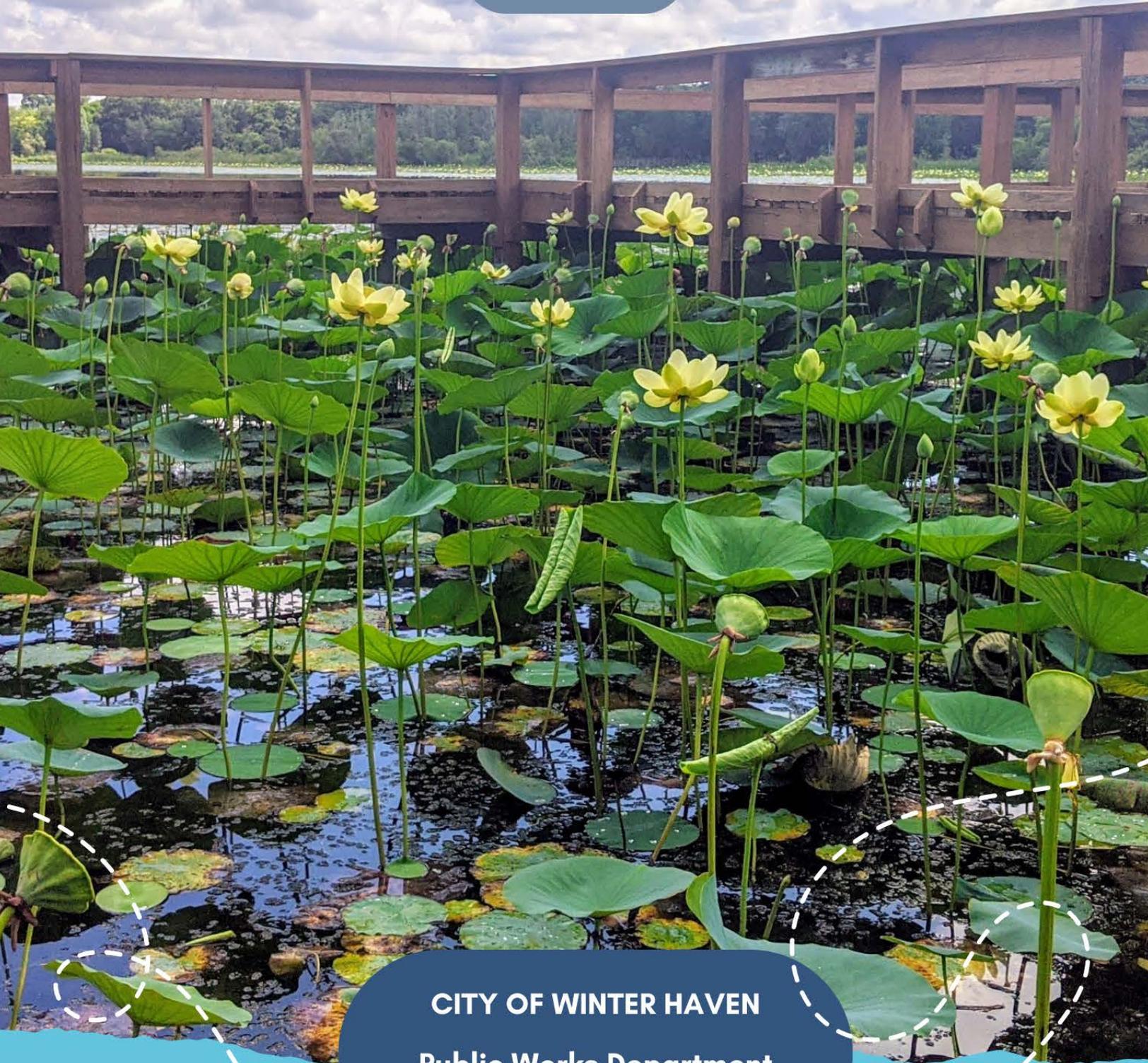# Winter Haven Lakes Report
Presented by the Lakes Advisory Committee

2022

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, Winter Haven Natural Resources staff 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 265 - 266. 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. A review of the 2022 Lake Health Index values showed that 67% (or 25) of the lakes met or exceeded their score from the previous year; while 32% (or 12) of the lakes exhibited decreasing scores. This indicates overall improvement in lake health for Winter Haven's waterbodies.

Water Quality: In 2022, 51% of lakes met all regulatory water quality targets—an increase from 48% in 2021. Of the 18 lakes that are currently impaired, 55% 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 64 inches of rainfall in 2022 which is well above the 51.6 inch average. As a result, many lakes approached record-high levels. For nearly 60% of these lakes, an increase in level correlates directly with an improvement in at least one primary water quality parameter. As a result, maintaining higher water levels should result in overall lake health improvement for the majority of lakes in the area.

Aquatic Biology: Comparing biological criteria scores from 2018 to 2022 indicates that vegetation abundance and diversity increased considerably from the previous year. Additionally, the presence of invasive species declined in the Winter Haven lakes as a whole. It can be inferred that aquatic plant management efforts are successful at removing invasive species while promoting robust and diverse vegetation 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 2022 that are listed in this summary. The initial construction phase of the Lake Conine Wetland Restoration project was completed in 2020 (pp. 67-68). In 2022 the City was awarded legislative funding to construct the recreational amenities phase of the project. Construction of these improvements is slated to begin in late 2023.

In order to more effectively manage City lakeshores and nature parks, in 2022 Natural Resources staff acquired the necessary certifications to treat and remove nuisance aquatic vegetation (pp. 55-56). Managing these areas in-house allows for greater flexibility and cost effectiveness.

Natural Resources staff continue to develop its outreach and education programming in 2022 (pp. 49-50, 60-61, 71-72). These efforts include expansion of the number of guided kayak tour offerings to the public, public outreach to community groups, and the re-establishment of a science and natural resources based curriculum for the local Montessori school. Staff are excited to provide these services in an effort to improve public understanding and engagement on issues related to our lakes.

Those who are familiar with previous versions of this report may notice some updates to the formatting and content. Most of the changes were made to the Data Presentation & Analysis section—specifically, data and management info has been broken down on a lake-by-lake basis. While the overall length of the report has increased, this change should streamline the location of lake-specific information. Like in previous report years, an interactive Story Map version of the report can be found online via the following web address: www.tinyurl.com/wh-fl-lakesreport-app

Finally, 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,

Devon Moore

City of Winter Haven
Natural Resources Division
Senior Environmental Scientist

ANNUAL LAKES REPORT

How to navigate this document

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- What is the purpose of the report?
- What lakes are being studied?
- How are the lakes being evaluated?

#2 | Management Strategies

- What management practices does the City utilize?
- What are the benefits of these efforts?
- What are the goals and success criteria?

#3 | Data Presentation & Analysis

- What is the health of a specific lake or lakes?
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- How do the lakes compare?

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#1 | Introduction

START

1.1 Purpose

The lakes of the greater Winter Haven area are considered some of its most important natural assets. The utilization of these waterbodies by visitors and residents alike has cemented their role as economic and social 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.

The purpose of this report, therefore, is to present a more comprehensive outlook on the characteristics that comprise lake health as well as provide 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 individual characteristics. Using methods and techniques that are technically sound, yet presented in a manner that is accessible ensures that the information contained herein can be understood and applied by the scientific community as well as the general public.

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

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 indicates 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).

There are numerous waterbodies in the municipal limits of Winter Haven and surrounding unincorporated Polk County. For the purposes of this study, the 37 lakes chosen for analysis were selected based on the following criteria:

- *Possess improved public access (i.e. boat ramp or navigable entry point)*
- *Located within or adjacent to City limits; or discharge directly to a waterbody within City limits*
- *Discharge surface water to the Peace Creek; either directly or via a series of conveyances*
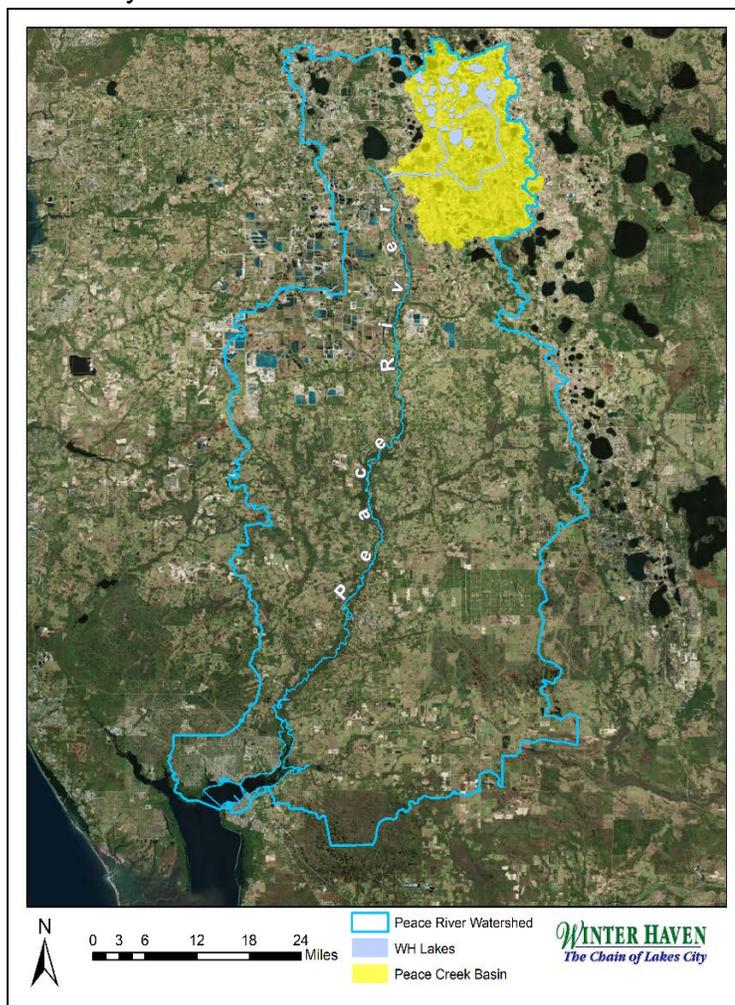- *Possess a sufficient record of water quality and/or hydrologic data*

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

The lakes discussed in this report have been grouped based on their geographic location, flow pathways, or other common characteristics such as shared connections to other waterbodies. However, it is noteworthy that each lake's health and management goals are considered separately. The five lake groups have been designated the following: North Chain of Lakes, North Central Lakes, South Chain of Lakes, South Central Lakes, & Outlying Lakes.

The primary means by which these lakes are categorized is based on how they move water to the Peace River via the numerous canals, ditches, and pipes in the area. The movement of water through these connections is determined by water control structures put in place primarily to conserve water in 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. These active control structures allow the managing authority to adjust the desired surface level of the upstream waterbody, whereas passive structures include weirs or pipes set at the lake's maximum desired water level—only allowing for the overflow of water above that set level. The Southwest Florida Water Management District (SWFWMD) and Lake Region Lakes Management District (LRLMD) maintain the majority of structures in the Winter Haven area, however, there exist a couple of passive structures managed by Polk County (Table 1-1).

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

Table 1-1. Control structure elevations, contributing waterbodies, and managing agencies of study area lakes.
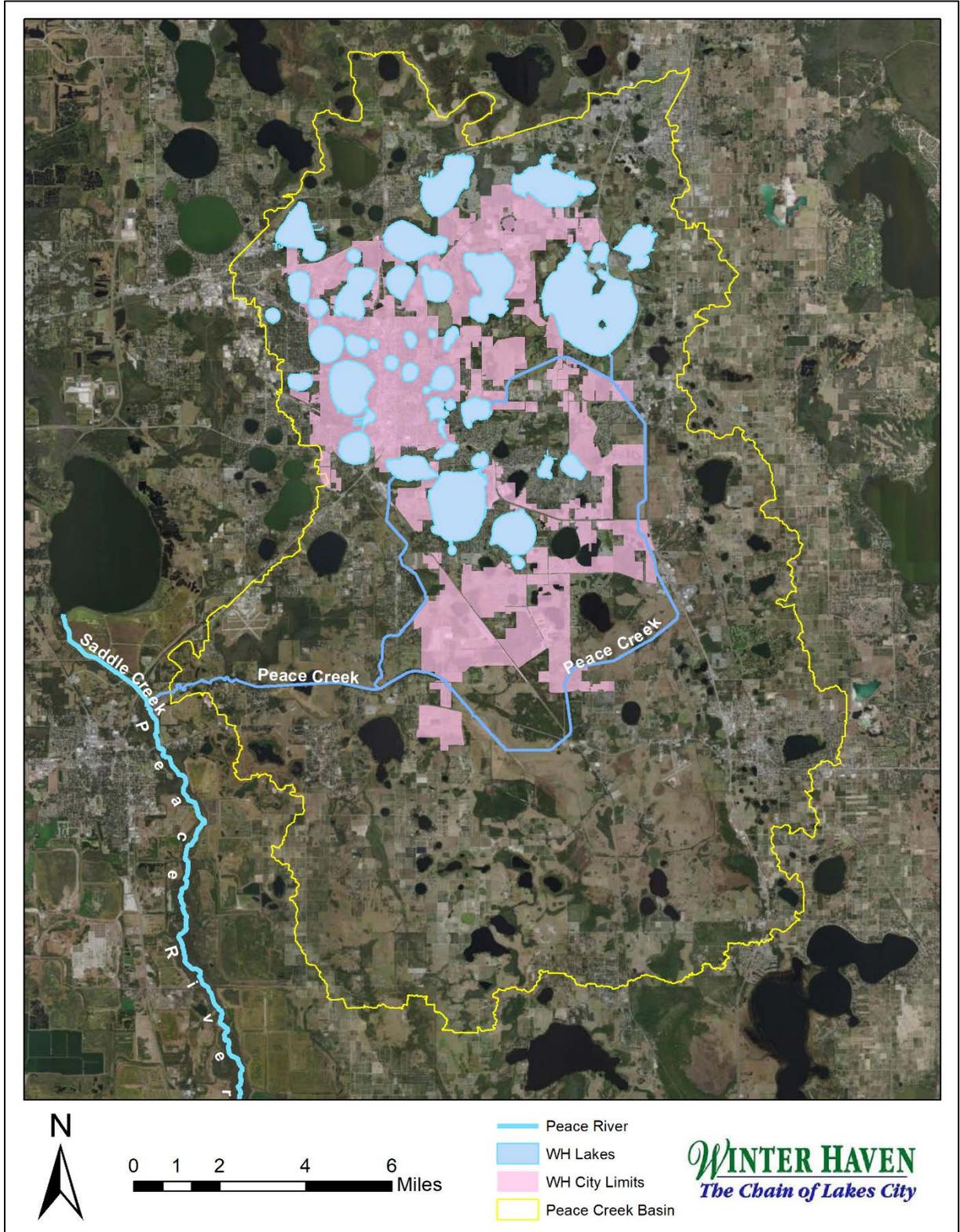
Figure 1-2. Map of the Peace Creek sub-basin, City of Winter Haven limits, contributing lakes and flow-ways.

North Chain of Lakes

The Winter Haven Chain of Lakes have historically been grouped into the distinct Northern and Southern sections that are separated by a boat lock system to allow for navigation between the two. The North Chain, which is located toward the outskirts of the Winter Haven area, is made up of the following 9 waterbodies:

- *Lake Conine*
- *Lake Fannie*
- *Lake Haines*
- *Lake Hamilton*
- *Little Lake Hamilton*

- *Middle Lake Hamilton*
- *Lake Henry*
- *Lake Rochelle*
- *Lake Smart*

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 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
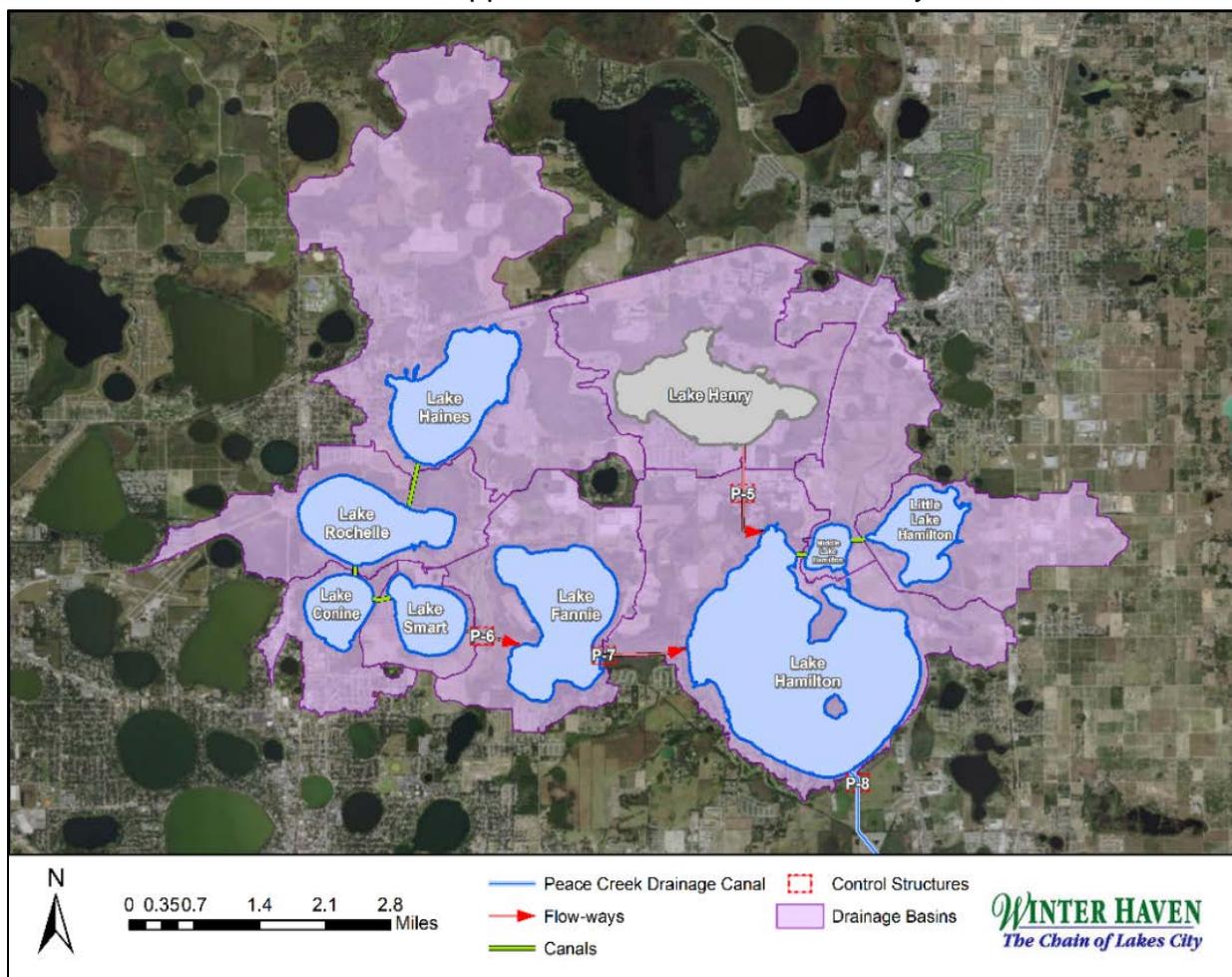

Figure 1-3. Map of North Chain of Lakes, Flow Pathways & Drainage Basins

west to east toward the terminal discharge point at Lake Hamilton (Figure 1-3). Lakes Conine, Haines, Rochelle, and Smart are all held roughly equal via a series of navigable canals. The P-6 water control structure, located downstream of Lake Smart, maintains the desired surface level for these four lakes. From Smart, water discharges to Lake Fannie which is controlled by the P-7 structure. Discharge from Lake Fannie flows to the Hamilton Chain (Lakes Hamilton, Little Hamilton, & Middle Hamilton) where the P-8 control structure maintains water in these three lakes before discharging to the Peace Creek. In addition to these 8 waterbodies, Lake Henry discharges to Hamilton via the P-5 structure. However, because Lake Henry lacks public access and a means of water quality data collection, it has been excluded from this study.

South Chain of Lakes

Spanning the majority of the City of Winter Haven boundary, the South Chain of Lakes is widely considered a recreational destination in Central Florida. This chain is composed of the following 14 waterbodies:

- Lake Cannon
- Lake Eloise
- Lake Hartridge
- Lake Howard
- Lake Idylwild
- Lake Jessie
- Lake Lulu

- Lake May
- Lake Mirror
- Lake Roy
- Lake Shipp
- Lake Spring
- Lake Summit
- Lake Winterset

The entirety of the Southern Chain is connected via a series of navigable canals. Many of these canals were constructed in the early 1900's, in part as a means to transport citrus through the region [Gernert, 2016]. A passive control structure located on the southern shore of Lake Lulu and managed by the Lake Region Lakes Management District (LRLMD), maintains the surface level of this entire chain. From this structure, the Southern Chain discharges to the Wahneta Farms Drainage Canal; traveling south until it joins with the final stretch of the Peace Creek near the City of Bartow (Figure 1-4).
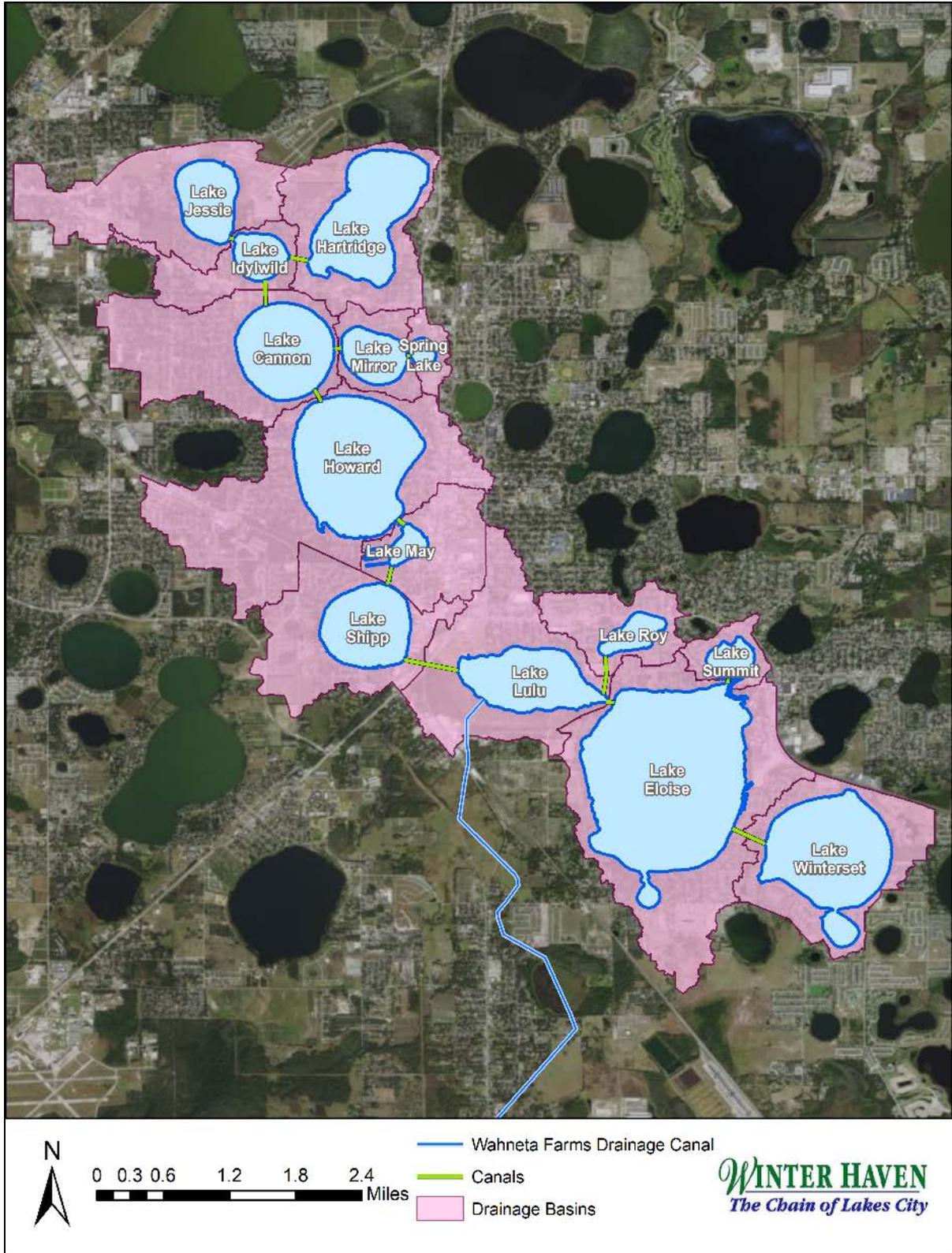
Figure 1-4. Map of South Chain of Lakes, Flow Pathways & Drainage Basins

North Central Lakes

This series of lakes is squarely situated in the northern part of Winter Haven's central urban area. The following 5 lakes flow to the northeast before discharging to the North Chain of Lakes:

- *Lake Buckeye*
- *Lake Idyl*
- *Lake Martha*
- *Lake Maude*
- *Lake Silver*

Beginning in the heart of downtown Winter Haven, water flows from Lake Silver to Martha, Maude, Idyl, and Buckeye, respectively (Figure 1-5). The ditches and pipes that connect these lakes also act as passive water control structures maintained by the LRLMD. At the downstream end of this lake group, overflow from Lake Buckeye discharges north to Lake Fannie through a natural wetland area.
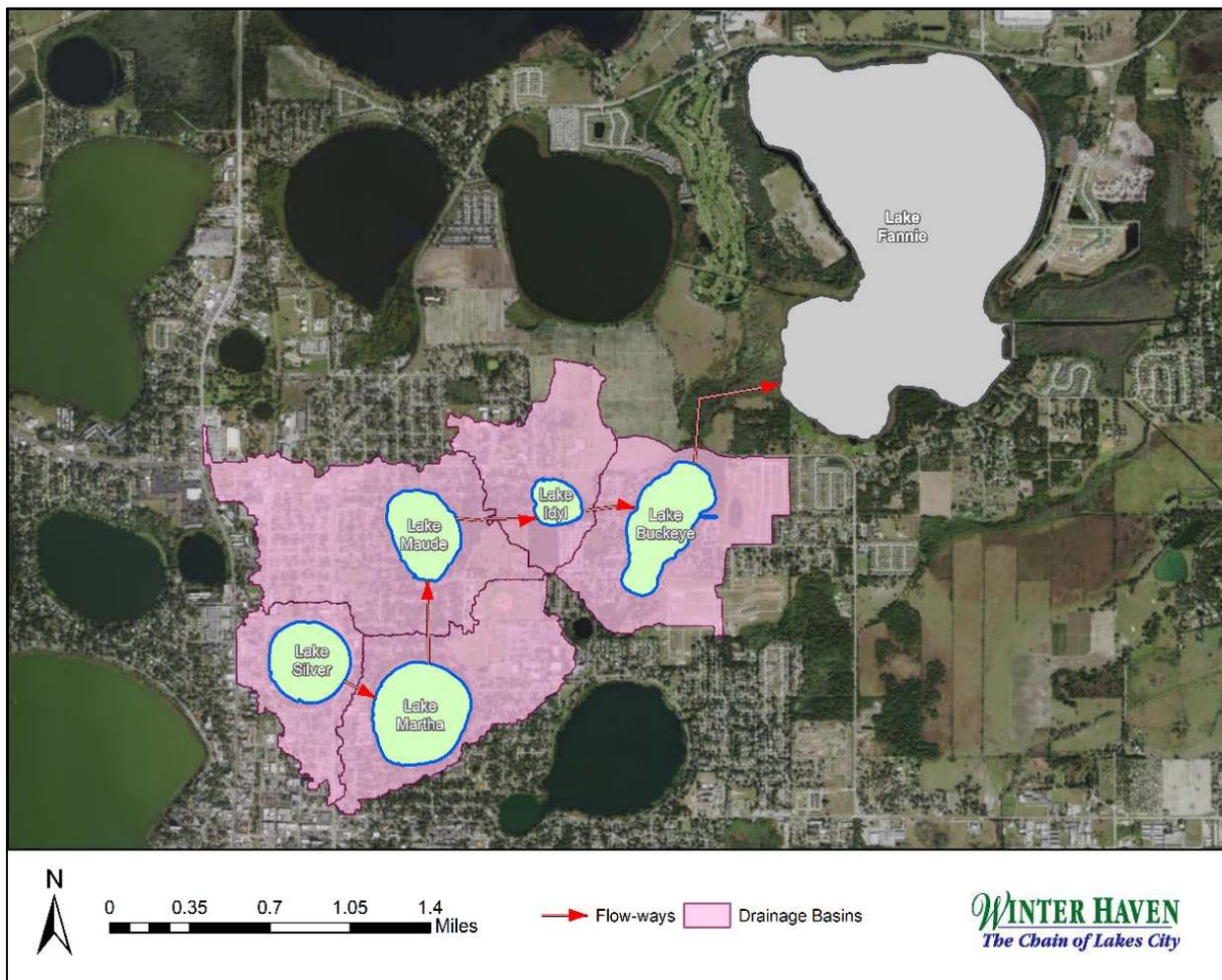

Figure 1-5. Map of North Central Lakes, Flow Pathways & Drainage Basins

South Central Lakes

Similar to the North Central group, the South Central Lakes are categorized based on their location on the southern side of Winter Haven's urban center. Comprised of the following 4 waterbodies, the South-Central group contributes surface flow to the Peace Creek Canal:

- *Lake Elbert*
- *Lake Link*
- *Lake Mariam*
- *Lake Otis*

Starting at Lake Elbert, water flows through an underground pipe to Lakes Otis and Link which are connected via a navigable canal. From Link, surface water is conveyed via another pipe to Lake Mariam which discharges to a small ditch that travels east until it meets with the Peace Creek (Figure 1-6). Within the non-navigable connections between these lakes, weirs control the maximum desired surface level for the purposes of flood prevention and water conservation.
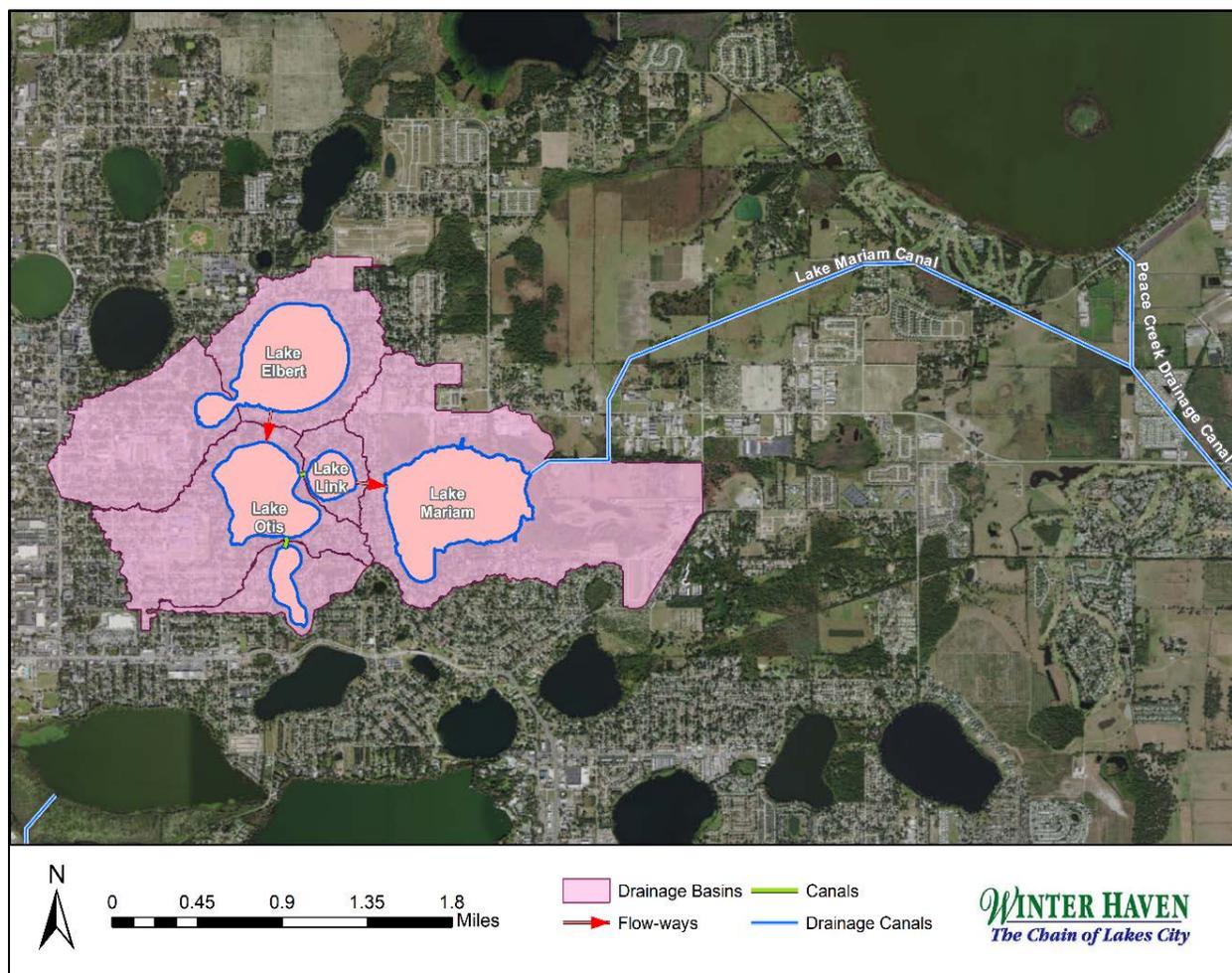

Figure 1-6. Map of South Central Lakes, Flow Pathways & Drainage Basins

Outlying Lakes

The Outlying lakes are made up of isolated waterbodies that don't discharge directly to the Peace Creek, but still meet the other selection criteria presented at the beginning of this section. These lakes are also located at the periphery of the other lake groups. The 6 lakes in this category include:

- *Lake Blue*
- *Lake Daisy*
- *Lake Deer*

- *Lake Mariana*
- *Lake Ned*
- *Lake Pansy*

The lakes in this group are mostly separate systems that flow into other area waterbodies (Figure 1-7). Lakes Blue and Deer, located west of downtown Winter Haven, both discharge to the Southern Chain of Lakes (Lake Cannon) via underground stormwater pipes managed by Polk County. Located mostly outside Winter Haven City limits, Lake Mariana was selected due to its contribution to the Southern Chain through a ditch and pipe system, which discharges into Lake Jessie. Lake Pansy doesn't appear to possess
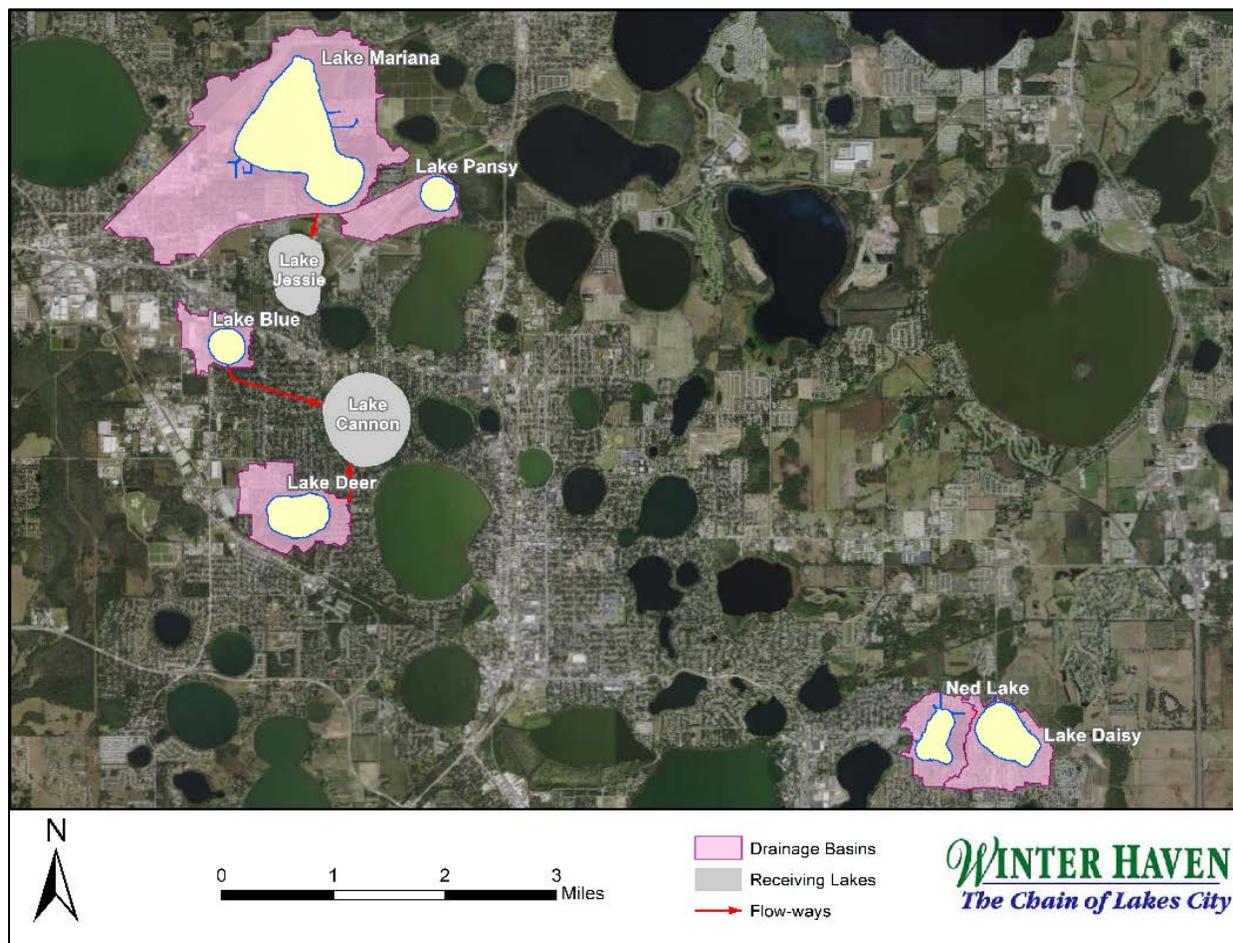

Figure 1-7. Map of Outlying Lakes, Flow Pathways & Drainage Basins

any man-made conveyances to other lakes. However, there is evidence to suggest that Lakes Pansy and Rochelle share a surface water connection via the wetland area between them. Because Pansy lacks a dedicated control structure, the surface level required for flow to occur is not well known. Lakes Ned and Daisy are located in Southeastern Winter Haven. They share a surface water connection and also connect with Lake Dexter—a publicly inaccessible lake to the southwest. However, there is evidence to suggest that Lake Daisy discharges to the east toward the Peace Creek.

1.3 Background on the Metrics

Just as a person's physical health is reliant on multiple factors, so are the facets of limnology 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

At face value, the term "water quality" simply 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 have to offer.

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 the primary 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 and a regulatory system that acts to reduce 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 our waterbodies. On the geologic time scale (thousands of years), lakes go through a natural process called eutrophication or an increase in productivity. 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 unrestricted 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, of which 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

Figure 1-8. Linear Regression of Chlorophyll-a vs. Total Phosphorus & Total Nitrogen

illustrated by their correlative relationships (Figure 1-8). 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 as a means to determine if a waterbody is impaired. Once
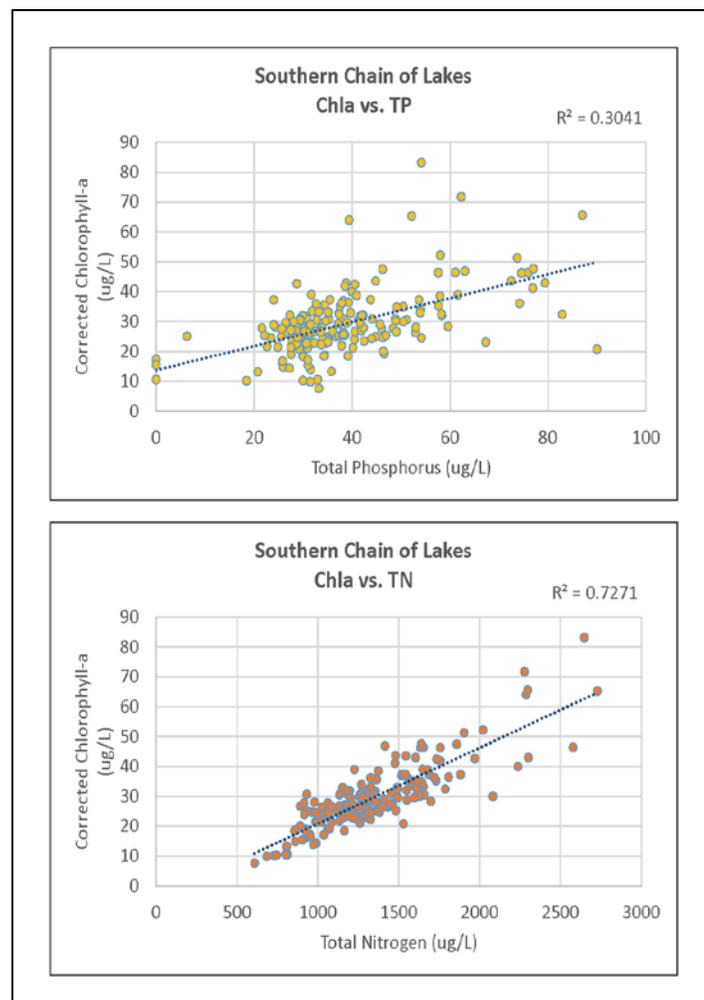
impairment has been established, action is taken to reduce water quality back to target concentrations.

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 as well as 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 CaCO$_3$), 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.

In order to simplify the NNC impairment determination process, a flow chart was developed by City staff as a step-by-step guide (Figure 1-9) [FDEP, 2013]. The initial
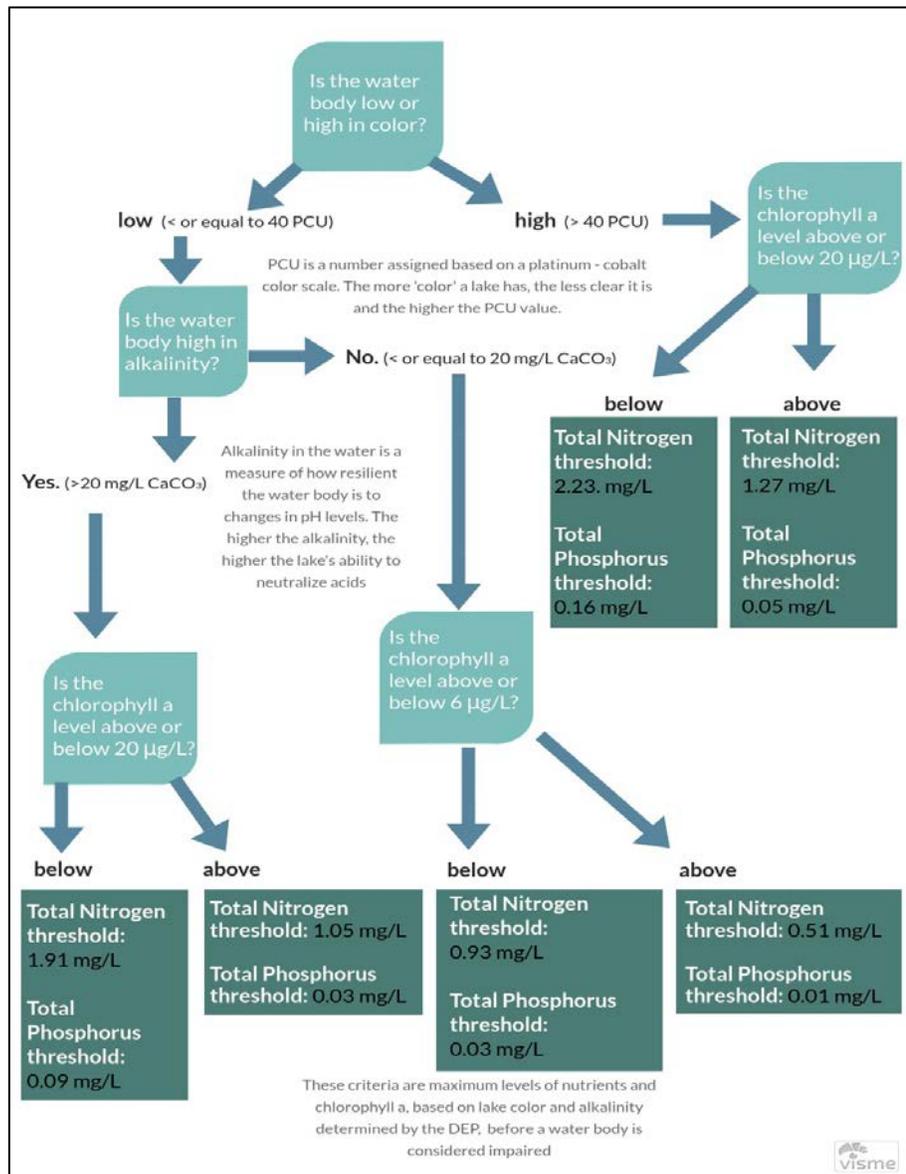

Figure 1-9. NNC Impairment Determination Flowchart

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 $CaCO_3$) 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. In order 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 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 assessed with 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 pollutant 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 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 [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 of point sources and non-point sources in weight of nutrient per year (e.g. lbs/year of TP). Point sources refer to discharge from wastewater treatment plants and **M**unicipal **S**eparate **S**torm **S**ewer **S**ystems (MS4s). Non-point sources refer to the introduction of pollutants through surface runoff, atmospheric deposition, groundwater, sediments, and any other sources that don't possess a discreet 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 of 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 at an annual frequency 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 1-10) [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 fairly clear, relatively 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 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
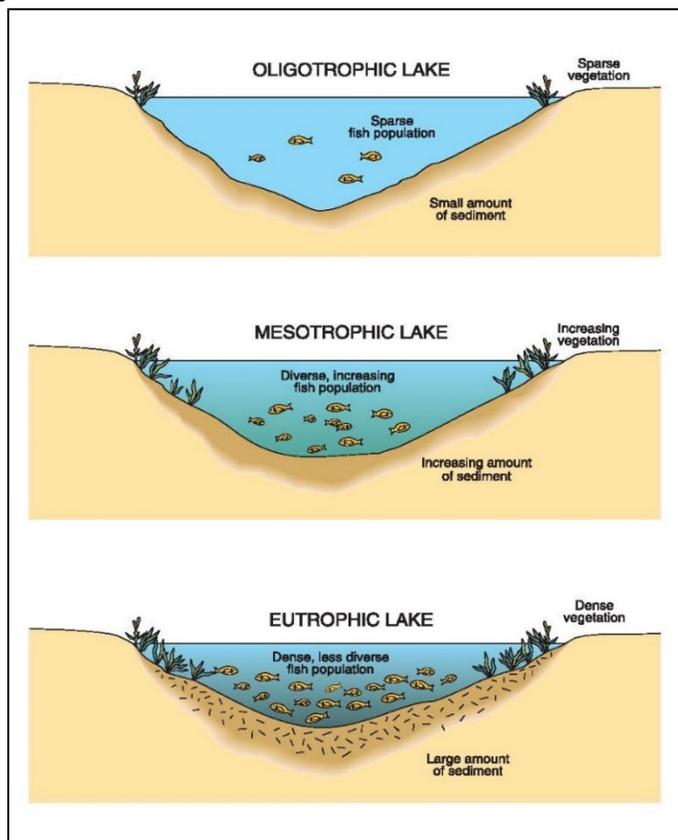

Figure 1-10. Diagram of Lake Trophic States [USGS, 1998].

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.

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 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 in one way or another. 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 1-11). 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 not only for the ecological outlook of our lakes, but also for 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.
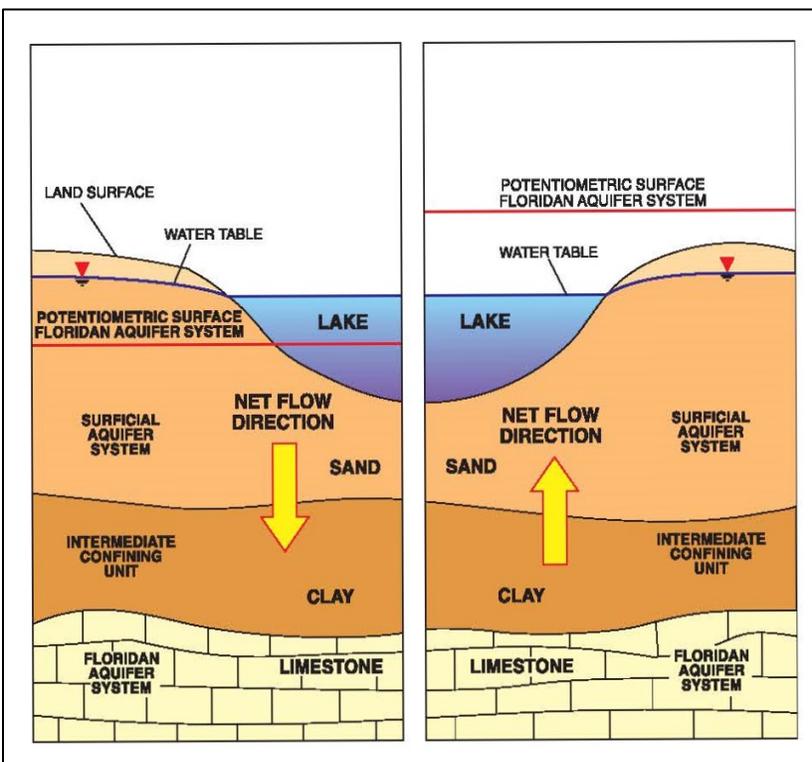

Figure 1-11. Diagram of Groundwater Interactions

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 course 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'.*
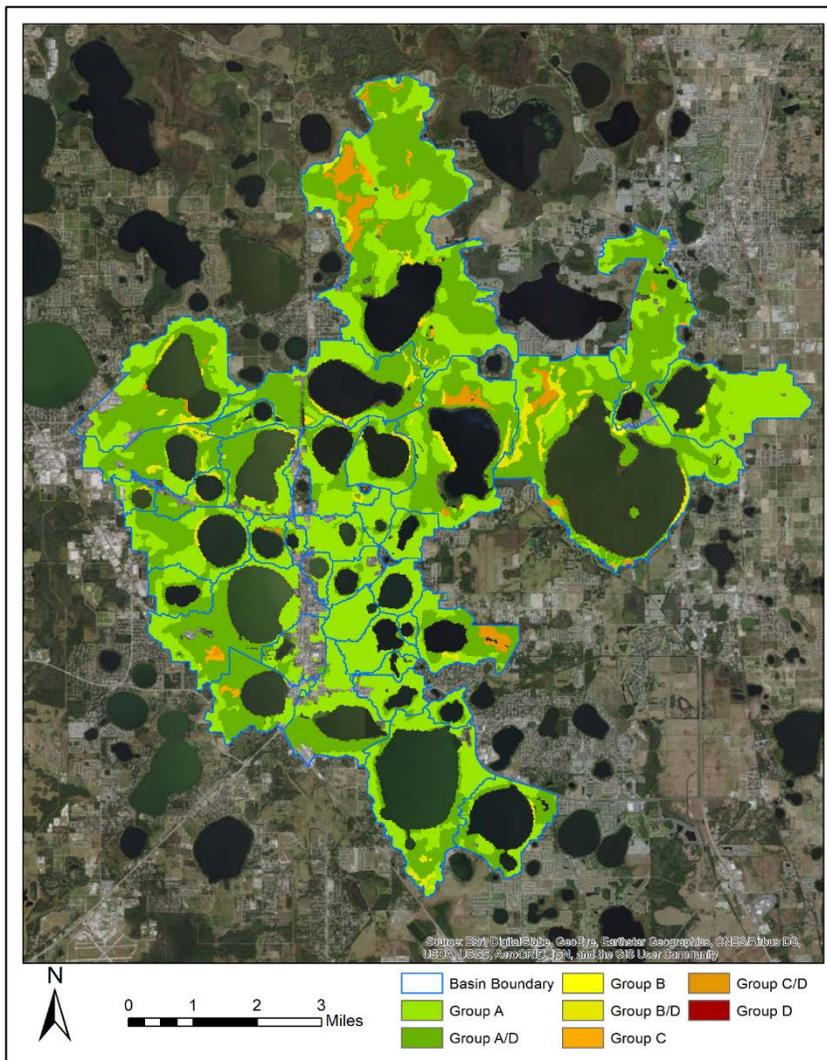
Figure 1-12. Hydrologic Soil Groups of the Winter Haven Lakes

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 1-12). 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 1-13).
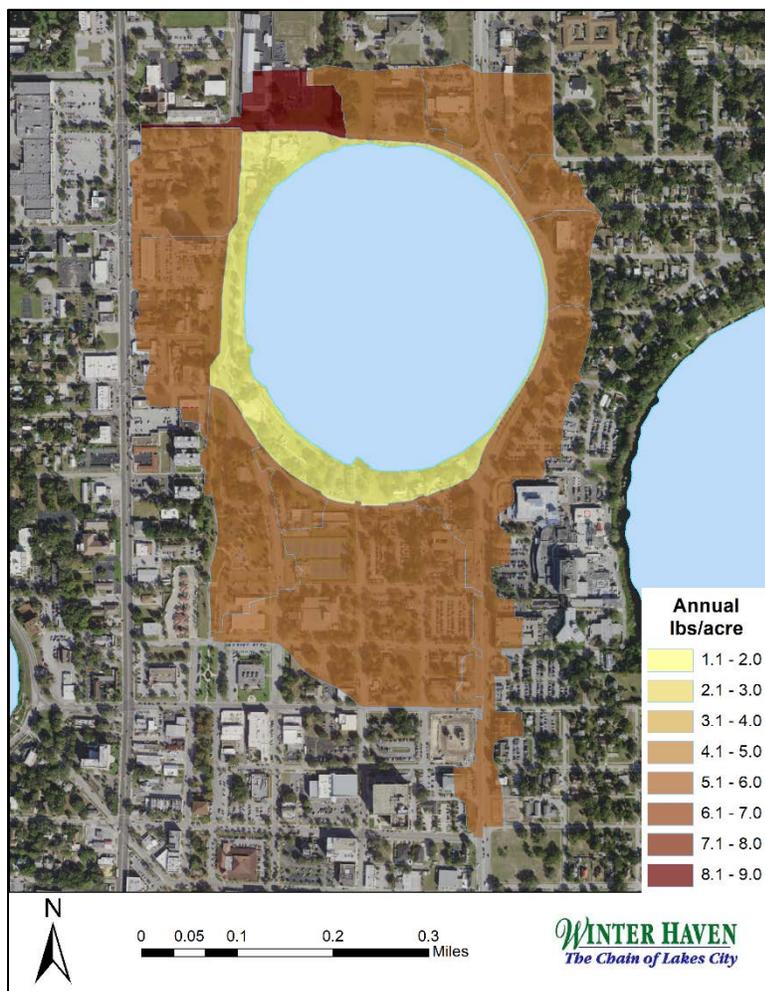
Figure 1-13. Annual Total Nitrogen Loads to Lake Silver in lbs/acre

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 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 prior to 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, in the vicinity of 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. The 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 of native 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 1-14). 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

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 eel grass (*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
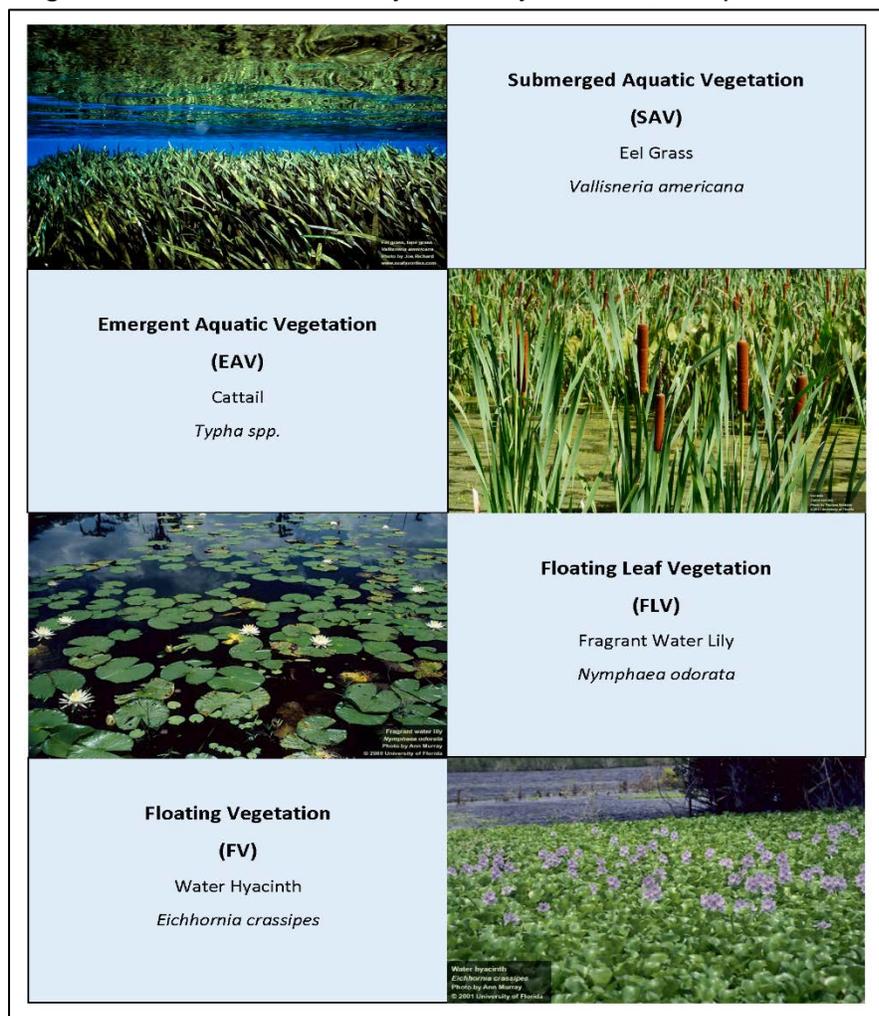
Figure 1-14. Examples of Aquatic Vegetation Categories

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 as well as 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 1-15 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.
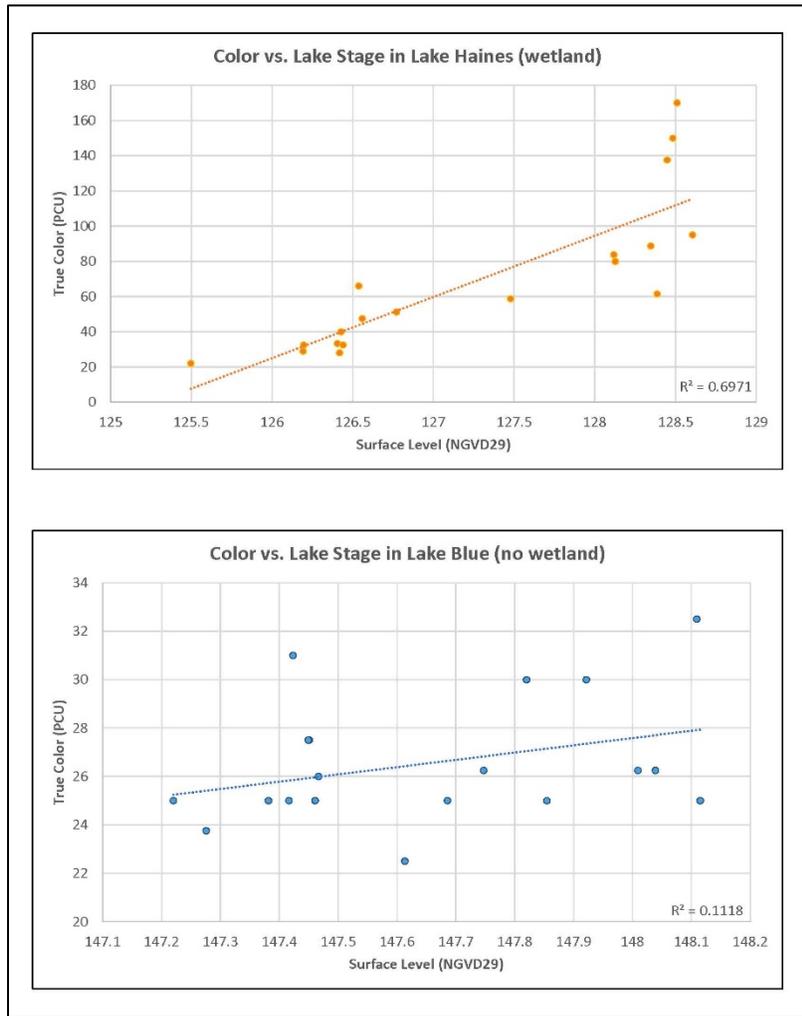
Figure 1-15. Correlation between Wetlands and True Color in Lake Haines & Lake Blue

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 1-16). 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 diversity 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 for 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.
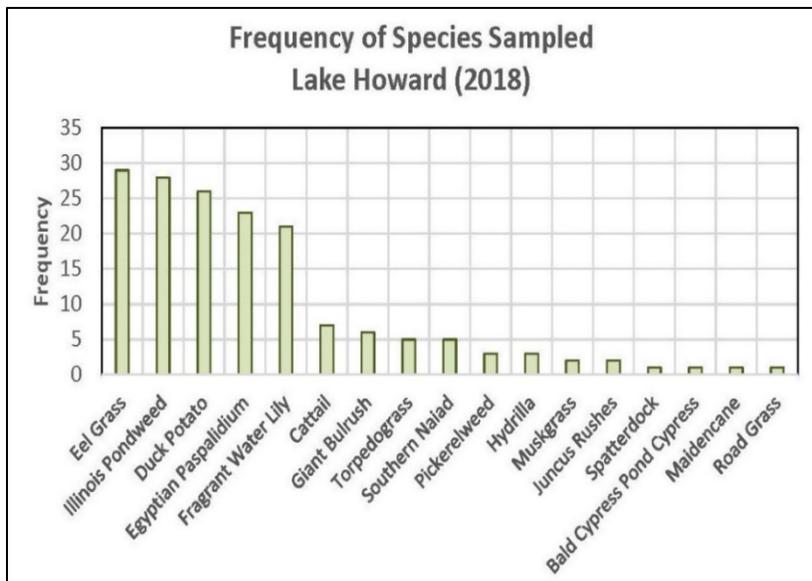
Figure 1-16. Species Frequency Chart of Aquatic Vegetation in Lake Howard

#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. 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 <u>Mission</u>. 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 <u>Purpose</u>. By providing tools and education to the development community and internal staff the hope is to further perpetuate the "community ethic" therefore realizing the <u>Vision</u>.

