depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 1,006 acre drainage basin comprised of 13 individual sub-basins (Figure 3-140). Ranked by area, the primary land uses in this drainage area are commercial, medium-density residential, wetlands, agricultural, and high-density residential. Based on stormwater pollutant modelling, this basin contributes 2,791 lbs of TN and 483 lbs of TP to Lake Lulu annually. There are 46 Onsite Sewage Treatment and Disposal (OSTD/septic) systems located within the County portion of the basin. This constitutes a moderate density which can have potential impacts on water quality. To combat stormwater pollutant loading, the City conducts 11.6 miles of street sweeping monthly for residential roads and twice monthly for larger roadways.

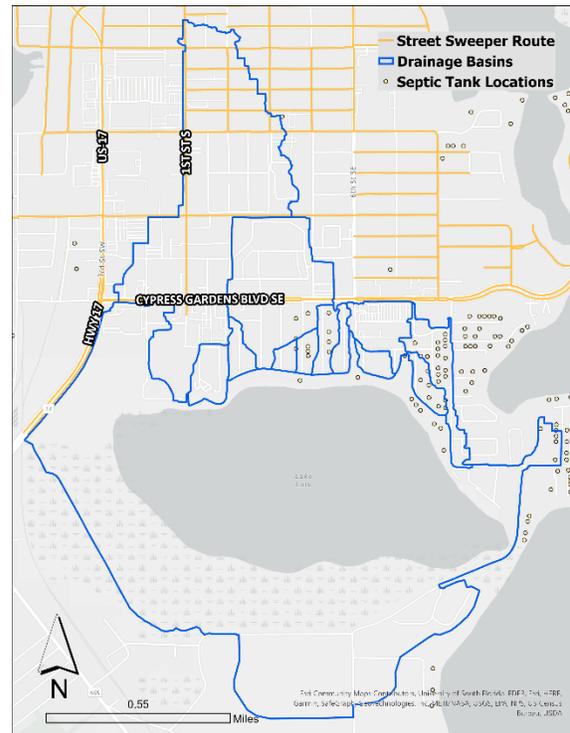


Figure 3-140. Map of Lake Lulu’s drainage basin, City street sweeper routes, and nearby septic systems.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain’s surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the

South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake Lulu’s surface level correlate with TN and clarity (see appendix). This carries management implications as an increase in levels should result in improved water quality.

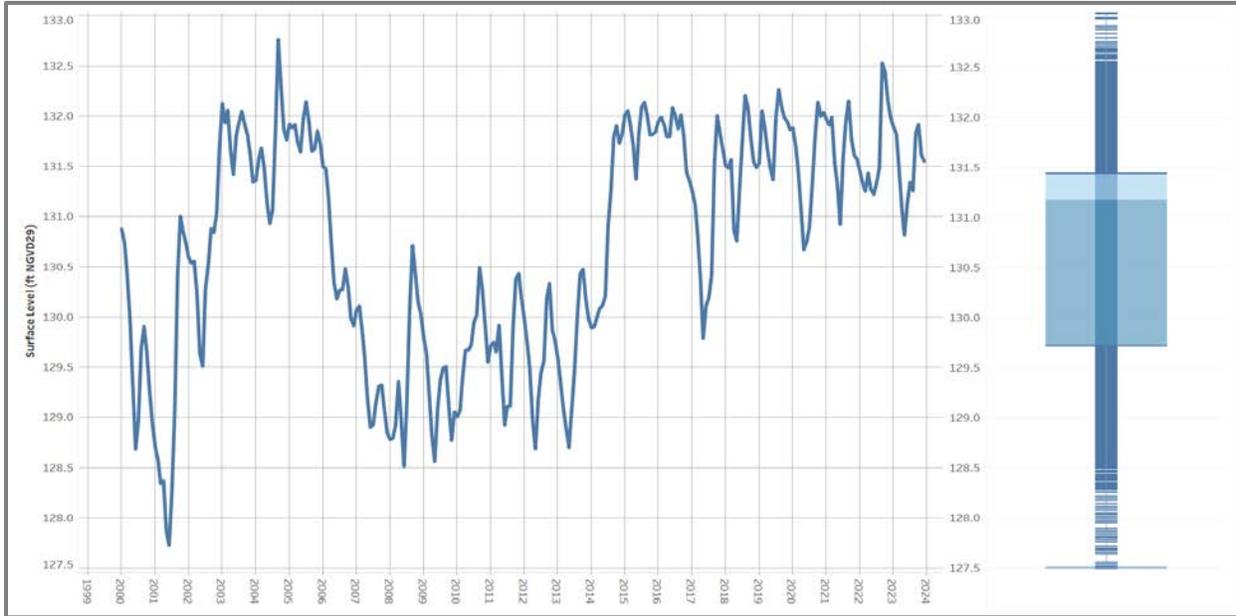


Figure 3-141. Hydrograph of Lake Lulu depicting monthly surface level readings from 2000 to 2023. A box and whisker plot detail total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Lulu is categorized as a clear, alkaline waterbody. Due to consistent NNC exceedances during the assessment period, Lake Lulu is considered impaired for Chl-a, TN, and TP (Figure 3-142). This equates to an impairment criterion score of 0. In 2019, the FDEP established a total maximum daily load for Lake Lulu stipulating a 35% reduction in TN in order to meet NNC guidelines. It should be noted that the 2022 AGM values were below NNC impairment thresholds for Chl-a, TN, and TP.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on these data, all four of these parameters exhibit significant improving trends. While on the right track, it will still take some time for water quality values to consistently meet NNC guidelines for Lake Lulu to be considered unimpaired.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3

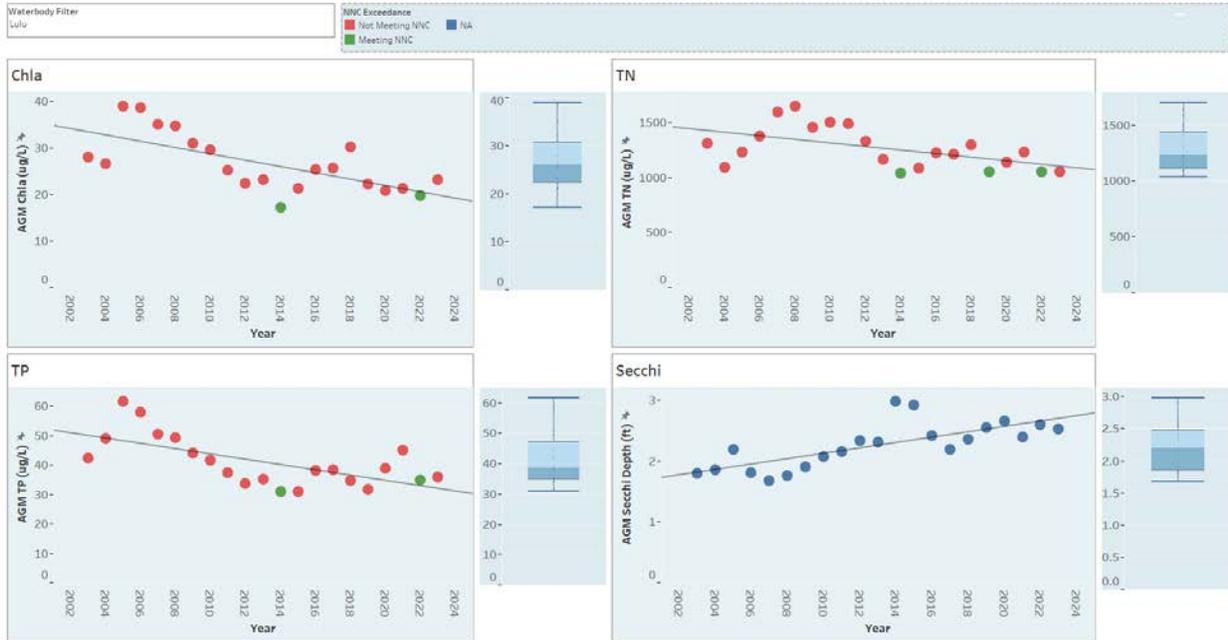


Figure 3-142. Lake Lulu AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Lulu on 6/15/2023. The PAC during this survey was 46.3% and the total BV was 12.21% (Figure 3-143). This equates to a vegetation abundance criterion score of 3. Lake Lulu has traditionally supported high vegetation abundance due to its shallow depth and gradually sloping lake bed. The abundance observed during 2023 is currently the highest on record.

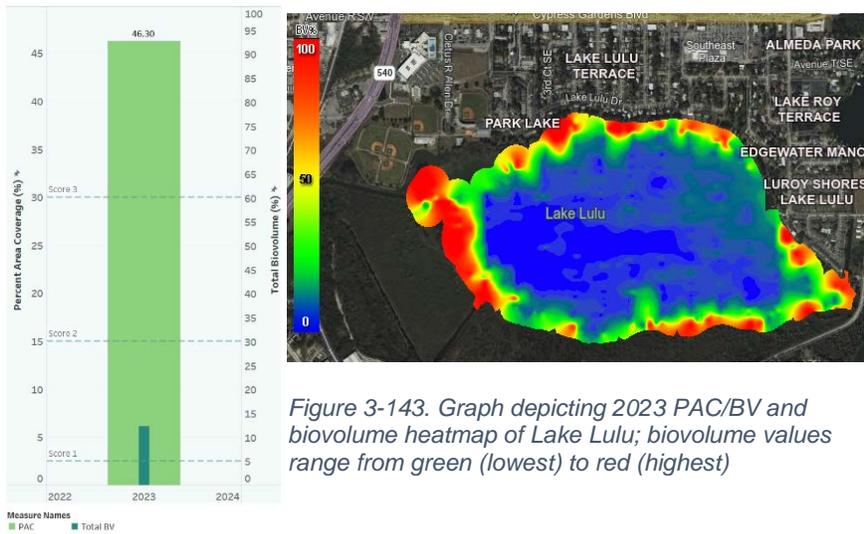


Figure 3-143. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Lulu; biovolume values range from green (lowest) to red (highest)

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, Lake Lulu maintains a healthy mix of submerged, emergent, and floating leaf plants. The most dominant species present is the native fragrant water lily at 12% (Figure 3-143). Hydrilla and water hyacinth constitute the managed invasive species detected during the survey at 3.12%. While a minor contributor to the whole community, this percentage equates to an invasive criterion score of 1. Throughout the period of

record, the invasive presence in Lake Lulu has traditionally fluctuated between zero and four percent—requiring continual maintenance to keep invasives from expanding.

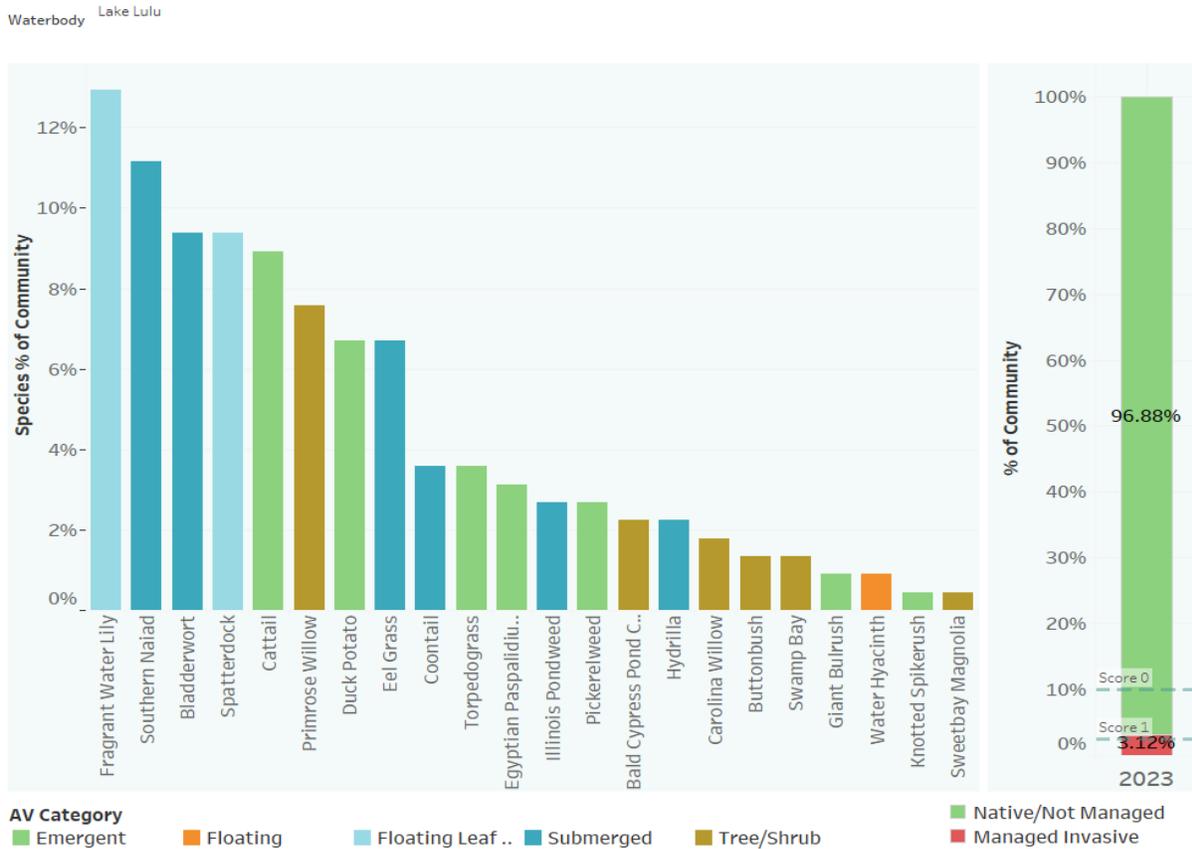


Figure 3-144. Chart depicting species frequency and invasive species percentage of Lake Lulu during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, all three of Lake Lulu’s diversity indices met or exceeded their respective median values (Figure 3-145). This equates to a diversity criterion score of 3. While varying slightly, Lake Lulu’s diversity has been consistently above average during the last three years. The overall vegetation community has been relatively diverse through the period of record. A portion of this diversity may be due to the undeveloped shoreline to the south of the lake. A lack of disturbance on this shoreline may provide an opportunity for smaller or less robust species to survive.

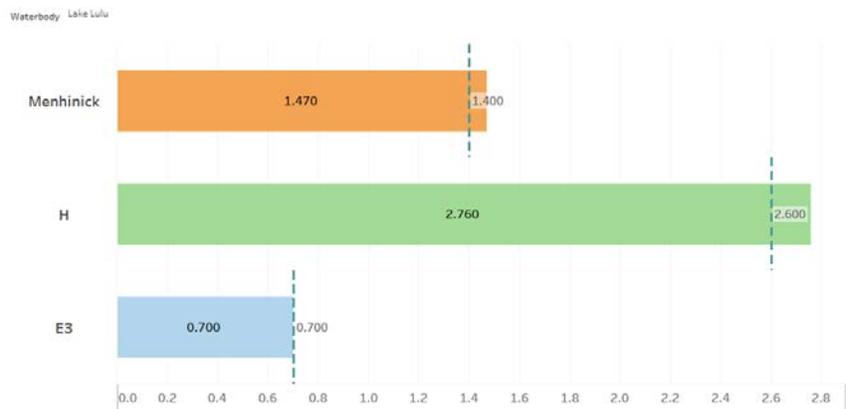


Figure 3-145. Chart depicting 2023 diversity indices for Lake Lulu. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Lulu’s health index scores from 2018 to 2023 shows some improvement, increasing from 2.1 to 2.4 (Figure 3-146). Regarding the water quality metrics, impairment hasn’t changed. However, TN concentrations began to exhibit significant improving trends starting in 2020. From a biological perspective, Lake Lulu has consistently maintained high vegetation abundance. However, the invasive presence and diversity metrics have been the largest source of score fluctuation. This is mostly due to cycles of invasive expansion and subsequent management efforts. Overall, Lake Lulu is lower on the priority list, but also a lake to keep a close eye on to ensure that it continues to improve.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	3	2	3	3	3	1	1	2.0
2019	0	3	2	3	3	3	2	1	2.1
2020	0	3	3	3	3	3	3	1	2.4
2021	0	3	3	3	3	3	2	3	2.5
2022	0	3	3	3	3	3	1	3	2.4
2023	0	3	3	3	3	3	1	3	2.4

Figure 3-146. Chart depicting a comparison of Lake Lulu’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- In addition to stormwater and potential OSTD pollutant loads, Lake Lulu received historic point-source discharges from a now defunct City wastewater treatment plant as well as several citrus fertilizer processing facilities. These historic pollutant loads may contribute to internal nutrient loading from the legacy sediments.
- The management of invasive species remains a consistent concern. Species like hydrilla can take over large areas of a waterbody in a single growing season.
- Several water quality metrics are significantly correlated with Lake Link’s surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- City staff may explore source analysis of both the historic point-source and OSTD pollutant loading. Future management actions may involve sediment removal/inactivation, septic-to-sewer conversion, and stormwater infrastructure improvements.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- In addition to street sweeping, the City combats stormwater loading through an alum injection system designed to reduce TN loads by 8% and TP loads by 21% annually. The

Lake Mariam

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	0	2	1	2	3	0	3	1.8

Location, Characteristics, & Hydrology:

Lake Mariam is located far to the east of downtown Winter Haven. The City limits border the lake along the north and east sides while the remainder of the waterbody is surrounded by unincorporated Polk County. Lake Mariam receives excess water from Lake Link and discharges its own excess water to the Peace Creek via a series of ditches. Lake Mariam is a moderately sized, but very shallow waterbody at 193 acres, an average depth of 4.8 feet, and a maximum depth of around 8 feet (Figure 3-147). The shallow nature of this waterbody likely contributes to higher sediment suspension.

Stormwater is conveyed to this waterbody from a 622 acre drainage basin (Figure 3-148). Ranked by area, the primary land uses within this basin are medium-density residential, wetlands, commercial, and high-density residential. Based on pollutant load modelling, this basin contributes 1609 lbs of TN and 275 lbs of TP to Lake Mariam annually. There are 132 Onsite Sewage Treatment and Disposal (OSTD/septic) systems located within this drainage area. This constitutes a moderate density and may be a potential contributor of nutrient loading via groundwater leaching. To combat stormwater loading, the City conducts 1.9 miles of street sweeping per month on residential roads and twice monthly on Dundee Rd.

Over the period of record, Lake Mariam’s surface level has fluctuated between 120.5 and 125.8 feet above sea level. The normal range for this waterbody is between 122.2 and 124.5 feet (Figure 3-149). During 2023, Lake Mariam’s level dropped from 124.5 feet in January to a low of 123.3 in May. The surface level ended the year right at the median of 123.5 feet. Changes in Lake Mariam’s surface level are not correlated with its water quality metrics (see appendix).

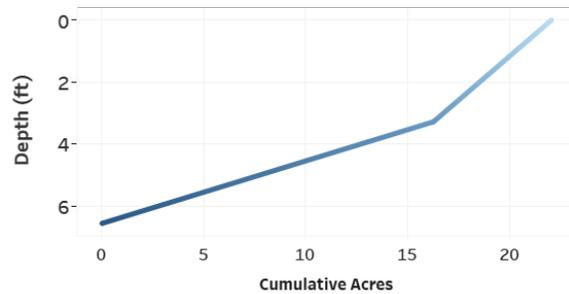


Figure 3-147. Hypsograph of Lake Mariam depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

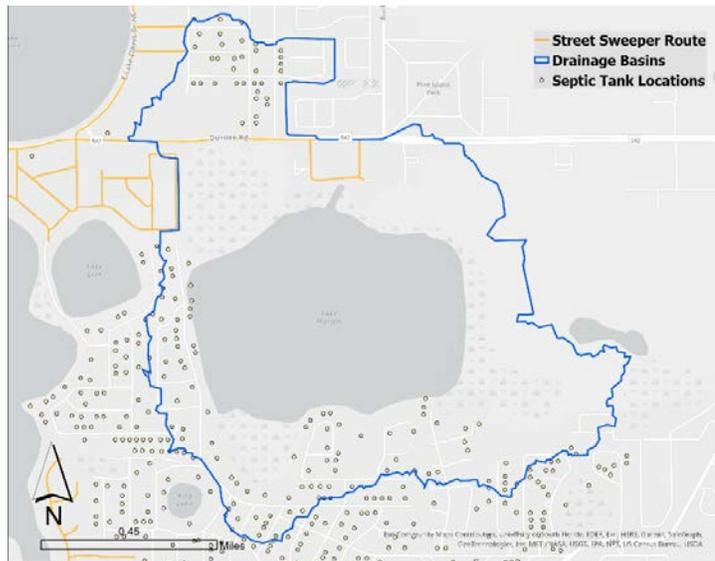


Figure 3-148. Map of Lake Mariam’s drainage basin, City street sweeper routes, and nearby septic systems.

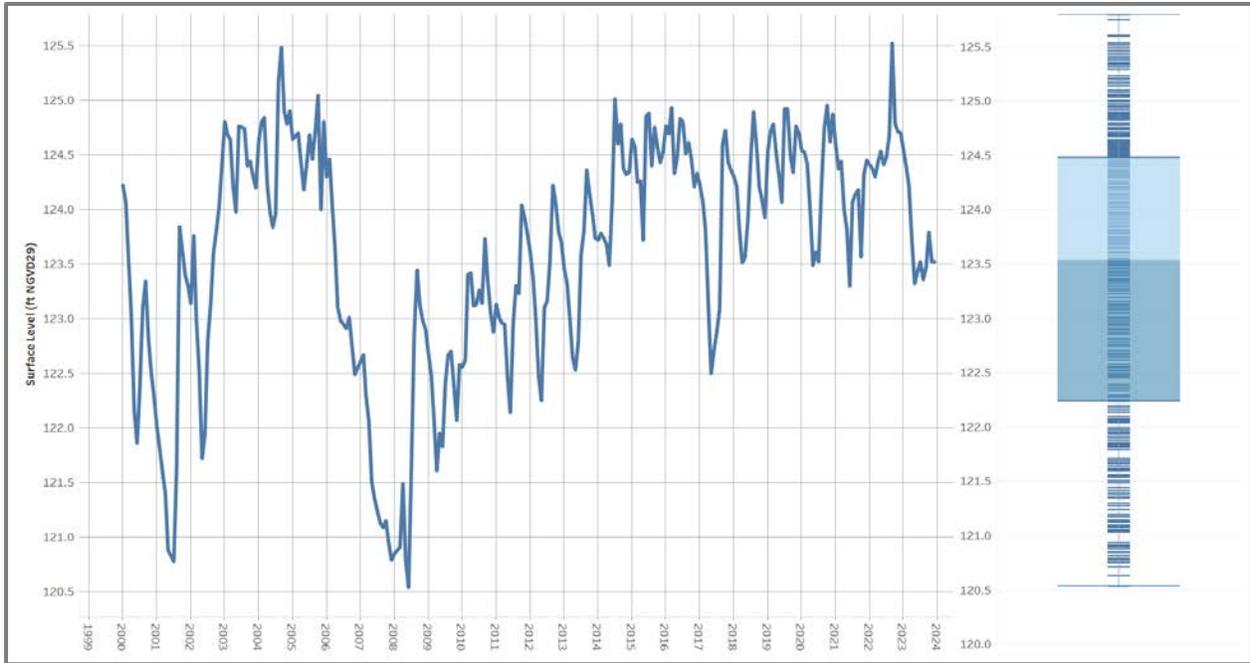


Figure 3-149. Hydrograph of Lake Mariam depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Mariam is categorized as a high-color waterbody. Based on the water quality data, Lake Mariam exhibited no NNC exceedances during the assessment period (Figure 3-150). This equates to an impairment criterion score of 3.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on these data, Chl-a exhibits a significant deteriorating trend, earning a score of 0. The remaining parameters exhibit non-significant trends; TP is gradually deteriorating while TN and Secchi depth. Individual AGM values and trend statistics can be found in the appendix while the criterion index scores are shown in the table below.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing (Deteriorating)	Significant	0
TN	Decreasing	Not Significant	2
TP	Increasing	Not Significant	1
Secchi	Increasing	Not Significant	2

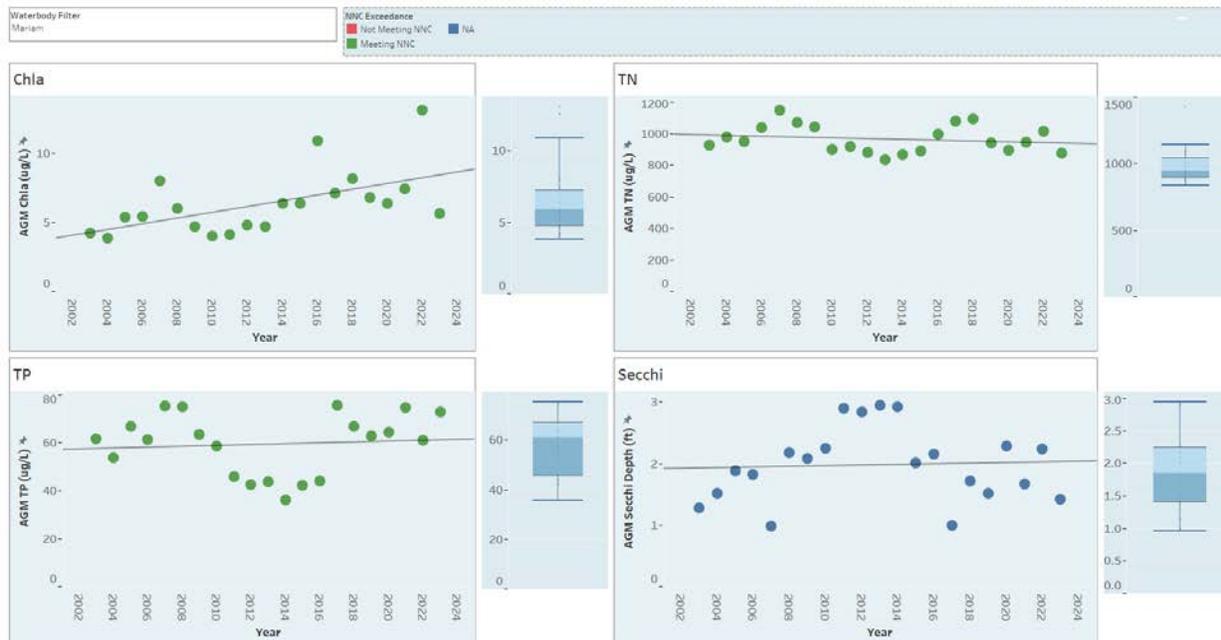


Figure 3-150. Lake Mariam AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Mariam on 5/19/2023. The PAC during this survey was 96.9% and the total BV was 55.1% (Figure 3-151). This equates to an abundance criterion score of 3. Due to Lake Mariam’s shallow depth and gradually sloping lake bed, its littoral zone is fairly wide and supports a high abundance of vegetation. That said, the abundance data may be erroneous due to SONAR detecting muck and detritus as living vegetation on the lake bed. Submerged vegetation has difficulty growing due to Lake Mariam’s high color content and low water clarity.

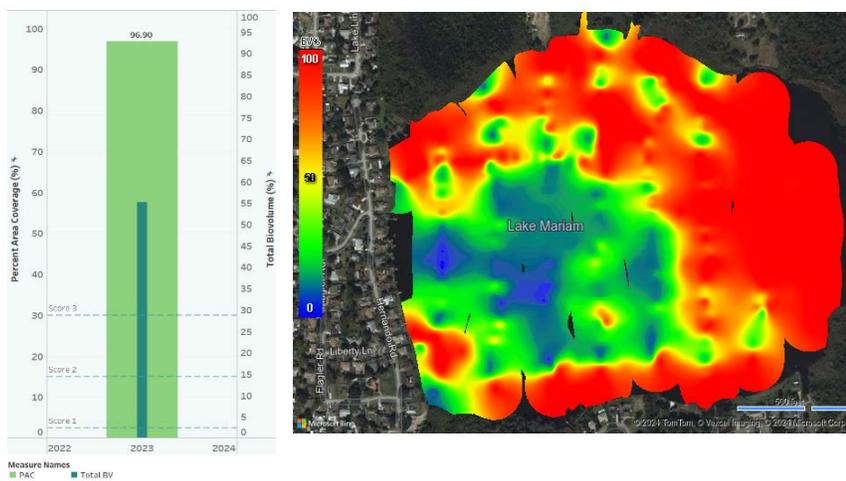


Figure 3-151. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Mariam; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on Lake Mariam’s high color concentration, it is dominated by emergent species like cattail and primrose willow (Figure 3-152). There was a considerable increase in the invasive species in 2023. Water hyacinth and burhead sedge made up over 11% of the community

earning a criterion score of 0. Greater effort should be made to keep these invasive plants under control.

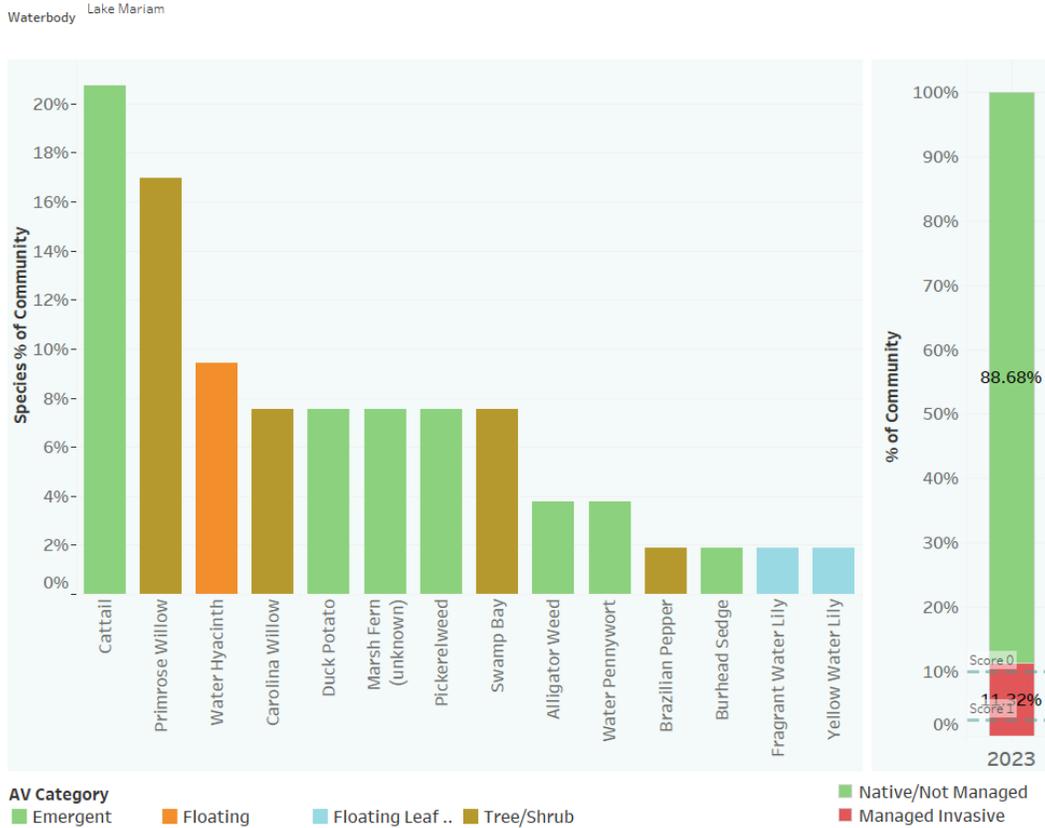


Figure 3-152. Chart depicting species frequency and invasive species percentage of Lake Mariam during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, all three of Lake Mariam’s diversity indices exceeded their median values (Figure 3-153). Relative to other waterbodies, Lake Mariam has low species richness since it can mostly only support emergent plant types. The increase in richness and evenness was likely due to shifts in the community, driven by the invasive plants.

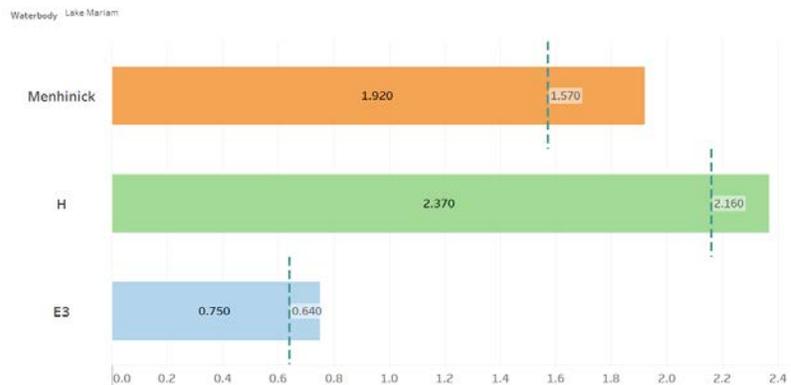


Figure 3-153. Chart depicting 2023 diversity indices for Lake Mariam. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Mariam’s health index scores from 2018 to 2023 shows some variation (Figure 3-154). While the impairment score has remained stable over the last six years, the water quality trend scores have gotten progressively worse. Vegetation abundance has increased, but this may be due to some errors with the SONAR detecting detritus in the center of the lake. The invasive presence has decreased considerably since monitoring began while diversity has gotten better in the last few years. Overall, Lake Mariam is in the middle of the priority rankings. It may not currently be impaired, but it is important to continue monitoring the water quality trends as well as the presence of invasive species.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	1	2	2	3	1	0	1	1.6
2019	3	1	2	2	2	2	0	2	1.8
2020	3	1	2	1	2	1	1	1	1.5
2021	3	1	2	1	2	3	3	2	2.1
2022	3	1	2	1	2	3	2	2	2.0
2023	3	0	2	1	2	3	0	3	1.8

Figure 3-154. Chart depicting a comparison of Lake Mariam’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- In addition to the moderate level of stormwater runoff from the drainage basin, the presence of so many OSTDs may be a contributing factor for nutrient pollutant loading. As these systems age, they may begin to leach nutrients into the water table—leading to water quality declines.
- The management of invasive species is a consistent concern for this waterbody. It can only take a single growing season for even a small population to take over large areas of a waterbody.

Lake Management Strategy:

- City staff may explore source analysis to determine if OSTD leachate is a potential contributor of nutrient pollutant loading. Further management action may involve working with Polk County in septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Mariana

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health Score
0	1	1	3	0	3	3	2	1.6

Location, Characteristics, & Hydrology:

Lake Mariana is located far to the northwest of downtown Winter Haven. Mostly within unincorporated Polk County, parts of Lake Mariana are bordered by the Cities of Lake Alfred, Auburndale, and Winter Haven. Excess water discharges via a passive overflow weir south to Lake Jessie. Based on these factors, Lake Mariana is considered part of the Outlying Lakes group. At an area of 518 acres, it is one of the larger study area lakes. It has an average depth of 9.7 feet and a maximum depth of over 18 feet (Figure 3-155).

Stormwater is conveyed to this waterbody from a 1,935 acre drainage basin (Figure 3-156). Ranked by area, the primary land uses within this basin are medium-density residential, agriculture, high-density residential, commercial, and industrial. Based on pollutant load modelling, the basin contributes 6,530 lbs of TN and 1160 lbs of TP annually. There are 158 known Onsite Sewage Treatment and Disposal (OSTD/septic) systems within this basin. This constitutes a high density and could be a potential contributor to nutrient loading via groundwater leaching. Lacking any City roadways bordering the lake, Winter Haven does not conduct street sweeping services within this basin.

Over its period of record, Lake Mariana’s surface level has fluctuated between 135.7 and 137.8 feet above sea level. The normal range for this lake is 136.6 and 137.3 feet (Figure 3-157). During 2023, Lake Mariana saw a considerable drop in surface level from a high in January at 136.6 feet to a low in May of 135.75 feet. The surface level did bounce back and ended the year in the lower portion of the normal range at 136.7 feet. Changes in this lake’s level are not correlated with the primary water quality metrics (see appendix).

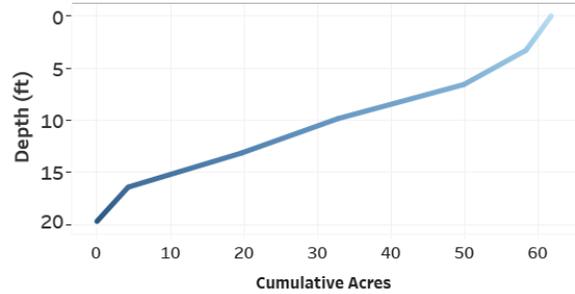


Figure 3-155. Hypsograph of Lake Mariana depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

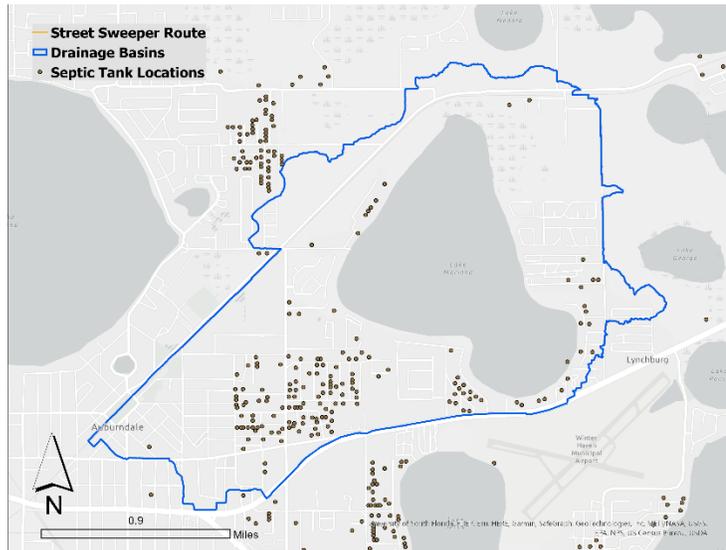


Figure 3-156. Map of Lake Mariana’s drainage basin and nearby septic systems.

Changes in this lake’s level are not correlated with the primary water quality metrics (see appendix).

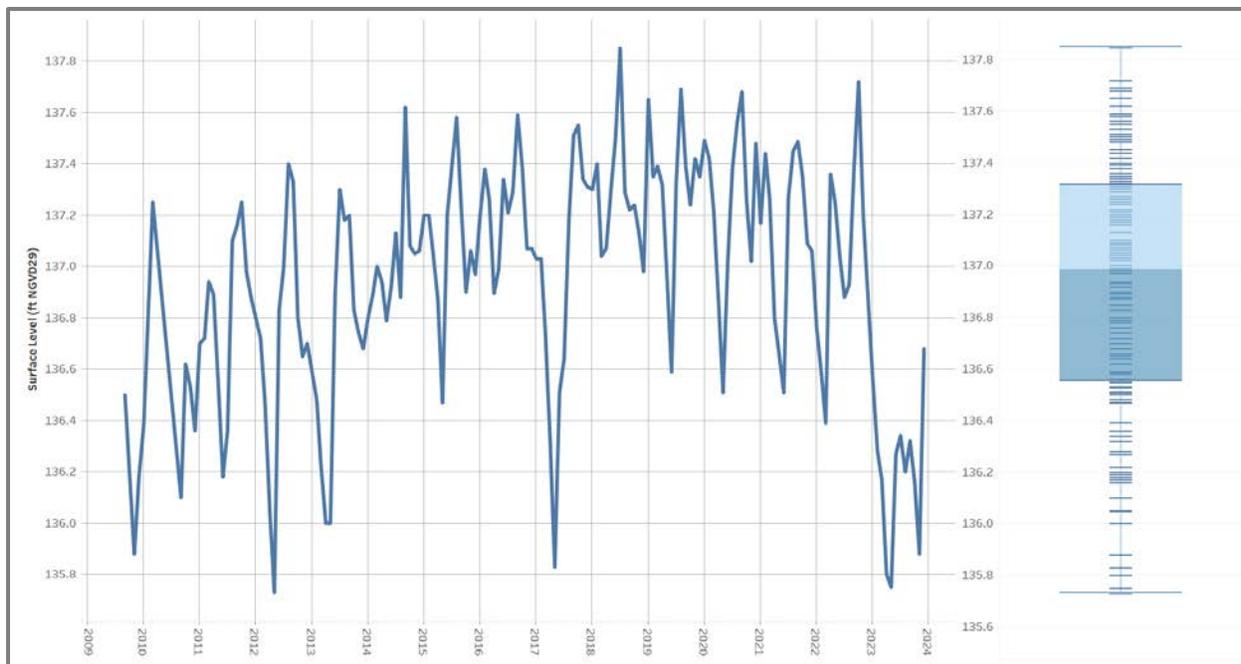


Figure 3-157. Hydrograph of Lake Mariana depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairments:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Mariana is categorized as a clear, alkaline waterbody. Due to numerous, consecutive NNC exceedances during the assessment period, Lake Mariana is considered impaired for Chl-a, TN, and TP (Figure 3-158). This equates to an impairment criterion score of 0. In 2018, the FDEP established a total maximum daily load for this lake, stipulating a 44% reduction in TN loading in order to meet NNC guidelines. It should be noted that 2023 Chl-a and TN concentrations were lower than the previous three years while Secchi depth was also higher than normal. This indicates some improvement.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. According to the data, only Secchi depth exhibited a significant deteriorating trend. Chl-a and TN shifted in their trend statistics such that their deteriorating trends are no longer significant while TP maintains a strong improving trend. Individual AGM values and trend statistics can be found in the appendix while the 2023 trend criterion scores can be found in the table below.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing (Deteriorating)	Significant	0
TN	Increasing (Deteriorating)	Significant	0
TP	Decreasing (Improving)	Significant	3
Secchi	Decreasing (Deteriorating)	Significant	0

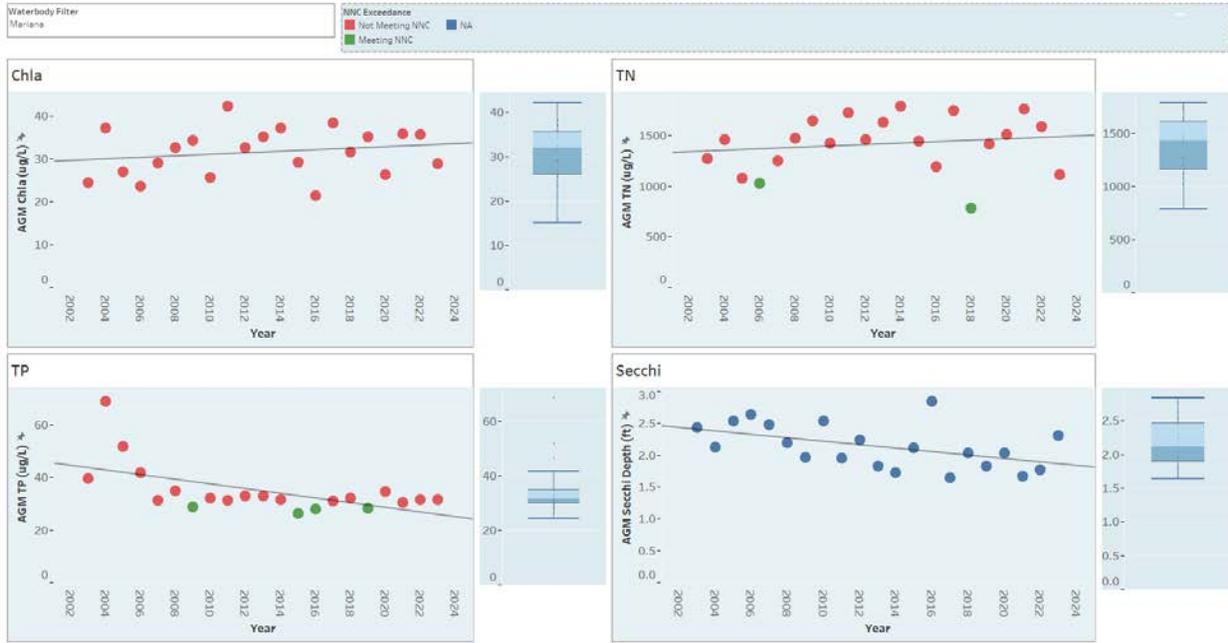


Figure 3-159. Lake Mariana AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Mariana on 11/9/2023. The PAC during this survey was 31.4% and the total BV was 4.6% (Figure 3-159). This equates to an abundance criterion score of 3. Throughout the monitoring period, Lake Mariana has maintained vegetation coverage between 22% and 28%, but 2023 marks the highest abundance on record. Due to its morphology, Lake Mariana has relatively low water clarity, but it is good to observe an improvement over time.

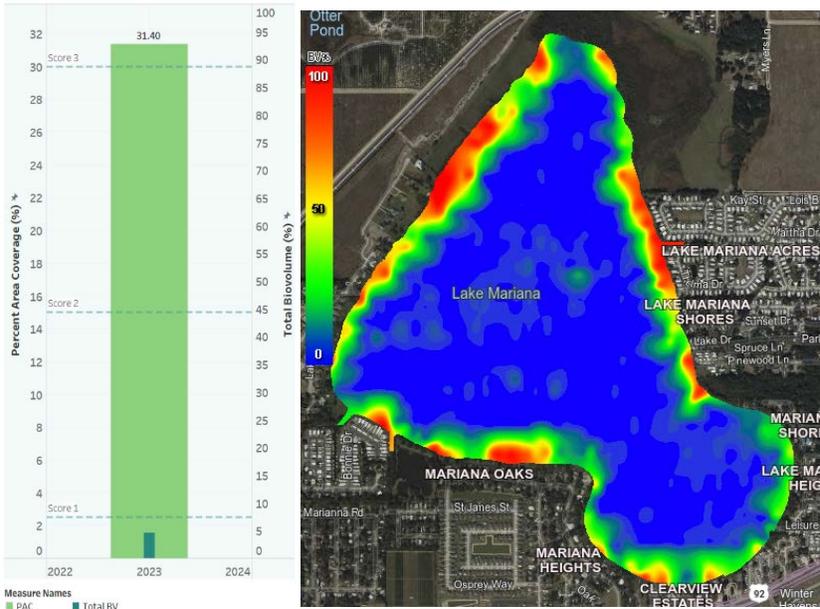


Figure 3-158. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Mariana; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, Lake Mariana possesses a health mix of

different vegetation types. The most dominant species detected was the native Illinois pondweed at over 25% (Figure 3-160). No invasive species were detected in 2023; similar to previous years. This equates to an invasive criterion score of 3.

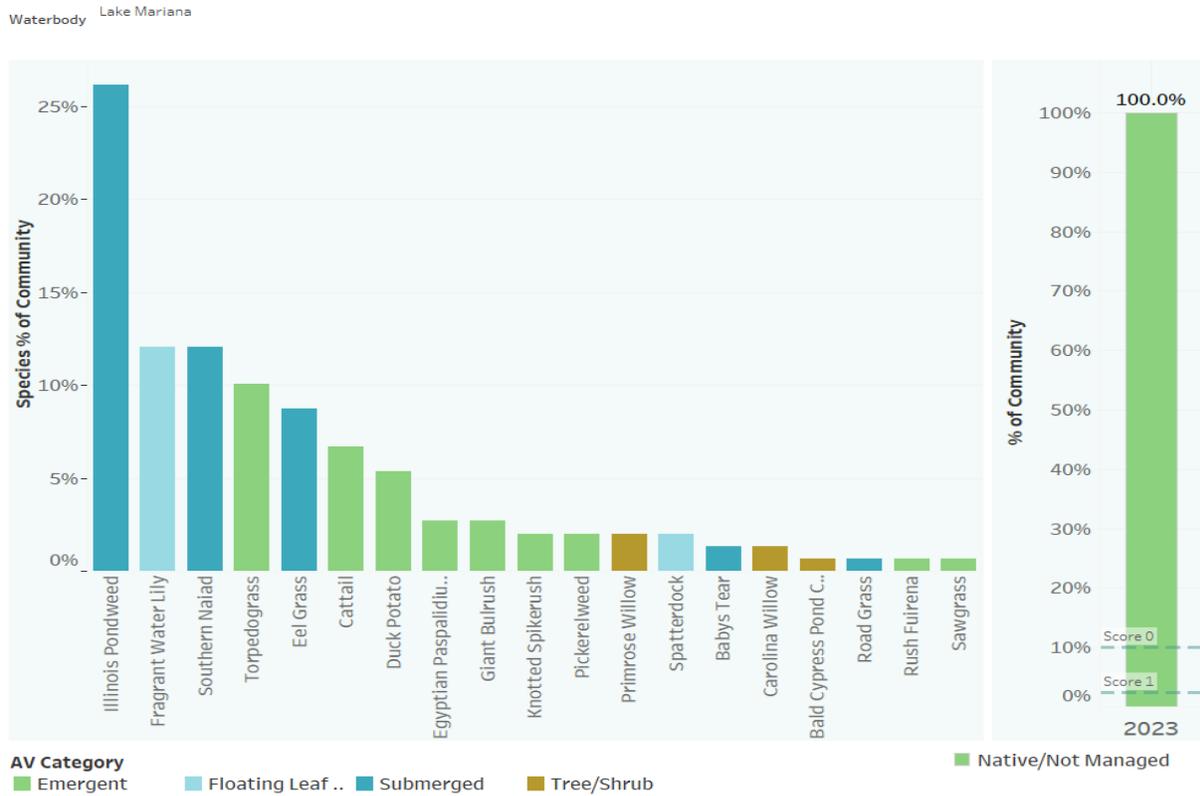


Figure 3-160. Chart depicting species frequency and invasive species percentage of Lake Mariana during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, Lake Mariana’s evenness and overall diversity indices met their median values (Figure 3-161). This equates to a diversity criterion score of 2. Despite the species richness index not meeting the long-term median value, it did exhibit a slight increase from the previous year. Due to a lack of invasive species, changes in Lake Mariana’s vegetation community are mostly due to natural shifts.

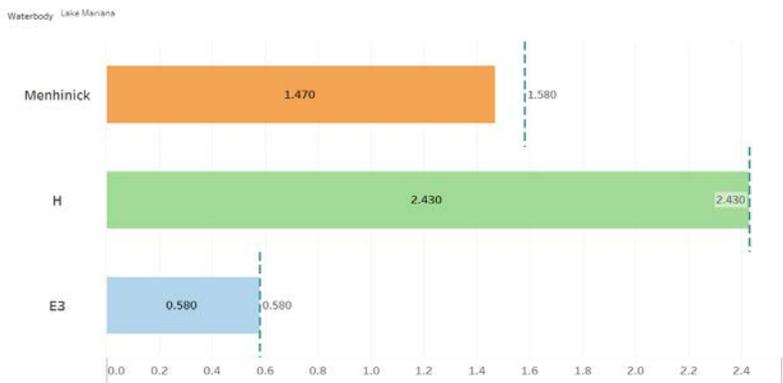


Figure 3-161. Chart depicting 2023 diversity indices for Lake Mariana. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Mariana’s health index scores from 2018 to 2023 shows little change (Figure 3-162). The impairment scores have remained static over this six year span. However, 2023 saw improvements in some of the water quality trend and vegetation abundance scores. With that, Lake Mariana is still considered a relatively high priority due to its water quality impairments and poor trend directions in Chl-a, TN, and Clarity.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	1	2	1	2	2	1	1.3
2019	0	1	1	2	0	2	3	2	1.4
2020	0	1	1	2	0	2	3	1	1.3
2021	0	1	1	2	0	2	2	2	1.3
2022	0	0	0	3	0	2	3	1	1.1
2023	0	1	1	3	0	3	3	2	1.6

Figure 3-162. Chart depicting a comparison of Lake Mariana’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- The presence of such a high density of OSTDs in the drainage basin is currently the leading theory for the water quality decline. With TN concentrations increasing, a likely contributor of nitrogen is a high number of septic systems leaching into the water table.
- Management of these is a consistent concern. It can only take a single growing season for even a small population to take over large areas of a waterbody.
- One major potential challenge in managing Lake Mariana is the coordination and collaboration between the various municipalities responsible for it. Unfortunately, many of the OSTDs in the basin aren’t within the Winter Haven limits. Management efforts will require strong direction to implement basin-wide improvements.