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:

- Gray to Green Development Guide was completed in 2018.
- Gray to Green Permit Design Manual was completed in 2021.
- Regularly engage the development community on the Gray to Green initiative during Development Review Committee meetings.
- Explore updating City Ordinances to promote green stormwater infrastructure and low impact development principles.

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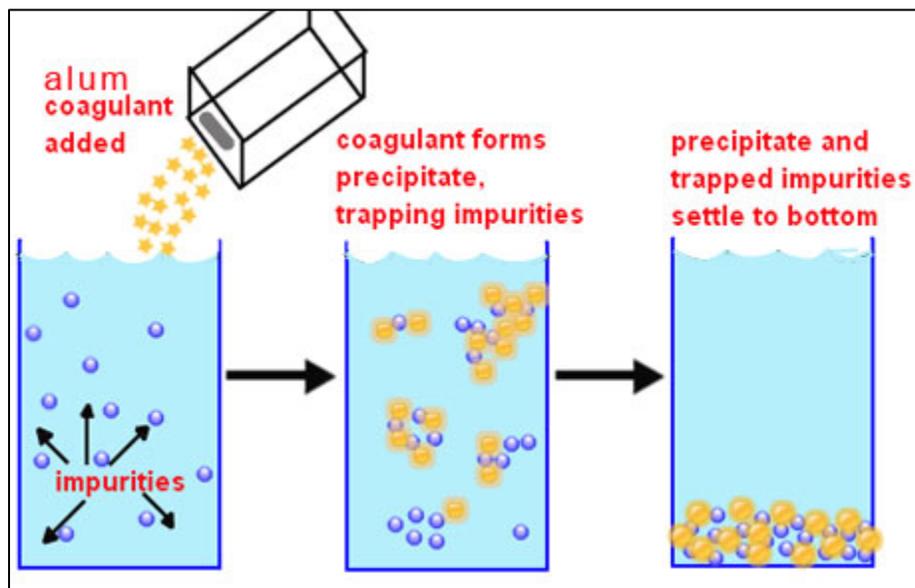
Figure 2-1 Diagram of alum floc adsorption properties. [Bionics, 2013]

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 will not solely 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 helped 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.
- Conduct cost-benefit analysis to determine if the continued use of alum is a cost-effective management strategy.

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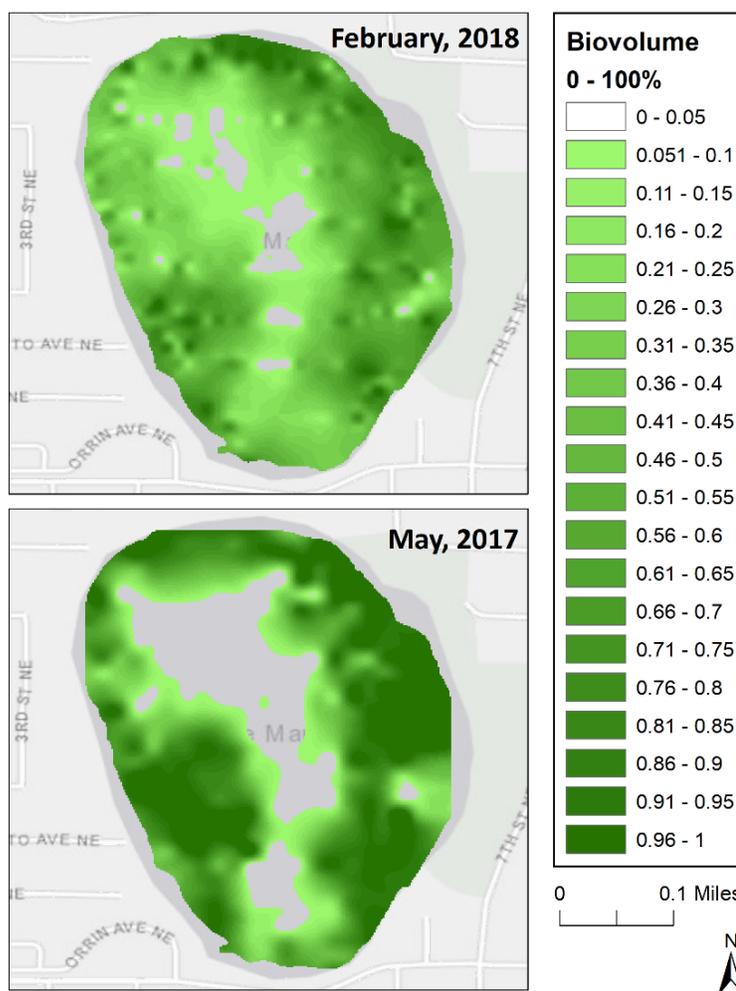
Figure 2-2. Biovolume heat map of Lake Maude. Color scale represents percent of water column occupied by plants.

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 39 area lakes in 2022.
- 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

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

reducing the area devoted to stormwater mitigation and can often be more aesthetically pleasing.

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 <u>Mission</u> 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 <u>Purpose</u>. LID construction is a realization of the <u>Vision</u>, 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:

- Completed restoration of raingardens along Ave A SW and 2nd St SW in 2021.
- Completion of Southwest Florida Water Management District Cooperative Funding project W772 is slated for the end of 2023. This will result in additional raingardens along MLK Blvd, Ave O NE, Ave H NE, and Ave I NE.
- Explore software options to assist with planning maintenance of existing green stormwater infrastructure.

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 intimate forum 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 also polled after each trip in an effort to ensure that the experiences are satisfactory and the messaging is clear. 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 <u>Mission</u>. 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 50 guests in 2022.
- Utilize user surveys to continue improving the experience and topics discussed.
- 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.

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.

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

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:

- Currently working with FWC's AHRES organization to deploy fish attractors in Lake Martha. This should be completed by the end of 2023.
- 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. Connected to the lakes are the aquifers, which provide the City with its potable water supply.

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:

- Deployed 7 surface level sensors (i.e. Lakes Buckeye, Elbert, Howard, Idyl, Martha, Maude, and Otis) in 2022.
- Budgeted for the purchase of 14 additional surface level sensors in 2023. This will result in continuous monitoring capabilities for all lake systems in the Winter Haven area.
- Explore funding opportunities to purchase and install weather stations at various locations in the Winter Haven area.

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. Since accessibility and aesthetics of City properties like nature parks, boat ramps, and lakeshores is important to residents, 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:

- Staff obtained aquatic vegetation management certifications to deploy herbicide in 2022. Staff will continue to maintain these certifications through training and education credits.
- Conducted 110 invasive species treatments in 2022 to maintain access, flow, and aesthetics of public lakeshores, stormwater outfalls, and drainage ditches.
- 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 5 Permit in 2022.
- Submit Cycle 4 Year 6 Permit and prepare to host FDEP staff for a local inspection in 2023.
- 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:

- Watershed Optimization Model slated for completion in 2023.
- Coordinate with Winter Haven Water to identify potential conservation lands for water storage and aquifer recharge activities.
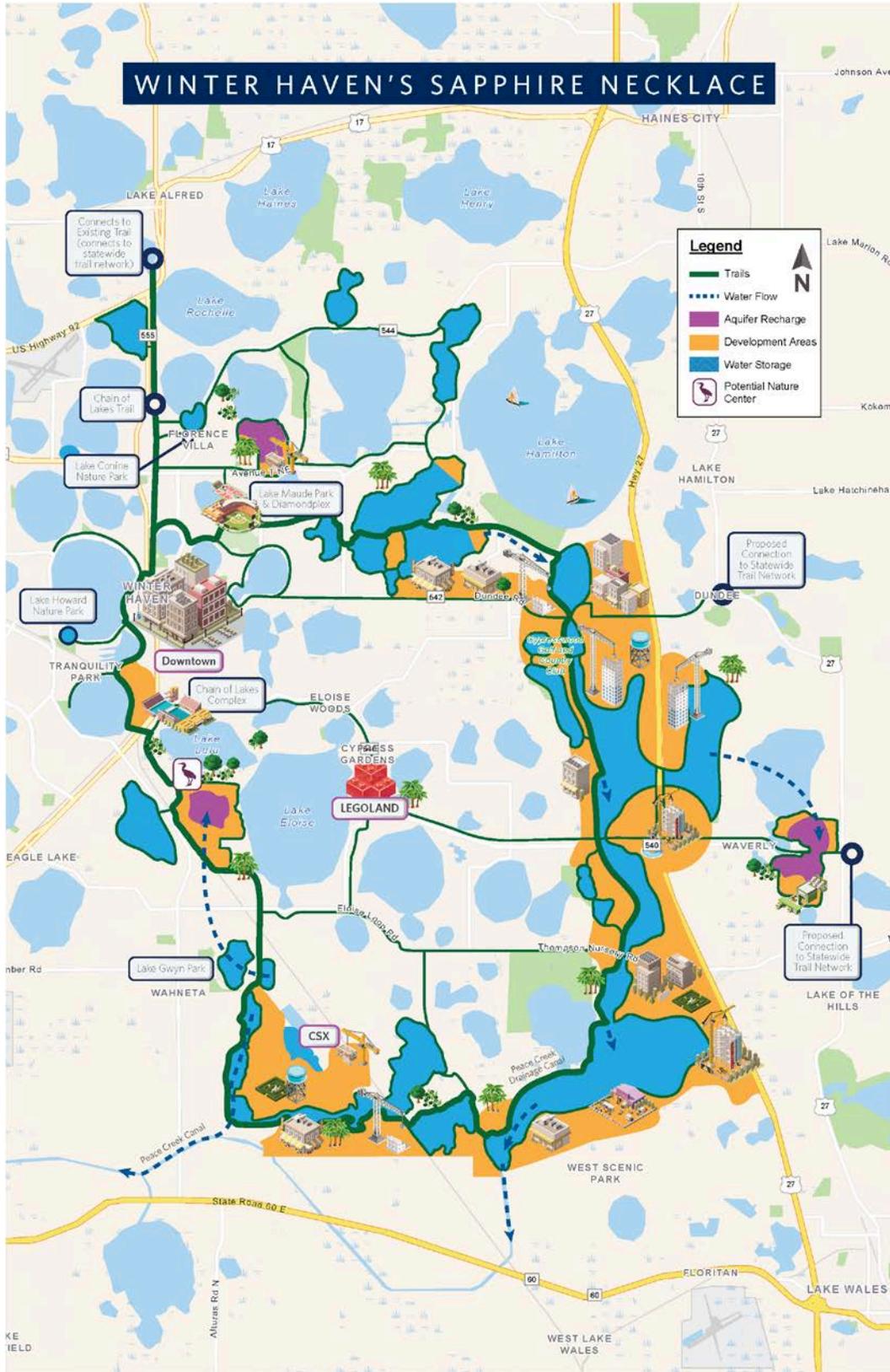
Figure 2-6. Rendering of the Sapphire Necklace concept that includes water storage, aquifer recharge, and nature park areas.

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 may consider 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

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

interact with several dozen to several hundred participants per 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:

- Conducted initial Watershed Seminar for Lakes Otis & Link in 2021. Over 30 attendees were counted during this event. Additional Watershed Seminars planned for 2023.
- Participated in several events (e.g. 7 Rivers Water Festival, Project Eagle) with a total outreach impact of over 130 people in 2022. This outreach count was lower than previous years due to continued impacts from COVID-19.
- Staff plan to expand outreach efforts to additional events in 2023.

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 yd^3, 1.0M yd^3, and 487K yd^3, 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 are 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:

- Currently seeking funding to initiate 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.
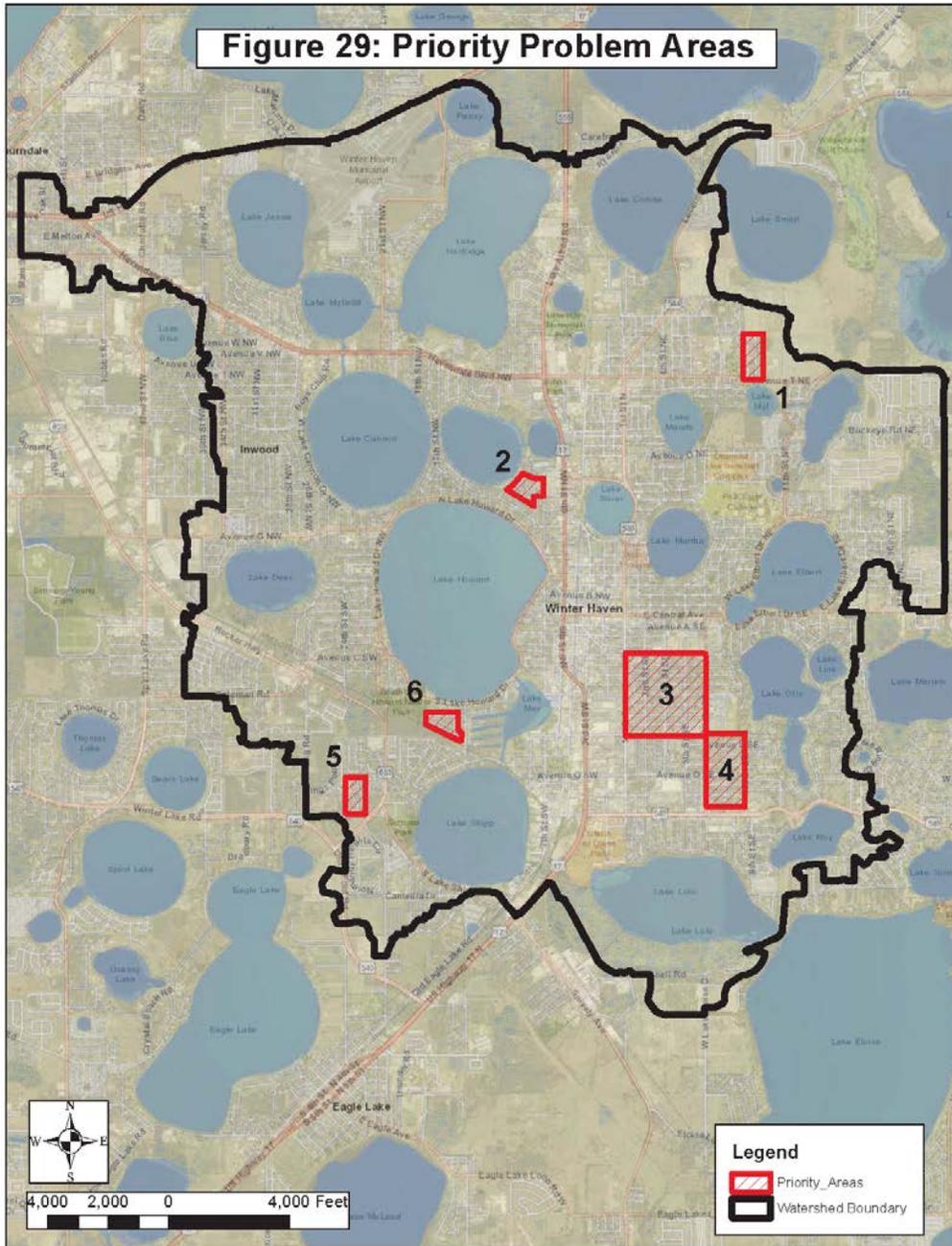
Figure 2-8. Priority sites indicated by increased flooding and pollutant load potential as determined by the Winter Haven SAIP.

Support of Mission, Vision, and Purpose:

Stormwater is a major component of the "social, economic, and ecological systems" identified in the Mission and having a "sound understanding" of this system positions staff to fulfill the Division's Purpose. Having this understanding also positions the City to be the "premier knowledge base for local resources" in support of the Vision which gives the community an advantage when working to address State and Federal mandates.

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 2023.
- Seek funding to implement stormwater improvements once the Pollutant Reduction Plan is approved.

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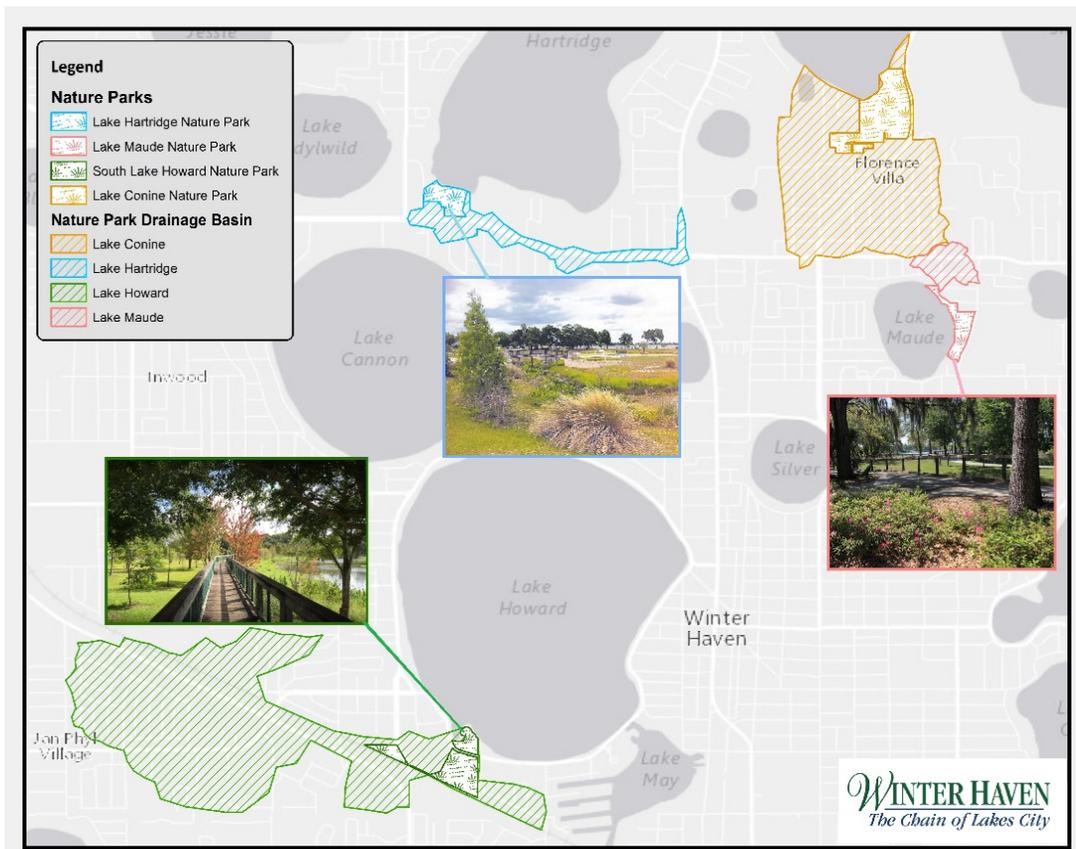
Figure 2-9. Map depicting the Winter Haven nature parks and their drainage basins.

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:

- Construction of the stormwater treatment components of Lake Conine Nature Park were completed in 2022.
- Hosted public meetings to gather community input on recreational improvements at the newly constructed Lake Conine Nature Park in 2022. Recreational phase design/build ranked high for State funding. Construction is anticipated to begin in 2023.
- Conducted 13 invasive species maintenance treatments of Lake Howard, Maude, and Hartridge nature parks in 2022.
- Plan to submit request for qualifications for a design/build project to expand stormwater treatment areas at South Lake Howard Nature Park in 2023.

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:

- 1856.4 centerline miles of public streets were swept in 2022; equating to 1872 lbs of TN reduction and 1200 lbs of TP reduction.
- Explore expansion of street sweeping services in 2023.
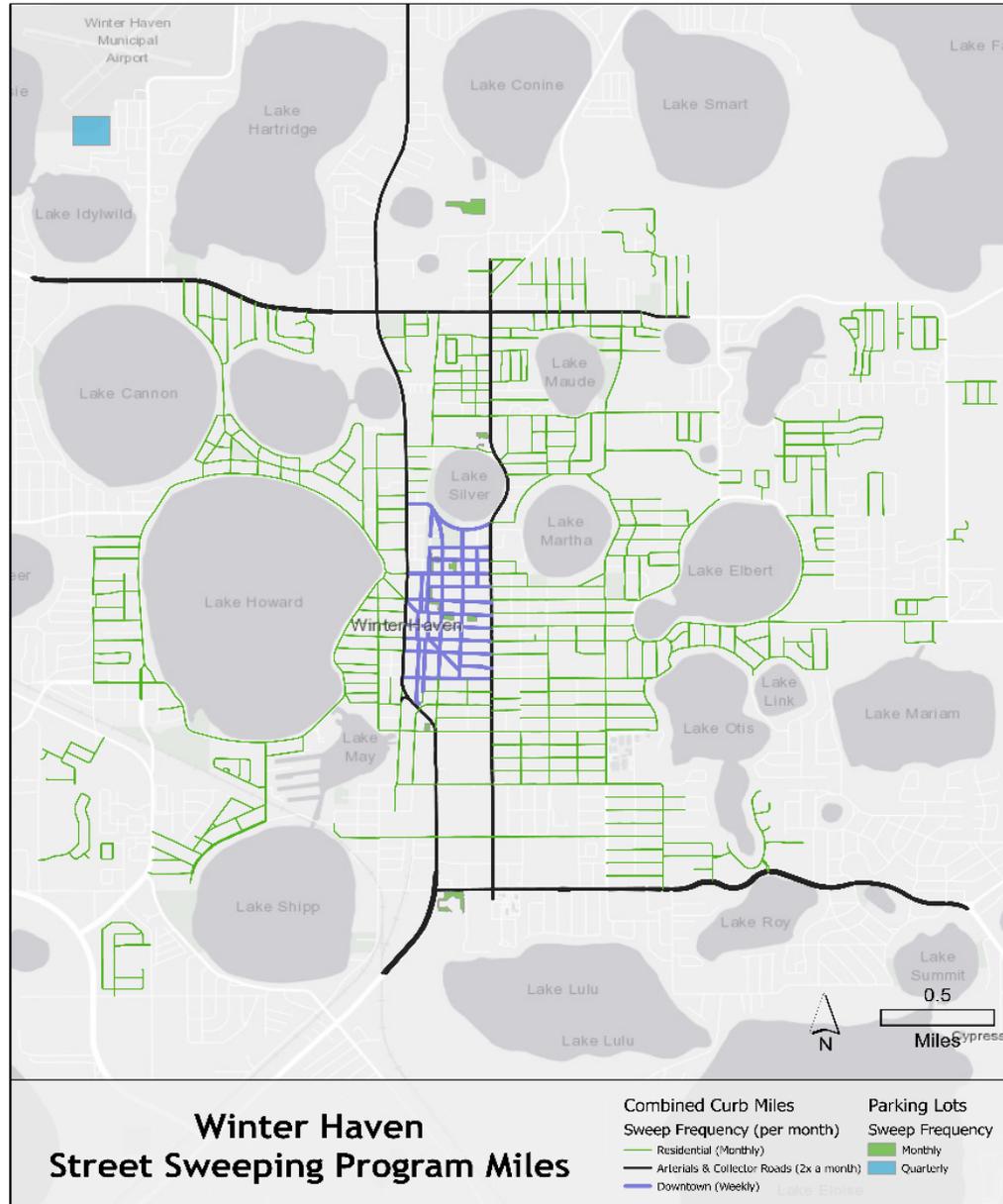
Figure 2-10. Map depicting roadways undergoing street sweeping. Legend indicates sweeping frequency of each street category.

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 <u>Mission</u> 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 <u>Vision</u> by creating an "engaged public" as well as the <u>Purpose</u> 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 21 youth outreach events in 2022, providing education to over 1000 participants.
- Established a full curriculum for the Cypress Junction Montessori School for the '22-'23 school year. This curriculum provided youth education to over 70 students.
- 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 reorganized so that lake-specific information is presented separately for each waterbody. Each lake is presented in alphabetical order to make it easier for readers to locate relevant information. 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 water quality and biological criteria. ***The Lake Health Index is an aggregate of 8 individual criterion scores on a 0 – 3 scale; with scores of 3 being the highest (preferred).*** The individual criterion values are averaged, resulting in a semi-quantitative lake health score that can be used to prioritize management efforts and track overall changes in lake health over time. The following are the individual lake health criteria:

Water Quality Criteria

- *Water Quality Impairments*
  - ○ *Chlorophyll-a (Chla)*
  - ○ *Total Nitrogen (TN)*
  - ○ *Total Phosphorus (TP)*
- *Chlorophyll-a Trends*
- *Total Nitrogen Trends*
- *Total Phosphorus Trends*
- *Clarity Trends*

Biological Criteria

- *Vegetation Abundance*
- *Invasive Species Percentage*
- *Species Diversity*
  - ○ *Menhinick Richness Index*
  - ○ *Hill Evenness Index #3 (E3)*
  - ○ *Shannon's Diversity Index (H)*

Water Quality Impairments: The impairment criterion employs the FDEP Numeric Nutrient Criteria (NNC) guidelines. Impairment is defined as more than one Annual Geometric Mean (AGM) exceedance of NNC thresholds in a 3 year span during the 7.5 year assessment period (2015 – 2022). A total possible score of 3 is awarded for lakes that don't exhibit impairment in any of the three assessment parameters (i.e. Chlorophyll-

a, Total Nitrogen, and Total Phosphorus). A point is deducted for each parameter that is deemed impaired during the assessment period.

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 monotonic trend direction and statistical significance (p-value ≤ 0.05) based on AGM values of each metric from 2000 to 2022 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 PACs 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 2022 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 given to each of the three diversity indices if their 2022 value meets or exceeds the respective long-term median; 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 decimal scale from 0 to 3; with a score of 3 equating to relatively higher overall lake health.* The individual indicator criteria do not incorporate magnitude. As a result, these scores are not applicable as absolute measurements of overall lake condition and only apply to lakes within the study area. The Lake Health Index was developed to be an unofficial evaluation metric used track changes in the Winter Haven area lakes over time.

Winter Haven Regional Hydrology

Winter Haven's regional hydrology is completely driven by precipitation. An abundance or dearth of rainfall can significantly impact water resources such as lake levels, stream flows, 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 groundwater system that supplies the City's potable water. 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 2022, the City of Winter Haven received 64.12 inches of rainfall which was over 12 inches above the annual average. Nearly half of this total was received during August and September—due mostly to an active season of subtropical thunderstorms and tropical cyclones like Hurricane Ian. Despite at or below average rainfall during several months, Winter Haven received rainfall above the normal range during March, April,
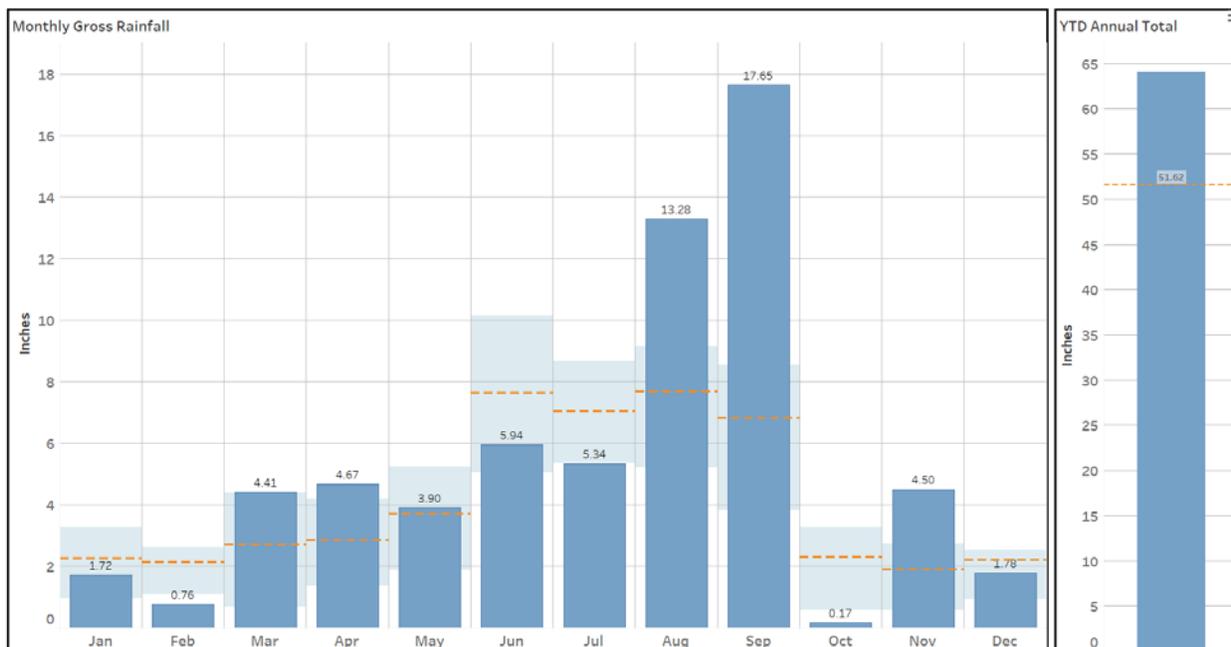
Figure 3-1. 2022 monthly and annual rainfall totals in relation to the long-term average.

August, September, and November. The result was a wetter year that had significant impacts on lake and groundwater levels.

Figure 3-2 depicts the upper surface elevation of the UFA and monthly rainfall totals from 2012 until 2022. 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. Even as levels began to decline towards the end of 2022, the UFA remained well above the normal range.
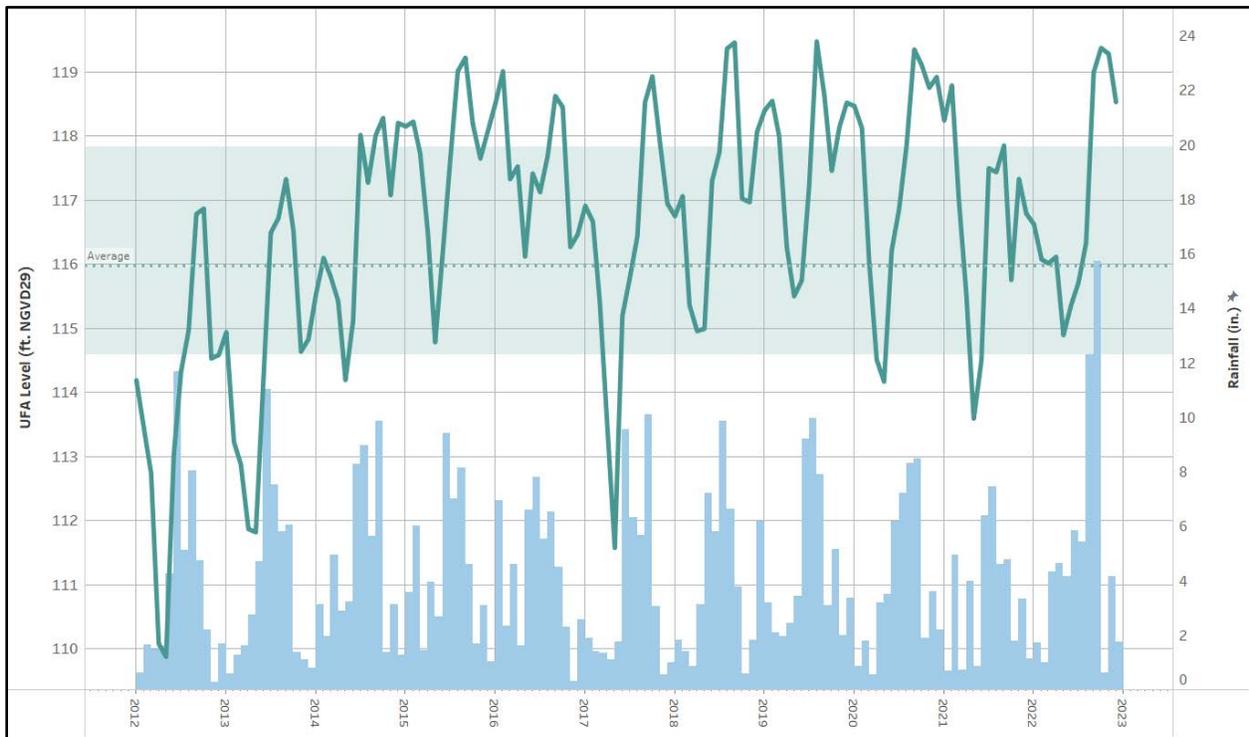
Figure 3-2. Monthly Upper Floridan Aquifer levels and monthly rainfall totals from 2012 to 2022. UFA levels graphed in relation to long-term mean and normal range.

Lake Blue

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

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. Based on these factors, it is considered part of the Outlying Lakes group. 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 modelling, 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.
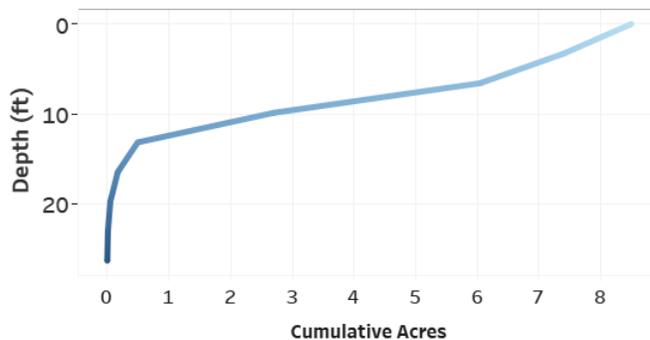

Figure 3-3. Hypsograph of Lake Blue depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.
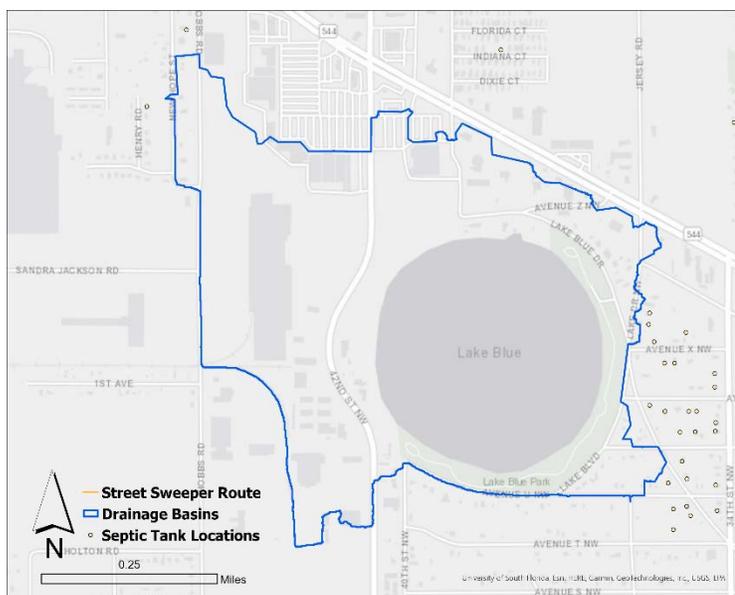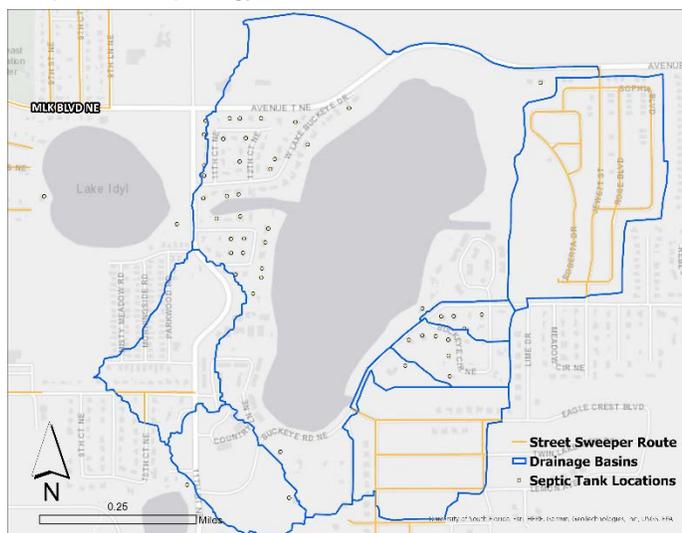

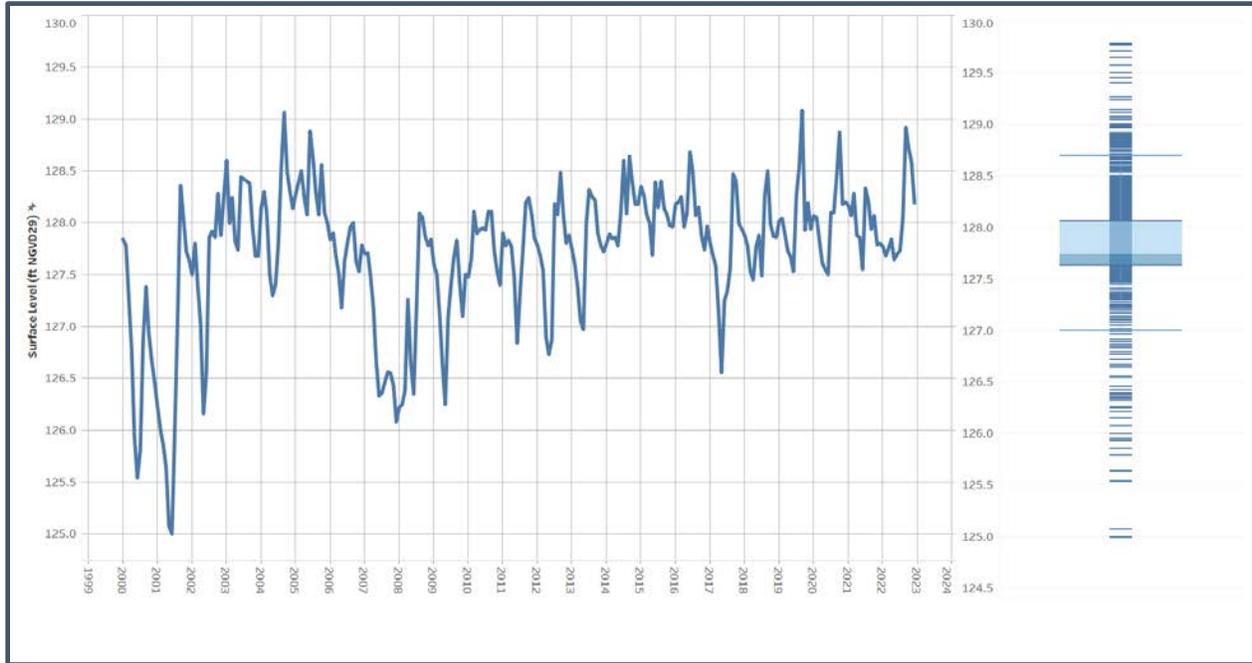Figure 3-4. Map of Lake Blue's drainage basin, City street sweeper routes, and nearby septic systems.

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 2022, Lake Blue reached a

wet season peak of 148.4 ft and a dry season low of 147.2 ft, but ended the year at 147.5 ft which is slightly below the median level of 147.7 ft. Changes in Lake Blue's surface level are not correlated with Chla, TN, TP, or clarity (see appendix).
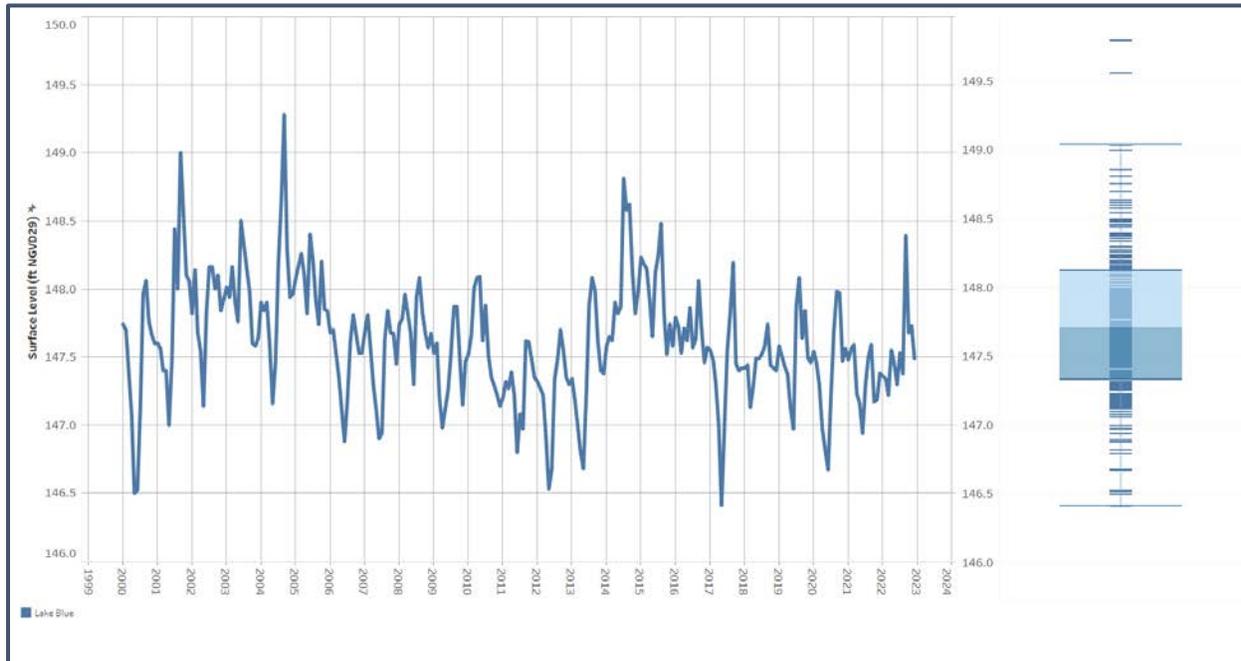
Figure 3-5. Hydrograph of Lake Blue depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details the total range, median, and normal range of surface level during the period of record.

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 Chla, TN, and TP due to exceedances of the NNC thresholds each year 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 in order to meet NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	
TN	Y	0
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 2000 to 2022. Total phosphorus exhibited a statistically significant improving trend; Chl-a, TN, and Secchi depth exhibited non-significant improving trends. 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
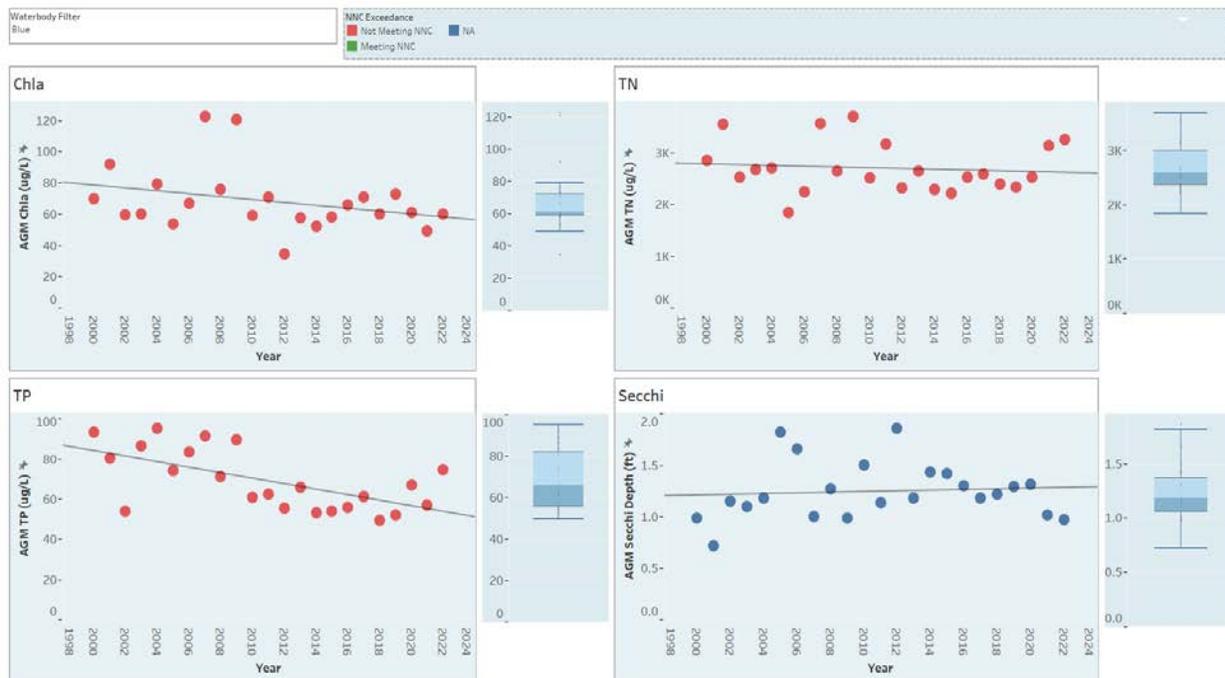
Figure 3-6. Lake Blue AGM Chl-a, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Blue on February 10th, 2022. The PAC during this survey as 46.9% and the total BV was 5.65% (Figure 3-7). While the PAC was much higher in 2022 compared to previous 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. Considering that the majority of vegetation is present around the shoreline, the actual PAC is likely much lower. Regardless, Lake Blue scores a 3 in this criterion.
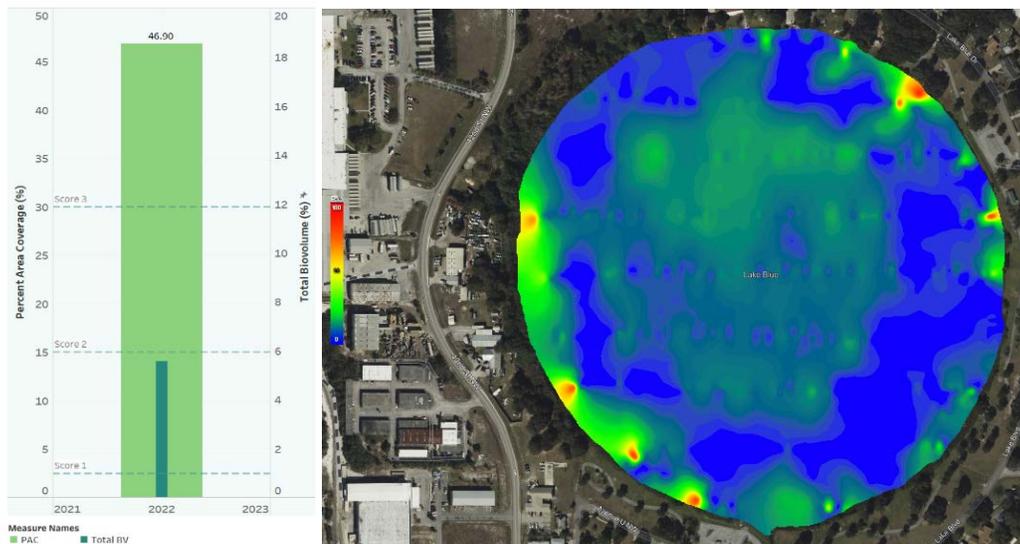
Figure 3-7. Graph depicting 2022 PAC/BV and biovolume heatmap; biovolume values range from green (lowest) to red (highest).

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 Blue's vegetation community was primarily made up of emergent vegetation, with less than 5% 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.
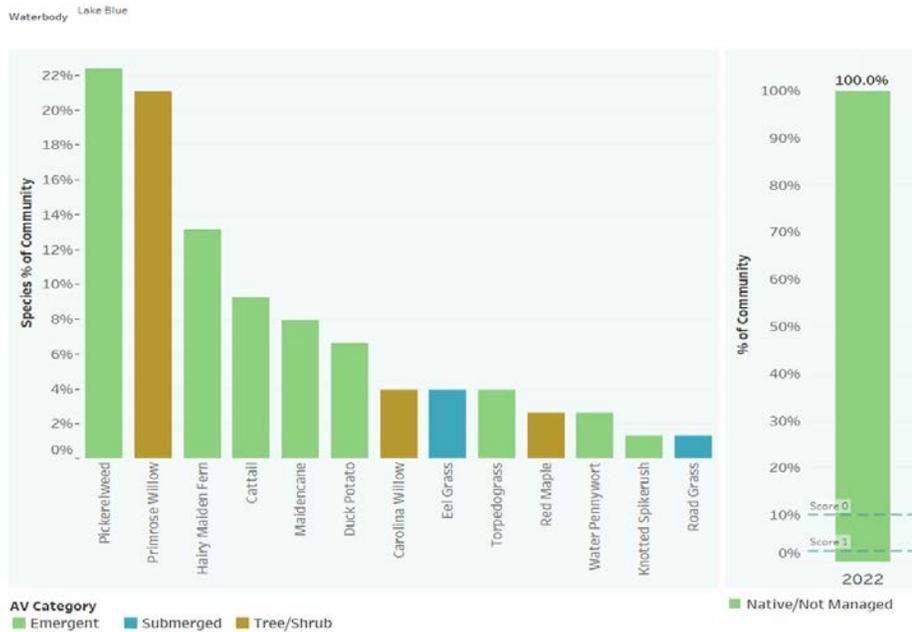
Figure 3-8. Chart depicting species frequency and invasive species percentage of Lake Blue during 2022.

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 2022, each of Lake Blue's diversity indices met or exceeded the long-term median; resulting in a diversity score of 3 (Figure 3-9). Comparison of 2022 species data and those from previous years shows a small, but measured increase in submerged species like eel grass and road grass. This resulted in an increase to the lake's richness and overall diversity scores.
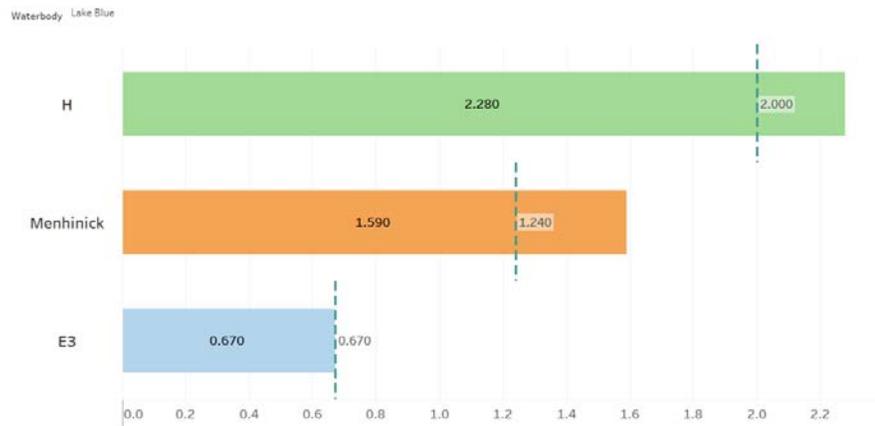
Figure 3-9. Chart depicting 2022 diversity index values for Lake Blue.

Lake Health Tracking:

A comparison of Lake Blue's health index scores from 2018 to 2022 shows a gradual decline and sudden improvement in overall lake health (Figure 3-10). During this five 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	0	1.8
2022	0	2	2	3	2	3	3	3	2.3

Figure 3-10. Chart depicting a comparison of Lake Blue's Lake Health Index scores from 2018 to 2022.

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 2022 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.

- City staff may provide future support to Polk County in developing stormwater treatment practices for Lake Blue.

Lake Buckeye

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

Location, Characteristics, & Hydrology:

Lake Buckeye is located to the northeast of central Winter Haven. It receives excess water flows from Lake Idyl and discharges downstreatm to Lake Fannie of the North Chain of Lakes via a passive overflow structure. Based on these factors, Buckeye is grouped into the North Central Lakes. 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).

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.
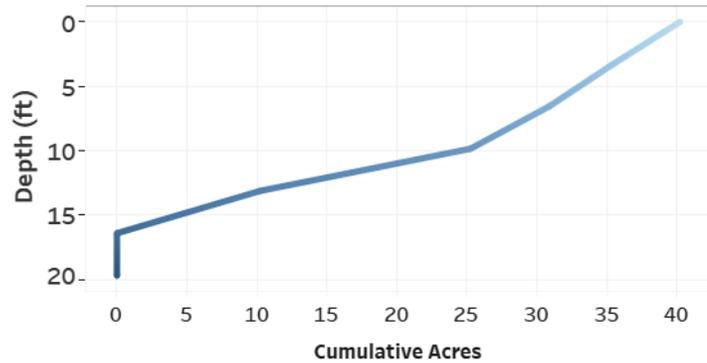

Figure 3-11. Hypsograph of Lake Buckeye depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.


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 2022, Lake Buckeye reached a wet season peak of 128.9 in September and a dry season low of 127.6 in May. The surface level ended the year above the normal range at 128.2 feet. Changes in Lake Buckeye's surface level is not correlated with Chla, TN, TP, or clarity (see appendix).
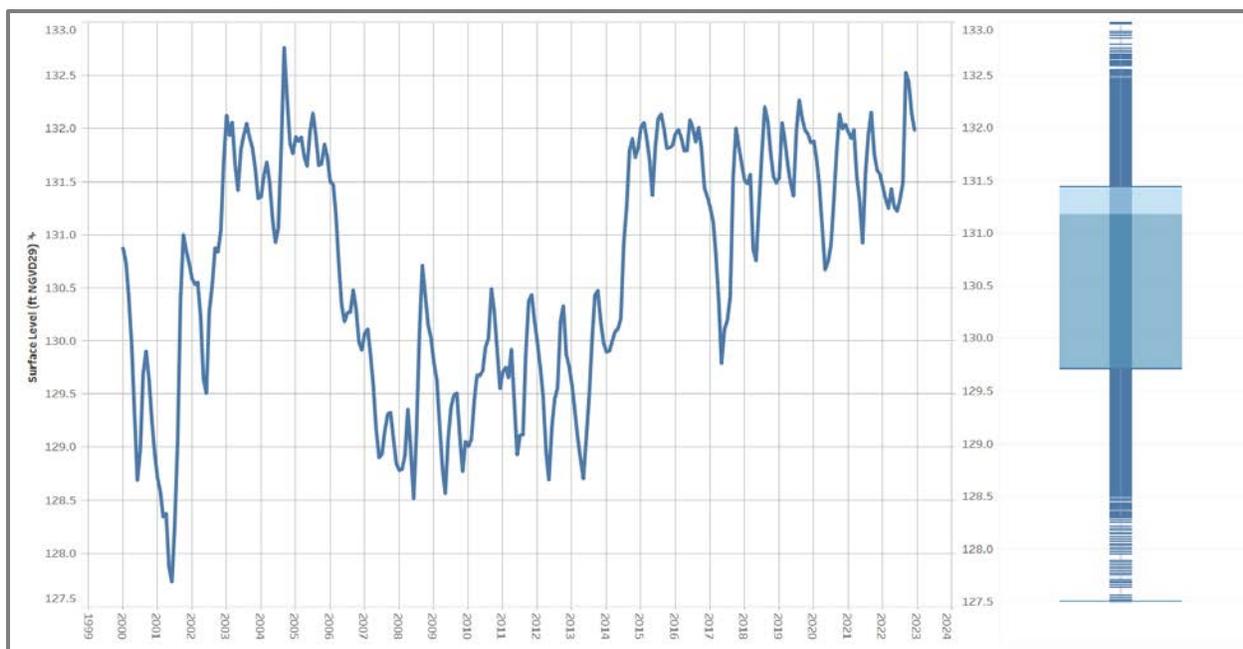
Figure 3-13. Hydrograph of Lake Buckeye depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 Chla and TP—2005 (Figure 3-14).

As of 2022, Lake Buckeye is not impaired for any of the NNC parameters. It should be noted that the 2022 AGM Secchi depth was lower AGM Chla and TN were also higher than the two previous years. Despite this all water quality metrics were within their respective normal ranges.

Parameter	Impaired	Index Score
Chla	N	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Each of these four parameters exhibit significant improving trends—earning lake health scores of 3 for each of the trend criteria. Individual AGM values and trend statistics can be found in the appendix.

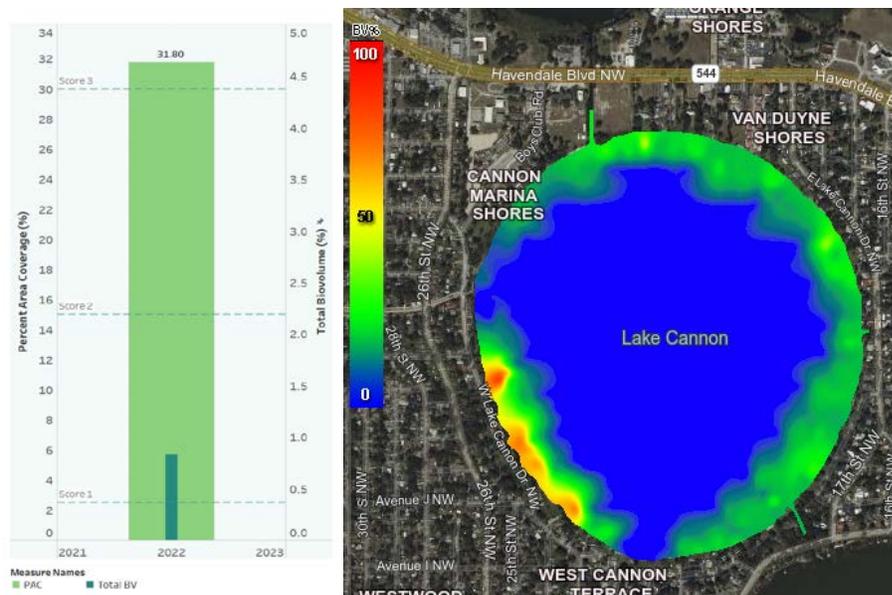| Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3
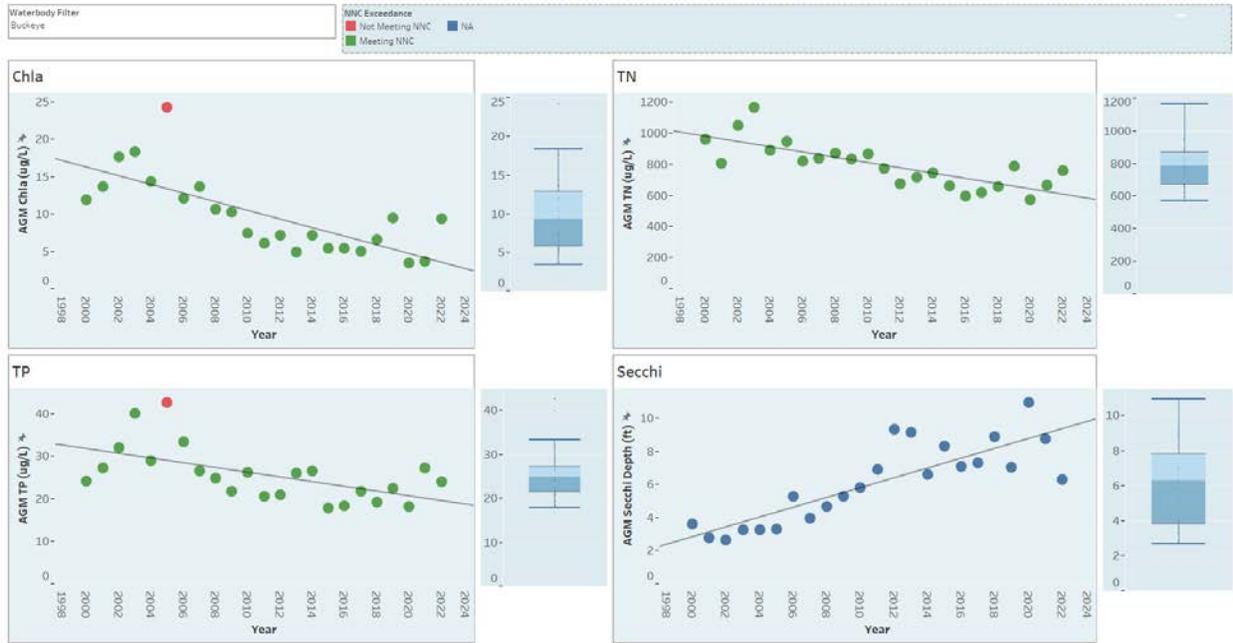
Figure 3-14. Lake Buckeye AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Buckeye on April 15th, 2022. The PAC during this survey was 98.8% and the total BV was 34.98%--equating to an abundance criterion score of 3 (Figure 3-15). Like during previous years, Lake Buckeye has a very dense vegetation community which covers the majority of the lake bed and takes up over a third of the water column. This likely contributes to its excellent water quality.
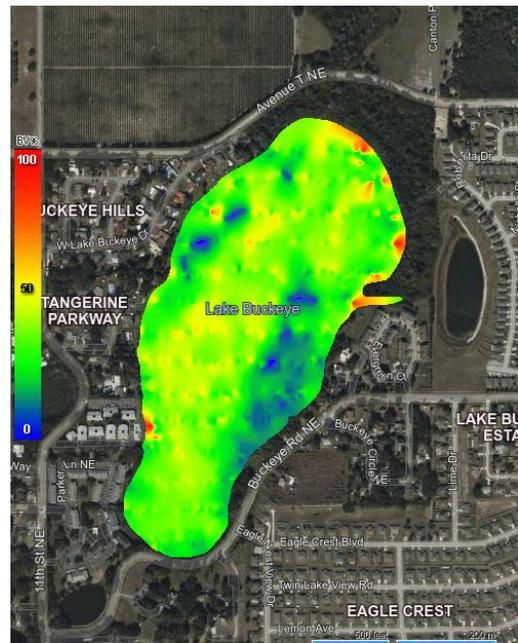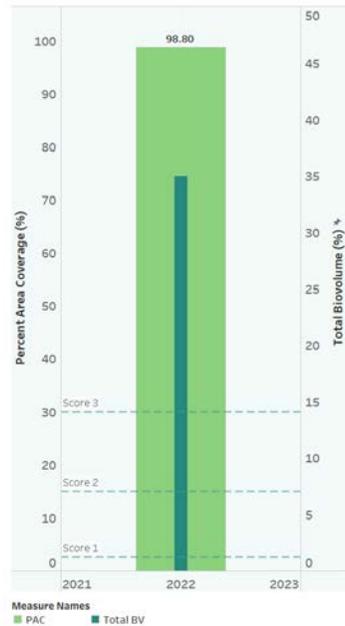
Figure 3-15. Graph depicting 2022 PAC/BV and biovolume heatmap; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, nearly 50% of the vegetation community was comprised of coontail—a submerged native plant. Making up the remaining 52% of the community was a relatively even mix of submerged, emergent, and floating leaf species. Invasive species like burhead sedge and parrotfeather made up just 2.98% of the community—earning an

invasive criterion score of 1. 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.
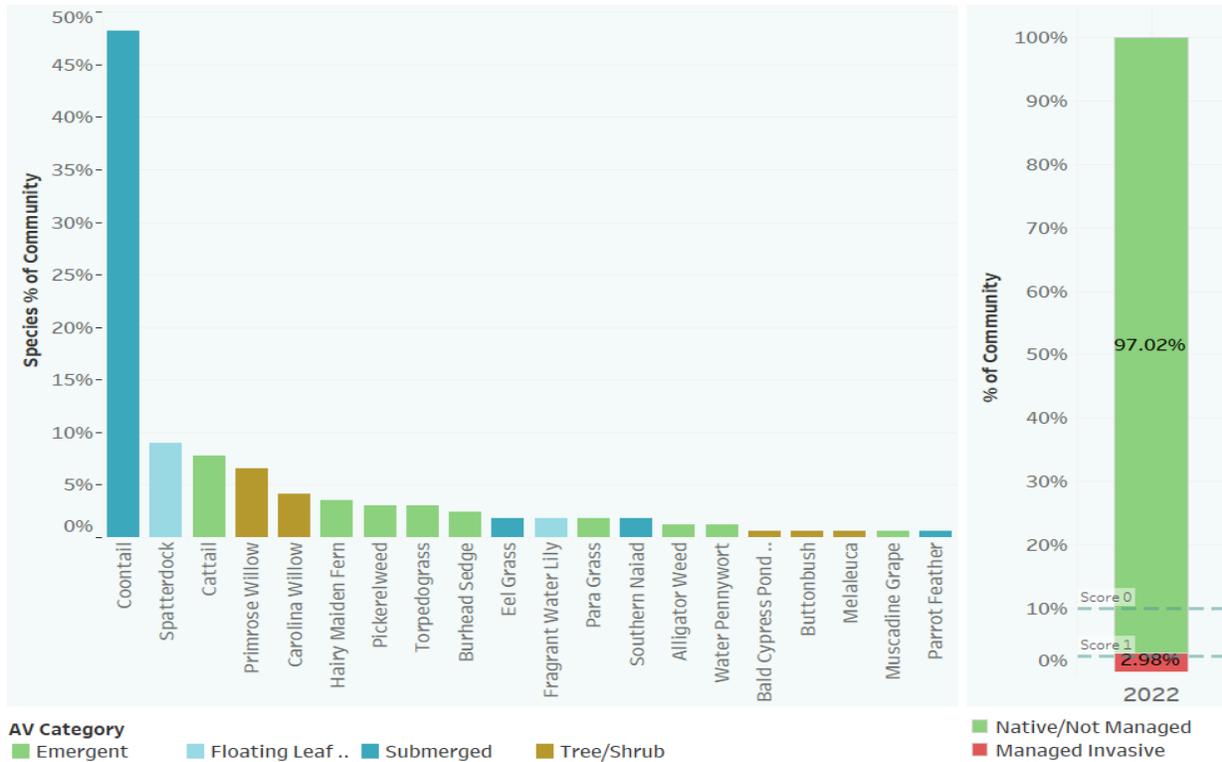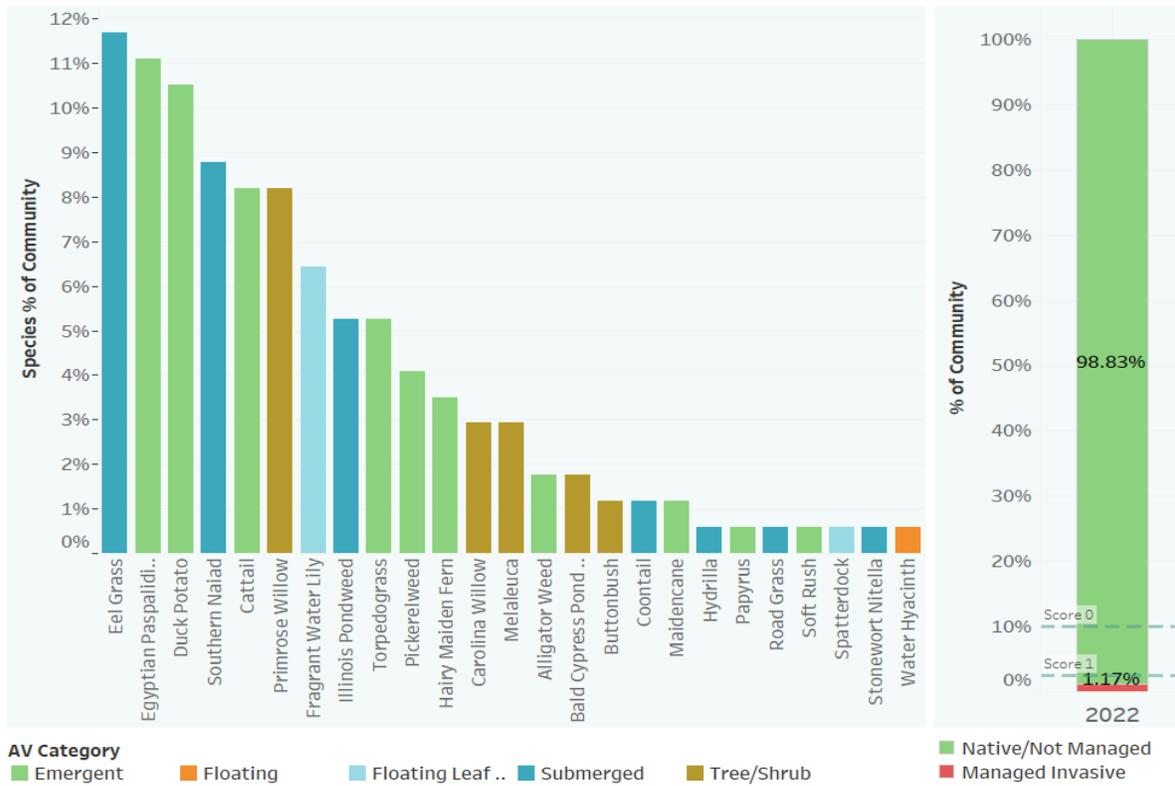

Figure 3-16. Chart depicting species frequency and invasive species percentage of Lake Buckeye during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, all three of the diversity index values fell below their respective medians; resuting in a score of 0 (Figure 3-17). In previous years, species richness and overall diversity were higher. It could be that the removal of hydrilla has led to a slight decrease in overall richness and diversity. It should be noted that despite coontail's dominance, species evenness has increased since 2021—likely due to a more even spread of the other remaining species.
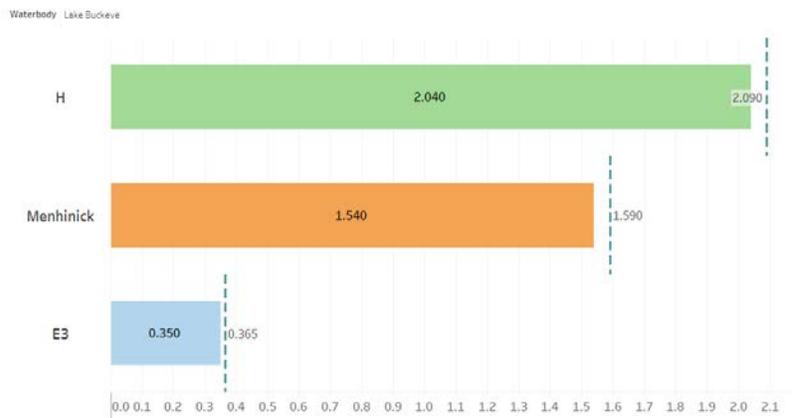
Figure 3-17. Chart depicting 2022 diversity indices for Lake Buckeye. Dashed lines represent median values.

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	2	2.6
2022	3	3	3	3	3	3	1	1	2.5

Figure 3-18. Chart depicting a comparison of Lake Buckeye's Lake Health Index scores from 2018 to 2022.

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.

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 Score
2	3	3	2	3	3	2	3	2.6

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 drainabe 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 2836 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 the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level.
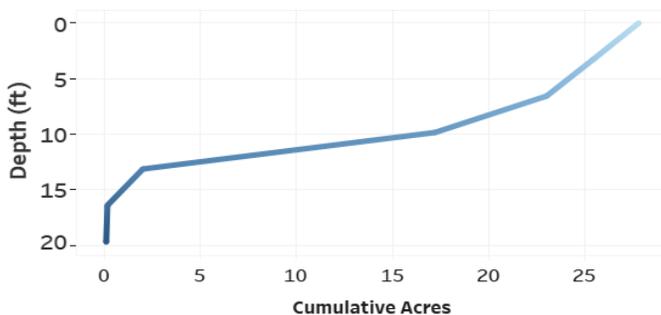

Figure 3-19. Hypsograph of Lake Cannon depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.
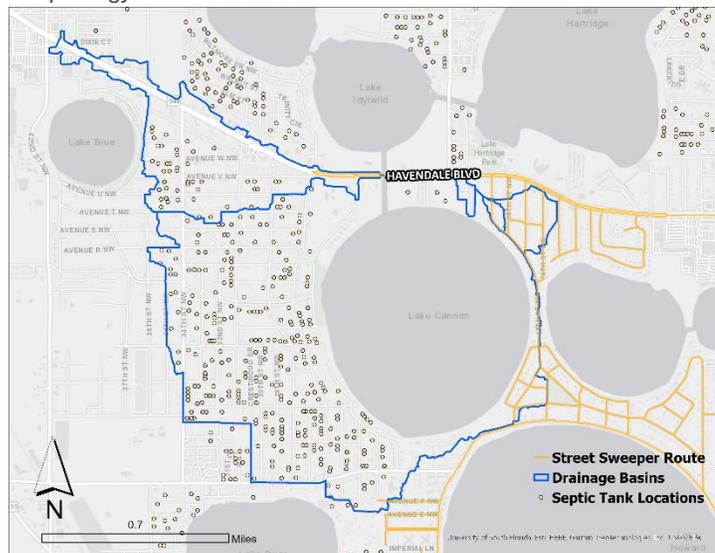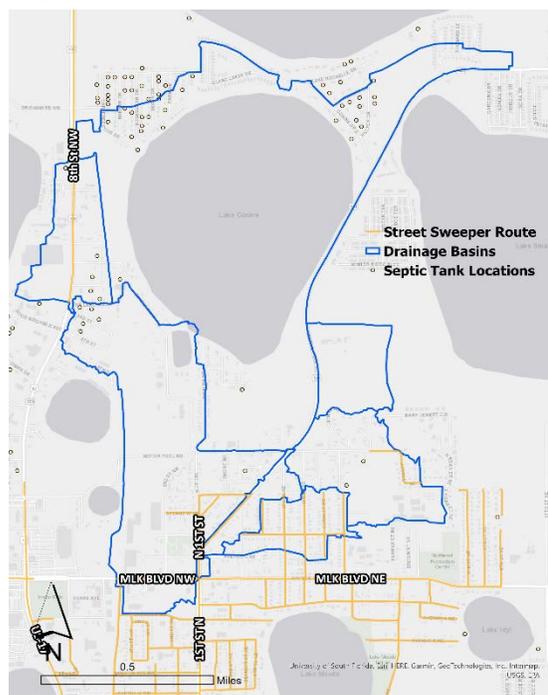

Figure 3-20. Map of Lake Cannon's drainage basin, City street sweeper routes, and nearby septic systems.

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 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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 Chla 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 2022. A box & 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 Cannon is categorized as a clear, alkaline waterbody. Based on exceedances of NNC thresholds in 2018, 2019, and 2020, it is considered impaired for Chla (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 Chla guidelines. It should be noted that Chla, TN, and TP all exceeded NNC thresholds in 2022. Continued exceedances may result in reinstatement of impaired status for the nutrient parameters.

Parameter	Impaired	Index Score
Chla	Y	
TN	N	2
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth

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

values from 2000 to 2022. Only Secchi depth exhibited a significant improving trend; Chla, TN, and TP exhibited non-significant improving trends during this period. Individual AGM values and trend statistics can be found in the appendix.
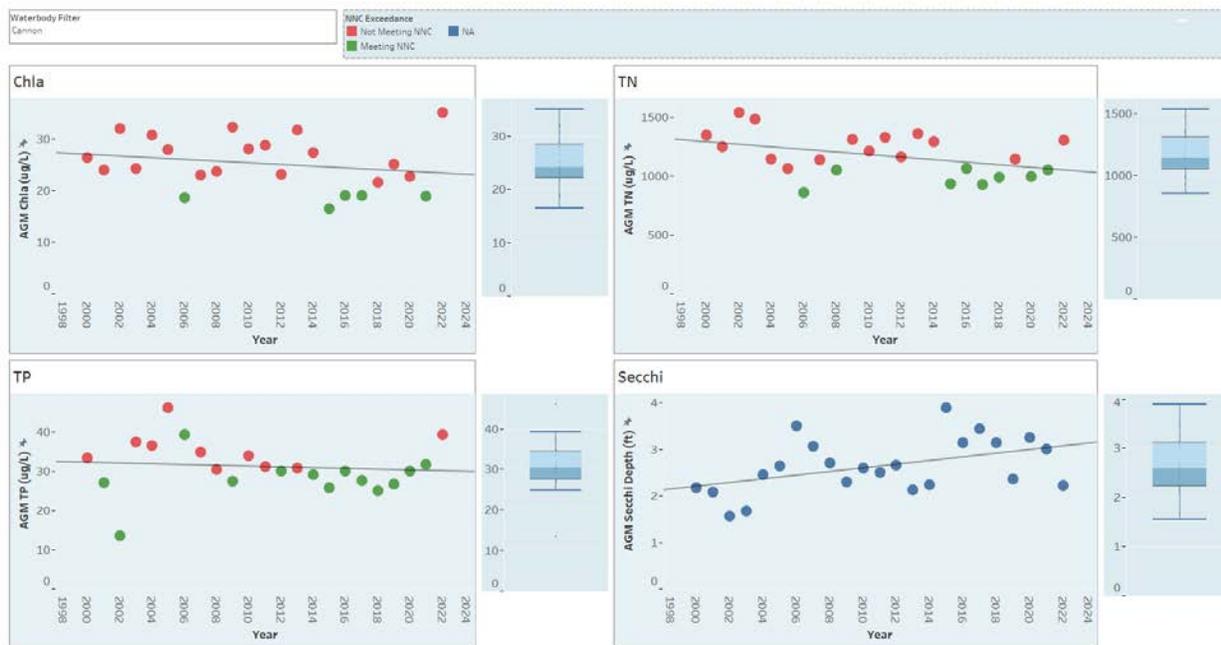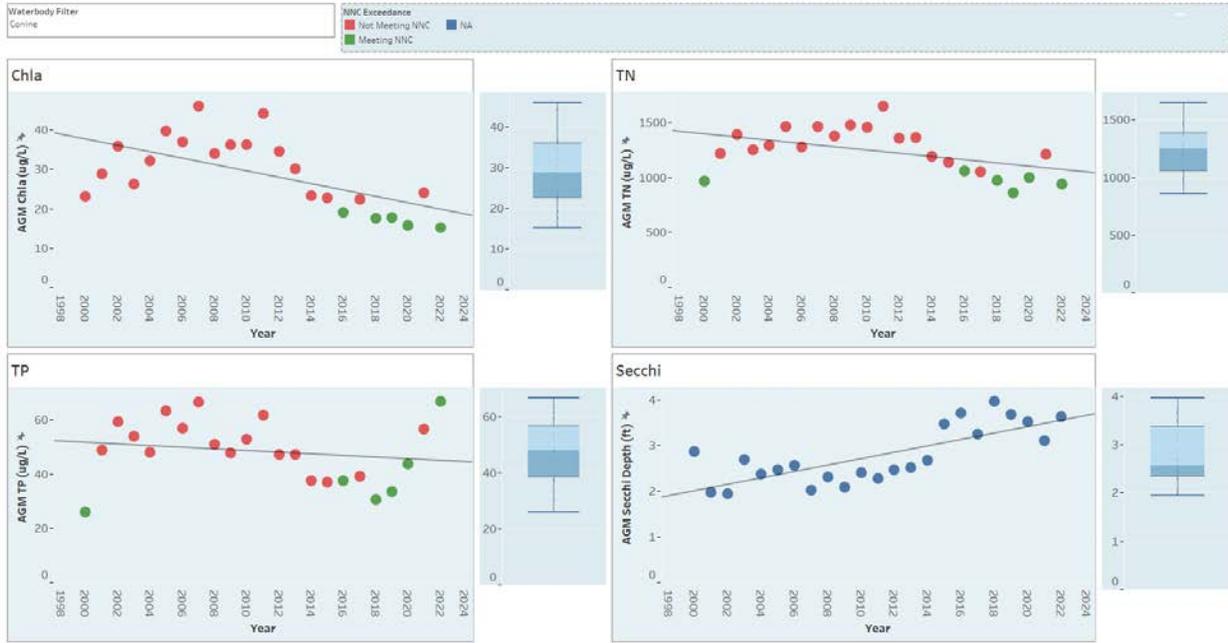

Figure 3-22. Lake Cannon AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted on Lake Cannon on August 2nd, 2022. The PAC during this survey was 31.8% and the total BV was 0.83% (Figure 3-23). Due to the slope of Lake Cannon's bed, the littoral zone is limited to around 10-12 feet in depth. A comparison to previous data shows consistent PAC values, but the BV during 2022 was much lower than usual. It appears that submerged vegetation was not reaching the surface like during previous survey years. This could be due to invasive species management or private vegetation removal by lakeshore residents. Regardless, the PAC exceeded the 30% threshold in 2022, resulting in an abundance criterion score of 3.
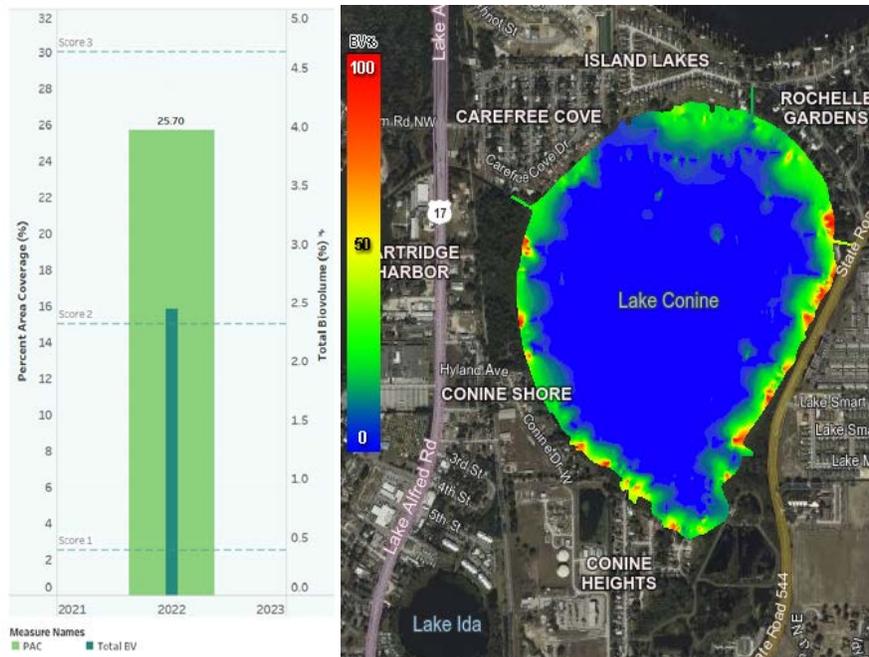

Figure 3-23. Graph depicting 2022 PAC/BV and biovolume heatmap; biovolume values range from green (lowest) to red (highest).

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 vegegation community was comprised of a good mix of submerged and emergent species. The most abundant species were natives like eel grass, Kissimmee grass, and duck potato (Figure 3-24). Invasive species like hydrilla and water hyacinth were present in minor amounts—not totalling more than 1.2% of the community. As a result, Lake Cannon scored a 2 in the invasive species presence criterion.

Figure 3-24. Chart depicting species frequency and invasive species percentage of Lake Cannon during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to 2022 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. In 2022 there was a higher number of emergent species recorded—likely due to
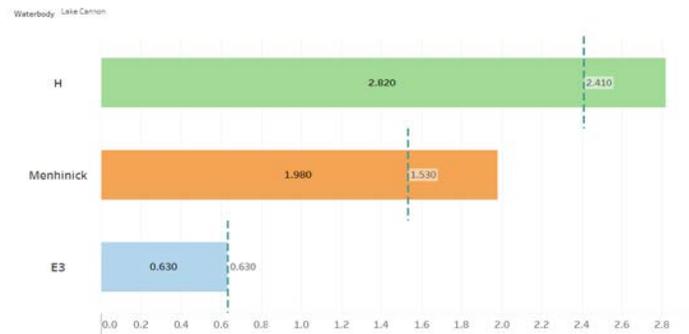
Figure 3-25. Chart depicting 2022 diversity index values for Lake Cannon. Dashed lines represent median values.

changes in how lakefront homeowners manage their shorelines. Additionally a reduction of hydrilla likely opened up habitat space for other submerged plants.

Lake Health Tracking:

A comparison of Lake Cannon's health index scores from 2018 to 2022 shows a gradual increase in overall lake health (Figure 3-26). In the five 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	2	2	2.3
2021	2	3	3	2	3	3	1	2	2.4
2022	2	2	2	2	3	3	2	3	2.4

Figure 3-26. Chart depicting a comparison of Lake Cannon's Lake Health Index scores from 2018 to 2022.

Lake Health Impacts/Challenges:

- Lake Cannon is still impaired in at least one NNC parameter. 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.

- 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 Score
0	3	2	2	3	2	1	1	1.8

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 2836 lbs of TN and 474 lbs of TP annually. There are 39 Onsite Sewage Treatment & Disposal (OSTD/septic) systems within this drainage basin at relatively low density. The City conducts monthly streets sweeping services up to 0.77 miles within this basin.

Over its 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 2022, Lake Conine reached a wet season peak of 129 feet in September and a dry season low of 128 feet in June. The surface level ended the year above the high end of the normal range at 128.47 feet.
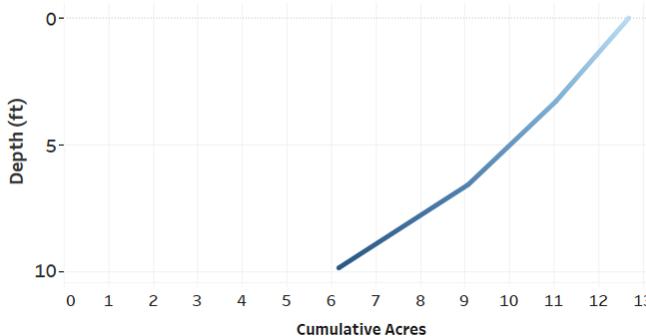

Figure 3-27. Hypsograph of Lake Conine depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.
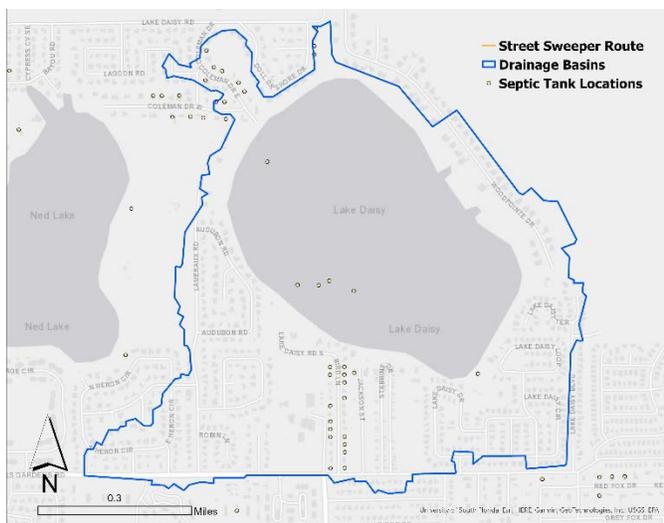

Figure 3-28. Map of Lake Conine's drainage basin, City street sweeper routes, and nearby septic systems.

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.
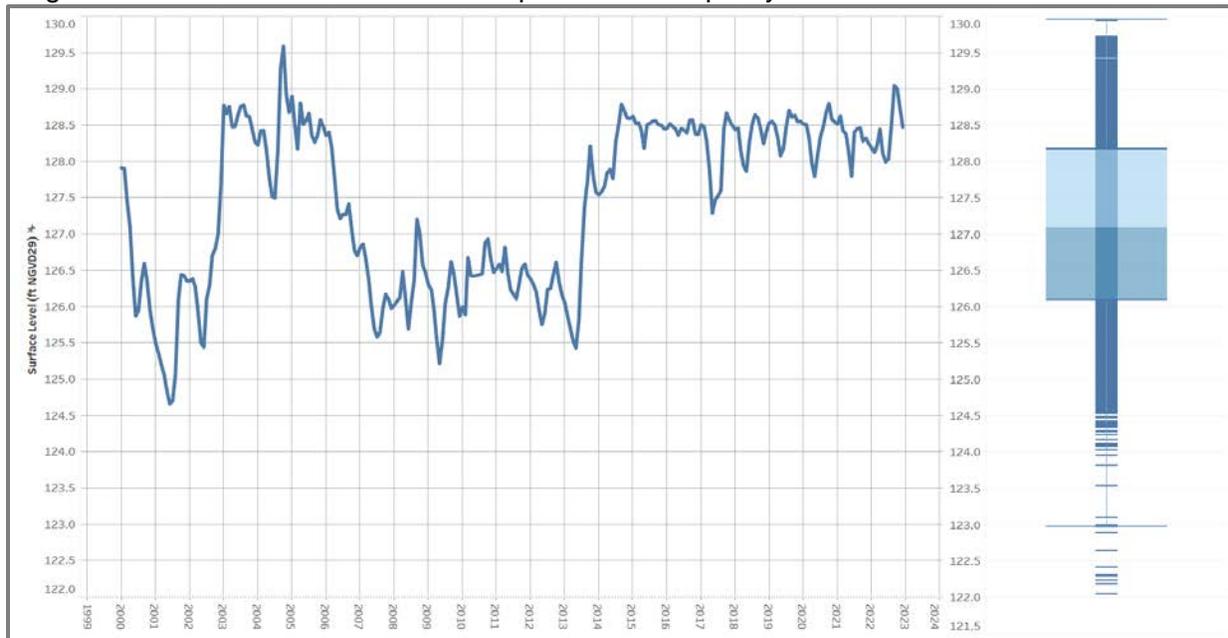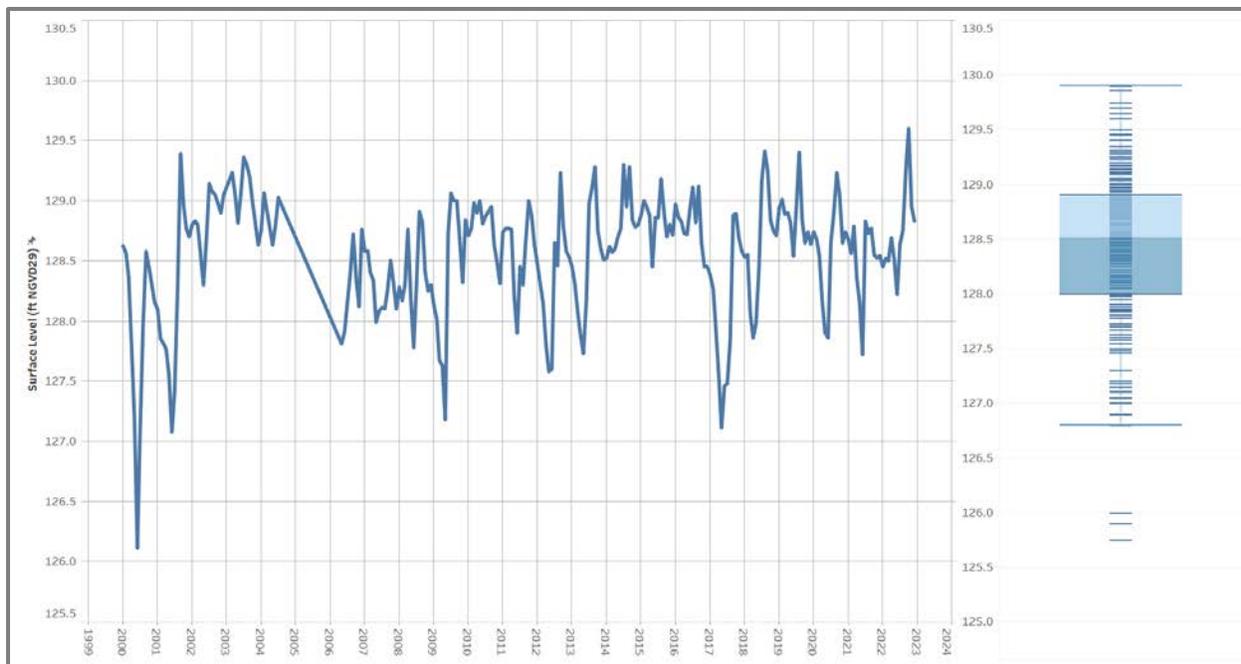

Figure 3-29. Hydrograph of Lake Conine depicting monthly surface level readings from 2000 to 2022. A box & whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impariment:

For the purposes of determining water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Conine is categorized as a clear, alkaline waterbody. Due to exceedances in 2015 and 2017 in each of the NNC parameters, Lake Conine is considered impaired for Chla, TN, and TP (Figure 3-30). Assuming that these metrics do not exceed NNC thresholds in the following years, Lake Conine should improve out of impairment status. 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.

Parameter	Impaired	Index Score
Chla	Y	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Lake Conine exhibits significant improving trends in Chla, TN, and Secchi depth and a non-significant improving trend in TP. This equates to water quality trend criteria scores of 3 for Chla, TN, and Secchi and a score of 2 for TP. 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 Chla, TN, TP, and Secchi depth values from 2000 to 2022. 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 July 29th, 2022. The PAC during this survey was 25.7% and the total BV was 2.44% (Figure 3-31). Comparison of vegetation abundance from 2018 to 2022 shows a marked drop in coverage and biovolume since 2021. This decline was likely due to treatment of invasive hydrilla stands. On a positive note, there was a slight increase in abundance from 2021 to 2022—indicating some recovery of vegetation coverage and volume.

Figure 3-31. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Conine; 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. During the 2022 surveye, only 12 unique species were recorded. Despite this low species richness, there was a relatively even mix of submerged and emergent plant types present. The most abundance species was the native eel grass at 27% (Figure 3-32). The only managed invasive species detected was hydrilla at 6%. However, this amount relates to an invasive presence criterion score of 1 for 2022. Hydrilla has historically been the primary invasive species present in Lake Conine.
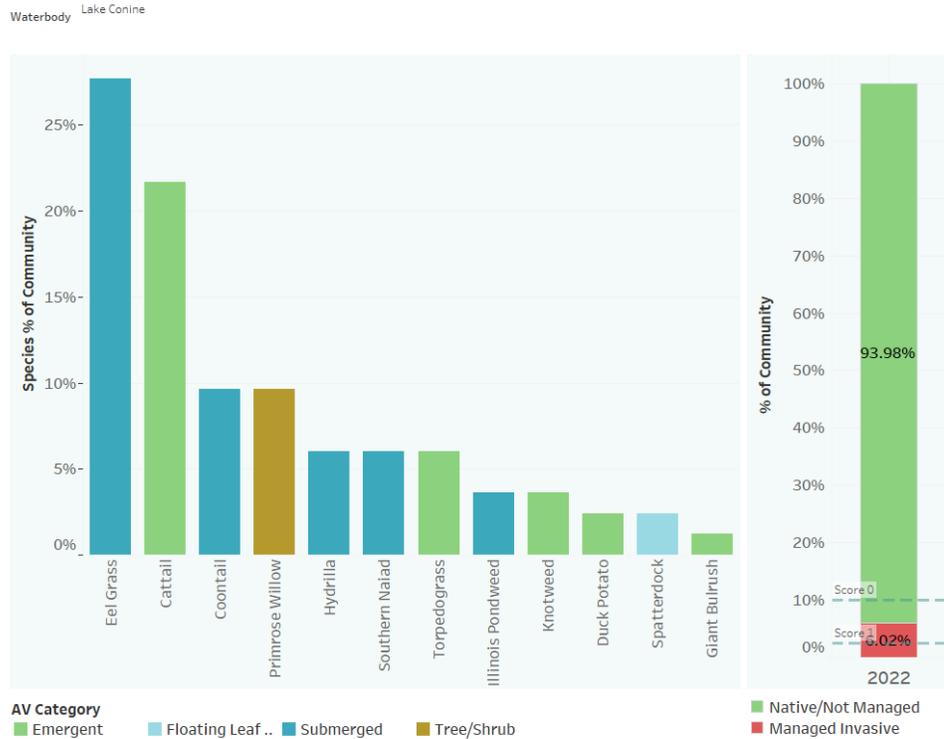
Figure 3-32. Chart depicting species frequency and invasive species percentage of Lake Conine during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, only the evenness index exceeded the long-term median for Lake Conine (Figure 3-33). Comparing 2022's data with previous years, there was a decline in both species richness and overall diversity. The number of species present was fewer than the previous survey. However, a decline in overall richness is not necessarily cause for concern if the species being removed are non-natives. The missing species were mostly exotics or invasives like alligator weed and burhead sedge.
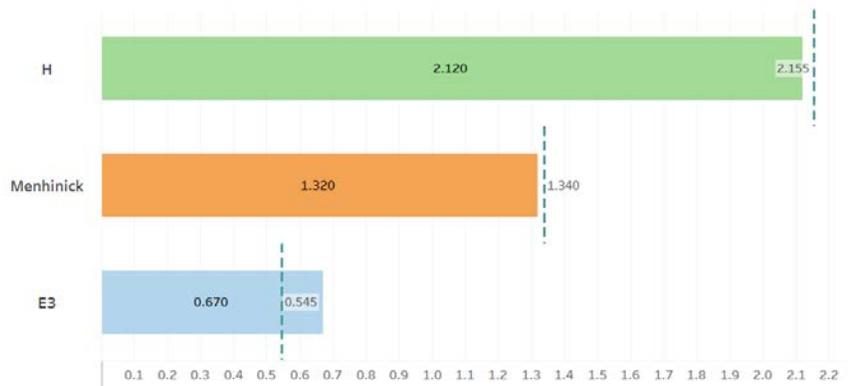
Figure 3-33. Chart depicting 2022 diversity indices for Lake Conine. Dashed line represent median values.

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 (Figure 3-34). Since impairment status hasn't changed during this five year span, the majority of the shifts have occurred through minor variation in trend and biological criteria scores. Trend significance has fluctuated during this time, but the direction of each of the water quality metrics has consistently been towards improvement. Vegetation abundance and diversity will often decrease in response to invasive species treatment. It is to be expected that treatment of hydrilla and burhead sedge led to minor declines in vegetation coverage and species richness.

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	1	2	2.1
2020	0	3	2	3	3	3	0	1	1.9
2021	0	3	2	2	3	2	1	3	2.0
2022	0	3	2	2	3	2	1	1	1.8

Figure 3-34. Chart depicting a comparison of Lake Buckeye's Lake Health Index scores from 2018 to 2022.

Lake Health Impacts/Challenges:

- In addition to stormwater influx to Lake Conine, the wastewater treatment plant in the vicinity was a contributor of historic point-source pollutants. These legacy nutrients in the lake bed are a potential source for 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 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:

- 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 Score
3	3	3	3	3	3	2	2	2.8

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. These factors place Lake Daisy in the Outlying Lakes group. 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 1717 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 2022, Lake Daisy reached a wet season peak of 129.6 feet in October and a dry season low of 128.2 feet in June. The surface level ended the year slightly above median at 128.8 feet. Changes in Lake Daisy's surface level are not correlated with Chla, 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 2022. A box and whisker plot detail total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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	
TN	N	0
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. 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
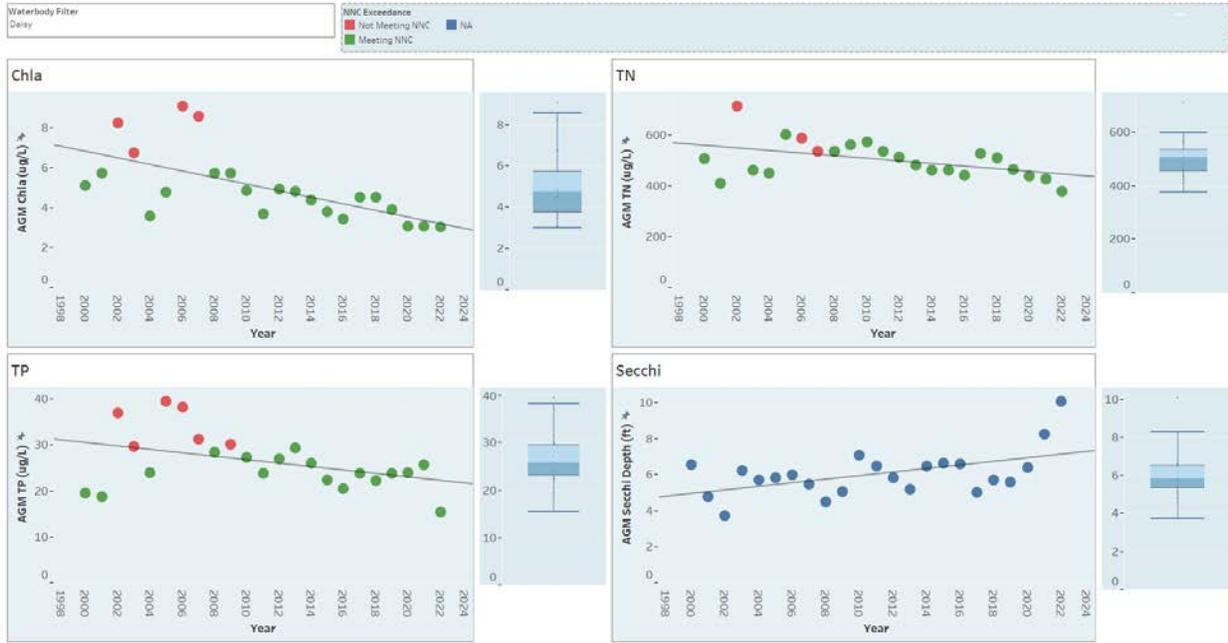
Figure 3-38. Lake Daisy AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Daisy on September 9th, 2022. The PAC during this survey was 31.1% and the total BV was 2.3% (Figure 3-39). Lake Daisy has traditionally lacked much submerged vegetation. The 2022 data shows a significant increase in submerged abundance from previous years—the result of an increased presence of native Baby's Tears in the lake. This increase in covered has resulted in an abundance criterion score of 3 for Lake Daisy.
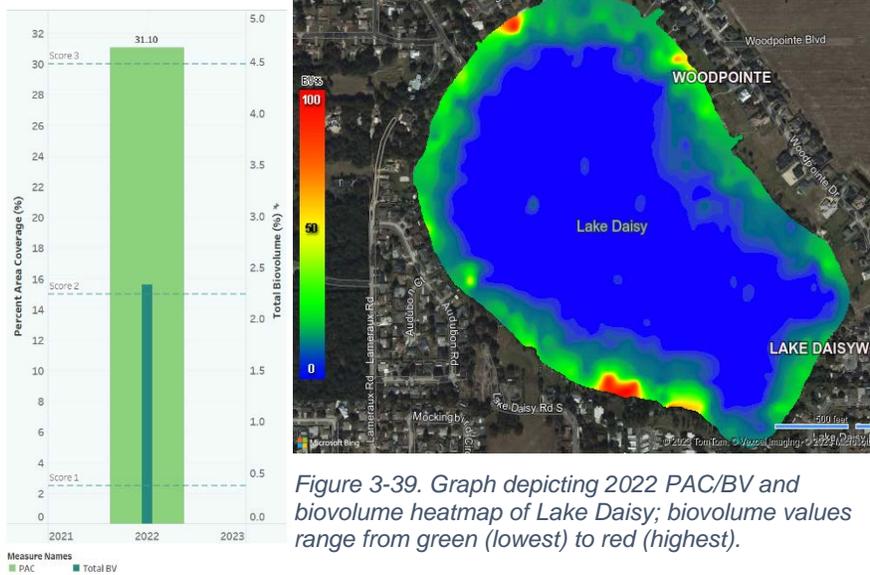
Figure 3-39. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Daisy; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, it is clear that Lake Daisy remains dominated by emergent species (Figure 3-40). However, the increased presence of Baby's Tears has increased the submerged counts by a large margin. Burhead sedge was the only managed

invasive species detected during the survey. It's presence made up less than 1% of the community—resulting in an invasive species criterion score of 2.
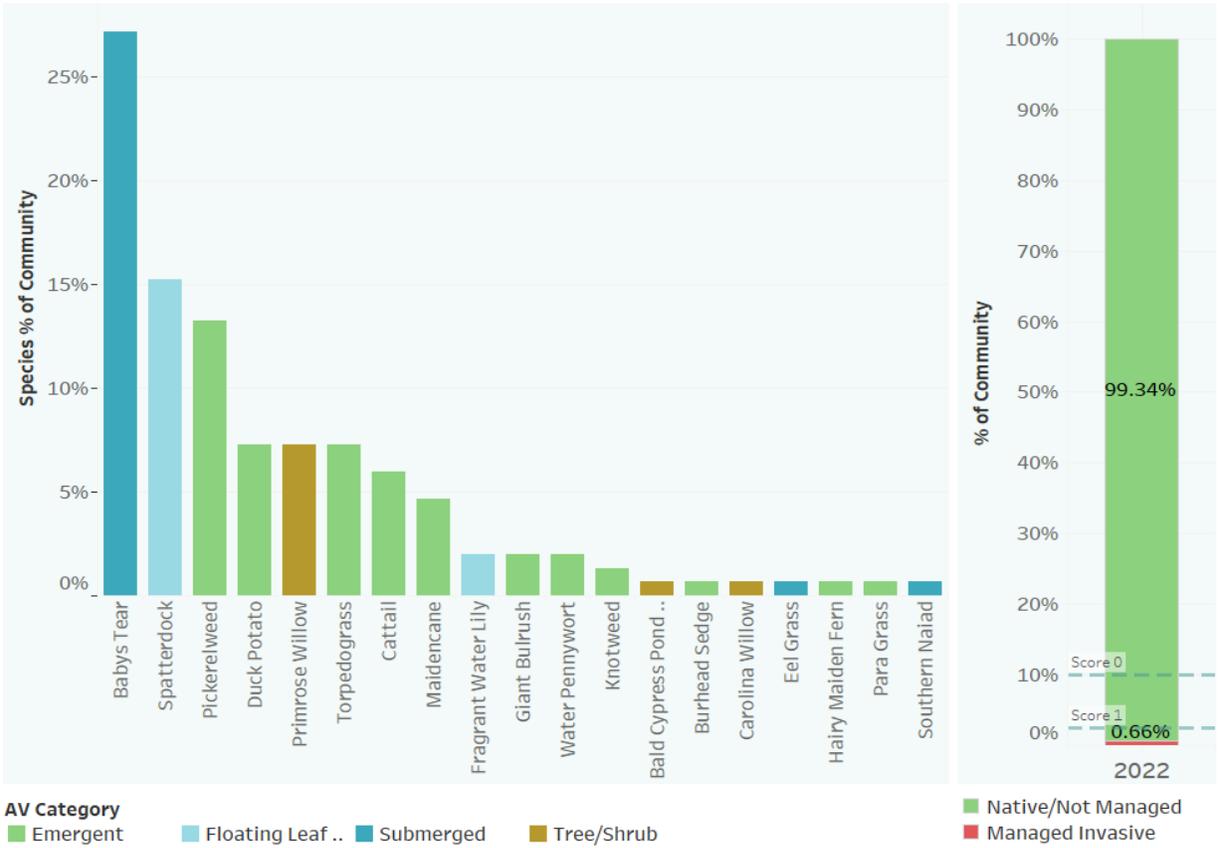
Figure 3-40. Chart depicting species frequency and invasive species percentage of Lake Daisy during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, both richness and diversity exceeded their respective median values (Figure 3-41). Richness saw an increase due to detections of native plants like southern naiad and young cypress trees not present during previous surveys. Evenness was lower likely because of increased dominance by the Baby's Tears. However, an increase in diversity without an added presence of invasive species is a boon to lake habitat and water quality.
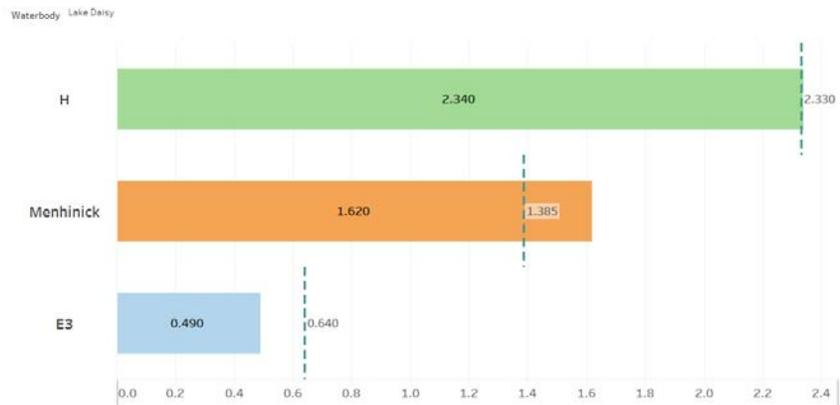
Figure 3-41. Chart depicting 2022 diversity indices for Lake Daisy. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Daisy's health index scores from 2018 to 2022 shows a substantial increase during the latest assessment and the highest lake health score for this waterbody on record (Figure 3-42). The majority of this increase has come from statistical significant changes in three of the four trend criteria. The increase in vegetation abundance has also pushed Lake Daisy's score higher. Maintaining a healthy vegetation community will help to ensure that water quality remains in a good place for the future.