Lake Management Strategy:

- The City plans to provide what support it can to manage the water quality issues in this basin. This may involve exploring source analysis of the nutrients in the water to identify the cause of water quality deterioration. Staff will also advocate for septic-to-sewer conversions where appropriate.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Martha

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	0	1	1	0	1	3	2	1.4

Location, Characteristics, & Hydrology:

Lake Martha is located in the heart of Winter Haven, just northeast of the downtown area. It receives excess water flows from Lake Silver and discharges excess water to Lake Maude via a passive overflow structure. Based on these factors, it is considered part of the North Central Lakes group. Lake Martha is a smaller, but deeper waterbody at 89 acres, an average depth of 12.6 feet, and a maximum depth of over 20 feet at times (Figure 3-163). This lake morphology is indicative of a classic sinkhole lake.

Stormwater is conveyed to this waterbody from a 224-acre drainage basin comprised of 14 individual sub-basins (Figure 3-164). Located in a mostly residential area, the primary land uses in this basin are medium density residential and institutional (e.g. schools). This basin contributes 1,217 lbs of TN and 199 lbs of TP to the lake annually. There is only one known Onsite Sewage Treatment and Disposal (OSTD/septic) system in the basin. This is not a potential pollutant concern. The City combats the local stormwater pollutant loading by conducting 7.15 miles of street sweeping in this basin per month.

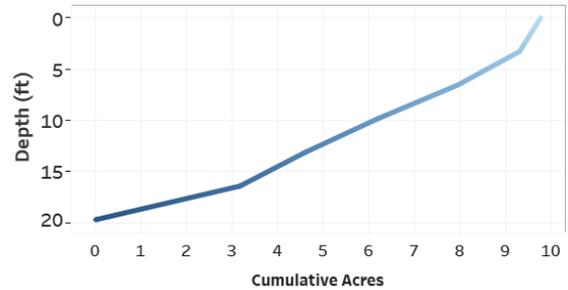


Figure 3-163. Hypsograph of Lake Martha depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Over its period of record, Lake Martha’s surface level has fluctuated between 136.7 and 142.6 feet above sea level. The normal range is much narrower—between 139.7 and 141.2 feet (Figure 3-165). During 2023, Lake Martha started at a high of 142.1 feet and dropped to a dry season low of 141.0 feet in May. The surface level ended the year above the normal range at 141.5 feet. Based on linear regression analysis, Chl-a rises as Lake Martha’s surface level increases; which is opposite to what would be expected. This correlation is most likely coincidental.

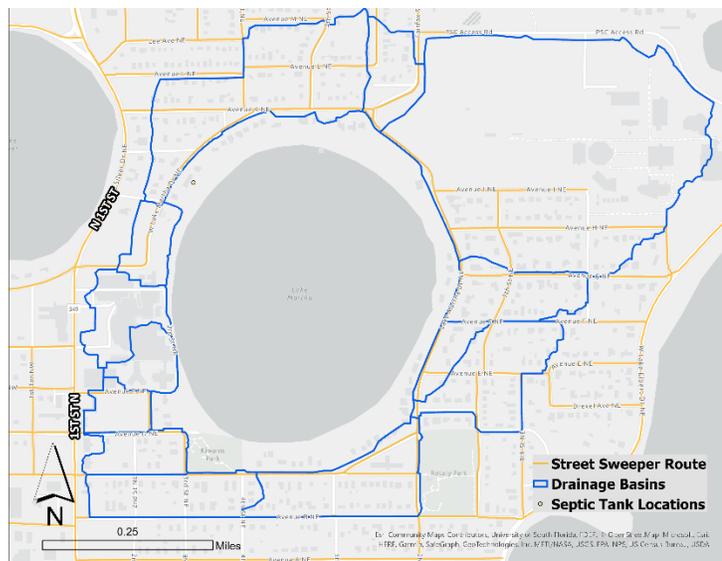


Figure 3-164. Map of Lake Martha’s drainage basin, City street sweeper routes, and nearby septic systems.

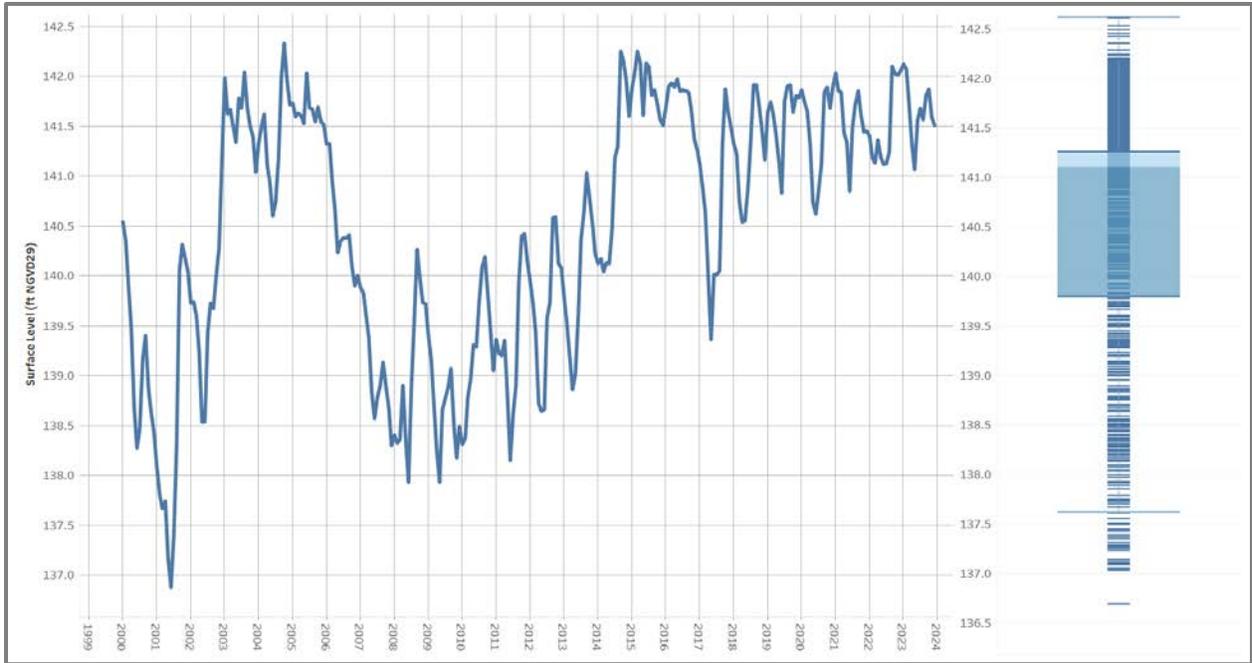


Figure 3-165. Hydrograph of Lake Martha depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Martha is categorized as a clear, alkaline waterbody. Throughout recent monitoring, Lake Martha has not exhibited any NNC exceedances in Chl-a, TN, or TP (Figure 3-166). This equates to an impairment score of 3. It should be noted that the 2023 Chl-a, TN and TP concentrations were lower than in the last few years—indicating some short-term improvement in water quality.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. According to the data, Chl-a and Secchi depth exhibited significant deteriorating trends. These equate to trend criteria scores of 0. The TN and TP trends, while in a deteriorating direction, were not significant—earning scores of 1. This is a slight change from previous years and indicates that some water quality metrics are exhibiting improvement. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing (Deteriorating)	Significant	0
TN	Increasing	Not Significant	1
TP	Increasing	Not Significant	1
Secchi	Decreasing (Deteriorating)	Significant	0

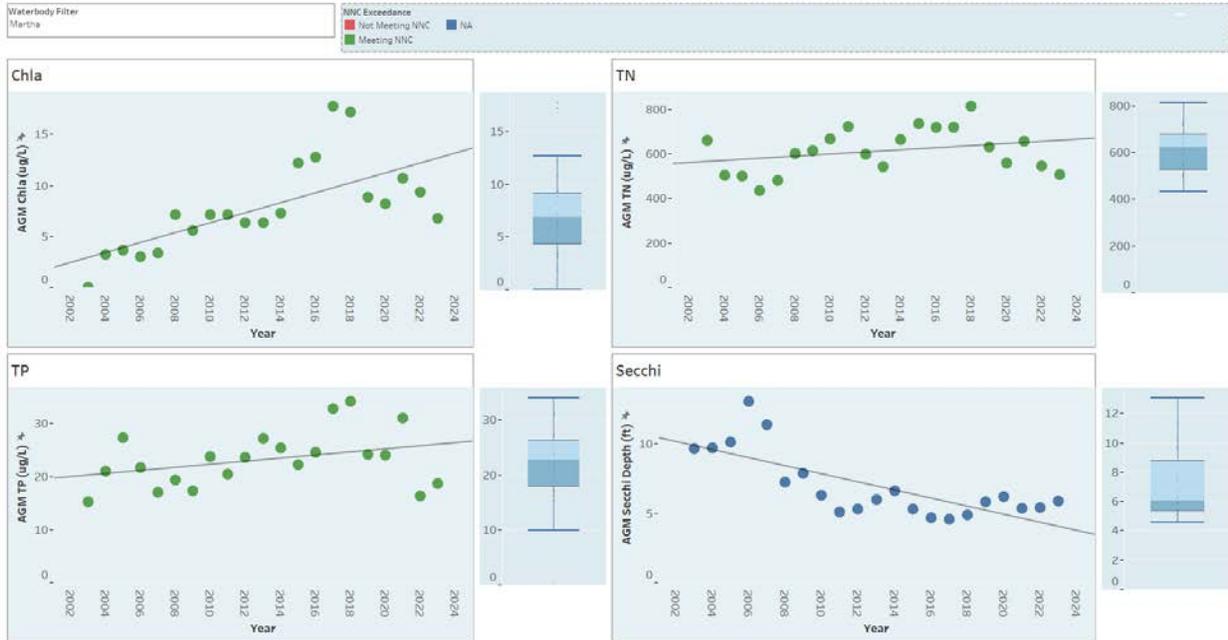


Figure 3-166. Lake Martha AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Martha on 9/8/2023. The PAC during this survey was 7.3% and the total BV was 0.75% (Figure 3-167). This equates to an abundance score of 1. A review of Lake Martha’s abundance values from 2018 to 2023 shows a lack of coverage and biovolume. While the lake bed steeply slopes into deeper water, its relatively high water clarity should support much more vegetation than is currently present. That said, these survey data show a very gradual increase in overall abundance over the last six years.

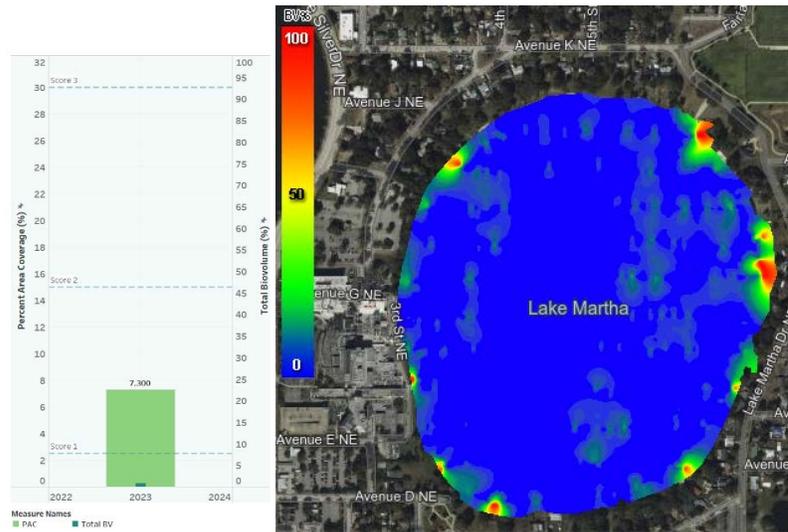


Figure 3-167. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Martha; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, it is clear that emergent species dominate the vegetation community. At 28% of the community, the exotic torpedo grass is the most abundant species by far (Figure 3-168). While there are several exotic species present, they don’t pose much of a management concern. The result is an invasive presence criterion score of 3. The lack of submerged vegetation is much more concerning since this lake should support it.

The leading theory is that triploid grass carp were stocked in the 2010s in an effort to biologically control hydrilla in the lake. The density of carp was likely higher than needed and this population has since denuded the lake of SAV.

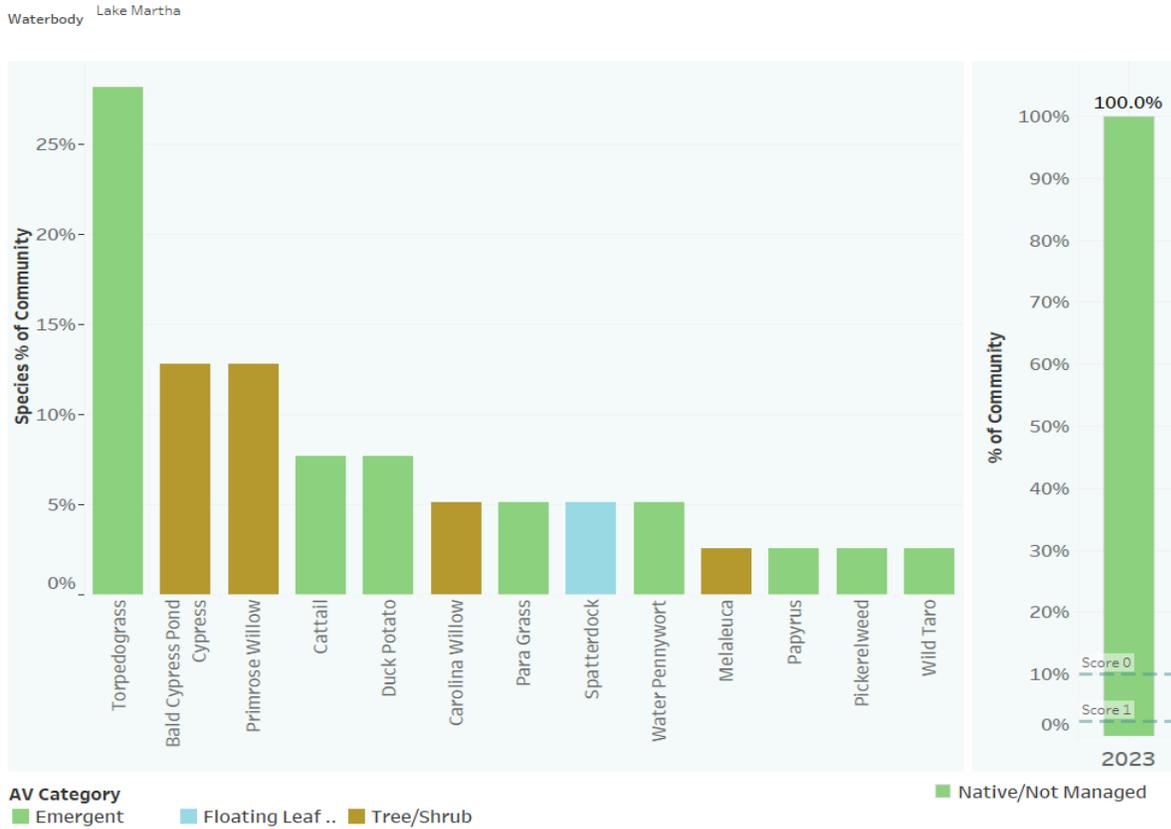


Figure 3-168. Chart depicting species frequency and invasive species percentage of Lake Martha during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, Lake Martha’s richness and overall diversity indices met or exceeded their respective median values (Figure 3-169). While species richness did drop slightly from 2022, evenness and overall diversity exhibited slight increases. The lack of active invasive species management efforts indicates that these fluctuations in diversity were the result of natural changes in the vegetation community.

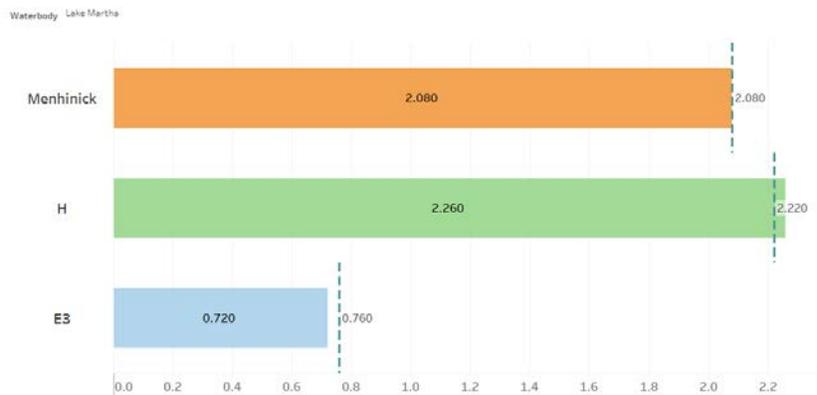


Figure 3-169. Chart depicting 2023 diversity indices for Lake Martha. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Martha’s health index scores from 2018 to 2023 shows gradual improvement from 0.9 to 1.4 (Figure 3-170). Since the City began documenting lake health, Lake Martha has exhibited no changes in impairment but has undergone some positive changes in the trend scores. This year is notable as both the TN and TP trends have shifted from significant to non-significant—indicating some improvement. Also notable is how the vegetation abundance has increased since the first year of monitoring. Diversity largely changes through natural selection in the vegetation community and the invasive presence has consistently remained low. Overall, improving Lake Martha’s water quality before it becomes impaired places it higher on the priority ranking.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	0	0	0	0	0	3	0	0.8
2019	3	0	0	0	0	1	2	3	1.1
2020	3	0	0	0	0	1	3	1	1.0
2021	3	0	0	0	0	1	3	2	1.1
2022	3	0	1	0	0	1	3	2	1.3
2023	3	0	1	1	0	1	3	2	1.4

Figure 3-170. Chart depicting a comparison of Lake Martha’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Despite Lake Martha not being impaired, its water quality trends are concerning. Stormwater pollutant loading from the surrounding drainage basin is one of the City’s primary management concerns for combating these water quality issues.
- A healthy, robust vegetation community is considered to provide a buffer against changes in water quality from increased nutrient loading. The lack of submerged vegetation and overall abundance is a concern. However, efforts to increase vegetation abundance through planting are curtailed by the presence of grass carp in the waterbody.
- In 2019, Lake Martha experienced a diesel fuel spill. While likely not a contributor to increased Chl-a or nutrient concentrations, this event led to a significant ecological disturbance. Fortunately, remediation efforts were somewhat successful at restoring the wildlife habitat in the lake.

Lake Management Strategy:

- Implementing stormwater infrastructure improvements to address the water quality trends is an ongoing goal.
- With the majority of the drainage basin comprised of residential housing, public education and outreach is a valid management strategy. These efforts aim to increase residents’ knowledge of best stormwater practices and ways they can individually reduce their pollutant load.
- City staff have explored habitat restoration via vegetation planting initiatives. However, the presence of grass carp poses a significant roadblock to successful implementation. Staff will continue to monitor vegetation and work with the FWC to track the presence of grass carp until such a time that planting becomes a viable solution.

Lake Maude

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	3	3	2	2	3	1	2	2.4

Location, Characteristics, & Hydrology:

Lake Maude is located a short distance northeast of downtown Winter Haven. It receives excess water from Lake Martha and discharges excess water to Lake Idyl via a passive overflow structure. Based on these factors, Maude is considered part of the North Central Lakes group. Lake Maude is a smaller waterbody at 55 acres, an average depth of 7.5 feet, and a maximum depth of over 17 feet in deeper holes (Figure 3-171).

Stormwater is conveyed to this waterbody from a 385-acre drainage basin, comprised of 14 individual sub-basins (Figure 3-172). Ranked by area, the primary land uses within this basin are medium-density residential, commercial, institutional, recreational, and industrial. Based on stormwater pollutant load modelling, this basin contributes 1,900 lbs of TN and 320 lbs of TP to the lake annually. There are no known Onsite Sewage Treatment and Disposal (OSTD/septic) systems within this basin. To combat stormwater pollutant loading, the City conducts 15.7 miles of street sweeping in this basin on a monthly basis.

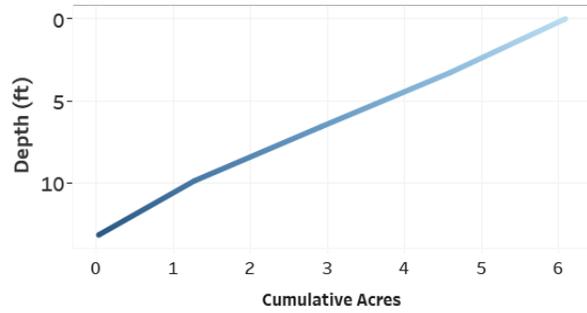


Figure 3-171. Hypsograph of Lake Maude depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Over its period of record, Lake Maude's surface level has fluctuated between 136 and 140.9 feet above sea level. The normal range is much narrower—between 138.9 and 139.5 feet (Figure 3-173). During 2023, Lake Maude reached a wet season peak of 140.04 feet in October and a dry season low of 138.9 feet in May. The surface level ended the year well above the high range at 136.7 feet. Changes in Lake Maude's surface level are weakly correlated with TN (see appendix). This carries some management considerations as maintaining higher surface levels should result in a decrease in TN concentrations.

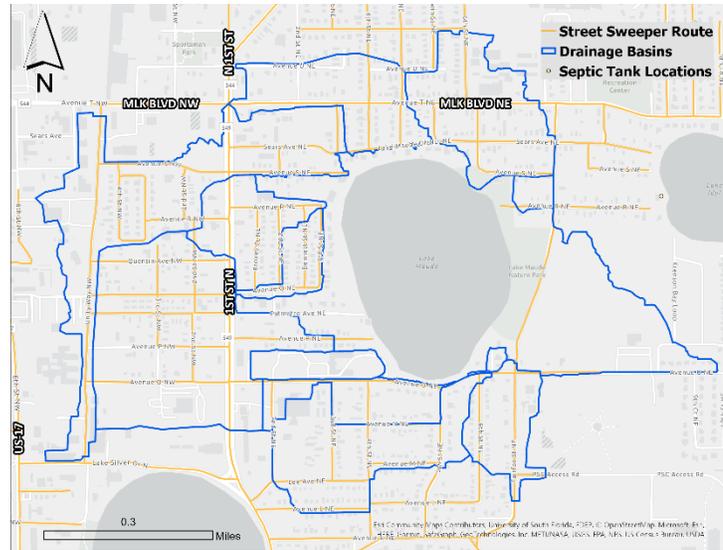


Figure 3-172. Map of Lake Maude's drainage basin and City street sweeper routes.

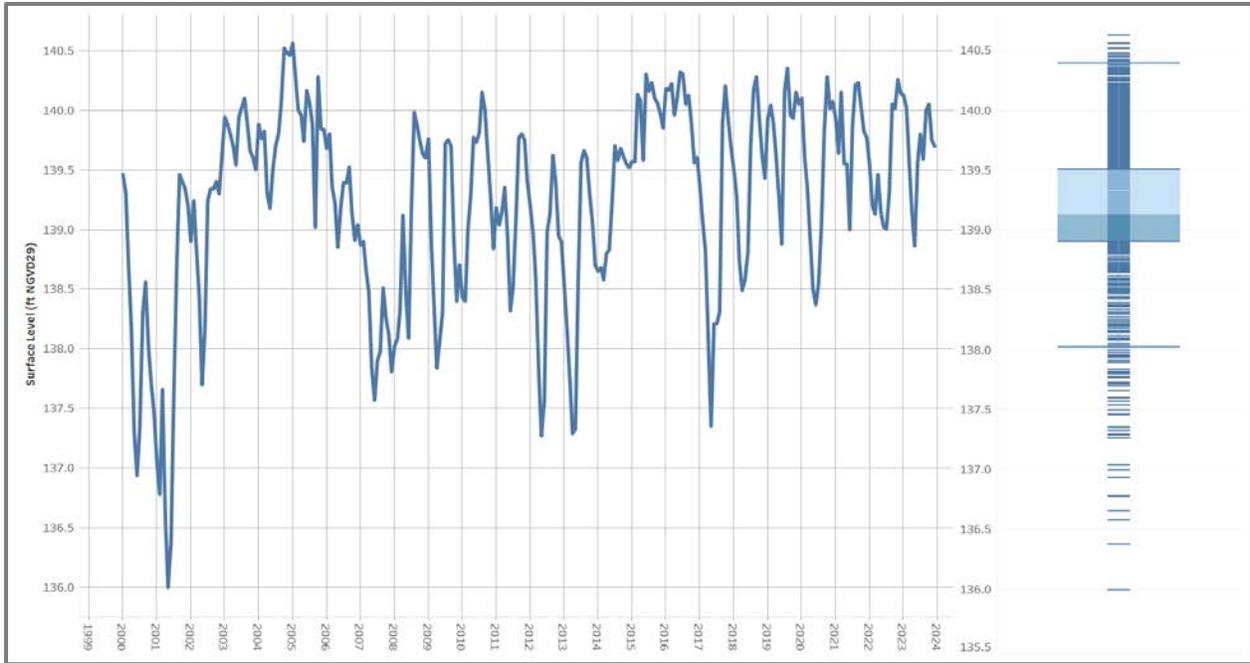


Figure 3-173. Hydrograph of Lake Maude depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Maude is categorized as a clear, alkaline waterbody. Lake Maude has not exhibited any NNC exceedances during the assessment period (Figure 3-174). This equates to an impairment criterion score of 3. The 2023 AGM concentrations for Chl-a, TN, and TP are notable for being higher than average.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on the data, Chl-a and TN exhibited significant improving trends—earning trend criteria score of 3. Lake Maude’s TP and Secchi depth trends, while not statistically significant, are also improving. This equates to a trend criterion score of 2. While Secchi depth was previously trending upward, the recent change to the statistical significance indicates that some recent activities have negatively impacted water clarity. This is something to keep a close eye on in the future. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing	Not Significant	2
Secchi	Increasing	Not Significant	2

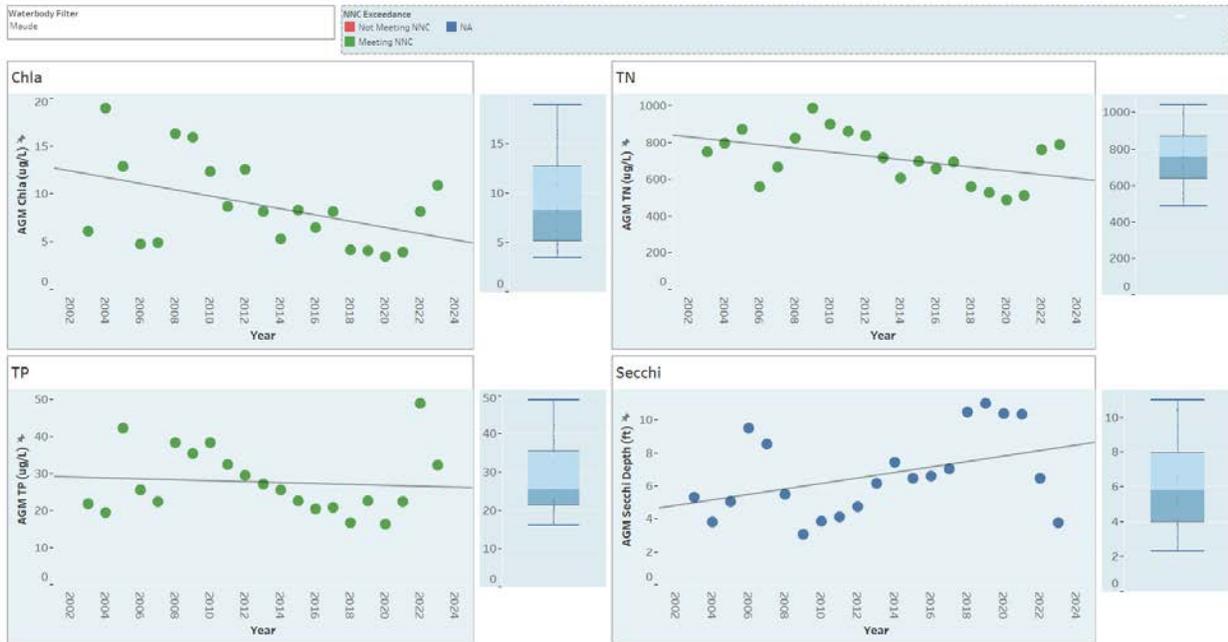


Figure 3-175. Lake Maude AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Maude on 1/6/2023. The PAC during this survey was 79.3% and the total BV was 9.3% (Figure 3-175). This equates to a vegetation abundance criterion score of 3. A comparison of coverage and BV values over the period of record indicates that Lake Maude maintains a very high vegetation abundance—typically in the 90% range. The recent decline in overall abundance may be a response to invasive hydrilla treatments.

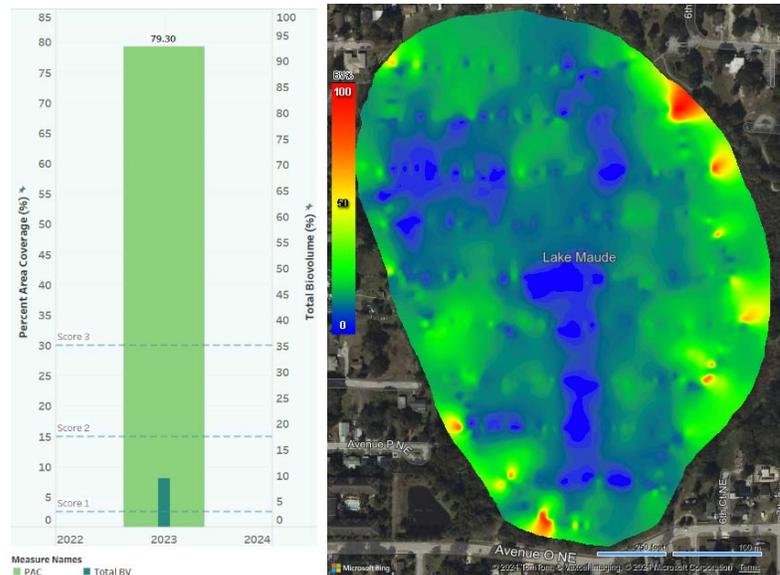


Figure 3-174. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Maude. Biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the data from the 2023 survey, Lake Maude is dominated by submerged vegetation (e.g. coontail and southern naiad) comprising almost 45% (Figure 3-176). The remaining vegetation types include floating leaf and emergent. Regarding managed invasive species, there was an increase in the amount of hydrilla and burhead sedge detected—up to 2.9% of the total population. This equates to an invasive presence criterion score of 1. While still manageable, this increase in invasive presence warrants management to keep it under control.

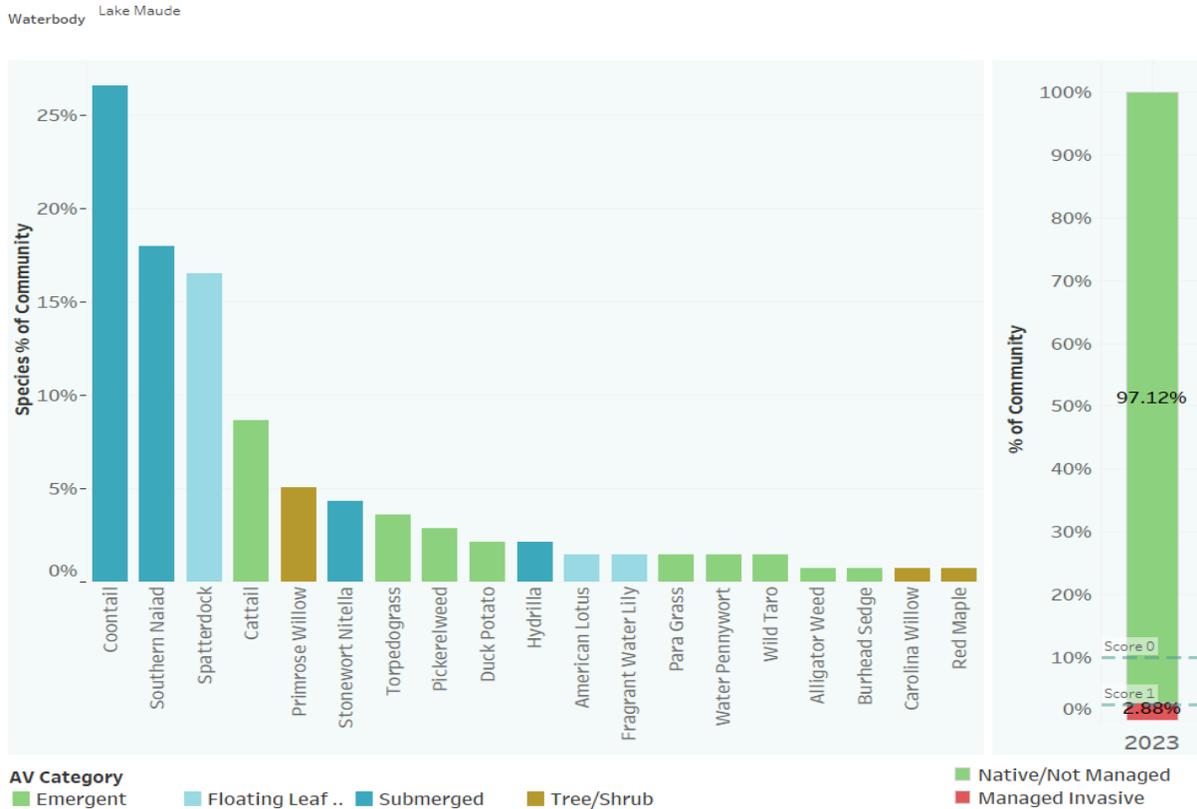


Figure 3-176. Chart depicting species frequency and invasive species percentage of Lake Maude during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, species richness and overall diversity indices exceeded their respective median values; whereas the evenness index fell below its long-term median (Figure 3-177). This equates to a diversity criterion score of 2. All three diversity indices dropped slightly from the previous year. This is likely due to fewer less prominent species being absent in the 2023 survey as well as a less even spread of species than in 2022. Minor invasive treatment took place in 2023 that may have slightly impacted the vegetation community. However, these changes in diversity are not massive and are not cause for alarm. That said, the City will continue to monitor the vegetation for major shifts in Lake Maude's ecology.

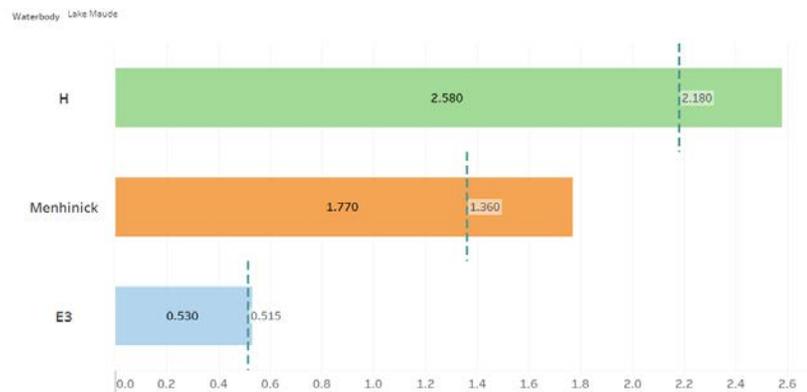


Figure 3-177. Chart depicting 2023 diversity indices for Lake Maude. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Maude’s health index scores from 2018 to 2023 shows relative stability with index scores ranging from 2.3 to 2.8 (Figure 3-178). Throughout this six year monitoring period, water quality impairment, trends, and vegetation abundance have remained largely the same. There have been some minor changes in the statistical significance of the TP and Secchi depth trends, however. Where the majority of the score changes derive are from the invasive species presence and species diversity scores. This is to be expected as invasive plant populations expand and are treated. Overall, Lake Maude falls lower on the priority ranking due to its excellent water quality and vegetation community.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	2	3	3	1	3	2.6
2019	3	3	3	2	3	3	1	1	2.4
2020	3	3	3	3	3	3	2	1	2.6
2021	3	3	3	3	3	3	1	0	2.4
2022	3	3	3	2	3	3	2	3	2.8
2023	3	3	3	2	2	3	1	2	2.4

Figure 3-178. Chart depicting comparison of Lake Maude’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Maude currently exhibits excellent water quality. However, stormwater pollutant loading is a potential concern if water quality trends begin to deteriorate.
- The management of invasive species like burhead sedge and hydrilla is a consistent concern. It can only take a single growing season for even a small population to take over large areas of a waterbody.

Lake Management Strategy:

- The City already mitigates quite a bit of stormwater pollutant loading through street sweeping as well as the construction of the Lake Maude Stormwater Treatment Park.
- With so much residential housing in the basin, public education and outreach is another viable strategy. Education aims to increase residents’ knowledge of best stormwater practices and ways they can individually reduce their pollutant load.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake May

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
0	3	3	3	3	3	0	3	2.3

Location, Characteristics, & Hydrology:

Lake May is located southwest of downtown Winter Haven. As part of the South Chain of Lakes, it is connected to Lakes Howard and Shipp via navigable canals. The South Chain discharges excess water to the Wahneta Farms Drainage canal through a passive control structure on the south shore of Lake Lulu. A smaller waterbody, Lake May has a surface area of 52 acres, an average depth of 4.4 feet, and a maximum depth of around 10 feet (Figure 3-179). Lake May’s shallowness coupled with its high boat traffic means that it likely has low water clarity due to increased suspended solids.

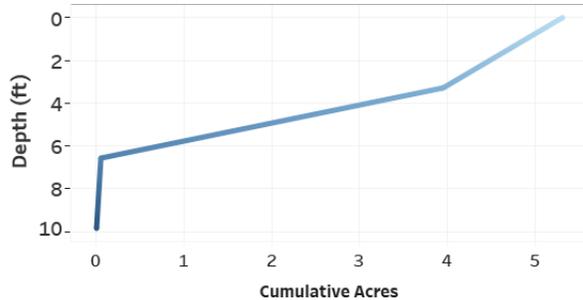


Figure 3-179. Hypsograph of Lake May depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake

Stormwater is conveyed to this waterbody from a 353-acre urbanized drainage basin comprised of six individual sub-basins (Figure 3-180). Ranked by area, the primary land uses within this basin are commercial, medium-density residential, industrial, open land, and institutional. Based on stormwater pollutant load modelling, this basin contributes 1,733 lbs of TN and 293 lbs of TP to the lake annually. There is one known Onsite Sewage Treatment and Disposal (OSTD/septic) system in the basin, but it is not a potential pollutant load concern. To mitigate stormwater nutrient loads, the City conducts 27.3 miles of street sweeping services within the drainage area on a monthly basis, with larger roads being swept twice monthly.

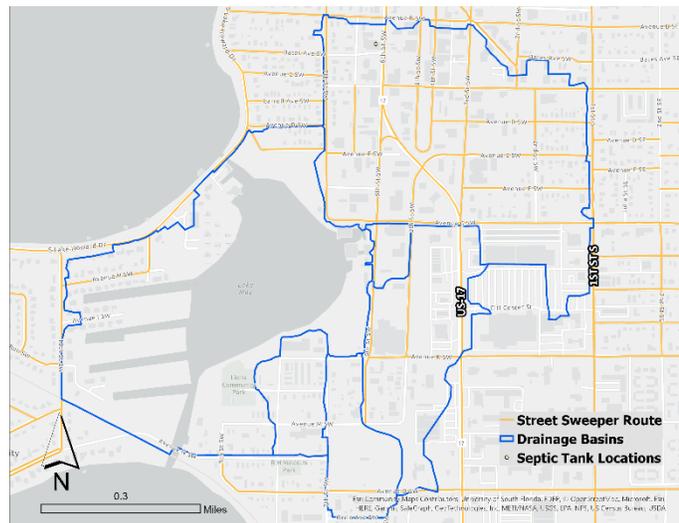


Figure 3-180. Map of Lake May’s drainage basin, City street sweeper routes, and nearby septic systems.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain’s surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the South Chain by the end of the year was slightly

above the top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake May’s surface level correlate with Chl-a, TN, TP, and clarity (see appendix). This carries management implications as an increase in levels should result in improved water quality across the board.

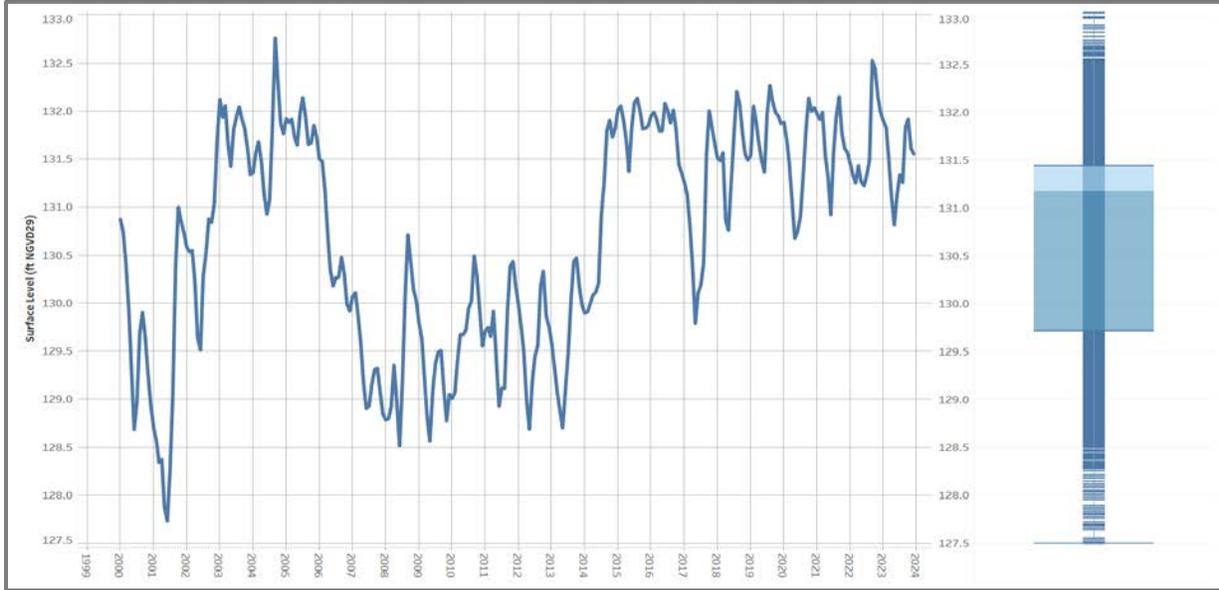


Figure 3-181. Hydrograph of Lake May depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake May is categorized as a clear, alkaline waterbody. Due to numerous consecutive NNC exceedances during the assessment period, Lake May is considered impaired for Chl-a, TN, and TP (Figure 3-182). This equates to an impairment criterion score of 0. In 2019, the FDEP established a total maximum daily load for Lake May, stipulating a 44% TN and 57% TP reduction to meet NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Based on the data, each of Lake May’s water quality parameters exhibited significant improving trends. The results are trend criteria scores of 3 for each of these parameters. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3

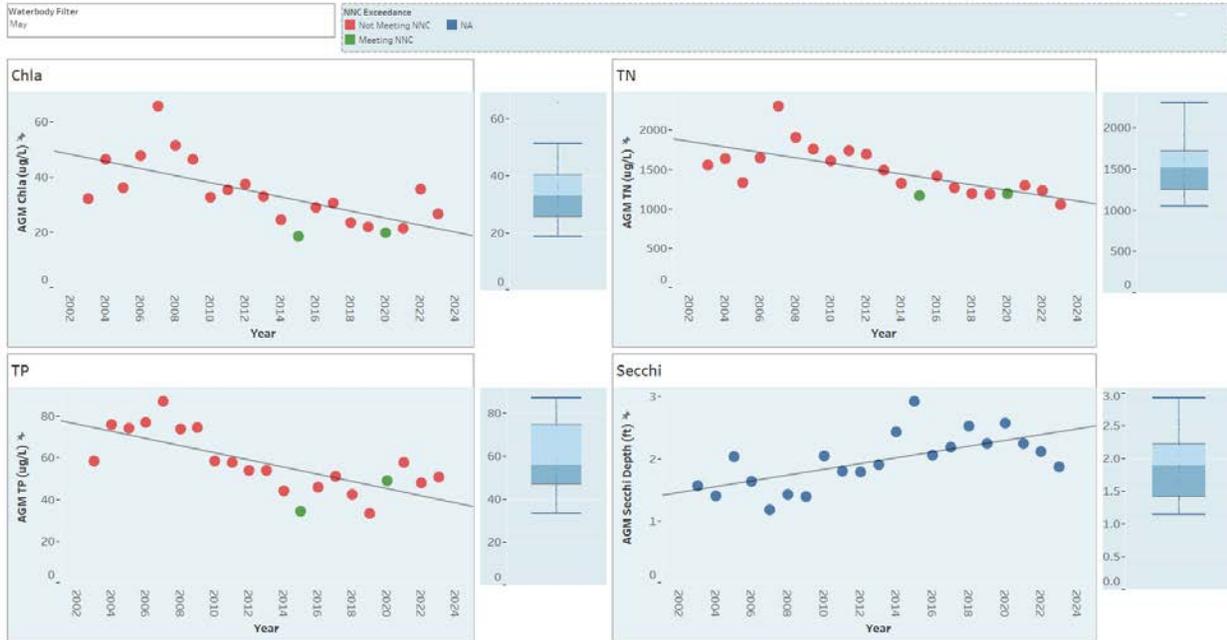


Figure 3-182. Lake May AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake May on 5/31/2023. The PAC during this survey was 76.7% and the total BV was 7.76% (Figure 3-183). This equates to an abundance criterion score of 3. Lake May has traditionally maintained a high vegetation abundance. Its shallow depth and gradually sloping lake bed lend itself well to a wide littoral zone. This has occasionally raised navigation concerns in the past as over 50% of the surface is occupied by aquatic plants. Striking a balance between ecology and recreation is one of the City’s management goals for this waterbody.

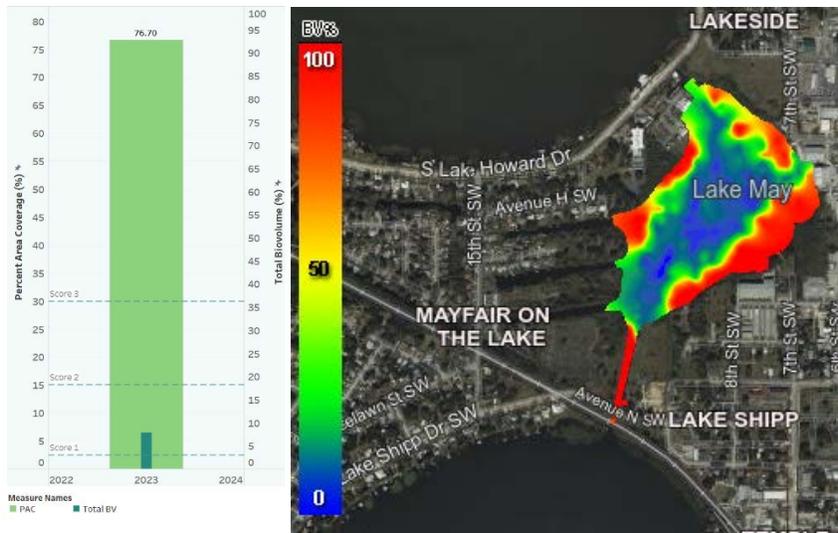


Figure 3-183. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake May; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2023 survey, there was a shift in the vegetation community as spatterdock and water hyacinth made up over 20% of the population (Figure 3-184). The remaining plants are a mix of emergent and submerged species. There was a large contingent of managed invasive species present during 2023. Hydrilla, water hyacinth, and parrot feather made

up over 17% of the community. This has resulted in an invasive percentage criterion score of 0. Invasive treatment efforts were implemented in 2023, but the results will likely not be visible until the 2024 survey.

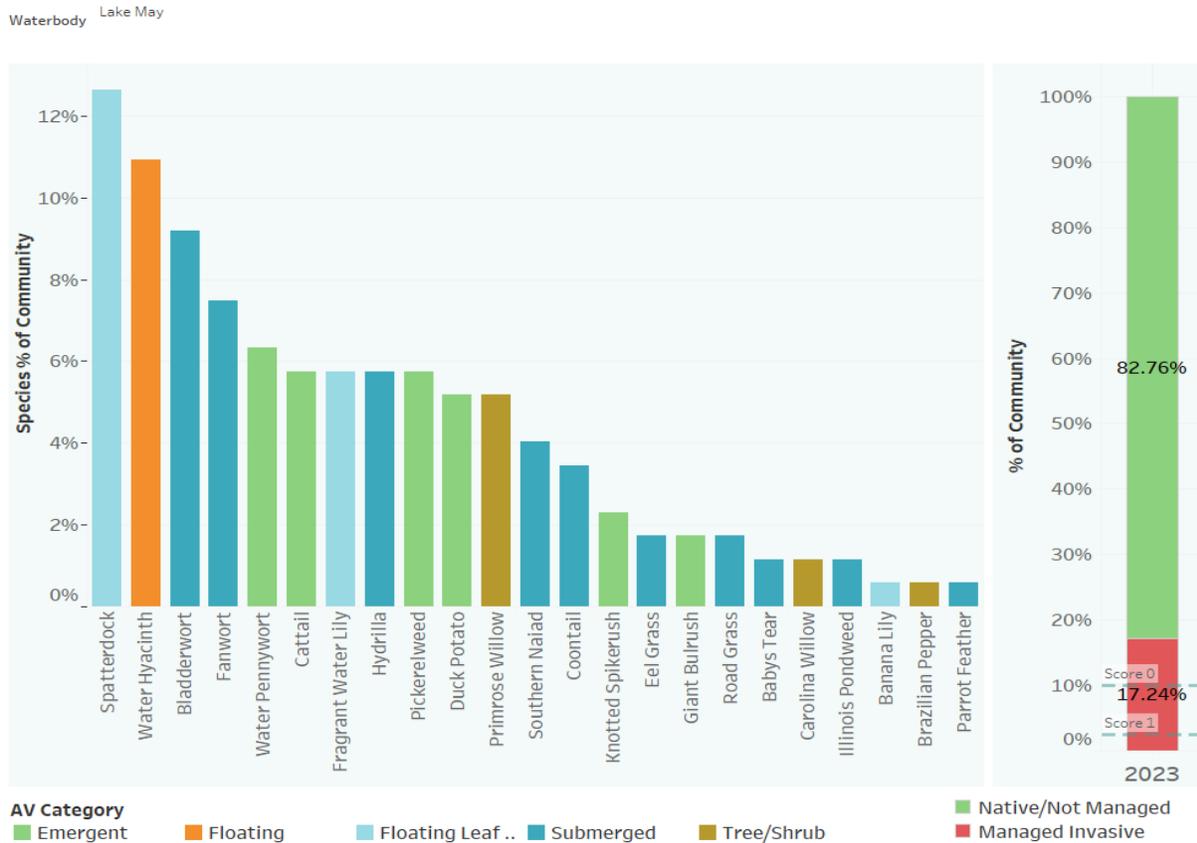


Figure 3-184. Chart depicting species frequency and invasive species percentage of Lake May during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, all three of Lake May’s diversity indices met or exceeded their respective median values (Figure 3-185). This equates to a diversity criterion score of 3. This recent shift in overall diversity from the previous year is mostly due to the treatment of invasive species allowing other, less prominent plant types to fill the open niches. Monitoring should indicate if future management efforts will continue to have positive effects on the vegetation community.

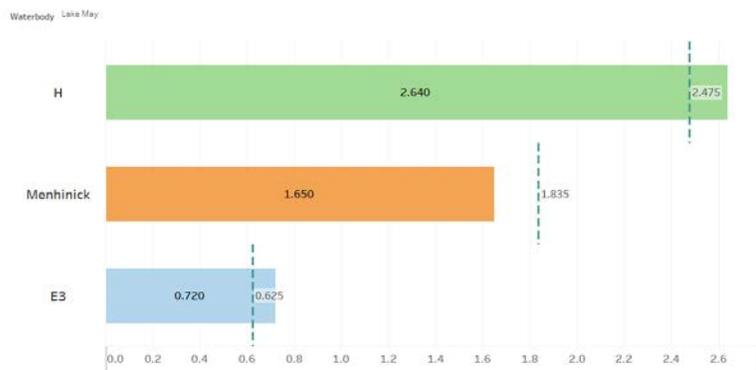


Figure 3-185. Chart depicting 2023 diversity indices for Lake May. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake May’s health index scores from 2018 to 2023 shows relative stability—with lake health ranging from 2.0 to 2.3 (Figure 3-186). In the six year span that Lake May has been monitored, the only changes in score have been in the invasive presence and diversity criteria. Based on these scores, it appears that the changes in diversity have mostly been the result of invasive species management efforts. Overall, Lake May ranks in the middle of the pack with regards to management priority. While it is impaired, its water quality and vegetation abundance indicate that its overall health is improving.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	3	3	3	3	3	1	0	2.0
2019	0	3	3	3	3	3	0	1	2.0
2020	0	3	3	3	3	3	0	3	2.3
2021	0	3	3	3	3	3	0	2	2.1
2022	0	3	3	3	3	3	0	2	2.1
2023	0	3	3	3	3	3	0	3	2.3

Figure 3-186. Chart depicting a comparison of Lake May’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- In addition to stormwater pollutant loading, Lake May received historic point-source discharges from the Imhoff Wastewater Treatment Plan as well as those from citrus and dairy processing facilities. The sediments in Lake May could house a considerable amount of these legacy nutrients and be a constant source of internal loading.
- Several water quality metrics are significantly correlated with Lake May’s surface level; likely due to increased flushing during wetter periods. The means that drought conditions could result in water quality declines.
- Management of invasive species is a consistent concern. Lake May’s invasive populations are currently outside of a controlled state. The large scale use of herbicides can result in water quality declines.
- In addition to invasives, tussock formation from the floating leaf spatterdock can impact recreational navigation.