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

Figure 3-42. Chart depicting a comparison of Lake Daisy's Lake Health Index scores from 2018 to 2022.

Lake Health Impacts/Challenges:

- Lake Daisy currently exhibits acceptable water quality. However, stormwater pollutant loading is a potential concern if water quality trends ever change for the worse.

- 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 Score
3	2	3	2	3	3	0	3	2.4

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. These factors place Lake Deer into the Outlying Lakes group. Lake Deer is a smaller waterbody at 119 acres, 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 1451 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 (Figure 3-45). That said, Deer's surface level has not exceeded 140.1 feet since before the year 2000. The normal range fluctuates between 136.9 and 139.6 feet.

Figure 3-43. Hypsograph of Lake Deer depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.
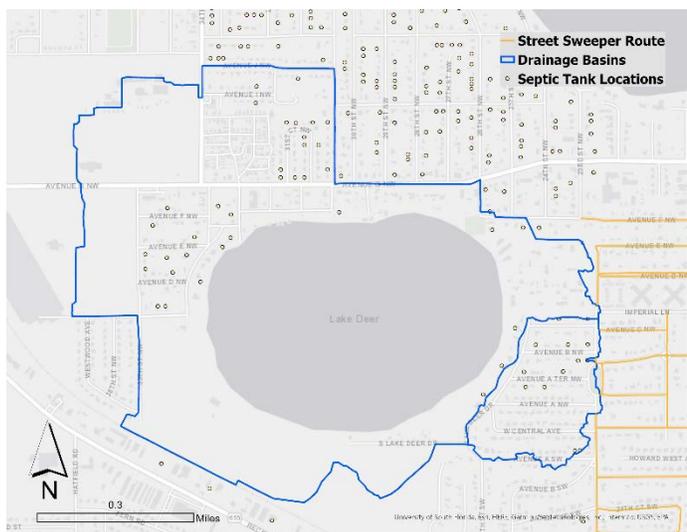
Figure 3-44. Map of Lake Deer's drainage basin, City street sweeper routes, and nearby septic systems.

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. As it stands, changes in Lake Deer's surface level are not correlated with any of the primary water quality metrics (see appendix).
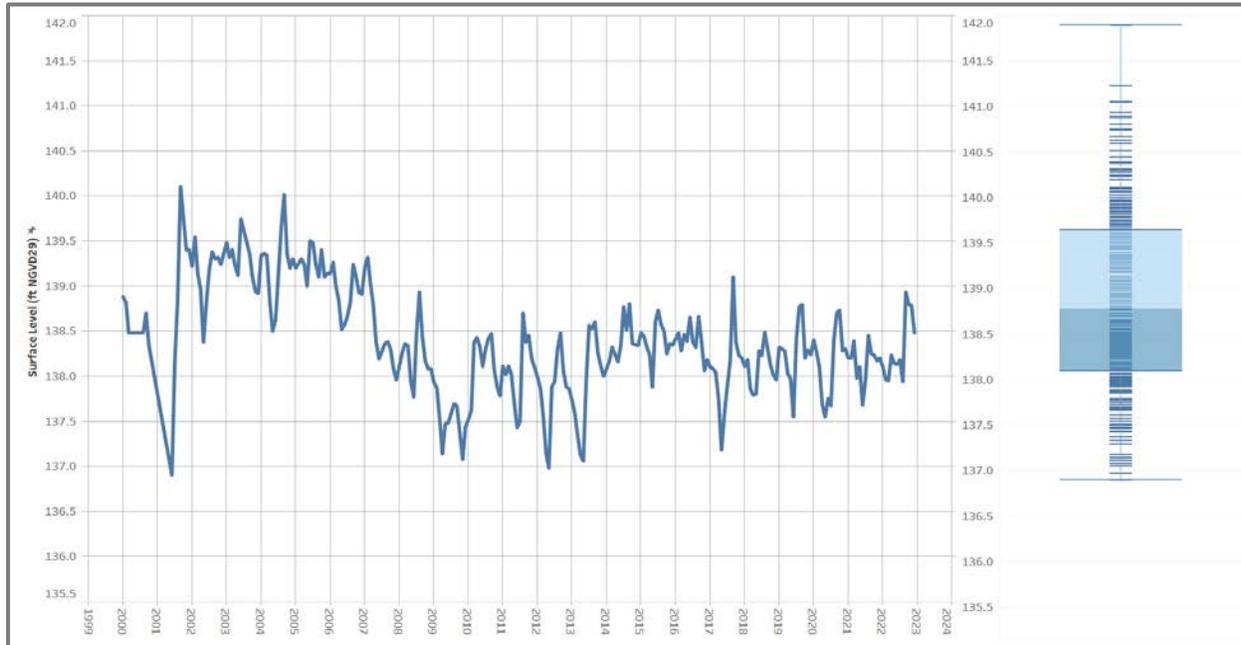
Figure 3-45. Hydrograph of Lake Deer depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface levels during the period of record.

Water Quality Impairment:

For the purposes of determining 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	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. As of 2022, TN and Secchi depth exhibit significant improving trends; while Chla and TP exhibit non-significant improving trends. 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 (Improving)	Significant	3
TP	Decreasing	Not Significant	2
Secchi	Increasing (Improving)	Significant	3
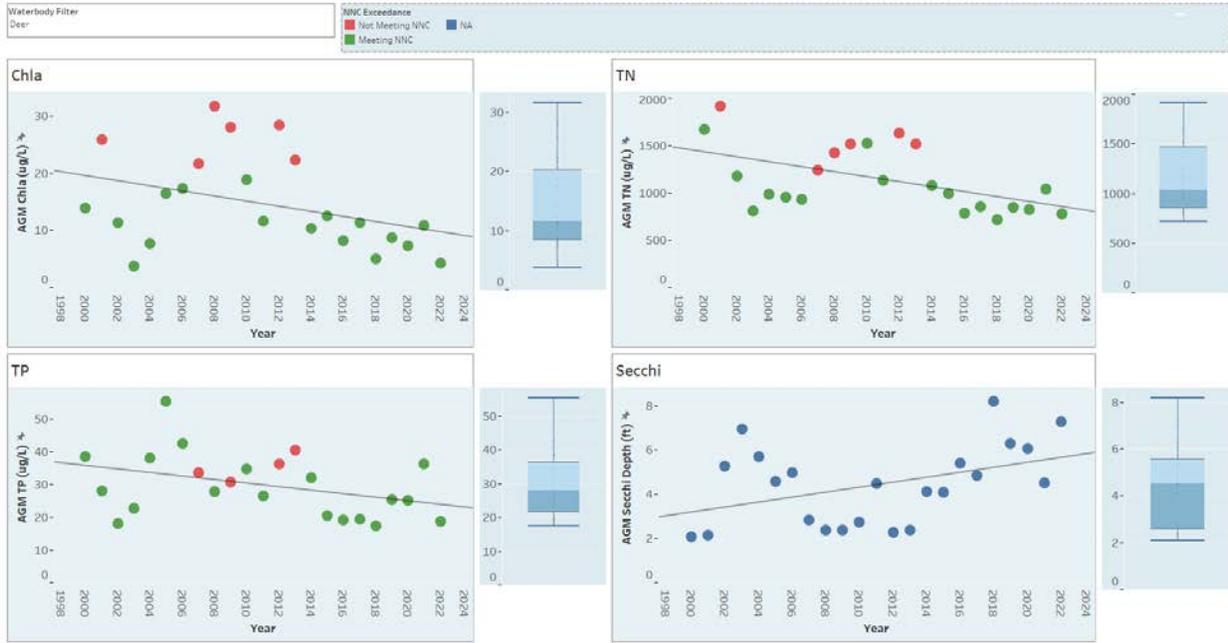
Figure 3-46. Lake Deer AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Deer on January 18th, 2022. The PAC during this survey was 71.9% and the total BV was 16% (Figure 3-47). Lake Blue has historically maintained very high abundances of aquatic vegetation due to a high presence of submerged aquatic plants. It is likely that the improvements in water quality observed are due, in part, to the nutrient sequestration capacity of this vegetation.

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, submerged plants make up a large percentage of the total vegetation community at 42%

Figure 3-47. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Deer; biovolume values range from green (lowest) to red (highest).

(Figure 3-48). The two major species competing for dominance are the native eel grass and the invasive hydrilla. As of 2022, eel grass is beating out the invasives. However, hydrilla still makes

up over 17% of the community. This abundance of invasive species equates to an invasive criterion score of 0.
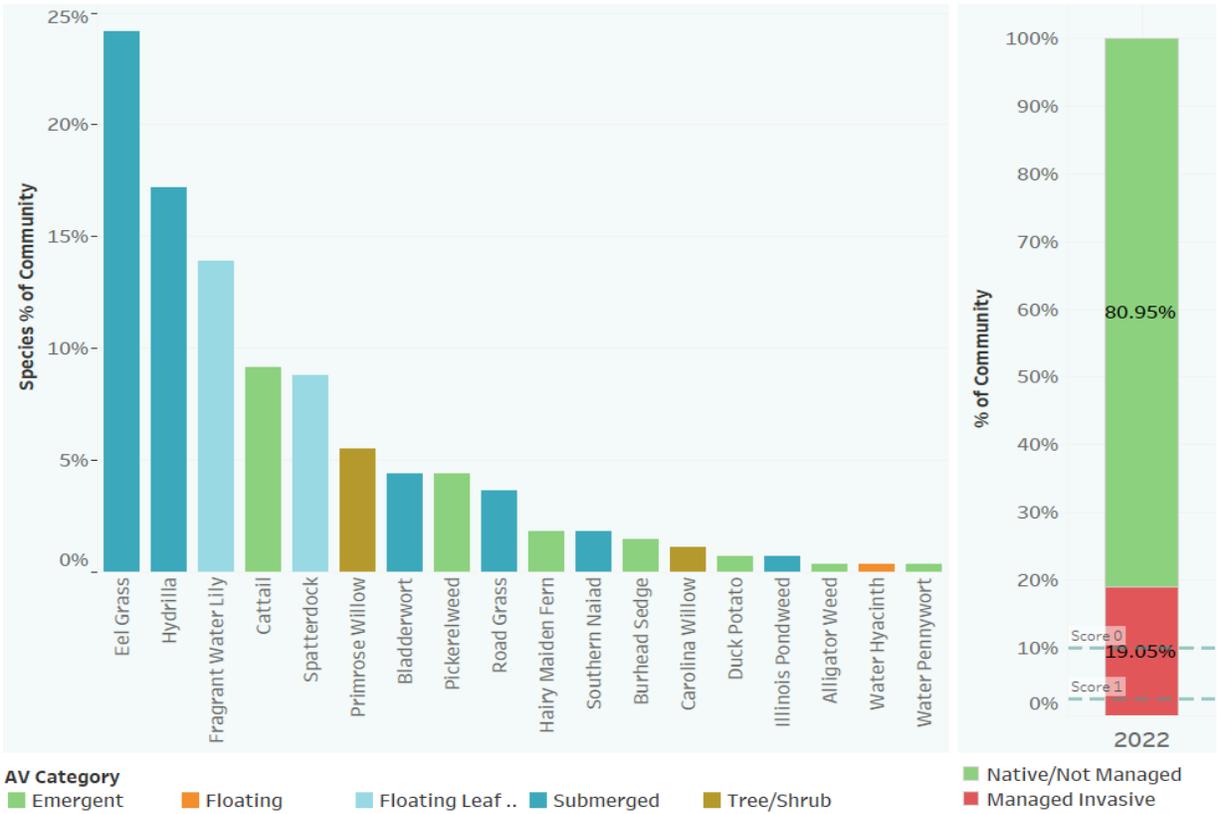
Figure 3-48. Chart depicting species frequency and invasive species percentage of Lake Deer during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, only the overall diversity index (H) met its median value; species richness and evenness fell below their respective medians (Figure 3-49). This earns Lake Deer a score of 1 in the diversity criterion. A comparison from the 2021 diversity values actually shows a slight increase in all three indices. The evenness and richness values likely change in reponse 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 time spans— leading to these fluctuations in diversity.
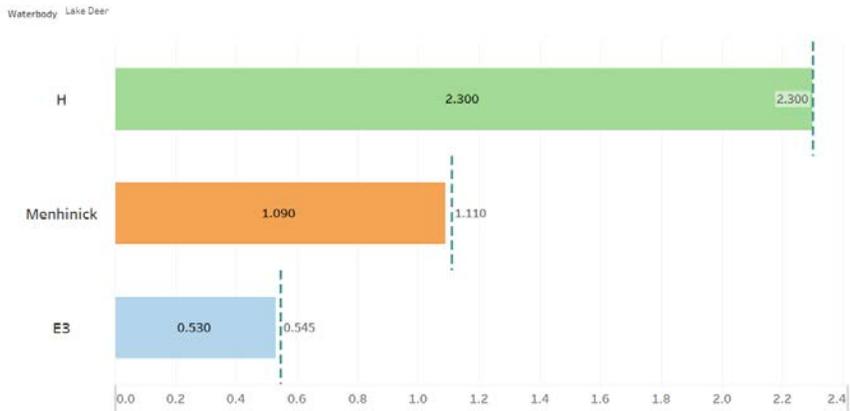
Figure 3-49. Chart depicting 2022 diversity indices for Lake Deer. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Deer's health index scores from 2018 to 2022 shows a substantial increase in the last year. Since the City began documenting lake health, Lake Deer has consistently been impaired. This change to the impairment status as well as the trend significance shifts are huge indicators of water quality improvement—resulting in an all time high score for Lake Deer (Figure 3-50). Vegetation abundance remains high, but the main issue plaguing Lake Blue is now 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	0	2	1.6
2019	0	2	2	2	2	3	0	2	1.6
2020	0	2	2	2	2	3	1	2	1.8
2021	0	2	3	2	2	3	0	0	1.5
2022	3	2	3	2	3	3	0	1	2.1

Figure 3-50. Chart depicting a comparison of Lake Buckeye's Lake Health Index scores from 2018 to 2022.

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 Score
3	0	0	0	0	3	0	2	**1.0**

Location, Characteristics, & Hydrology:

Lake Elbert is located to the east of central Winter Haven. Lake Elbert is the most upstream waterbody in the South Central Lakes group, 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, residential, and open land. Based on stormwater modelling, these land uses contribute up to 2365 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.
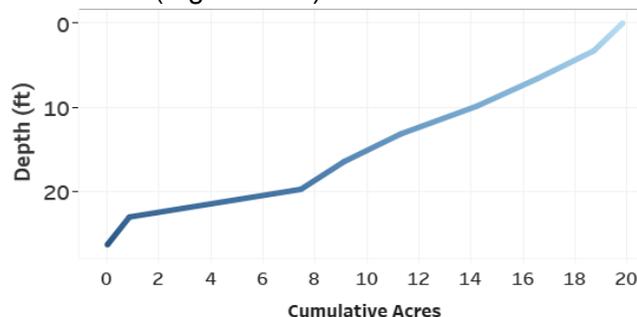
Figure 3-51. Hypsograph of Lake Elbert depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

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

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 2022, Elbert reached a wet season peak of 136.9 feet in October and a dry season low of 134.3 feet in July. The end of year level was 135.9—over one foot higher than the upper normal range. Based on 2019 regression analyses, changes

in Lake Elbert's level are significantly correlated with Chla, TN, TP, and clarity such that an increase in surface level should result in water quality improvements.
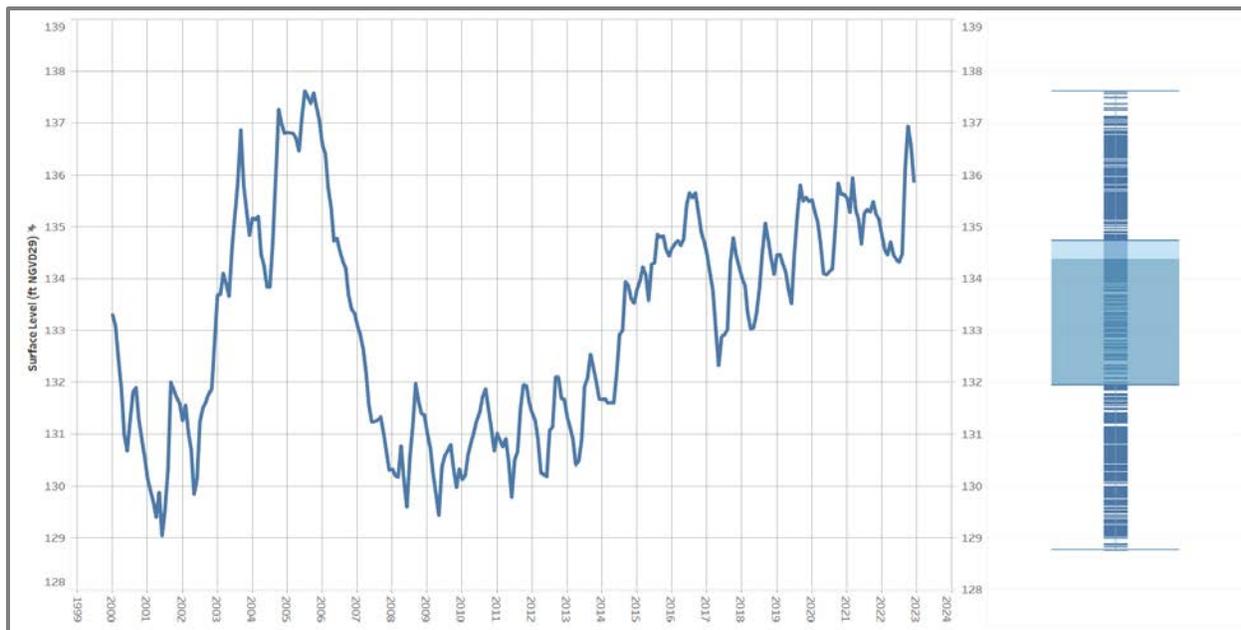
Figure 3-53. Hydrograph of Lake Elbert depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of 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	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Each of these four parameters are exhibiting significant declining trends—earning scores of 0 for each of the trend criteria. 2022 AGM values for Chla, TN, and Secchi depth were the poorest in the period of record. It is not abundantly clear what is driving this decline in water quality, but investigating the cause is a top priority for City staff. 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
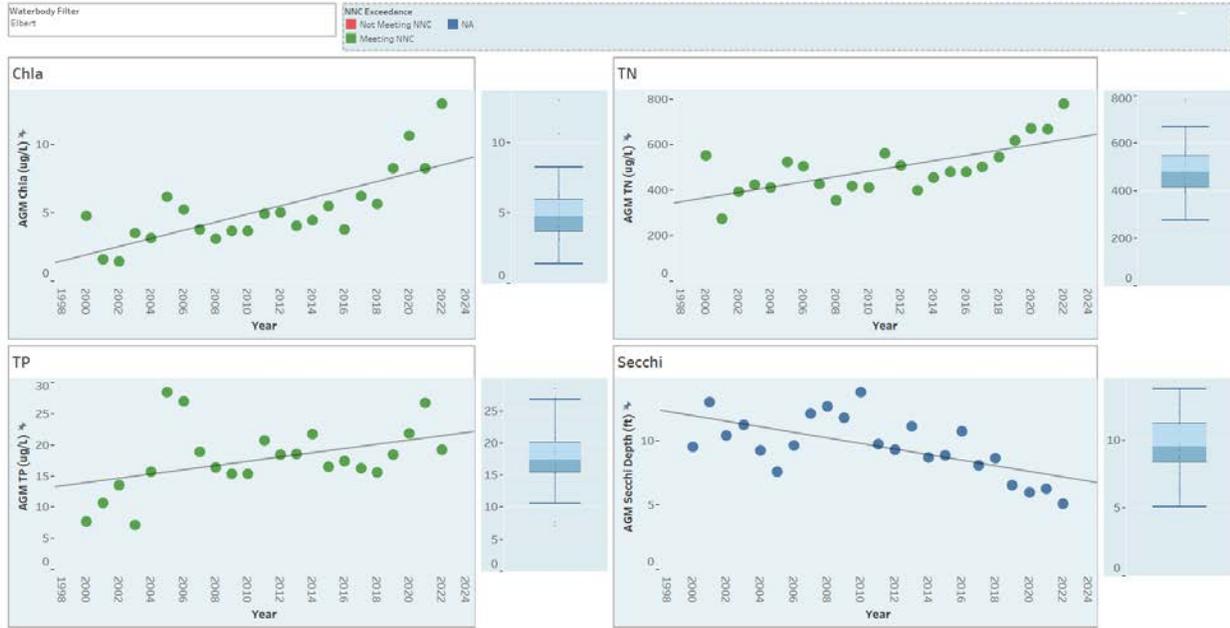
Figure 3-54. Lake Elbert AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Elbert on July 15th, 2022. The PAC during this survey was 46.4% and the total BV was 5.6% (Figure 3-55). A comparison of abundance from previous years shows a slight, but steady decline in PAC from 59% in 2018 to the current coverage. It appears that the deeper extent of the littoral zone may be shrinking—likely due to the decline in water clarity.
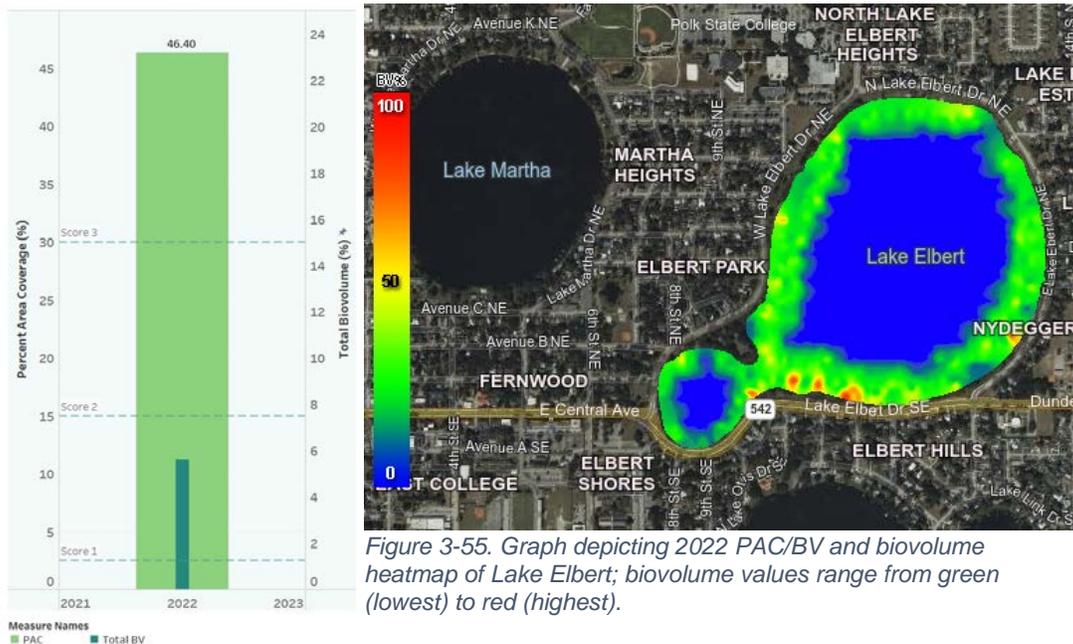
Figure 3-55. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Elbert; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on 2022 data, submerged plants made up the majority of the vegetation

community. Unfortunately, the invasive species hydrilla was the most dominant species at over 37%. Lake Elbert has historically had issues managing invasives and the dominance often shifts between hydrilla and eel grass on an annual basis. That said, the current amount of hydrilla is the highest on record. Currently Lake Elbert scores a 0 in the invasive species presence criterion.
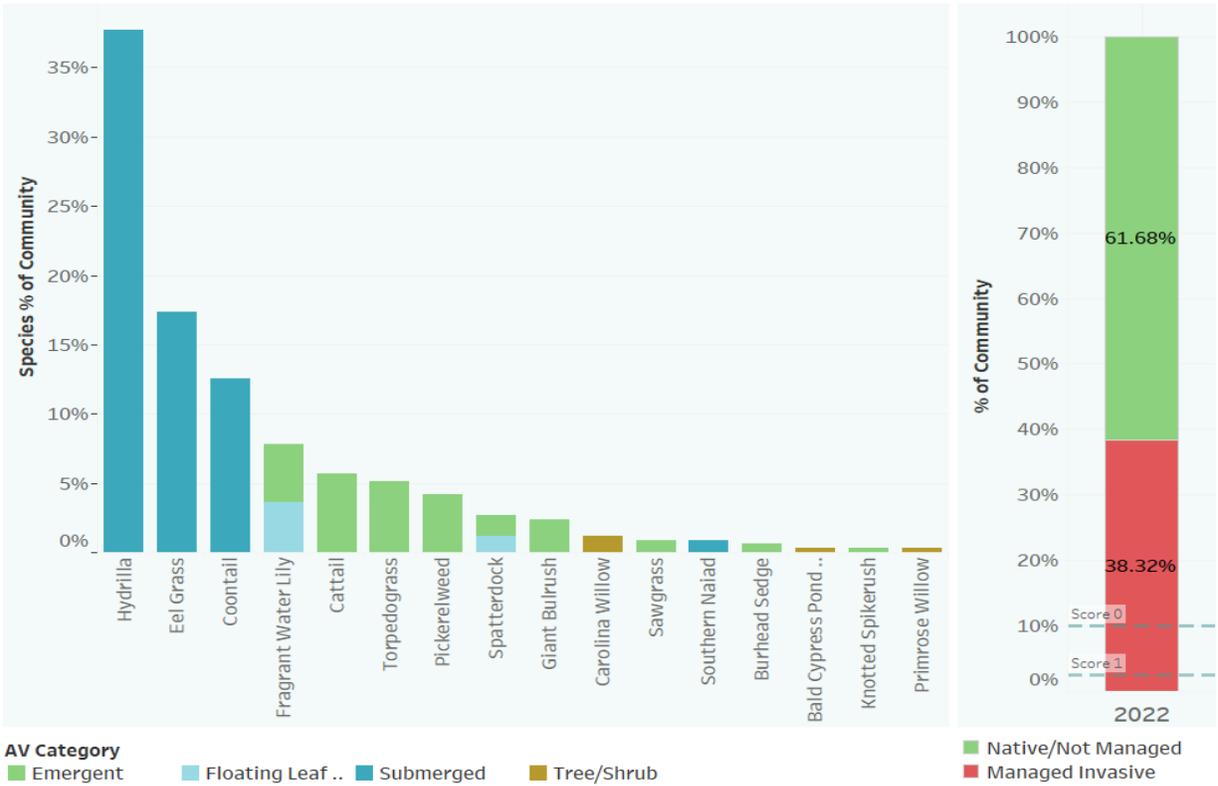
Figure 3-56. Chart depicting species frequency and invasive species percentage of Lake Elbert during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, the richness and evenness indices exceeded their respective median values—resulting in a diversity criterion score of 2 (Figure 3-57). Overall diversity exhibited a slight decrease from previous years—likely due to hydrilla reducing the habitable space for less competitive submerged species, like naiad and nitella. In addition to impeding navigation, the reduction in species diversity is one of the main ecological threats to invasive plants like hydrilla.
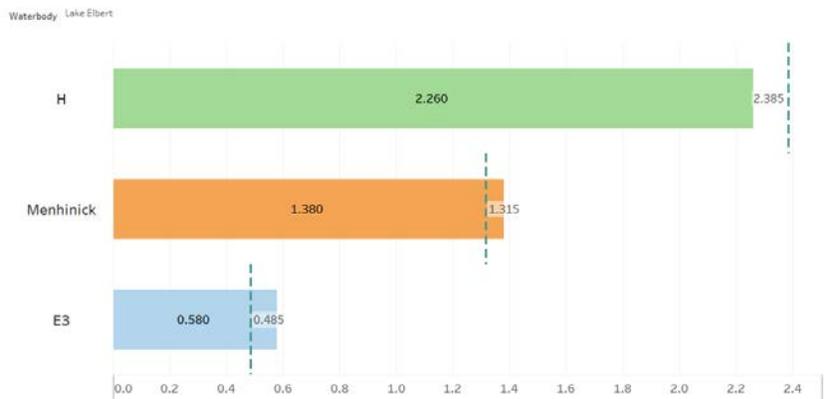
Figure 3-57. Chart depicting 2022 diversity indices for Lake Elbert. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Elbert's health index scores from 2018 to 2022 shows a gradual decline to the current score of 1 (Figure 3-58). Impairment status and vegetation abundance have remained static during this five year span. Invasive presence has consistently been high and the diversity scores fluctuate due to seemingly minor changes in the vegetation community. The major cause for concern is the transition from non-signficant to significant declining trends in 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	3	1	1	1.4
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

Figure 3-58. Chart depicting a comparison of Lake Elbert's Lake Health Index scores from 2018 to 2022.

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 hgih 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 herbidice applications are not advised due to the fagility 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.

- 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 in an effort 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 the drainage basin comprised of residential housing, 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 Score
0	2	2	2	3	2	2	1	1.8

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 1185 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 3875 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 at 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.

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.

Due to the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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 3-61). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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 Eloise's surface level do not correlate with water quality.
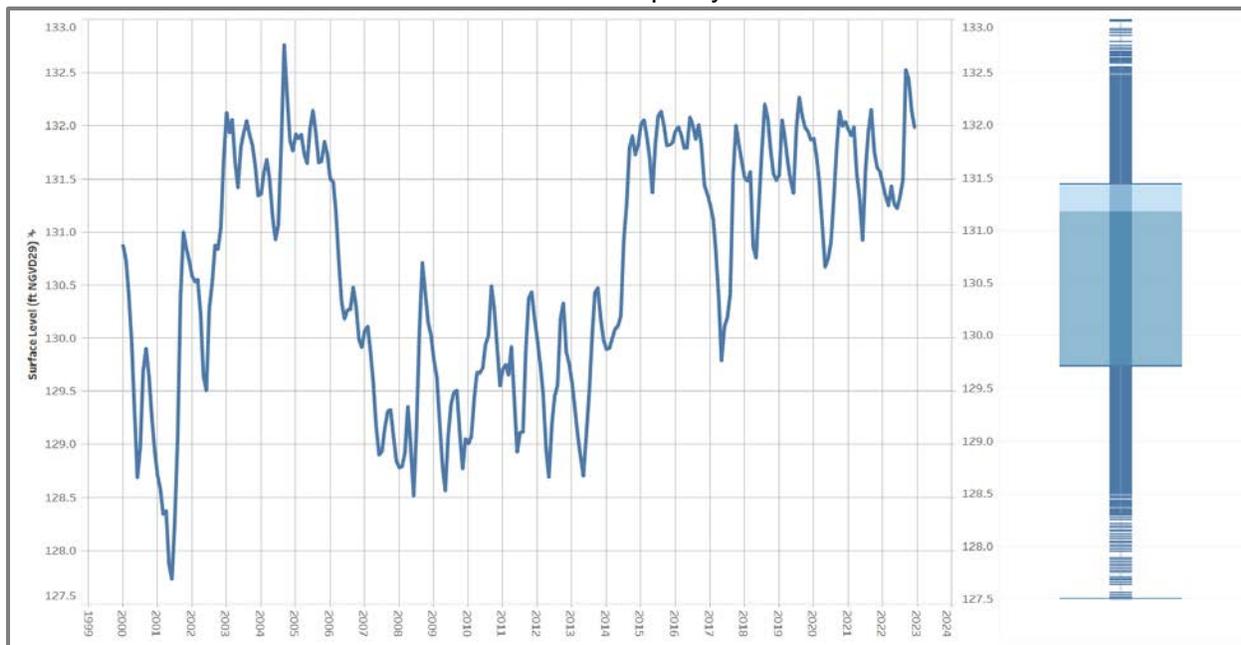
Figure 3-61. Hydrograph of the South Chain of Lakes depicting monthly surface level readings from 2000 to 2022. A box & whisker plot details the total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period, Lake Eloise is considered impaired for Chla, 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. It should be noted that 2022 AGM concentrations for Chla, TN, and TP were well below the normal range; and the first time Chla fell below NNC thresholds in recent record.

Parameter	Impaired	Index Score
Chla	Y	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Based on the trend data, Secchi depth exhibits a significant improving trend, resulting in a trend criterion score of 3. Chla, TN, and TP exhibit non-significant improving trends which equate to trend criteria scores of 2 for each. 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 (Improving)	Significant	3
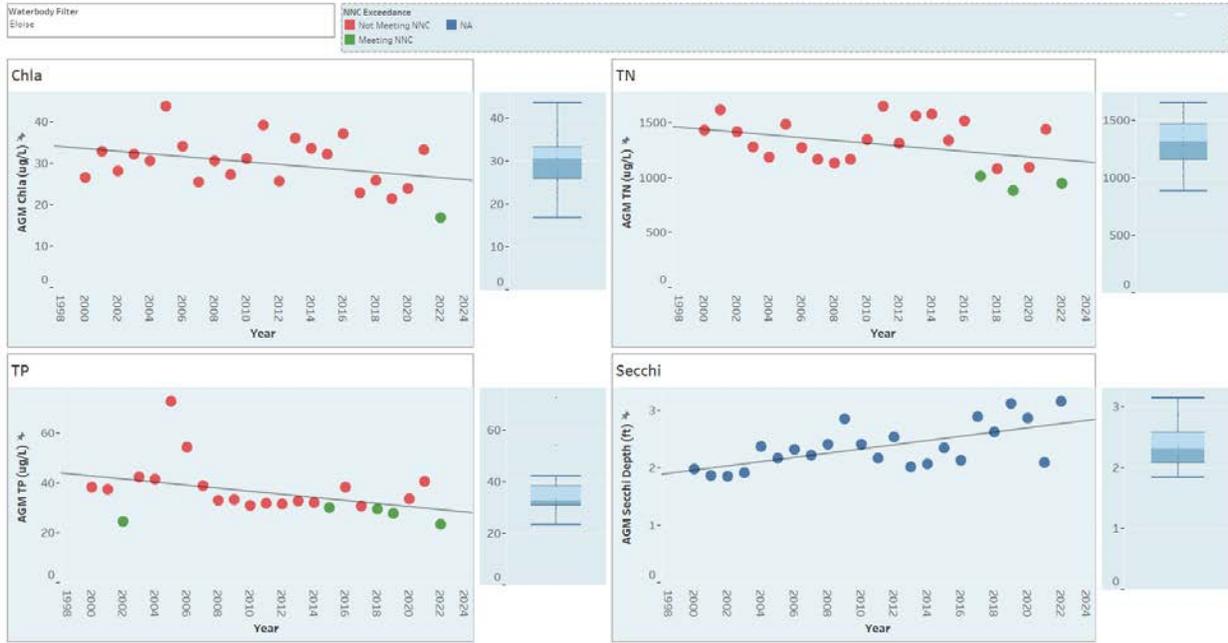
Figure 3-63. Lake Eloise AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative abundance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Eloise on December 14th, 2022. The PAC during this survey was 17.6% and the total BV was 1.92% (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 2022 abundance is still within the normal range for Lake Eloise.
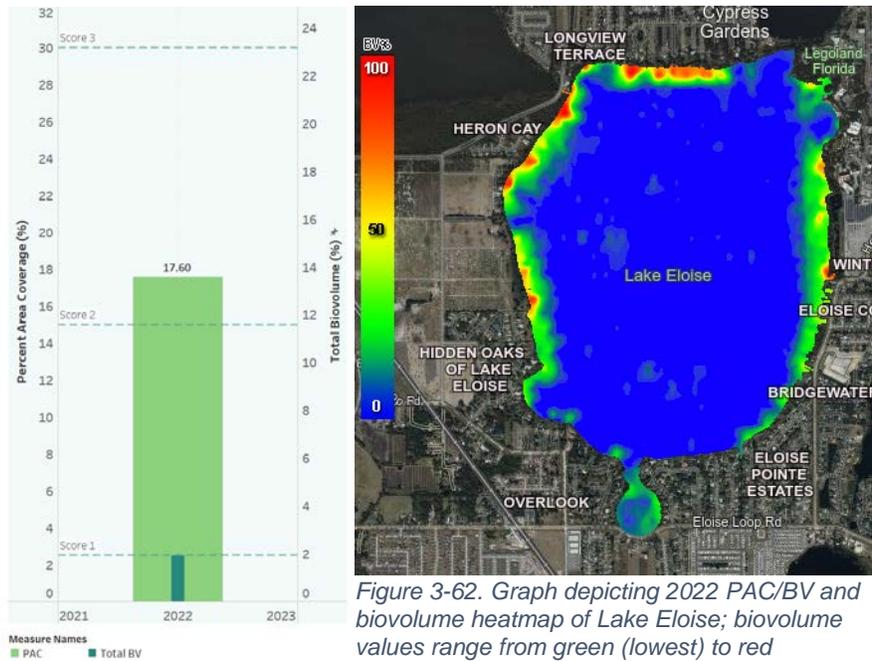
Figure 3-62. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Eloise; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation survey using point-intercept sampling methods. Based on 2022 species data, the native eel grass was the most dominant species at 27% 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 1.13%--earning Lake Eloise an invasive presence score of 2. Hydrilla has historically been a very minor issue and is considered controlled in Lake Eloise.
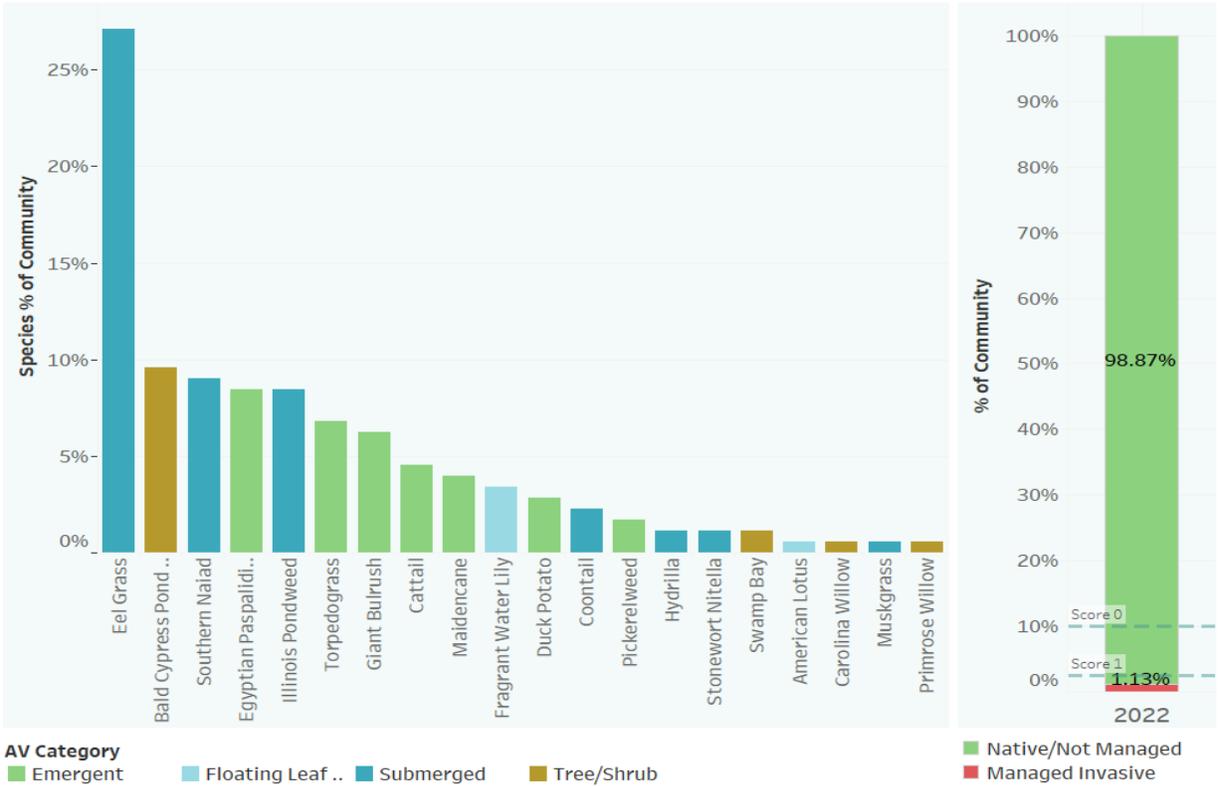
Figure 3-64. Chart depicting species frequency and invasive species percentage of Lake Eloise during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, richness was the only index that met or exceeded its median value—earning Lake Eloise a diversity criterion score of 1. A comparison to previous years' data shows a large increase in the percentage of eel grass relative to the other species present. This tracks with 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.
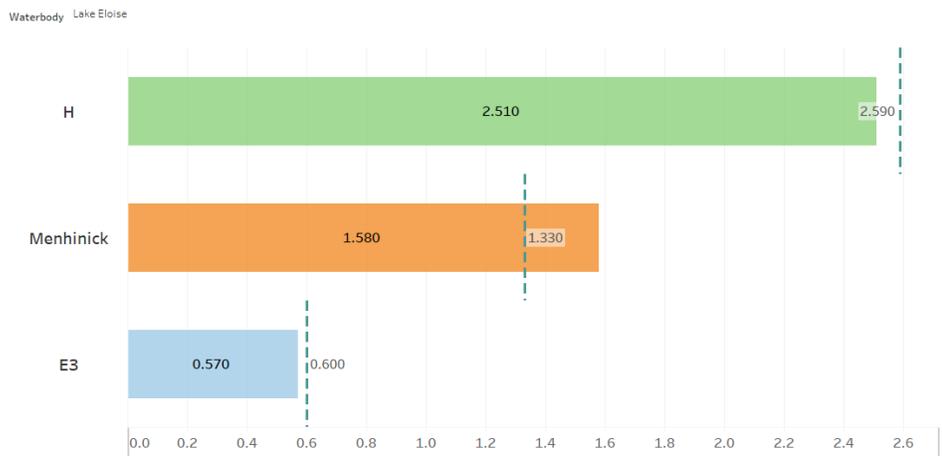
Figure 3-65. Chart depicting 2022 diversity indices for Lake Eloise. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Eloise's health index scores from 2018 to 2022 shows relative consistency. Since the City began documenting lake health, the only changes to Lake Eloise' scores has 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 steady 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	1	2	**1.8**
2020	0	2	2	2	3	2	2	0	**1.6**
2021	0	2	2	2	3	2	2	2	**1.9**
2022	0	2	2	2	3	2	2	1	**1.8**

Figure 3-66. Chart depicting a comparison of Lake Buckeye's Lake Health Index scores from 2018 to 2022.

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 Score
3	2	2	2	3	2	0	3	2.1

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, an average depth of 7.6 feet, and a maximum depth of only 10.75 feet (Figure 3-67).
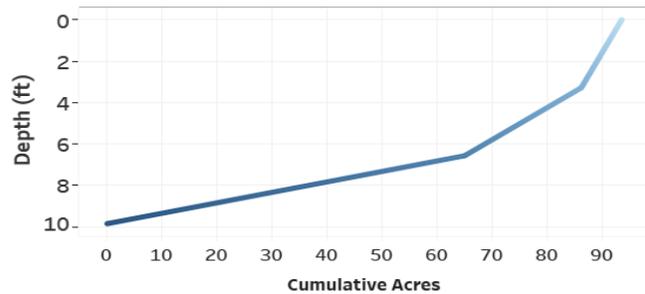
Figure 3-67. Hypsograph of Lake Fannie depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 2208 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 4133 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.

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 2022, Lake Fannie reached a wet season peak of 125.9 feet in September and a dry season low of 124.5 feet during July. At the end of 2022, the surface level was 125.3 feet; slightly above the normal high. With District managed control structures on

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

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 Chla, TN, TP, and clarity such that higher levels should result in improved water quality.
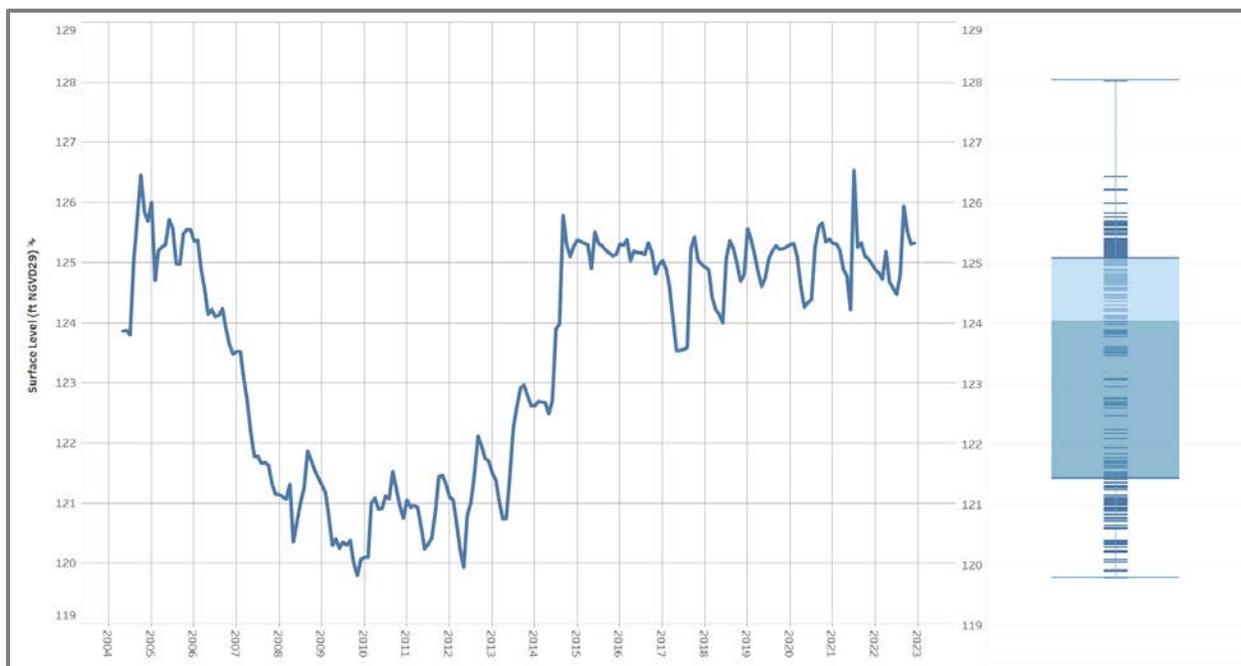
Figure 3-69. Hydrograph of Lake Fannie depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 Chla, TN, and TP during the 2015 to 2022 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	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Based on the water quality data, Secchi depth exhibits a significant improving trend—earning a trend criterion score of 3. Exhibiting non-significant improving trends, Chla, TN, and TP receive trend critera scores 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 (Improving)	Significant	3
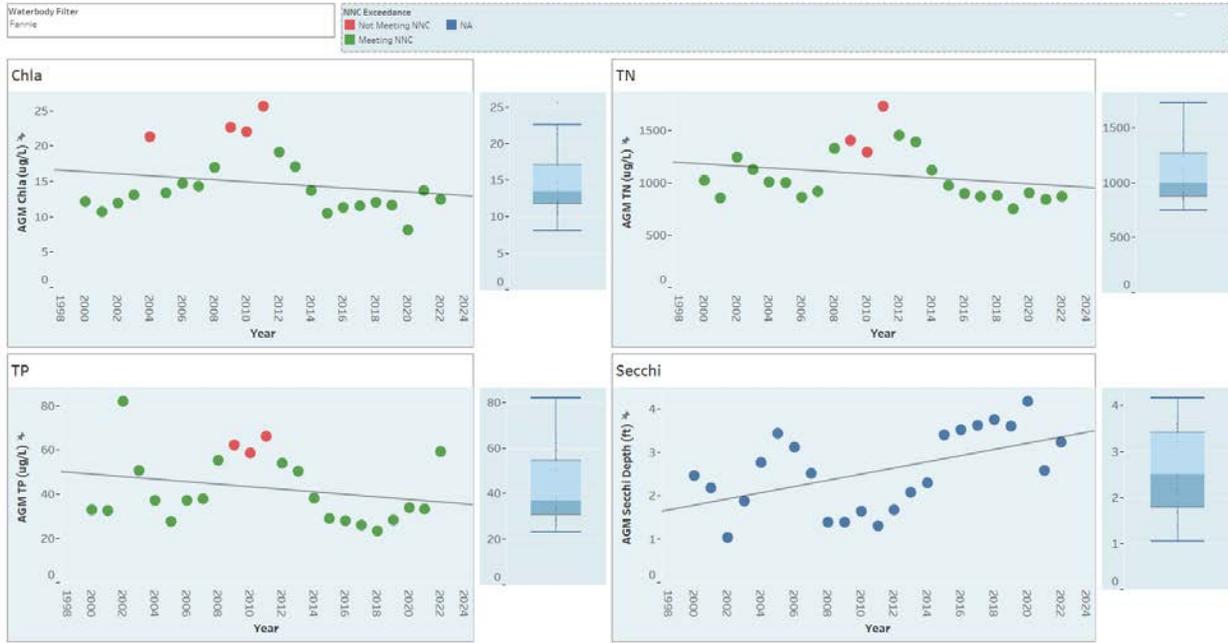
Figure 3-70. Lake Fannie AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Fannie on November 3rd, 2022. The PAC during this survey was 26.6% and the total BV was 3.86% (Figure 3-71). While the vegetation survey places the abundance criterion score at 2, the overall abundance of vegetation is much higher than 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.
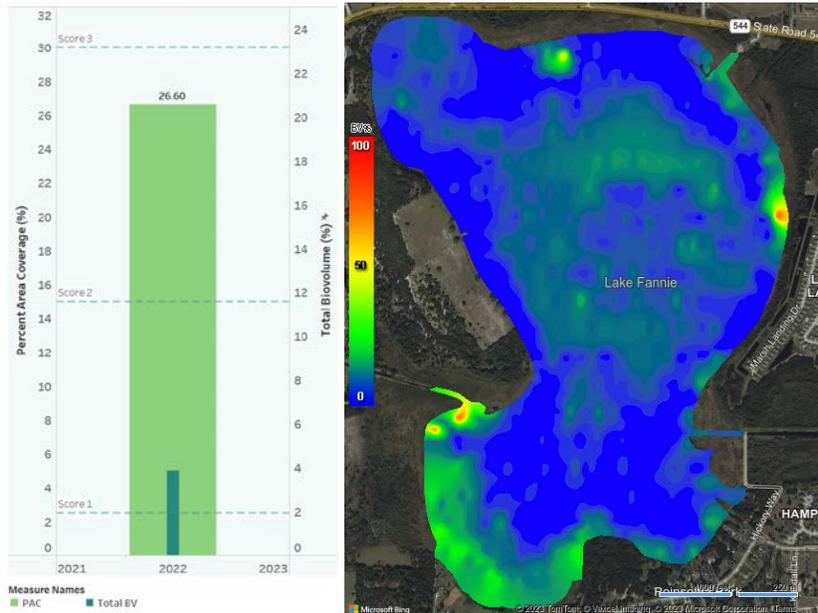
Figure 3-71. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Fannie; biovolume values range from green (lowest) to red (highest).

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 the invasive burhead sedge at 11.5%. Floating invasives like water lettuce and water hyacinth are also present on Lake Fannie—comprising a total managed invasive percentage of

16.97%. This places the invasive presence criterion score at 0. Fortunately, recent treatments of the invasive hydrilla have been successful as it was not detected during 2022.
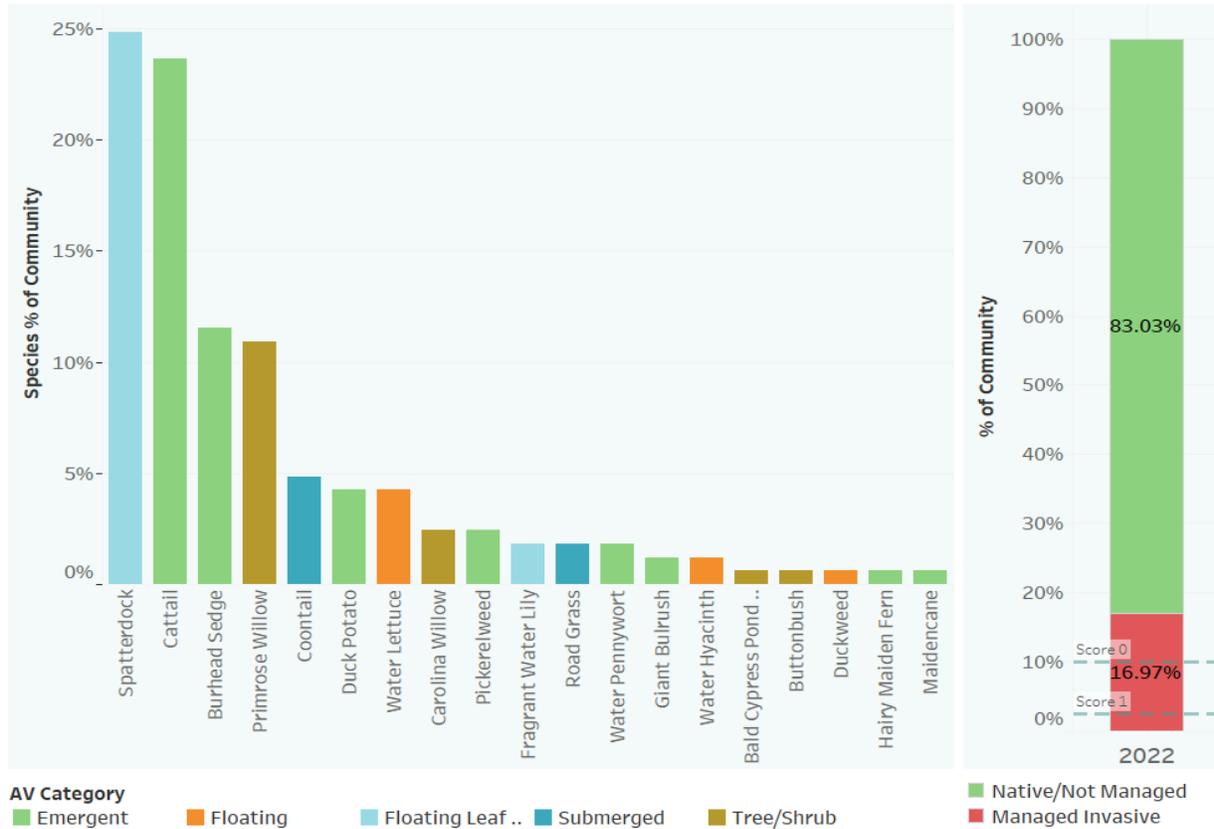
Figure 3-72. Chart depicting species frequency and invasive species percentage of Lake Fannie during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 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 newly documented presence of floating invasives, but also low-profile natives like coontail and road grass. Overall evenness has increased through the succession of other emergents in areas where private homeowners have cut paths through the dense cattail in the south part of the lake.
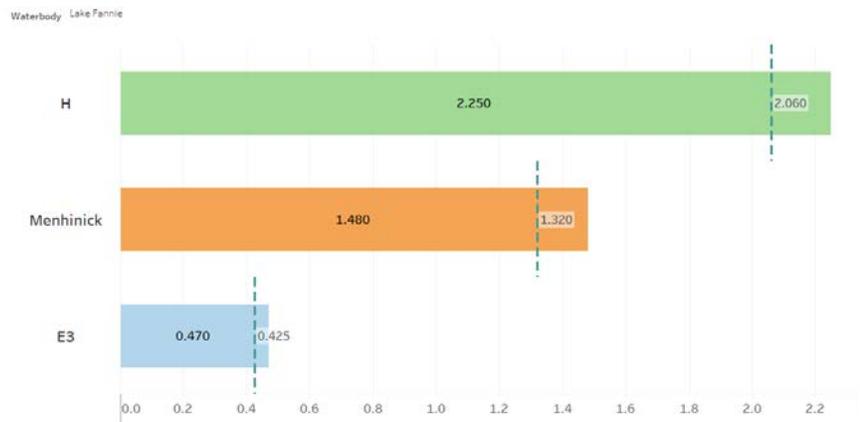
Figure 3-73. Chart depicting 2022 diversity indices for Lake Fannie. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Fannie's health index scores from 2018 to 2022 shows a significant improvement in 2019, followed by relative stability (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 with 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	1	1	2.0
2020	3	2	2	2	3	1	1	1	1.9
2021	3	2	2	2	3	2	1	2	2.1
2022	3	2	2	2	3	2	0	3	2.1

Figure 3-74. Chart depicting a comparison of Lake Fannie's Lake Health Index scores from 2018 to 2022.

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 Score
1	2	3	1	3	1	1	1	**1.6**

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 2317 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 5701 lbs of TN and 1055 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 its 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 3-77). During 2022, Lake Conine reached a wet season peak of 129 feet in September and a dry season low of 128 feet in June. The surface level ended the year above the high end of the
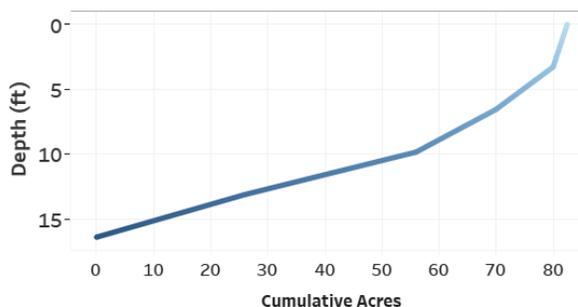
Figure 3-75. Hypsograph of Lake Haines depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.
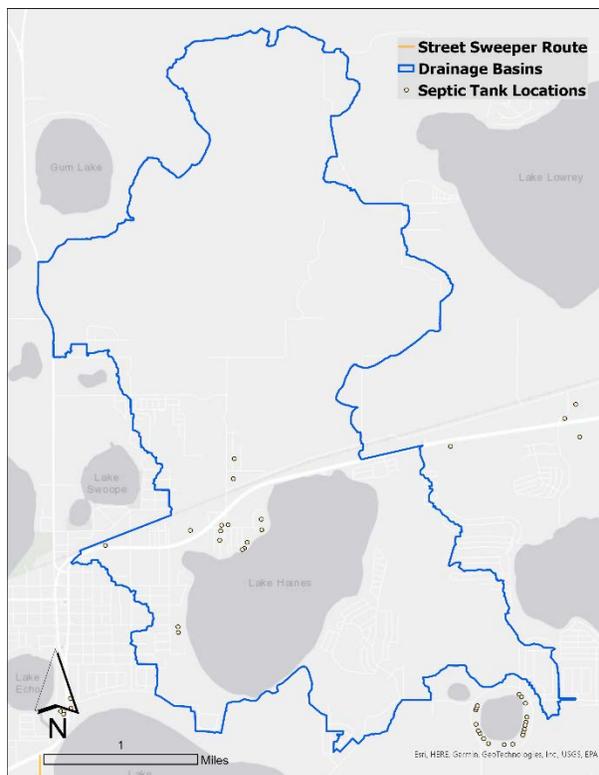
Figure 3-76. Map of Lake Haines' drainage basin and nearby septic systems.

normal range at 128.47 feet. Changes in Lake Haines' surface level are directly correlated with water clarity and indirectly correlated with TN (see appendix). This carries management implications as maintaining a higher surface level should result in improvements in these metrics.
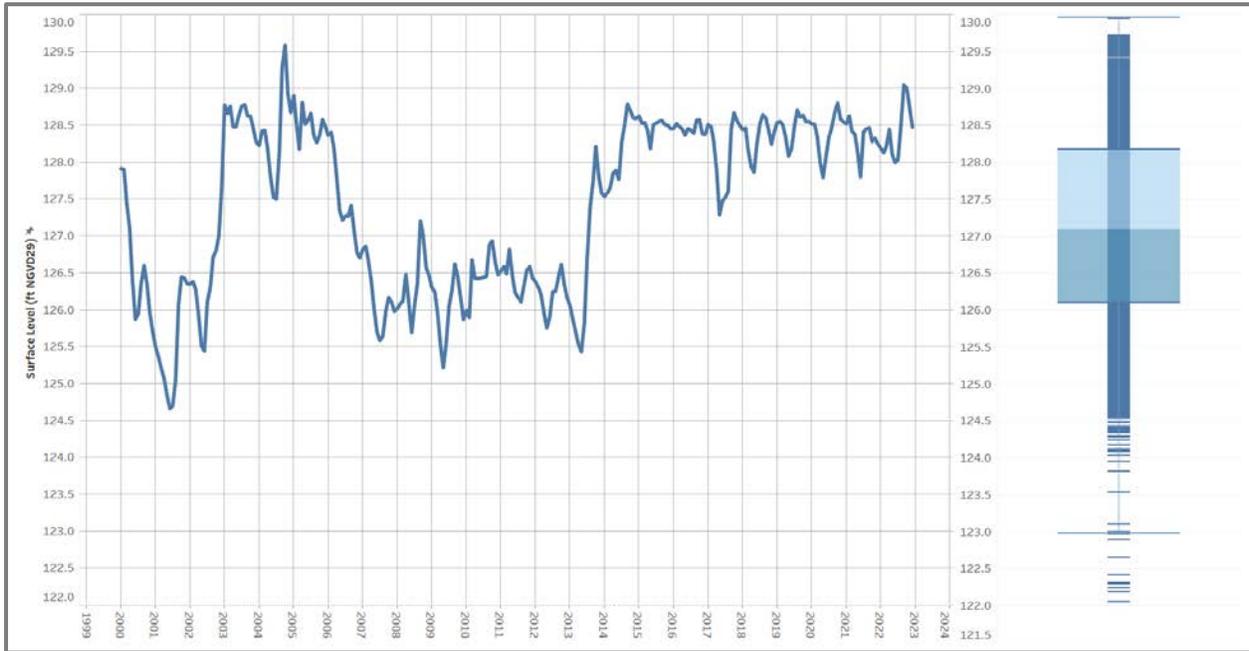
Figure 3-77. Hydrograph of Lake Haines depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 Chla and TP. While TN did exceed the NNC threshold in 2021, there have not been more than one 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 in order to achieve NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	
TN	N	1
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of Chla, TN, TP, and Secchi depth values from 2000 to 2022. Based on the water quality data, Lake Haines exhibits significant improving trends in TN and Secchi depth—earning trend criteria scores of 3. Chla exhibits a non-significant improving trend, for a score of 2. While 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.

Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing	Not Significant	2
TN	Decreasing (Improving)	Significant	3
TP	Increasing	Not Significant	1
Secchi	Increasing (Improving)	Significant	3
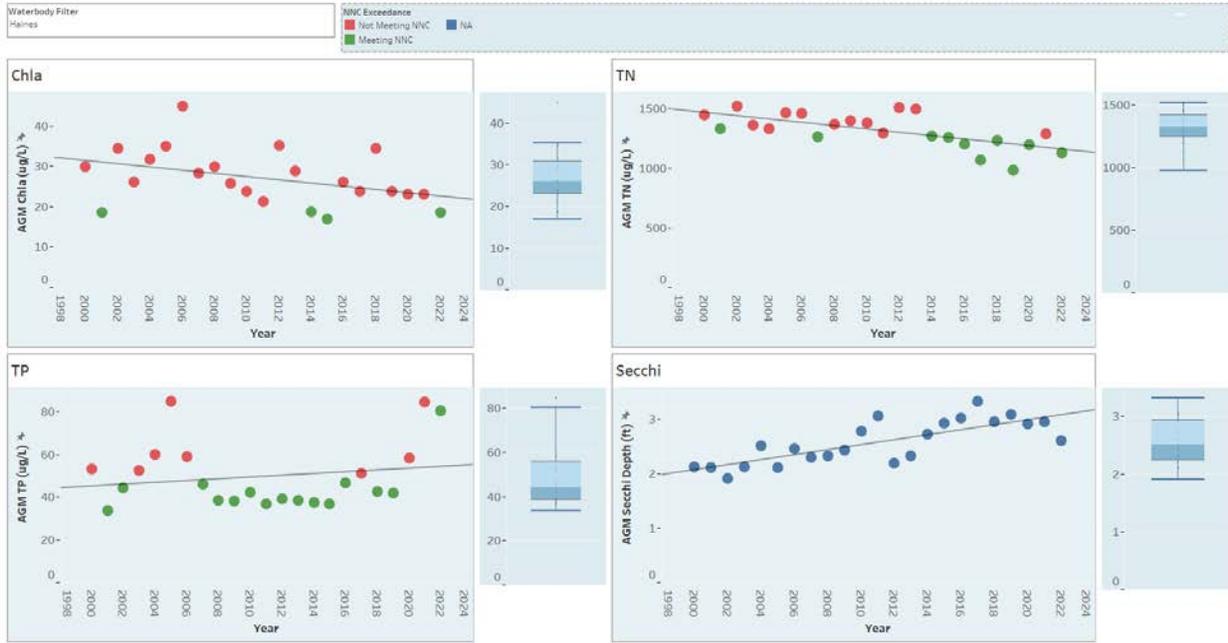
Figure 3-78. Lake Haines AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Haines on December 2nd, 2022. The PAC during this survey was 7.5% and the total BV was 0.97% (Figure 3-79). A comparison of abundance data from 2018 to 2022 shows that this is the lowest amount of vegetation coverage observed in Lake Haines since monitoring began. Some of this decline is likely due to invasive hydrilla treatments in recent years. It should
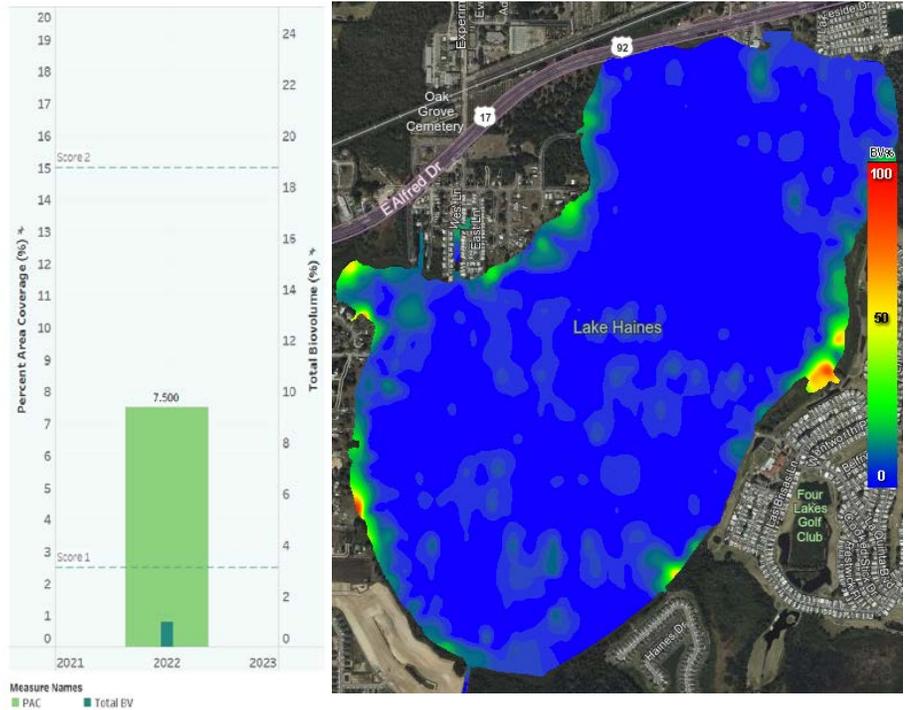
Figure 3-79. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Haines; biovolume values range from green (lowest) to red (highest).

be noted like Lake Fannie, Haines possesses dense stands of emergent vegetation (e.g. cattails) that do not translate well to SONAR mapping. In actuallity, the overall coverage is much higher. The City is seeking alternative methods to capture these dense littoral areas.

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on 2022 species data, emergent vegetation remains the most dominant vegetation type in Lake Haines. The only submerged species detected were the native eel grass and invasive hydrilla. Water hyacinth made up the majority of invasive presence in 2022 at 3.9% of the community; followed by hydrilla at 1.3% (Figure 3-80). The total invasive percentage was 5.19%, for an invasive criterion score of 1. Comparing this survey to previous years, there has been a significant reduction in invasive presence—going from 25.8% in 2022 to the current percentage. This is indicative of the success of invasive species treatments.
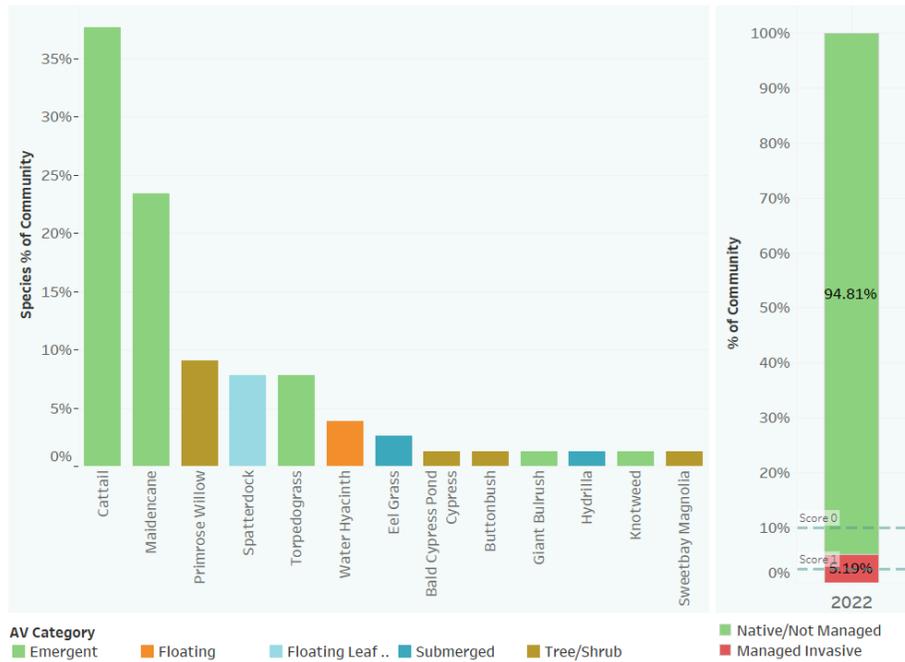
Figure 3-80. Chart depicting species frequency and invasive species percentage of Lake Haines during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, richness was the only index to meet or exceed Lake Haines' median value—earning a diversity score of 1 (Figure 3-81). There were some emergent and tree/shrub type plants detected during the 2022 survey that were not included previously. That said, species evenness was lessened as cattail begain more of the dominant species present during the survey. Some other less robust submerged plants like coontail and southern naiad were absent from the most recent survey—which is the likely justification for the lower diversity index value.
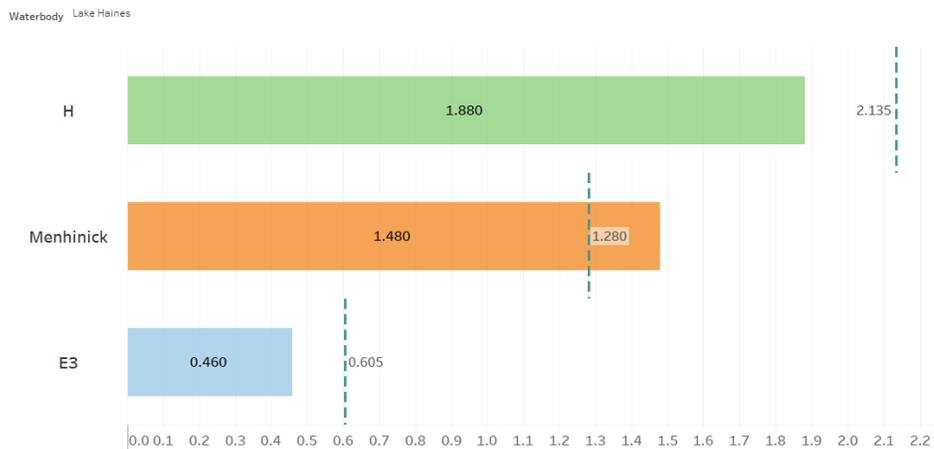
Figure 3-81. Chart depicting 2022 diversity indices for Lake Haines. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Haines' health index scores from 2018 to 2022 shows some minor decline 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 resulted in higher invasive presence scores. Diversity has remained relatively static until 2022.

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	2	**1.8**
2019	1	2	3	2	3	2	0	2	**1.9**
2020	2	2	3	2	3	2	0	2	**2.0**
2021	1	2	3	1	3	1	2	2	**1.9**
2022	1	2	3	1	3	1	1	1	**1.6**

Figure 3-82. Chart depicting a comparison of Lake Haines' Lake Health Index scores from 2018 to 2022.

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 Score
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).

Figure 3-83. Hypsograph of 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 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 6701 lbs of TN and 1167 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 2022, Lake Hamilton reached a wet season peak of 121.8 feet

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

in October and a dry season low of 120.25 feet in March. Changes in Lake Hamilton's surface level are not correlated with Chla, TN, TP, or clarity (see appendix).
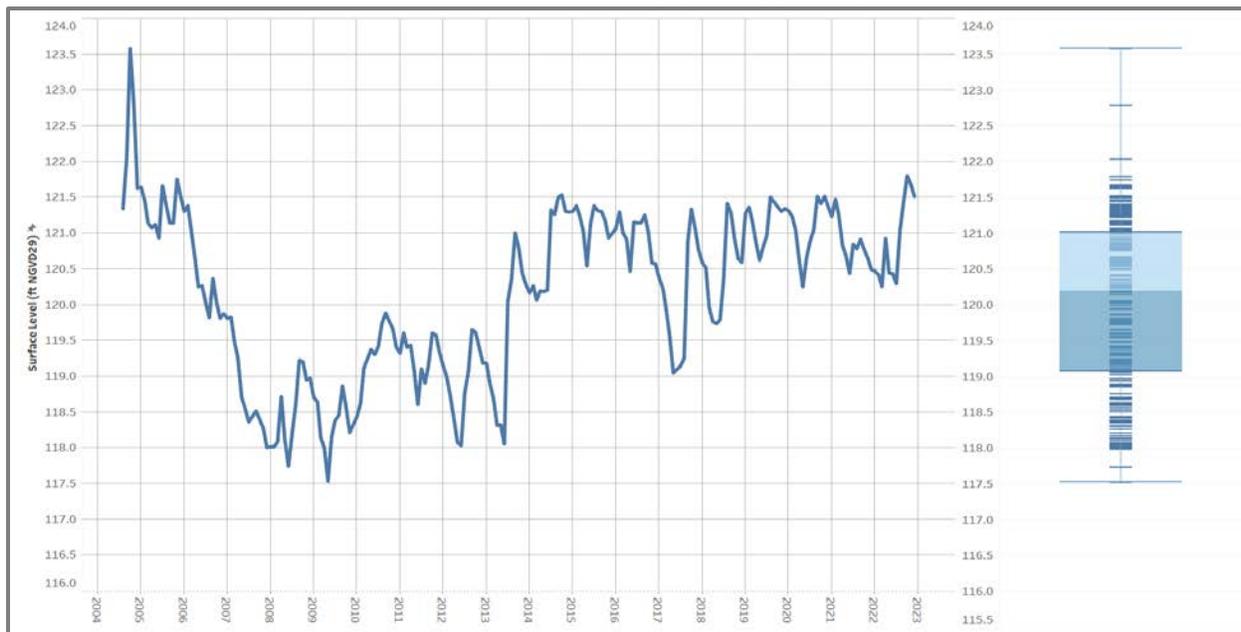
Figure 3-85. Hydrograph of Lake Hamilton depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period, Lake Hamilton is considered impaired in Chla, 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 effort is still pending acceptance.

Parameter	Impaired	Index Score
Chla	Y	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Chla, 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 occuring in Lake Hamilton—increasing Chla and TN concentrations while decreasing TP and clarity. Further study is need 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
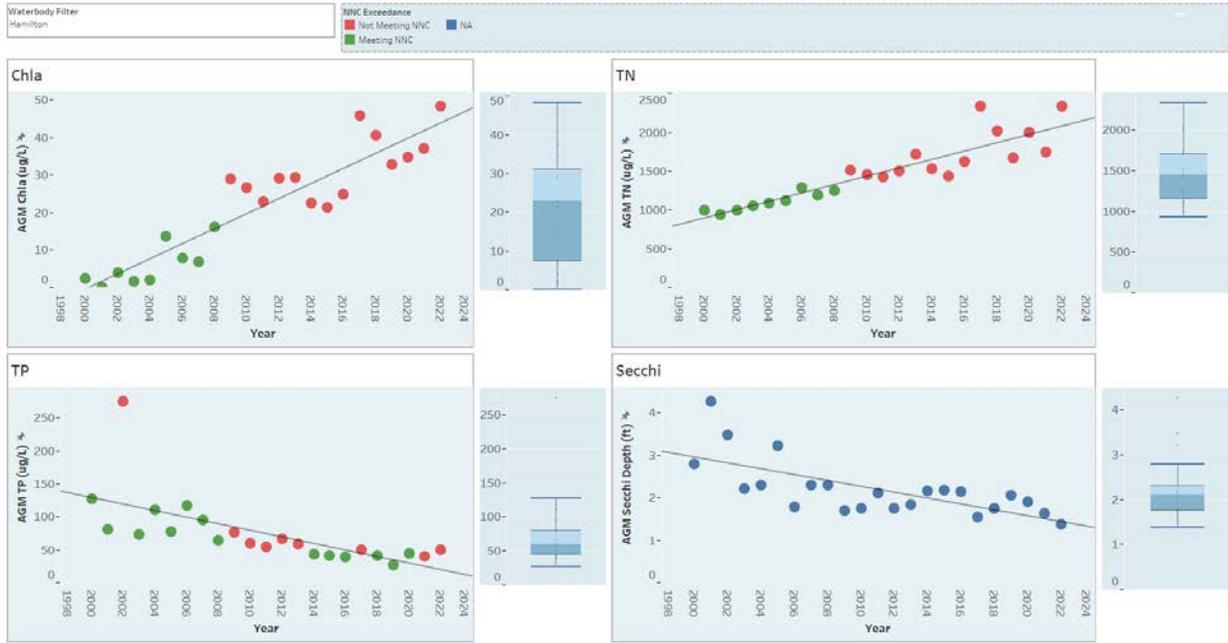
Figure 3-87. Lake Hamilton AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Hamilton on June 13th, 2022. The PAC during this survey was 10.2% and the total BV was 1.32% (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.
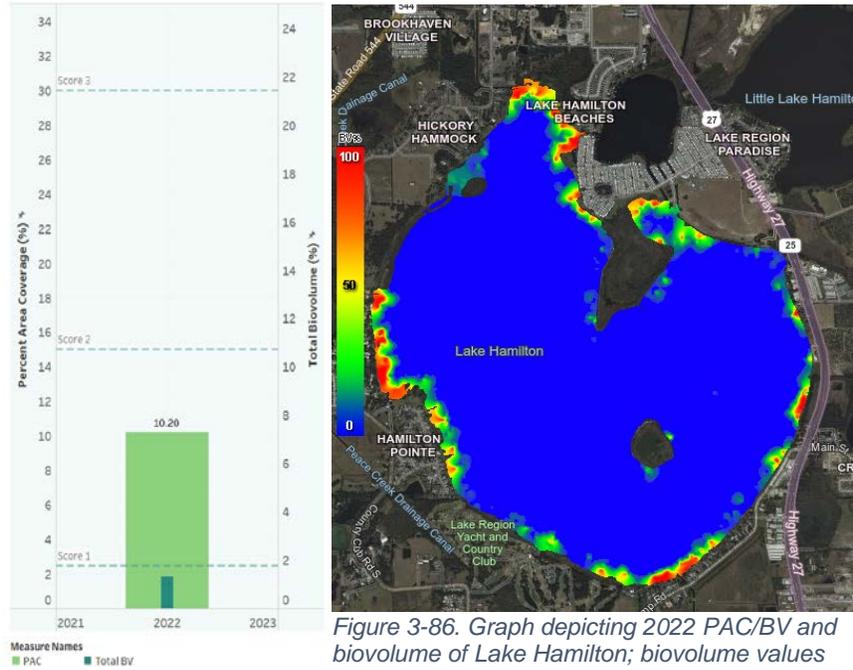
Figure 3-86. Graph depicting 2022 PAC/BV and biovolume of Lake Hamilton; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on 2022 species data, the dominant plant type in the lake is emergent, with giant bulrush comprising almost 35% of the community (Figure 3-88). This is followed by submerged and floating leaf natives, respectively. Fortunately, there were no managed invasive species detected during the 2022 survey—resulting in an invasive presence criterion score of 3.

This was a decline from previous years where invasives made up over 3% of the community. This demonstrates the effectiveness of invasive species control efforts.
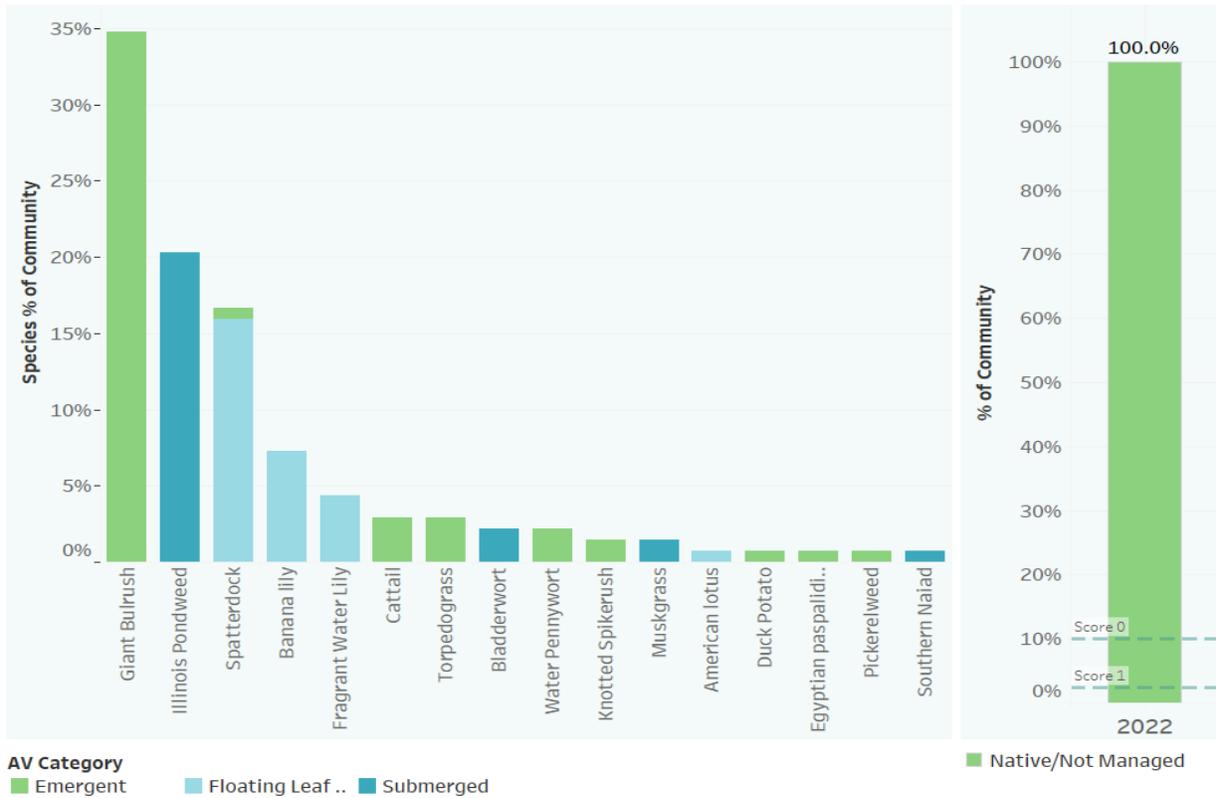
Figure 3-88. Chart depicting species frequency and invasive species percentage of Lake Hamilton during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, all three of Lake Hamilton's diversity indices met or exceeded their respective median values (Figure 3-89). The effective elimination of the invasive water hyacinth allowed other native species to fill those gaps with no reduction in abundance. There was also a notable increase in some of the other species which helped to even the spread in the community. Overall, a positive improvement compared to previous years.
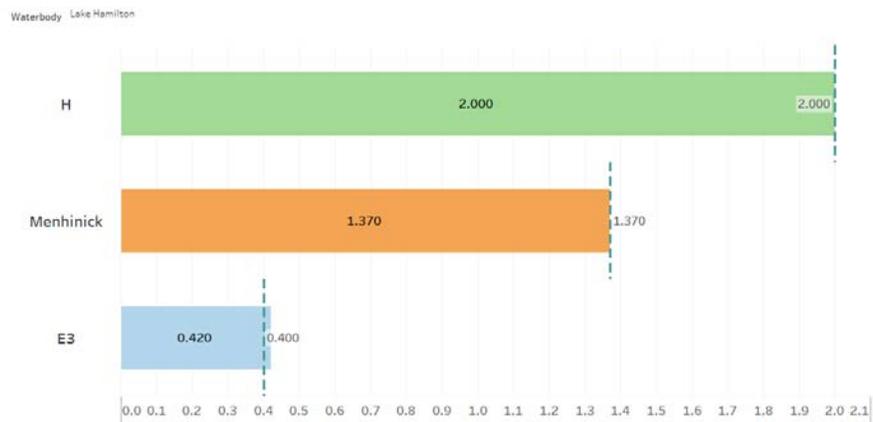
Figure 3-89. Chart depicting 2022 diversity indices for Lake Hamilton. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Hamilton's health index scores from 2018 to 2022 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 desparate 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	2	1	0.9
2021	1	0	0	3	0	1	2	3	1.3
2022	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 2022.

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:

  o 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;

  o Street sweeping in the Haines City area;

  o Seepage study and septic-to-sewer conversion project proposed for the City of Lake Hamilton;

  o 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 Score
1	0	0	1	0	3	2	2	1.1

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 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).

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

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 2658 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 of over 17 miles along Havendale Blvd and US Hwy 17.

Due to the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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 3-93). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively.

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

During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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).
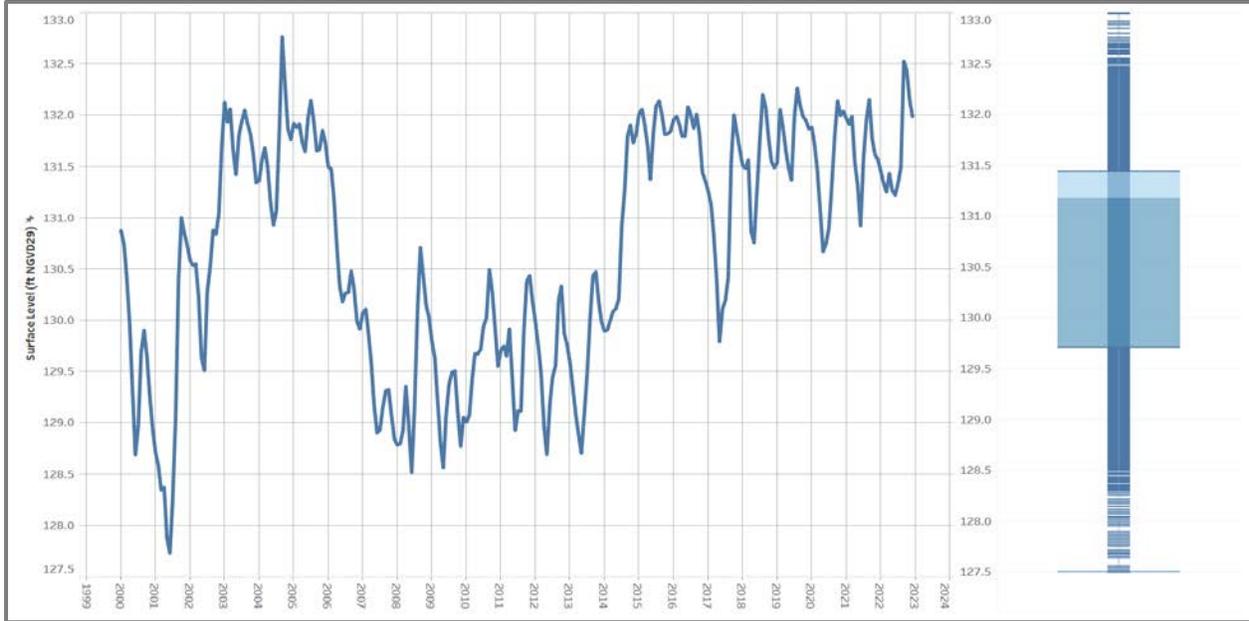
Figure 3-93. Hydrograph of Lake Hartridge depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period, Lake Hartridge is considered impaired for Chla 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	
TN	Y	1
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of Chla, TN, TP, and Secchi depth values from 2000 to 2022. During this period, Chla, TN, and Secchi depth exhibit significant deteriorating trends—equating to trend criteria scores of 0. TP exhibits a non significant deteriorating trend, for a criterion score of 1.

Parameter	Trend Direction	Significance	Index Score
Chla	Increasing (Deteriorating)	Significant	0
TN	Increasing (Deteriorating)	Significant	0
TP	Increasing	Not Significant	1
Secchi	Decreasing (Deteriorating)	Significant	0
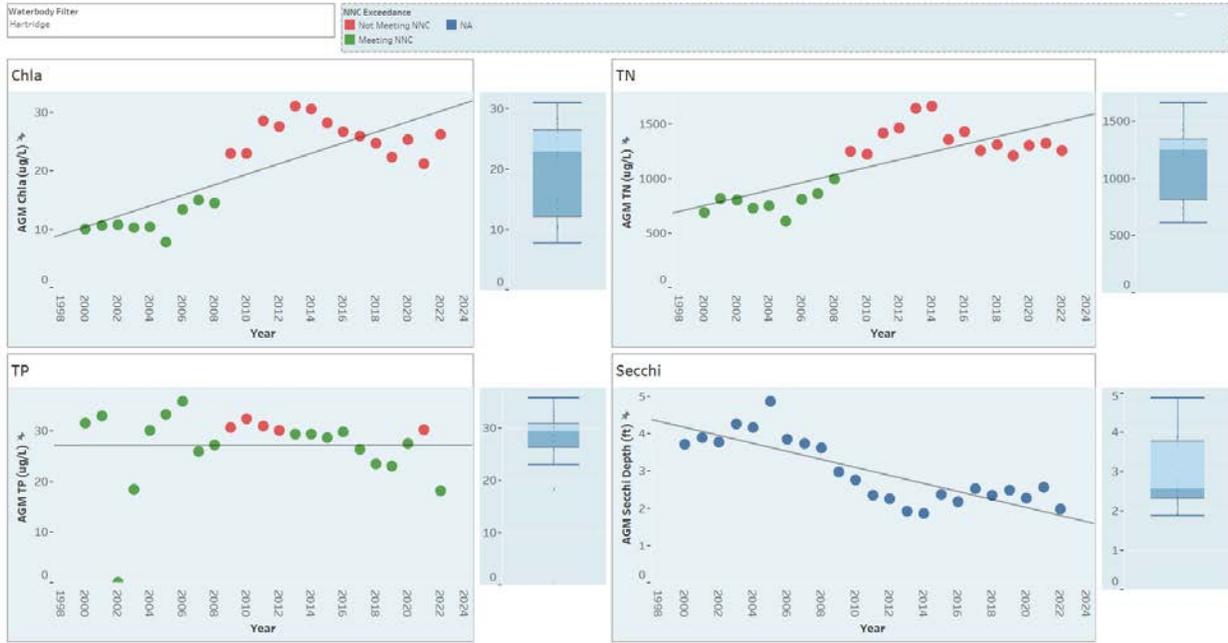
Figure 3-94. Lake Hartridge AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Hartridge on October 21st, 2022. The PAC during this survey was 37.9% and the total BV was 6.9% (Figure 3-95). A comparison to previous years shows that vegetation abundance has remained relatively consistent since monitoring began; with PAC values ranging from 35% to 40%. 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 2022 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). The only managed invasive species present was hydrilla—at less than
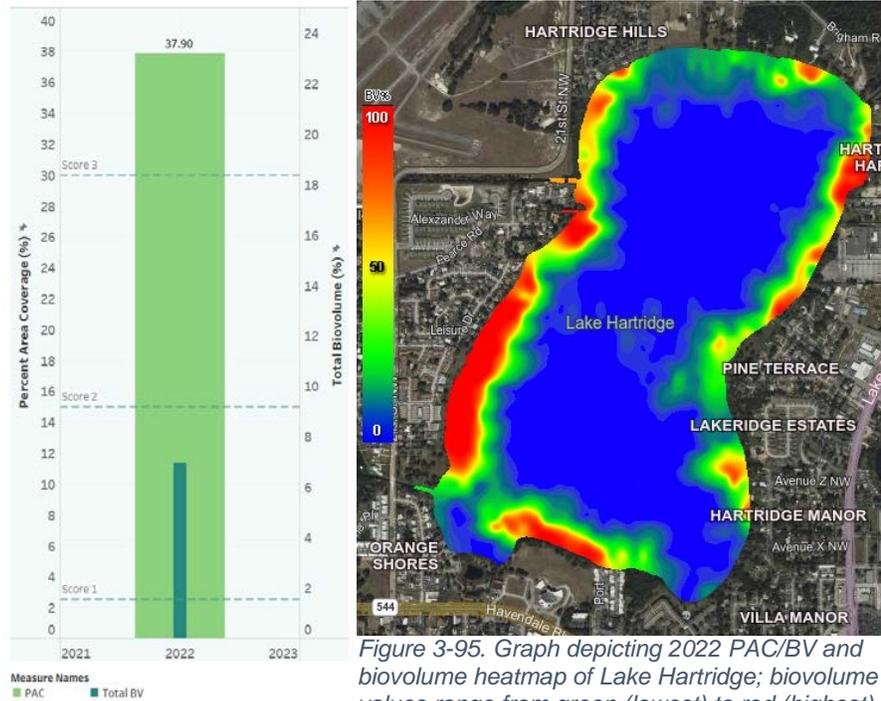
Figure 3-95. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Hartridge; biovolume values range from green (lowest) to red (highest).

1% of the community. A comparison to previous years shows that invasives are generally controlled with total community percentages consistently falling below 2% each year since 2018. An invasive presence less than 2.5% has resulted in an invasive criterion score of 2.
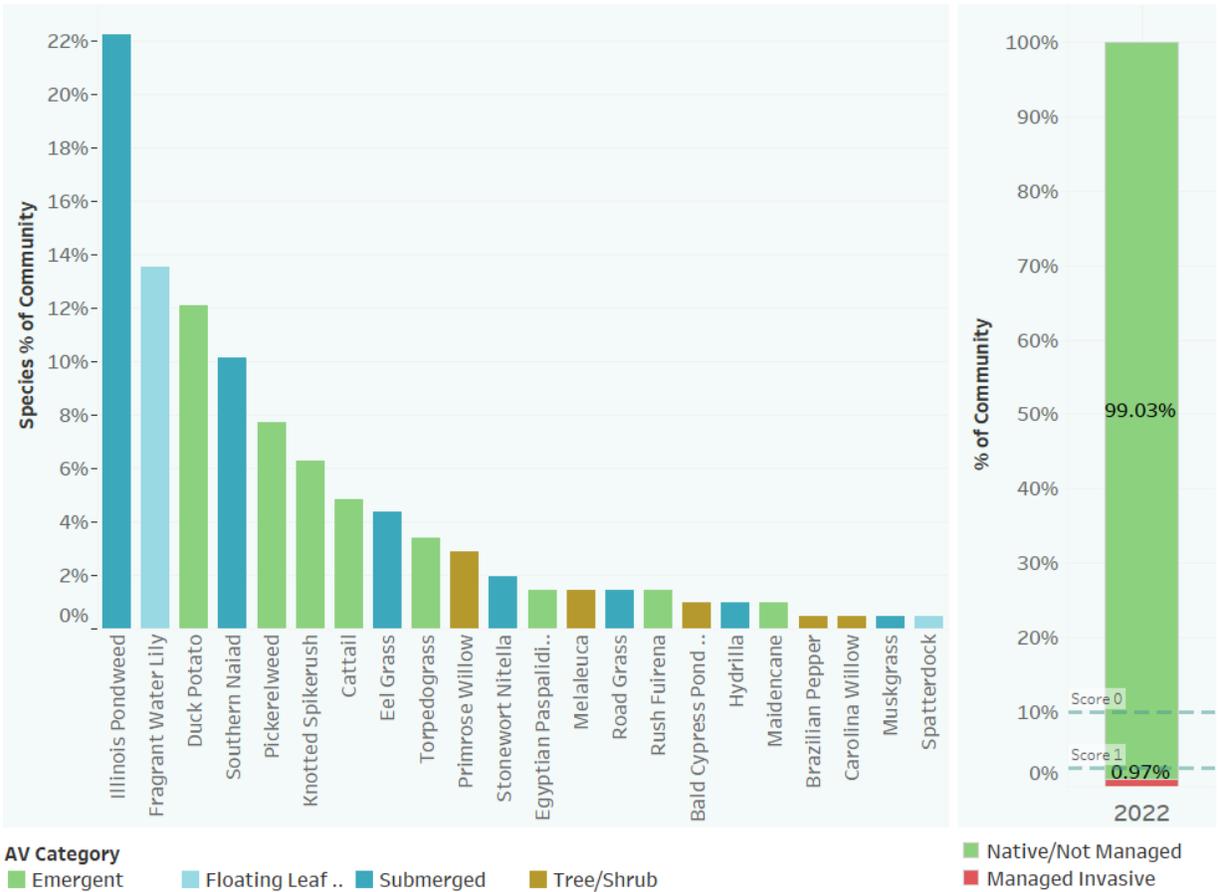
Figure 3-96. Chart depicting species frequency and invasive species percentage of Lake Hartridge during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, Lake Hartridge's richness and overall diversity indices met or exceeded their long-term median values (Figure 3-97). The evenness index was lower likely due to the increased relative percentage of Illinois pondweed compared to other species present—its percentage rose from 18.7% in 2021 to 22% in 2022. Otherwise, Lake Hartridge has an adequate number and diversity of aquatic plant species.
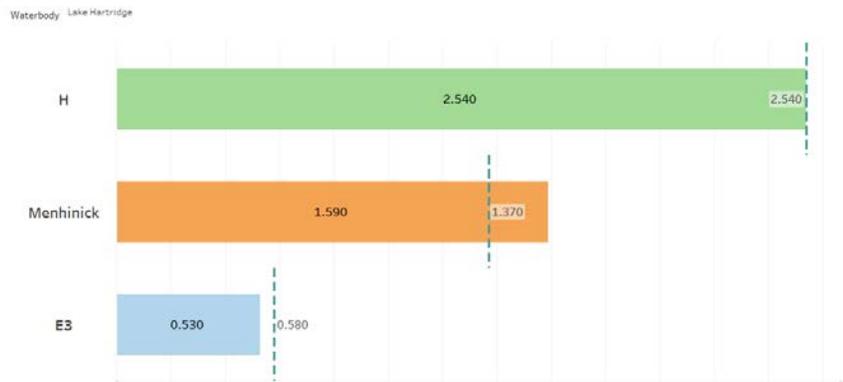
Figure 3-97. Chart depicting 2022 diversity indices for Lake Hartridge. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Hartridge's health index scores from 2018 to 2022 shows little change (Figure 3-98). The impairment criterion score improved in 2019 due to TP no longer exceeding the NNC thresholds. However, the trend scores have consistently been pointing to deteriorating water quality. Vegetation abundance has remained high over the last five 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	2	2	1.1
2019	1	0	0	1	0	3	1	2	1.0
2020	1	0	0	1	0	3	2	1	1.0
2021	1	0	0	1	0	3	3	3	1.4
2022	1	0	0	1	0	3	2	2	1.1

Figure 3-98. Chart depicting a comparison of Lake Hartridge's Lake Health Index scores from 2018 to 2022.

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 Score
1	3	3	2	3	2	3	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 6321 lbs of TN and 1097 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 of more than 50 miles per month.

Due to the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. Throughout the period of record, the South Chain's surface level has fluctuated between
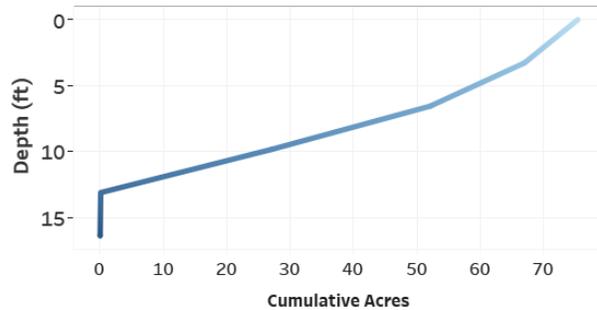
Figure 3-99. Hypsograph of Lake Howard depicting cumulative area a regular depth intervals. Demonstrates the slope and morphology of the lake bed.
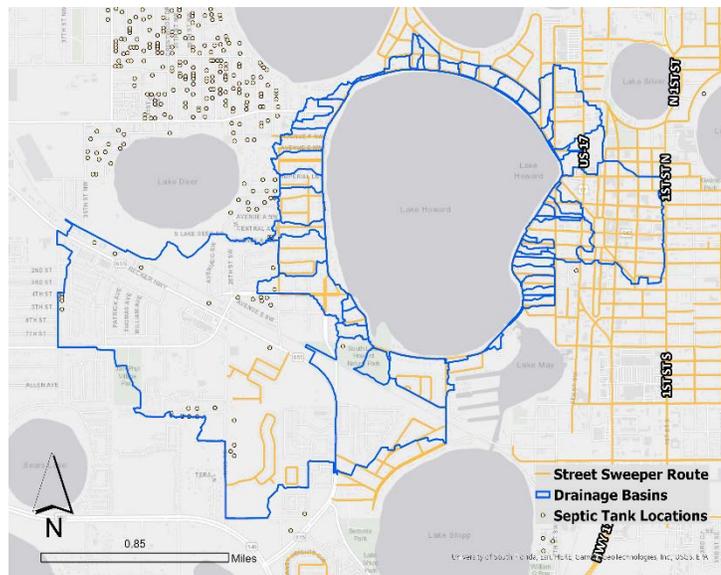
Figure 3-100. Map of Lake Howard's drainage basin, City street sweeping routes, and nearby septic systems.

127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-101). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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 Chla, TN, and clarity (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.
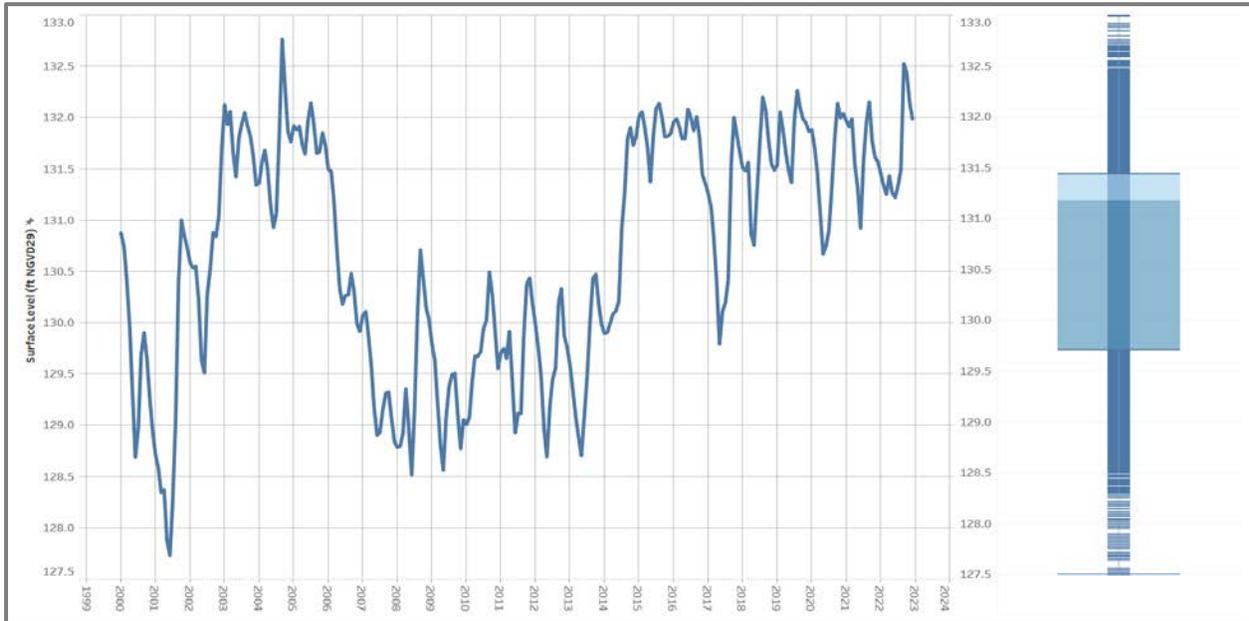
Figure 3-101. Hydrograph of Lake Howard depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period, Lake Howard is considered impaired for Chla 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	
TN	Y	1
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Based on the data, Chla, TN, and Secchi depth all exhibit significant improving trends—earning trend critera scores of 3. TP exhibits a non-significant improving trend, for a 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
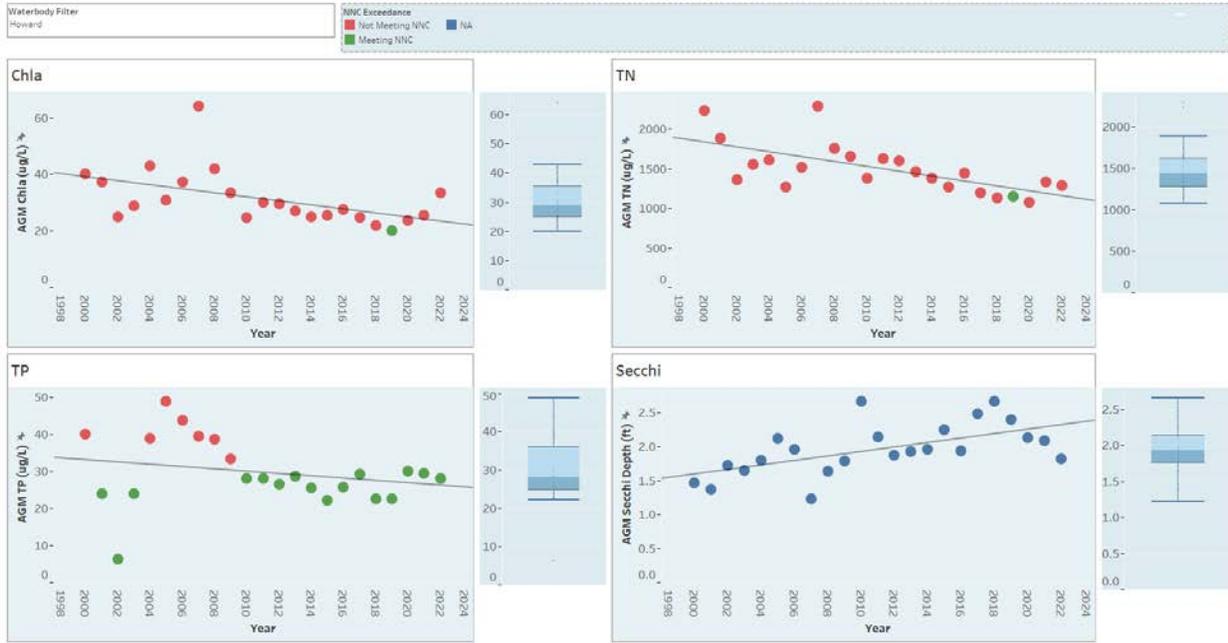
Figure 3-102. Lake Howard AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Howard on May 10th, 2022. The PAC during this survey was 27.1% and the total BV was 4.35% (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 2022 values equates to an abundance criterion score of 2.
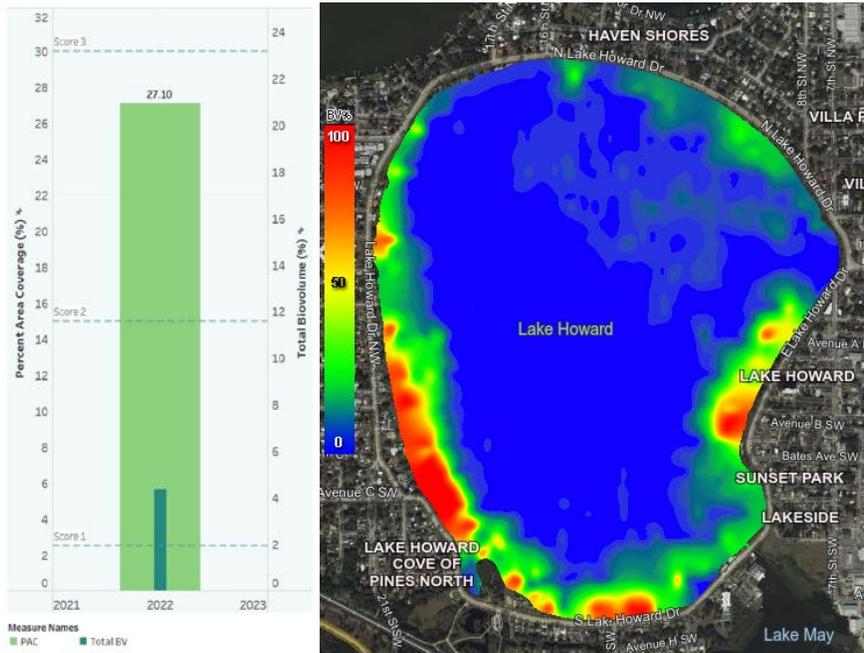
Figure 3-103. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Howard; biovolume values range from green (lowest) to red (highest).

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. Since there were no invasives detected during the 2022 survey, Lake Howard scores a 3 in the invasive percentage criterion.
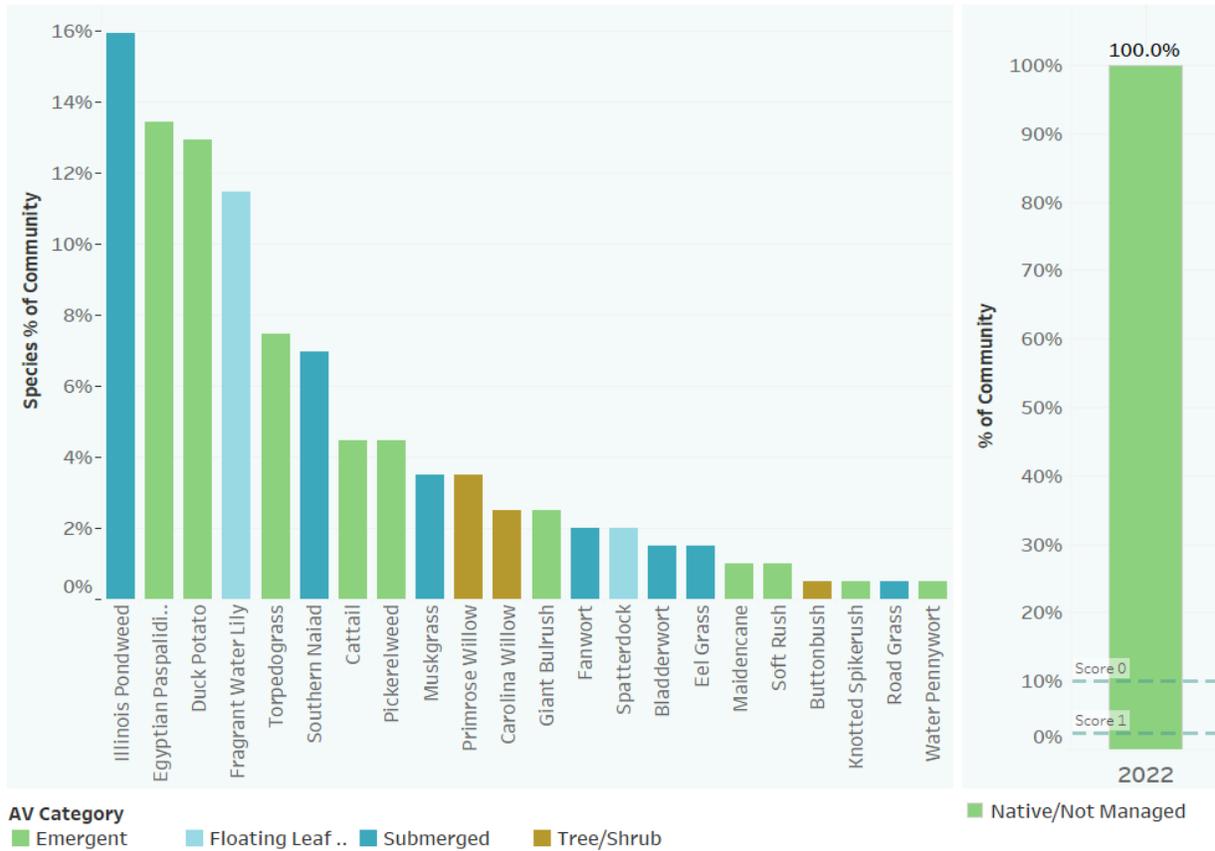
Figure 3-104. Chart depicting species frequency and invasive species percentage of Lake Howard during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, Lake Howard's richness and overall diversity indices met or exceed their respective median values (Figure 3-105). These were the highest index values on record for this waterbody. 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 remaining 22. These results equate to a diversity criterion score of 2.
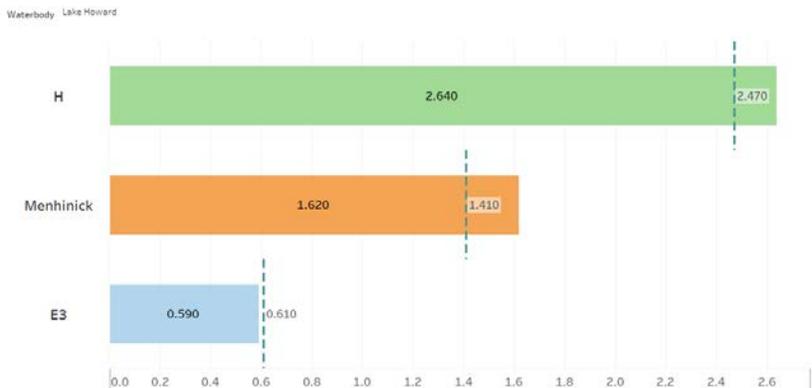
Figure 3-105. Chart depicting 2022 diversity indices for Lake Howard. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Howard's health index scores from 2018 to 2022 shows consistently good values (Figure 3-106). In the five years this monitoring has been conducted, there have been no changes 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 unchanged since 2019; with the majority of the variation occuring in the abundance and diversity criteria. As previously stated, invasive management is minimal in Lake Howard which indicates that aquatic vegetation largely self-regulates.