Lake Management Strategy:

- To mitigate stormwater pollutant loading, the City has implemented street sweeping, an alum injection system designed to reduce TN loads by 10% and TP loads by 45%, and general stormwater infrastructure improvements as part of the 7th Street complete streets project.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC for invasive species management planning.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Mirror

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	3	3	3	3	3	1	1	2.5

Location, Characteristics, & Hydrology:

Lake Mirror is located just northwest of downtown Winter Haven. As part of the South Chain of Lakes, it connects with Lakes Cannon and Spring via navigable canals. The South Chain discharges excess water to the Wahneta Farms Drainage Canal via a passive control structure on the south shore of Lake Lulu. A moderately sized waterbody, Lake Mirror has a surface area of 129 acres, an average depth of 10 feet, and a maximum depth of 17 feet (Figure 3-187).

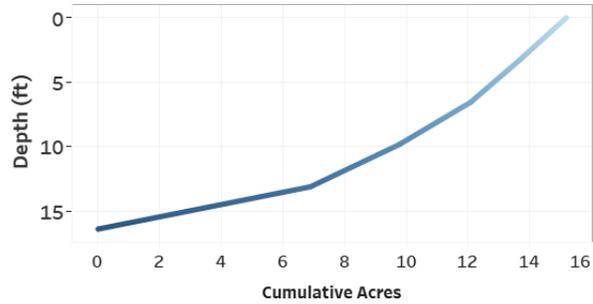


Figure 3-187. Hypsograph of Lake Mirror depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake

Stormwater is conveyed to this waterbody from a 278-acre drainage basin comprised of 11 individual sub-basins (Figure 3-188). The dominant land use within this basin is medium-density residential, followed by commercial, open land, and wetlands, respectively. According to stormwater pollutant load modeling, this drainage area contributes 749 lbs of TN and 120 lbs of TP to the lake annually—which is relatively low. There are no known Onsite Sewage Treatment and Disposal (OSTD/septic) systems within this basin. To mitigate stormwater loading, the City conducts 6.7 miles of street sweeping in this basin on a monthly basis.

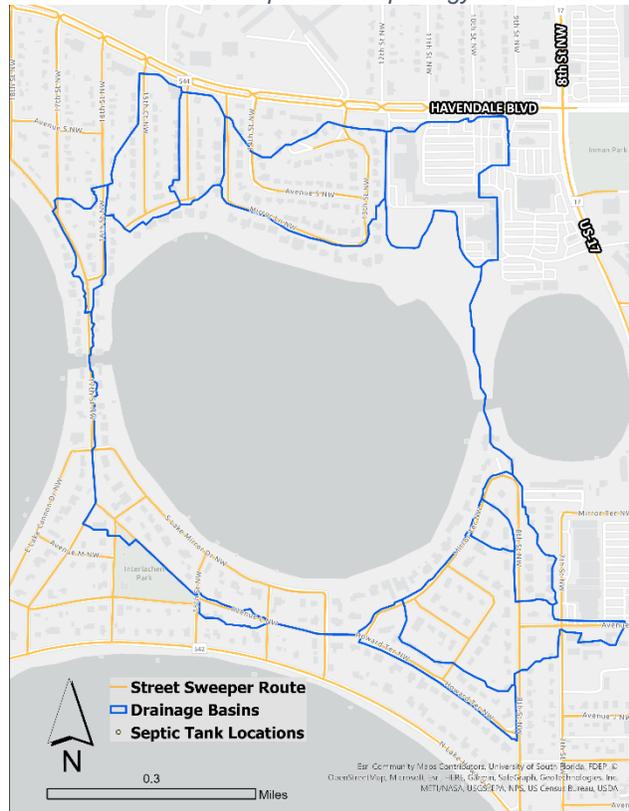


Figure 3-188. Map of Lake Mirror's drainage basin and City street sweeper routes.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the South Chain by the end of the year was slightly above the

top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake Mirror’s surface level correlate with TN (see appendix). This carries some management implications as maintaining higher levels should result in a decrease in TN concentrations.

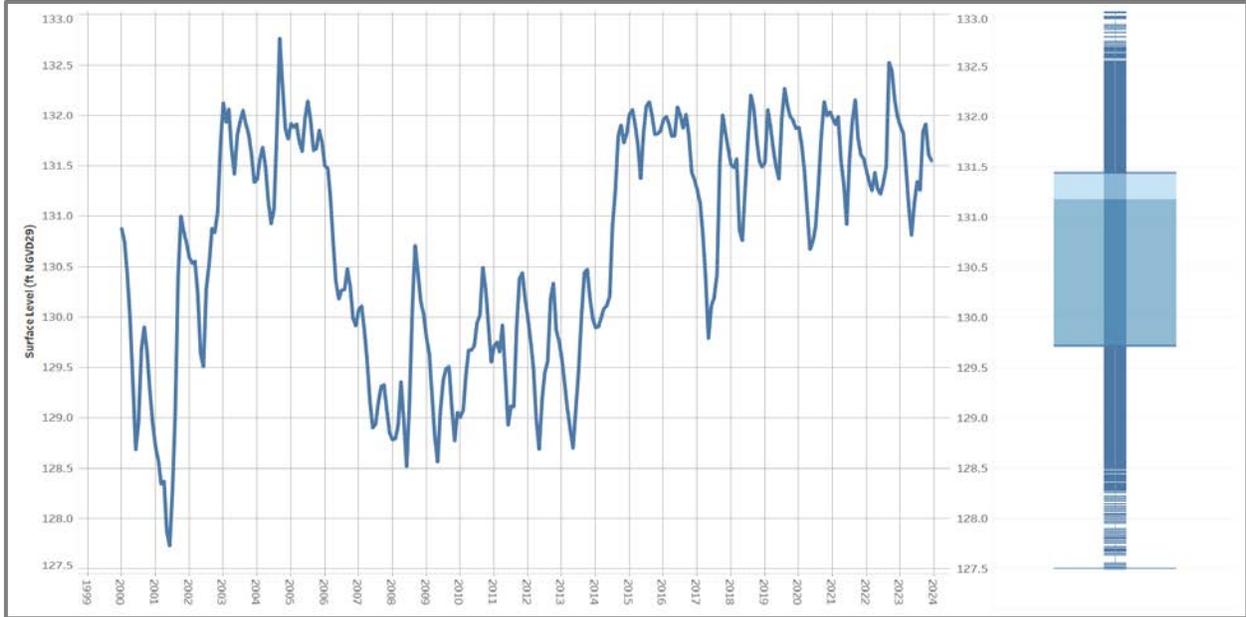


Figure 3-189. Hydrograph of Lake Mirror depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Mirror is categorized as a clear, alkaline waterbody. Based on the data during the assessment period, Lake Mirror is considered un-impaired (Figure 3-190). While the FDEP did establish a total maximum daily load for Lake Mirror in 2007, it is now meeting NNC guidelines and has been removed from the impaired list. That said, each of the NNC parameters exceeded the impairment thresholds in 2023—something to keep a close eye on.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Each of these four parameters has exhibited significant improving trends, resulting in trend criteria scores of 3. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3

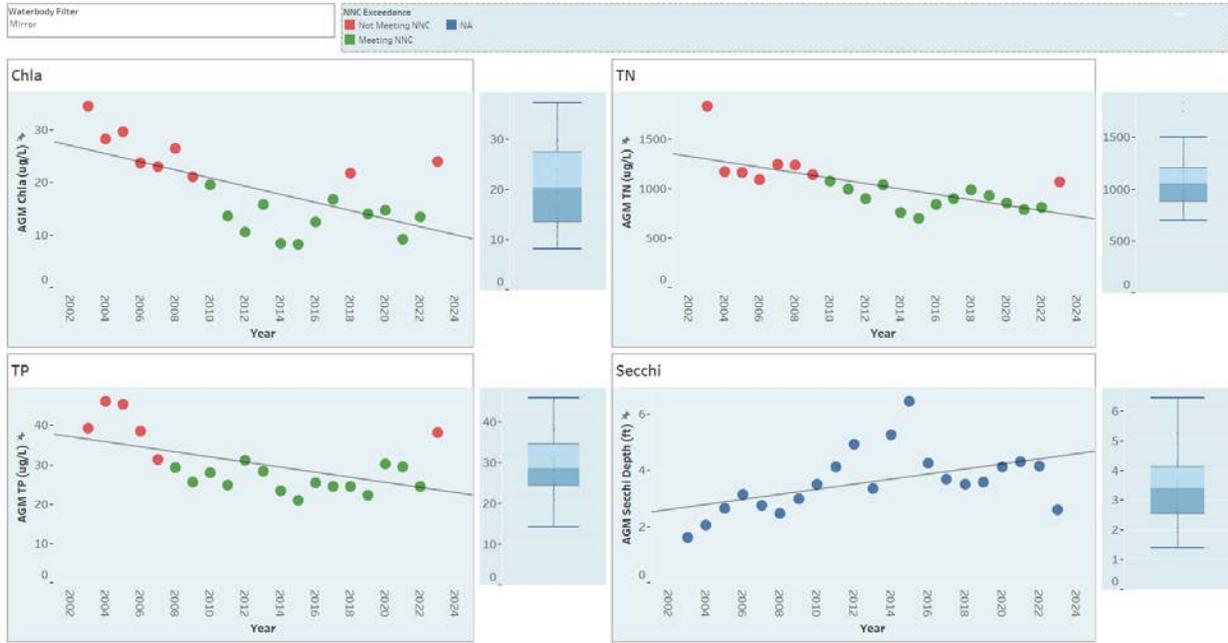


Figure 3-190. Lake Mirror AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Mirror on 1/11/2023. The PAC during this survey was 48.4% and the total BV was 7% (Figure 3-191). This equates to a vegetation abundance criterion score of 3. Throughout the period of record, Lake Mirror has maintained exceptional vegetation abundance; which has likely contributed to its water quality improvements. The coverage observed during 2023 was the second-highest on record.

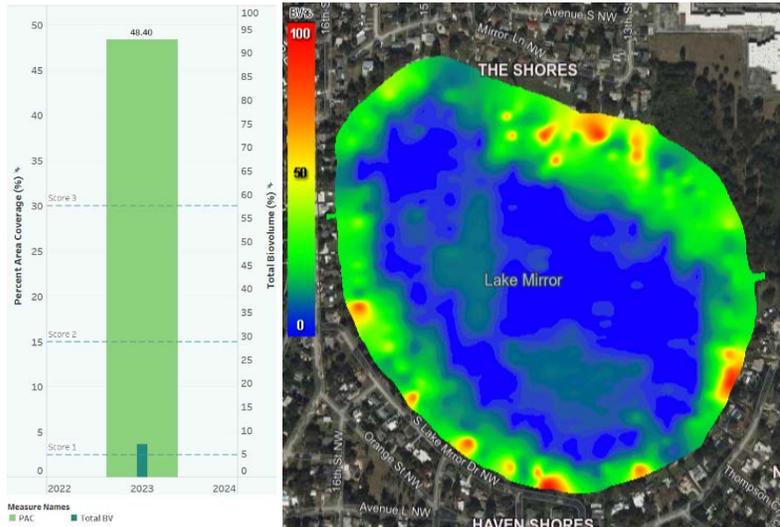


Figure 3-191. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Mirror; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using poin-intercept sampling methods. Based on the 2023 survey, Lake Mirror is dominated by submerged vegetation. Eelgrass and southern naiad comprised over 32% of the community (Figure 3-192). A high number of remaining plants are representative of all vegetation types—indicative of high diversity. Of course, invasive species were present in moderate numbers. Hydrilla and burhead sedge made up almost 3% of the community. This equates to an invasive criterion score of 1. This invasive presence was a marked decline from the previous year—indicating that management efforts were generally successful.

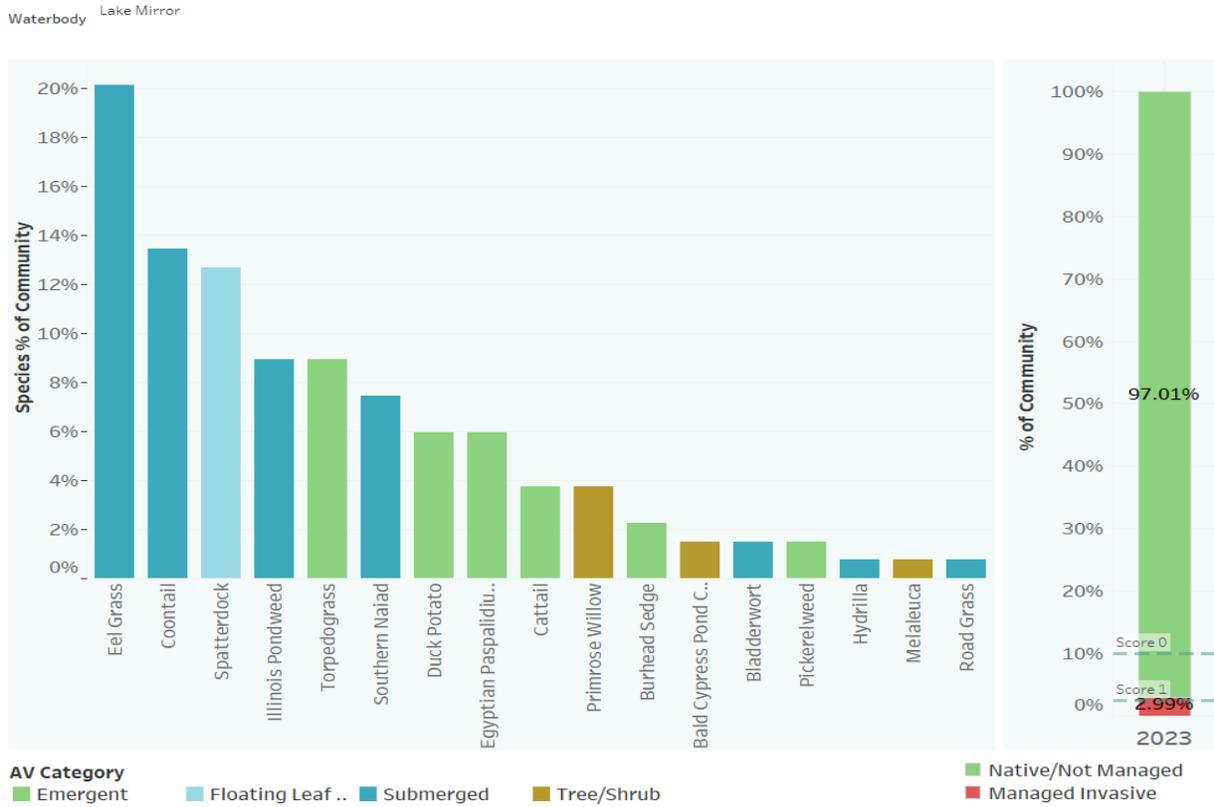


Figure 3-192. Chart depicting species frequency and invasive species presence of Lake Mirror during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, only the evenness index met or exceeded its median value (Figure 3-193). This equates to a diversity criterion score of 1. Invasive species treatment efforts likely had a slight impact on the vegetation community, reducing the prevalence of the less prominent species which had reduced the overall richness index value. With the area of invasive plants reduced, this should allow the growth of beneficial native species in the future.

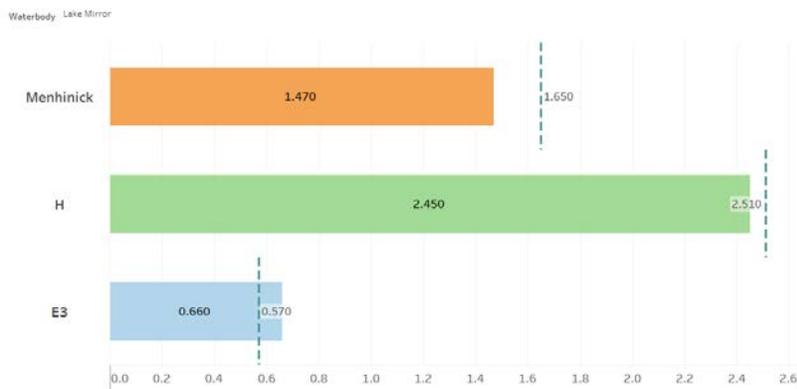


Figure 3-193. Chart depicting 2023 diversity indices for Lake Mirror. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Mirror’s health index scores from 2018 to 2023 shows relative stability (Figure 3-194). Over this six-year span, there has been no change in the water quality or vegetation abundance criteria. The only fluctuation has come from changes in invasive presence and diversity. Of note is the seemingly inverse relationship between invasive presence and diversity scores. This is likely due to slight decreases in diversity when invasive plants are treated and increases when these invasive species return. Overall, Lake Mirror is lower on the priority list as it has excellent water quality and continues to trend in a positive direction.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	3	3	3	2	0	2.5
2019	3	3	3	3	3	3	1	2	2.6
2020	3	3	3	3	3	3	1	1	2.5
2021	3	3	3	3	3	3	2	1	2.6
2022	3	3	3	3	3	3	1	3	2.8
2023	3	3	3	3	3	3	1	1	2.5

Figure 3-194. Chart depicting a comparison of Lake Mirror’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Mirror currently exhibits excellent water quality. However, stormwater pollutant loading is a potential concern if water quality trends begin to deteriorate.
- The management of invasive species like hydrilla is a consistent concern. As observed in Lake May during 2022, it can only take a single growing season for even a small population to take over large areas of a waterbody.

Lake Management Strategy:

- With the majority of the drainage basin comprised of residential housing, public education and outreach is a valid stormwater management strategy. Education aims to increase residents’ knowledge of best stormwater practices and ways they can individually reduce their pollutant load.
- The Stormwater Assessment and Improvement Project has identified a priority area in the southeastern part of Lake Mirror’s drainage basin. Implementation of green infrastructure can reduce flooding in addition to stormwater pollutant loads where treatment has historically been lacking. Staff can explore funding opportunities to implement green infrastructure in these areas.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Ned

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	0	0	0	0	2	3	2	1.3

Location, Characteristics, & Hydrology:

Lake Ned is located far to the southeast of downtown Winter Haven; technically outside of City limits. It receives excess flows from Lake Dexter and discharges excess water to Lake Daisy via a pipe and ditch system. Based on these factors, Ned is considered part of the Outlying Lakes group. Lake Ned is a relatively small waterbody at 76 acres, an average depth of 6.4 feet, and a maximum depth of 18 feet, in some deeper holes (Figure 3-195).

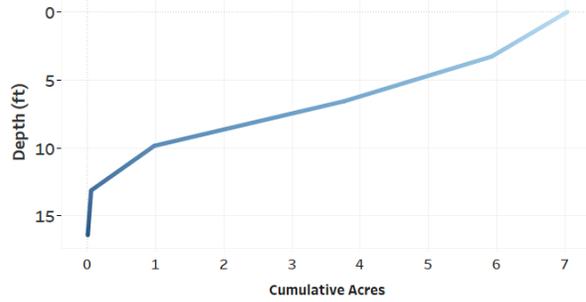


Figure 3-195. Hypsograph of Lake Ned depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 256-acre drainage basin (Figure 3-196). Ranked by area, the primary land uses within this basin are medium-density residential, high-density residential, and open/forested lands. Based on stormwater pollutant load modelling, this drainage area contributes 1,002 lbs of TN and 202 lbs of TP to the lake annually. There are 53 known Onsite Sewage Treatment and Disposal (OSTD/septic) systems within the basin. These could be a contributor of pollutant loads via groundwater leaching. Since all parts of Lake Ned’s basin are outside City limits, Winter Haven does not conduct street sweeping services in the drainage area.

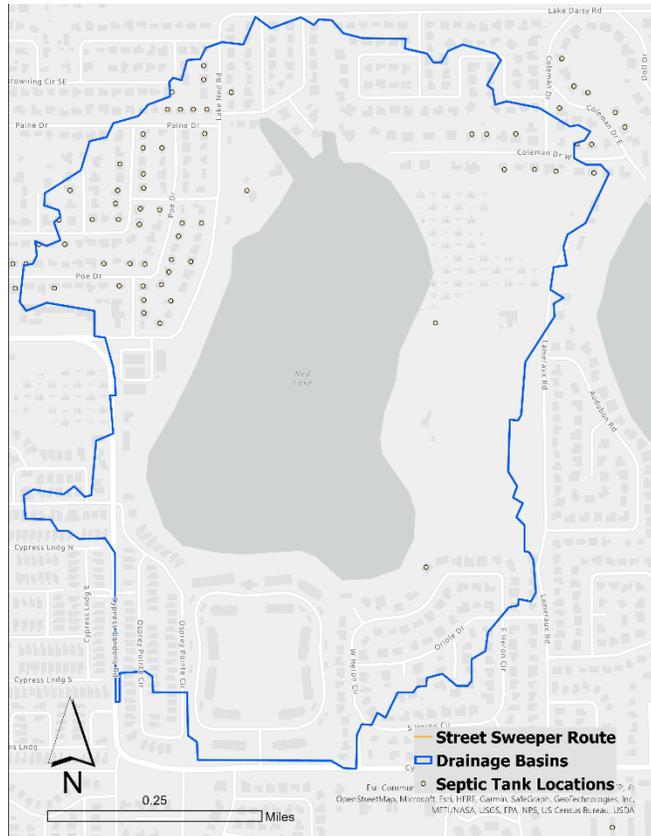


Figure 3-196. Map of Lake Ned’s drainage basin and nearby septic systems.

Over its period of record, Lake Ned’s surface level has fluctuated between 124 and 129.2 feet above sea level. The normal range fluctuates between 126.9 and 128 feet (Figure 3-197). During 2023, Lake Ned’s surface level dropped from a January high of 128 ft to a dry season low of 126.65 ft in August. Late fall and winter rainfall left the surface level at 127.75 ft in December. Changes in Lake Ned’s surface level are not correlated with its primary water quality metrics (see appendix).

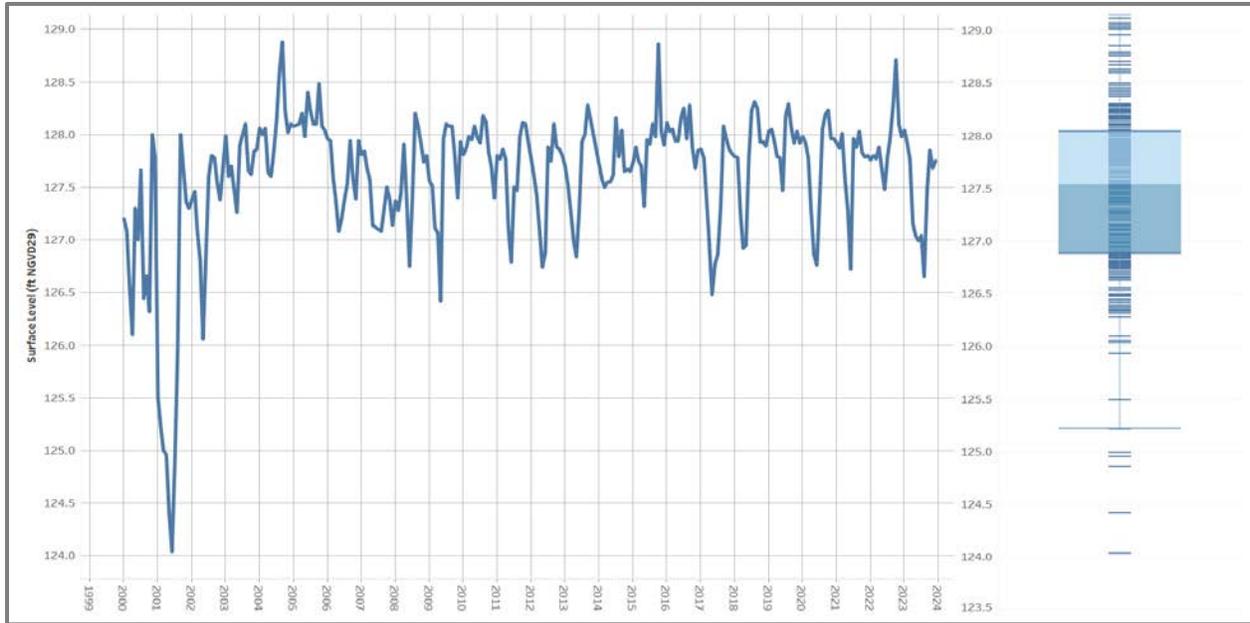


Figure 3-197. Hydrograph of Lake Ned depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Ned is categorized as a clear, alkaline waterbody. Due to a lack of exceedances in any of the NNC parameters during the assessment period, Lake Ned is considered un-impaired (Figure 3-198). This equates to an impairment criterion score of 3. It should be noted that the 2023 Chl-a and TN concentrations were the highest on record, while the 2023 Secchi depth was the lowest on record.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Chl-a, TN, TP, and Secchi depth all exhibited significant deteriorating trends. This equates to trend criteria scores of 0. It is evident that Lake Ned’s water quality is trending in a negative trajectory. Management efforts will be critical in order to prevent water quality impairment in the future. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing (Deteriorating)	Significant	0
TN	Increasing (Deteriorating)	Significant	0
TP	Increasing (Deteriorating)	Significant	0
Secchi	Decreasing (Deteriorating)	Significant	0

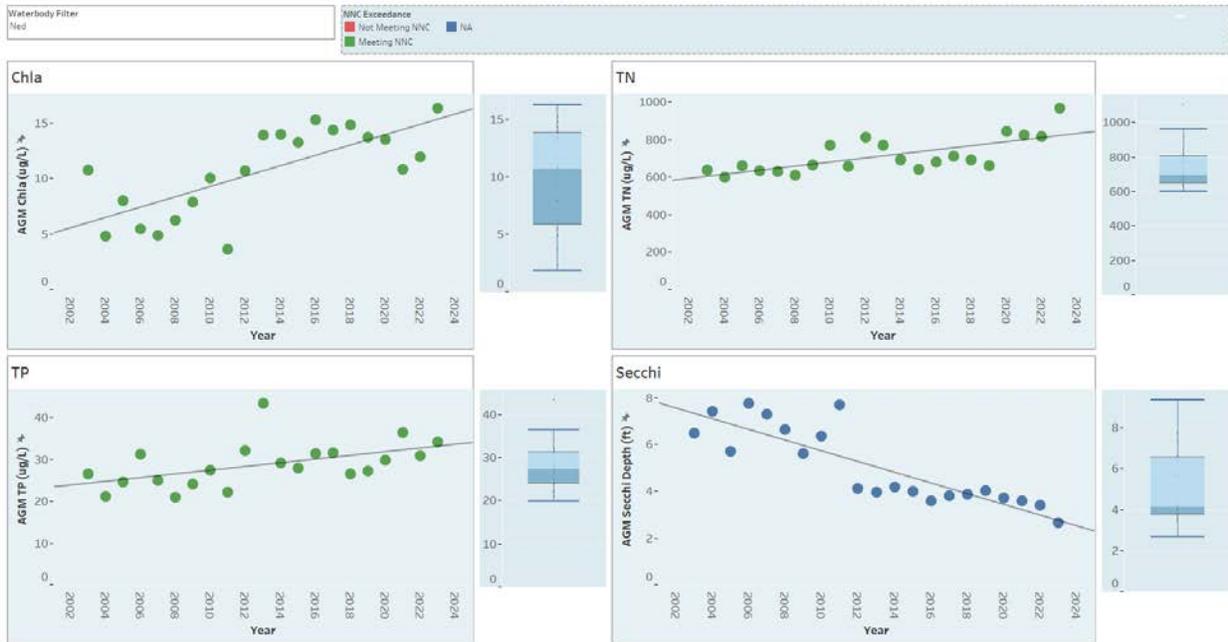


Figure 3-199. Lake Ned AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Ned on 6/7/2023. The PAC during this period was 27% and the total BV was 3.8% (Figure 3-199). By exceeding the 15% coverage threshold, Ned receives a vegetation abundance criterion score of 2. Since monitoring began, Lake Ned has consistently had low vegetation abundance scores—between 4.8% and 16%. The coverage and biovolume values detected in 2023 are the highest on record—indicating some improvement in the vegetation community. Triploid grass carp were stocked in Lake Ned in 2011 to combat increasing hydrilla populations. It is believed that the carp completely denuded the lake of SAV. Fortunately, it appears that the vegetation community is starting to recover.

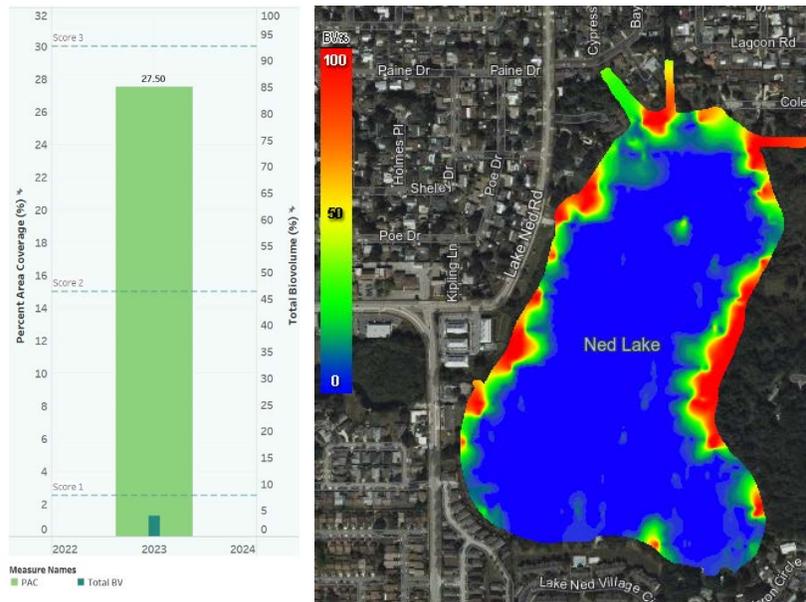


Figure 3-198. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Ned; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2023 survey data, spatterdock was the most abundant species

present, followed by eelgrass at 18% and 13%, respectively (Figure 3-200). This increase in eelgrass abundance is a good sign of recovery as submerged plants help to stabilize sediments and uptake nutrients in the water column. There were no managed invasive species detected in 2023; equating to an invasive management criterion score of 3.

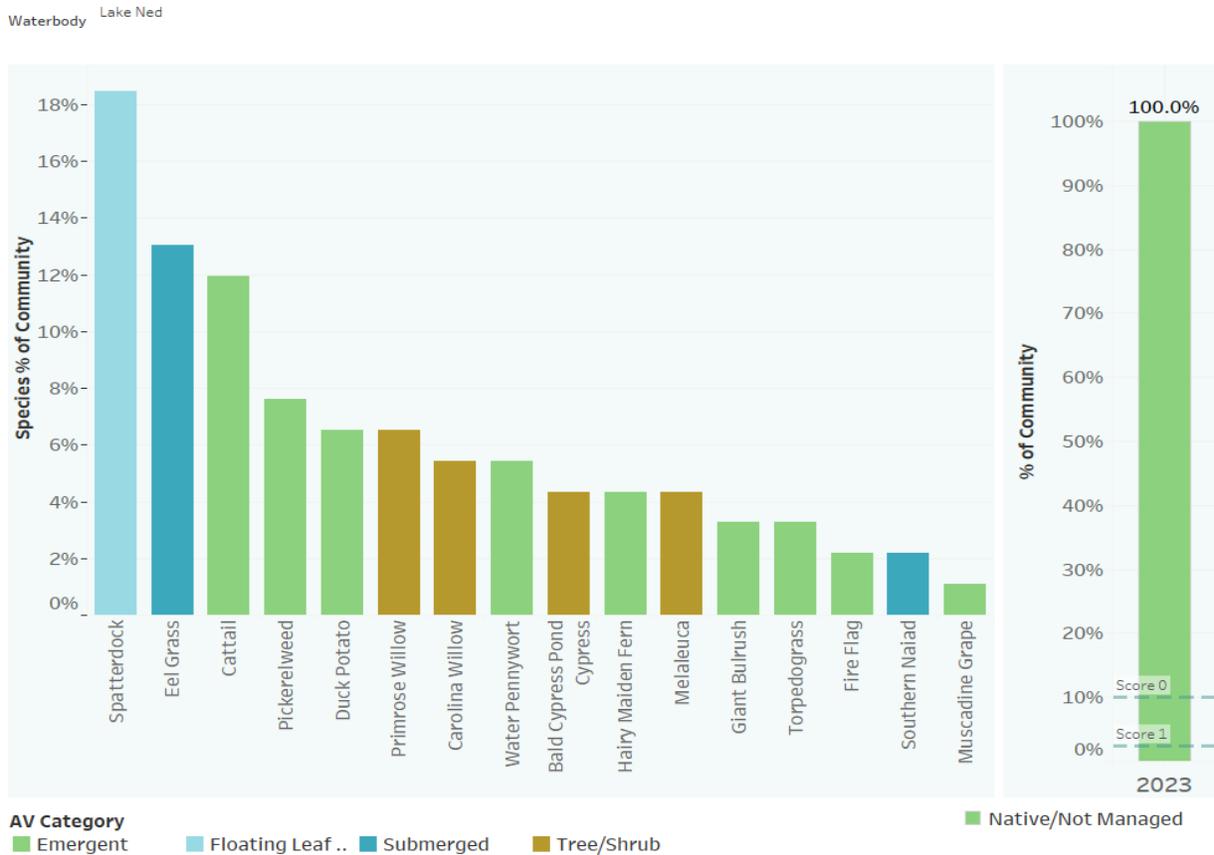


Figure 3-200. Chart depicting species frequency and invasive species percentage of Lake Ned during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, Lake Ned’s evenness and overall diversity indices met or exceeded their respective median values (Figure 3-201). This equates to a diversity criterion score of .

While there was an increase in eelgrass abundance, other less prevalent species like baby’s tears and road grass led to a slight decrease in species richness.

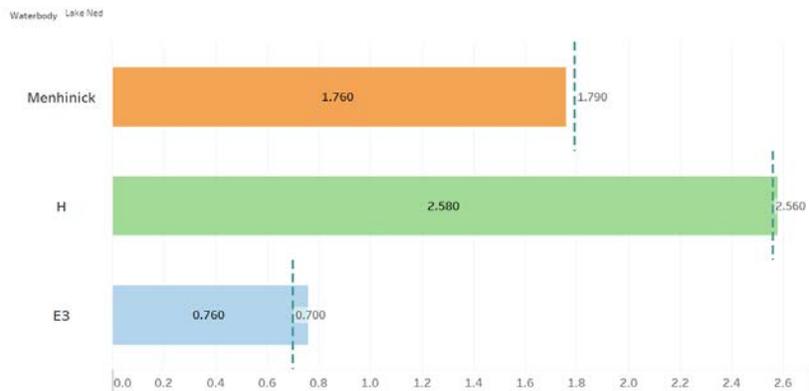


Figure 3-201. Chart depicting 2023 diversity indices for Lake Ned. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Ned’s health index scores from 2018 to 2023 shows some slight variance between 1.1 and 1.4 (Figure 3-202). Regarding water quality, the impairment and trend scores have remained largely unchanged. However, the recent shift in the TN trend significance resulted in a slight reduction in overall lake health. The majority of the score fluctuation has occurred from the biological criteria. As stated, vegetation abundance is recovering. While hydrilla was detected in 2022, it has since been managed to undetectable levels. The diversity has also improved as the vegetation community recovered. Overall, Lake Ned is in the middle of the priority list. Efforts should focus on improving water quality before the lake becomes impaired.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	0	1	0	0	1	1	3	1.1
2019	3	0	2	0	0	1	1	3	1.3
2020	3	0	2	0	0	1	3	0	1.1
2021	3	0	2	0	0	1	3	1	1.3
2022	3	0	1	0	0	2	2	3	1.4
2023	3	0	0	0	0	2	3	2	1.3

Figure 3-202. Chart depicting a comparison of Lake Ned’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- While stormwater pollutant loading remains a potential concern, the presence of so many OSTDs within the basin may be a contributor of nutrients via groundwater leaching.
- The management of the vegetation community includes ensuring adequate abundance and invasive species control. While hydrilla wasn’t detected in 2023, it can take a single growing season for this plant to expand exponentially. Early detection and rapid response is crucial to keep these invasive plants from becoming a larger problem that would necessitate larger-scale control (which comes with potentially negative impacts).

Lake Management Strategy:

- City staff can provide support to Polk County in exploring source analysis to determine if the OSTDs are contributing to increased pollutant loads in Lake Ned. Further management efforts may explore septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large scale herbicide treatments and the potential water quality issues that follow.

Lake Otis

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health Score
3	1	2	1	1	3	1	2	1.8

Location, Characteristics, & Hydrology:

Lake Otis is located to the east of downtown Winter Haven. It is able to receive emergency overflows from Lake Elbert via a pump system and pipe connection. Otis is connected to Lake Link via navigable canal which is also where it discharges excess water downstream toward Lake Mariam. Based on these factors, it is considered part of the South Central Lakes group. Lake Otis is a moderately sized waterbody comprised of a main lake basin and Little Lake Otis to the south. It has a surface area of 150 acres, an average depth of 11.3 feet, and a maximum depth of over 30 feet in deeper holes (Figure 3-203).

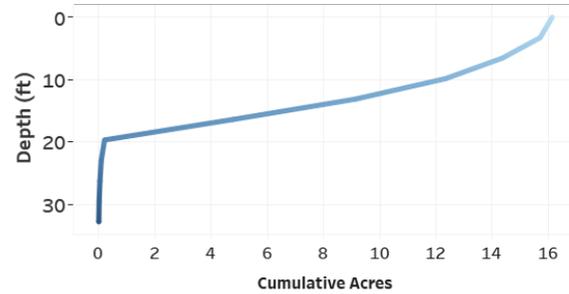


Figure 3-203. Hypsograph of Lake Otis depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 587 acre drainage basin comprised of 11 individual sub-basins (Figure 3-203). By far, the most dominant land use type in this basin is medium density residential; followed by low density residential, institutional, and commercial uses, respectively. Based on stormwater pollutant modelling, this drainage area contributes 2291 lbs of TN and 372 lbs of TP to the lake annually. There are 66 Onsite Sewage Treatment and Disposal (OSTD/septic) systems located within the drainage basin. These constitute a moderate density and may contribute to pollutant loading via groundwater leaching. To mitigate stormwater loads, the City conducts 12.8 miles of street sweeping within the basin.

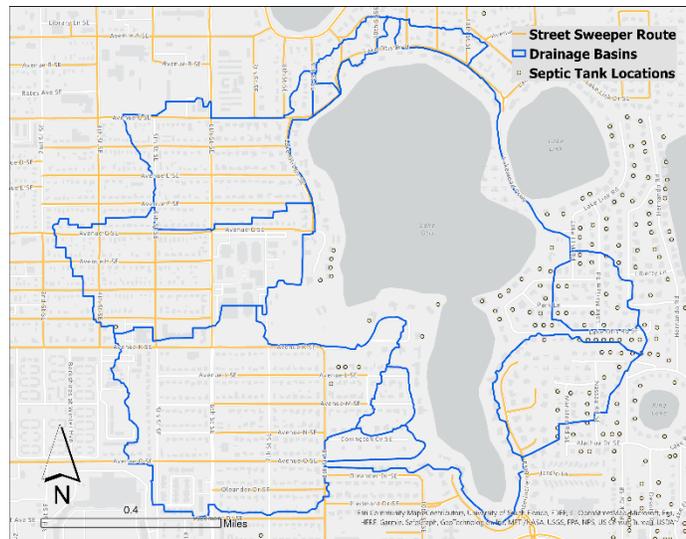


Figure 3-204. Map of Lake Otis' drainage basin, City street sweeper routes, and nearby septic systems.

Over its period of record, the shared surface level of Lakes Link and Otis has fluctuated between 120.3 and 128.8 feet above sea level. The wide range of fluctuation (without flooding the nearby residents) is possible because of the steep-sloped morphology of these lakes. The normal range of fluctuation is much narrower—between 124.9 and 127.2 feet (Figure 3-133). During 2023, Lake

Otis reached a wet season peak of 126.9 feet in June and a dry season low of 126.2 feet in May. The surface level ended the year below the median at 126.4 feet. According to linear regression analysis, changes in Lake Otis’ surface level are correlated with Chl-a, TN, and Secchi depth (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.

Water Quality Impairment:

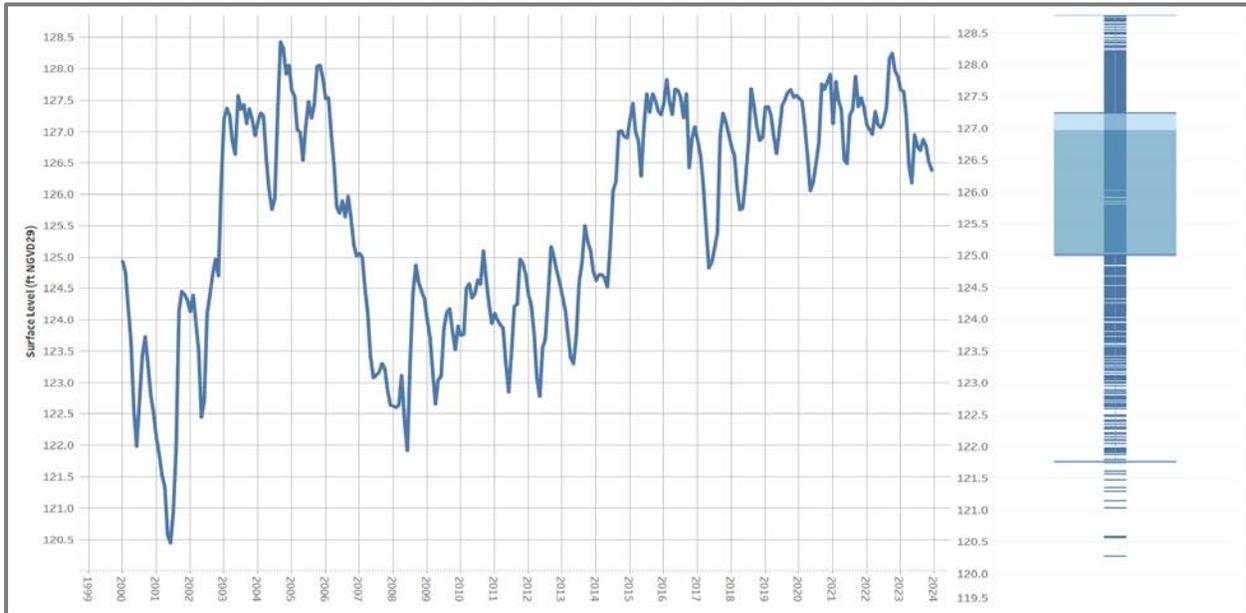


Figure 3-205. Hydrograph of Lake Otis depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

For the purposes of determining water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Otis is categorized as a clear, alkaline waterbody. Due to a lack of NNC exceedances during the assessment period, Lake Otis is considered un-impaired (Figure 3-206). This equates to an impairment criterion score of 3. Lake Otis did exhibit Chl-a impairment as late as 2019, but has since improved to the point of being delisted.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Lake Otis exhibits no statistically significant trends. However, Chl-a, TP, and Secchi depth trends are in a deteriorating direction, while TN’s trend direction is improving. Deteriorating trend directions earn scores of 1 while improving directions earn scores of 2. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing	Not Significant	1
TN	Decreasing	Not Significant	2
TP	Increasing	Not Significant	1
Secchi	Decreasing	Not Significant	1

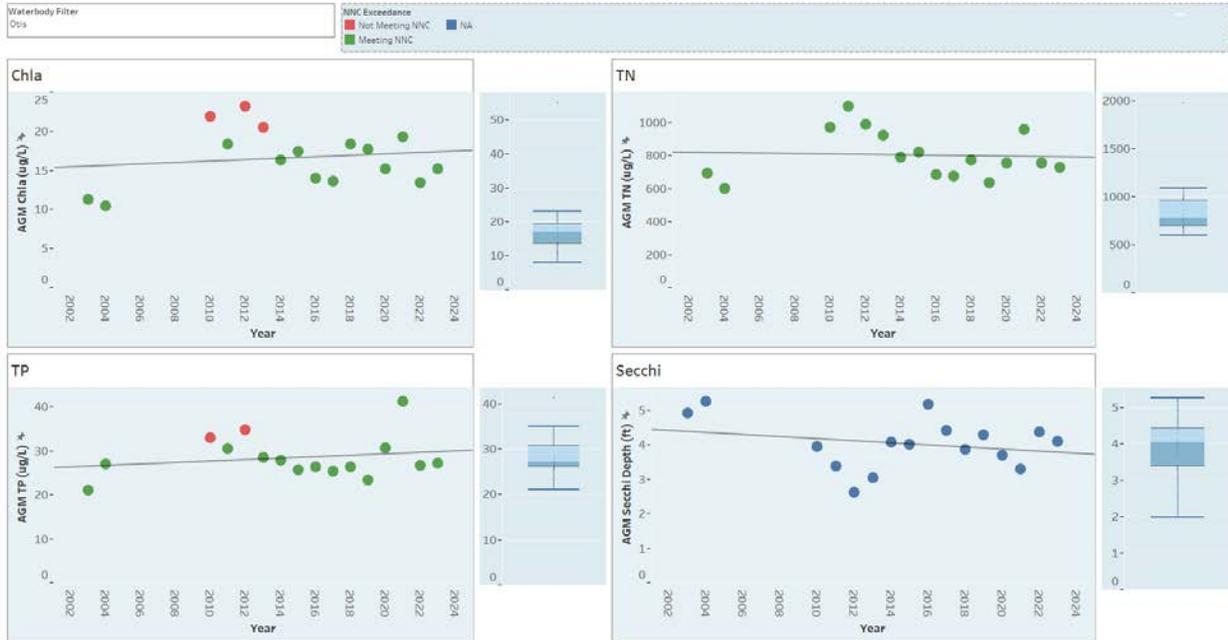


Figure 3-207. Lake Otis AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Otis on 9/15/2023. The PAC during this survey was 31.9% and the total BV was 4.4% (Figure 3-207). Exceeding the 30% PAC threshold results in an abundance criteria of 3. A comparison of abundance records from 2018 to the present shows that Lake Otis’ coverage is typically between 15% and 30%. The coverage value for 2023 is the highest on record, indicating an upward trend in vegetation abundance—a good sign.

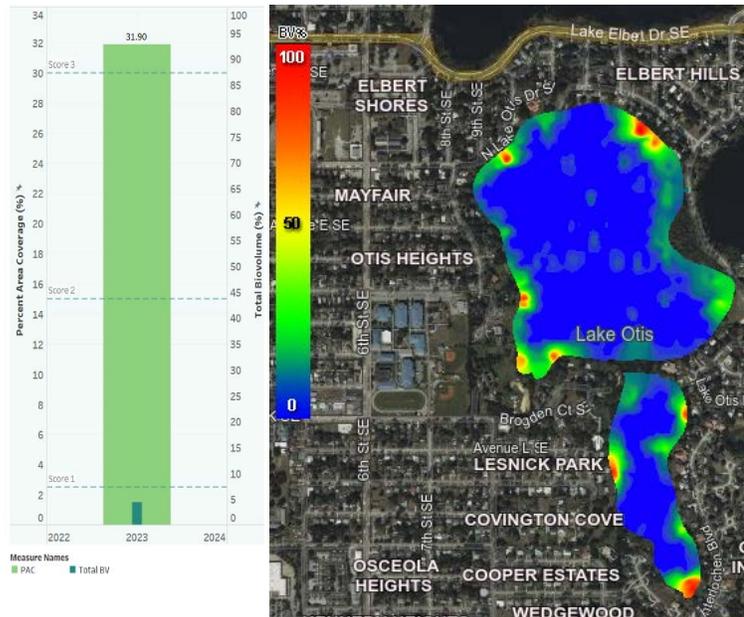


Figure 3-206. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Otis; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2023 survey data, Lake Otis maintains a healthy mix of vegetation types. The most dominant species was fragrant water lily at over 20% of the population (Figure 3-208). Regarding invasive species, water hyacinth and hydrilla made up just over 2.9% of the community. This equates to an invasive criterion score of 1. Prior to 2018, hydrilla was the primary invasive species to be controlled. Grass carp were stocked in 2019 and appear to be

having a positive impact on the control of the hydrilla while also allowing other native submerged species to grow.

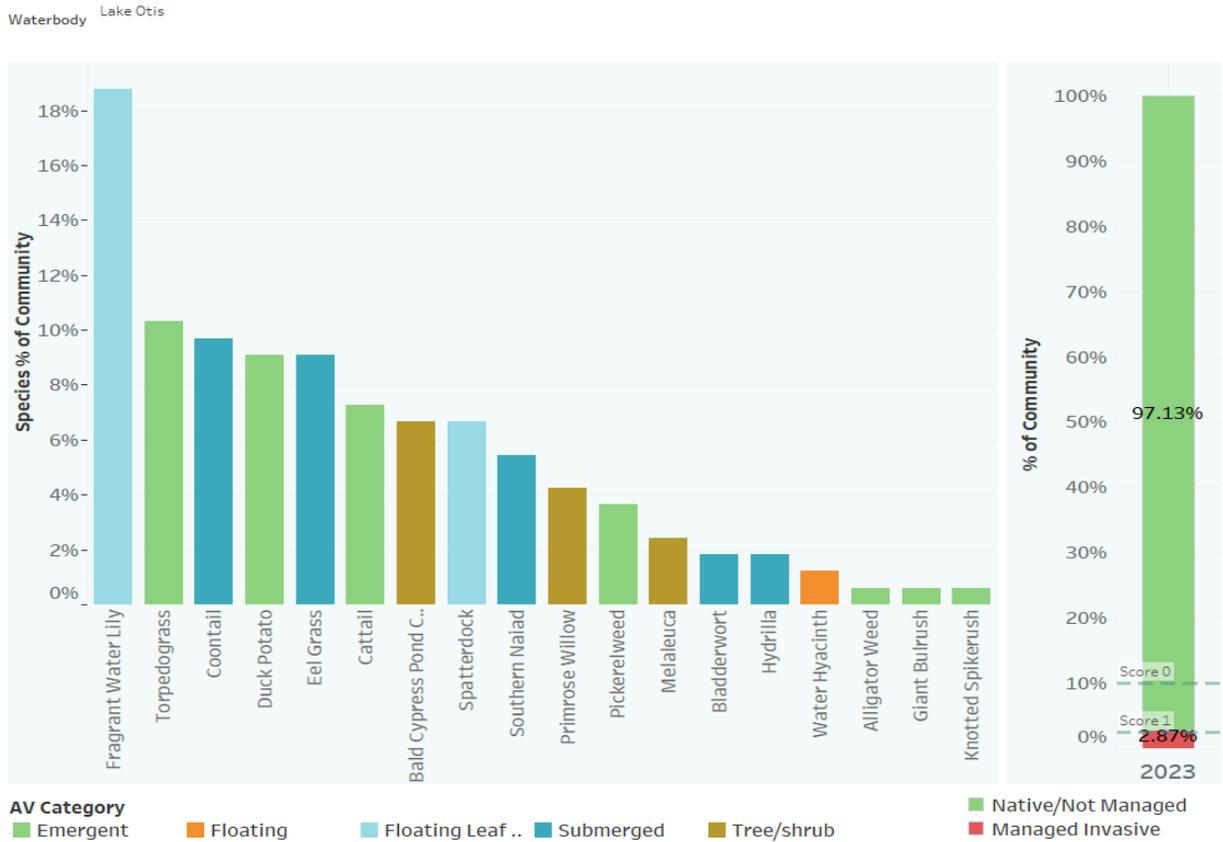


Figure 3-208. Chart depicting species frequency and invasive species percentage of Lake Otis during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on 2023 species data, Lake Otis’ species richness and evenness indices met their respective median values (Figure 3-209). This equates to a diversity criterion score of 2. While it didn’t meet its median levels, overall diversity has not changed much over time. While invasive species treatment efforts likely have some impact on the vegetation community, these impacts have been relatively minor.