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	2	2.5
2022	1	3	3	2	3	2	3	2	2.4

Figure 3-106. Chart depicting a comparison of Lake Buckeye's Lake Health Index scores from 2018 to 2022.

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. The 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:

  o Street Sweeping over 50 miles per month in the downtown area.

  o Construction of a stormwater treatment/nature park on the south side of Lake Howard in the early 2000s.

  o 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.

  o The Stormwater Assessment and Improvement Project: identified priority areas for green infrastructure in southern drainage sub-basins to prevent flooding and improve water quality.

  o 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 Score
0	1	1	0	1	3	1	2	**1.1**

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. Lake Idyl is part of the North Central Lakes which discharges excess water downstream to Lake Fannie of the North Chain. 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).

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.

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 and 132.5 feet (Figure 3-109). During 2022, Lake Idyl reached a wet season peak of 133.3 feet in September and a dry season low of 132.3 feet in May. Changes in Lake Idyl's

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

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

surface level are not signficantly 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 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 to 2022 assessment period, Lake Idyl is considered impaired for Chla, TN, and TP (Figure 3-110). This equates to an impairment criterion score of 0. Fortunately, the 2022 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 un-impaired.

Parameter	Impaired	Index Score
Chla	Y	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Based on the data, TP exhibits a significant deteriorating trend—equating to a trend criterion score of 0. Chla, TN, and Secchi depth exhibit non-significant deteriorating trends—resulting in criteria 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	Increasing	Not Significant	1
TP	Increasing (Deteriorating)	Significant	0
Secchi	Decreasing	Not Significant	1
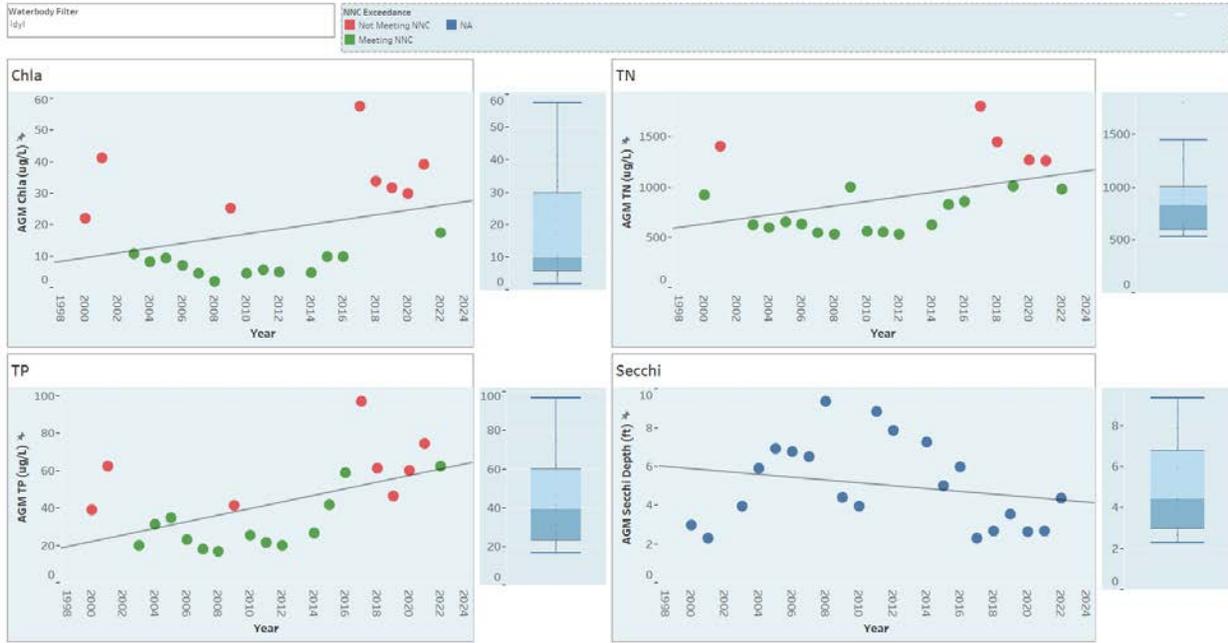
Figure 3-110. Lake Idyl AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Idyl on January 21st, 2022. The PAC during this survey was 53% and the total BV was 6.1% (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 2022 data, over 40% of the plant community was comprised of spatterdock, followed by mostly emergent species (Figure 3-112). Managed invasive species made up just over 6% of the community; comprised of burhead sedge and floating
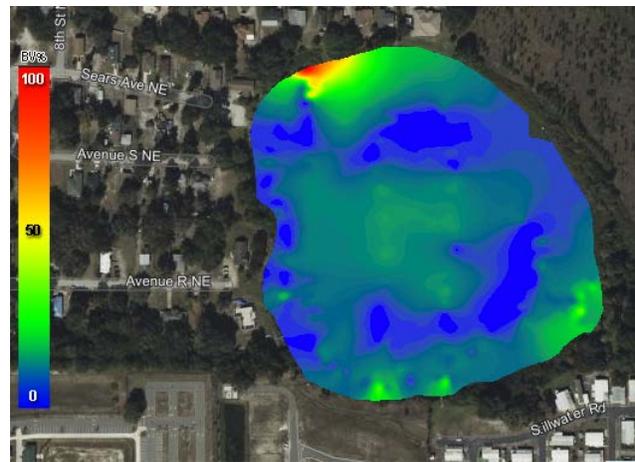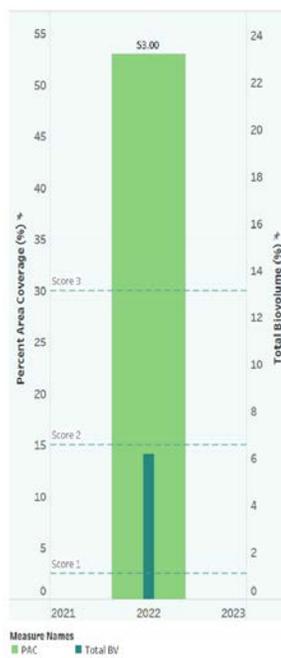
Figure 3-111. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Idyl; biovolume values range from green (lowest) to red (highest).

water hyacinth. A comparison of data over the last five years shows that invasive presence fluctuates between 4% and 24%. The current percentage earns Lake Idyl an invasive criterion score of 1.
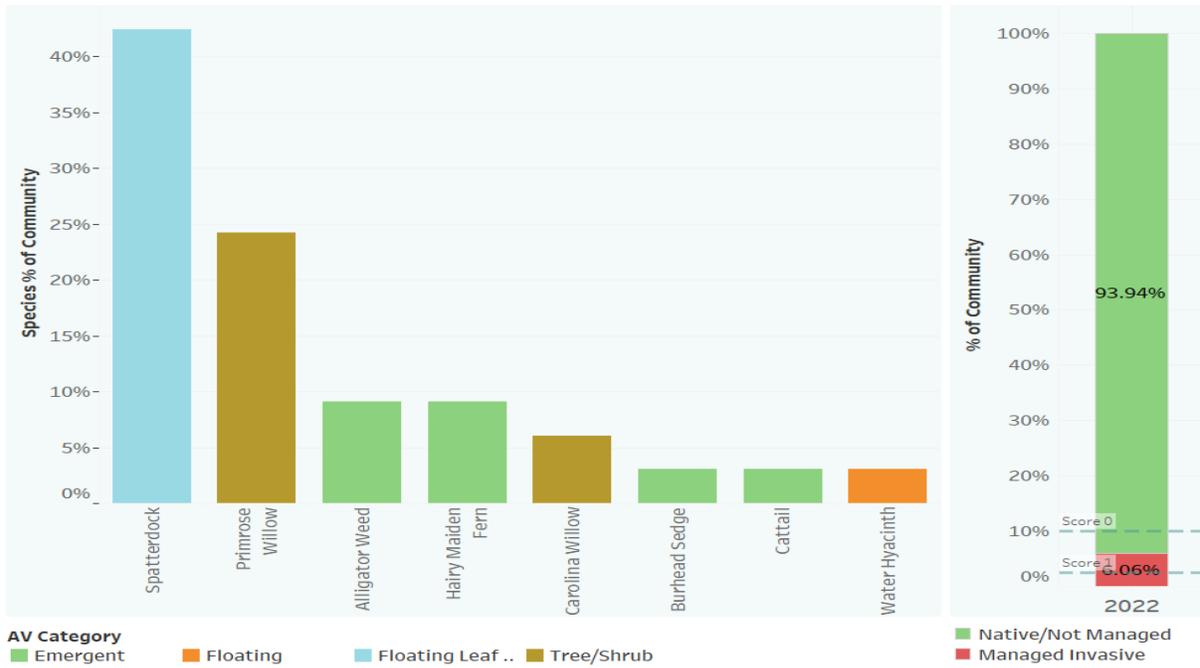
Figure 3-112. Chart depicting species frequency and invasive species percentage of Lake Idyl during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, Lake Idyl's richness and overall diversity indices met or exceeded their respective median values (Figure 3-113). This equates to a diversity criterion score of 2. 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 from 2021. However evenness still remains below its median value for the third year running. Spatterdock's dominance over the lake's area has resulted in low evenness values.
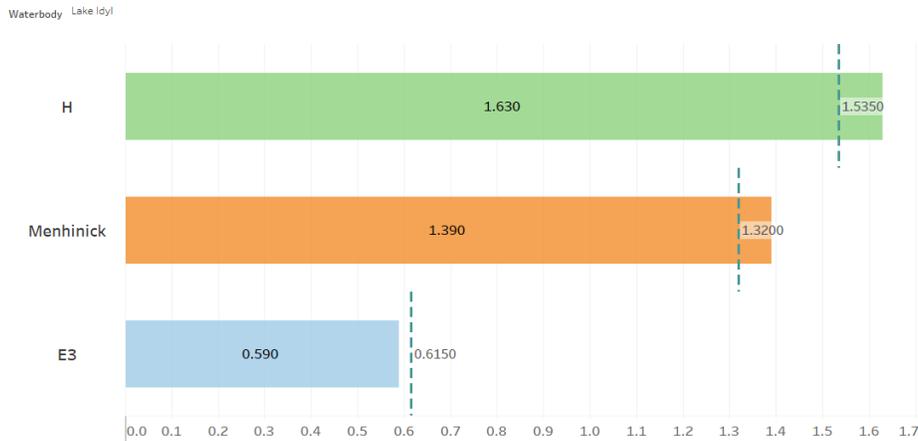
Figure 3-113. Chart depicting 2022 diversity indices for Lake Idyl. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Idyl's health index scores from 2018 to 2022 shows fluctuation between middling and poor lake health scores (Figure 3-114). Since monitoring began, Lake Idyl has remained impaired and exhibited a decline in the TP and Clarity trend scores. The presence of managed invasive species has also shifted in a negative direction. 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	2	3	1.6
2019	0	1	1	1	2	1	1	1	1.0
2020	0	1	1	1	1	3	1	2	1.3
2021	0	1	1	0	1	3	0	0	0.8
2022	0	1	1	0	1	3	1	2	1.1

Figure 3-114. Chart depicting a comparison of Lake Idyl's Lake Health Index scores from 2018 to 2022.

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 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 occurance 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 green stormwater infrastructure in the north drainage sub-basins.

  o A raingarden at the Recreation & Cultural Center is estimated to remove 17.6 lbs of TN and 0.76 lbs of TP annually.

  o The Stormwater Assessment and Improvement Plan (SAIP) has identified the residential area to the north of Lake Idyl as priority area 1. Proposed stormwater improvements are estimated to remove 386 lbs of TN and 60 lbs of TP annually.

- 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 has recently engaged in habitat restoration activities in the form of tussock removal on Lake Idyl. Staff will continue to monitor the lake for tussock formation and removal where necessary.

Lake Idylwild

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health Score
2	2	2	2	3	3	1	2	2.1

Location, Characteristics, & Hydrology:

Lake Idylwild is located to the 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 on a monthly basis.

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

Due to the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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 3-117). That said, wetter and drier periods

often result in more extreme peaks and troughs, respectively. During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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 Chla, TN, and clarity (see appendix). This carries management implications as maintaining higher levels should correlate with improved water quality.
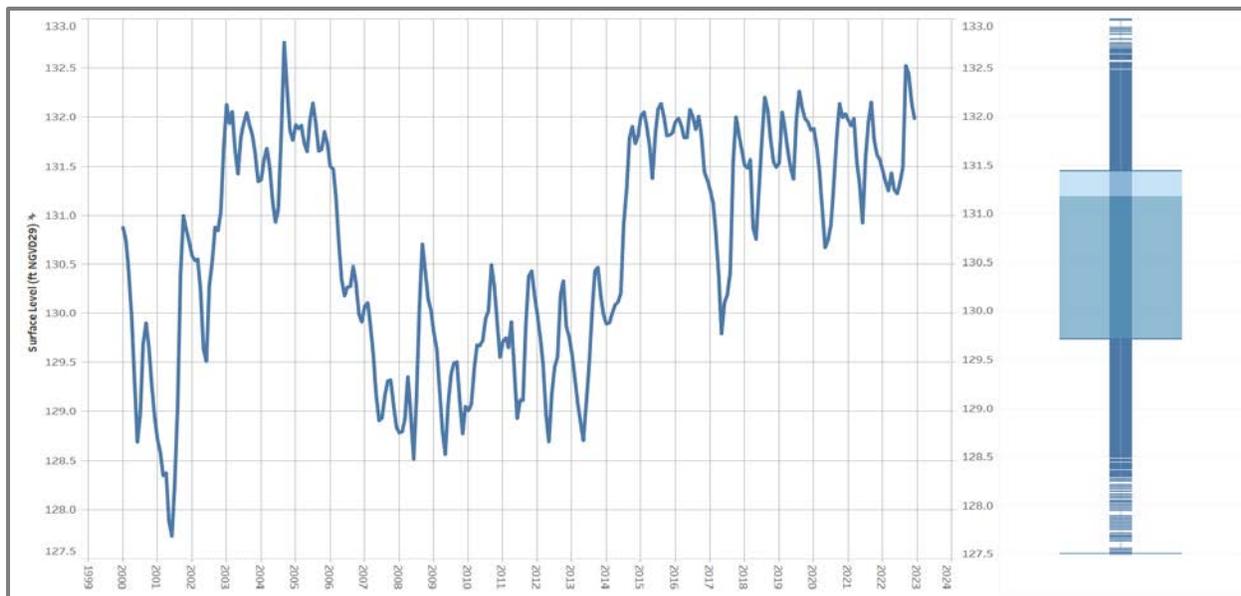
Figure 3-117. Hydrograph of Lake Idylwild depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 Chla (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	
TN	N	2
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Based on the data, Secchi depth exhibits a significant improving trend; resulting in a trend criterion score of 3. While not statistically significant, Chla, TN, and TP all exhibit improving trends—for 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	Not Significant	2
TN	Decreasing	Not Significant	2
TP	Decreasing	Not Significant	2
Secchi	Increasing (Improving)	Significant	3
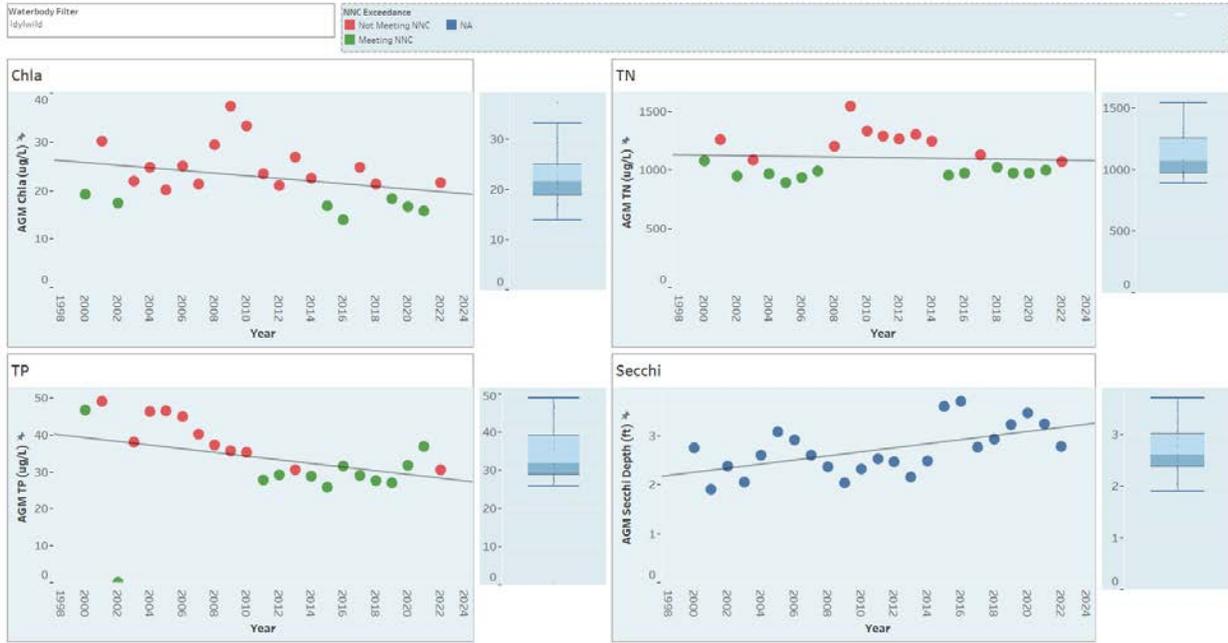
Figure 3-118. Lake Idylwild AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Idylwild on May 3rd, 2022. The PAC during this survey was 58.9% and the total BV was 35.9% (Figure 3-119). The 2022 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.
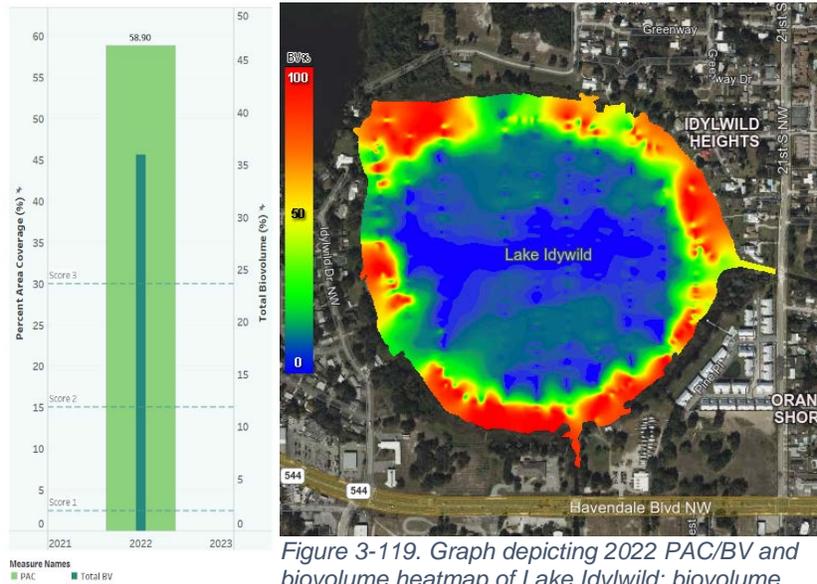
Figure 3-119. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Idylwild; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2022 survey data, native species dominated the vegetation community. The most dominant species were eel grass and fragrant water lily, both at 15% (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 3.65% of the community; resuting in an invasive criterion score of 1. Based on data from 2018 to 2022, the invasive percentage has consistently been between 1.75% and 6%. This indicates that invasive populations are in a controlled state.
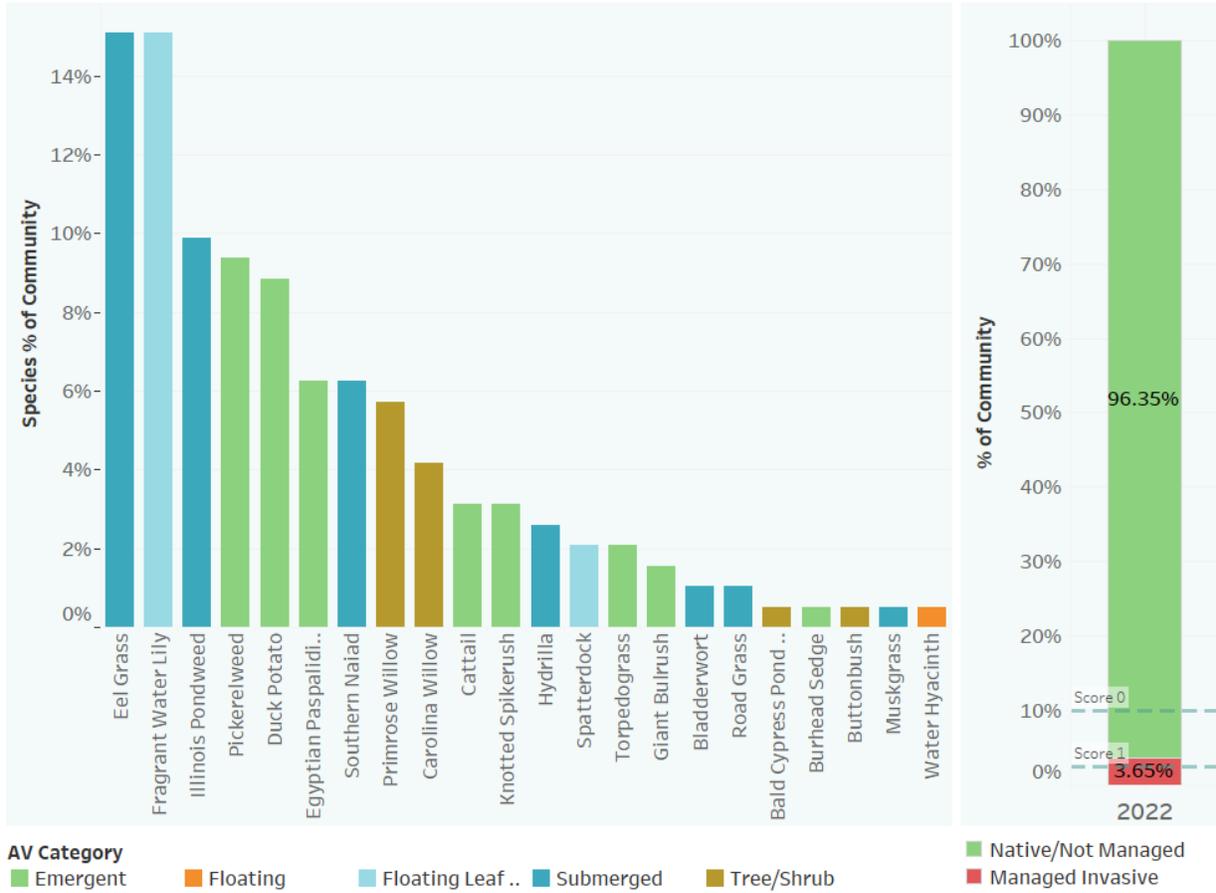
Figure 3-120. Chart depicting species frequency and invasive species percentage of Lake Idylwild during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, Lake Idylwild's richness and overall diversity indices exceeded their respective median values (Figure 3-121). This equates to a diversity criterion score of 2. Despite the two most dominant species being mostly equal, more species were detected at lower relative percentages. This ultimately brought the evenness index lower than the median.
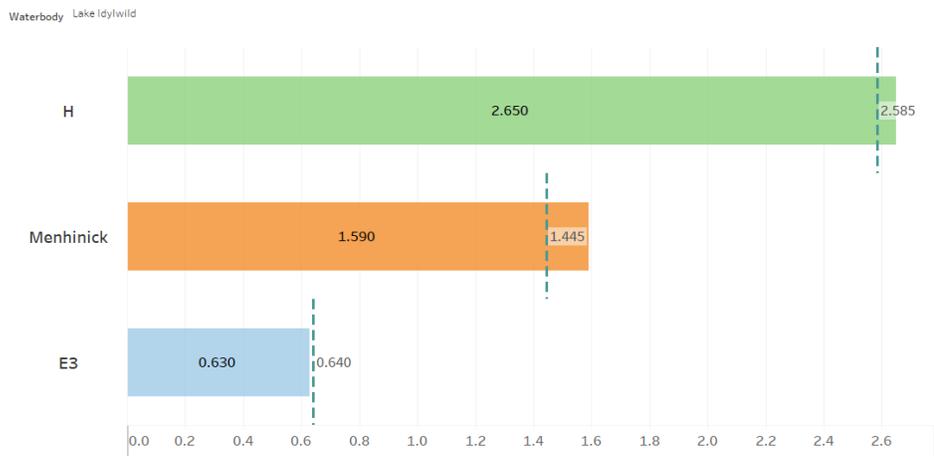
Figure 3-121. Chart depicting 2022 diversity indices for Lake Idylwild. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Idylwild's health index scores from 2018 to 2022 shows some slight 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 for TN and Clarity 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	2	0	**1.9**
2021	2	2	2	2	3	3	1	2	**2.1**
2022	2	2	2	2	3	3	1	2	**2.1**

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. The 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 utilize this mindset are better prepared to utilize green infrastructure in their on-site stormwater treatment.

- Due to the 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.

Lake Jessie

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

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 around 10 feet (Figure 3-123).

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

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 3871 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 consitiues a relatively high density and a potential nutrient source via septic leaching into groundwater. Lacking public roadways or stormwater infrastructure on the east side of the lake, the City does not conduct any street sweeping services within this basin.

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

Due to the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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 3-117). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2022, the South Chain

reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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 Jessie's surface level correlate with Chla, TN, and clarity (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.
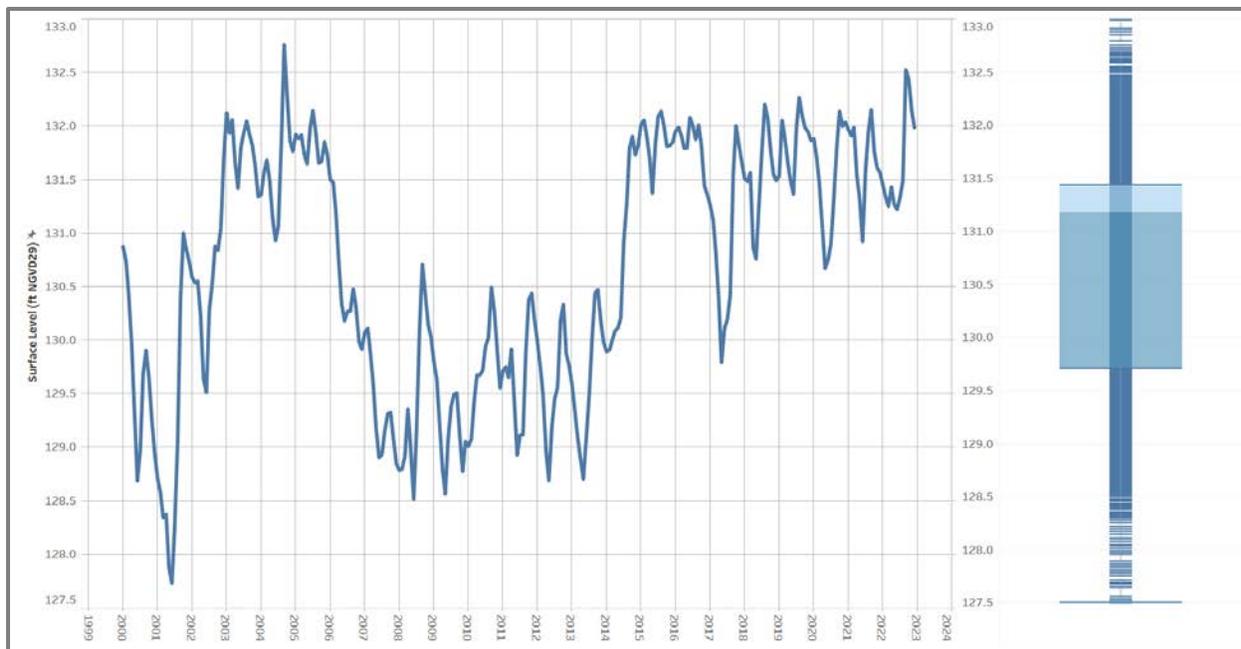
Figure 3-125. Hydrograph of Lake Jessie depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface levels during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 to 2022 assessment period, Lake Jessie is considered impaired for Chla, 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	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. None of Lake Jessie's water quality metrics exhibit significant trends. Chla and TN earn trend criteria score of 1 for their non-significant deteriorating trends, while TP and Secchi depth receive criteria scores of 2 for improving trends (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	1
TN	Increasing	Not Significant	1
TP	Decreasing	Not Significant	2
Secchi	Increasing	Not Significant	2
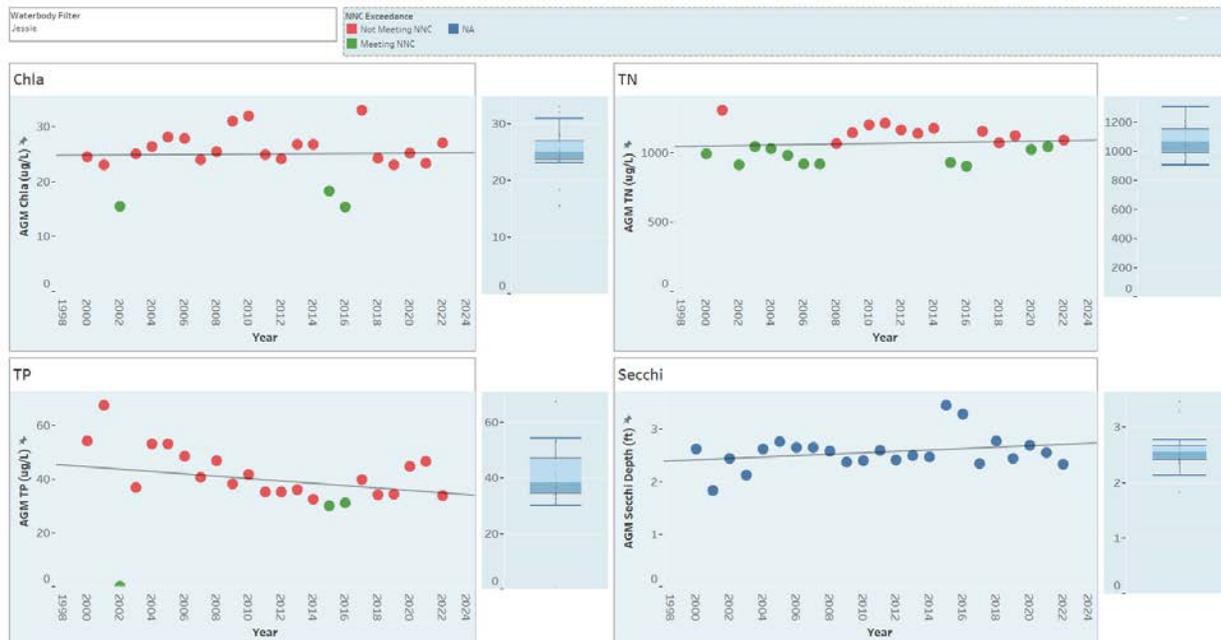
Figure 3-127. Lake Jessie AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Jessie on February 11th, 2022. The PAC during this survey was 43.5% and the total BV was 7.26% (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.

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data

Figure 3-126. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Jessie; biovolume values range from green (lowest) to red (highest).

from the 2022 survey, Lake Jessie is clearly dominated by eel grass. At 23% of the community, this native submerged plant has more than double the presence of any other 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 just 2.55% of the community. This is slightly over the 2.5% threshold, resulting in an invasive criterion score of 1.

Figure 3-128. Chart depicting species frequency and invasive species percentage of Lake Buckeye during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, only the overall diversity index met or exceeded its long-term median value (Figure 3-129). While there was an increase in species richness over the two previous years, the number of unique species was not over the median value. Species evenness was below the median likely because a reduction in invasive plants like hydrilla and burhead sedge allowed some species to gain a greater presence in the community than others. In previous years, species besides eel grass were more evenly distributed. Due to this, the 2022 diversity criterion score for Lake Jessie is 1.
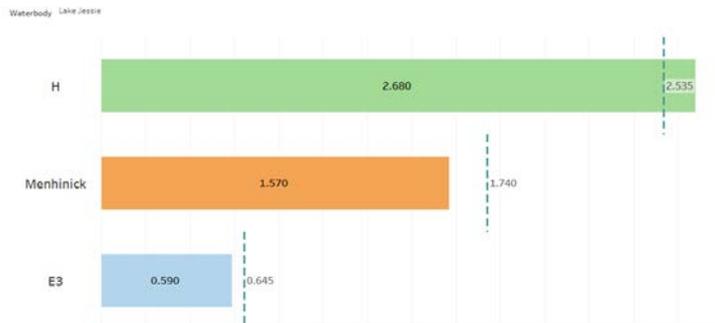
Figure 3-129. Chart depicting 2022 diversity indices for Lake Jessie. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Jessie's health index scores from 2018 to 2022 shows some minor decline (Figure 3-130). While impairment criterion scores have not changed in this five year span, there have been some changes in some of the trend scores. The TP trend lost statistical significance in 2019 and there was a brief period in 2021 where the Chla trend switched directions. The majority of the score variance has come from species diversity. This is likely due to minute changes in the vegetation community, due in part to the invasive species management efforts. Overall, 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	1	2	1.6
2022	0	1	1	2	2	3	1	1	1.4

Figure 3-130. Chart depicting a comparison of Lake Jessie's Lake Health Index scores from 2018 to 2022.

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. The 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 Score
3	2	3	2	2	2	1	1	2.0

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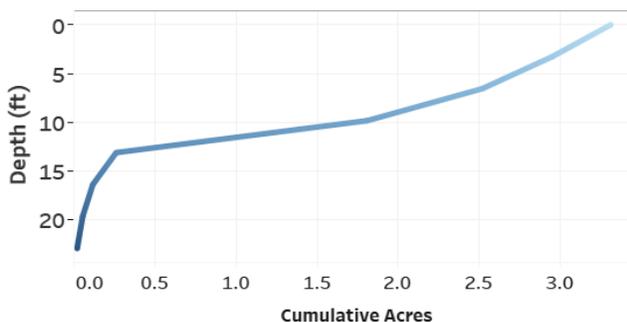
Figure 3-131. Hypsograph of Lake Link depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

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.

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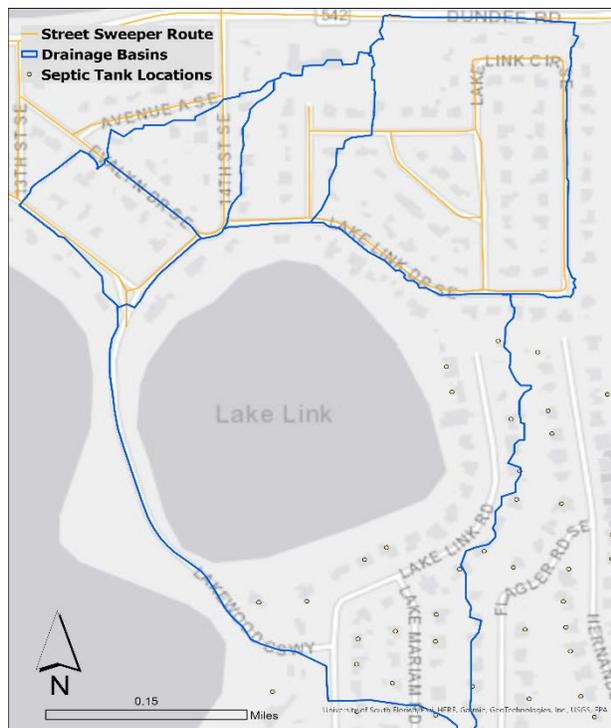
Figure 3-132. Map of Lake Link's drainage basin, City street sweeper routes, and nearby septic systems.

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 2022, Lake Link reached a wet season peak of 128.2 feet in October and a dry season low of 126.9 feet in March. The surface level ended the year at 127.9 feet—above the high end of the normal range. 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.
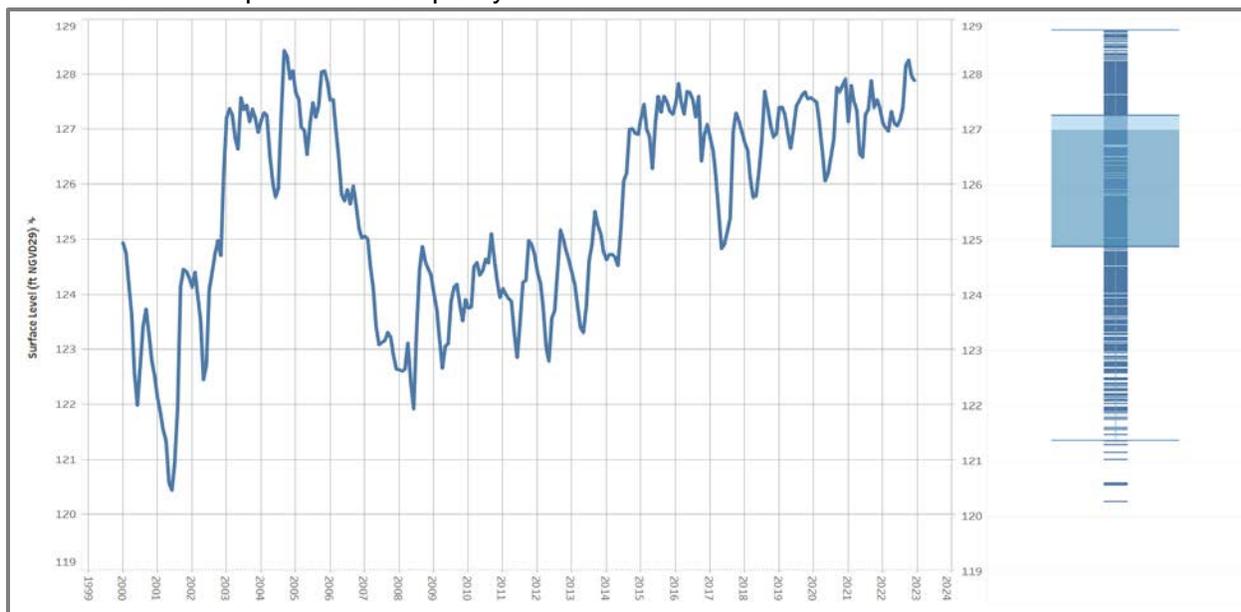
Figure 3-133. Hydrograph of Lake Link depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 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	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Based on the data, TN exhibits a significant improving trend; resulting in a tend criterion score of 3. Chla, TP, and Secchi depth all exhibit non-significant improving trends which equate with criteria scores 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 (Improving)	Significant	3
TP	Decreasing	Not Significant	2
Secchi	Increasing	Not Significant	2
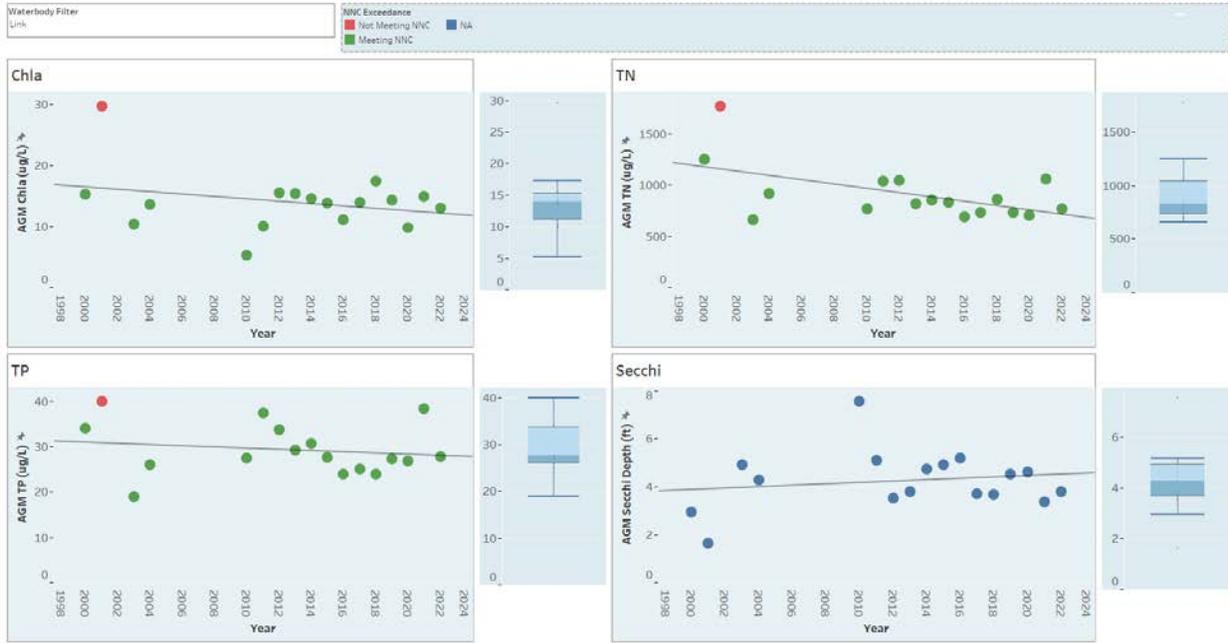
Figure 3-134. Lake Link AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Link on August 2nd, 2022. The PAC during this survey was 24.6% and the total BV was 2% (Figure 3-135). This equates to an abundance criterion score of 2. Over the period of record, Lake Link has had coverage values above the 30% ideal threshold in 2018 and 2020. However, abundance has dwindled below this level since 2021. Management of invasive species like hydrilla is a likely driver of this decrease in overall vegetation abundance. The lake relies on natural recruitment of native species to fill this gap in coverage.
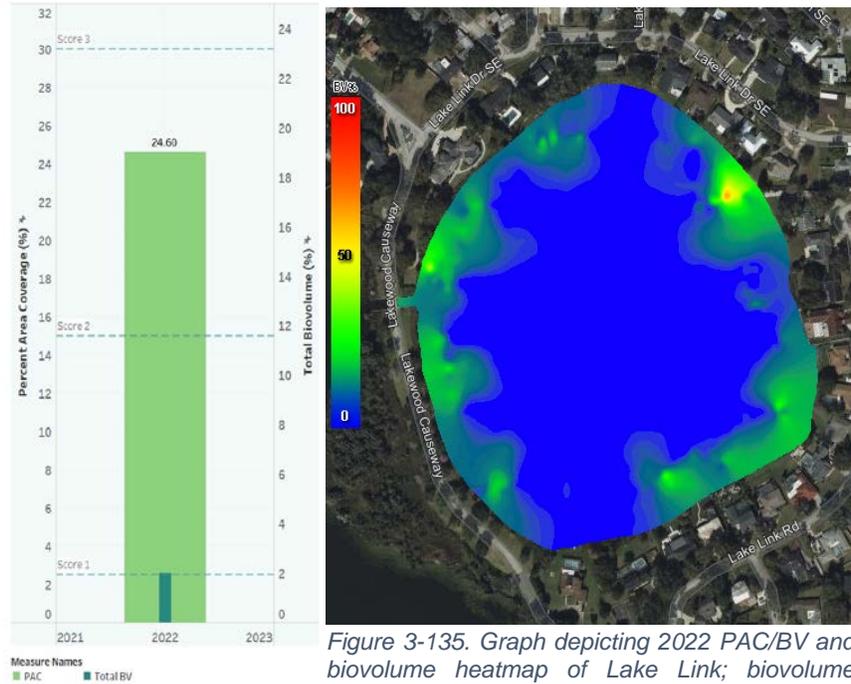
Figure 3-135. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Link; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2022 survey, over 50% of the vegetation community was

dominated by floating leaf and emergent plants (Figure 3-136). Submerged plants like coontail and eel grass made up around 16% of the community. The managed invasive percentage was 5.45%, which earns a criterion score of 1. Hydrilla and water hyacinth were the primary contributors of this score. The hydrilla was not detected in 2021, but has made a resurgence within one growing season—indicating a need to continue monitoring.
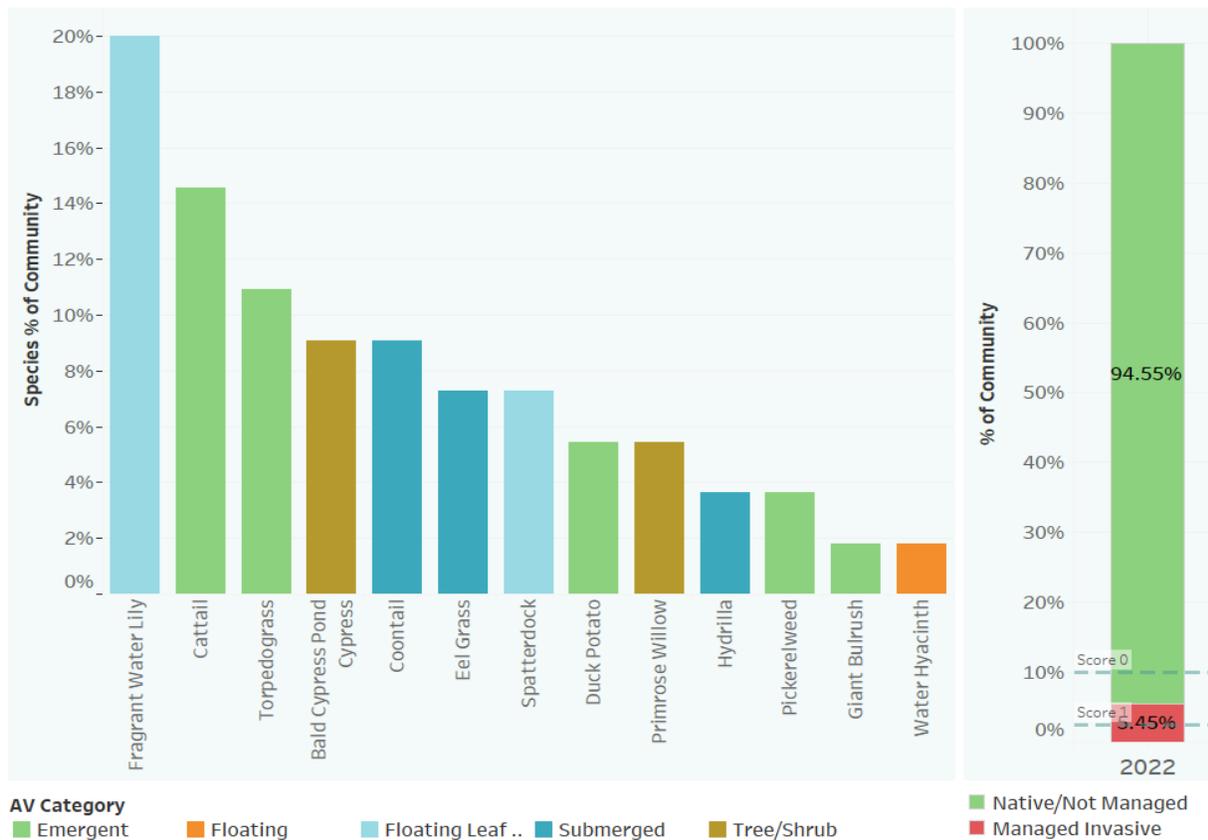
Figure 3-136. Chart depicting species frequency and invasive species percentage of Lake Link during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, Lake Link's richness index exceeded its long-term median value; for a diversity criterion score of 1 (Figure 3-137). While not all of the indices met their median values, they weren't far off from the goal and there was an increase in overall diversity and richness from the previous year.
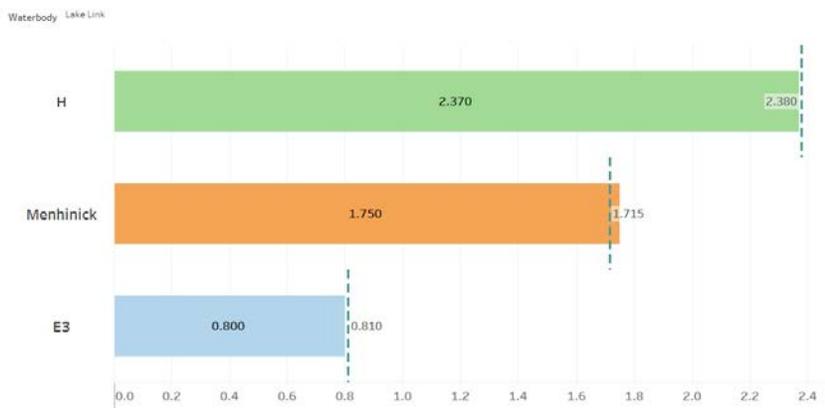
Figure 3-137. Chart depicting 2022 diversity indices for Lake Link. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Link's health index scores from 2018 to 2022 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. Through this five year span, the water quality scores have remained stationary. Based on the 2018 score, it appears that invasive species management has been a constant issue. It is likely that the treatment of invasives has 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.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	2	3	2	2	3	1	2	2.3
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

Figure 3-138. Chart depicting a comparison of Lake Link's Lake Health Index scores from 2018 to 2022.

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. The 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 this basin is comprised of residential housing, public outreach and education is an ideal management strategy. 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 Score**
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 Wahneta 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).
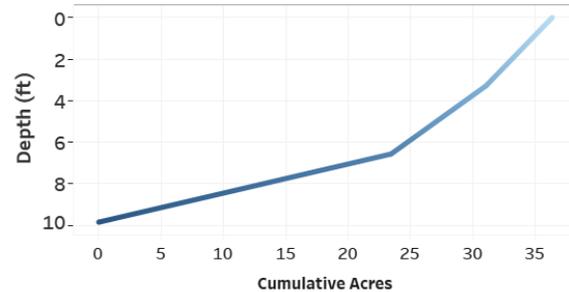
Figure 3-139. Hypsograph of Lake Lulu depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Stormwater is conveyed to this waterbody from a 1006 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 2791 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 on a monthly basis.

Due to the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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 3-141). That said, wetter and

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

drier periods often result in more extreme peaks and troughs, respectively. During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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.
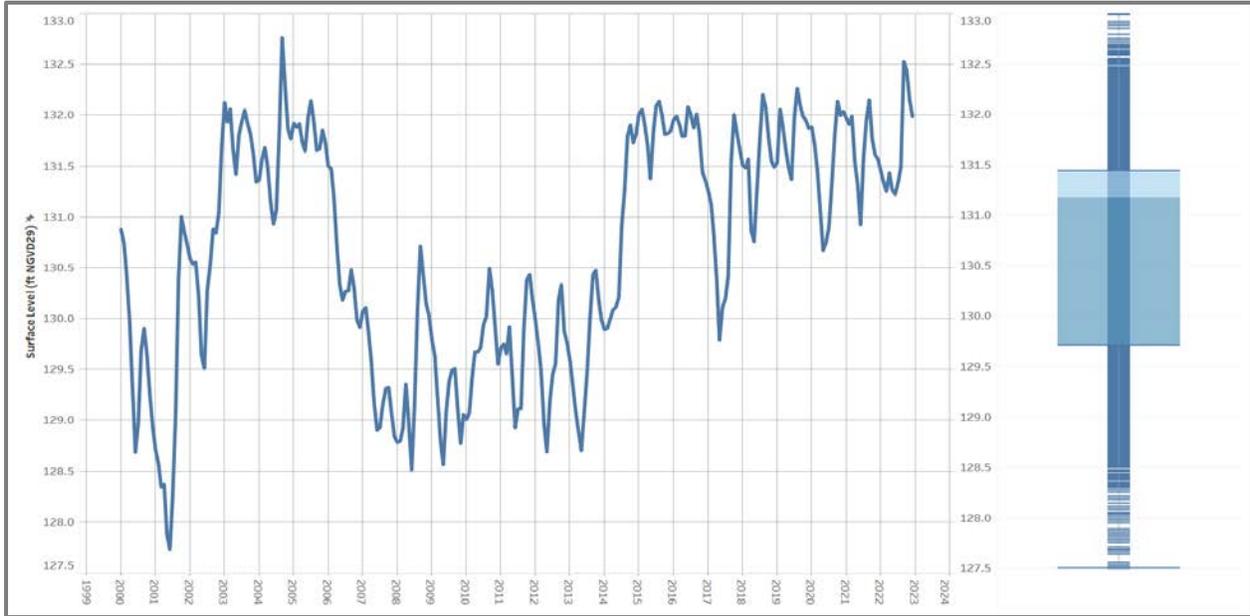
Figure 3-141. Hydrograph of Lake Lulu depicting monthly surface level readings from 2000 to 2022. A box and whisker plot detail total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period, Lake Lulu is considered impaired for Chla, 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 Chla, TN, and TP.

Parameter	Impaired	Index Score
Chla	Y	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Based on these data, all four of these parameters exhibit significant improving trends. It will still take at least 7.5 years of water quality values that meet NNC guidelines for Lake Lulu to be considered unimpaired. However, the trends indicate that this waterbody is well on its way to meeting those goals.

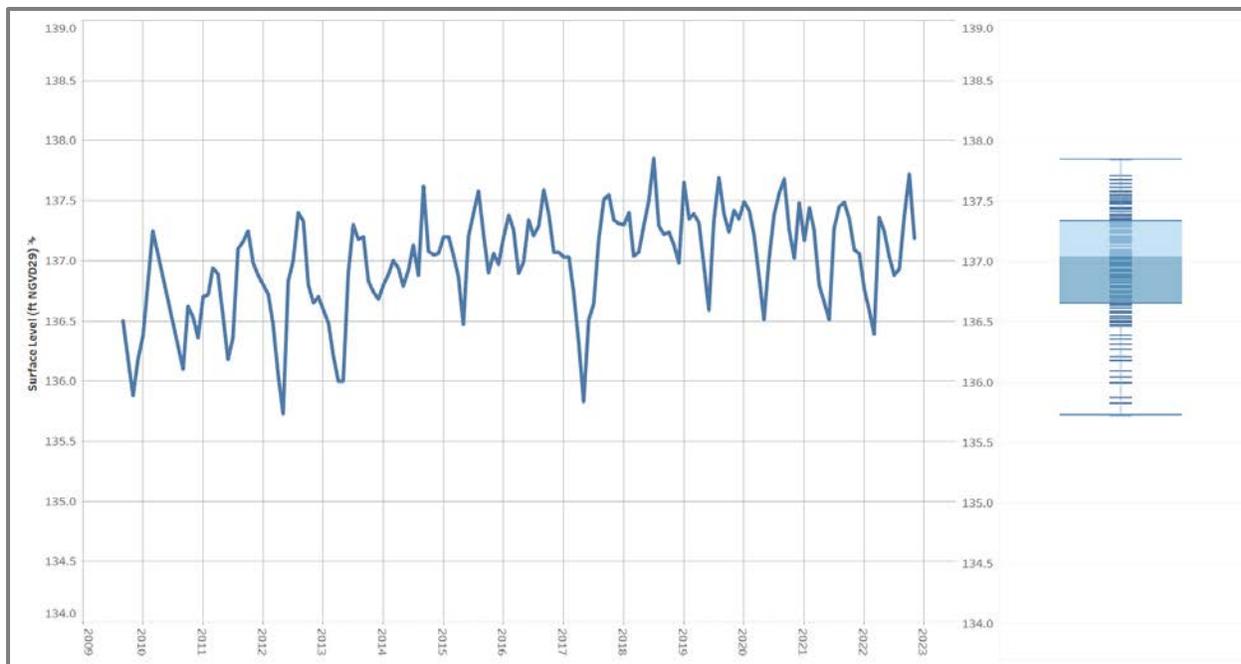| Parameter	Trend Direction	Significance	Index Score
Chla	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing (Improving)	Significant	3
Secchi	Increasing (Improving)	Significant	3
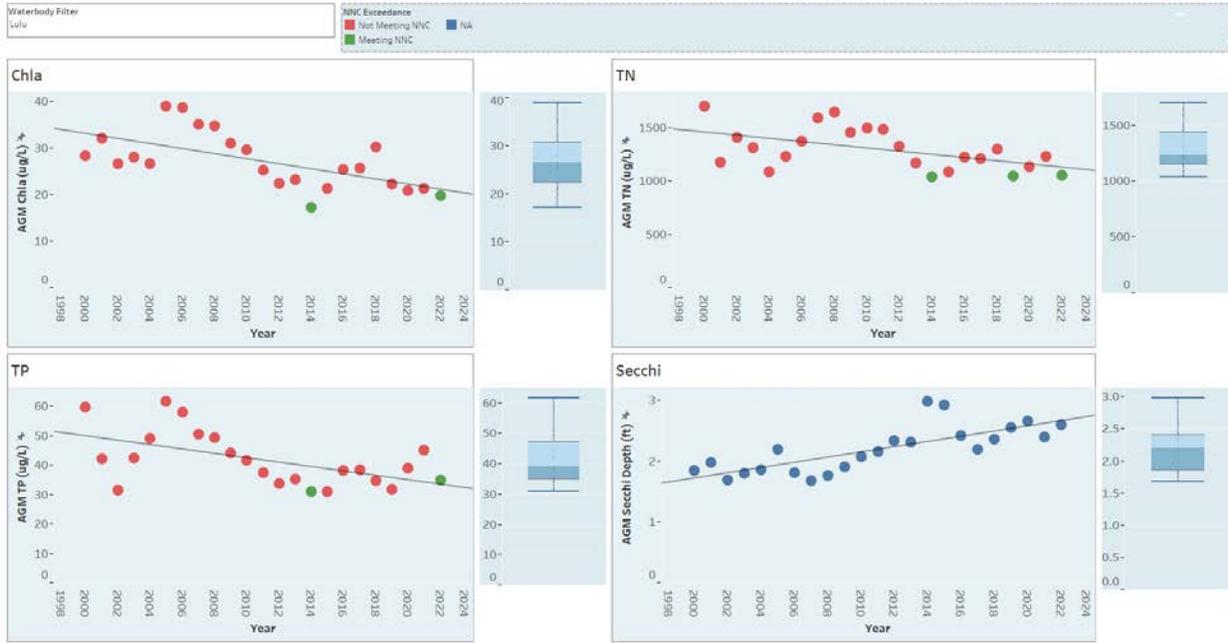
Figure 3-142. Lake Lulu AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Lulu on June 30th, 2022. The PAC during this survey was 45.7% and the total BV was 6.57% (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 2022 is currently the highest on record.
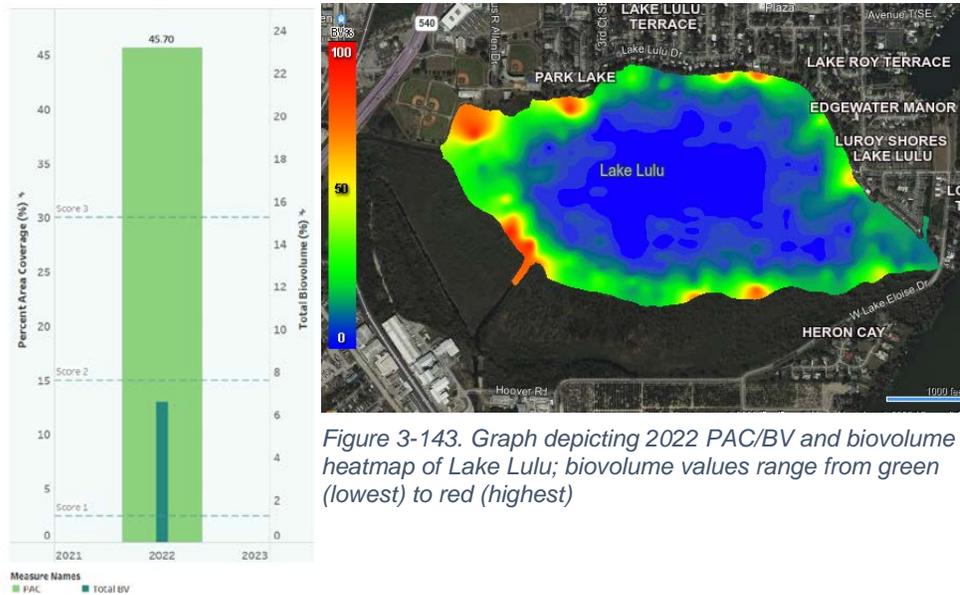
Figure 3-143. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Lulu; biovolume values range from green (lowest) to red (highest)

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, Lake Lulu maintains a healthy mix of submerged, emergent, and floating leaf plants. The most dominant species present is the native submerged Southern naiad at 15.2% (Figure 3-143). Hydrilla constitutes the only managed invasive species detected during the survey at 3.55%. While a minor contributor to the whole community, this percentage equates to an invasive criterion score of 1. Through 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.
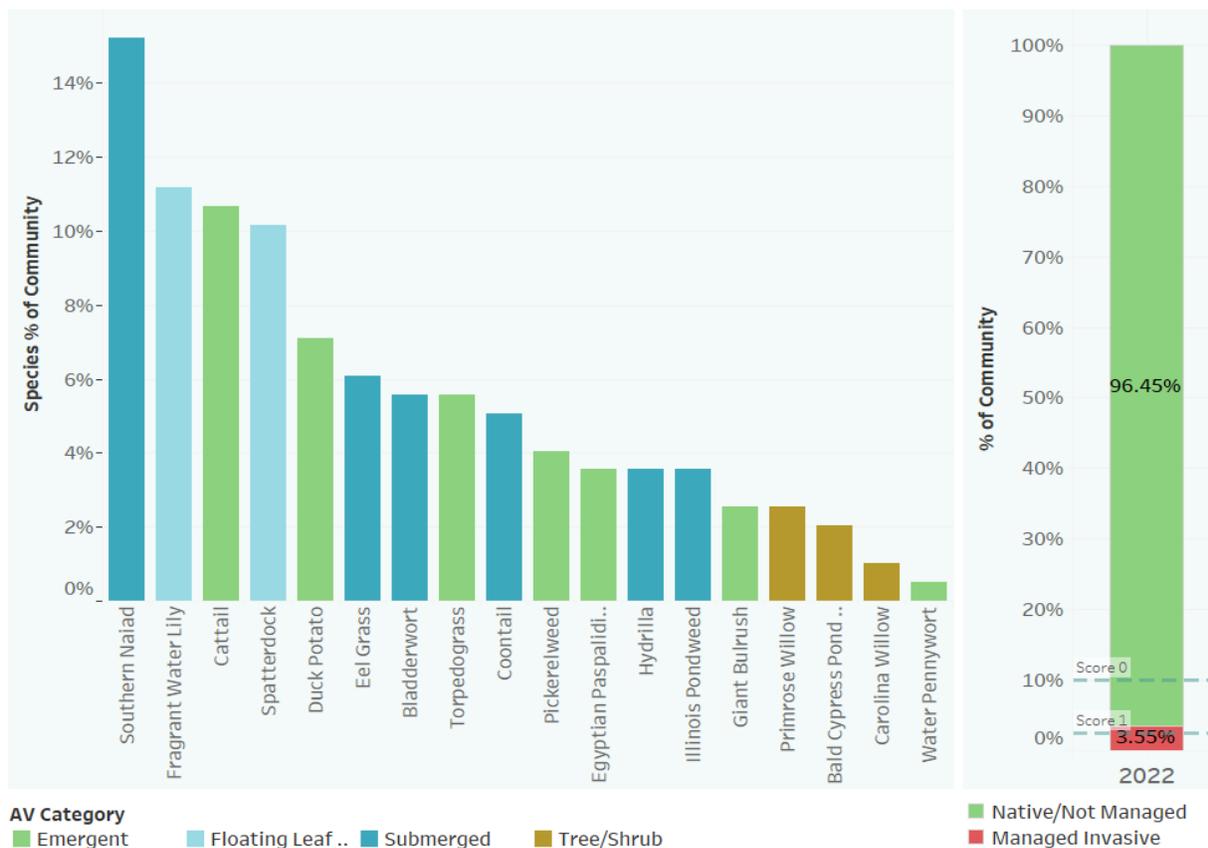
Figure 3-144. Chart depicting species frequency and invasive species percentage of Lake Lulu during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 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 species richness hasn't changed in the last three years, 2022 evenness and overall diversity were the highest on record. The overall vegetation community has been relatively diverse through the period of record. Part of this diversity may be owed to the large undeveloped wetland area on the south side of the lake.
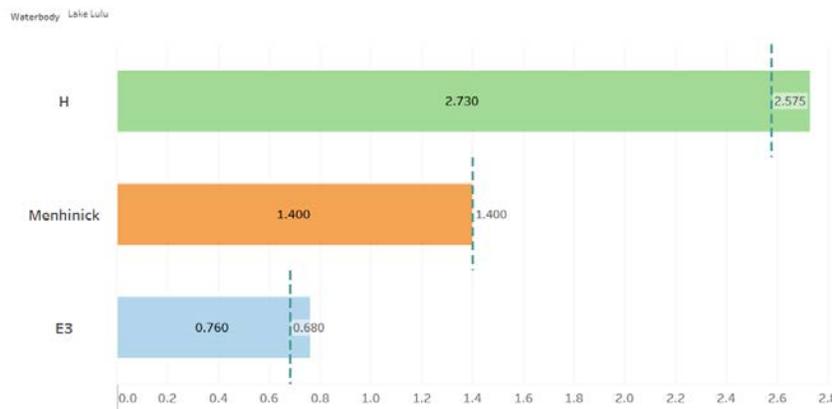
Figure 3-145. Chart depicting 2022 diversity indices for Lake Lulu. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Lulu's health index scores from 2018 to 2022 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	2	1	2.1
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

Figure 3-146. Chart depicting a comparison of Lake Lulu's Lake Health Index scores from 2018 to 2022.

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 be a contributor of 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. The 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 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 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 Stormwater Assessment and Improvement Plan has also identified a priority area for green infrastructure implementation in one of Lake Lulu's northern drainage sub-basins.

Lake Mariam

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

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 surounded 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.

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

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 on a monthly basis. This is limited to the parts of the basin that are within City limits.

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 2022, Lake Mariam reached a wet season

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

peak of 125.5 feet in September and a dry season low of 124.3 feet in March. Throughout the last year, Lake Mariam remained above median surface level—ending the year at 124.7 feet. Changes in Lake Mariam's surface level are not correlated with its water quality metrics (see appendix).
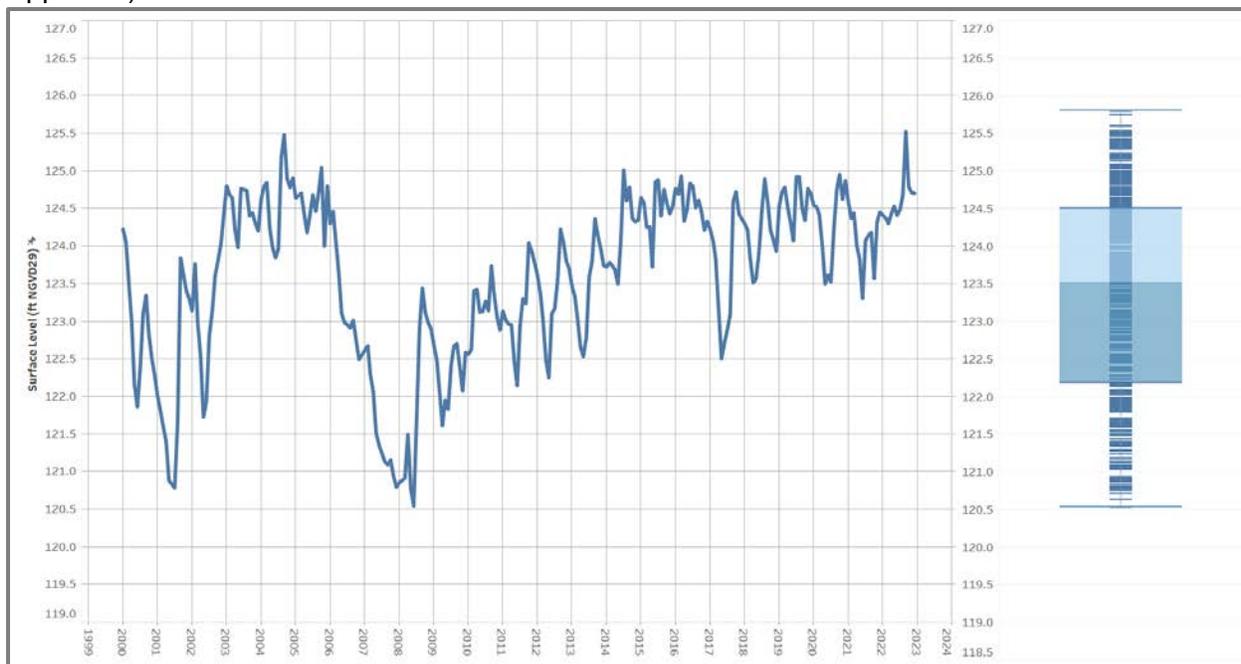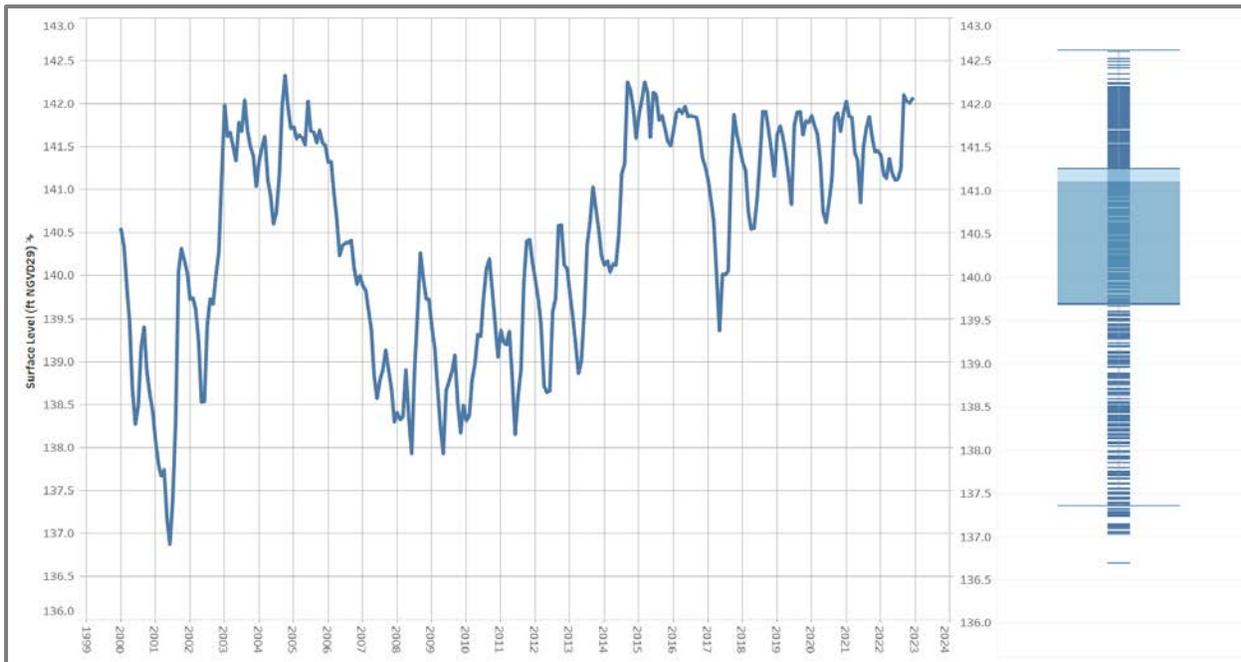

Figure 3-149. Hydrograph of Lake Mariam depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period (Figure 3-150). This equates to an impairment criterion score of 3. It should be noted that the 2022 AGM Chla concentration was the highest on record. However, the high color content likely limits the growth of algae in the water column.

Parameter	Impaired	Index Score
Chla	N	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. While none of Lake Mariam's water quality trends are statistically significant, Chla and TN and moving in a deteriorating direction—earning trend criteria score of 1. The TN and Secchi depth trends are moving in an improving direction, however; earning 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	Increasing	Not Significant	2
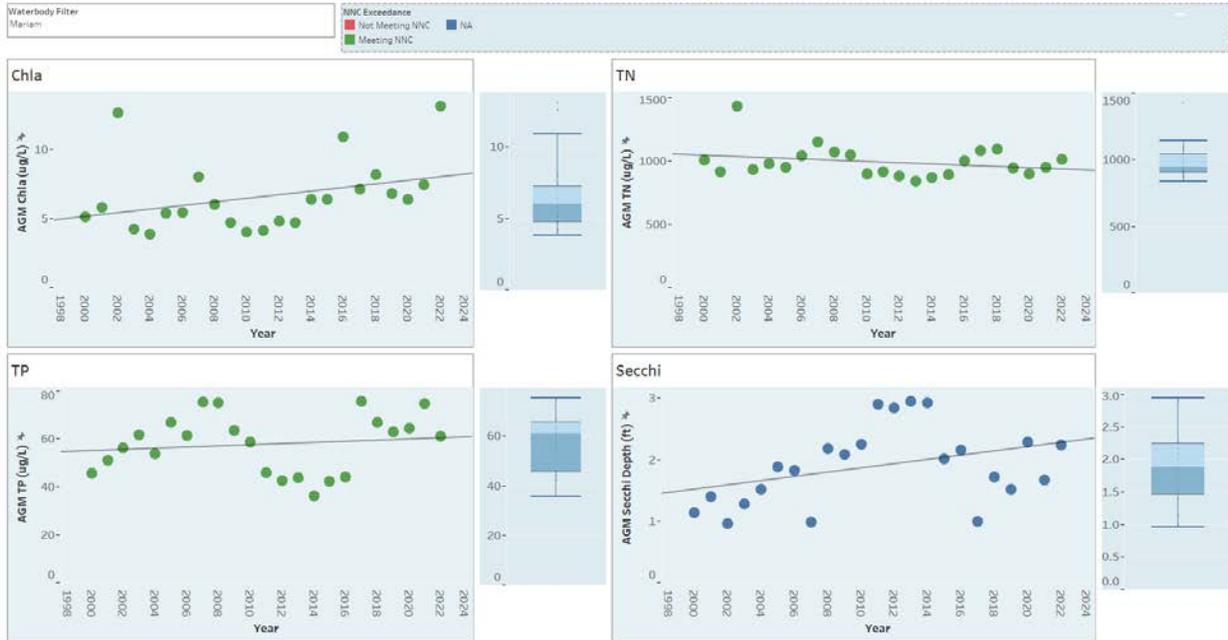
Figure 3-150. Lake Mariam AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Mariam on May 27th, 2022. The PAC during this survey was 34.9% and the total BV was 45.5% (Figure 3-151). This equates to an abundance criterion score of 3. Due to Lake Mariam's shallow depth and gradually sloping lake bed, it's littoral zone is fairly wide and supports a high abundance of vegetation. That said, the biovolume value for 2022 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.

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling

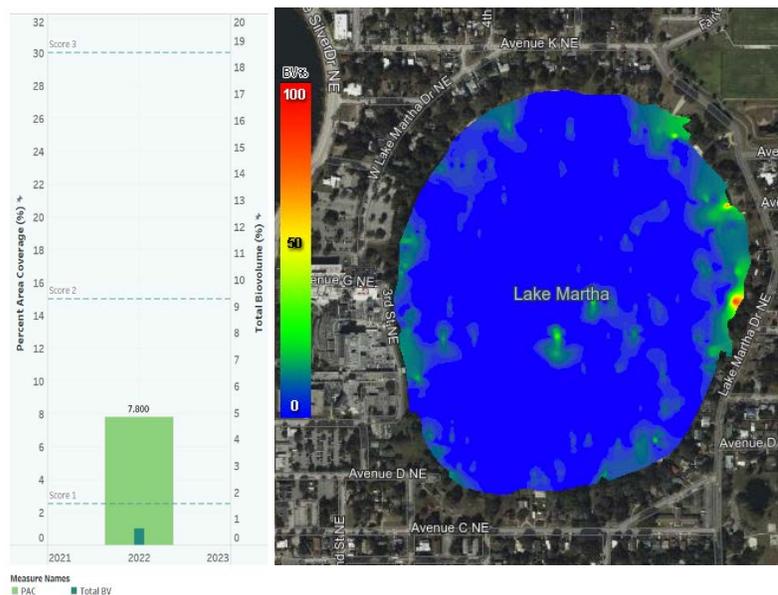*Figure 3-151. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Mariam; biovolume values range from green (lowest) to red (highest).*

methods. Based on Lake Mariam's high color concentration, it is dominated by emergent species. Of these, primrose willow, cattail, and duck potato comprised over 50% of the community (Figure 3-152). While there were several exotic species detected during 2022 (e.g. melaleuca and

alligator weed), the only managed invasive species present, water hyacinth, made up just 2% of the community. This equates to an invasive criterion score of 2. A comparison to previous years shows that invasives like the hyacinth and burhead sedge have comprised up to 30% of the community. This demonstrates that much of these invasives have been controlled.
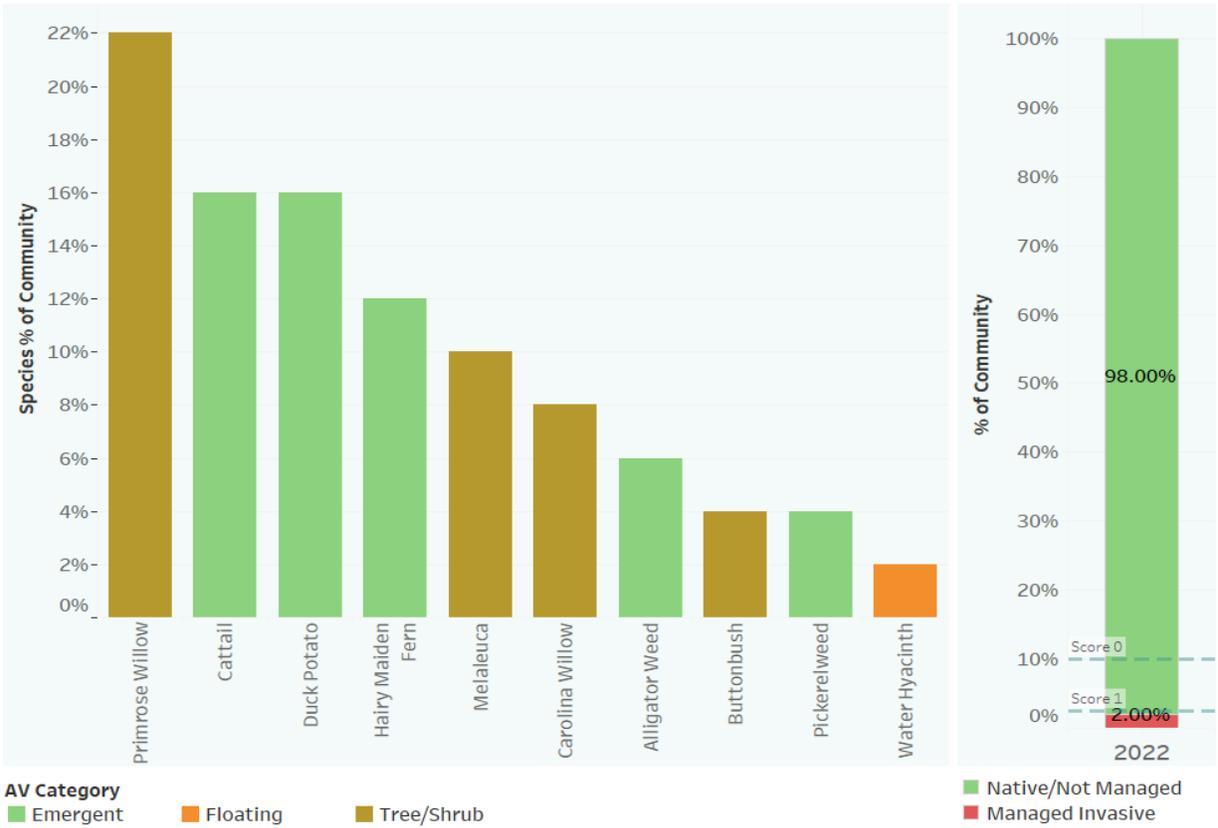
Figure 3-152. Chart depicting species frequency and invasive species percentage of Lake Mariam during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, Lake Mariam's species evennes and overall diversity indices met or exceeded their respective 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 2022 evenness index was the highest on record while species richness remained relatively stable. This resulted in an increase in overall diversity.
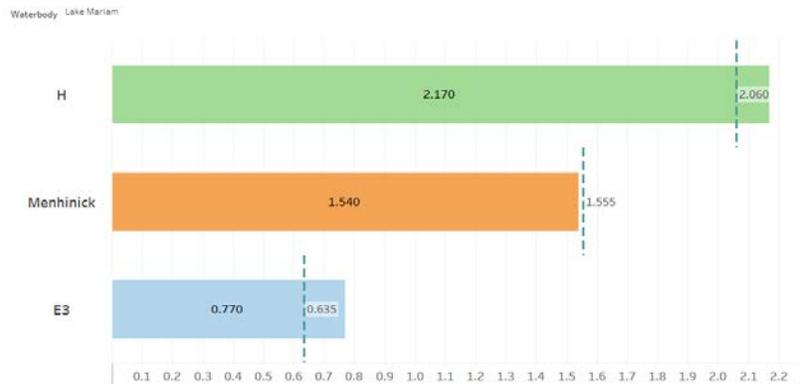
Figure 3-153. Chart depicting 2022 diversity indices for Lake Mariam. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Mariam's health index scores from 2018 to 2022 shows slight improvement from 1.8 to 2.0 (Figure 3-154). While the impairment score has remained stable over the last five years, there have been some minor changes in the significance and direction of some of the water quality trend scores. 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 remained relatively stable. This shows success in the invasive plant management efforts. 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	2	1.8
2019	3	1	2	2	2	2	0	2	1.8
2020	3	1	2	1	2	1	2	1	1.6
2021	3	1	2	1	2	3	3	2	2.1
2022	3	1	2	1	2	3	2	2	2.0

Figure 3-154. Chart depicting a comparison of Lake Mariam's Lake Health Index scores from 2018 to 2022.

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 herbicde 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	0	0	3	0	2	3	1	1.1

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 1935 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 6530 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 of nutrient loading via groundwater leaching. Lacking any City roadways bordering the lake, Winter Haven does not conduct street sweeping services within this basin.
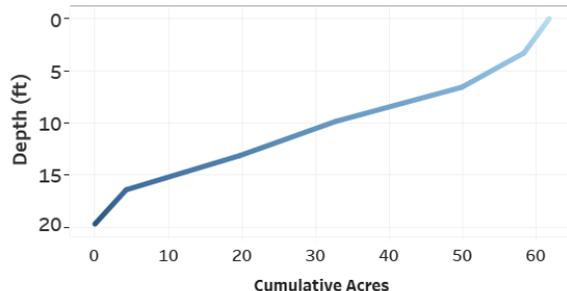
Figure 3-155. Hypsograph of Lake Mariana depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

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

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 2022, Lake Mariana reached a wet season peak of 137.7 feet in October and a dry season low of 136.4 feet in March. Lake Mariana's level ended the year sitting just above the median level at 137.2 feet. 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 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairments:

For the purposes of determining 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 2015 – 2022 assessment period, Lake Mariana is considered impaired for Chla, 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 meed NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. According to the data, Chla, TN, and Secchi depth exhibited significant deteriorating trends. This has resulted in trend criteria scores of 0 for these parameters. Incidentally, TP exhibited a significant improving trend during this period, for a criterion score of 3. 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	Decreasing (Improving)	Significant	3
Secchi	Decreasing (Deteriorating)	Significant	0
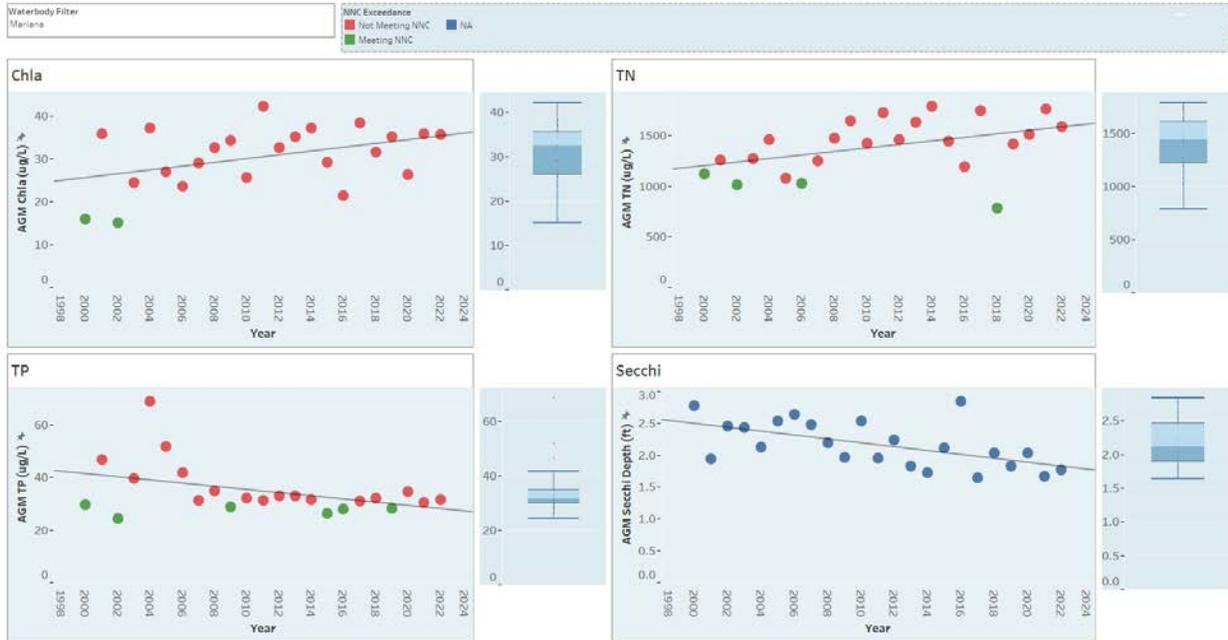
Figure 3-159. Lake Mariana AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Mariana on November 18th, 2022. The PAC during this survey was 27.8% and the total BV was 5.98% (Figure 3-159). This equates to an abundance criterion score of 2. Throughout the monitoring period, Lake Mariana has maintained vegetation coverage between 22% and 28%. Due to its morphology and the relatively low water clarity, the littoral zone is limited for this lake. That said, the 2022 coverage value was Lake Mariana's highest on record.
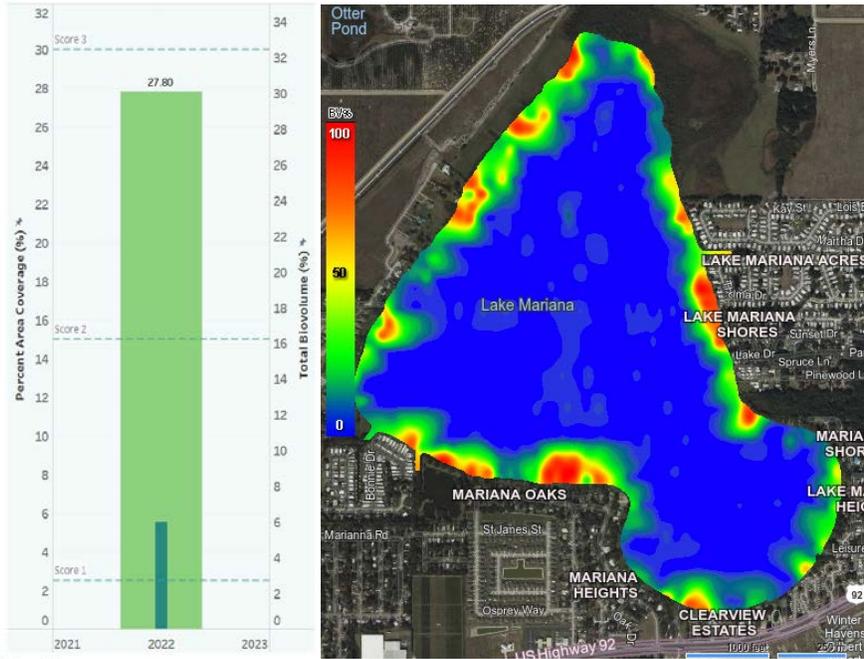
Figure 3-158. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Mariana; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, Lake Mariana posseses a health mix of difference vegetation types. The most dominant species detected was the native Illinois

pondweed at 26.8% (Figure 3-160). While there were some exotic species detected (e.g. torpedograss and primrose willow), no managed invasive species were observed during the survey. This equates to an invasive criterion score of 3. In previous years, water hyacinth has been the primary invasive species managed. However, it appears to be currently in a controlled state.

AV Category
- Emergent
- Floating Leaf ..
- Submerged
- Tree/Shrub

Native/Not Managed
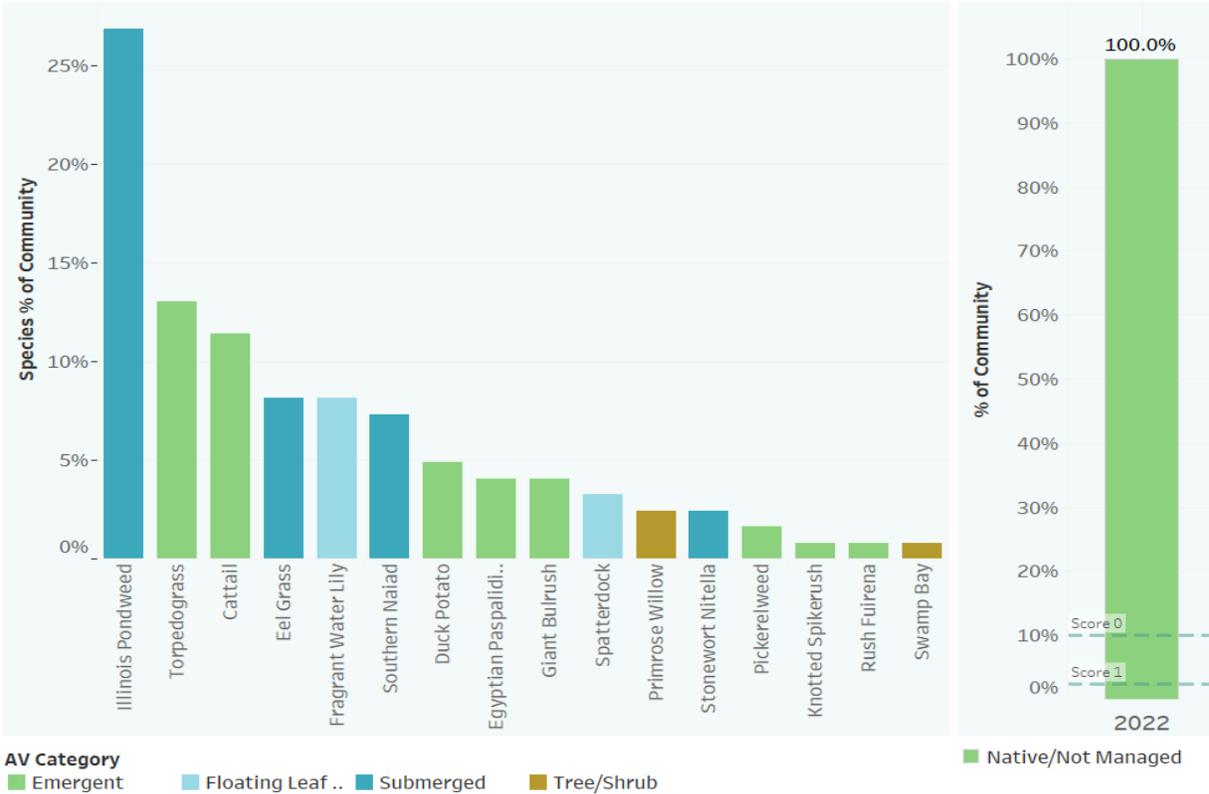
Figure 3-160. Chart depicting species frequency and invasive species percentage of Lake Mariana during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, Lake Mariana's species evenness value was the only diversity index to meet or exceed its median value (Figure 3-161). This equates to a diversity criterion score of 1. Species richness and overall diversity declined from 2021 due to an absence of water hyacinth, wild taro, and some other rarely encountered species. None of these absent species constituted a large presence in the community and the amount of invasive treatment in 2022 was minimal. It can be inferred that the changes in the vegetation community were largely self-regulated natural fluctuations.
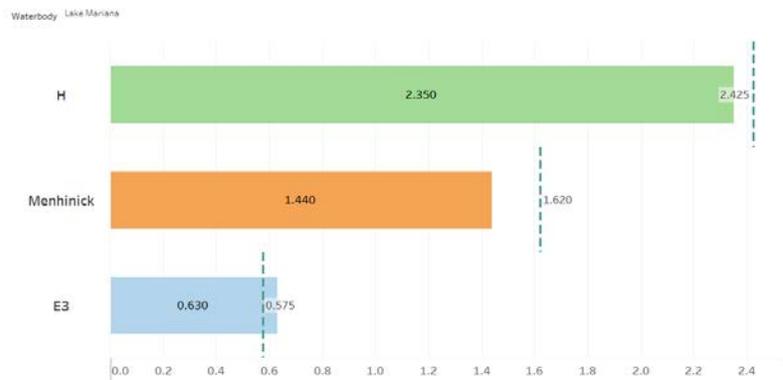
Figure 3-161. Chart depicting 2022 diversity indices for Lake Mariana. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Mariana's health index scores from 2018 to 2022 shows little change (Figure 3-162). The impairment and vegetation abundance scores have remained static over this five year span. While the significance of the Chla, TN, TP, and Secchi depth trends has shifted over the years, the majority of the score fluctuation has come from the invasive presence and diversity criteria. Overall, Lake Mariana is considered high priority 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	1	1	1.1
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

Figure 3-162. Chart depicting a comparison of Lake Mariana's Lake Health Index scores from 2018 to 2022.

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.

- While the current presence of invasive species is low, 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 in order to implement basin-wide improvements.

Lake Management Strategy:

- The City plans to provide what support it can to manage for 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 Score
3	0	1	0	0	1	3	2	**1.3**

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 1217 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 on a monthly basis.
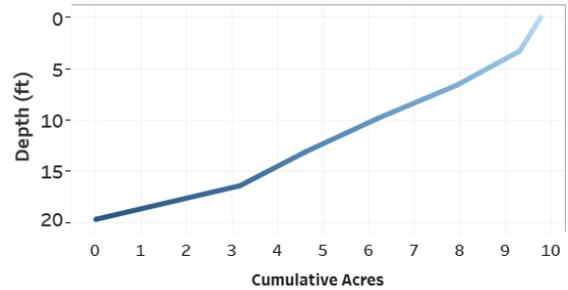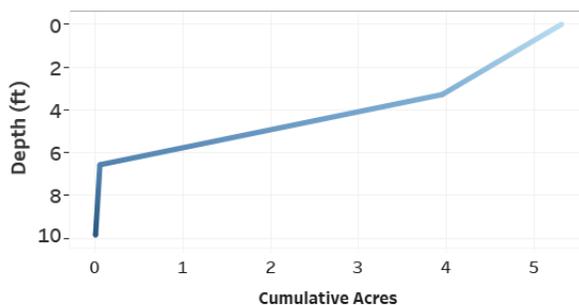

Figure 3-163. Hypsograph of Lake Martha depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

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 2022, Lake Martha reached a wet season peak of 142.1 feet in September and a dry season low of 141.1 feet in June. The surface level ended the year well above the normal range at 142.06 feet. Based on linear regression analysis, changes in Lake Martha's surface level are directly correlated with Chla concentration (see appendix).
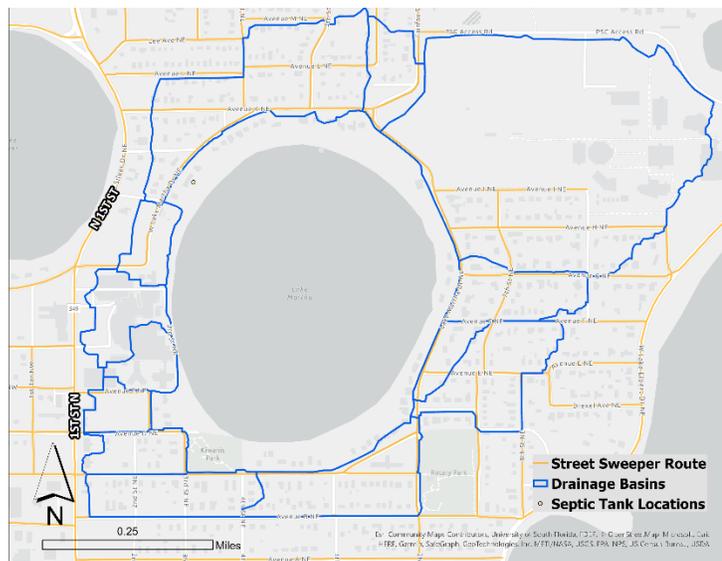
Figure 3-164. Map of Lake Martha's drainage basin, City street sweeper routes, and nearby septic systems.

Considering that this is the opposite relationship to most other waterbodies in the area, it is likely that this correlation is spurious.
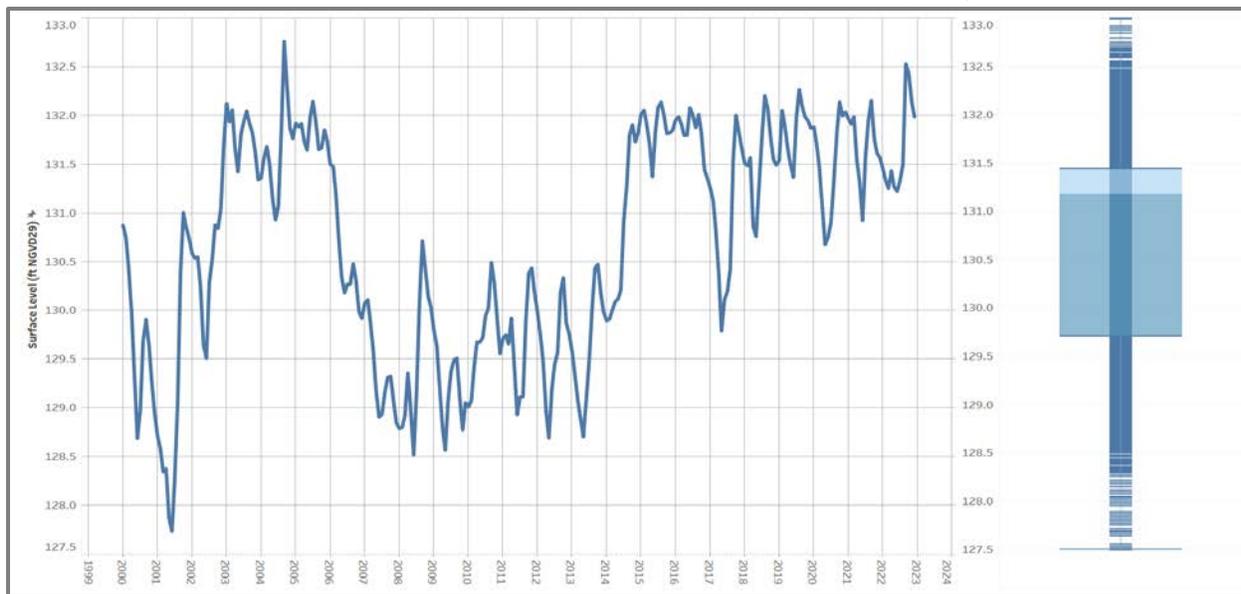

Figure 3-165. Hydrograph of Lake Martha depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Martha is categorized as a clear, alkaline waterbody. Over the course of recent monitoring, Lake Martha has not exhibited any NNC exceedances in Chla, TN, or TP (Figure 3-166). This equates to an impairment score of 3. It should be noted that the 2022 TN and TP concentrations were well below the normal range—indicating some improvement in water quality.

Parameter	Impaired	Index Score
Chla	N	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. According to the data, Chla, TP, and Secchi depth exhibited significant deteriorating trends. These equate to trend criteria scores of 0. The TN trend, while in a deteriorating direction, was not significant—earning a trend score of 1. This is a change in trend significance from previous years and indicates that at least one water quality metric is exhibiting signs of 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 (Deteriorating)	Significant	0
Secchi	Decreasing (Deteriorating)	Significant	0
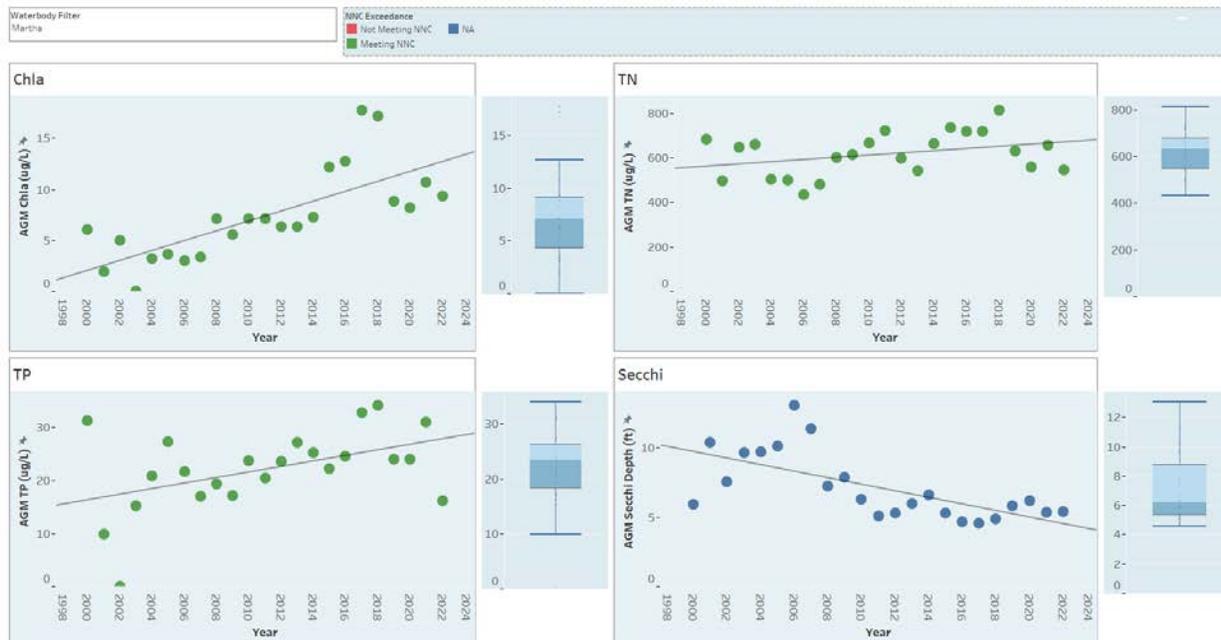
Figure 3-166. Lake Martha AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Martha on August 24th, 2022. The PAC during this survey was 7.8% and the total BV was 0.6% (Figure 3-167). This equates to an abundance score of 1. A review of Lake Martha's abundance values from 2018 to 2022 shows a lack of coverage and biovolume. While the lake bed steeply slopes into deeper water, its relateively high water clarity should support much more vegetation than is currently present. That said, these survey data show a slow, but steady increase in overall abundance over the last five years.

Figure 3-167. Graph depicting 2022 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 2022 survey, it is clear that emergent species dominate the vegetation community. At nearly 35% of the community the exotic torpedograss 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 need and this population has since denuded the lake of SAV.
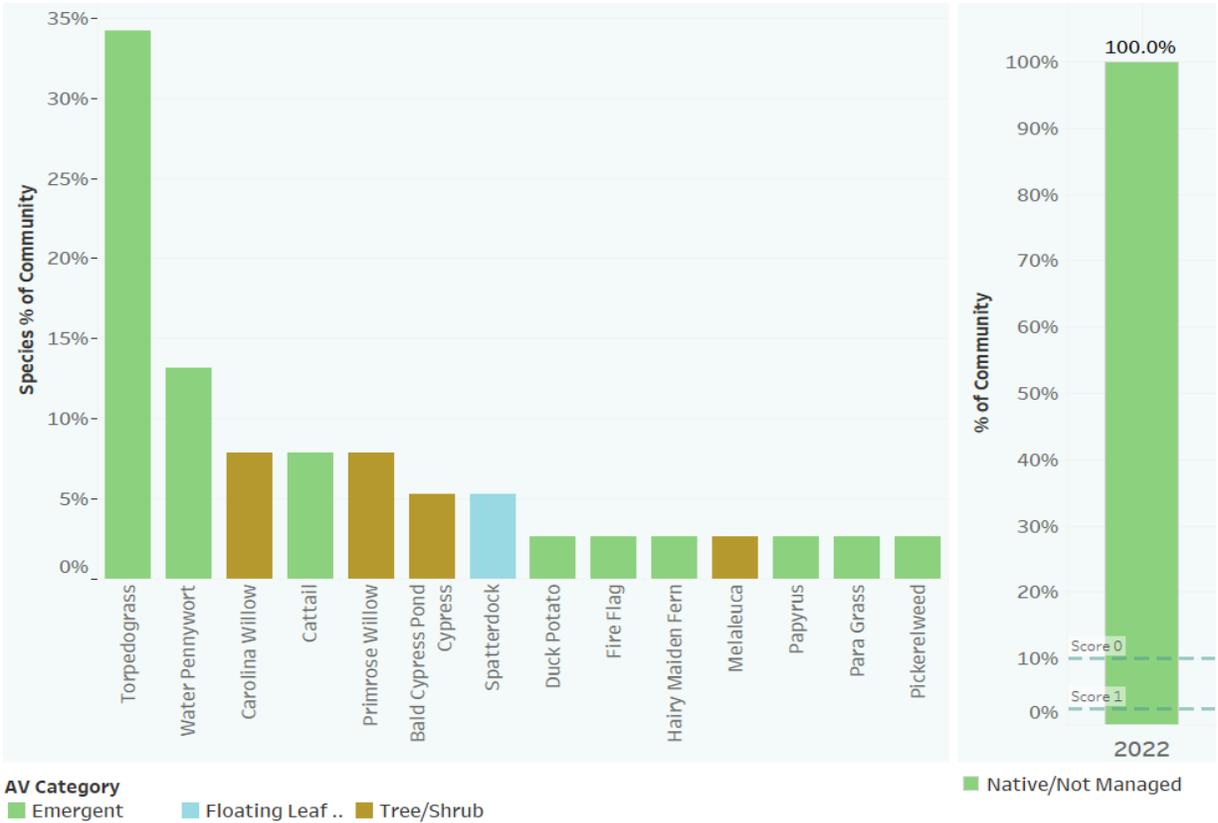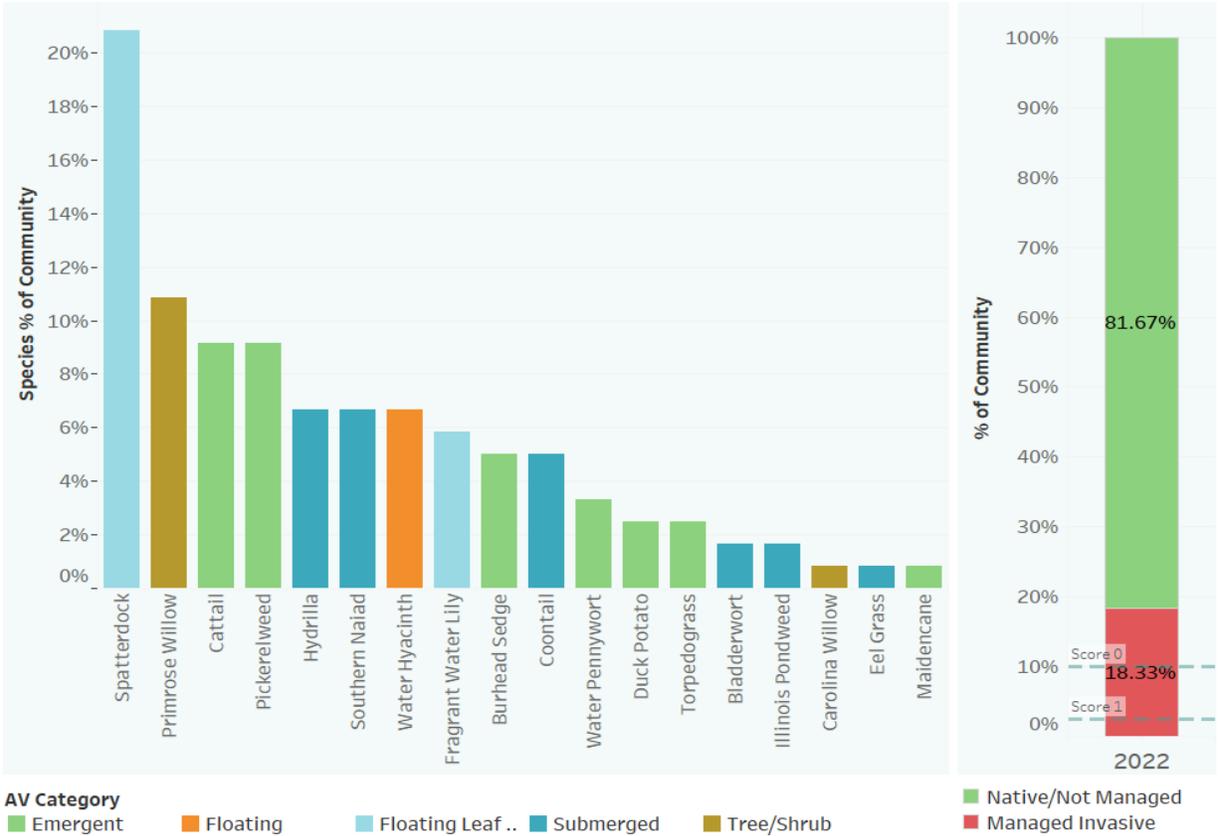

Figure 3-168. Chart depicting species frequency and invasive species percentage of Lake Martha during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, Lake Martha's richness and overall diversity indices met or exceeded their respective median values (Figure 3-169). This equates to a diversity criterion score of 2. The number of unique species detected rose from 10 in 2021 to 14 in 2022. This coupled with an overall increase in the abundance of vegetation led to the inceases in these indices. However, the overall distribution was skewed higher in just a few species. The lack of active invasive species management efforts indicates that these fluctuations in diversity were the result of natural changes in the vegetation community.
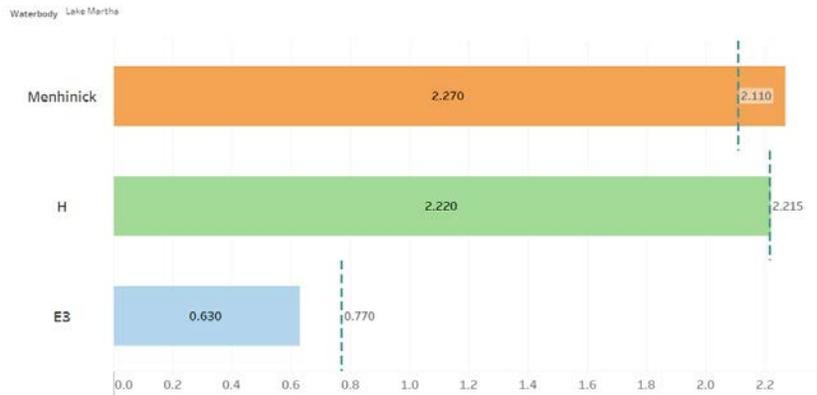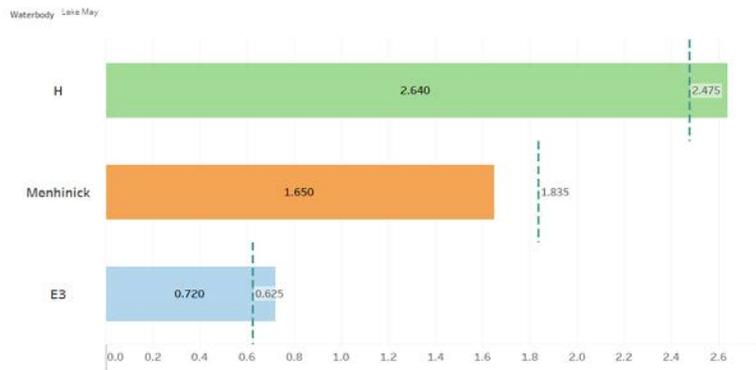

Figure 3-169. Chart depicting 2022 diversity indices for Lake Martha. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Martha's health index scores from 2018 to 2022 shows some slight improvement from 0.9 to 1.3 (Figure 3-170). Since the City began documenting lake health, Lake Martha has exhibited no changes in impairment and mostly no changes in the deteriorating water quality trends. Again, this year is notable as the TN trend has 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	1	0.9
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

Figure 3-170. Chart depicting a comparison of Lake Martha's Lake Health Index scores from 2018 to 2022.

Lake Health Impacts/Challenges:

- Despite Lake Martha not being impaired, its water quality is trending in a negative direction. 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 Chla 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:

- In order to combat stormwater pollutant loading, the City conducts monthly street sweeping within the drainage basin. Future plans to mitigate stormwater is implementation of green infrastructure. The City has plans to construct several raingardens along Ave H & I.