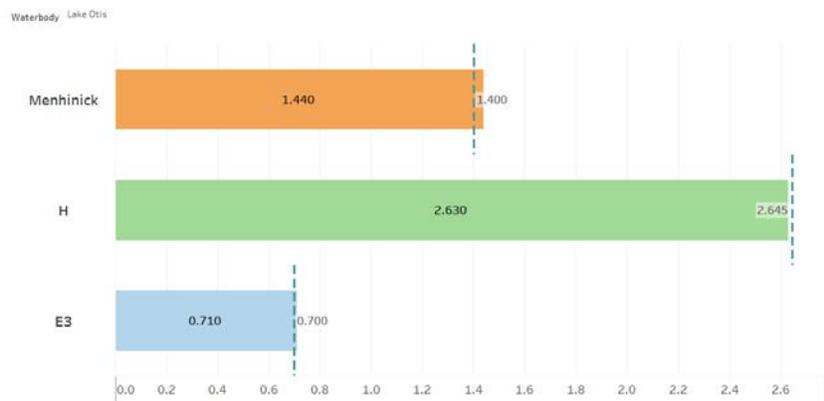


Figure 3-209. Chart depicting 2023 diversity indices for Lake Otis. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Otis’ health index scores from 2018 to 2023 shows values ranging from 1.6 to 2.2 (Figure 3-210). Over this six year span, the impairment criterion has seen improvement as Chl-a began meeting NNC guidelines. The water quality trends have remained relatively static, with TP and Clarity shifting directions slightly from year to year. Vegetation abundance and species diversity have shown improvement in recent years. Overall, Lake Otis ranks lower on the priority list as it is currently meeting water quality standards and the trends do not indicate deterioration.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	2	2	2	2	2	2	1	2	1.9
2019	2	2	2	2	2	2	0	2	1.8
2020	3	2	2	2	2	2	NA	NA	2.2
2021	3	2	2	1	1	1	2	1	1.6
2022	3	2	2	1	2	2	2	2	2.0
2023	3	1	2	1	1	3	1	2	1.8

Figure 3-210. Chart depicting a comparison of Lake Otis’ Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Stormwater pollutant loading from the western portion of the basin is a concern. Additionally, the presence of OSTDs on the eastern side of the basin could potentially leach pollutants to the lake via groundwater.
- The management of invasive species like hydrilla is a consistent concern. There are also potential impacts from all types of invasive management strategies. Finding the right balance is important.
- Several water quality metrics are significantly correlated with Lake Otis’ surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- The City’s current stormwater management strategy includes street sweeping and the implementation of green infrastructure (swales) along 6th St SE. The Stormwater Assessment and Improvement Plan has also identified several other potential areas in the basin where stormwater improvements can be made. Staff will explore funding opportunities to make these a reality.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC.
- The City may explore source analysis to determine if the OSTDs in the basin are a contributor of pollutant loading. Further management may involve septic-to-sewer conversions.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Pansy

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	0	2	1	1	2	2	1	1.5

Location, Characteristics, & Hydrology:

Lake Pansy is located to the northwest of downtown Winter Haven, at the northern edge of City limits. While it has no confirmed connections to other lakes in the area, it is believed to discharge excess water during wet periods to Lake Rochelle through a wetland on its northeast shore. Based on these factors, Pansy is considered part of the Outlying Lakes group. Lake Pansy is a relatively small waterbody at just 52 acres, an average depth of 7.8 feet, and a maximum depth of over 11 feet (Figure 3-211).

Stormwater is conveyed to this waterbody from a 244-acre drainage basin (Figure 3-212). The majority of this basin is comprised of the Winter Haven Airport, a transportation land use; while the remaining land uses include medium-density residential and wetlands. Based on stormwater pollutant load modelling, this drainage area contributes 880 lbs of TN and 111 lbs of TP to the lake annually. There are no known Onsite Sewage Treatment and Disposal (OSTD/septic) systems within the drainage basin. While the airport drainage is treated via a stormwater pond prior to discharging to Lake Pansy, the City does not conduct any street sweeping services in this basin. However, 21st Street is a potential sweeper route expansion area.

Over its period of record, Lake Pansy’s surface level has fluctuated between 124.5 and 129.7 feet above sea level. The normal range of fluctuation is much narrower—between 126.6 and 128.5 feet (Figure 3-213). During 2023, Lake Pansy reached a wet season peak of 128.9 feet in October and a dry season low of 127.5 feet in May. The surface level ended the year above the normal range at 128.65 feet. According to linear regression analysis,

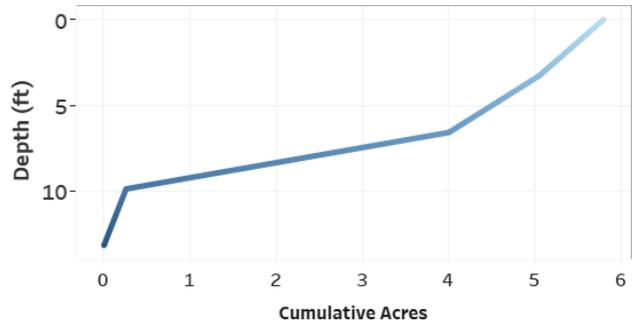


Figure 3-211. Hypsograph of Lake Pansy depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.



Figure 3-212. Map of Lake Pansy’s drainage basin and nearby septic systems.

changes in Lake Pansy’s surface level correlates directly with water clarity (see appendix). This indicates that higher surface levels result in increased flushing and water clarity.

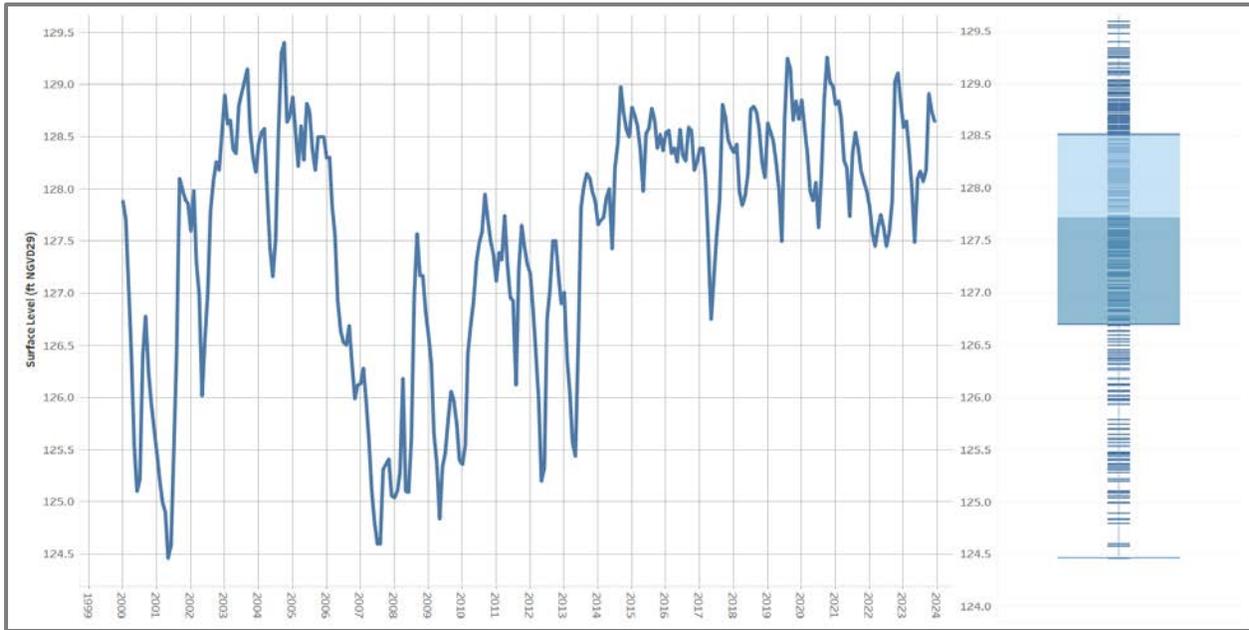


Figure 3-213. Hydrograph of Lake Pansy depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Pansy is categorized as a highly colored waterbody. Aside from a single NNC exceedance in Chl-a during the assessment period, Lake Pansy’s water quality has met the NNC guidelines (Figure 3-214). Pansy’s status is currently un-impaired which earns it an impairment criterion score of 3.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. During this time frame, Chl-a exhibits a significant deteriorating trend; for a trend criterion score of 0. The trends for the remaining parameters were non-significant with TN in an improving direction and TP and Secchi depth in a deteriorating direction. These trend stats equate to the criterion index scores in the table below. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing (Deteriorating)	Significant	0
TN	Decreasing	Not Significant	2
TP	Increasing	Not Significant	1
Secchi	Decreasing	Not Significant	1

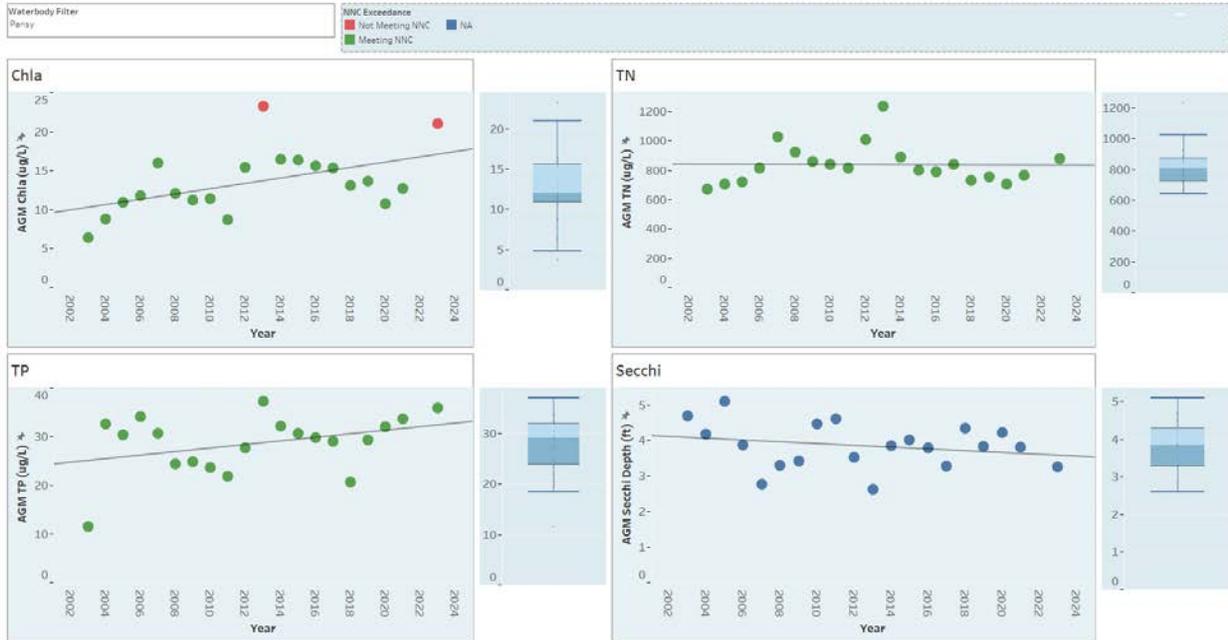


Figure 3-215. Lake Pansy AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Pansy on 9/22/2023. The PAC during this survey was 20.6% and the total BV was 0.4% (Figure 3-215). Since the PAC exceeded the 15% threshold, this equates to an abundance criterion score of 2. Comparing Lake Pansy’s abundance values from 2018 to 2023 indicates that its coverage often fluctuates between 15% and 45%. This may be the result of consistent invasive species treatments.

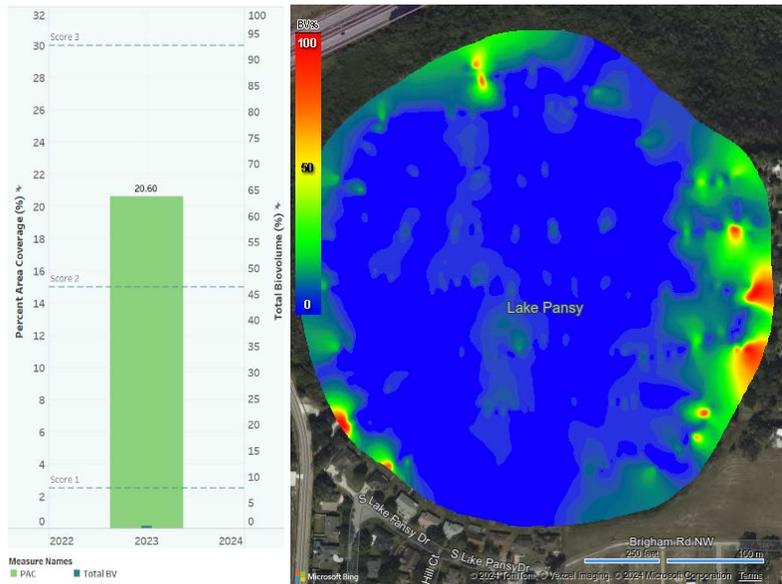


Figure 3-214. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Pansy; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2023 survey, Lake Pansy is dominated by spatterdock at over 30% of the community (Figure 3-216). The remaining species were mostly comprised of emergent plant types, with submerged plants at only 1.6%. Water hyacinth was the only managed invasive species detected in 2023, making up just over 1.5% of the community. This equates to an invasive criterion score of 2. In previous years, hydrilla was the primary invasive species, but its absence indicates that control efforts have been effective.

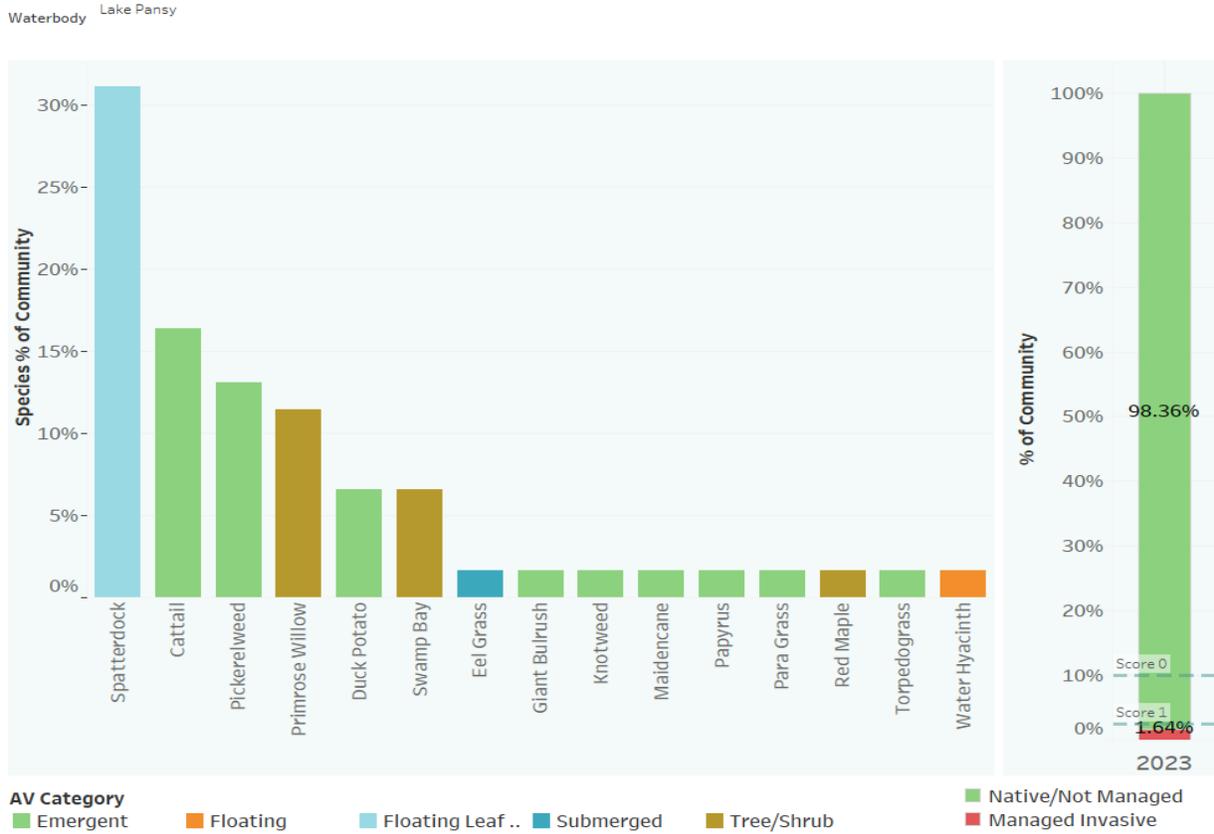


Figure 3-216. Chart depicting species frequency and invasive species percentage of Lake Pansy during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, only Lake Pansy’s species richness index met its long-term median value (Figure 3-217). This equates to a diversity criterion score of 1. The low evenness and overall diversity scores are mainly due to the minuscule abundance of less prevalent species. This may be due to the long-term treatment efforts for invasive species like water hyacinth. Additionally, the dominance of floating leaf plants like spatterdock often reduces the ability for submerged plants to gain a foot-hold.

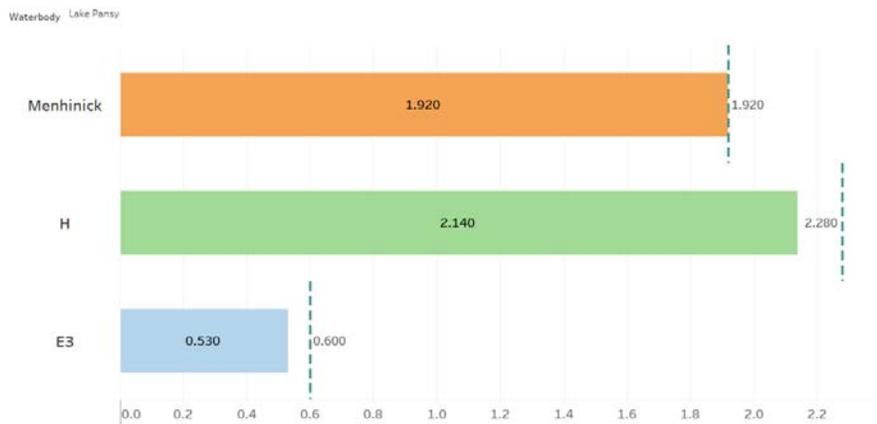


Figure 3-217. Chart depicting 2023 diversity indices for Lake Pansy. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Pansy’s health index scores from 2018 to 2023 shows some fluctuation between 1.1 and 1.5 (Figure 3-218). The majority of these changes have been the result of the biological criteria. Impairment has remained static over the past six years, as have most of the water quality trends. Vegetation abundance, invasive presence, and diversity scores have shown variance. This is likely due to both positive and negative impacts of invasive species management. Overall, Lake Pansy sits in the middle of the priority ranking. While it is not currently impaired, its water quality trends are not ideal and the changes to the vegetation community could further impact water quality.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	0	1	1	1	2	0	1	1.1
2019	3	0	1	1	1	3	0	3	1.5
2020	3	0	1	1	2	2	0	3	1.5
2021	3	0	1	1	2	3	0	2	1.5
2022	3	0	1	1	2	2	1	0	1.3
2023	3	0	2	1	1	2	2	1	1.5

Figure 3-218. Chart depicting a comparison of Lake Pansy’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Stormwater pollutant loading is one of the primary concerns for water quality management. While the City does not possess much stormwater infrastructure in the area, there is room for measures to reduce pollutant loading in the drainage basin.
- The management of invasive species is a consistent concern. It can only take a single growing season for even a small population to take over large areas of a waterbody.
- Lake Pansy’s water clarity is correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- The City can explore expanding street sweeping services to 21st Street to reduce potential stormwater pollutant loading.
- The residential communities around the lake provide opportunities for public outreach and education. This aims to increase residents’ knowledge of best stormwater practices and ways they can individually reduce their pollutant load.
- City staff will continue to monitor aquatic vegetation and share the information with Polk County and the FWC. Staff will also take a more active role in advocating for the most effective, but least impactful invasive management strategies to ensure proper balance of the vegetation community.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Rochelle

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health Score
3	3	3	2	3	2	1	1	2.3

Location, Characteristics, & Hydrology:

Lake Rochelle is located north of downtown Winter Haven; bordered by the City of Winter Haven to the south and the town of Lake Alfred to the north. With navigable connections to Lake Haines and Conine, Lake Rochelle is part of the North Chain of Lakes. Excess water from the North Chain eventually drains via the SWFWMD-managed P-8 control structure to the south of Lake Hamilton and enters the Peace Creek. Lake Rochelle is a larger waterbody at 570 acres, an average depth of 9.9 feet, and a maximum depth of 19 feet (Figure 3-219).

Stormwater is conveyed to this waterbody from a 1,670 acre, relatively rural drainage basin (Figure 3-220). Ranked by area, the primary land uses comprising this basin are wetlands, medium-density residential, agricultural, high-density residential, and commercial. Based on stormwater pollutant load modelling, this drainage area contributes 3,002 lbs of TN and 522 lbs of TP to the lake annually. There are over 40 Onsite Sewage Treatment and Disposal (OSTD/septic) systems within the basin. These constitute a relatively low density based on the number of systems per acre. To mitigate stormwater pollutant loading, the City conducts 4.4 miles of street sweeping twice monthly along US Highway 17.

Over the period of record, surface levels in this section of the North Chain (Lakes Conine, Haines, Rochelle, and Smart) have fluctuated between 122 and 129.5 feet above sea level. The normal range fluctuates much less between 126.1 and 128.2 feet (Figure 3-29). During 2023, Lake Conine reached a wet season peak of 128.6 feet in September and a dry season low of 127.8 feet in May. The surface level ended the year above the high end of the normal range at 128.6 feet. Changes in Lake Rochelle’s surface level are directly correlated

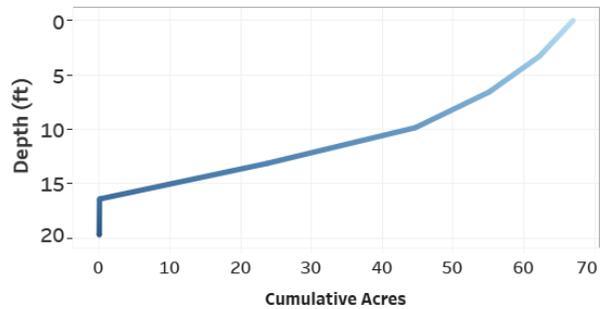


Figure 3-220. Hypsograph of Lake Rochelle depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.



Figure 3-219. Map of Lake Rochelle’s drainage basin, City street sweeper routes, and nearby septic systems.

with water clarity and indirectly correlated with Chl-a and TN (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.

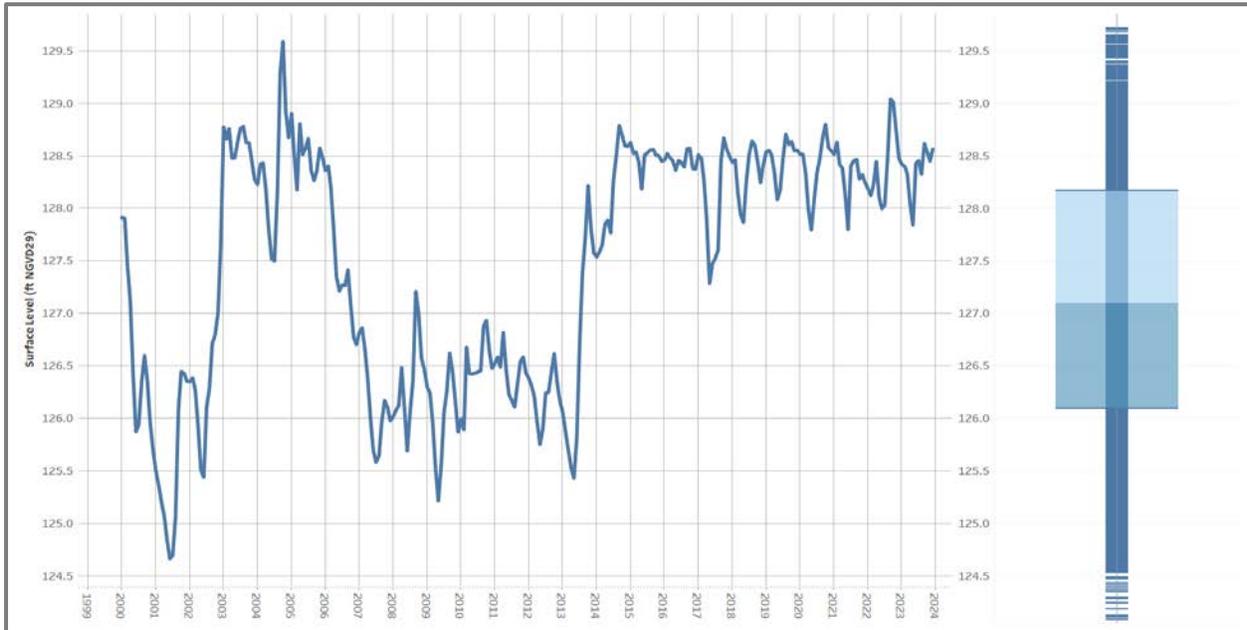


Figure 3-221. Hydrograph of Lake Rochelle depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria, Lake Rochelle is categorized as a clear, alkaline waterbody. While Lake Rochelle was previously impaired, a lack of NNC exceedances during the assessment period has resulted in its currently un-impaired status (Figure 3-222). This equates to an impairment criterion score of 3. In 2018, the FDEP established a total maximum daily load stipulating a 32% TN reduction to meet NNC guidelines. Lake Rochelle has been meeting all NNC thresholds since 2015.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. During the most recent analysis, Ch-la, TN, and Secchi depth exhibited significant improving trends—equating to trend criteria scores of 3. TP exhibited a non-significant improving trend; for a trend score of 2. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing	Not Significant	2
Secchi	Increasing (Improving)	Significant	3

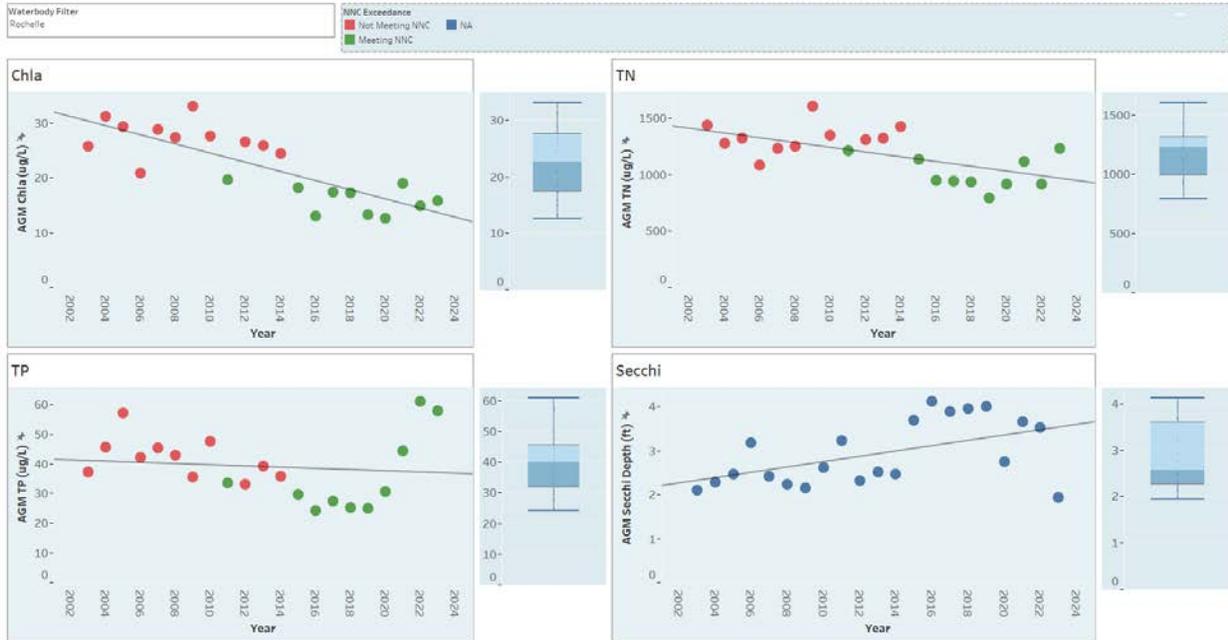


Figure 3-223. Lake Rochelle AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Rochelle on 2/24/2023. The PAC during this survey was 27% and the total BV was 4.6% (Figure 3-223). This equates to an abundance criterion score of 2. Lake Rochelle has consistently maintained vegetation coverage above 30% in the six years since monitoring began. This recent decrease in coverage and biovolume is likely due to recent hydrilla management efforts as well as some predation of native plants by grass carp that were released in 2017. Overall, the abundance is not bad, but the decrease has lowered its criterion score from previous years.

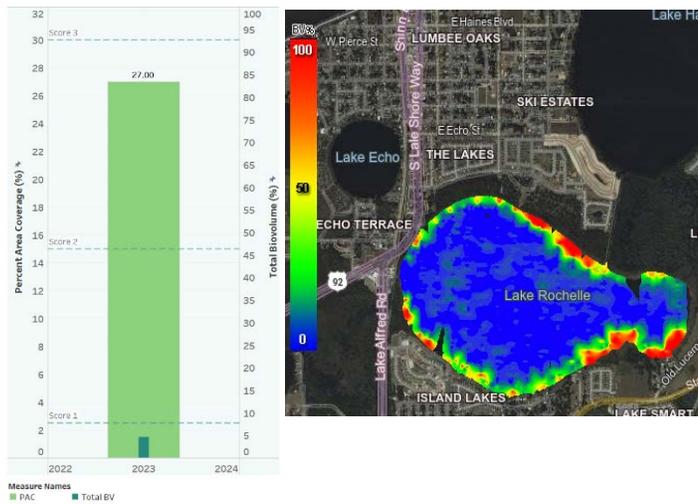


Figure 3-222. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Rochelle; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, Lake Rochelle boasts a healthy mix of both submerged and emergent vegetation—with eelgrass dominating the community at 18% (Figure 3-224). Hydrilla, burhead sedge, and water hyacinth comprised the managed invasive species present; at just 3% of the community; equating to an invasive presence criterion score of 1. The invasive presence has been a constant since 2019 but has exhibited a gradual decline

from 22.5% to the current percentage. Management efforts are still underway to control these populations.

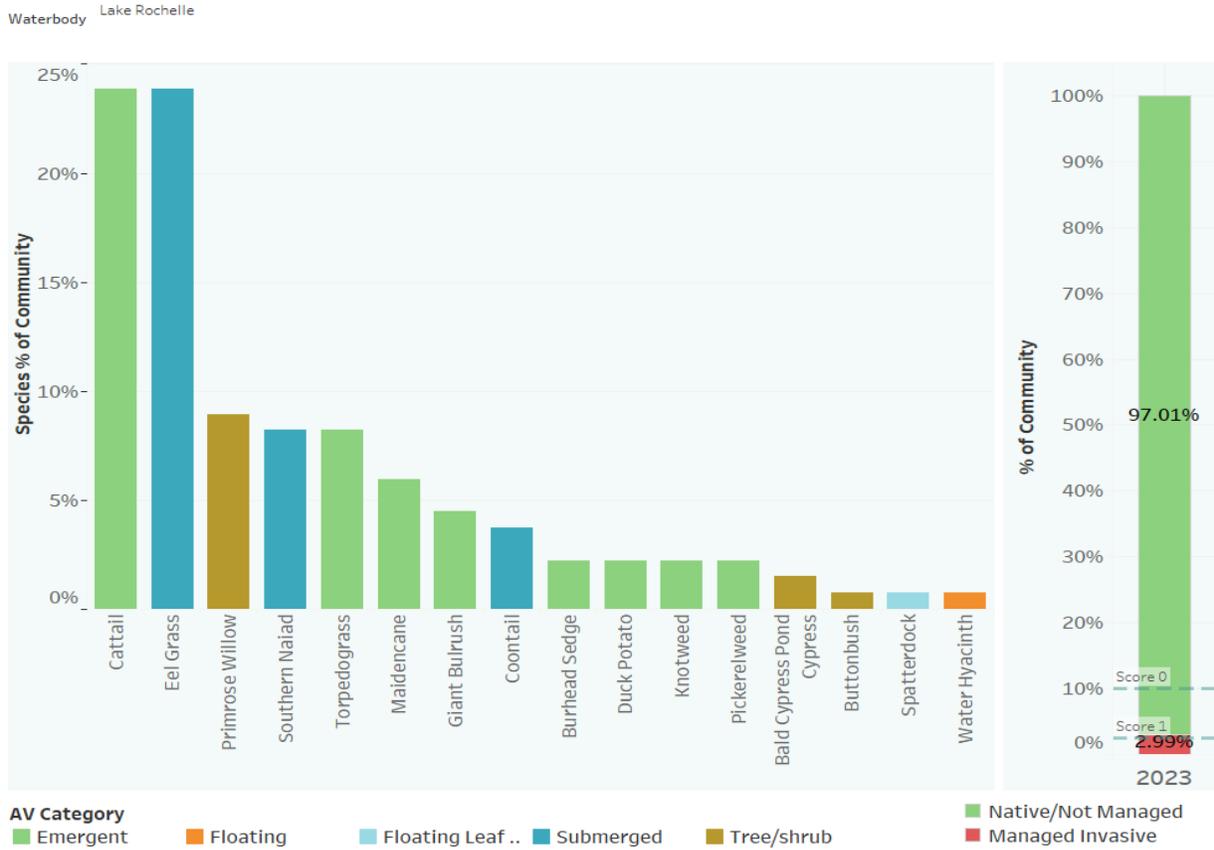


Figure 3-224. Chart depicting species frequency and invasive species percentage of Lake Rochelle during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, only Lake Rochelle’s species evenness index exceeded its long-term median value (Figure 3-225). This equates to a diversity criterion score of 1. Overall, Lake Rochelle exhibits moderate diversity compared with other waterbodies in the area. Despite not meeting the long-term median values, the species richness and overall diversity aren’t too far from the target.

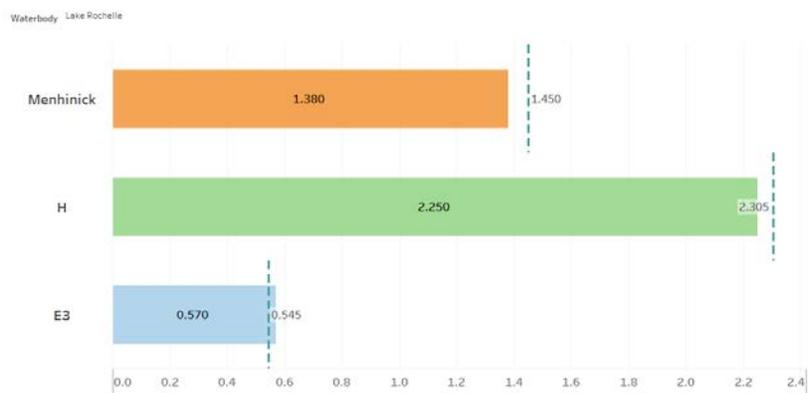


Figure 3-225. Chart depicting 2023 diversity indices for Lake Rochelle. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Rochelle’s health index scores from 2018 to 2023 shows relative stability—with values ranging from 1.9 to 2.5 (Figure 3-226). Over this span, Rochelle’s water quality has improved considerably; both exhibiting improving trends and meeting NNC guidelines after 2020. Its vegetation abundance has remained high, aside from the recent decrease in coverage. Much of the lake health score variability has been the result of shifts in the invasive species and diversity criteria over the years. Overall, Lake Rochelle ranks lower on the priority list since its water quality is now meeting standards and continues to exhibit improvement. The main area for management action is controlling invasive plants.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	3	2	3	3	3	1	3	2.3
2019	0	3	3	3	3	3	0	3	2.3
2020	0	3	3	3	3	3	0	1	2.0
2021	3	3	3	3	3	3	0	0	2.3
2022	3	3	3	3	3	3	0	2	2.5
2023	3	3	3	2	3	2	1	1	2.3

Figure 3-226. Chart depicting a comparison of Lake Rochelle’s Lake Health Index scores from 2018 to 2023.

Lake Health Impact/Challenges:

- Lake Rochelle currently exhibits good water quality and improving trends. However, stormwater pollutant loading is a potential concern and one of the primary factors to look to if water quality begins trending in an unfavorable direction.
- Several of Lake Rochelle’s water quality parameters are correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- The management of invasive species like hydrilla is one of the primary concerns. Large-scale herbicide treatments can lead to water quality declines; which is a possibility as hydrilla is still not in a controlled state.

Lake Management Strategy:

- In order to mitigate stormwater pollutant loading, the City conducts street sweeping along one of the few public roads in the basin. The addition of new housing in the area provides opportunities for public education and outreach. This aims to increase residents’ knowledge of best stormwater practices and ways they can individual reduce their pollutant loads.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Recent invasive species management efforts have included herbicide treatment and minimal stocking of triploid grass carp. This measured, but integrated approach appears to be gradually improving the invasive presence in Lake Rochelle, but more effort is required to keep these under control.

Lake Roy

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health Score
3	3	2	3	2	3	2	2	2.5

Location, Characteristics, & Hydrology:

Lake Roy is located to the southeast of downtown Winter Haven. It is bordered to the north by City limits, and to the south by unincorporated Polk County. Roy is considered part of the South Chain of Lakes due to its connection to Lake Lulu via a navigable canal. The South Chain discharges excess water to the Wahneta Farms Drainage Canal via a passive control structure located on the south shore of Lake Lulu. Lake Roy is a smaller, but deeper waterbody at 75 acres, an average depth of 13 feet, and a maximum depth of almost 25 feet (Figure 3-227).

Stormwater is conveyed to this waterbody from a 354-acre drainage basin comprised of 13 individual sub-basins (Figure 3-228). Medium-density residential is, by far, the primary land use in this basin; followed by commercial, institutional, and low/high-density residential, respectively. This basin contributes 1,448 lbs of TN and 241 lbs of TP to the lake annually. There are 125 Onsite Sewage Treatment and Disposal (OSTD/septic) systems located within the basin—constituting a high density and greater potential for pollutant loading via groundwater leaching. To combat stormwater pollutant loading within the Winter Haven portion of the drainage area, the City conducts 11.8 miles of street sweeping on a monthly basis.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain’s surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the South Chain by the end

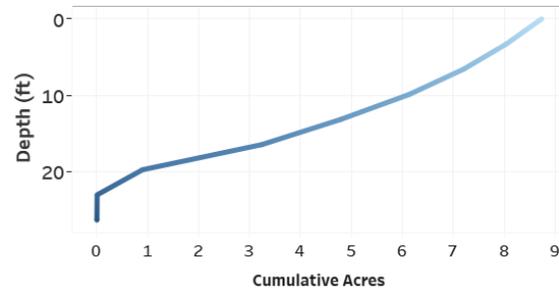


Figure 3-227. Hypsograph of Lake Roy depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

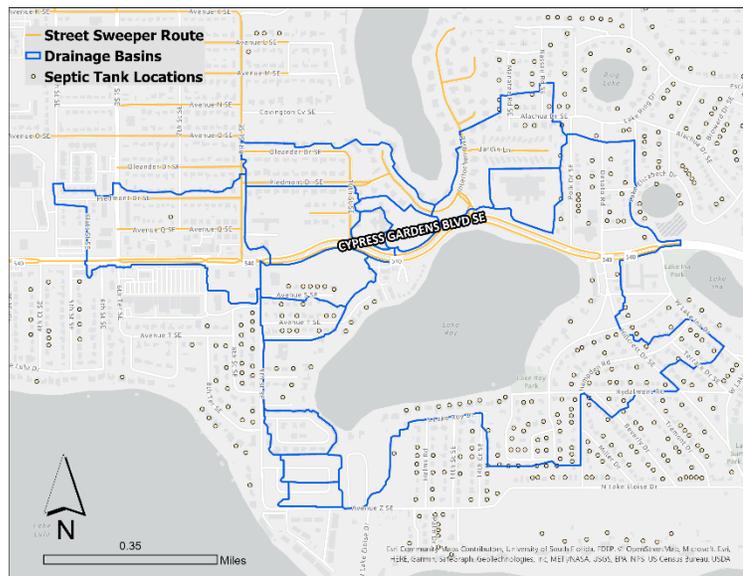


Figure 3-228. Map of Lake Roy’s drainage basin, City street sweeper routes, and nearby septic systems.

of the year was slightly above the top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake Roy’s surface level correlates with TN and water clarity (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.

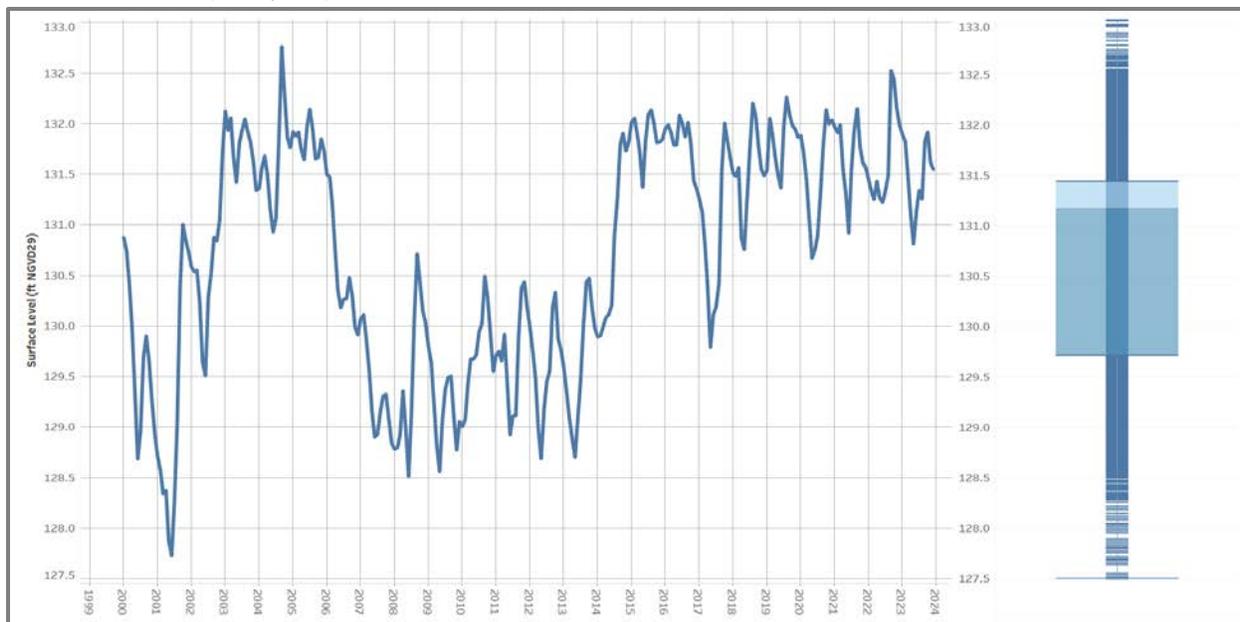


Figure 3-229. Hydrograph of Lake Roy depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Roy is categorized as a clear, alkaline waterbody. Aside from an outlier year during 2021, Lake Roy has not exhibited any NNC exceedances during the assessment period (Figure 3-230). As a result, Roy is considered un-impaired and earns an impairment criterion score of 3. Despite the high Chl-a and nutrient concentrations in 2021, Lake Roy exhibited much better water quality than typical during 2022.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. During this period, Chl-a and TP exhibited significant improving trends. This equates to a trend criteria score of 3 for these parameters. Secchi depth and TN exhibited non-significant improving trends; for criterion scores of 2. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing	Not Significant	2
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing	Not Significant	2

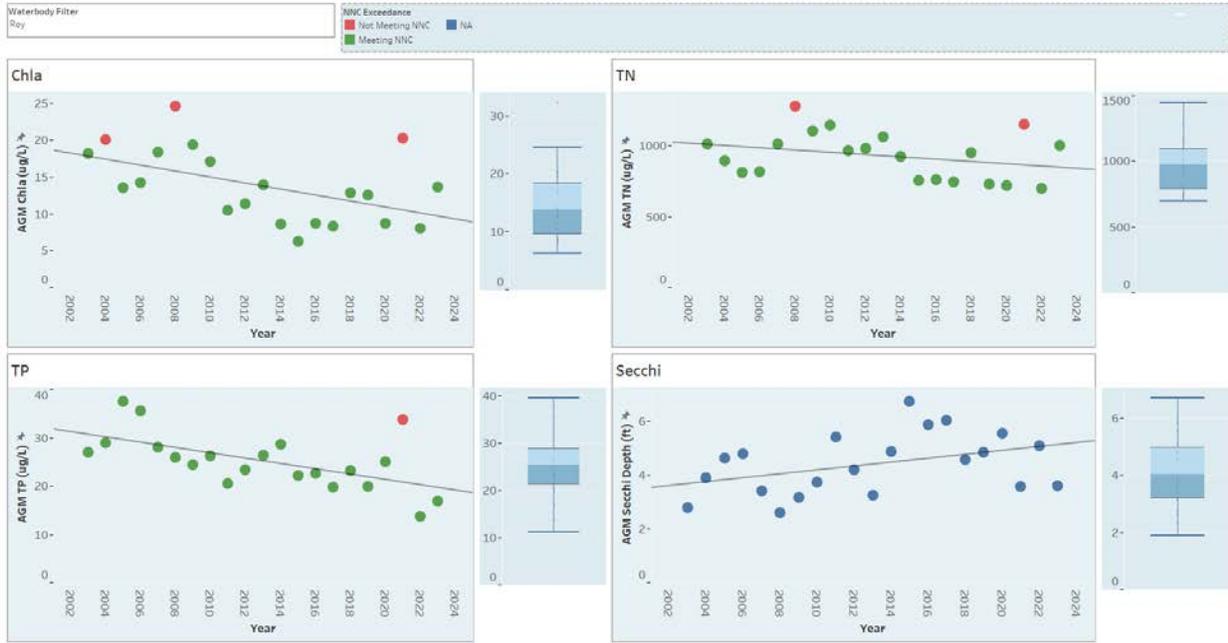


Figure 3-230. Lake Roy AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Roy on 4/7/2023. The PAC during this survey was 43.3% and the total BV was 7.9% (Figure 3-231). PAC over the 30% threshold equates to an abundance criterion score of 3. In 2018, Lake Roy had a PAC of over 50%. However, in 2019, this abundance value dropped to 17%. This was likely due to large-scale invasive species treatments between these two surveys. Fortunately, the abundance has recovered significantly and is now close to pre-treatment levels.

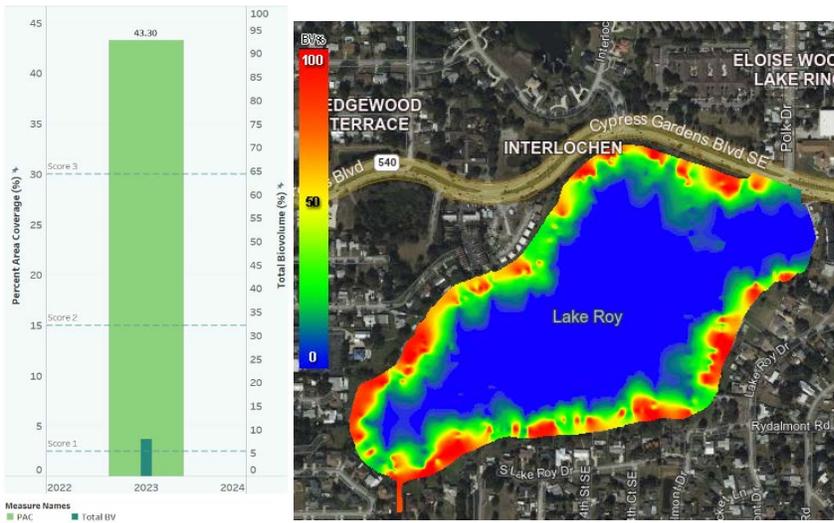


Figure 3-231. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Roy; biovolume values range from green (lowest) and red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, Lake Roy is very clearly dominated by submerged plants with native eelgrass and Illinois pondweed making up close to 30% of the community (Figure 3-232). Managed invasives made up less than 1% of the community; comprised of a small occurrence of hydrilla. This equates to an invasive presence criterion score

of 2. A comparison of data over the last five years confirms that the vegetation community in 2018 was over 17% invasive. This backs up the inference that large-scale treatment efforts have an impact on vegetation abundance. Fortunately, abundance has increased with invasive proportions remaining relatively low.

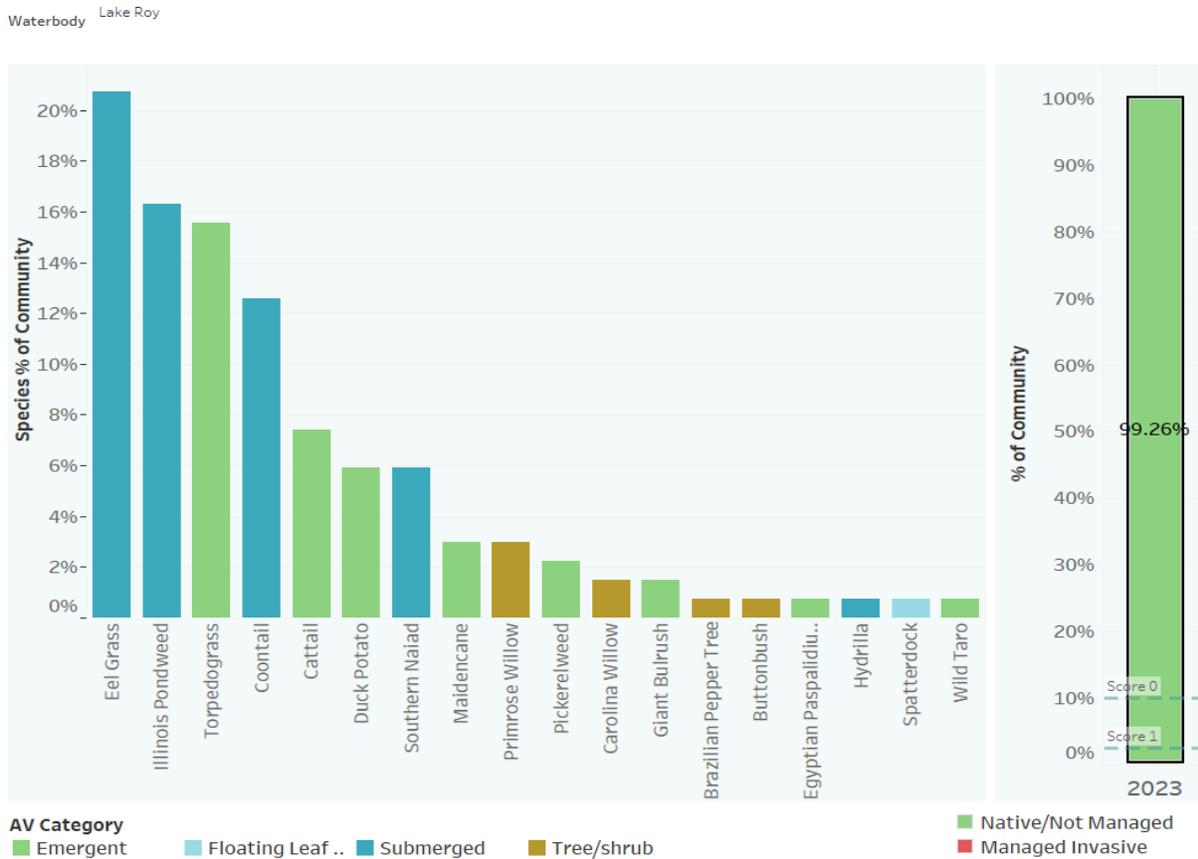


Figure 3-232. Chart depicting species frequency and invasive species percentage of Lake Roy during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2023 species data, the evenness and overall diversity indices exceeded their respective median values (Figure 3-233). This equates to a diversity criterion score of 2. While species richness decreased slightly in 2023, it remains relatively high. This indicates that Lake Roy’s vegetation management program has been successful at maintaining a diverse community while keeping invasive species controlled.

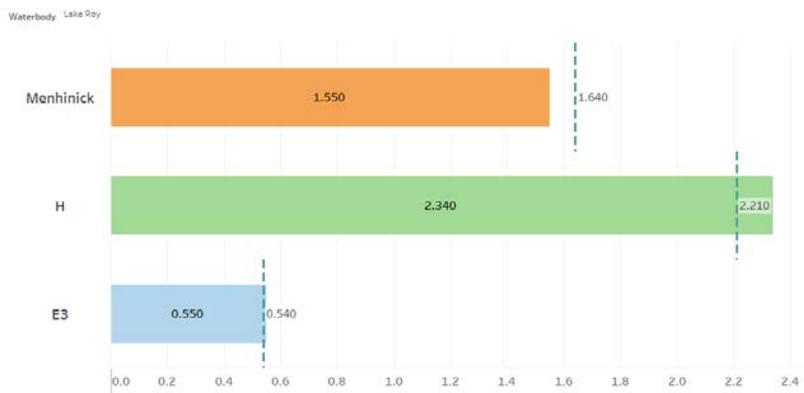


Figure 3-233. Chart depicting 2023 diversity indices for Lake Roy. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Roy’s health index scores from 2018 to 2023 shows consistently high lake health—with values ranging from 2.4 to 2.8 (Figure 3-234). Over this span, the water quality criteria scores have changed very little. Lake Roy has excellent water quality and continues to exhibit improving trends. Vegetation abundance exhibited a decline in 2019 and 2020, but has since recovered. Invasive presence and its impact on species diversity continues to fluctuate and is the primary source of lake health changes at this point. Overall, Lake Roy is ranked low on the priority list due to these higher lake health scores.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	2	3	3	0	2	2.4
2019	3	3	3	3	3	2	1	2	2.5
2020	3	3	3	3	3	2	2	3	2.8
2021	3	3	3	2	3	3	1	2	2.5
2022	3	3	3	2	3	3	2	3	2.8
2023	3	3	2	3	2	3	2	2	2.5

Figure 3-234. Chart depicting a comparison of Lake Roy’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Roy currently exhibits excellent water quality with no signs of deterioration. However, if this changes, the City would look to stormwater and the OSTD presence as potential primary drivers of water quality decline.
- The management of invasive species like hydrilla has been a concern in the past. While current populations appear to be controlled, it can take just a single growing season for these to take over large areas of a waterbody.
- Several of Lake Roy’s water quality parameters are correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- The City currently conducts street sweeping and has implemented treatment swales in the northern portion of the drainage basin. Future stormwater mitigation efforts may be construction of green infrastructure in one of the northern sub-basins identified by the Stormwater Assessment and Improvement Plan.
- If water quality begins to decline, the City may explore source analysis to determine if OSTDs may be leaching pollutants into the water table. Further management may be septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response helps to prevent large-scale herbicide treatments and potential water quality impacts that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Shipp

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
0	3	3	3	3	3	2	2	2.4

Location, Characteristics, & Hydrology:

Lake Shipp is located to the southwest of downtown Winter Haven. It is bordered by City limits to the north and unincorporated Polk County to the south. Lake Shipp is considered part of the South Chain of Lakes due to its navigable connections with Lakes Lulu and May. The South Chain discharges excess water to the Wahneta Farms Drainage canal via a passive control structure on the south shore of Lake Lulu. A moderately sized waterbody, Lake Shipp has a surface area of 286 acres, an average depth of 7.2 feet, and a maximum depth of over 13 feet (Figure 3-235).

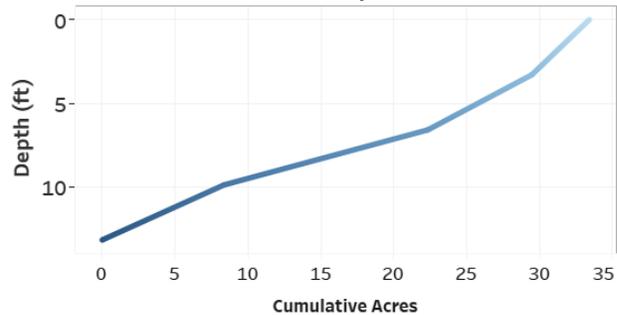


Figure 3-235. Hypsograph of Lake Shipp depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 910 acre drainage basin comprised of 9 individual sub-basins (Figure 3-236). Ranked by area, the primary land uses in this basin are medium-density residential, commercial, high-density residential, industrial, and agricultural/open land. Based on stormwater pollutant load modeling, this drainage area contributes 3,614 lbs of TN and 655 lbs of TP to the lake annually. There are over 50 Onsite Sewage Treatment and Disposal (OSTD/septic) systems within the basin. This constitutes a moderate density with some potential for contributing pollutant loading through groundwater leaching. To combat stormwater pollutant loading, the City conducts 12.4 miles of street sweeping in the basin on a monthly basis.

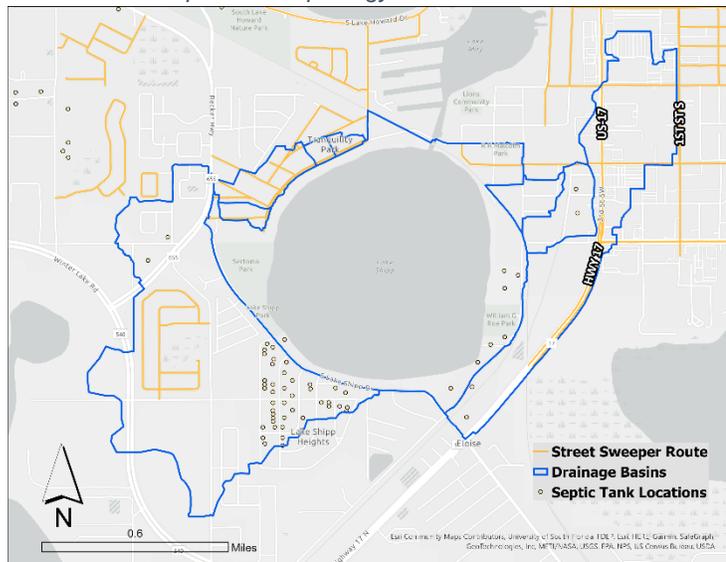


Figure 3-236. Map of Lake Shipp's drainage basin, City street sweeper routes, and nearby septic systems.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the South Chain by the end of the year was slightly

above the top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake Shipp’s surface level correlates with TN and water clarity (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.

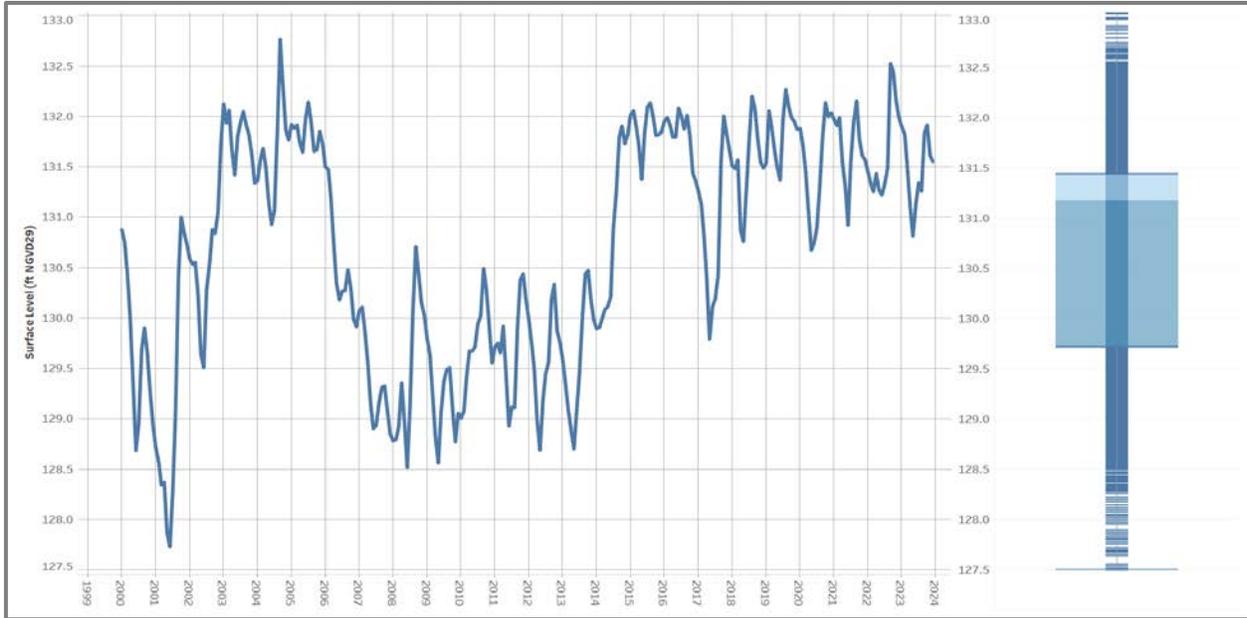


Figure 3-237. Hydrograph of Lake Shipp depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Shipp is categorized as a clear, alkaline waterbody. Due to consistent NNC exceedances during the assessment period, Lake Shipp is considered impaired for Chl-a, TN, and TP (Figure 3-238). This equates to an impairment criterion score of 0. In 2019, the FDEP established a total maximum daily load stipulating a 53% reduction in TN in order for Lake Shipp to meet NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Each of Lake Shipp’s water quality parameters exhibited significant improving trends during this period. This equates to trend criteria scores of 3 for Chl-a, TN, TP, and Secchi depth. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3

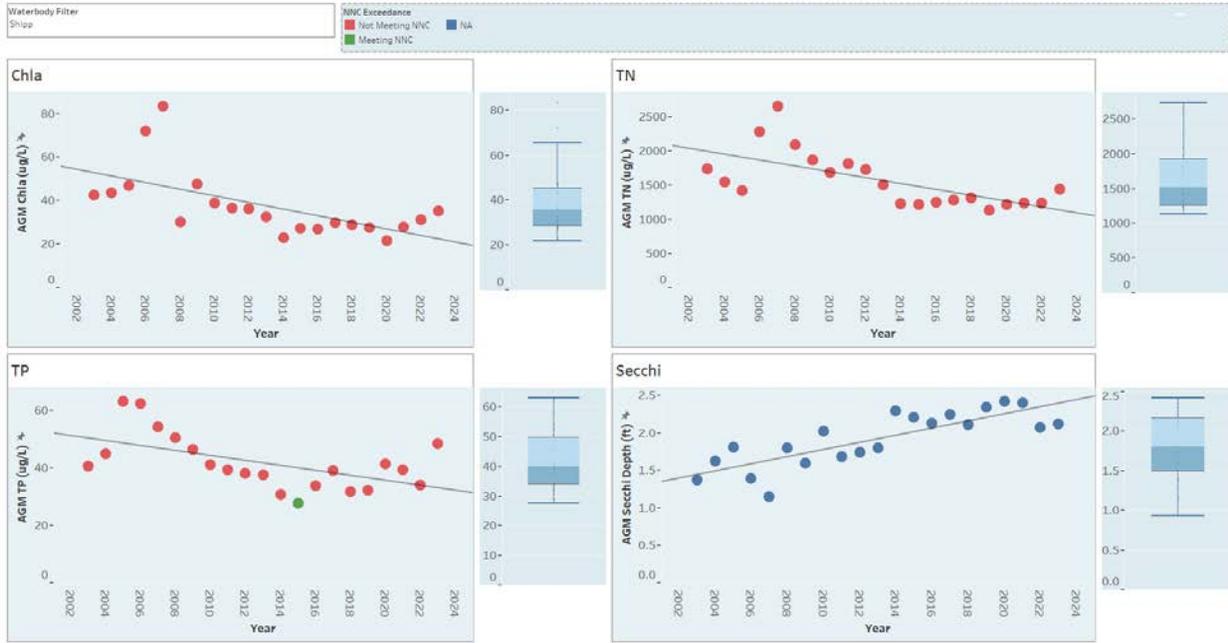


Figure 3-239. Lake Shipp AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Shipp on 10/19/2023. The PAC during this survey was 50.6% and the total BV was 12.3% (Figure 3-239). A PAC exceeding the 30% threshold equates to an abundance criterion score of 3. Since monitoring began, Lake Shipp has consistently exhibited PAC around in the 50% range. The robustness of this lake’s littoral zone can be attributed to its gradual sloping bed and the abundance of vegetation likely contributes to the improving water quality trends.

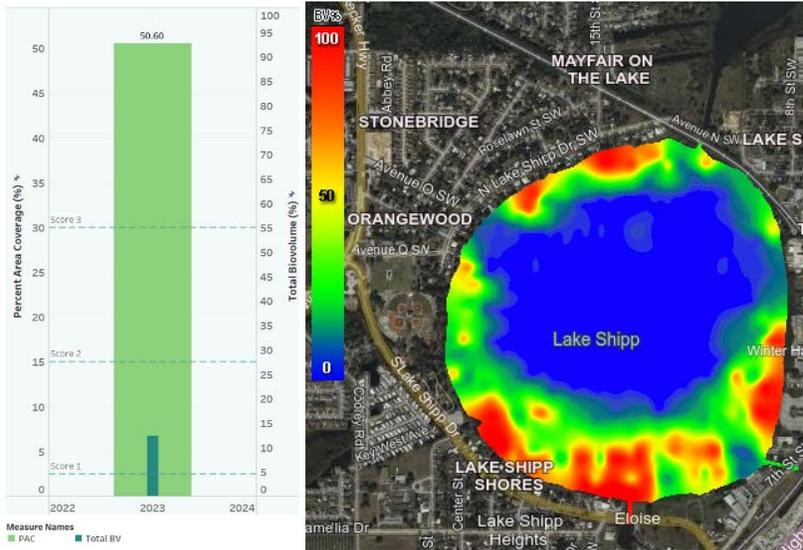


Figure 3-238. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Shipp; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2023 survey data, Lake Shipp has a healthy mix of vegetation types. It is currently dominated by submerged species like eelgrass, southern naiad, and fanwort; making up almost 40% of the community (Figure 3-240). Managed invasive species made up just 1.7% of the community; mostly comprised of burhead sedge and hydrilla. This equates to an invasive presence criterion score of 2. Hydrilla has previously been the major management

concern for Lake Shipp with percentages exceeding the 2.5% threshold in 2019 and 2020. Fortunately, treatments have been able to keep it in a managed state since then.

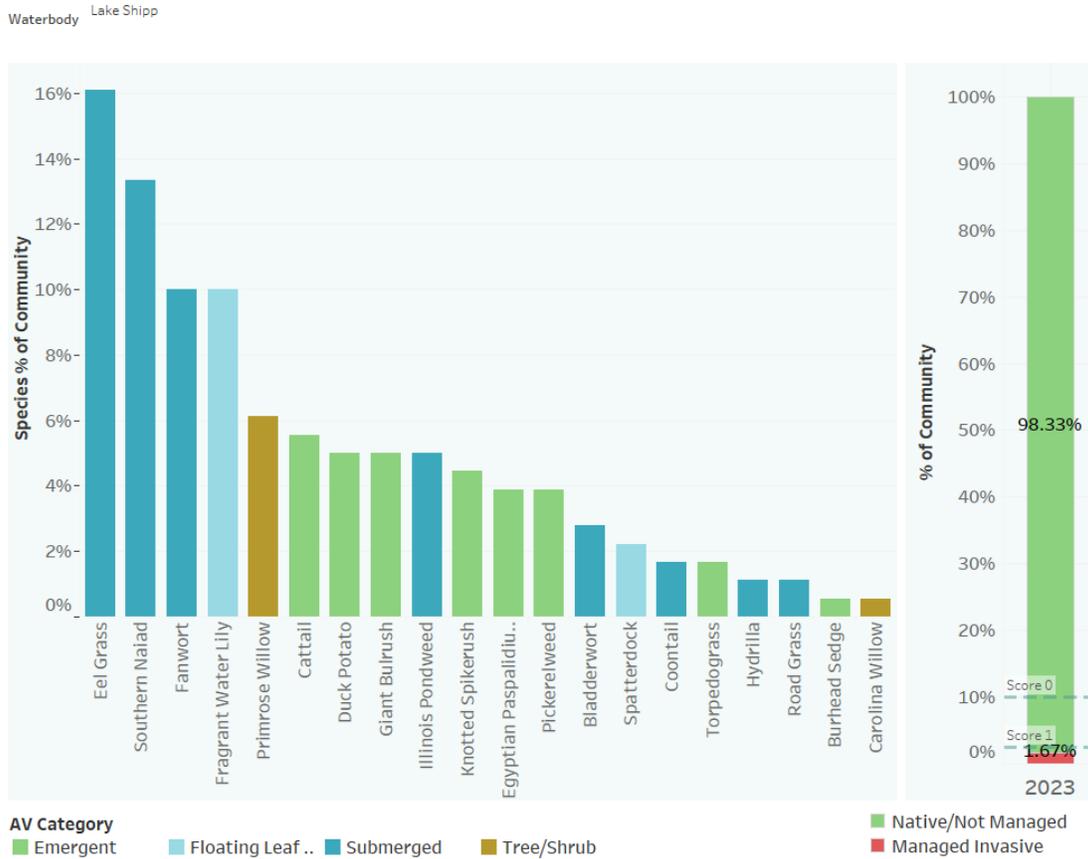


Figure 3-240. Chart depicting species frequency and invasive species percentage of Lake Shipp during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2023 species data, Lake Shipp’s evenness and overall diversity indices met or exceeded their respective median values (Figure 3-241). This equates to a diversity criterion score of 2. While species richness decreased slightly, this is mostly due to lower numbers of less-prevalent species—a couple of which are classified as invasive. Despite the lower richness score, Lake Shipp does boast relatively high overall diversity which has held somewhat constant despite regular minor invasive treatment efforts.

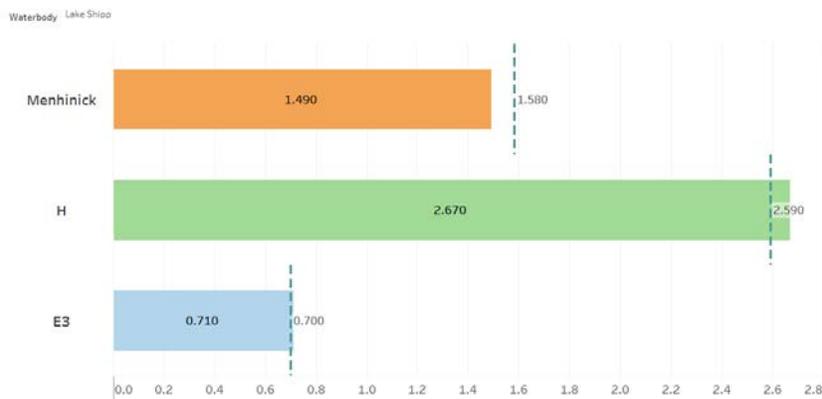


Figure 3-241. Chart depicting 2023 diversity indices for Lake Shipp. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Shipp’s health index scores from 2018 to 2023 shows relative consistency—with values ranging from 2.1 to 2.4 (Figure 3-242). Throughout this six year span, the water quality criteria have remained the same. While Lake Shipp remains impaired, it has been consistently improving. Vegetation abundance has remained high, but the largest improvement has been improvements in the invasive species and diversity scores from 2021 to the present. Overall, Lake Shipp ranks moderately low on the priority list. While it is impaired, the trend and biological scores indicate that management efforts have been having a positive impact.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	3	3	3	3	3	1	1	2.1
2019	0	3	3	3	3	3	1	1	2.1
2020	0	3	3	3	3	3	1	1	2.1
2021	0	3	3	3	3	3	2	1	2.3
2022	0	3	3	3	3	3	2	2	2.4
2023	0	3	3	3	3	3	2	2	2.4

Figure 3-242. Chart depicting a comparison of Lake Shipp’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- In addition to considerable stormwater pollutant loading, Lake Shipp historically received point-source inputs from multiple agricultural processing facilities. These legacy sediments may contribute to internal nutrient loading. Furthermore, the moderate density of OSTDs may potentially contribute to additional loading.
- The management of invasive species like hydrilla has been a concern in the past. While current populations appear to be controlled, it can take just a single growing season for these to take over large areas of a waterbody.
- Several of Lake Shipp’s water quality parameters are correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- To mitigate stormwater loading, the City has implemented street sweeping in the basin and has plans to construct green infrastructure along the northwest portion of the drainage basin as part of a streets improvement project.
- The City may explore sediment removal and/or OSTD source analysis to determine if these alternative loading pathways are a significant contributor of nutrients.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Now that hydrilla is in a controlled state, maintaining that control is a high priority to prevent future large scale herbicide treatments.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Silver

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	2	2	2	2	1	3	2	2.1

Location, Characteristics, & Hydrology:

Lake Silver is centrally located within the heart of Winter Haven’s downtown area. Its elevation is the highest in the City. By virtue of this, it discharges excess water downstream to Lake Martha. Its location and hydrologic pathways make Silver part of the North Central Lakes group. Lake Silver is a small, but deep waterbody with a surface area of 55 acres, an average depth of 15 feet, and a maximum depth of over 33 feet (Figure 3-243).

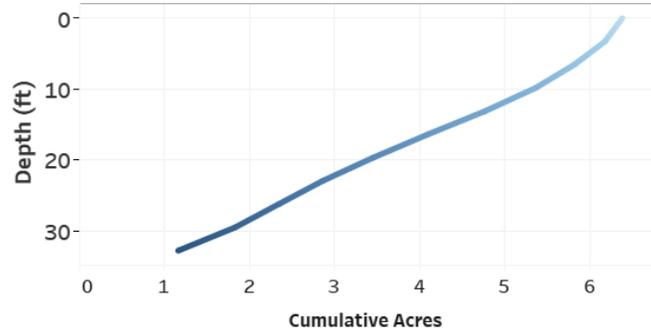


Figure 3-243. Hypsograph of Lake Silver depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from an urbanized 164-acre drainage basin, comprised of 12 individual sub-basins (Figure 3-244). By far, the most dominant land use in this basin is commercial, followed by institutional, medium-density residential, recreational, and industrial, respectively. Based on stormwater pollutant load modeling, this drainage area contributes 633 lbs of TN and 106 lbs of TP to the lake annually. There are no known Onsite Sewage Treatment and Disposal (OSTD/septic) systems within this basin. To combat stormwater pollutant loading, the City conducts 20.15 miles of street sweeping in the basin on a monthly basis.

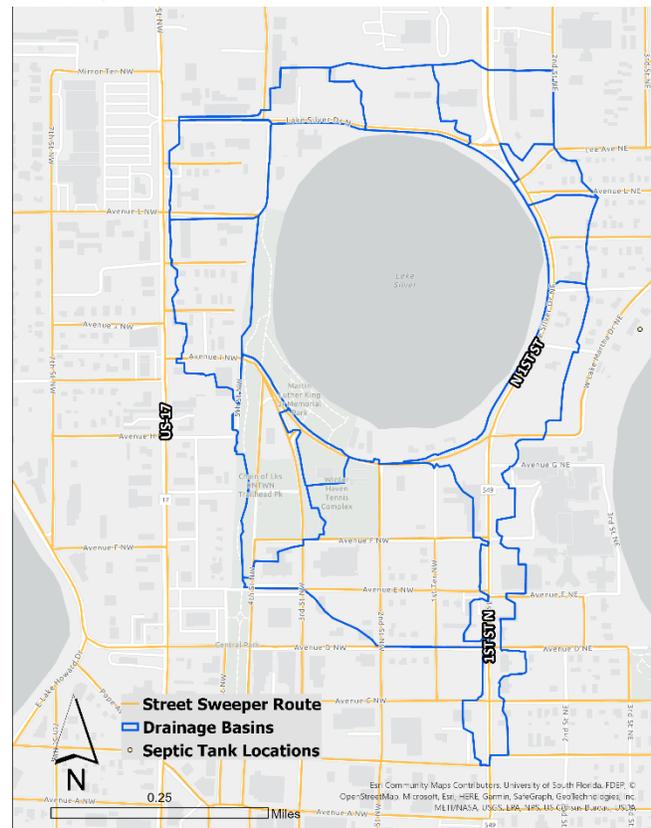


Figure 3-244. Map of Lake Silver’s drainage basin, City street sweeper routes, and nearby septic systems.

Over its period of record, Lake Silver’s surface level has fluctuated between 139.9 and 147.1 feet above sea level. The normal level range fluctuates between 142.3 and 145.3 feet (Figure 3-245). During 2023, Lake Silver started high at 146.3 ft in January and dropping to a dry season low of 143.9 in May. The surface level ended the year near the 75th percentile at 145.2 ft. Changes in Lake

Silver’s surface level are not significantly correlated with any of its water quality metrics (see appendix).

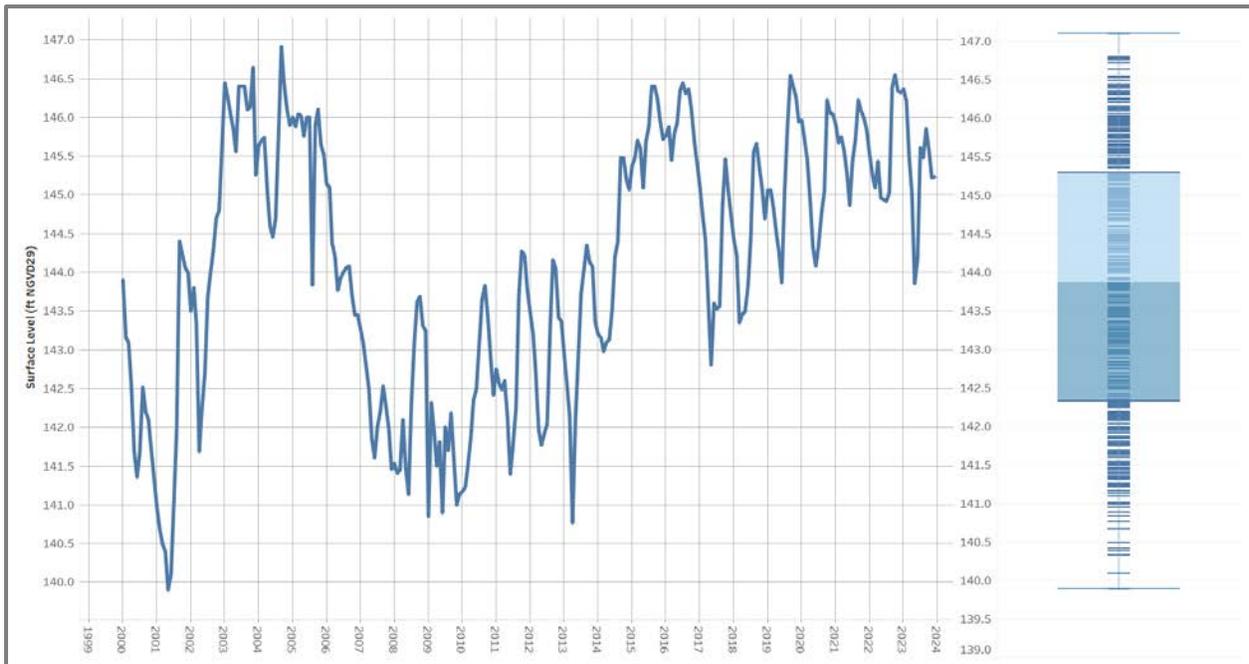


Figure 3-245. Hydrograph of Lake Silver depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria, Lake Silver is categorized as a clear, alkaline waterbody. Aside from an exceedance of the Chl-a threshold in 2017, Lake Silver has not exhibited any other NNC exceedances during the assessment period (Figure 3-246). Consequently, Lake Silver is not considered impaired and earns an impairment criterion score of 3. It should be noted that Silver’s 2023 Chl-a, TN, and TP concentrations were well below the normal range—indicating better water quality than normal.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. During this period, Chl-a, TN, TP, and Secchi depth exhibited non-significant improving trends; equating to trend criteria scores of 2. The trend direction for Secchi depth switched from decreasing to increasing in 2023—indicating some improvement. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing	Not Significant	2
TN	Decreasing	Not Significant	2
TP	Decreasing	Not Significant	2
Secchi	Increasing	Not Significant	2

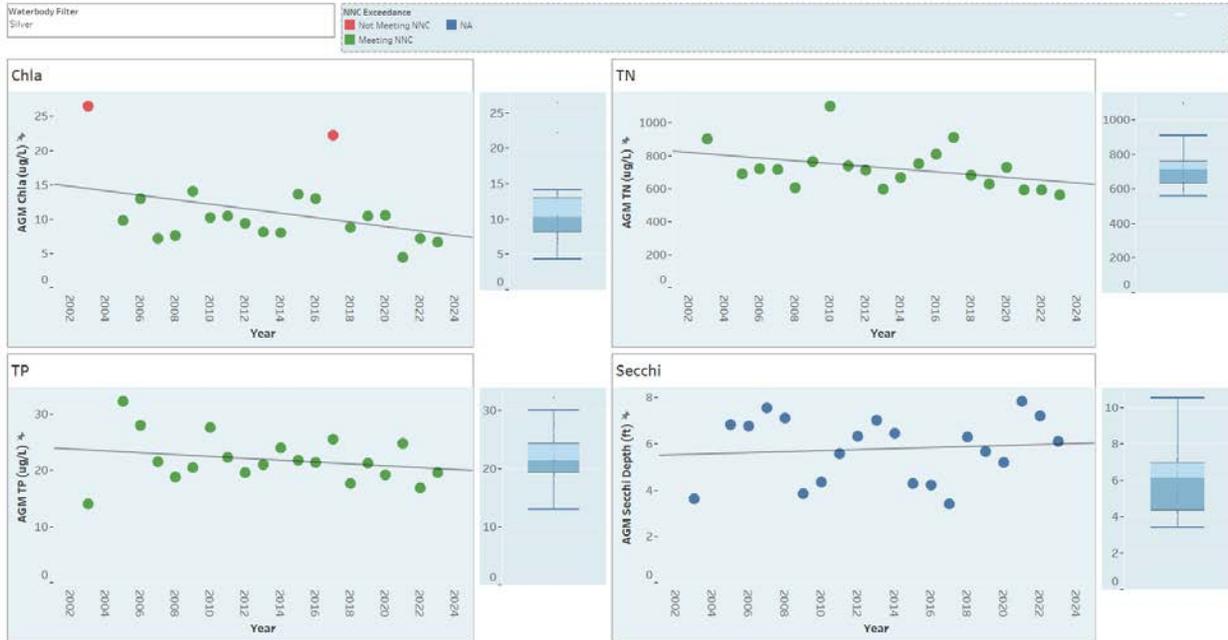


Figure 3-246. Lake Silver AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Silver on 9/1/2023. The PAC during this survey was 5% and the total BV was 0.24% (Figure 3-247). PAC between 2.5% and 15% earns a vegetation abundance score of 1. Since monitoring began, Lake Silver has displayed very low vegetation abundance. That said 2023 saw some slight improvement. While the steep slope of the lake bed is a factor limiting the effective width of the littoral zone, the water clarity should be high enough to support a much more robust community. It is believed that one of the primary factors limiting vegetation is excessive boating in the lake—contributing to wave action that prevents most plants from rooting and expanding into deeper water.

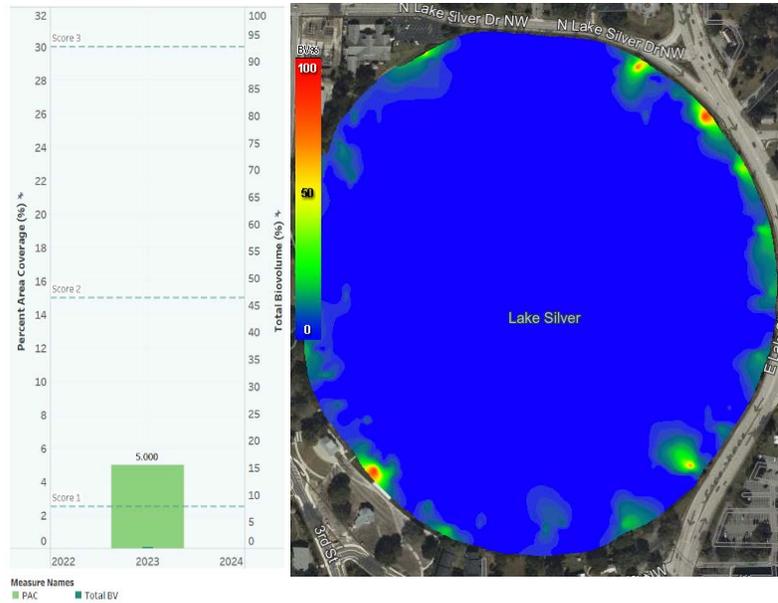


Figure 3-247. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Silver; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, Lake Silver continues to be dominated by emergent plants like cattail and torpedo grass that made up almost 40% of the community (Figure 3-248). However, there was a substantial increase in submerged presence as eelgrass

became the 3rd most abundant species present. Since it lacks a presence of managed invasive species, Silver earns an invasive criterion score of 3. This lack of invasives has been consistent across the lake’s period of record.

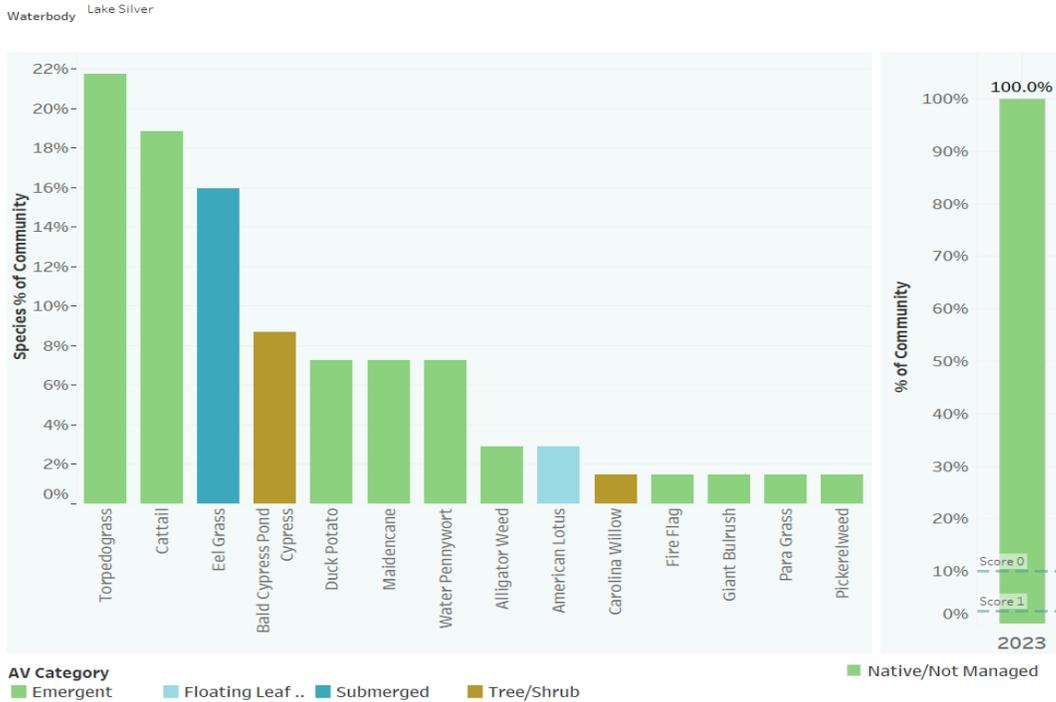


Figure 3-248. Chart depicting species frequency and invasive species percentage of Lake Silver during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2023 species data, Lake Silver’s richness and overall diversity indices met their respective median values (Figure 3-249). This equates to a diversity criterion score of 3. The increases in species richness and diversity are likely due to the resurgence of eelgrass in 2023. Overall, Lake Silver’s vegetation community changes very little.

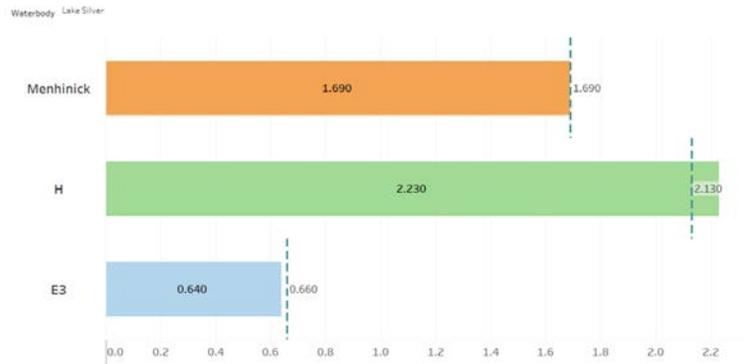


Figure 3-249. Chart depicting 2023 diversity indices for Lake Silver. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Silver’s health index scores from 2018 to 2023 shows some variability, with values ranging from 1.6 to 2.1 (Figure 3-250). Over this span, the impairment, trends, and invasive presence criteria were unchanged. The primary form of score variance came from diversity—with wide swings from year to year. Overall, Lake Silver ranks in the middle of the list. While it is not impaired, its water quality trends should be closely monitored and management action could be taken to improve its vegetation abundance.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	2	2	2	1	0	3	1	1.8
2019	3	2	2	2	1	1	3	3	2.1
2020	3	2	2	2	1	0	3	0	1.6
2021	3	2	2	2	1	0	3	3	2.0
2022	3	2	2	2	1	0	3	0	1.6
2023	3	2	2	2	2	1	3	2	2.1

Figure 3-250. Chart depicting a comparison of Lake Silver’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Silver currently exhibits good water quality. However, stormwater pollutant loading is a potential concern if trends begin to indicate a decline.
- While Lake Silver has no invasive species present, its lack of vegetation abundance could hinder its ability to buffer against changes in water quality in addition to negative impacts on fish and wildlife habitat.

Lake Management Strategy:

- To mitigate stormwater loading, the City conducts street sweeping over large areas of the drainage basin. Raingardens and other green infrastructure have been constructed in the downtown areas south of the lake.
- City staff will explore aquatic vegetation planting efforts to increase the abundance of plants in Lake Silver. The development of plans to protect the submerged plants is especially critical for Lake Silver considering its morphology limits the depth that emergent plants can grow.

Lake Smart

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
0	2	2	2	2	2	1	3	1.8

Location, Characteristics, & Hydrology:

Lake Smart is located northeast of downtown Winter Haven. As part of the North Chain of Lakes, it is connected to Lake Conine via a navigable canal and to Lake Fannie via a water control structure. Excess water from the North Chain discharges to the Peace Creek from the P-8 water control structure on the south shore of Lake Hamilton. Lake Smart is moderately sized at 282 acres, an average depth of 10 feet, and a maximum depth of over 15 feet (Figure 3-251).

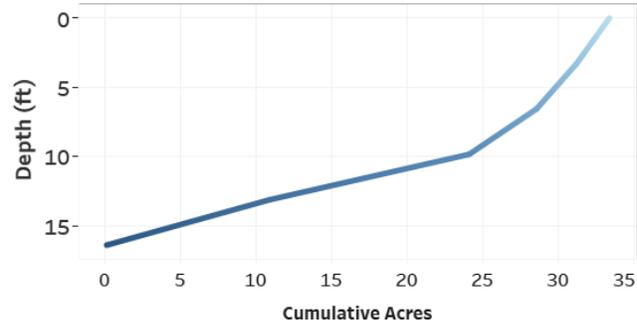


Figure 3-251. Hypsograph of Lake Smart depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 643-acre drainage basin (Figure 3-252). The primary land uses in this basin, ranked by area, are high-density residential, medium-density residential, agricultural, and wetlands. Based on stormwater pollutant modelling, this drainage area contributes 1,673 lbs of TN and 349 lbs of TP to the lake annually. There are no known Onsite Sewage Treatment and Disposal (OSTD/septic) systems within the basin. Due to a lack of drainage infrastructure discharging stormwater from City roadways, Winter Haven does not currently conduct street sweeping services in Lake Smart’s drainage basin.

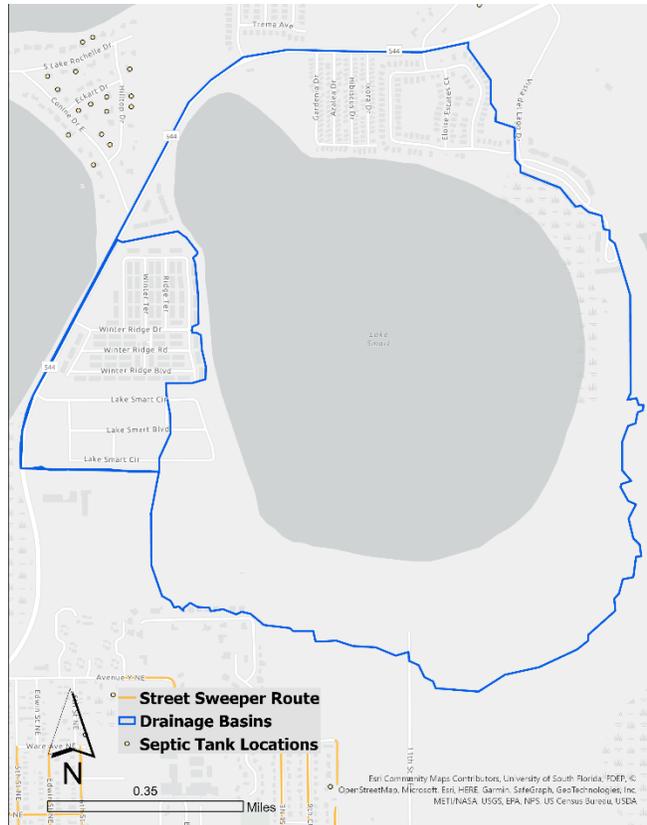


Figure 3-252. Map of Lake Smart’s drainage basin and nearby septic systems.

Over the period of record, surface levels in this section of the North Chain (Lakes Conine, Haines, Rochelle, and Smart) have fluctuated between 122 and 129.5 feet above sea level. The normal range fluctuates much less between 126.1 and 128.2 feet (Figure 3-29). During 2023, Lake Smart reached a wet season peak of 128.6 feet in September and a dry season low of 127.8 feet in May. The surface level ended the year above the high end of the normal range at 128.6 feet. Changes in Lake Smart’s surface level are directly correlated with water clarity and

indirectly correlated with Chl-a and TN (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.

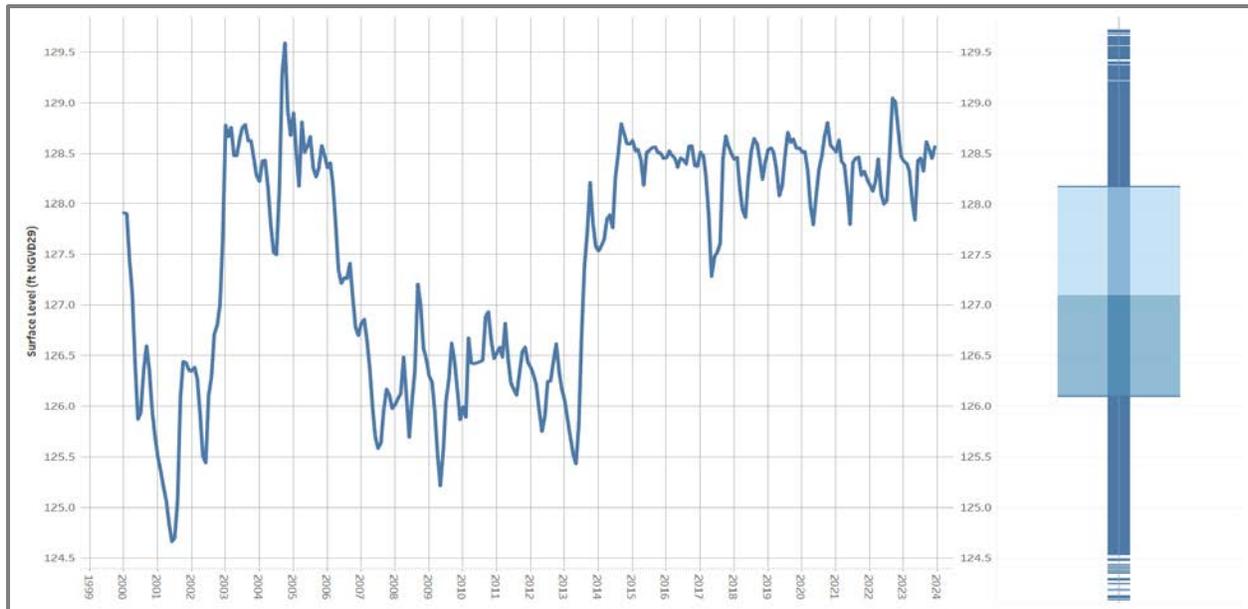


Figure 3-253. Hydrograph of Lake Smart depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Smart is categorized as a clear, alkaline waterbody. Due to numerous NNC exceedances during the assessment period, Lake Smart is considered impaired for Chl-a, TN, and TP (Figure 3-254). This equates to an impairment criterion score of 0. As of 2022, the FDEP began developing a total maximum daily load for Lake Smart. The City and Polk County are partnering to develop a pollutant load reduction plan for the lake.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. All four of these parameters exhibited non-significant improving trends during this period. The result is that each parameters receives a trend criterion score of 2. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing	Not Significant	2
TN	Decreasing	Not Significant	2
TP	Decreasing	Not Significant	2
Secchi	Increasing	Not Significant	2

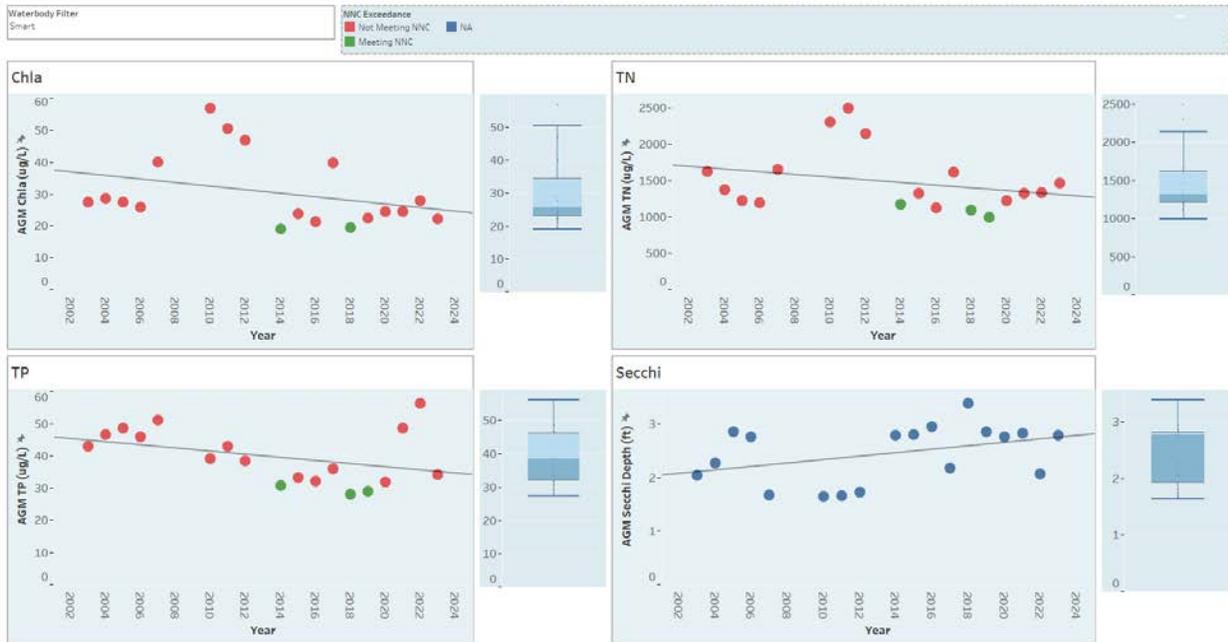


Figure 3-255. Lake Smart AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Smart on 3/17/2023. The PAC during this survey was 28.5% and the total BV was 4.5% (Figure 3-255). A PAC value between 15% and 30% equates to an abundance criterion score of 2. While abundance was higher in the previous year, it may have been an erroneous reading from the sonar. The 2023 abundance values are much more in line with historic levels.

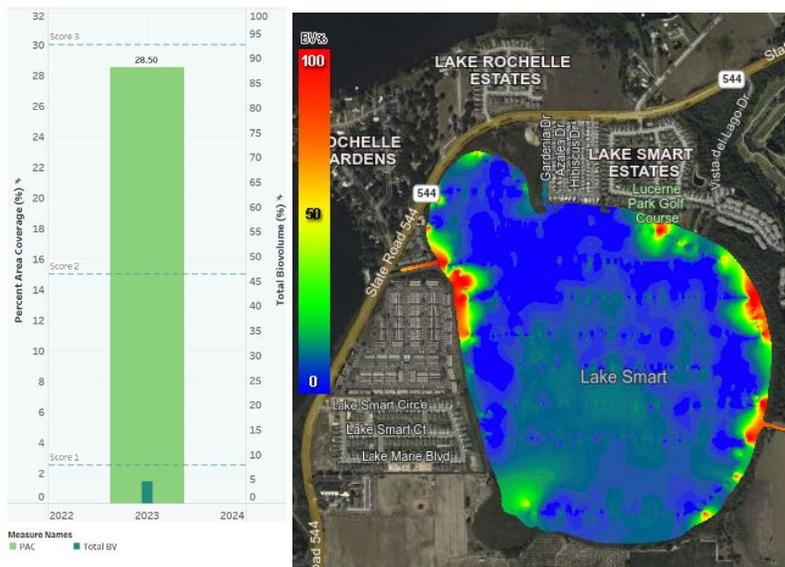


Figure 3-254. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Smart; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, Lake Smart supports a healthy mix of vegetation types. Cattail and eelgrass were the most dominant species at 21% and 19%, respectively (Figure 3-256). The invasive hydrilla made up 4.4% of the community—resulting in an invasive presence criterion score of 1. Hydrilla has historically been the primary invasive concern for Lake Smart. Its population peaked at 12.9% in 2019 but has remained below 10% since. Management efforts have effectively kept it in a controlled state.

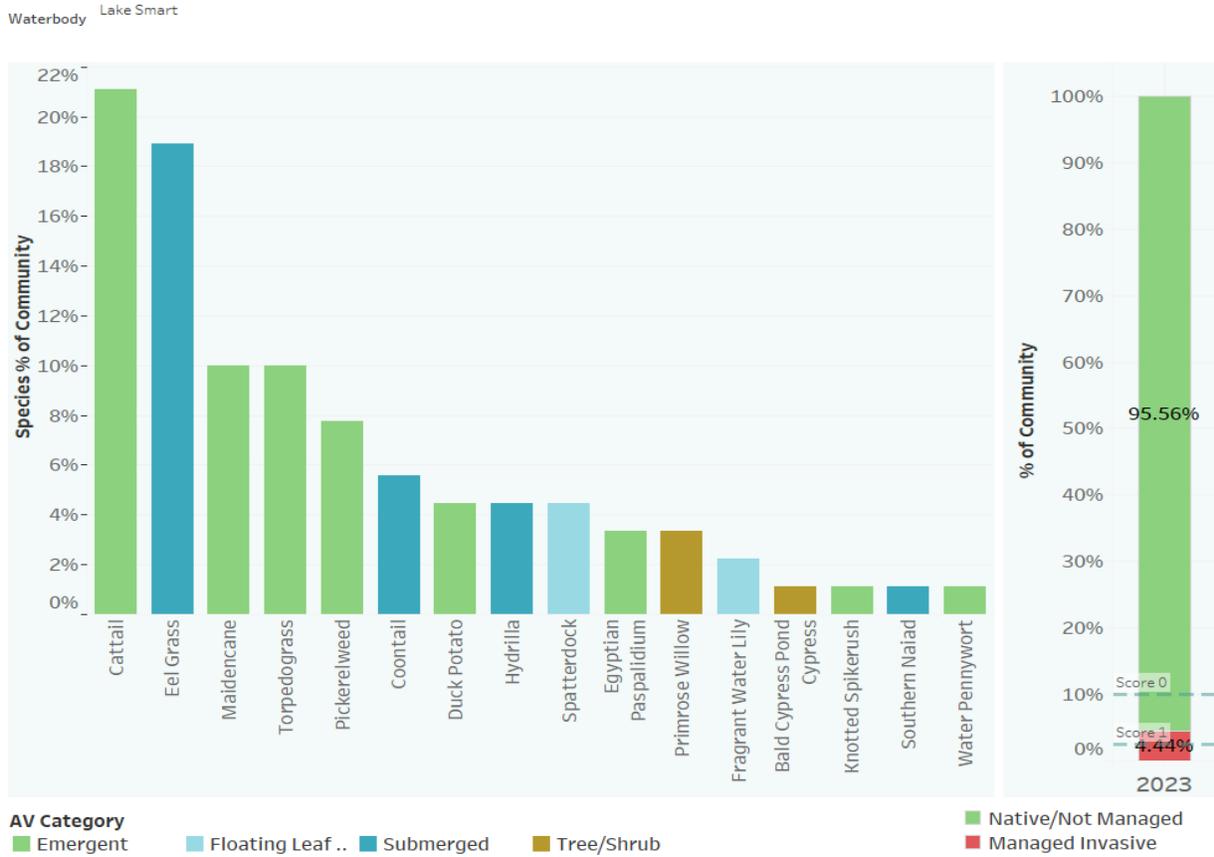


Figure 3-256. Chart depicting species frequency and invasive species percentage of Lake Smart during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2023 species data, all three of Lake Smart's diversity indices met or exceeded their respective median values (Figure 3-257). This equates to a diversity score of 3. An increase in the number of unique species identified was the primary factor for richness, while the evenness index is a factor of how equally distributed each species is. This increase in diversity despite ongoing invasive species management efforts is a good sign.

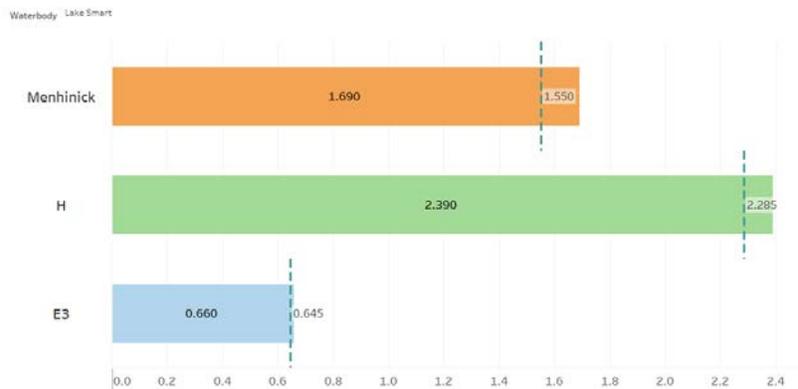


Figure 3-257. Chart depicting 2023 diversity indices for Lake Smart. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Smart’s health index scores from 2018 to 2023 shows some improvement—with values ranging from 1.3 to 2.0 (Figure 3-258). The impairment criterion score has not shifted during this period. However, the trend scores have varied somewhat. For now, the trends all remain non-significant, but heading in a direction of improvement. Lake Smart’s initial vegetation abundance was low, but has since improved; as have its diversity scores. Invasive presence is the primary criterion exhibiting decline. Overall, Lake Smart ranks moderate-to-high on the ranking list. Management action is required to definitively improve water quality and control invasive plants.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	1	2	2	1	2	0	1.3
2019	0	2	2	3	2	3	0	1	1.6
2020	0	2	2	3	2	2	2	3	2.0
2021	0	2	2	2	3	2	1	2	1.8
2022	0	2	2	2	3	3	1	2	1.9
2023	0	2	2	2	2	2	1	3	1.8

Figure 3-258. Chart depicting a comparison of Lake Smart’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- While stormwater loading may be a potential contributor to water quality impairment, much of Lake Smart’s basin lacks direct stormwater inflows to the waterbody. The large presence of agriculture on the south side of the basin may be an area for runoff mitigation, however.
- The management of invasive species like hydrilla is a consistent concern. The hydrilla population, while low, can rapidly take over large areas of the lake without constant management.
- Several of Lake Smart’s water quality parameters are correlated with surface level; likely due to increased flushing during wetter periods. The means that drought conditions could result in water quality declines.

Lake Management Strategy:

- Polk County submitted a pollutant reduction plan for Lake Smart in 2023. The plan involves some sediment inactivation to help reduce phosphorus flux into the water column by the highly organic material in the lake bed.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Spring

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	3	3	3	3	3	0	1	2.4

Location, Characteristics, & Hydrology:

Lake Spring (aka Spring Lake) is located near Winter Haven’s center, slightly northwest of the downtown area. As part of the South Chain of Lakes, it connects with Lake Mirror via a navigable canal. The South Chain discharges excess water to the Wahnetta Farms Drainage Canal through a passive control structure on the south shore of Lake Lulu. Lake Spring is a fairly small, but deep lake with a surface area of 25 acres, an average depth of 10.6 feet, and a maximum depth of over 20 feet (Figure 3-259). Spring’s morphology is indicative of a traditional sinkhole-formed lake.

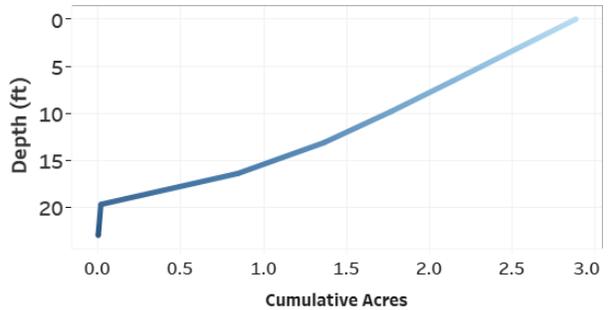


Figure 3-259. Hypsograph of Lake Spring depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 120 acre drainage basin, comprised of 7 individual sub-basins (Figure 3-260). The most dominant land use within this basin is commercial, followed by medium-density residential, high-density residential, and institutional, respectively. Based on stormwater pollutant load modeling, this drainage area contributes 520 lbs of TN and 91 lbs of TP to the lake annually. There are no known Onsite Sewage Treatment and Disposal (OSTD/septic) systems located in this drainage basin. To combat stormwater loading, the City conducts 7.4 miles of street sweeping in this basin on a monthly basis.

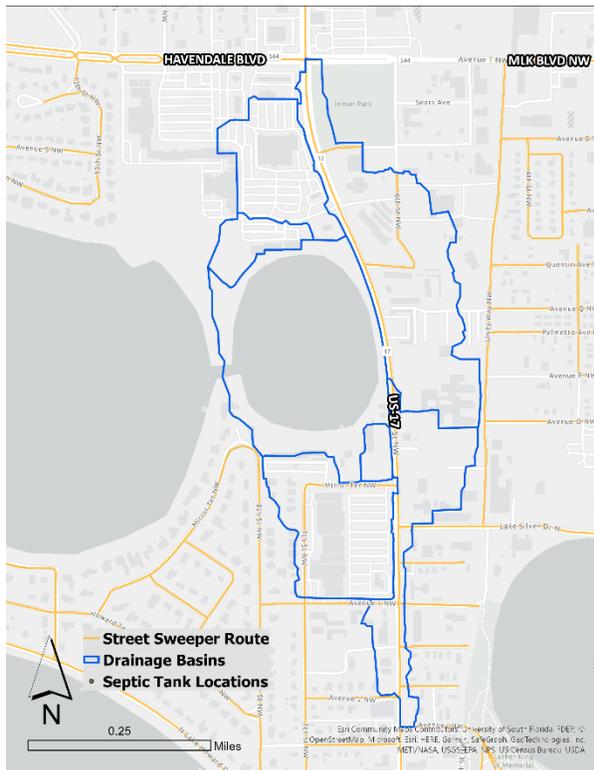


Figure 3-260. Map of Lake Spring’s drainage basin and City street sweeper routes.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain’s surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft.

The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, Lake Spring’s surface level is not correlated with its water quality parameters (see appendix).

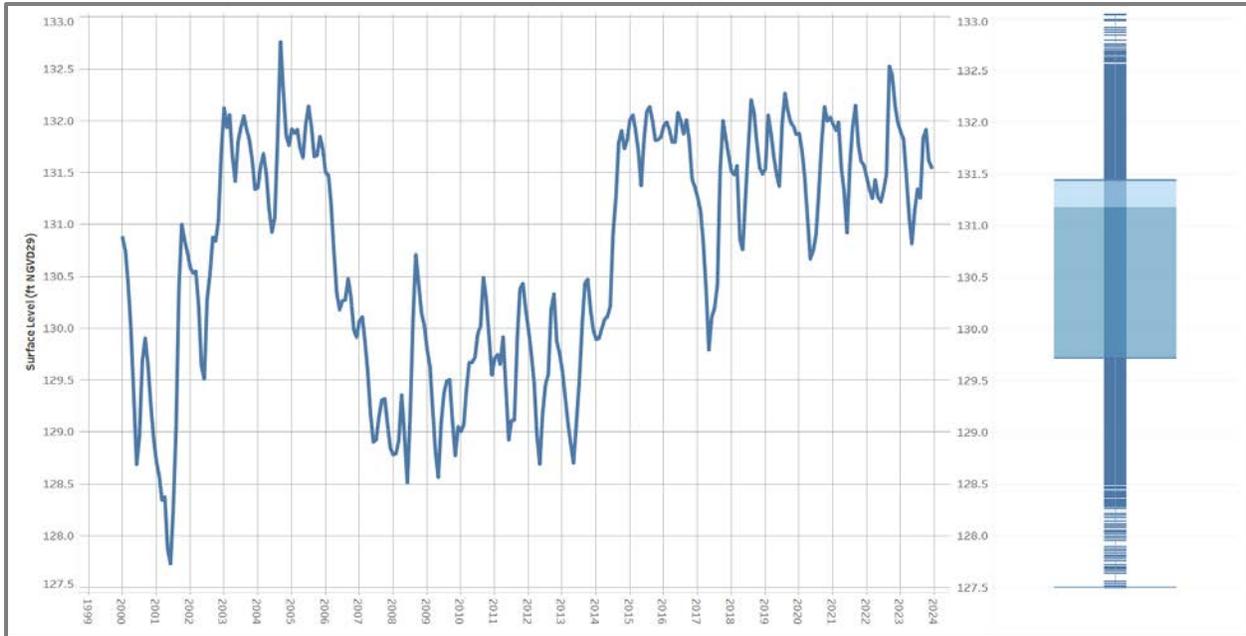


Figure 3-261. Hydrograph of Lake Spring depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Spring is categorized as a clear, alkaline waterbody. Despite an exceedance of Chl-a in 2015, Lake Spring has exhibited no other NNC exceedances during the assessment period (Figure 3-262). Due to this, Spring is considered un-impaired and earns an impairment criterion score of 3.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. All four of these parameters exhibited significant improving trends during this period. This equates to trend criteria scores of 3 for Chl-a, TN, TP, and Secchi depth. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3

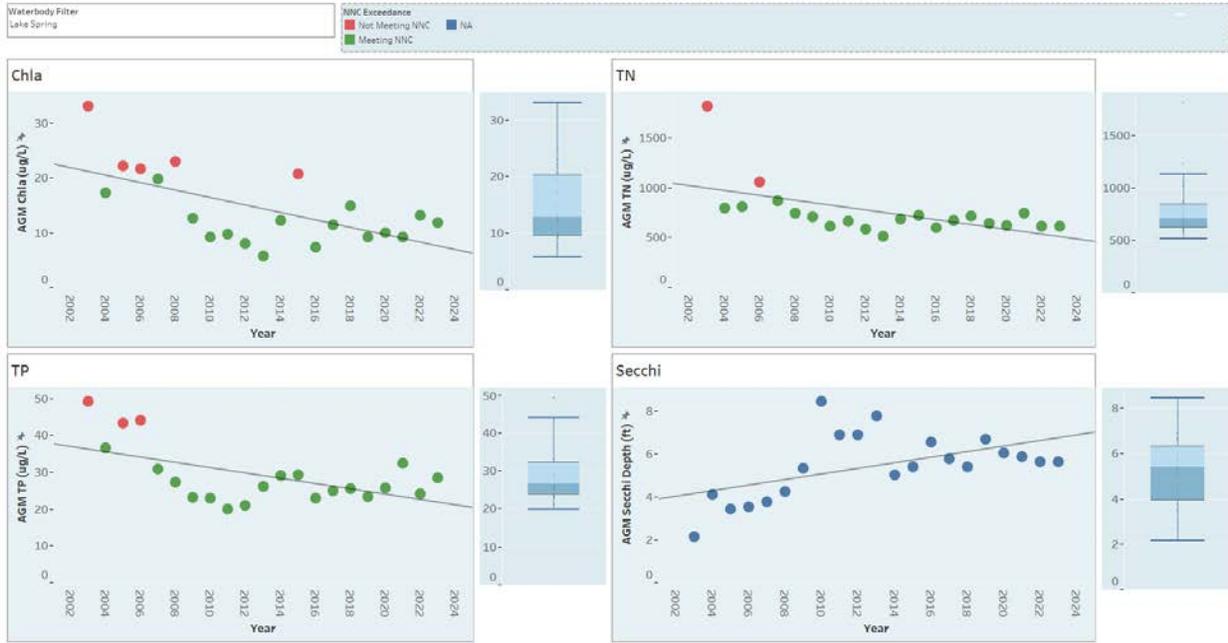


Figure 3-263. Lake Spring AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Spring on 1/11/2023. The PAC during this survey was 56.9% and the total BV was 87.6% (Figure 3-263). A PAC over the 30% threshold equates to a vegetation abundance criterion score of 3. Over the last six years, Lake Spring has maintained high vegetation abundance—with coverage consistently above 50%. The primary changes in abundance have been due to invasive species treatment efforts.

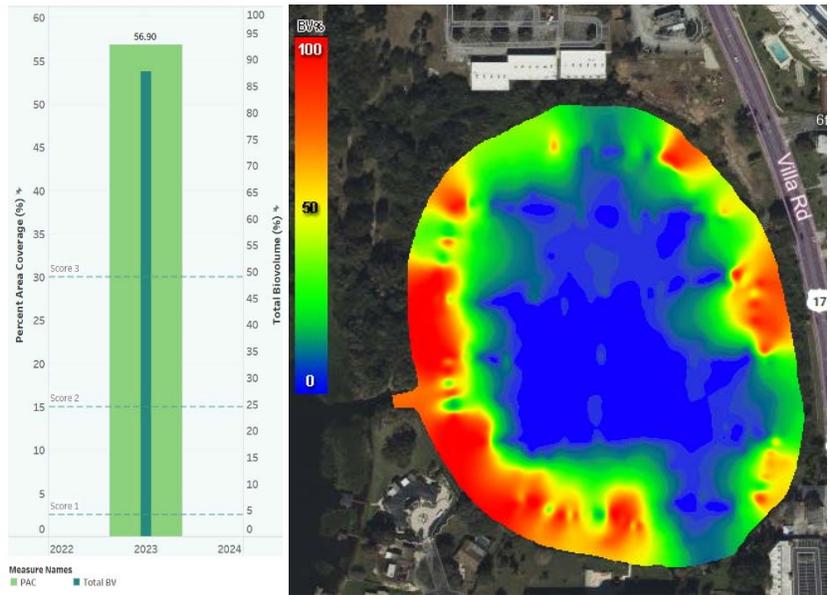


Figure 3-262. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Spring: biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, Lake Spring possesses a mix of vegetation types. Eelgrass was the most dominant at 15%, followed closely by the invasive hydrilla at 13.75% (Figure 3-264). Invasive species were represented by hydrilla and burhead sedge and made up 22% of the community. This equates to an invasive criterion score of 0.

Historically, hydrilla has been the primary invasive species present and can rapidly increase in abundance in a short time frame—as evidenced by the 2023 numbers.

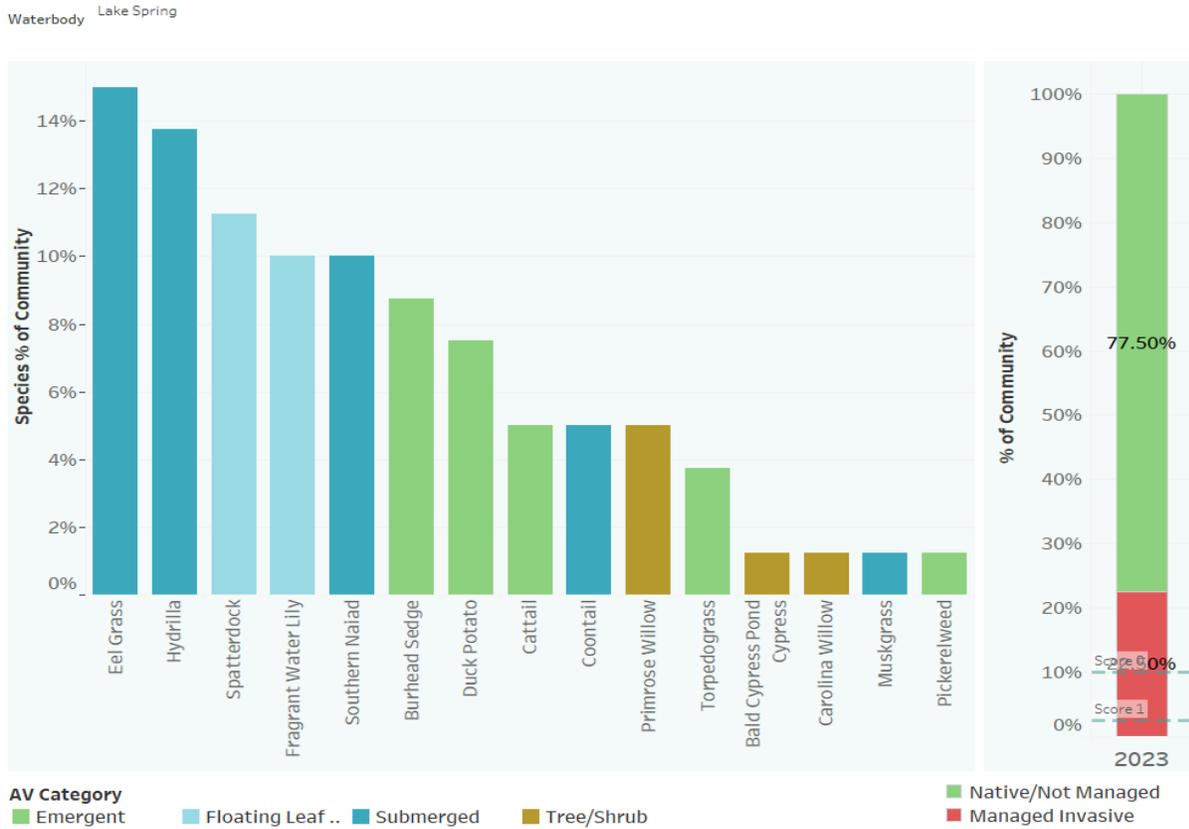


Figure 3-264. Chart depicting species frequency and invasive species percentage of Lake Spring during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2023 species data, only Lake Spring’s overall diversity index exceeded its median value (Figure 3-265). This equates to a criterion score of 1. The explosion of hydrilla likely decreased the total number of plant species as well as their distribution, resulting in the index values exhibited.

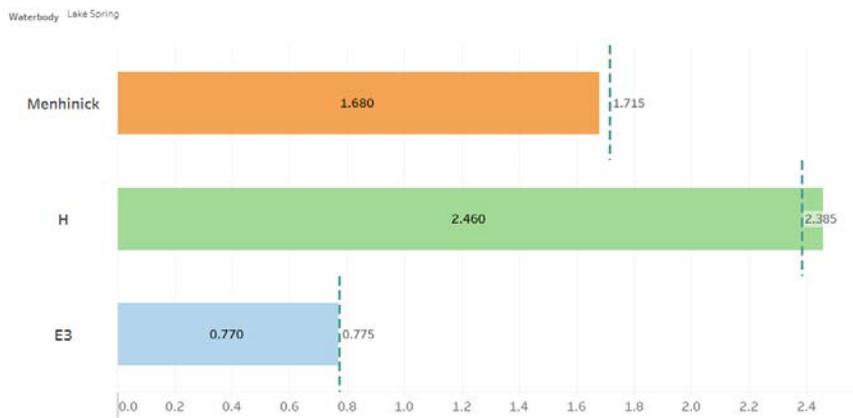


Figure 3-265. Chart depicting 2023 diversity indices for Lake Spring. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Spring’s health index scores from 2018 to 2023 shows consistently good values ranging from 2.3 to 2.6 (Figure 3-266). During this span, there have been no changes in the impairment, trend, and vegetation abundance criteria scores. The primary source of lake health change has been through the surge and subsequent treatment of invasive plants; which impacts species diversity in turn. Overall, Lake Spring ranks low on the priority list due to it exhibiting good water quality, improving trends, and excellent vegetation abundance.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	3	3	3	0	1	2.4
2019	3	3	3	3	3	3	0	2	2.5
2020	3	3	3	3	3	3	0	2	2.5
2021	3	3	3	3	3	3	0	1	2.4
2022	3	3	3	3	3	3	1	2	2.6
2023	3	3	3	3	3	3	0	1	2.4

Figure 3-266. Chart depicting a comparison of Lake Spring’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Spring currently exhibits excellent water quality and improving trends. However, stormwater pollutant loading is the leading vector for water quality issues in the future.
- The management of invasive species is currently the primary management concern for Lake Spring. While hydrilla was effectively controlled during 2023, it can take only a single growing season for a small population to take over large areas of a waterbody, as evidenced by the 2023 invasive percentage.

Lake Management Strategy:

- The City currently conducts street sweeping along the major roadway in the drainage basin to mitigate stormwater loading. Future stormwater management may aim to implement green infrastructure, if necessary.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Summit

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	3	2	2	3	3	1	3	2.5

Location, Characteristics, & Hydrology:

Lake Summit is located to the southeast of downtown Winter Haven. While it is mostly surrounded by unincorporated Polk County, it borders City limits along its southeast shoreline. As part of the South Chain of Lakes, it is connected to Lake Eloise via a navigable canal. The South Chain discharges excess water to the Wahnetta Farms Drainage Canal through a passive control structure on the south shore of Lake Lulu. Lake Summit is a small, but deep waterbody; at 68 acres, an average depth of 12.7 feet, and a maximum depth of over 26 feet (Figure 3-267).

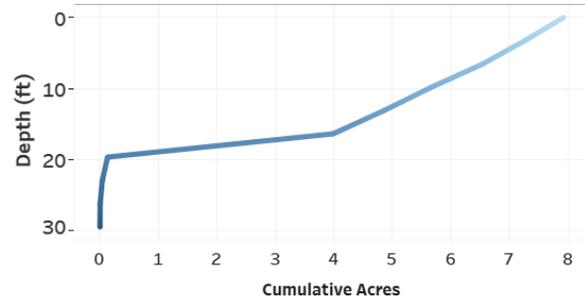


Figure 3-268. Hypsograph of Lake Summit depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake

Stormwater is conveyed to this waterbody from a 166-acre drainage basin (Figure 3-268). The basin is dominated by medium-density residential land use, followed by recreational and low-density residential, respectively. Based on stormwater pollutant load modelling, this drainage area contributes 513 lbs of TN and 83 lbs of TP to the lake annually. There are 52 Onsite Sewage Treatment and Disposal (OSTD/septic) systems present in the basin. This constitutes a moderate density that may contribute some pollutant loading through groundwater leaching. Due to the drainage basin being mostly outside of Winter Haven limits, the City does not conduct any street sweeping that benefits this lake.



Figure 3-267. Map of Lake Summit's drainage basin and nearby septic systems.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft and a dry season low of 130.8 ft. The level of the South Chain by the end of the year was slightly

above the top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake Summit’s surface level are correlated with Chl-a, TN, and water clarity (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.

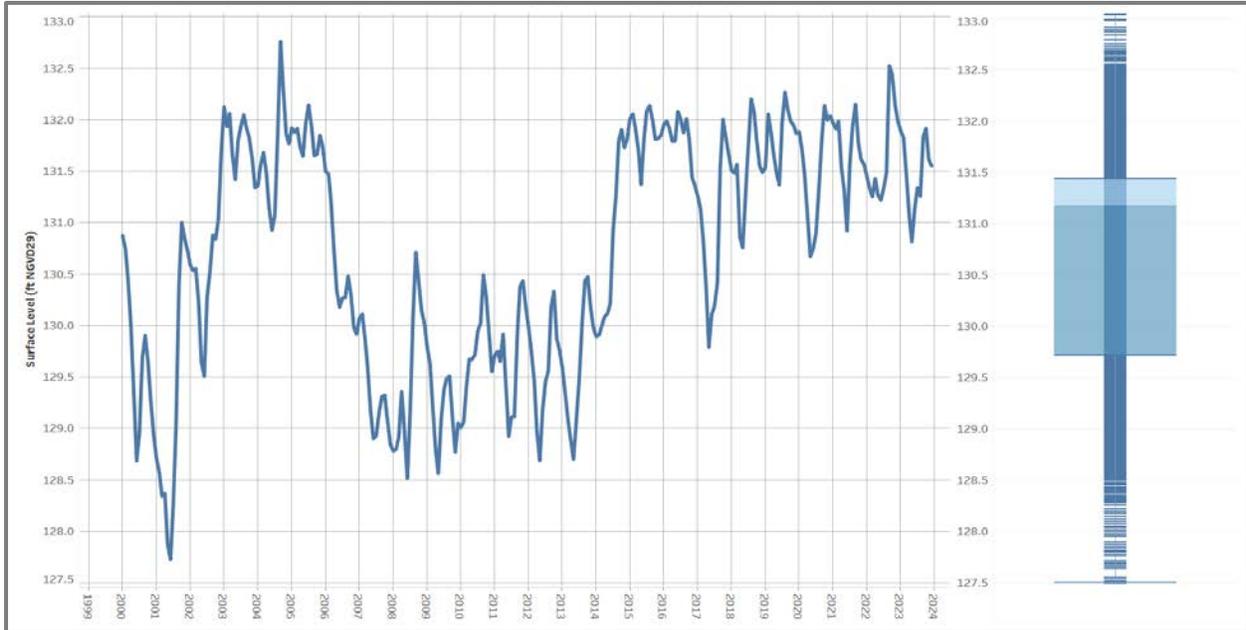


Figure 3-269. Hydrograph of Lake Summit depicting monthly surface level readings from 2000 to 2023. A box and whisker plot detail total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Summit is categorized as a clear, alkaline waterbody. Lake Summit has not exhibited any NNC exceedances during the assessment period (Figure 3-270). This equates to an impairment criterion score of 3. Lake Summit has consistently maintained excellent water quality throughout its period of record.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. During this period, Chl-a and Secchi depth exhibited significant improving trends; earning trend a criteria score of 3 for these parameters. TN and TP exhibited non-significant improving trends; for trend criterion scores of 2. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing	Not Significant	2
TP	Decreasing	Not Significant	2
Secchi	Increasing (Improving)	Significant	3

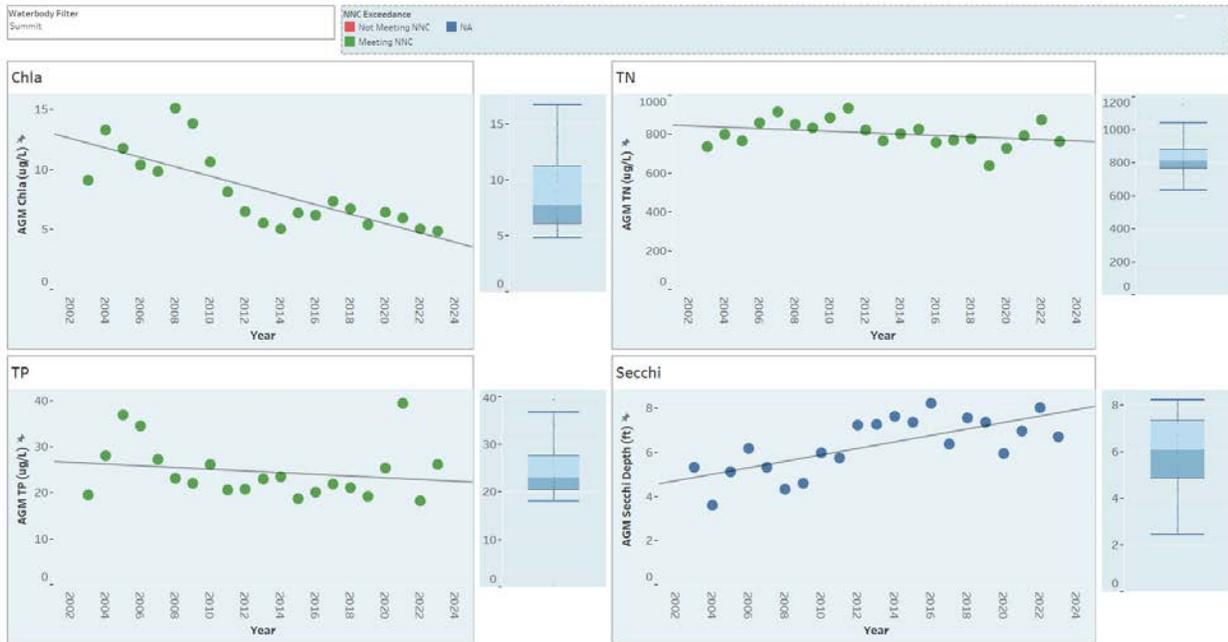


Figure 3-271. Lake Summit AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation

Abundance:

An aquatic vegetation survey was conducted for Lake Summit on 3/10/2023. The PAC during this survey was 54.3% and the total BV was 7.8% (Figure 3-271). A PAC above the 30% threshold equates to a vegetation abundance criterion score of 3. Since 2018, Lake Summit has maintained consistently high abundance, with coverage between 48% and 63%. The excellent water clarity is likely the main factor for this robust vegetation community.

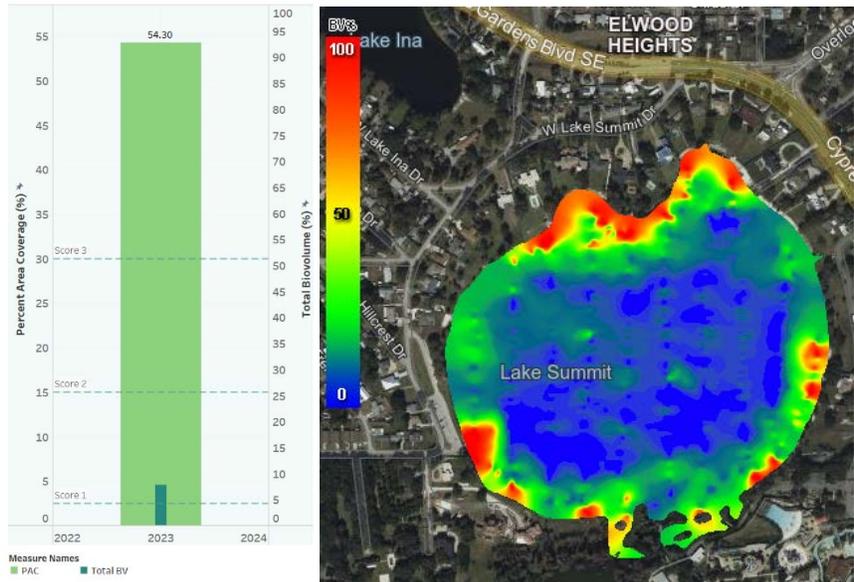


Figure 3-270. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Summit; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2023 data, Lake Summit is dominated by submerged aquatic vegetation. The top two most abundant species, making up over 40% of the community, are eelgrass and southern naiad (Figure 3-272). Hydrilla was the only managed invasive species present; at 3.7% of the community. An invasive percentage between 2.5% and 10% earns an invasive criterion score of 1. Hydrilla has been a consistent management issue for Lake Summit.

While its presence has not gotten over 5% since 2018, treatment efforts have not been successful in lowering it below 2.5%.

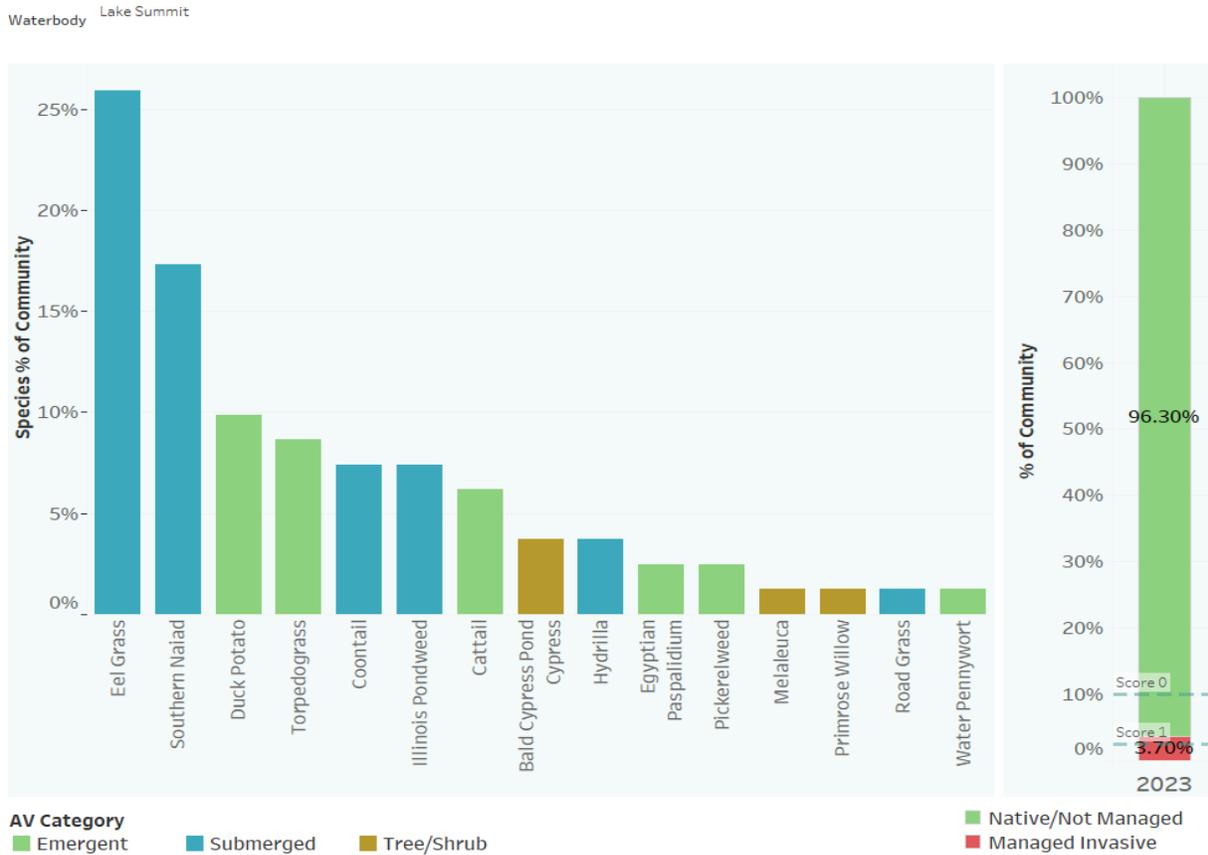


Figure 3-272. Chart depicting species frequency and invasive species percentage of Lake Summit during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2023 species data, all three of Lake Summit's diversity indices exceeded their respective median values (Figure 3-273). This equates to a diversity criterion score of 3. This score was made possible by an increase in the number of unique species identified in addition to a more even distribution of species in 2023, compared with previous years.

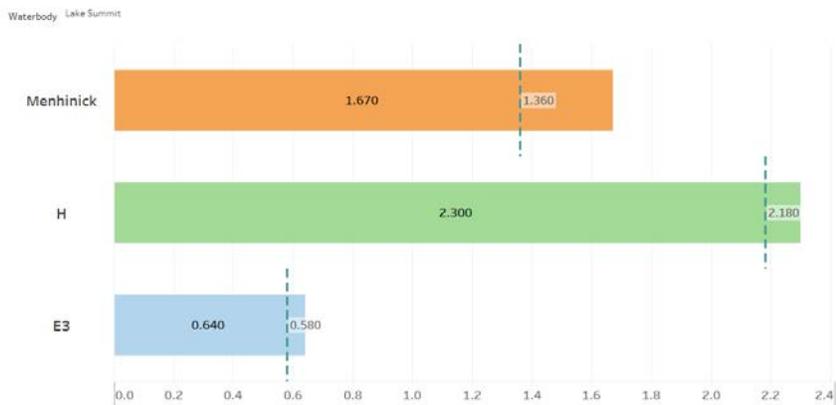


Figure 3-273. Chart depicting 2023 diversity indices for Lake Summit. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Summit’s health index scores from 2018 to 2023 shows consistently good values ranging from 2.4 to 2.6 (Figure 3-274). Throughout this span, the primary source of score fluctuation has been due to the diversity criterion. This likely changes in response to natural factors as well as invasive species treatment efforts. It should be noted that the only change between 2022 and 2023 was a shift in the significance of the TN trend. A minor decrease, but not indicative of negative impacts. Overall, Lake Summit ranks low on the City’s management priority list due to its excellent water quality and improving trends.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	3	3	3	1	1	2.5
2019	3	3	3	2	3	3	1	2	2.5
2020	3	3	3	2	3	3	1	1	2.4
2021	3	3	3	2	3	3	1	1	2.4
2022	3	3	3	2	3	3	1	3	2.6
2023	3	3	2	2	3	3	1	3	2.5

Figure 3-274. Chart depicting a comparison of Lake Summit’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Lake Summit currently exhibits excellent water quality. However, stormwater and OSTD pollutant sources remain a potential concern if trends ever begin to deteriorate.
- The management of invasive species like hydrilla is a consistent concern. It can only take a single growing season for even a small population to take over large areas of a waterbody.
- Several of Lake Summit’s water quality parameters are correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Winterset

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	3	3	3	3	3	1	2	2.6

Location, Characteristics, & Hydrology:

Lake Winterset is located to the southeast of downtown Winter Haven. It is mostly surrounded by unincorporated Polk County but does border small sections of City limits at the north and southeast portions of its shoreline. As part of the South Chain of Lakes, it is connected to Lake Eloise via a navigable canal. The South Chain discharges excess water to the Wahneta Farms Drainage canal through a passive control structure on the south shore of Lake Lulu. A moderately large and deep waterbody, Lake Winterset has a surface area of 558 acres, an average depth of 15.5 feet, and a maximum depth of over 32 feet (Figure 3-275).

Stormwater is conveyed to this waterbody from a 1074 acre drainage basin. The primary land uses in this basin are medium, low, and high-density residential, in that order. Other land uses include open land, commercial, wetlands, and agricultural. Based on stormwater pollutant load modelling, this drainage area contributes 2,259 lbs of TN and 408 lbs of TP to the lake annually. There are 71 Onsite Sewage Treatment and Disposal (OSTD/septic) systems located within the basin. These constitute a moderate density with pollutant load potential via groundwater leaching. Located mostly outside Winter Haven limits, the City does not conduct any street sweeping services within Lake Winterset’s drainage basin.

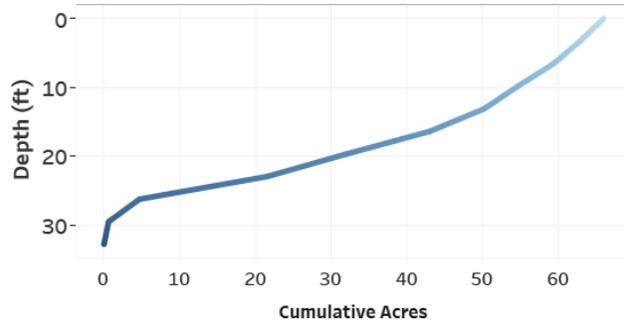


Figure 3-276. Hypsograph of Lake Winterset depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

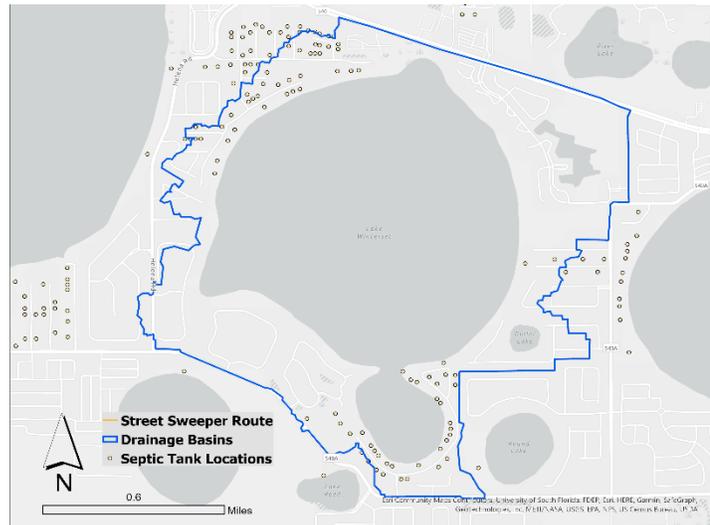


Figure 3-275. Map of Lake Winterset’s drainage basin and nearby septic systems.

Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain’s surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-21). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2023, the South Chain reached a wet season peak of 131.9 ft

and a dry season low of 130.8 ft. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain’s level remained at or above the high end of the normal range throughout most of the year. According to linear regression analysis, changes in Lake Winterset’s surface level are correlated with TN concentrations—likely due to slight increases in flushing during rainy periods (see appendix).

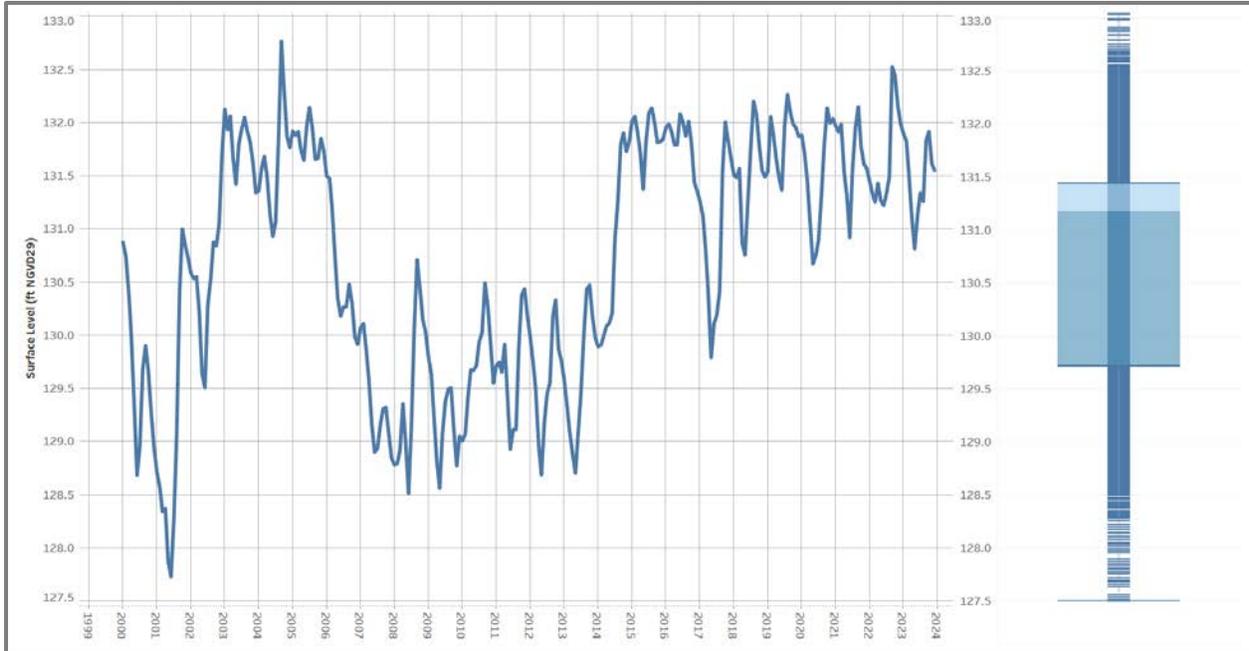


Figure 3-277. Hydrograph of Lake Winterset depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Winterset is categorized as a clear, alkaline waterbody. Due to the presence of no NNC exceedances of Chl-a, TN, or TP during the assessment period, Lake Winterset is considered unimpaired (Figure 3-278). This equates to an impairment criterion score of 3.

Parameter	Impaired	Index Score
Chla	N	3
TN	N	
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. During this period, all four of these parameters exhibited statistically significant improving trends. This equates to trend criteria scores of 3 for each of these. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3

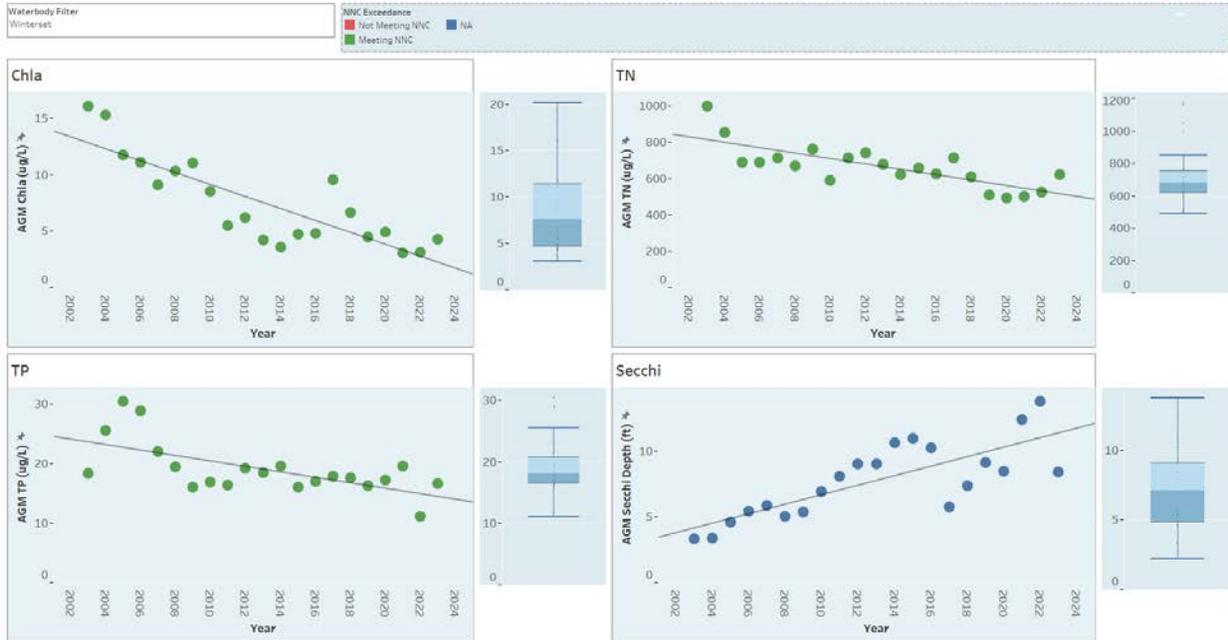


Figure 3-278. Lake Winterset AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Winterset on 3/3/2023. The PAC during this survey was 44.7% and the total BV was 4.6% (Figure 3-279). A PAC value over the 30% threshold equates to a vegetation abundance criterion score of 3. Since 2018, Lake Winterset’s vegetation coverage percentage has remained high. This robust vegetation community is likely the result of and a contributor to Winterset’s excellent water clarity and improving water quality trends.

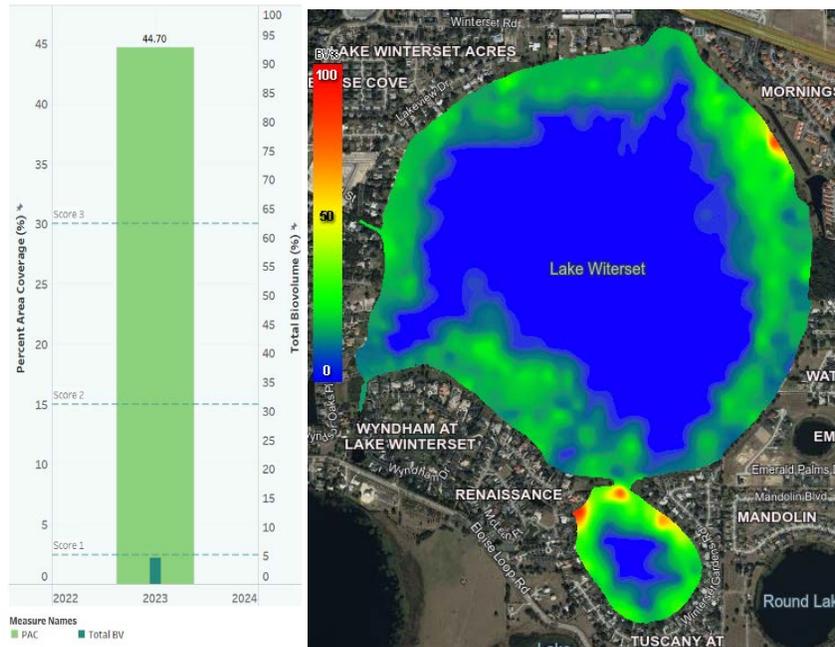


Figure 3-279. Graph depicting 2023 PAC/BV and biovolume heatmap of Lake Winterset; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, Lake Winterset is dominated by submerged species. Eelgrass and southern naiad made up close to 36% of the vegetation community (Figure 3-280). Invasives like hydrilla and burhead sedge constituted 7.9% of the population. This equates

to an invasive percentage score of 1. It should be noted that invasive treatment efforts resulted in a reduction of invasives by 10 percentage points since 2022.

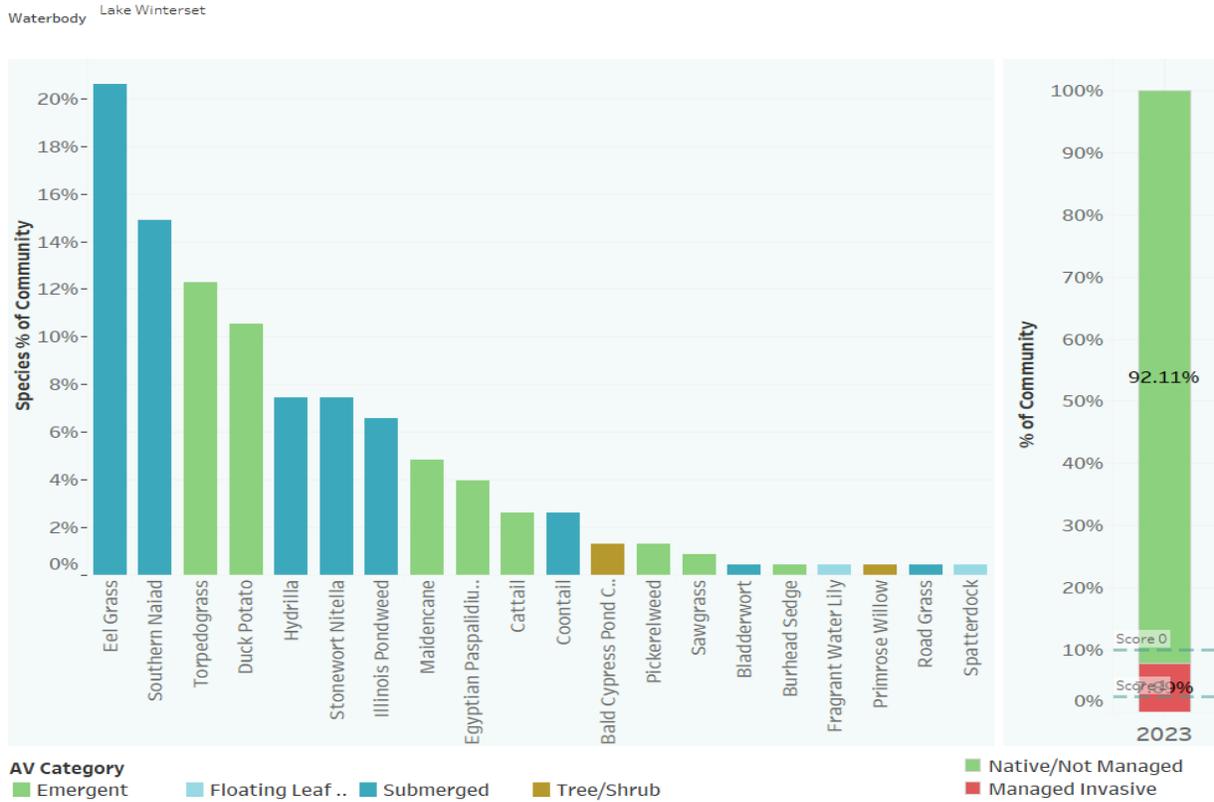


Figure 3-280. Chart depicting species frequency and invasive species presence of Lake Winterset during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity. According to the 2023 species data, Lake Winterset’s species richness and evenness indices met or exceeded their median values. This equates to a diversity criterion score of 2. The reduction in invasive percentages likely led to a slight drop in the overall diversity index value for 2023. On the whole, Lake Winterset boasts a relatively robust and diverse vegetation community.

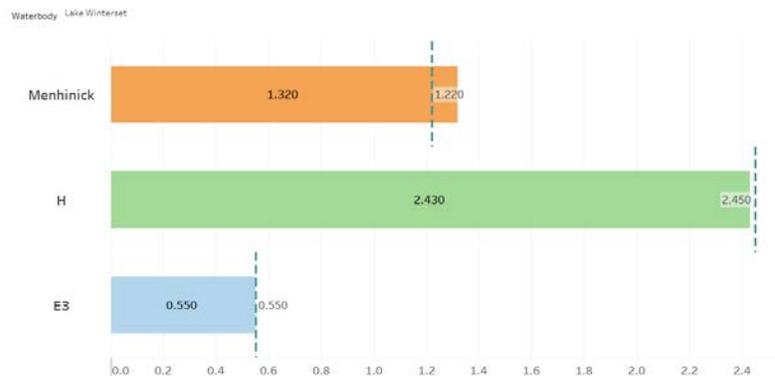


Figure 3-281. Chart depicting 2023 diversity indices for Lake Winterset. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Winterset’s health index scores from 2018 to 2022 shows consistently high values ranging from 2.4 to 2.8 (Figure 3-282). The primary changes in score have been the result of invasive species presence and diversity criteria fluctuations. While invasive species percentage has increased somewhat, this doesn’t appear to have impacted species diversity in a meaningful way. It can be inferred that species diversity fluctuates naturally instead of due to management actions. Overall, Lake Winterset ranks low on the City’s management priority list due to its excellent water quality and improving trends.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	3	3	2	1	1	2.4
2019	3	3	3	3	3	3	1	3	2.8
2020	3	3	3	3	3	3	1	3	2.8
2021	3	3	3	3	3	3	0	3	2.6
2022	3	3	3	3	3	3	0	1	2.4

Figure 3-282. Chart depicting a comparison of Lake Winterset’s Lake Health Index scores from 2018 to 2022.

Lake Health Impacts/Challenges:

- Lake Winterset currently exhibits excellent water quality. However, stormwater and OSTD loading are potential concerns if trends ever shift toward deterioration.
- The management of invasive species like hydrilla is a consistent concern. Based on the species data, the hydrilla population appears to be expanding in Lake Winterset. This may prompt the FWC to conduct more impactful treatment efforts in order to control it; which may result in some temporary declines in water quality.

Lake Management Strategy:

- If water quality becomes a future issue, City staff may explore source analysis to determine if OSTD leachate is a potential contributor of nutrient pollutant loading. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Bringing the hydrilla population down to a managed state should reduce the future need for large scale herbicide treatments and the potential water quality issues that follow.
- With the majority of the drainage basin comprised of residential housing, future management of stormwater may consist of public education and outreach. This aims to increase residents’ knowledge of best stormwater practices and ways they can individually reduce their nutrient load.

Little Lake Hamilton

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
0	1	1	2	1	2	3	2	1.5

Location, Characteristics, & Hydrology:

Little Lake Hamilton is located to the far northeast of downtown Winter Haven, completely outside of City limits. Its north shore is bordered by Haines City, with the remainder surrounded by unincorporated Polk County. While not technically within Winter Haven limits, Little Hamilton is part of the North Chain of Lakes due to its navigable connection with Middle Lake Hamilton. The North Chain discharges excess water to the Peace Creek via the P-8 control structure on the south shore of Lake Hamilton. A moderately sized waterbody, Little Hamilton has a surface area of 351 acres, an average depth of 8.4 feet, and a maximum depth of over 20 feet (Figure 3-283).

Stormwater is conveyed to this waterbody from a 1,016 acre drainage basin (Figure 3-284). Ranked by area, the primary land uses within this basin are agricultural, medium-density residential, wetlands, and low-density residential. Based on stormwater pollutant load modelling, this drainage area contributes 1,472 lbs of TN and 198 lbs of TP to the lake annually—a relatively low loading rate by area. There are 26 Onsite Sewage Treatment and Disposal (OSTD/septic) systems present in the basin—constituting a low density. Since Little Hamilton is completely outside Winter Haven limits, the City does not conduct any street sweeping services in the basin.

Over its period of record, Little Hamilton’s surface level has fluctuated between 117.5 and 123.6 feet above sea level. The normal range of fluctuation is between 119 and 121 feet (Figure 3-285). In 2017, the SWFWMD enacted new water level management protocols with the intent to restore seasonal level fluctuations within the lake’s normal range. This is accomplished by releasing water downstream during the rainy season and storing water during the dry season. During 2023, the Hamilton chain reached a wet season peak of 121.5 feet in September and a dry season low of 120.4 feet in May. According to linear regression analysis, changes in Little Hamilton’s surface

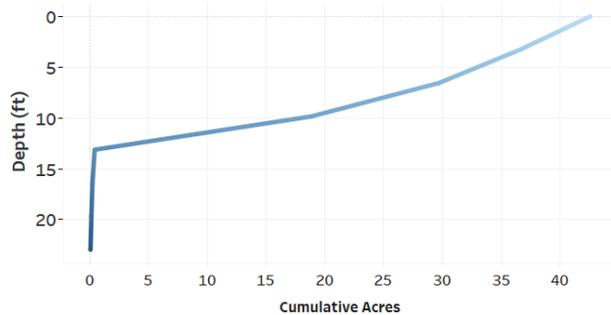


Figure 3-284. Hypsograph of Little Lake Hamilton depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

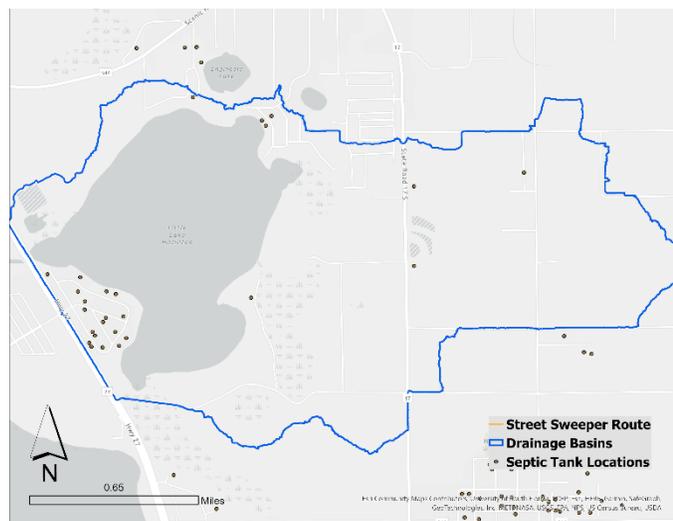


Figure 3-283. Map of Little Lake Hamilton’s drainage basin and nearby septic systems.

level are strongly correlated with Chl-a, TN, TP, and water clarity (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.

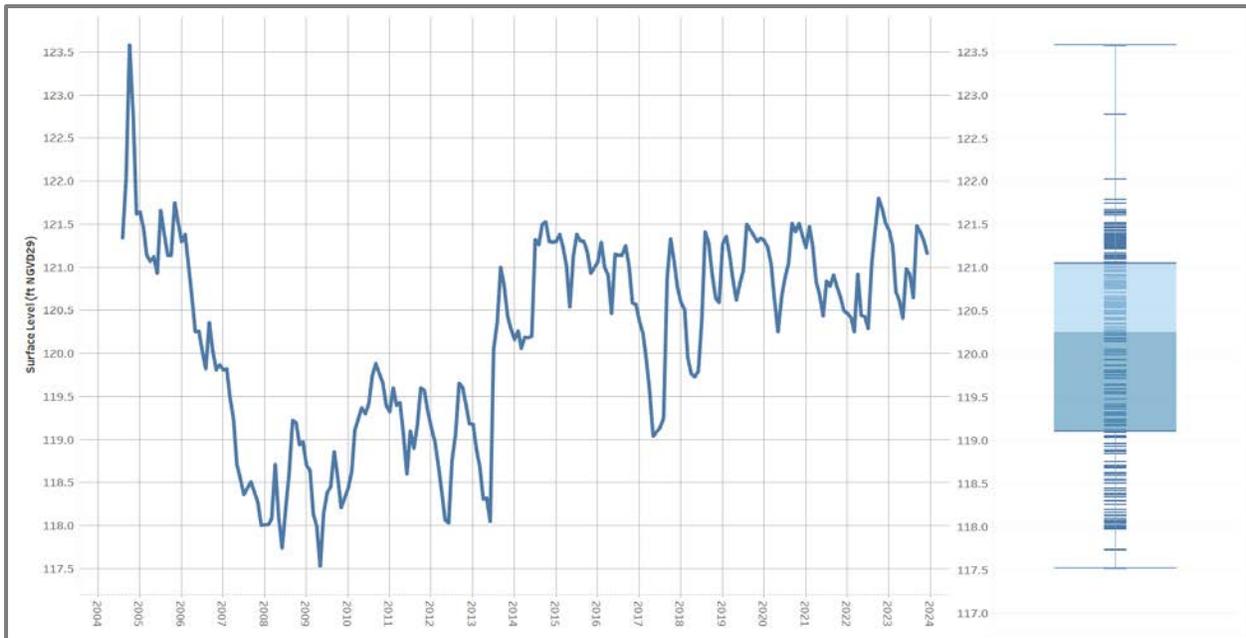


Figure 3-285. Hydrograph of Little Lake Hamilton depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Little Lake Hamilton is categorized as a clear, alkaline waterbody. Since impairment can be determined by more than one exceedance in any three year span during the assessment period, Little Hamilton is considered impaired for Chl-a, TN, and TP based on exceedances in the last two years (Figure 3-286). This equates to an impairment criterion score of 0. In 2021, the FDEP adopted a Polk County proposed pollutant reduction plan for the Lake Hamilton Chain. This plan stipulates that existing or planned pollutant reduction strategies have been accepted in lieu of a total maximum daily load.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. During this period, Chl-a, TN, and Secchi depth exhibited non-significant deteriorating trends—equating to trend criteria scores of 1. TP exhibited a non-significant improving trend—for a trend criterion score of 2. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing	Not Significant	1
TN	Increasing	Not Significant	1
TP	Decreasing	Not Significant	2
Secchi	Decreasing	Not Significant	1

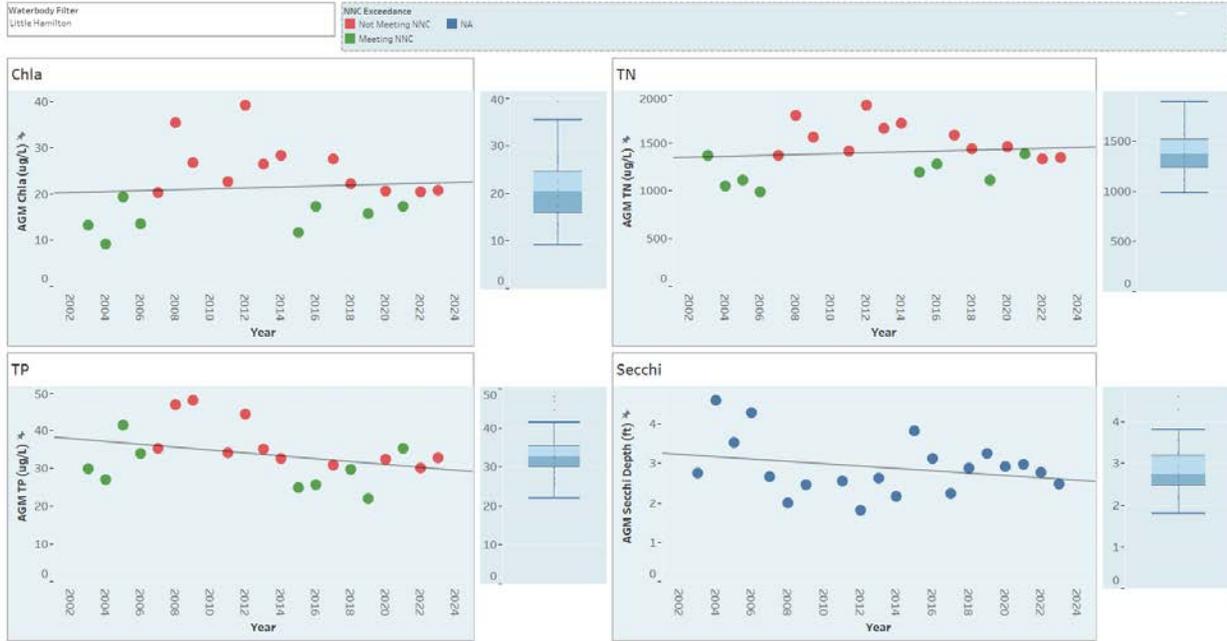


Figure 3-287. Little Lake Hamilton AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Little Lake Hamilton on 10/10/2023. The PAC during this survey was 18.6% and the total BV was 2% (Figure 3-287). A PAC between 15% and 30% equates to an abundance criterion score of 2. Since 2018, Little Hamilton has exhibited moderate vegetation abundance with values less than 20%.

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2023 survey data, Little Lake Hamilton is dominated by floating leaf plants. The native banana lily, spatterdock, and fragrant water lily made up over 35% of the community (Figure 3-288). Fortunately, there were no managed invasive species detected during the last two annual surveys. This absence equates to an invasive criterion score of 3. In previous years, hydrilla, burhead sedge, and elodea were invasives to be managed. The lack of these and the expansion of vegetation abundance is indicative of a healthy vegetation community.

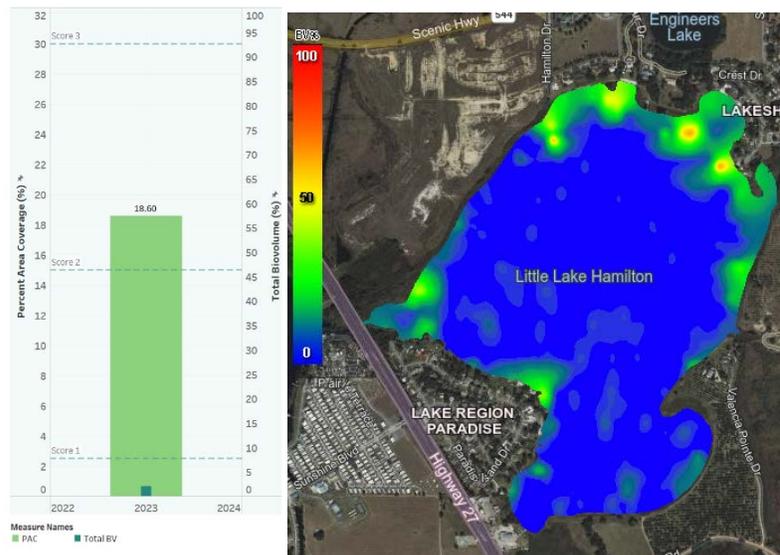


Figure 3-286. Graph depicting 2023 PAC/BV and biovolume heatmap of Little Lake Hamilton; biovolume values range from green (lowest) to red

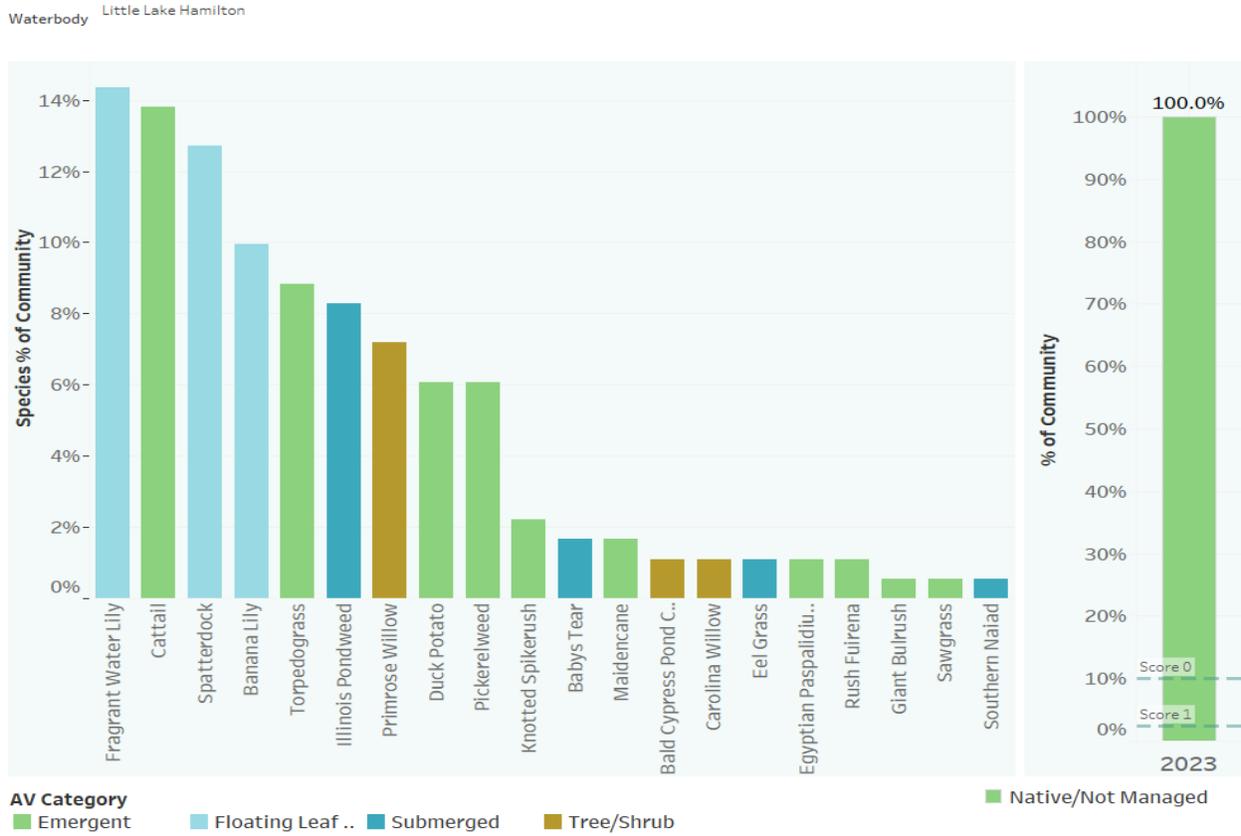


Figure 3-288. Chart depicting species frequency and invasive species percentage of Little Lake Hamilton during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2023 species data, Little Hamilton’s evenness and overall diversity indices met or exceeded their respective median values (Figure 3-289). This equates to a diversity criterion score of 3. There were slightly more unique species detected in 2022 which is why the species richness was higher last year. Overall, Little Hamilton exhibits little change in diversity; any changes are likely due to natural shifts in community dynamics.

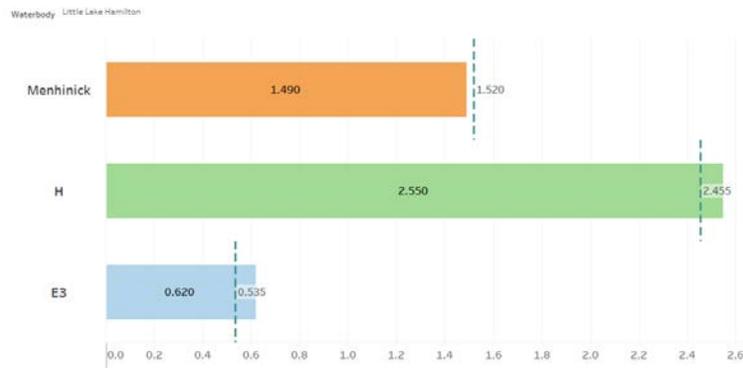


Figure 3-289. Chart depicting 2023 diversity indices for Little Lake Hamilton. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Little Lake Hamilton’s health index scores from 2018 to 2023 shows slight improvement—with values ranging from 1.3 to 1.6 (Figure 3-290). During this time frame, there has been very little change in the water quality criteria scores. While vegetation abundance has remained mostly static, invasive species presence appears to have fluctuated the most. Species diversity and invasive presence have exhibited the most improvement; with relatively high scores in the last couple of years. Overall Little Lake Hamilton ranks high on the priority list due to its water quality impairments and deteriorating trends.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	1	2	1	2	2	1	1.3
2019	0	1	1	2	1	2	3	0	1.3
2020	0	1	1	2	1	2	2	3	1.5
2021	1	1	1	2	1	1	1	3	1.4
2022	0	1	1	2	1	2	3	3	1.6
2023	0	1	1	2	1	2	3	2	1.5

Figure 3-290. Chart depicting a comparison of Little Lake Hamilton’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Stormwater and OSTD pollutant loading remain the primary factors likely impacting water quality. Since Little Hamilton’s drainage basin falls outside of Winter Haven’s jurisdiction, the City is limited in its capacity to manage these potential pollution sources.
- Several of Little Lake Hamilton’s water quality parameters are correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- The management of invasive species is a consistent concern. While invasive species were not detected in 2023, it can take a single growing season for even small populations to take over large areas of a waterbody.

Lake Management Strategy:

- The City plans to provide support to Polk County and other municipalities in the vicinity of Little Lake Hamilton as water quality management plans are developed and implemented.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.

Middle Lake Hamilton

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
0	1	2	3	3	3	0	3	1.9

Location, Characteristics, & Hydrology:

Middle Lake Hamilton is located far northeast of downtown Winter Haven. It is bordered by the City on its north shore, but surrounded by unincorporated Polk County around its remaining perimeter. Nestled between and sharing navigable connections with Lake Hamilton and Little Lake Hamilton, it is considered part of the North Chain of Lakes. The North Chain discharges excess water to the Peace Creek via the P-8 control structure on the south shore of Lake Hamilton. Middle Lake Hamilton is a smaller waterbody at just 103 acres, an average depth of 5.6 feet, and a maximum depth of 8.6 feet (Figure 3-291).

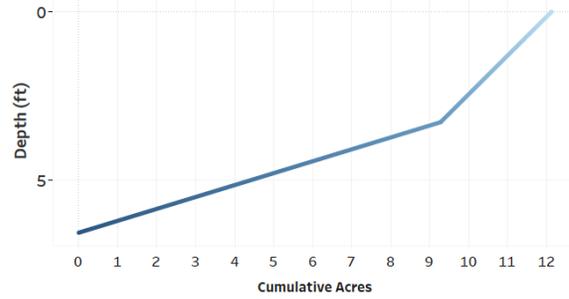


Figure 3-291. Hypsograph of Middle Lake Hamilton depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 1540 acre drainage basin that extends far to the north (Figure 3-292). Ranked by area, the primary land uses within this basin are high-density residential, agricultural, commercial, wetlands, and low-density residential. Based on stormwater pollutant load modelling, this drainage area contributes 11,621 lbs of TN and 1,072 lbs of TP to the lake annually. There are a little over 30 Onsite Sewage Treatment and Disposal (OSTD/septic) systems in the basin. However, the majority of these are very far from the actual waterbody and don't constitute a high enough density to be a major pollutant concern. With the majority of the basin outside of Winter Haven limits, the City does not conduct any street sweeping services in the vicinity.

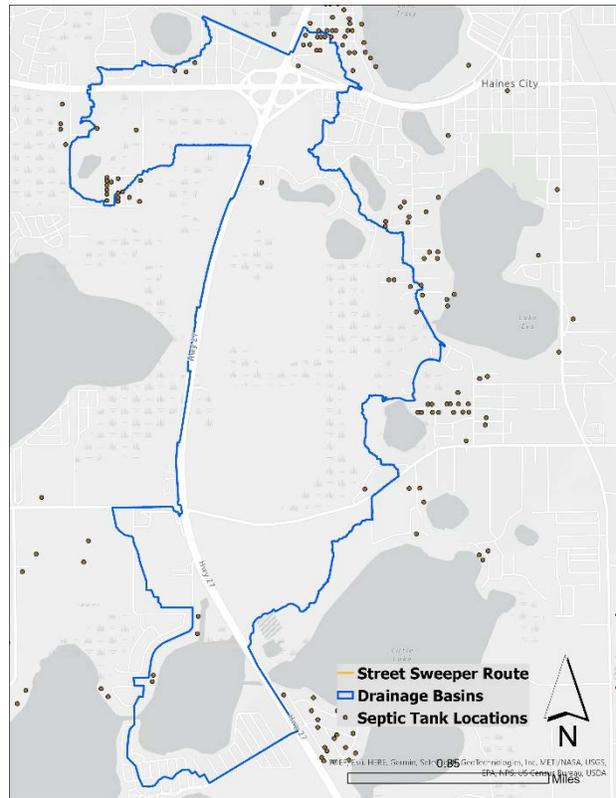


Figure 3-292. Map of Middle Lake Hamilton's drainage basin and nearby septic systems.

Over its period of record, Middle Hamilton's surface level has fluctuated between 117.5 and 123.6 feet above sea level. The normal range of fluctuation is between 119 and 121 feet (Figure 3-293). In 2017, the SWFWMD enacted new water level management protocols with the intent to restore seasonal level fluctuations within the lake's normal range. This is accomplished

by releasing water downstream during the rainy season and storing water during the dry season. During 2023, the Hamilton chain reached a wet season peak of 121.5 feet in September and a dry season low of 120.4 feet in May. According to linear regression analysis, changes in Middle Hamilton’s surface level are strongly correlated with Chl-a, TN, TP, and water clarity (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.

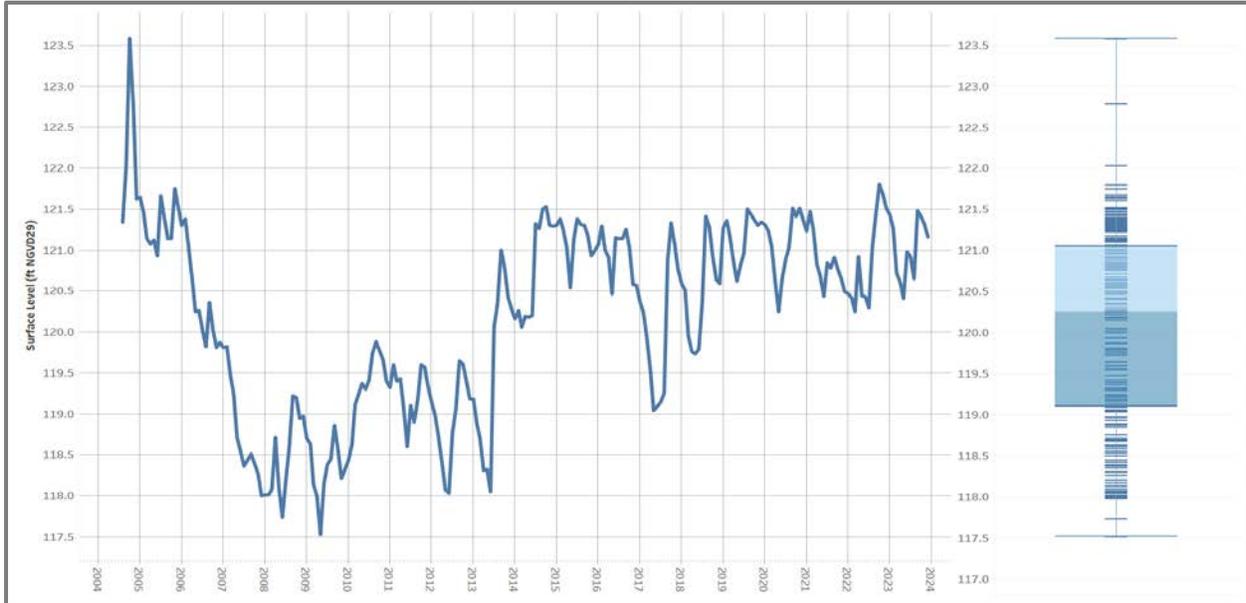


Figure 3-293. Hydrograph of Middle Lake Hamilton depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Middle Lake Hamilton is categorized as a clear, alkaline waterbody. Due to numerous NNC exceedances during the assessment period, Middle Hamilton is considered impaired for Chl-a, TN, and TP (Figure 3-294). Like with Lakes Hamilton and Little Hamilton, the FDEP has adopted a Polk County-developed pollutant reduction plan in lieu of a total maximum daily load.

Parameter	Impaired	Index Score
Chla	Y	0
TN	Y	
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. During this period, TP and Secchi depth exhibited significant improving trends; for trend criteria score of 3. TN exhibited a non-significant improving trend; for a trend score of 2. While Chl-a exhibited a non-significant deteriorating trend; for a trend criterion score of 1. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing	Not Significant	1
TN	Decreasing	Not Significant	2
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3

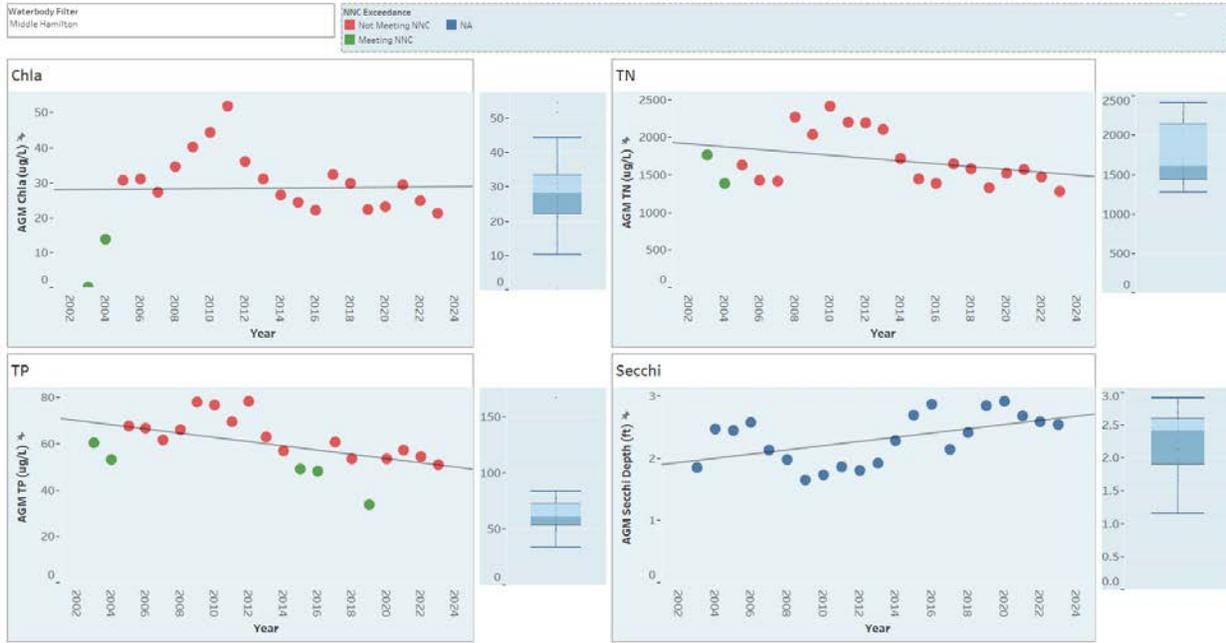


Figure 3-295. Middle Lake Hamilton AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Middle Lake Hamilton on 6/23/2023. The PAC during this survey was 61.2% and the total BV was 8.6% (Figure 3-295). A PAC above 30% equates to an abundance criterion score of 3. Middle Hamilton’s vegetation abundance has previously been low. Values have ranged from 8.6% in 2021 to the current highest value in 2023. This record high is indicative of an expanding vegetation community—most likely due to invasive species.

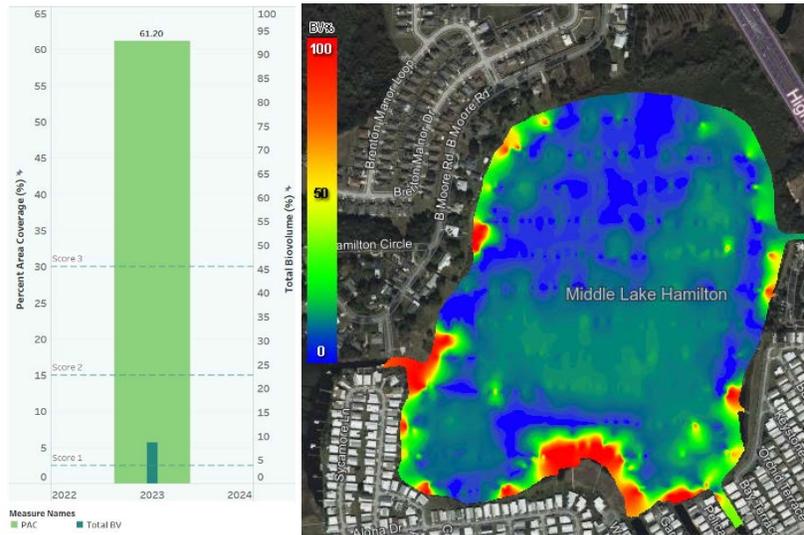


Figure 3-294. Graph depicting 2022 PAC/BV and biovolume heatmap of Middle Lake Hamilton; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2023 survey, Middle Hamilton had two dominant species—hydrilla and spatterdock, which made up 25% of the community (Figure 3-296). The remaining plants are a mix of other plant types (mostly emergent). Invasive species like hydrilla, water hyacinth, and burhead sedge made up 25% of the community. This equates to an invasive criterion score of 0. This constitutes a significant increase in the invasive percentage.

Waterbody Middle Lake Hamilton

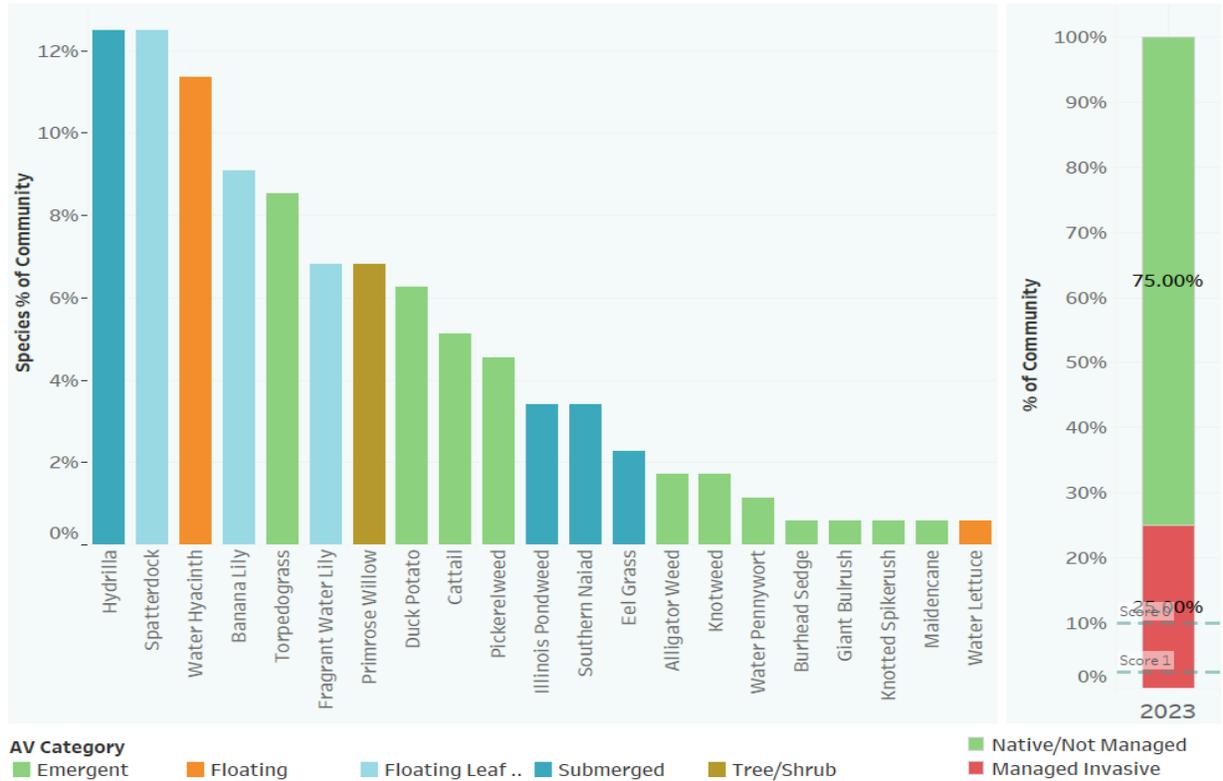


Figure 3-296. Chart depicting species frequency and invasive species percentage of Middle Lake Hamilton during 2023.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to 2023 species data, all three of Middle Hamilton’s diversity indices exceeded their respective median values (Figure 3-297). This equates to a diversity criterion score of 3. This result is easily explained as 2023 exhibited a massive increase in the number of unique species as well as a more even distribution of frequency below the top 3 ranked species.

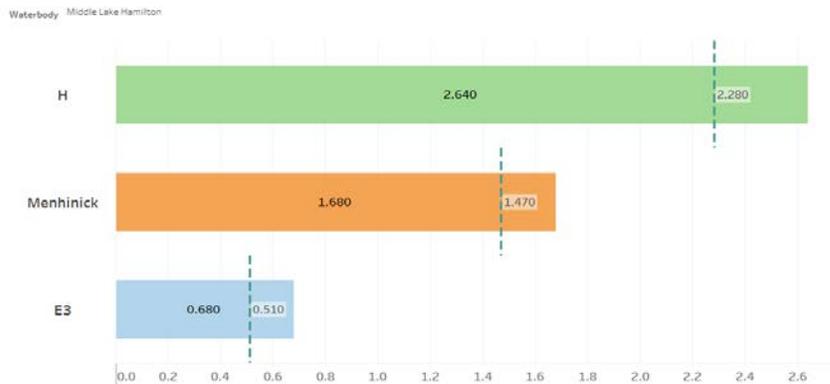


Figure 3-297. Chart depicting 2022 diversity indices for Middle Lake Hamilton. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Middle Lake Hamilton’s health index scores shows gradual improvement from values of 1.3 in 2018 to 1.9 in 2023 (Figure 3-298). While impairment has not changed in this six-year span, the water clarity trend score has increased to a significant improving trend. Aquatic vegetation abundance and invasive percentage have fluctuated slightly. However, the most improvement has been in the species diversity criterion. Overall, Middle Lake Hamilton ranks moderately high due to its water quality impairment and deteriorating Chl-a trend.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	2	3	2	1	1	0	1.3
2019	0	1	2	3	2	2	1	1	1.5
2020	0	1	2	3	2	1	3	2	1.8
2021	0	1	2	3	3	1	1	3	1.8
2022	0	1	2	3	3	2	1	3	1.9
2023	0	1	2	3	3	3	0	3	1.9

Figure 3-298. Chart depicting a comparison of Middle Lake Hamilton’s Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Stormwater pollutant loading remains the primary factor likely impacting water quality. Since the majority of Middle Hamilton’s drainage basin falls outside of Winter Haven’s jurisdiction, the City is limited in its capacity to manage these potential pollution sources.
- Several of Little Lake Hamilton’s water quality parameters are correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- The management of invasive species is a consistent concern. It can take a single growing season for even small populations to take over large areas of a waterbody.

Lake Management Strategy:

- The City will provide support to Polk County as water quality management plans are developed and implemented.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.

Lake Management Summary

Using the Lake Health Index scores as a ranking system, the City is able to objectively prioritize management efforts for the study area lakes according to where the need is greatest. The following table displays the current priority ranking based on the 2023 Lake Health Index scores (Table 3-1).

Waterbody	Lake Health Index								Lake Health Score
	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	
Lake Idyl	0	0	0	0	0	3	0	1	0.5
Lake Hamilton	0	0	0	3	0	1	3	3	1.3
Lake Ned	3	0	0	0	0	2	3	2	1.3
Lake Elbert	3	0	0	1	0	2	2	3	1.4
Lake Hartridge	1	0	0	2	0	3	3	2	1.4
Lake Martha	3	0	1	1	0	1	3	2	1.4
Lake Pansy	3	0	2	1	1	2	2	1	1.5
Little Lake Hamilton	0	1	1	2	1	2	3	2	1.5
Lake Mariana	0	1	1	3	0	3	3	2	1.6
Lake Jessie	0	2	1	3	2	3	1	2	1.8
Lake Otis	3	1	2	1	1	3	1	2	1.8
Lake Link	3	1	2	1	1	3	2	1	1.8
Lake Mariam	3	0	2	1	2	3	0	3	1.8
Lake Smart	0	2	2	2	2	2	1	3	1.8
Lake Haines	1	3	3	1	3	3	1	0	1.9
Middle Lake Hamilton	0	1	2	3	3	3	0	3	1.9
Lake Blue	0	2	2	3	1	3	3	2	2.0
Lake Eloise	0	3	2	3	3	2	2	1	2.0
Lake Deer	3	2	2	3	2	3	0	2	2.1
Lake Silver	3	2	2	2	2	1	3	2	2.1
Lake Cannon	2	2	2	3	2	3	1	3	2.3
Lake Fannie	3	3	2	2	3	2	0	3	2.3
Lake May	0	3	3	3	3	3	0	3	2.3
Lake Rochelle	3	3	3	2	3	2	1	1	2.3
Lake Howard	1	3	3	3	3	2	2	2	2.4
Lake Lulu	0	3	3	3	3	3	1	3	2.4
Lake Maude	3	3	3	2	2	3	1	2	2.4
Lake Shipp	0	3	3	3	3	3	2	2	2.4
Lake Spring	3	3	3	3	3	3	0	1	2.4
Lake Roy	3	3	2	3	2	3	2	2	2.5
Lake Conine	3	3	3	2	3	2	1	3	2.5
Lake Idylwild	2	3	2	3	3	3	1	3	2.5
Lake Mirror	3	3	3	3	3	3	1	1	2.5
Lake Summit	3	3	2	2	3	3	1	3	2.5
Lake Buckeye	3	3	3	2	3	2	2	3	2.6
Lake Daisy	3	3	3	3	3	2	1	3	2.6
Lake Winterset	3	3	3	3	3	3	1	2	2.6

Table 3-1. 2023 Lake Health Index scores ranking the Winter Haven study area lakes from highest to lowest priority.

The highest ranked waterbodies similar qualities—water quality impairments and/or exhibiting multiple significantly deteriorating water quality trends. While the biological criteria also factor into these lake health scores, changes in vegetation abundance, invasive species presence, and species diversity are more variable and generally less impactful to overall lake health compared with water quality. Water quality issues are typically more challenging and costly to solve as well.

According to the 2023 Lake Health Index, the top five highest-priority waterbodies are Lake Idyl (p. 144), Lake Hamilton (p. 128), Lake Ned (p. 199), Lake Elbert (p.108), and Lake Hartridge (p. 133) in that order. The City and partnering agencies are engaged in various management strategies to improve the water quality in these lakes. These strategies can be reviewed in each lake’s respective section (see the page numbers listed above). Some specific management actions estimated to have the greatest impact on water quality include:

- Lake Idyl Water Quality Improvement Plan. The City submitted a restoration plan to the Florida Department of Environmental Protection aimed at addressing the pollutant sources to the lake. Projects associated with this plan include construction of stormwater improvements within the drainage basin and inactivating the highly organic sediments with innovative technologies. Both of these projects will be dependent on funding availability and City staff are currently seeking grant funding during the FY 2024 and 2025 cycles.
- Green stormwater infrastructure within the Lake Elbert drainage basin. The Lake Elbert trail project started in 2024 and will include several raingardens to help filter much of the stormwater before it enters the lake.
- Source analysis for Lakes Ned, Hartridge, and Hamilton. Lacking substantial stormwater inputs, it is critical to determine the source of pollutants in these waterbodies. The City is currently looking into developing a study to help identify the possible nonpoint pollutant sources within these waterbodies. Future management action will be driven by the results of this study.

Comparing the Lake Health Index scores over time provides insights into how successful these management strategies have been. Taking the mean of Lake Health criteria values from 2018 to 2023 shows that Winter Haven’s lakes have improved in most areas (Table 3-2). The following are some highlights of this comparison:

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	1.3	1.8	1.9	2.2	2.1	2.2	1.3	1.3	1.8
2019	1.5	1.9	2.0	2.2	2.1	2.3	1.1	2.0	1.9
2020	1.5	1.9	2.1	2.2	2.1	2.4	1.3	1.5	1.9
2021	1.7	1.9	2.1	2.0	2.1	2.3	1.3	1.7	1.9
2022	1.7	1.9	2.1	2.0	2.2	2.5	1.5	1.9	2.0
2023	1.8	1.9	2.0	2.2	1.9	2.5	1.5	2.1	2.0

Table 3-2. Mean Lake Health Index scores for all Winter Haven area lakes from 2018 to 2023.

- Since 2018, several lakes have been starting to meet the Numeric Nutrient Criteria (NNC), resulting in gradual improvements to the impairment criterion scores.
- The trend criterion scores for chlorophyll-a, total nitrogen, and water clarity have all increased since Lake Health monitoring began. Unfortunately, some lakes have exhibited a regression to water clarity trends.

- Vegetation abundance, invasive presence, and species diversity scores are all higher than in 2018. It can be inferred that, on the whole, aquatic plant communities are expanding; and not because of an increase in invasive species. This indicates that plant management efforts are mostly successful.

While these scores show general improvement, many individual waterbodies aren't meeting the high standards set forth by both the State and the City of Winter Haven. There is still much to accomplish to meet these goals. It will take the combined efforts of the City, partner organizations, local stakeholders, and Winter Haven residents in order to make these improvements a reality. Please reach out to the Winter Haven Natural Resources Division if you would like more information about a specific lake or management strategy.

Email: naturalresources@mywinterhaven.com

Phone: 863-291-5881

#4 | Appendix



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4.2 Data Sources:

Water Quality Data

Collected from: <https://polk.wateratlas.usf.edu/datadownload/>; Surface Water Quality

Parameters:

- Alkalinity, Total (hydroxide+carbonate+bicarbonate)
- Chlorophyll-a, corrected for pheophytin
- Nitrogen, Total
- Phosphorus as P, Total
- Secchi disk depth
- True Color, Total

Data Sources:

- POLKCO_NRD_WQ
- WIN_21FLPOLK
- WIN_21FLCEN
- LAKEWATCH_V
- SWFWMD_LAKES_WQ
- STORET_21FLTPA
- LEGACYSTORET_21FLA
- USGS_NWIS

Hydrologic Data

Southwest Florida Water Management District Environmental Data Portal: <https://www.swfwmd.state.fl.us/resources/data-maps/environmental-data-portal>

- Rainfall
- Lake (surface elevation)
- Well (Upper Floridan Aquifer elevation)

University of Florida IFAS Extension; Florida Automated Weather Network: <https://fawn.ifas.ufl.edu/data/>

- Rainfall
- Evapotranspiration

City of Winter Haven Lake Level Sensors: <http://hydrometcloud.com/hydrometcloud/index.jsp>

- Lake (surface elevation)

Biological Data

Aquatic vegetation abundance collected using SONAR devices (e.g. Lowrance, Garmin, etc.).

SONAR data is processed using BIOBASE: <https://www.biobasemaps.com/Solutions/AquaticPlants>

Species data is collected using the Florida Fish and Wildlife Commission (FWC) point-intercept sampling methodology.

- Collected by City of Winter Haven staff, Polk County staff, and FWC staff.

4.3 Supplemental Data

Annual Geometric Mean Data

Table 4-1. Annual geometric mean corrected chlorophyll-a concentrations from 2003 – 2023 for all study area lakes.

Waterbody	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Lake Blue	60.1	79.2	53.8	66.8	122.4	75.7	120.5	58.8	70.7	34.4	57.7	52.3	58.1	65.9	70.9	59.8	72.6	61.1	49.0	60.0	51.3
Lake Buckeye	18.3	14.3	24.2	12.1	13.6	10.6	10.2	7.4	6.0	7.1	4.9	7.1	5.3	5.4	4.9	6.5	9.5	3.4	3.6	9.3	18.1
Lake Cannon	24.2	30.6	27.8	18.5	22.9	23.7	32.2	28.0	28.7	23.1	31.7	27.3	16.5	19.0	19.0	21.5	25.0	22.6	18.9	35.0	18.3
Lake Conine	26.2	32.0	39.6	36.8	45.9	34.0	36.1	36.2	44.1	34.5	30.1	23.3	22.7	19.0	22.3	17.5	17.6	15.7	24.0	15.1	25.6
Lake Daisy	6.7	3.6	4.8	9.0	8.5	5.7	5.7	4.8	3.7	4.9	4.8	4.4	3.8	3.4	4.5	4.5	3.9	3.0	3.0	3.0	2.6
Lake Deer	3.7	7.6	16.4	17.3	21.6	31.6	27.9	18.8	11.5	28.4	22.2	10.3	12.4	8.1	11.3	4.9	8.7	7.2	10.8	4.2	10.1
Lake Elbert	3.5	3.1	6.2	5.2	3.7	3.1	3.7	3.6	4.9	5.0	4.0	4.4	5.5	3.7	6.2	5.6	8.2	10.6	8.2	13.0	8.0
Lake Eloise	32.1	30.6	43.7	34.1	25.5	30.5	27.1	31.0	39.0	25.6	36.0	33.5	32.0	37.0	22.8	25.9	21.4	23.8	33.2	16.9	28.3
Lake Fannie	13.0	21.3	13.4	14.7	14.3	16.9	22.6	22.0	25.6	19.1	17.1	13.7	10.5	11.3	11.5	12.0	11.6	8.1	13.6	12.4	11.3
Lake Haines	26.1	31.7	34.9	44.8	28.3	29.8	25.8	23.7	21.3	35.2	28.7	18.7	16.8	26.0	23.8	34.4	23.7	23.1	23.0	18.5	25.5
Lake Hamilton	1.5	2.0	13.6	7.7	6.8	16.0	28.9	26.5	22.8	29.0	29.2	22.5	21.3	24.9	45.8	40.5	32.8	34.7	37.1	48.2	31.4
Lake Hartridge	10.2	10.3	7.7	13.3	14.9	14.4	22.9	22.8	28.5	27.5	31.0	30.5	28.1	26.7	25.9	24.6	22.3	25.2	21.1	26.1	20.1
Lake Howard	28.8	42.9	31.0	37.4	64.0	41.9	33.3	24.7	30.0	29.6	26.9	25.0	25.4	27.6	24.7	21.7	20.0	23.7	25.5	33.4	23.0
Lake Idyl	10.6	8.0	9.2	7.0	4.4	1.9	25.1	4.4	5.5	4.8		4.7	9.7	9.6	57.5	33.6	31.7	29.7	38.9	17.4	17.1
Lake Idylwild	21.9	24.7	20.1	25.0	21.3	29.3	37.3	33.2	23.3	21.0	26.8	22.5	16.8	13.9	24.8	21.3	18.3	16.6	15.8	21.6	14.8
Lake Jessie	25.0	26.4	28.1	27.8	24.0	25.4	30.9	31.9	25.0	24.0	26.8	26.8	18.3	15.4	33.0	24.3	23.0	25.2	23.3	27.0	20.8
Lake Link	10.4	13.6						5.2	10.0	15.5	15.3	14.5	13.8	11.1	13.9	17.3	14.2	9.8	14.9	13.0	15.6
Lake Lulu	28.0	26.7	39.0	38.6	35.0	34.8	30.9	29.6	25.2	22.3	23.1	17.2	21.2	25.4	25.7	30.2	22.3	20.8	21.3	19.8	23.1
Lake Mariam	4.2	3.8	5.4	5.4	8.0	6.0	4.7	4.0	4.1	4.8	4.7	6.3	6.3	10.9	7.1	8.2	6.8	6.3	7.4	13.1	5.6
Lake Mariana	24.3	37.0	26.9	23.4	28.9	32.5	34.2	25.5	42.1	32.4	35.0	37.1	29.1	21.3	38.2	31.5	35.1	26.3	35.6	35.6	28.8
Lake Martha	0.0	3.2	3.6	3.0	3.4	7.1	5.6	7.1	7.1	6.3	6.3	7.3	12.2	12.7	17.7	17.2	8.8	8.2	10.7	9.3	6.7
Lake Maude	6.1	18.9	12.8	4.7	4.9	16.3	15.9	12.3	8.7	12.6	8.2	5.3	8.3	6.5	8.2	4.1	4.0	3.4	3.9	8.1	10.9
Lake May	32.0	46.4	36.1	47.6	65.6	51.3	46.3	32.6	35.3	37.3	33.0	24.4	18.5	29.1	30.6	23.5	21.7	19.9	21.3	35.6	26.6
Lake Mirror	34.4	28.2	29.6	23.6	22.9	26.4	21.0	19.5	13.5	10.5	15.8	8.2	8.1	12.4	16.7	21.7	14.0	14.7	9.2	13.4	24.0
Lake Ned	10.7	4.8	8.0	5.4	4.9	6.2	7.9	10.0	3.6	10.7	13.9	13.9	13.2	15.2	14.3	14.8	13.7	13.5	10.8	11.9	16.3
Lake Otis	11.2	10.4						21.9	18.3	23.2	20.4	16.3	17.3	13.9	13.5	18.0	13.7	15.1	19.3	13.3	15.2
Lake Pansy	6.4	8.8	10.9	11.7	15.9	12.1	11.2	11.4	8.7	15.4	23.3	16.5	16.4	15.6	15.3	13.0	13.7	10.7	12.7	13.1	21.0
Lake Rochelle	25.8	31.2	29.3	20.9	28.8	27.4	33.1	27.6	19.7	26.6	26.0	24.5	18.2	13.0	17.4	17.2	13.3	12.6	19.0	14.9	15.8
Lake Roy	18.1	20.0	13.5	14.2	18.4	24.6	19.4	17.1	10.4	11.4	13.9	8.6	6.2	8.7	8.3	12.8	12.5	8.7	20.3	8.0	13.7
Lake Shipp	42.5	43.6	46.9	71.7	83.2	30.0	47.5	38.8	36.4	36.2	32.5	22.7	27.2	26.6	29.6	28.9	27.4	21.5	27.7	30.9	35.2
Lake Silver	26.4		9.8	12.9	7.1	7.6	14.0	10.2	10.4	9.4	8.1	8.0	13.6	12.9	22.2	8.7	10.4	10.5	4.3	7.2	6.5
Lake Smart	27.5	28.7	27.5	25.7	40.1			56.9	50.5	46.9		19.0	23.7	21.3	39.8	19.5	22.4	24.5	24.3	28.0	22.1
Lake Spring	33.1	17.2	22.1	21.6	19.7	22.9	12.6	9.2	9.7	8.0	5.7	12.3	20.7	7.4	11.4	14.8	9.1	9.9	9.2	13.1	11.8
Lake Summit	9.0	13.2	11.7	10.3	9.8	15.1	13.8	10.6	8.1	6.4	5.5	5.0	6.3	6.2	7.3	6.7	5.4	6.4	5.9	3.1	4.3
Lake Winterset	16.0	15.2	11.7	11.1	9.1	10.3	11.0	8.5	5.5	6.2	4.2	3.5	4.7	4.8	9.5	6.6	4.5	4.9	3.0	3.1	4.3
Little Lake Hamilton	13.2	9.1	19.4	13.6	20.4	35.4	26.8		22.6	39.2	26.4	28.3	11.6	17.3	27.5	22.2	15.8	20.6	17.3	20.5	20.9
Middle Lake Hamilton	0.0	13.6	30.6	31.0	27.2	34.4	40.1	44.3	51.7	35.9	31.1	26.3	24.3	22.0	32.2	29.8	22.2	23.1	29.2	24.7	21.3

Table 4-2. Annual geometric mean total nitrogen concentrations from 2003 - 2023 for all study area lakes.

Waterbody	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Lake Blue	2664.8	2692.6	1836.2	2239.6	3561.0	2633.2	3691.4	2508.2	3155.2	2308.2	2633.9	2280.7	2203.4	2515.2	2587.2	2387.2	2332.2	2528.3	3127.2	3242.9	1764.8
Lake Buckeye	1163.8	888.8	944.3	818.3	834.9	870.2	830.4	864.2	773.2	671.7	716.7	744.2	657.7	592.0	618.9	653.9	784.9	571.5	663.2	757.2	1046.8
Lake Cannon	1479.5	1142.8	1061.8	856.1	1137.4	1046.9	1306.1	1206.3	1328.2	1162.7	1355.1	1289.6	931.8	1059.8	922.6	985.7	1143.9	995.0	1046.3	1304.0	848.1
Lake Corinne	1251.1	1289.9	1460.6	1278.6	1464.4	1378.7	1475.8	1455.7	1647.9	1359.1	1364.1	1193.2	1140.2	1056.7	1054.4	970.0	859.7	997.9	1211.1	938.7	1356.4
Lake Daisy	459.9	448.2	598.9	585.8	533.0	531.8	558.7	569.5	532.3	509.5	479.6	459.4	459.6	439.8	524.3	506.4	463.0	435.3	425.2	376.1	377.8
Lake Deer	809.3	980.8	955.2	932.4	1235.3	1425.5	1511.5	1519.0	1129.2	1629.6	1515.7	1079.4	990.6	782.3	850.8	716.1	846.5	821.9	1035.5	774.9	1052.8
Lake Elbert	422.5	409.5	520.7	504.1	424.7	353.7	415.4	409.9	560.0	506.3	397.0	454.2	477.1	476.7	501.3	542.3	616.9	669.2	665.9	777.9	544.2
Lake Eloise	1276.9	1186.3	1480.1	1270.1	1166.6	1134.4	1167.2	1344.5	1648.2	1313.7	1559.7	1574.9	1336.2	1519.4	1012.7	1078.5	883.8	1094.3	1436.5	948.5	1100.2
Lake Fannie	1124.3	1003.1	997.5	863.4	913.5	1326.9	1401.4	1288.3	1727.9	1453.5	1389.2	1114.5	970.3	898.2	870.0	873.5	750.3	899.2	842.5	869.8	841.1
Lake Haines	1357.6	1329.2	1464.2	1458.5	1263.5	1363.9	1398.7	1379.8	1292.2	1506.4	1497.0	1267.2	1258.0	1204.3	1069.2	1232.2	979.9	1192.9	1289.4	1126.9	1483.9
Lake Hamilton	1053.1	1083.0	1113.9	1286.9	1194.5	1244.7	1511.3	1451.0	1426.4	1503.2	1715.9	1524.7	1432.8	1620.9	2329.0	2016.4	1672.6	1994.1	1741.0	2332.5	1689.8
Lake Hartridge	729.4	744.5	608.9	808.0	860.8	991.8	1246.7	1217.5	1415.4	1463.1	1638.1	1659.3	1355.7	1425.4	1251.6	1308.5	1204.6	1297.6	1318.5	1252.3	1172.1
Lake Howard	1550.7	1605.2	1266.3	1521.1	2288.3	1758.0	1652.8	1381.3	1628.9	1597.2	1461.6	1378.6	1267.8	1439.4	1196.6	1134.1	1150.9	1077.2	1336.7	1283.1	1054.2
Lake Idyl	619.0	594.0	649.8	630.0	544.4	530.0	1000.0	557.8	546.8	529.6	619.3	825.2	850.2	1797.4	1446.9	1000.4	1266.9	1254.0	971.5	1079.4	
Lake Idylwild	1080.8	965.7	891.5	937.7	988.8	1203.7	1540.9	1328.4	1288.4	1260.8	1299.4	1243.2	955.9	973.4	1125.5	1022.2	969.6	971.4	998.2	1069.6	927.6
Lake Jessie	1040.2	1027.3	980.0	914.4	916.8	1063.3	1140.5	1197.3	1208.6	1163.6	1134.2	1174.0	927.9	902.1	1153.5	1067.4	1117.5	1021.3	1043.5	1091.1	929.6
Lake Link	660.0	920.0						764.9	1036.5	1043.3	816.5	855.2	829.0	688.3	734.2	862.4	732.8	701.6	1060.7	769.6	834.4
Lake Lulu	1308.6	1087.4	1226.5	1373.9	1587.7	1643.1	1454.7	1495.6	1482.5	1327.1	1164.7	1037.9	1084.7	1219.6	1204.9	1296.0	1047.5	1132.2	1228.9	1051.3	1051.8
Lake Mariana	927.7	976.3	947.5	1036.9	1147.3	1070.5	1042.3	897.1	915.7	878.7	836.4	867.3	891.0	996.5	1078.0	1092.6	939.9	893.2	945.7	1012.2	877.8
Lake Mariana	1271.7	1456.3	1075.1	1030.1	1250.7	1476.0	1648.0	1421.1	1726.8	1456.3	1635.1	1789.2	1441.2	1190.6	1746.0	786.9	1415.4	1509.6	1759.3	1589.7	1110.7
Lake Martha	657.3	500.4	500.1	433.3	479.2	601.1	613.0	664.4	720.1	597.1	539.6	660.5	732.7	716.3	717.2	811.3	630.7	558.9	656.4	545.7	505.5
Lake Maude	748.3	796.1	870.4	559.2	663.1	822.7	984.9	898.3	859.1	836.4	718.1	607.2	694.8	658.5	691.5	559.3	524.9	488.4	512.1	760.5	787.1
Lake May	1549.2	1635.4	1326.4	1640.6	2298.1	1904.8	1756.5	1609.6	1731.9	1688.7	1490.8	1322.8	1163.8	1409.7	1268.1	1190.9	1182.1	1188.7	1291.3	1224.8	1053.5
Lake Mirror	1832.8	1169.5	1161.1	1091.6	1246.5	1234.8	1138.2	1077.6	991.4	900.0	1038.8	756.2	696.5	836.7	897.9	984.4	926.0	856.2	784.3	810.6	1067.1
Lake Ned	634.5	598.7	659.4	632.4	627.3	609.6	661.6	767.8	656.7	808.9	766.2	691.3	639.9	678.0	708.5	691.2	657.5	842.0	820.6	814.4	965.0
Lake Otis	690.0	600.0						970.0	1095.3	985.8	921.0	788.0	819.8	681.1	769.7	769.1	753.1	953.5	750.9	727.3	
Lake Pansy	669.9	705.8	720.3	810.7	1025.4	920.9	855.6	835.3	813.2	1007.9	1233.7	885.8	796.2	788.9	835.8	789.1	835.4	703.4	761.4	739.2	876.3
Lake Rochelle	1434.1	1274.2	1322.9	1084.7	1228.4	1249.6	1603.5	1346.5	1208.9	1306.6	1319.5	1426.7	1134.0	946.5	942.1	934.6	792.8	914.3	1114.2	916.4	1228.1
Lake Roy	1011.4	890.9	812.8	814.9	1009.2	1277.0	1103.3	1142.8	964.3	977.3	1062.2	925.4	754.1	759.1	742.0	950.8	729.9	720.5	1148.5	697.8	1000.3
Lake Shipp	1734.9	1544.2	1415.8	2277.6	2647.7	2082.6	1859.5	1681.1	1808.3	1722.2	1495.5	1228.1	1217.1	1249.6	1274.7	1307.9	1130.9	1210.5	1234.0	1235.8	1433.9
Lake Silver	900.0		689.4	718.6	713.0	603.7	763.1	1098.1	735.7	712.1	595.9	666.8	749.4	805.7	910.1	681.4	624.2	726.7	591.3	591.2	560.3
Lake Smart	1622.9	1374.9	1221.8	1194.7	1654.9			2300.0	2490.1	2141.4	1173.0	1316.8	1122.0	1606.6	1093.4	989.2	1217.0	1320.7	1327.8	1460.9	
Lake Spring	1811.1	793.6	809.7	1052.9	867.8	741.2	707.8	613.3	665.3	580.0	510.6	680.5	721.0	593.7	666.1	712.8	643.3	615.5	742.7	611.5	613.2
Lake Summit	733.6	798.0	764.0	856.8	912.2	849.1	830.5	882.4	931.1	819.9	762.4	800.2	821.6	755.6	767.2	773.4	635.1	726.6	789.1	870.2	758.2
Lake Winterset	995.6	851.0	688.9	666.6	713.8	669.4	760.4	589.7	713.0	739.0	674.7	618.6	654.0	625.2	712.5	609.9	506.2	490.0	499.6	523.1	621.6
Little Lake Hamilton	1371.0	1052.0	1108.0	986.7	1365.8	1786.2	1559.7		1416.7	1891.5	1650.0	1701.6	1191.7	1274.2	1580.4	1433.1	1111.8	1455.5	1384.8	1332.1	1345.0
Middle Lake Hamilton	1761.6	1388.0	1630.4	1426.8	1412.3	2260.0	2030.0	2408.9	2196.3	2183.4	2096.8	1711.7	1442.3	1379.1	1648.2	1582.0	1325.9	1520.2	1563.9	1467.0	1273.3

Table 4-3. Annual geometric mean total phosphorus concentrations from 2003 – 2023 for all study area lakes.

Waterbody	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Lake Blue	80.3	54.0	86.2	95.2	74.2	83.2	91.2	71.2	89.3	60.6	62.4	55.4	65.7	53.1	54.1	55.8	61.0	49.4	51.9	67.0	56.8	74.6	50.5
Lake Buckeye	27.1	32.0	39.9	28.8	42.5	33.3	26.5	24.8	21.6	26.1	20.5	20.9	25.9	26.5	17.8	18.2	21.7	19.2	22.3	18.2	27.1	24.0	40.6
Lake Cannon	27.1	13.4	37.3	36.3	46.0	39.2	34.8	30.4	27.3	33.8	31.0	29.9	30.6	29.0	25.7	30.0	27.6	24.9	26.7	30.0	31.6	39.3	29.3
Lake Conine	48.6	59.2	53.9	48.1	63.2	56.6	66.5	50.9	47.7	52.7	61.5	47.2	47.1	37.4	36.9	37.6	39.1	30.4	33.4	43.7	56.5	66.7	62.7
Lake Daisy	18.8	36.9	29.7	24.0	39.4	38.1	31.2	28.3	30.0	27.2	23.7	26.9	29.2	25.9	22.4	20.4	23.7	22.1	23.7	23.9	25.7	15.4	16.7
Lake Deer	28.1	17.9	22.6	38.1	55.4	42.5	33.7	27.9	30.8	34.7	26.5	36.2	40.5	32.0	20.4	19.2	19.4	17.5	25.3	25.1	36.3	18.7	28.8
Lake Elbert	10.6	13.5	7.1	15.6	28.4	27.0	18.8	16.3	15.2	15.2	20.7	18.4	18.5	21.7	16.4	17.3	16.2	15.5	18.4	21.7	26.7	19.2	17.7
Lake Eloise	37.4	24.4	42.3	41.2	72.5	54.0	38.6	32.8	33.2	30.8	31.7	31.3	32.6	31.9	29.9	38.2	30.7	29.3	27.6	33.5	40.5	23.3	28.2
Lake Fannie	32.5	81.9	50.6	37.1	27.7	37.0	37.9	55.1	62.0	58.4	65.9	53.8	50.4	38.2	28.8	28.1	26.1	23.3	28.3	33.7	33.3	59.2	33.2
Lake Haines	33.6	44.3	52.5	60.0	84.7	58.9	45.9	38.4	38.2	42.3	36.7	39.0	38.4	37.4	36.8	46.6	50.9	42.6	41.8	58.1	84.5	80.3	118.3
Lake Hamilton	80.3	274.7	72.6	110.0	76.8	117.1	95.2	64.5	76.6	59.8	53.7	66.0	58.2	43.3	41.1	38.2	50.1	40.9	26.5	44.6	39.5	50.1	42.8
Lake Hartridge	33.0	0.0	18.4	30.0	33.2	35.8	25.9	27.3	30.6	32.3	30.9	30.1	29.4	28.6	29.8	26.3	23.5	23.0	27.4	30.1	18.1	21.0	21.0
Lake Howard	24.0	6.3	24.0	38.8	48.8	43.8	39.4	38.5	33.3	28.0	28.1	26.4	28.6	25.5	22.2	25.7	29.3	22.6	29.9	29.4	28.1	28.4	28.4
Lake Idyl	62.0		20.0	31.0	34.7	23.0	23.0	17.9	16.7	41.3	25.1	21.4	20.0		26.5	41.6	58.8	96.8	61.0	46.2	59.9	74.1	62.3
Lake Idylwild	49.0	0.0	37.9	46.3	46.4	44.8	40.2	37.3	35.5	35.2	27.7	29.2	30.4	28.7	25.8	31.6	28.9	27.5	27.0	31.7	36.7	30.6	25.5
Lake Jessie	67.3	0.0	36.7	53.0	53.1	48.4	40.5	46.9	38.2	41.7	35.1	35.1	36.0	32.4	30.0	31.0	39.7	34.0	34.4	44.7	46.6	33.7	38.0
Lake Link	40.0		19.0	26.0						27.5	37.5	33.7	29.2	30.7	27.7	23.9	25.0	23.9	27.4	26.9	38.4	27.7	32.3
Lake Lulu	42.0	31.3	42.4	49.0	61.6	58.0	50.5	49.1	44.2	41.6	37.3	33.7	35.1	31.0	30.9	38.0	38.3	34.6	31.7	38.9	45.0	35.0	35.9
Lake Mariani	51.0	56.1	61.4	53.6	66.7	61.1	75.0	74.8	63.2	58.5	45.7	42.3	43.6	35.9	42.0	44.1	75.4	66.8	62.8	64.1	74.4	61.0	72.6
Lake Mariana	46.6	24.2	39.5	68.7	51.7	41.6	31.1	34.8	28.6	32.1	31.1	33.0	32.7	31.4	26.2	27.9	30.9	31.9	28.1	34.6	30.4	31.4	31.6
Lake Martha	9.9	0.0	15.2	20.9	27.3	21.6	16.9	19.3	17.2	23.7	20.3	23.5	27.1	25.2	22.1	24.5	32.7	34.0	24.0	23.9	30.9	16.2	18.6
Lake Maude	35.2	20.1	21.8	19.5	42.1	25.5	22.3	38.3	35.4	38.2	32.3	29.5	27.1	25.4	22.6	20.4	20.8	16.7	22.6	16.2	22.4	48.9	32.2
Lake May	82.9	37.5	58.3	76.0	74.2	77.0	87.0	73.7	74.6	58.2	57.7	53.7	53.9	44.0	34.3	45.7	51.1	42.4	33.0	48.9	57.8	48.0	50.7
Lake Mirror	31.0	14.4	39.2	46.0	45.2	38.5	31.2	29.1	25.5	27.9	24.7	31.0	28.2	23.4	20.9	25.2	24.3	24.3	22.2	30.1	29.5	24.4	38.1
Lake Ned	22.0	23.8	26.5	21.0	24.5	31.1	24.9	20.9	24.0	27.3	22.2	32.1	43.3	29.0	27.9	31.3	31.6	26.4	27.1	29.7	36.4	30.8	34.1
Lake Otis	35.0		21.0	27.0						33.0	30.5	34.8	28.5	27.8	25.6	26.3	25.4	26.4	23.3	30.6	41.2	26.7	27.2
Lake Pansy	27.1	19.8	11.5	32.4	30.3	33.9	30.5	24.2	24.8	23.5	21.8	27.6	37.1	32.0	30.6	29.6	28.9	20.5	29.2	31.9	33.6	30.6	35.7
Lake Rochelle	41.9	40.7	37.1	45.6	56.9	42.0	45.3	42.8	35.5	47.4	33.6	33.0	39.2	35.7	29.6	24.2	27.4	25.1	25.0	30.6	44.2	60.9	57.7
Lake Roy	31.5	11.2	26.9	28.9	37.5	35.5	28.0	25.8	24.4	26.2	20.4	23.3	26.3	28.6	22.2	22.6	19.7	23.2	19.9	25.0	33.7	13.7	16.9
Lake Shipp	52.2	28.7	40.6	44.8	63.1	62.3	54.2	50.5	46.2	40.9	39.3	37.9	37.4	30.7	27.5	33.7	39.0	31.6	32.2	41.2	39.2	34.0	48.4
Lake Silver	30.0	23.0	14.0		32.2	27.9	21.4	18.8	20.4	27.6	22.2	19.5	21.0	23.9	21.7	21.3	25.5	17.5	21.2	19.1	24.6	16.8	19.5
Lake Smart			42.8	46.5	48.6	45.9	51.0			39.0	42.9	38.5		30.6	33.2	32.1	35.9	28.1	29.0	31.9	48.5	56.2	34.1
Lake Spring	33.0	25.1	49.2	36.5	43.3	44.0	30.8	27.2	23.2	22.8	19.9	21.0	26.1	29.1	29.3	22.9	24.8	25.6	23.3	25.7	32.3	24.1	28.5
Lake Summit	28.8	0.0	19.4	27.9	36.7	34.4	27.2	23.0	22.0	26.0	20.6	20.8	22.9	23.4	18.7	20.1	21.8	21.1	19.0	25.3	39.3	18.1	26.0
Lake Winterset	23.0	11.7	18.3	25.5	30.4	28.8	21.9	19.4	16.0	16.9	16.4	19.1	18.5	19.5	15.9	16.9	17.7	17.6	16.2	17.2	19.5	11.1	16.5
Little Lake Hamilton	28.5	44.4	29.9	27.0	41.4	33.9	35.2	46.9	48.0		34.1	44.4	35.0	32.6	24.9	25.7	30.9	29.8	22.0	32.4	35.3	30.0	32.8
Middle Lake Hamilton	167.0	83.5	60.5	53.0	67.4	66.5	61.4	66.0	78.0	76.6	69.5	78.2	62.8	56.8	49.0	48.2	60.7	53.5	33.6	53.4	57.1	54.4	51.0

Table 4-4. Annual geometric mean Secchi depth from 2003 – 2023 for all study area lakes.

Waterbody	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Lake Blue	0.72	1.15	1.10	1.18	1.81	1.66	1.00	1.26	0.98	1.50	1.13	1.86	1.18	1.43	1.42	1.30	1.18	1.22	1.29	1.31	1.01	0.97	1.20
Lake Buckeye	2.77	2.65	3.25	3.26	3.31	5.26	3.97	4.65	5.25	5.81	6.89	9.29	9.11	6.59	8.27	7.06	7.26	8.86	7.00	10.93	8.72	6.26	3.26
Lake Cannon	2.08	1.56	1.67	2.46	2.64	3.49	3.07	2.70	2.29	2.40	2.51	2.65	2.13	2.23	3.89	3.14	3.45	3.14	2.36	3.24	3.00	2.22	2.91
Lake Conine	1.97	1.94	2.70	2.38	2.47	2.56	2.02	2.31	2.08	2.40	2.27	2.46	2.51	2.67	3.47	3.70	3.24	3.96	3.67	3.52	3.11	3.63	3.04
Lake Daisy	4.75	3.71	6.21	5.68	5.80	6.00	5.45	4.50	5.03	7.06	6.46	5.80	5.16	6.47	6.63	6.59	5.00	5.69	5.56	6.40	8.26	10.06	7.60
Lake Deer	2.13	5.25	6.95	5.68	4.56	4.96	2.83	2.37	2.35	2.71	4.48	2.28	2.37	4.11	4.07	5.39	4.83	8.18	6.28	6.03	4.50	7.26	4.68
Lake Elbert	12.96	10.35	11.22	9.19	7.54	9.62	12.05	12.61	11.76	13.73	9.69	9.28	11.09	8.65	8.84	10.70	8.03	8.63	6.53	5.96	6.24	5.09	5.64
Lake Eloise	1.86	1.84	1.90	2.36	2.16	2.31	2.21	2.40	2.85	2.40	2.16	2.53	2.01	2.06	2.34	2.13	2.88	2.61	3.11	2.86	2.09	3.15	2.71
Lake Fannie	2.18	1.04	1.87	2.75	3.43	3.11	2.51	1.38	1.38	1.64	1.31	1.68	2.07	2.29	3.40	3.51	3.62	3.75	3.59	4.16	2.57	3.22	2.73
Lake Haines	2.10	1.91	2.13	2.51	2.10	2.46	2.29	2.31	2.43	2.78	3.05	2.19	2.32	2.72	2.92	3.01	3.32	2.94	3.07	2.90	2.95	2.60	2.07
Lake Hamilton	4.27	3.48	2.21	2.30	3.21	1.78	2.30	2.30	1.70	1.74	2.11	1.75	1.83	2.16	2.18	2.14	1.54	1.74	2.05	1.91	1.63	1.38	1.67
Lake Hartridge	3.88	3.77	4.25	4.16	4.86	3.85	3.72	3.61	2.97	2.74	2.35	2.25	1.91	1.86	2.36	2.16	2.52	2.34	2.47	2.26	2.55	1.98	2.30
Lake Howard	1.37	1.72	1.64	1.80	2.12	1.96	1.23	1.64	1.78	2.66	2.14	1.87	1.92	1.95	2.25	1.93	2.47	2.66	2.39	2.13	2.09	1.82	2.55
Lake Idyl	2.30		3.94	5.91	6.89	6.76	6.50	9.34	4.40	3.94	8.80	7.85		7.24	5.00	5.96	2.27	2.68	3.51	2.62	2.65	4.35	3.51
Lake Idylwild	1.90	2.38	2.05	2.60	3.07	2.92	2.60	2.36	2.03	2.32	2.53	2.47	2.16	2.48	3.60	3.70	2.77	2.93	3.23	3.47	3.25	2.78	3.37
Lake Jessie	1.83	2.43	2.13	2.62	2.76	2.65	2.65	2.58	2.36	2.39	2.59	2.42	2.50	2.47	3.45	3.29	2.35	2.76	2.44	2.68	2.55	2.32	2.62
Lake Link	1.64		4.92	4.27						7.55	5.08	3.52	3.80	4.73	4.92	5.17	3.70	3.68	4.51	4.61	3.37	3.80	3.67
Lake Lulu	1.97	1.69	1.80	1.86	2.19	1.80	1.68	1.75	1.90	2.07	2.15	2.34	2.31	2.98	2.92	2.42	2.19	2.35	2.55	2.65	2.39	2.59	2.52
Lake Marlam	1.39	0.96	1.28	1.51	1.88	1.82	0.98	2.18	2.08	2.25	2.90	2.84	2.94	2.91	2.00	2.16	0.99	1.72	1.51	2.28	1.67	2.24	1.41
Lake Mariana	1.94	2.46	2.43	2.12	2.53	2.63	2.47	2.18	1.95	2.53	1.95	2.24	1.83	1.72	2.11	2.84	1.65	2.03	1.82	2.03	1.67	1.77	2.30
Lake Marthia	10.38	7.55	9.65	9.68	10.12	13.06	11.40	7.24	7.85	6.29	5.09	5.30	5.96	6.59	5.32	4.67	4.55	4.87	5.80	6.19	5.35	5.40	5.90
Lake Maude	2.30	4.18	5.28	3.81	5.04	9.48	8.49	5.46	3.03	3.85	4.08	4.72	6.12	7.40	6.44	6.58	6.99	10.45	10.98	10.36	10.33	6.42	3.73
Lake May	1.15	1.37	1.56	1.39	2.03	1.64	1.18	1.42	1.39	2.04	1.79	1.79	1.91	2.43	2.92	2.05	2.19	2.53	2.24	2.57	2.25	2.11	1.87
Lake Mirror	2.07	1.39	1.61	2.04	2.64	3.12	2.74	2.47	2.97	3.49	4.10	4.92	3.33	5.25	6.43	4.24	3.67	3.48	3.58	4.11	4.30	4.13	2.60
Lake Ned	3.48	9.35	6.48	7.41	5.70	7.75	7.29	6.63	5.61	6.33	7.69	4.10	3.95	4.17	3.97	3.59	3.79	3.85	4.00	3.71	3.57	3.40	2.66
Lake Otis	1.97		4.92	5.25					3.94	3.38	2.62	3.03	3.03	4.07	4.00	5.17	4.41	3.85	4.28	3.69	3.30	4.37	4.09
Lake Pansy	2.60	2.84	4.69	4.18	5.09	3.87	2.77	3.29	3.43	4.45	4.61	3.51	2.61	3.85	4.00	3.79	3.27	4.33	3.83	4.22	3.81	3.68	3.25
Lake Rochelle	1.97	1.94	2.11	2.29	2.47	3.17	2.42	2.23	2.15	2.62	3.23	2.32	2.51	2.47	3.69	4.12	3.88	3.96	4.00	2.74	3.66	3.52	1.94
Lake Roy	1.88	2.32	2.77	3.88	4.60	4.77	3.39	2.58	3.15	3.72	5.39	4.17	3.24	4.86	6.72	5.84	6.02	4.55	4.84	5.54	3.55	5.08	3.59
Lake Shipp	0.93	1.28	1.36	1.62	1.80	1.39	1.15	1.80	1.59	2.02	1.68	1.74	1.80	2.29	2.20	2.12	2.24	2.10	2.34	2.42	2.39	2.07	2.11
Lake Silver	4.92	4.27	3.61		6.80	6.74	7.53	7.09	3.82	4.33	5.56	6.31	7.01	6.44	4.26	4.20	3.40	6.27	5.66	5.17	7.82	7.20	6.09
Lake Smart			2.04	2.27	2.86	2.76	1.67		1.64	1.66	1.73			2.79	2.80	2.95	2.17	3.38	2.86	2.76	2.83	2.06	2.78
Lake Spring	2.62	2.95	2.14	4.12	3.44	3.53	3.75	4.24	5.31	8.45	6.90	6.89	7.76	5.04	5.39	6.56	5.77	5.40	6.67	6.02	5.87	5.62	5.64
Lake Summit	2.70	2.43	5.32	3.59	5.10	6.15	5.32	4.31	4.59	5.98	5.75	7.22	7.27	7.61	7.34	8.22	6.38	7.56	7.35	5.93	6.96	8.02	6.70
Lake Winterset	3.28	2.20	3.31	3.36	4.59	5.43	5.88	5.03	5.35	6.88	8.05	8.97	8.98	10.57	10.92	10.19	5.72	7.34	9.09	8.44	12.39	13.75	8.39
Little Lake Hamilton	2.70	2.13	2.74	4.59	3.53	4.29	2.66	1.99	2.46		2.55	1.80	2.62	2.16	3.81	3.12	2.23	2.88	3.25	2.91	2.96	2.77	2.48
Middle Lake Hamilton	1.15	2.41	1.84	2.46	2.44	2.57	2.12	1.97	1.64	1.73	1.86	1.80	1.92	2.27	2.68	2.86	2.14	2.40	2.83	2.91	2.67	2.58	2.53

Linear Regression Statistics

Table 4-5. Trendline statistics for linear regressions of chl-a, TN, TP, and Secchi depth from 2003 - 2023. Stats include regression direction (+/-), R-squared value, and p-value.

Waterbody	Chl-a			Secchi			TN			TP		
	Dir.	R ²	p-value	Dir.	R ²	p-value	Dir.	R ²	p-value	Dir.	R ²	p-value
Lake Blue	-	0.1220	0.121	-	0.0626	0.274	-	0.0114	0.646	-	0.5033	0.000
Lake Buckeye	-	0.2590	0.018	+	0.3240	0.007	-	0.2646	0.017	-	0.1392	0.096
Lake Cannon	-	0.0600	0.285	+	0.0727	0.237	-	0.1028	0.156	-	0.2585	0.019
Lake Conine	-	0.5306	0.000	+	0.5614	0.000	-	0.3683	0.004	-	0.0570	0.296
Lake Daisy	-	0.4717	0.001	+	0.2817	0.013	-	0.4365	0.001	-	0.5550	0.000
Lake Deer	-	0.1583	0.074	+	0.0980	0.167	-	0.0980	0.167	-	0.2561	0.019
Lake Elbert	+	0.5441	0.000	-	0.4767	0.001	+	0.4982	0.000	+	0.0216	0.525
Lake Eloise	-	0.2202	0.032	+	0.2786	0.014	-	0.0879	0.192	-	0.3429	0.005
Lake Fannie	-	0.2619	0.018	+	0.2133	0.035	-	0.1693	0.064	-	0.0871	0.194
Lake Haines	-	0.2403	0.024	+	0.2359	0.026	-	0.2217	0.031	+	0.1128	0.137
Lake Hamilton	+	0.7413	0.000	-	0.3447	0.005	+	0.6945	0.000	-	0.6424	0.000
Lake Hartridge	+	0.3969	0.002	-	0.6366	0.000	+	0.3799	0.003	-	0.1612	0.071
Lake Howard	-	0.3174	0.008	+	0.2663	0.017	-	0.4299	0.001	-	0.3317	0.006
Lake Idyl	+	0.3220	0.009	-	0.3031	0.012	+	0.4586	0.001	+	0.5321	0.000
Lake Idylwild	-	0.2573	0.019	+	0.3307	0.006	-	0.0337	0.425	-	0.5411	0.000
Lake Jessie	+	0.0949	0.174	+	0.0169	0.574	+	0.0021	0.845	-	0.1964	0.044
Lake Link	+	0.1265	0.176	-	0.1676	0.115	-	0.0009	0.908	+	0.0945	0.247
Lake Lulu	-	0.4611	0.001	+	0.5382	0.000	-	0.2912	0.012	-	0.4221	0.001
Lake Mariam	+	0.3139	0.008	+	0.0028	0.819	-	0.0329	0.431	+	0.0078	0.702
Lake Mariana	+	0.0393	0.389	-	0.2396	0.024	+	0.0261	0.484	-	0.3301	0.006
Lake Martha	+	0.4616	0.001	-	0.5599	0.000	+	0.0877	0.192	+	0.1170	0.128
Lake Maude	-	0.2005	0.042	+	0.1670	0.065	-	0.2083	0.037	-	0.0077	0.705
Lake May	-	0.4420	0.001	+	0.4203	0.002	-	0.4921	0.000	-	0.5186	0.000
Lake Mirror	-	0.4059	0.002	+	0.2449	0.023	-	0.4840	0.001	-	0.2965	0.011
Lake Ned	+	0.5385	0.000	-	0.7392	0.000	+	0.5041	0.000	+	0.2639	0.017
Lake Otis	+	0.0221	0.583	-	0.0589	0.365	-	0.0027	0.848	+	0.0409	0.452
Lake Pansy	+	0.2538	0.024	-	0.0554	0.318	-	0.0001	0.964	+	0.1311	0.117
Lake Rochelle	-	0.6445	0.000	+	0.2646	0.017	-	0.3857	0.003	-	0.0133	0.618
Lake Roy	-	0.2533	0.020	+	0.1581	0.074	-	0.0917	0.182	-	0.3446	0.005
Lake Shipp	-	0.3811	0.003	+	0.6622	0.000	-	0.4388	0.001	-	0.3055	0.009
Lake Silver	-	0.1395	0.105	+	0.0089	0.693	-	0.1492	0.093	-	0.0554	0.318
Lake Smart	-	0.1039	0.192	+	0.1509	0.111	-	0.0791	0.258	-	0.1420	0.123
Lake Spring	-	0.3854	0.003	+	0.2771	0.014	-	0.3123	0.008	-	0.3121	0.009
Lake Summit	-	0.5977	0.000	+	0.5066	0.000	-	0.1026	0.157	-	0.0379	0.398
Lake Winterset	-	0.7033	0.000	+	0.6118	0.000	-	0.5987	0.000	-	0.4080	0.002
Little Lake Hamilton	+	0.0068	0.729	-	0.0681	0.266	+	0.0144	0.614	-	0.1180	0.138
Middle Lake Hamilton	+	0.0005	0.921	+	0.2716	0.015	-	0.1128	0.137	-	0.2685	0.016

Table 4-6. Trend statistics for linear regressions of lake surface levels against chl-a, TN, TP, and Secchi depth from 2000 - 2021. Stats include regression direction (+/-), R-squared value, and p-value.

Waterbody	Chl-a			Secchi			TN			TP		
	Dir.	R2	p-value	Dir.	R2	p-value	Dir.	R2	p-value	Dir.	R2	p-value
Lake Blue	-	0.006	0.740	+	0.002	0.830	-	0.081	0.200	+	0.010	0.660
Lake Buckeye	-	0.020	0.540	+	0.171	0.056	-	0.041	0.370	+	0.010	0.676
Lake Cannon	-	0.610	0.002	+	0.386	0.023	-	0.550	0.004	-	0.151	0.189
Lake Conine	-	0.350	0.004	+	0.533	0.000	-	0.314	0.007	-	0.102	0.146
Lake Daisy	-	0.053	0.315	+	0.054	0.310	-	0.009	0.684	+	0.011	0.653
Lake Deer	-	0.124	0.107	+	0.107	0.138	-	0.060	0.270	+	0.041	0.368
Lake Elbert	+	0.315	0.007	-	0.466	0.000	+	0.289	0.010	+	0.193	0.041
Lake Eloise	-	0.024	0.612	+	0.006	0.800	-	0.073	0.371	-	0.013	0.710
Lake Fannie	-	0.588	0.000	+	0.809	0.000	-	0.724	0.000	-	0.868	0.000
Lake Haines	-	0.003	0.794	+	0.263	0.015	-	0.244	0.020	+	0.233	0.023
Lake Hamilton	-	0.007	0.734	+	0.094	0.215	+	0.002	0.853	-	0.012	0.661
Lake Hartridge	-	0.039	0.517	-	0.044	0.491	-	0.040	0.512	-	0.346	0.035
Lake Howard	-	0.235	0.022	+	0.191	0.042	-	0.449	0.001	-	0.024	0.489
Lake Idyl	-	0.080	0.227	+	0.053	0.331	-	0.049	0.350	-	0.003	0.819
Lake Idylwild	-	0.681	0.001	+	0.855	0.000	-	0.915	0.000	-	0.097	0.301
Lake Jessie	-	0.379	0.025	+	0.353	0.032	-	0.553	0.004	-	0.015	0.695
Lake Link	-	0.172	0.110	+	0.097	0.240	-	0.524	0.002	-	0.415	0.007
Lake Lulu	-	0.138	0.212	+	0.413	0.018	-	0.453	0.012	-	0.074	0.370
Lake Mariam	+	0.001	0.906	+	0.016	0.575	-	0.114	0.124	-	0.044	0.352
Lake Mariana	-	0.034	0.548	-	0.002	0.873	-	0.137	0.213	-	0.004	0.833
Lake Martha	+	0.219	0.032	-	0.031	0.431	+	0.046	0.340	+	0.172	0.061
Lake Maude	-	0.091	0.172	+	0.157	0.068	-	0.248	0.018	-	0.112	0.128
Lake May	-	0.762	0.000	+	0.622	0.001	-	0.794	0.000	-	0.616	0.002
Lake Mirror	-	0.135	0.217	+	0.157	0.180	-	0.544	0.004	-	0.113	0.262
Lake Ned	+	0.202	0.036	+	0.013	0.615	-	0.171	0.056	+	0.040	0.374
Lake Otis	-	0.341	0.018	+	0.398	0.009	-	0.570	0.001	-	0.129	0.172
Lake Pansy	+	0.017	0.569	+	0.274	0.012	-	0.144	0.081	+	0.011	0.636
Lake Rochelle	-	0.334	0.005	+	0.328	0.005	-	0.232	0.023	-	0.096	0.161
Lake Roy	-	0.157	0.180	+	0.359	0.030	-	0.414	0.018	-	0.001	0.941
Lake Shipp	-	0.207	0.034	+	0.318	0.006	-	0.521	0.000	-	0.111	0.130
Lake Silver	+	0.067	0.256	-	0.046	0.350	-	0.000	0.955	+	0.000	0.977
Lake Smart	-	0.866	0.000	+	0.800	0.000	-	0.869	0.000	-	0.216	0.150
Lake Summit	-	0.361	0.030	+	0.331	0.040	-	0.378	0.025	+	0.015	0.692
Lake Winterset	-	0.255	0.078	+	0.272	0.068	-	0.440	0.014	-	0.001	0.943
Little Lake Hamilton	-	0.537	0.001	+	0.519	0.001	-	0.448	0.003	-	0.522	0.001
Middle Lake Hamilton	-	0.541	0.001	+	0.661	0.000	-	0.540	0.001	-	0.486	0.001
Spring Lake	+	0.118	0.251	-	0.176	0.153	+	0.110	0.268	+	0.233	0.095

Table 4-7. Stormwater pollutant loading rates for all study area lakes.

Waterbody	Drainage Basin Area (Acres)	Total TN Load	Total TP Load	TN Load/Acre	TP Load/Acre
Lake Blue	183.72	871.51	154.23	4.74	0.84
Lake Buckeye	305.78	867.10	154.76	2.84	0.51
Lake Cannon	1039.11	3863.09	637.80	3.72	0.61
Lake Conine	796.43	2836.20	474.36	3.56	0.60
Lake Daisy	356.67	1717.66	382.25	4.82	1.07
Lake Deer	377.43	1451.11	261.19	3.84	0.69
Lake Elbert	605.00	2365.80	385.07	3.91	0.64
Lake Eloise	1981.43	3875.24	665.40	1.96	0.34
Lake Fannie	2208.68	4133.27	717.67	1.87	0.32
Lake Haines	2317.85	5701.02	1055.90	2.46	0.46
Lake Hamilton	4177.60	6701.70	1167.79	1.60	0.28
Lake Hartridge	920.07	2658.28	458.94	2.89	0.50
Lake Henry	2409.92	6902.81	1379.68	2.86	0.57
Lake Howard	1869.01	6321.28	1097.50	3.38	0.59
Lake Idyl	230.98	934.96	154.55	4.05	0.67
Lake Idylwild	225.44	669.14	121.61	2.97	0.54
Lake Jessie	973.41	3871.23	652.31	3.98	0.67
Lake Link	63.11	197.24	31.74	3.13	0.50
Lake Lulu	1006.48	2791.48	483.02	2.77	0.48
Lake Mariam	622.11	1609.45	274.81	2.59	0.44
Lake Mariana	1935.67	6530.83	1160.57	3.37	0.60
Lake Martha	307.50	1217.07	199.11	3.96	0.65
Lake Maude	385.75	1900.55	320.03	4.93	0.83
Lake May	353.57	1732.69	292.88	4.90	0.83
Lake Mirror	277.95	749.60	120.88	2.70	0.43
Lake Ned	256.97	1002.90	202.66	3.90	0.79
Lake Otis	586.90	2291.05	372.60	3.90	0.63
Lake Pansy	243.82	880.73	111.22	3.61	0.46
Lake Rochelle	1669.70	3002.65	522.22	1.80	0.31
Lake Roy	353.73	1448.34	241.53	4.09	0.68
Lake Shipp	910.64	3614.35	654.69	3.97	0.72
Lake Silver	164.17	633.20	106.11	3.86	0.65
Lake Smart	642.59	1673.37	348.90	2.60	0.54
Lake Spring	120.18	520.71	90.81	4.33	0.76
Lake Summit	166.52	513.32	82.73	3.08	0.50
Lake Winterset	1074.54	2258.84	407.59	2.10	0.38
Little Lake Hamilton	1015.97	1472.72	198.04	1.45	0.19
Middle Lake Hamilton	1539.88	11621.29	1072.03	7.55	0.70

Table 4-8. Count and density of known OSTD systems within each lake drainage basin.

Waterbody	OSTD Count	Density (OSTD/acre)
Lake Blue	0	0.00
Lake Buckeye	42	0.18
Lake Cannon	338	0.49
Lake Conine	40	0.07
Lake Daisy	33	0.15
Lake Deer	48	0.18
Lake Elbert	2	0.00
Lake Eloise	186	0.23
Lake Fannie	33	0.02
Lake Haines	15	0.01
Lake Hamilton	62	0.03
Lake Hartridge	65	0.14
Lake Howard	30	0.02
Lake Idyl	6	0.03
Lake Idylwild	33	0.25
Lake Jessie	111	0.14
Lake Link	15	0.23
Lake Lulu	42	0.06
Lake Mariam	132	0.32
Lake Mariana	0	0.00
Lake Martha	1	0.00
Lake Maude	0	0.00
Lake May	1	0.00
Lake Mirror	0	0.00
Lake Otis	66	0.15
Lake Pansy	0	0.00
Lake Rochelle	38	0.03
Lake Roy	125	0.44
Lake Shipp	57	0.09
Lake Silver	0	0.00
Lake Smart	0	0.00
Lake Summit	52	0.52
Lake Winterset	71	0.14
Little Lake Hamilton	0	0.00
Middle Lake Hamilton	4	0.02
Ned Lake	53	0.29
Spring Lake	0	0.00

Table 4-9. List of aquatic plant species detected in Winter Haven area lakes.

Common Name	Scientific Name	Common Name	Scientific Name
Alligator Weed	Alternanthera philoxeroides	Red Maple	Acer rubrum
American Lotus	Nelumbo lutea	Redtop Panicum	Panicum rigidulum
Bald Cypress Pond Cypress	Taxodium spp.	Road Grass	Eleocharis baldwinii
Banana Lily	Nymphoides aquatica	Rosy Camphorweed	Pluchea rosea
Bladderwort	Utricularia spp.	Rush Fuirena	Fuirena scirpoidea
Brazilian Pepper	Schinus terebinthifolius	Sacred Lotus	Nelumbo nucifera
Bulrushes	Scirpus spp.	Sawgrass	Cladium jamaicense
Burhead Sedge	Oxycaryum cubense	Soft Rush	Juncus effusus
Buttonbush	Cephalanthus occidentalis	Southern naiad	Najas guadalupensis
Carolina Willow	Salix caroliniana	Spatterdock	Nuphar advena
Cattail	Typha spp.	Stonewort Nitella	Nitella spp.
Climbing Hempweed	Mikania scandens	Swamp Bay	Persea palustris
Coontail	Ceratophyllum demersum	Sweetbay Magnolia	Magnolia virginiana
Duck Potato	Sagittaria lancifolia	Torpedograss	Panicum repens
Duckweed	Lemna spp.	Water Hyacinth	Eichhornia crassipes
Eel Grass	Vallisneria americana	Water Lettuce	Pistia stratiotes
Egyptian Paspalidium	Paspalidium geminatum	Water Pennywort	Hydrocotyle spp.
Elodea Waterweed	Egeria densa	Water Spangles	Salvinia minima
Filamentous Algae	Lyngbya species	Wild Taro	Colocasia esculenta
Fire Flag	Thalia geniculata		-
Fragrant Water Lily	Nymphaea odorata		-
Hairy Maiden Fern	Thelypteris hispida		-
Hydrilla	Hydrilla verticillata		-
Illinois Pondweed	Potamogeton illinoensis		-
Knotted Spikerush	Eleocharis interstincta		-
Knotweed	Polygonum spp.		-
Maidencane	Panicum hemitomon		-
Melaleuca	Melaleuca quinquenervia		-
Muskgrass	Chara spp.		-
Papyrus	Cyperus papyrus		-
Para grass	Urochloa mutica		-
Parrot Feather	Myriophyllum aquaticum		-
Pickeralweed	Pontederia cordata		-
Primrose Willow	Ludwigia spp.		-

Table 4-10. Percent area coverage values from 2018 – 2023 for all study area lakes.

Waterbody	2018	2019	2020	2021	2022	2023
Lake Blue	19.5	6.5		17.6	46.9	78.9
Lake Buckeye	98	99.7	99.1	98.9	98.8	20.1
Lake Cannon	32.4	34.9	33.6	37.1	31.8	30.5
Lake Conine	29	38.8	36.5	24.2	25.7	23.1
Lake Daisy	3.4	14.3	9	21.7	31.1	
Lake Deer	83.6	91	57.6	80.3	71.9	86.6
Lake Elbert	59.7	58.9	54.9	48.4	46.4	23.3
Lake Eloise	12.2	17.1	36.7	29	17.6	17
Lake Fannie	26.9	26.2	13.3	21.4	26.6	21
Lake Haines	24.1	26	34.7	10.4	7.5	31
Lake Hamilton	7.7	8.8	9.5	9.6	10.2	13.5
Lake Hartridge	35.6	39.7	63.1	36.4	37.9	42.4
Lake Howard	28.35	29	30	39.2	27.1	27.6
Lake Idyl	52.9	3.6	35.2	52.9	53	50.5
Lake Idylwild	49.1	52.5	54	66.7	58.9	60.4
Lake Jessie	35.7	51.6	36.1	34.7	43.5	
Lake Link	53.5		47.7	26.5	24.6	34.9
Lake Lulu	37.5	40	38.2	38.9	45.7	46.3
Lake Mariam	5.8	20	13.5	45.7	34.9	96.9
Lake Mariana	22.4	26.1	27.3	24.5	27.8	31.4
Lake Martha	0.7	3.1	4.1	4.3	7.8	7.3
Lake Maude	96.2	99.1	99.1	96.3	71.6	79.3
Lake May	56	69.7	71	78	63.2	76.7
Lake Mirror	42.9	43.6	39.9	41.7	49.3	48.4
Lake Ned	7	13.6	4.8	10.1	16	27.5
Lake Otis	21.2	23.3	27.7	11.4	19.6	31.9
Lake Pansy	20.4	45	24.1	31	15.1	20.6
Lake Rochelle	34.3	33.9	34.1	31.5	43.8	27
Lake Roy	53.5	17	29.9	32.9	34.8	43.3
Lake Shipp	49.3	52.3	56.4	50.7	51.8	50.6
Lake Silver	1	7.3	2.4	1.7	2.3	5
Lake Smart	13.1	30.6	16.6	28.9	61.9	28.5
Lake Spring	56.7	57.8	60.4	53.9	56.3	56.9
Lake Summit	59.5	48.4	61.2	54.8	63	54.3
Lake Winterset	28.1	36.3	37.5	44.7	56	44.7
Little Lake Hamilton	18.2	17.4	15.9	14.9	21.3	18.6
Middle Lake Hamilton	12.3	19	12.2	8.6	21.8	61.2

Table 4-11. Invasive species percentage values from 2018 to 2023 for all study area lakes.

Waterbody	2018	2019	2020	2021	2022	2023
Lake Blue	0	0	0	0	0	0
Lake Buckeye	14.18	11.32	13.14	6.8	2.98	2.22
Lake Cannon	1.89	1.47	3.1	7.04	1.17	6.98
Lake Conine	13.29	25.24	16.87	10.84	6.02	6.1
Lake Daisy	0	0	0.94	0.65	0.66	5.1
Lake Deer	8.13	26.33	15.33	28.39	19.05	17.78
Lake Elbert	9.31	11.83	15.48	20.22	38.32	1.75
Lake Eloise	1.26	2.3	1.61	1.03	1.13	0.42
Lake Fannie	16.41	17.79	11.81	14.37	16.97	13.86
Lake Haines	24.07	28.99	25.76	4.29	5.19	4.76
Lake Hamilton	1.39	0.74	3.73	3.6	0	5.83
Lake Hartridge	0	1.81	0.43	0	0.97	0
Lake Howard	0.96	0	0	0	0	0.52
Lake Idyl	4.35	16.67	13.33	24	6.06	15.38
Lake Idylwild	1.76	3.76	3.14	5.94	3.65	7.37
Lake Jessie	1.27	6.33	4.65	11.84	2.55	5.14
Lake Link	10.71	0	0	5.66	5.45	2
Lake Lulu	4.07	1.55	0	1.63	3.55	3.12
Lake Mariam	30.65	23.6	3.03	0	2	11.32
Lake Mariana	1.63	0	0	0.57	0	7.37
Lake Martha	0	2.33	0	0	0	0
Lake Maude	2.86	4.38	2.23	5.69	1.63	2.88
Lake May	7.37	11.32	11.32	13.83	18.33	17.24
Lake Mirror	0.65	3.36	3.68	1.23	7.14	2.99
Lake Ned	5.81	5.48	0	0	1.27	0
Lake Otis	3.96	11.16	0	1.18	2.29	2.53
Lake Pansy	13.16	12.5	16	21.28	6.06	1.64
Lake Rochelle	8	22.5	20.11	15.48	14.71	7.37
Lake Roy	17.69	4.76	1.08	7.81	1.55	4.62
Lake Shipp	3.68	6.25	6.63	1.8	2.33	1.67
Lake Silver	0	0	0	0	0	0
Lake Smart	1.33	12.9	2.25	3.16	3.39	4.44
Lake Spring	17.81	18.64	17.65	11.86	5.8	22.5
Lake Summit	4.4	3.45	4.21	2.86	4.96	3.7
Lake Winterset	3.09	7.93	6.49	13.82	17.55	7.89
Little Lake Hamilton	1.27	0	1.86	3.43	0	0
Middle Lake Hamilton	3.85	3.29	0	2.61	6.34	25

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