- 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 for 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 Score
3	3	3	2	3	3	2	3	2.8

Location, Characteristics, & Hydrology:

Lake Maude is located a short distance northeast from 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 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 1900 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.
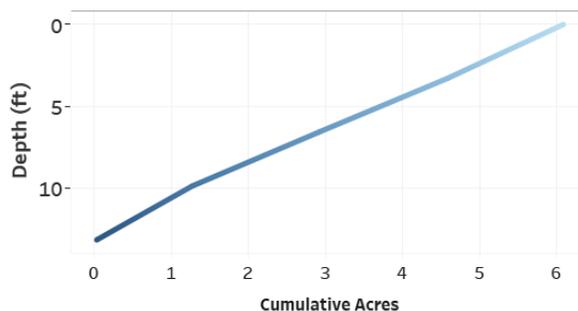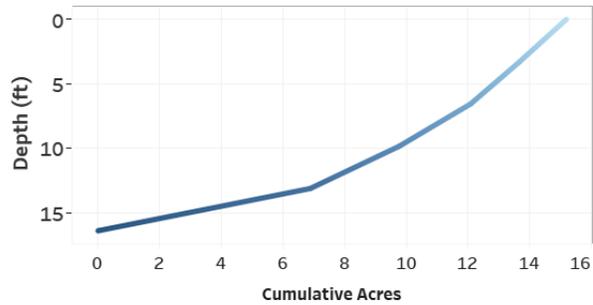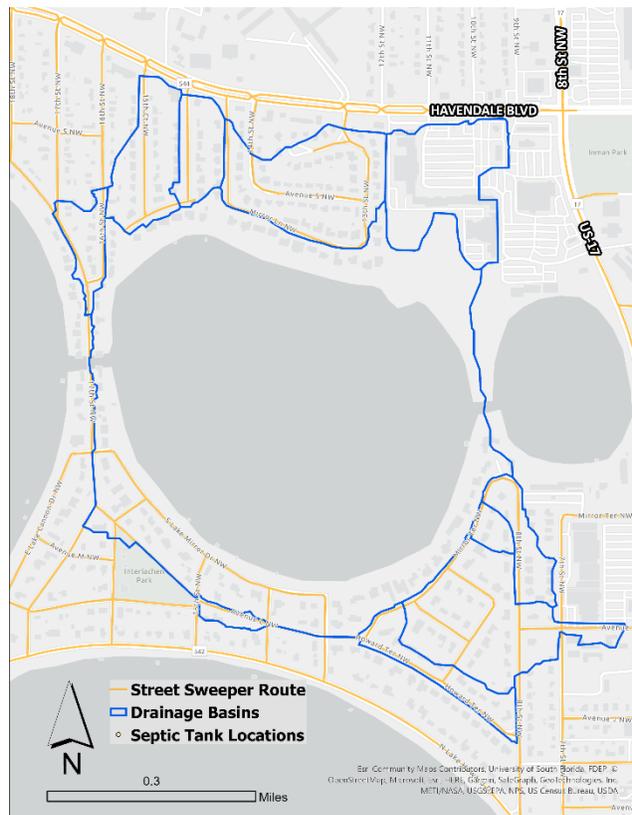

Figure 3-171. Hypsograph of Lake Maude depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

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 2022, Lake Maude reached a wet season peak of 140.2 feet in November and a dry season low of 139 feet in July. The surface level ended the year well above the high range at 140.1 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.
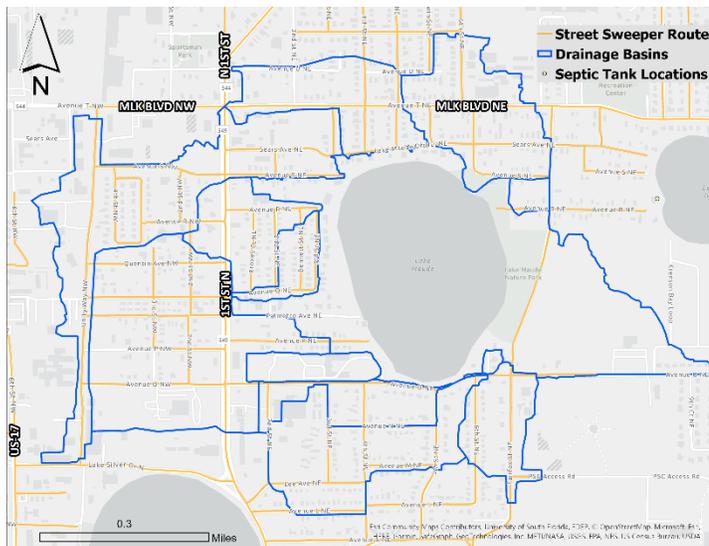
*Figure 3-172. Map of Lake Maude's drainage basin and City street sweeper routes.*
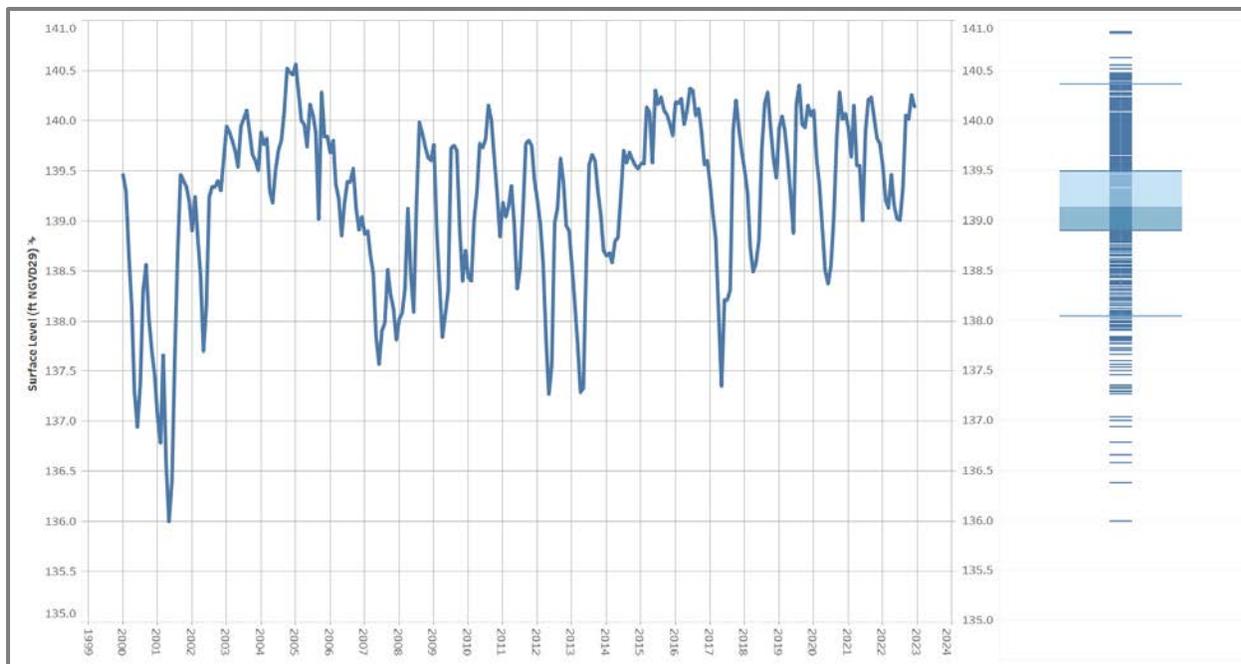
Figure 3-173. Hydrograph of Lake Maude depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period (Figure 3-174). This equates to an impairment criterion score of 3. The 2022 AGM concentrations for Chla, TN, and TP are notable for being higher than average; with the TP concentration being a record high.

Parameter	Impaired	Index Score
Chla	N	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Based on the data, Chla, TN, and Secchi depth exhibited significant improving trends—earning trend criteria score of 3. Lake Maude's TP trend, while not statistically significant, is also in an improving direction. This equates to 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 (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing	Not Significant	2
Secchi	Increasing (Improving)	Significant	3
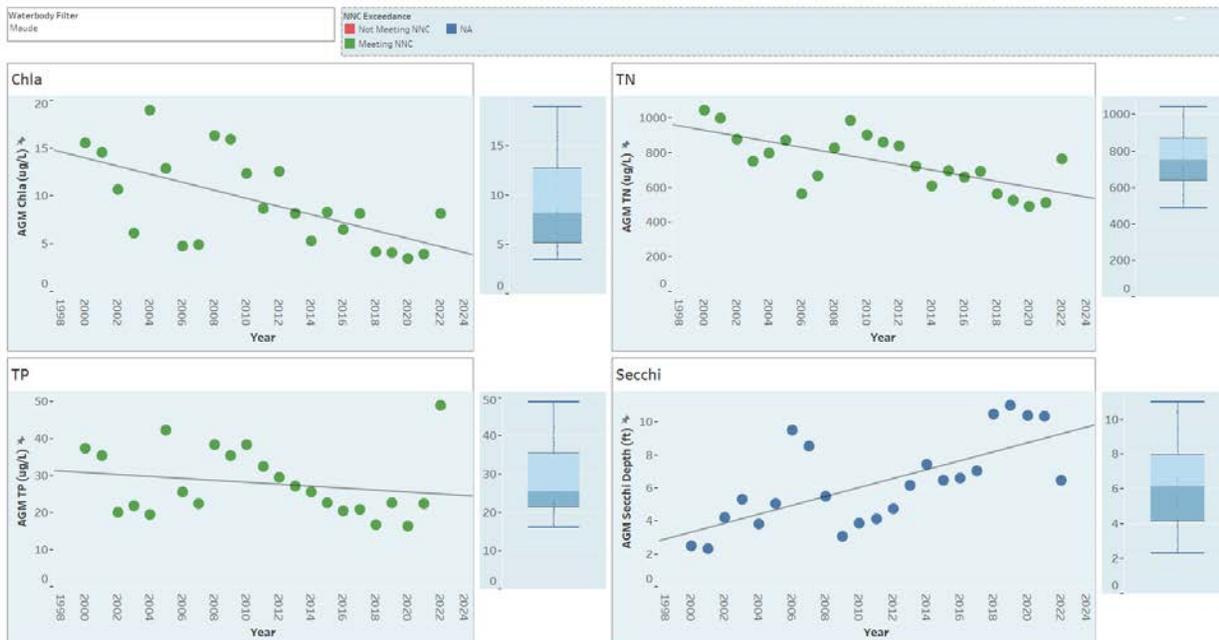
Figure 3-175. Lake Maude AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Maude on January 13th, 2022. The PAC during this survey was 71.6% and the total BV was 7.4% (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 which was higher in previous years.
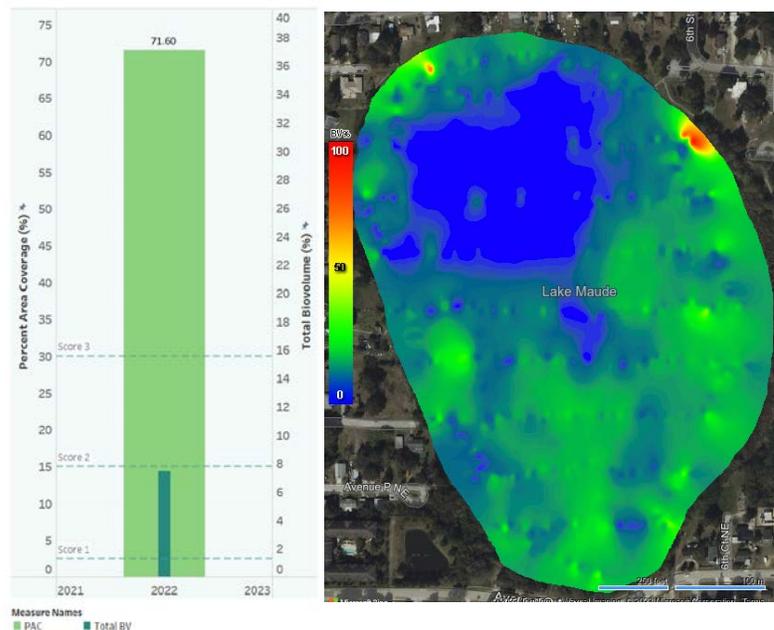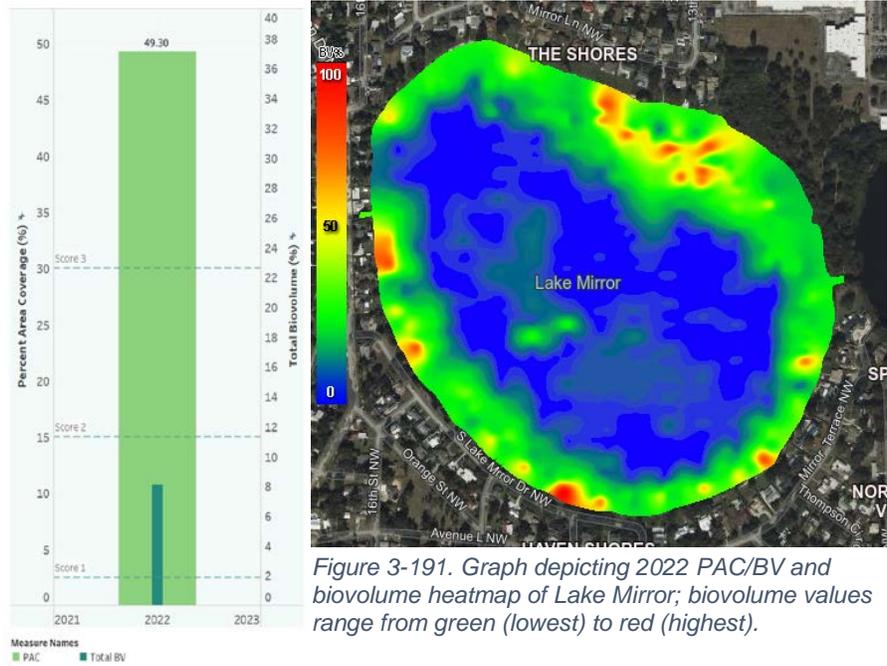

Figure 3-174. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Maude. Biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the data form the 2022 survey, Lake Maude is dominated by submerged vegetation (e.g. coontail, southern naiad, and bladderwort) at almost 45% (Figure 3-176). The remaining vegetation types include floating leaf and emergent. Regarding managed invasive species, burhead sedge was the only contributor at 1.6% of the

community. This equates to an invasive presence criterion score of 2. Burhead sedge has been the most prominent invasive species present on Lake Maude in the last five years.
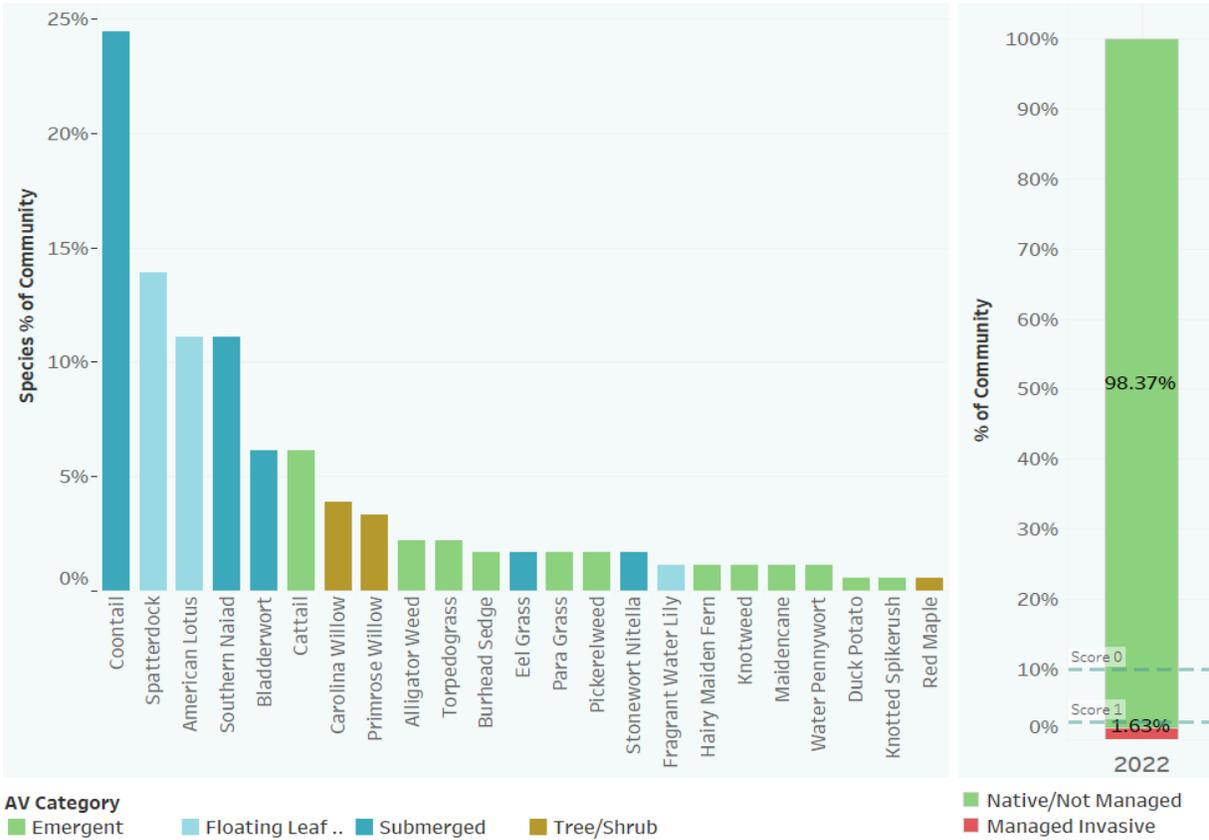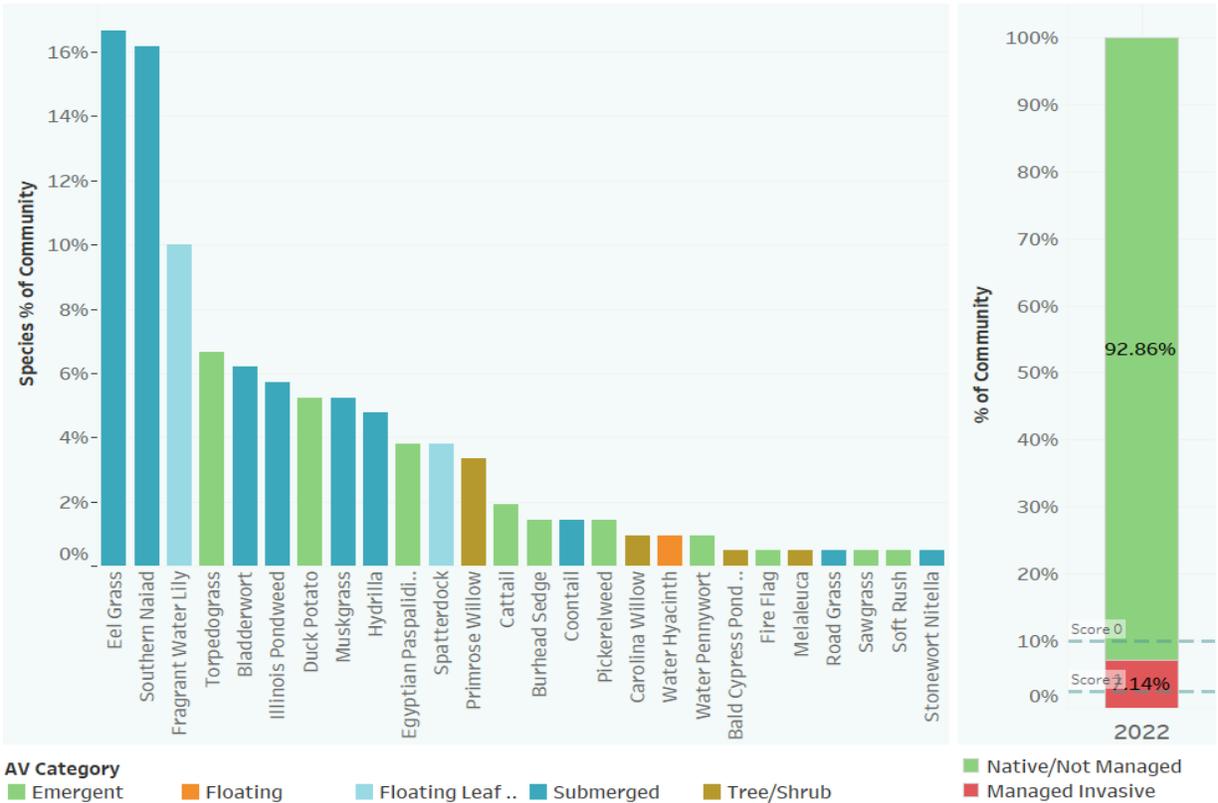

Figure 3-176. Chart depicting species frequency and invasive species percentage of Lake Maude during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, all three of Lake Maude's diversity indices met or exceeded their respective median values (Figure 3-177). This equates to a diversity criterion score of 3. This marks a significant increase in all three indices over previous years. Just comparing richness, there were 15 unique species detected in 2021 and 23 observed in 2022. A more even distribution amongst the four most abundance species also led to an evenness increase. There was a minimal amount of invasive species management in 2022, so these changes have mostly been from natural selection and succession.
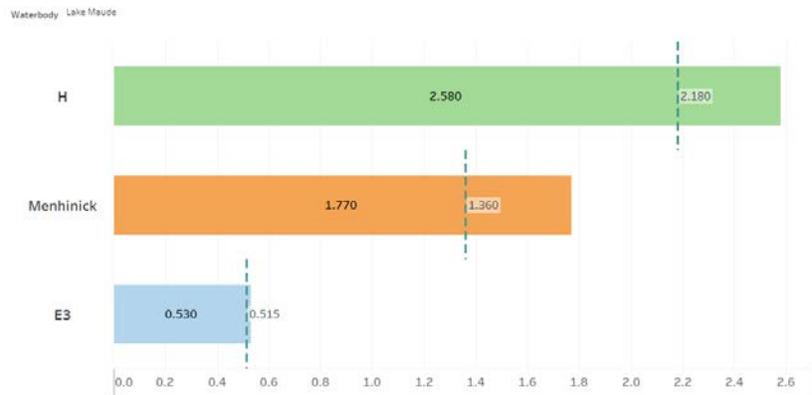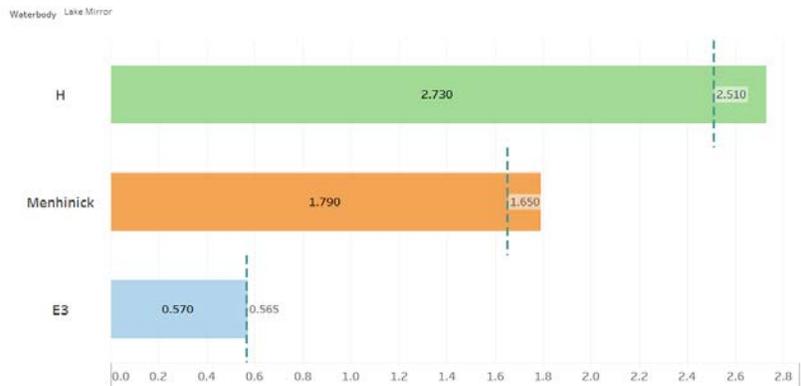

Figure 3-177. Chart depicting 2022 diversity indices for Lake Maude. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Maude's health index scores from 2018 to 2022 shows relative stability with index scores ranging from 2.3 to 2.8 (Figure 3-178). Throughout this five year monitoring period, water quality impairment, trends, and vegetation abundance have remained largely the same. There has been some minor changes in the statistical significance of the TP trend, 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	0	1	2.3
2020	3	3	3	3	3	3	2	2	2.8
2021	3	3	3	3	3	3	1	1	2.5
2022	3	3	3	2	3	3	2	3	2.8

Figure 3-178. Chart depicting comparison of Lake Maude's Lake Health Index scores from 2018 to 2022.

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 Score
0	3	3	3	3	3	0	2	2.1

Location, Characteristics, & Hydrology:

Lake May is located to the 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 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.
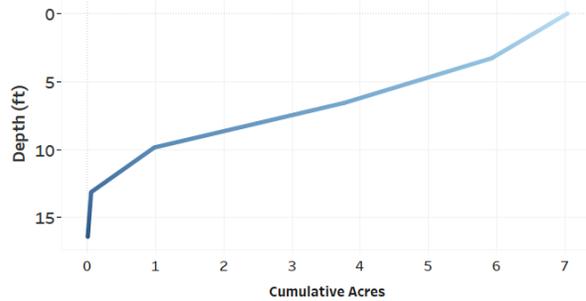

Figure 3-179. Hypsograph of Lake May depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

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 1733 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.
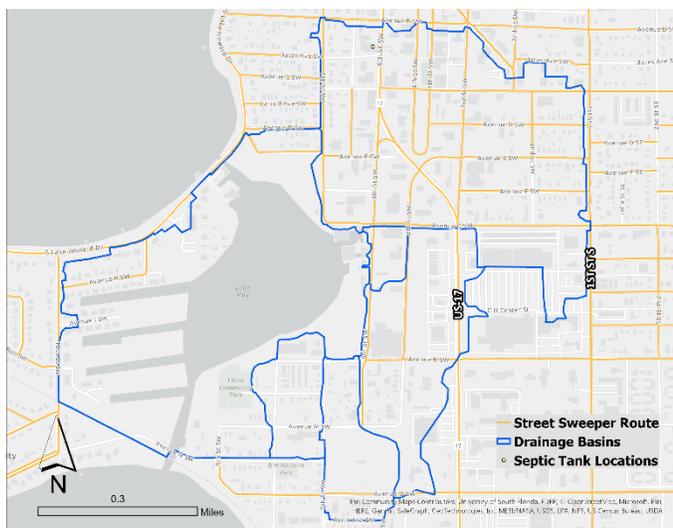
Figure 3-180. Map of Lake May's drainage basin, City street sweeper routes, and nearby septic systems.

Due to the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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 3-181). That said, wetter and drier periods

often result in more extreme peaks and troughs, respectively. During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season trough of 131.2 ft, but ended the year at 131.99 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 Chla, TN, TP, and clarity (see appendix). This carries management implications as an increase in levels should result in improved water quality across the board.
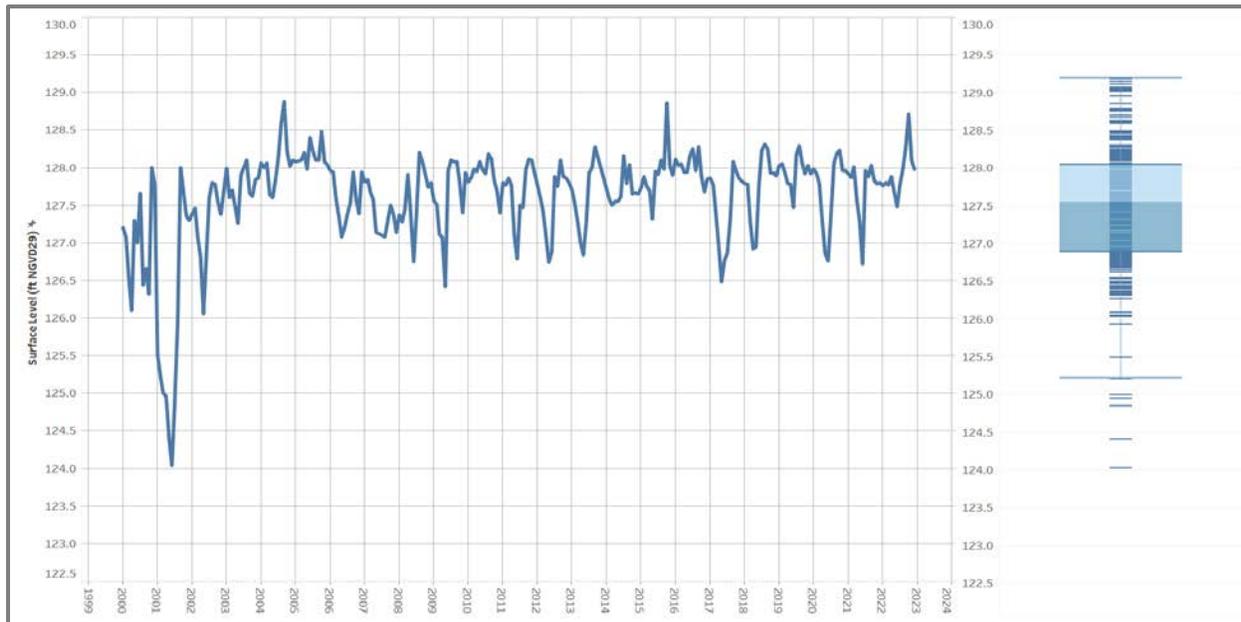

Figure 3-181. Hydrograph of Lake May depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period, Lake May is considered impaired for Chla, 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 in order to meet NNC guidelines.

Parameter	Impaired	Index Score
Chla	Y	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Based on the data, each of Lake May's water quality parameters exhibited significant improving trends. The result 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
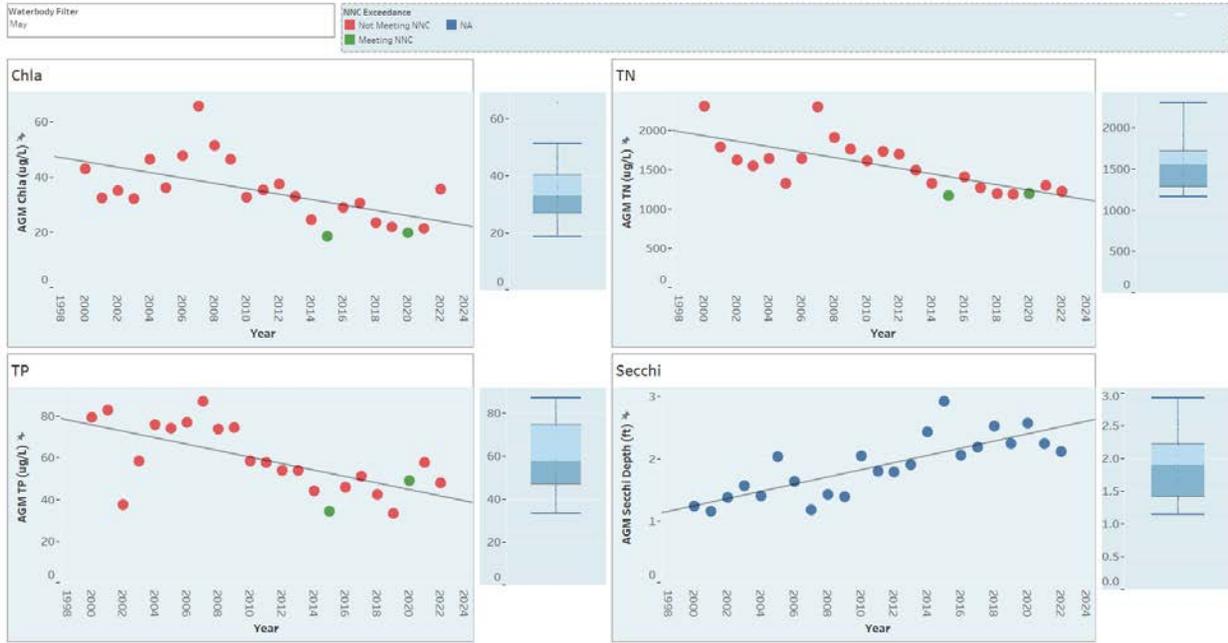
Figure 3-182. Lake May AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake May on June 16th, 2022. The PAC during this survey was 63.2% and the total BV was 11.04% (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 occassionally 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 on this waterbody.
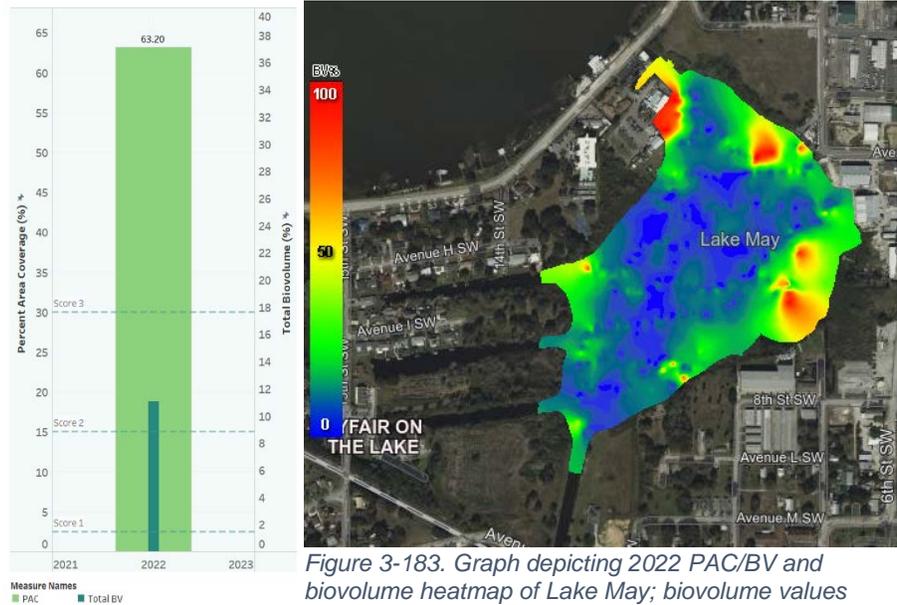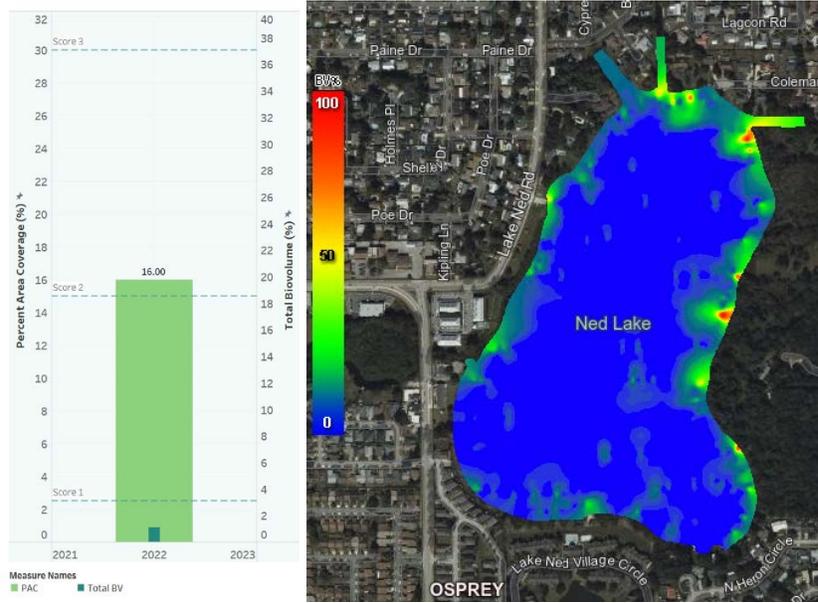

Figure 3-183. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake May; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2022 survey, the floating leaf spatterdock dominates; at over 20% of the community (Figure 3-184). The remaining plants are a mix of emergent and submerged species that creat a rich diversity underneath and around the spatterdock. There was

a large contingent of managed invasive species present during 2022. Hydrilla, water hyacinth, and burhead sedge made up over 18% of the community. This has resulted in an invasive percentage criterion score of 0. It must be noted that this percentage of invasives is the highest recorded in the last five years.
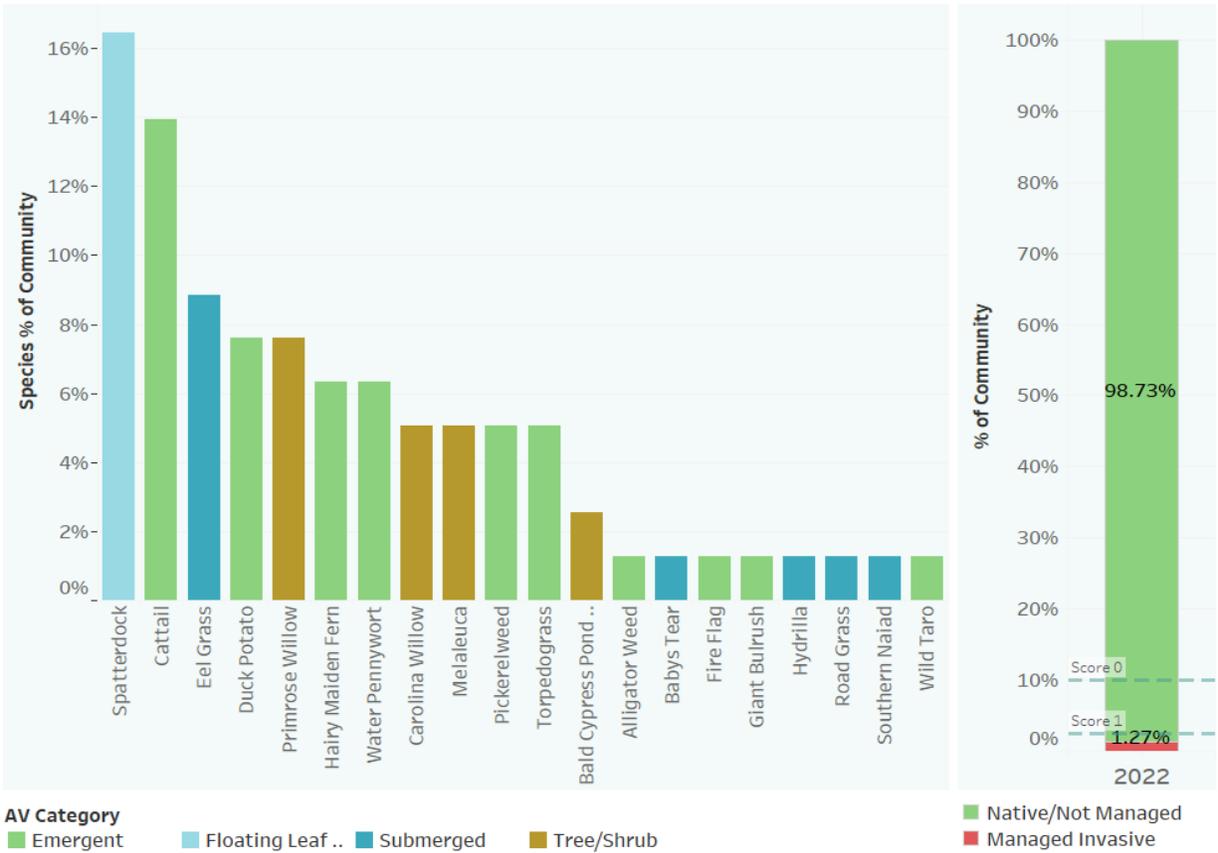

Figure 3-184. Chart depicting species frequency and invasive species percentage of Lake May during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, Lake May's evenness and overall diversity indices met or exceed their respective median values (Figure 3-185). This equates to a diversity criterion score of 2. While the number of species detected was a bit lower than in previous years, the distribution of these species is likely what led to the increased evenness and diversity values.
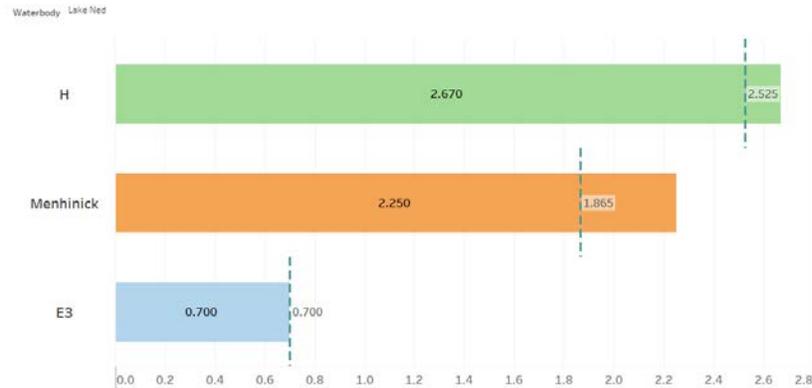

Figure 3-185. Chart depicting 2022 diversity indices for Lake May. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake May's health index scores from 2018 to 2022 shows relative stability—with lake health ranging from 2.0 to 2.4 (Figure 3-186). In the five 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	1	1	2.1
2020	0	3	3	3	3	3	1	3	2.4
2021	0	3	3	3	3	3	0	2	2.1
2022	0	3	3	3	3	3	0	2	2.1

Figure 3-186. Chart depicting a comparison of Lake May's Lake Health Index scores from 2018 to 2022.

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 has implemented:

    o Street sweeping of up to 27.3 miles within the drainage basin.

    o An alum injection system designed to reduced TN loads by 10% and TP loads by 45%.

    o Green infrastructure constructed as part of the 7th Street complete streets project.

- The City is currently exploring sediment removal options in order to reduce the internal load from the historic point-sources. Staff are seeking legislative funding to establish a pilot project that will remove a considerable amount of sediment from Lake May.

- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC for invasive species management planning.

- City staff have recently coordinated with the Lakes Region Lakes Management District in tussock removal efforts in Lake May to ensure clear navigation channels through the canals. Tussock removal also helps improve fish habitat and reduce nutrients in the lake.

- 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 Score
3	3	3	3	3	3	1	3	2.8

Location, Characteristics, & Hydrology:

Lake Mirro is located just to the 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 bed.

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 modelling, 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.

Due to the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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 3-189). That said, wetter and drier periods often result

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

in more extreme peaks and troughs, respectively. During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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 correlates with TN (see appendix). This carries some management implications as maintaining higher levels should result in a decrease in TN concentrations.
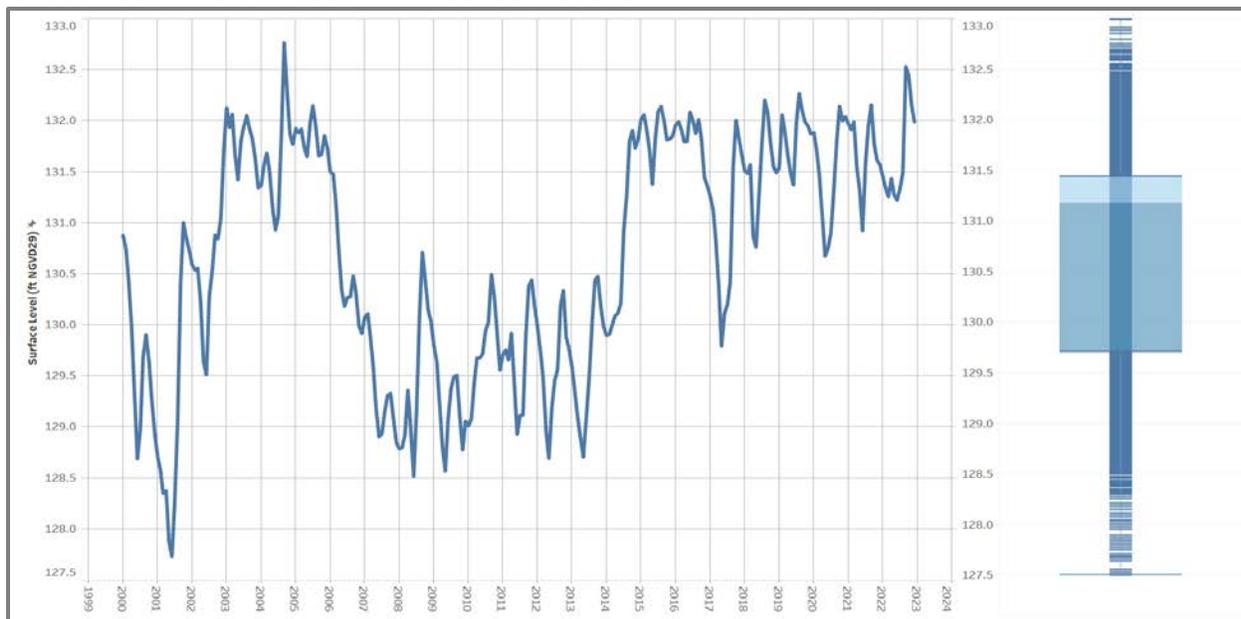
Figure 3-189. Hydrograph of Lake Mirror depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Mirror is categorized as a clear, alkaline waterbody. Within the 2015 – 2022 assessment period, Lake Mirror exhibited one NNC exceedance in Chla and no exceedances in TN or TP (Figure 3-190). As a result, Mirror is considered un-impaired for each of these parameters—equating to an impairment criterion score of 3. 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.

Parameter	Impaired	Index Score
Chla	N	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. 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
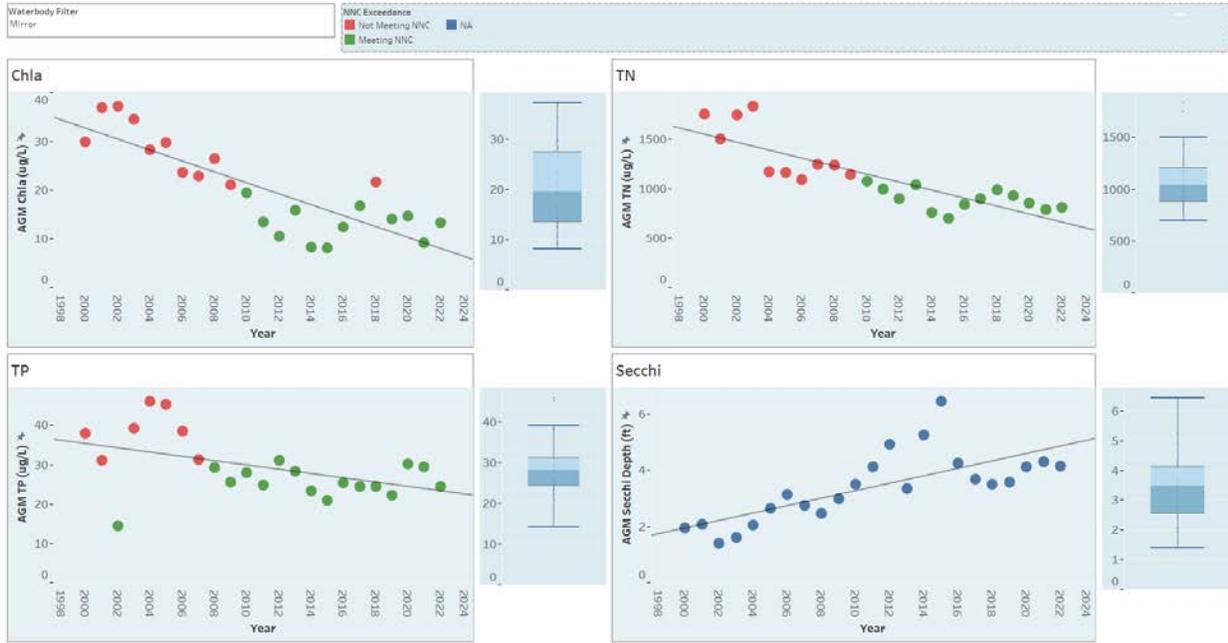
Figure 3-190. Lake Mirror AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Mirror on January 7th, 2022. The PAC during this survey was 49.3% and the total BV was 8.04% (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 2022 was the highest during this five year period.

Figure 3-191. Graph depicting 2022 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 2022 survey, Lake Mirror is dominated by submerged vegetation. Eel grass and southern naiad comprised over 32% of the community (Figure 3-192).

The high number of remaining plants are representative of all vegetation types—indicative of high diversity. Of course, invasive species were present in moderately high numbers. Hydrilla, burhead sedge, and water hyacinth made up over 7% of the community. This equates to an invasive criterion score of 1. These invasives have had a presence in previous years, but 2022 marks the highest percentage on record.

Figure 3-192. Chart depicting species frequency and invasive species presence of Lake Mirror during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, all three of Lake Mirror's diversity indices met or exceeded their respective median values (Figure 3-193). This equates to a diversity criterion score of 3. While species evenness has not changed much since 2021, richness and overall diversity saw a considerable increase. The majority of these changes are likely from an increase in detected species—from 19 in 2021 to 26 in 2022.
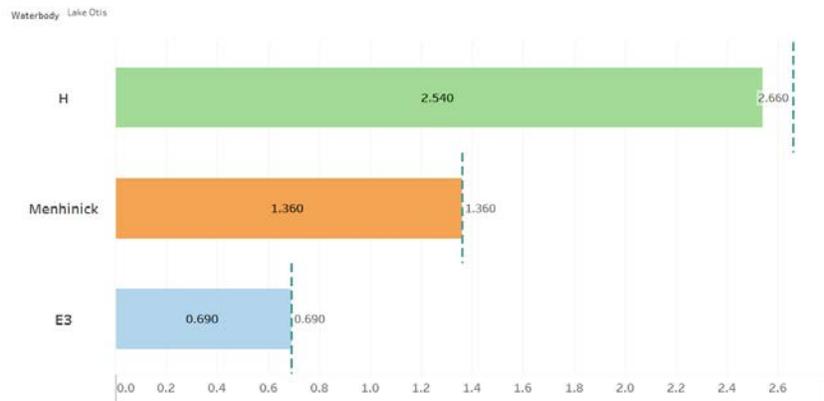

Figure 3-193. Chart depicting 2022 diversity indices for Lake Mirror. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Mirror's health index scores from 2018 to 2022 shows relative stability. 2022 marks a slight increase from the typical scores of 2.6 to a new high of 2.8 (Figure 3-194). Over this five 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 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	1	2.6
2019	3	3	3	3	3	3	1	2	2.6
2020	3	3	3	3	3	3	1	2	2.6
2021	3	3	3	3	3	3	2	1	2.6
2022	3	3	3	3	3	3	1	3	2.8

Figure 3-194. Chart depicting a comparison of Lake Mirror's Lake Health Index scores from 2018 to 2022.

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.

- Currently, the City does conduct street sweeping within the basin. However, 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 informaiton 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 Score
3	0	1	0	0	2	2	3	**1.4**

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).

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 1002 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 is outside City limits, Winter Haven does not conduct street sweeping services in the drainage area.

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 2022, Lake Ned reached a wet season peak of 128.7 feet during October and a dry season low of 127.5 feet in June. The surface level ended the year at the high end of the normal range
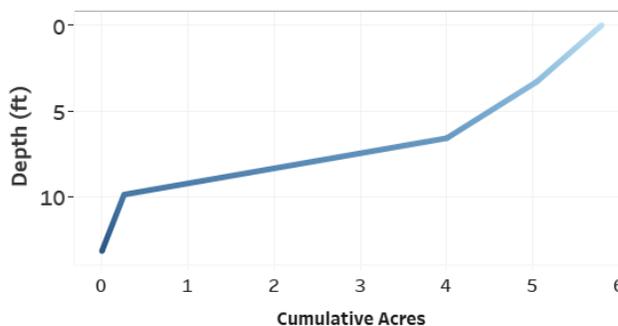

Figure 3-195. Hypsograph of Lake Ned depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Figure 3-196. Map of Lake Ned's drainage basin and nearby septic systems.

at 127.98 feet. Changes in Lake Ned's surface level are not correlated with its primary water quality metrics (see appendix).
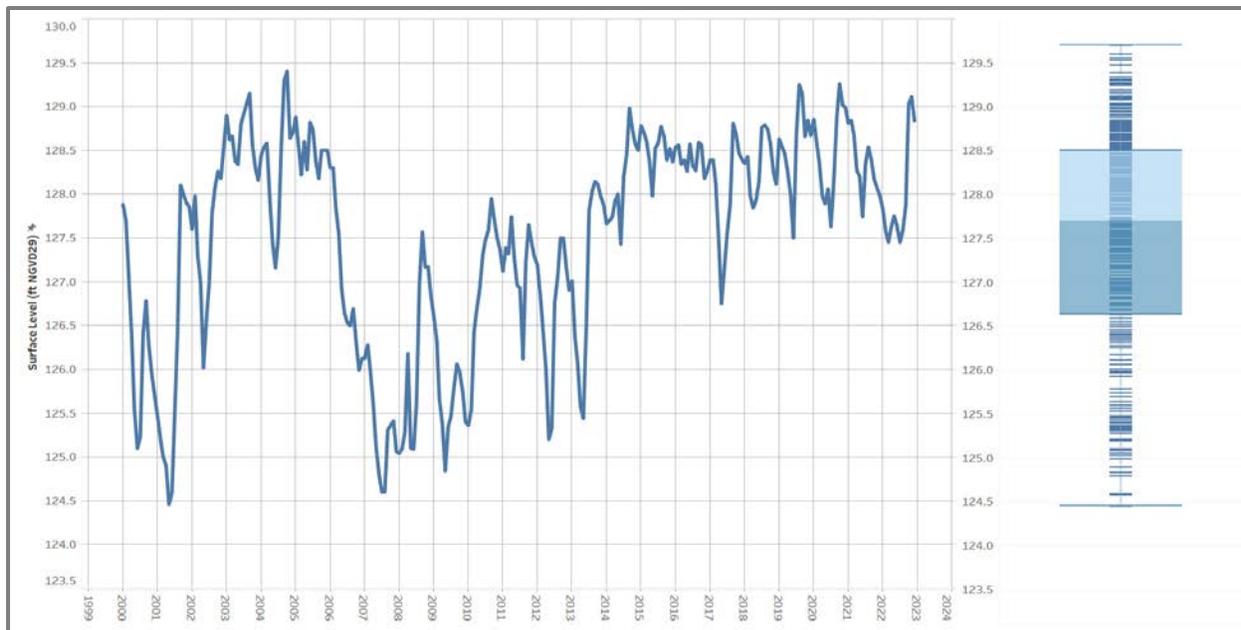

Figure 3-197. Hydrograph of Lake Ned depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period, Lake Ned is considered un-impaired (Figure 3-198). This equates to an impairment criterion score of 3. While the 2022 AGM concentrations of Chla, TN, and TP were all above the respective median values, these are not the highest on record.

Parameter	Impaired	Index Score
Chla	N	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Chla, TP, and Secchi depth all exhibited significant deteriorating trends. This equates to trend critera scores of 0. TN exhibited a non-significant, but slightly increasing trend during this period; resulting in a trend criteria score of 1. 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 (Deteriorating)	Significant	0
Secchi	Decreasing (Deteriorating)	Significant	0
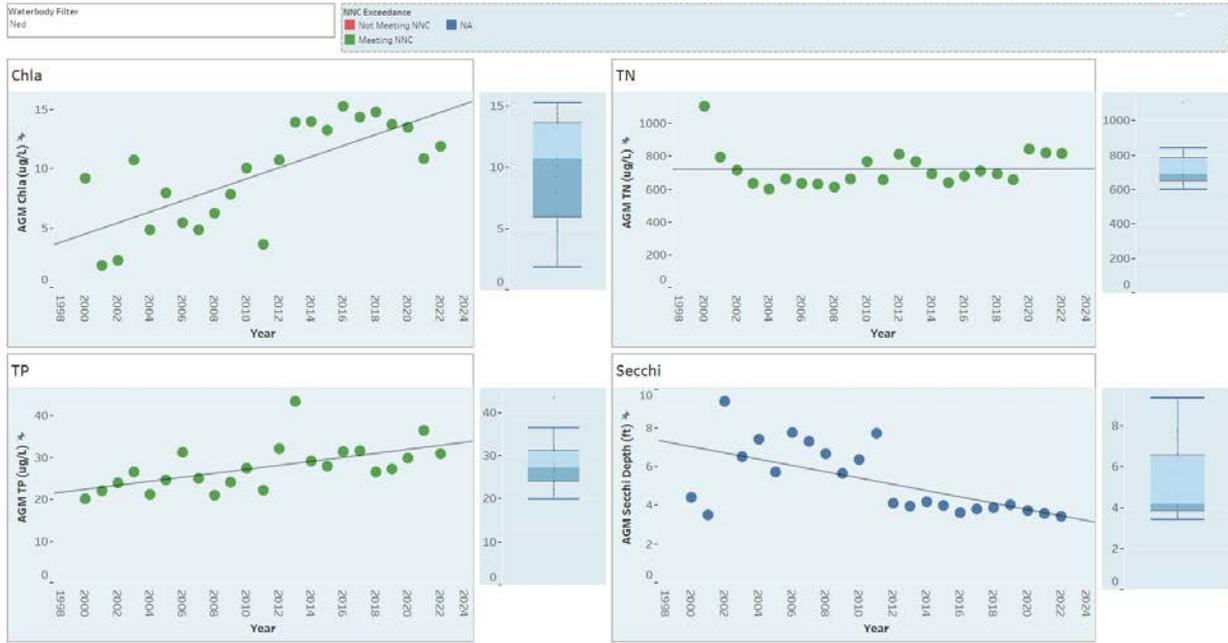
Figure 3-198. Lake Ned AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Ned on June 9th, 2022. The PAC during this period was 16% and the total BV was 1.1% (Figure 3-199). By exceeding the 15% coverage threshold, this equates to a vegetation abundance criterion score of 2. Since monitoring began, Lake Ned has consistently had low vegetation abundance scores—between 4.8% and 13.6%. The 16% coverage observed during 2022 is the highest abundance on record. Triploid grass carp were stocked in Lake Ned in 2011 to combat increasing hydrilla

Figure 3-199. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Ned; biovolume values range from green (lowest) to red (highest).

populations. It is believed that the carp completed denuded the lake of SAV. Fortunately, it appears that the vegetation community is starting to recover.

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2022 survey data, floating leaf and emergent species made up the vast majority of the vegetation community (Figure 3-200). However, previously absent

submerged species like eel grass, baby's tears, and southern naiad were detected in 2022. As stated, this is indicative of recovery from previous invasive management efforts. Regarding invasive species, a small population of hydrilla was detected. At just 1.27% of the community, this equates to an invasive criterion score of 2.
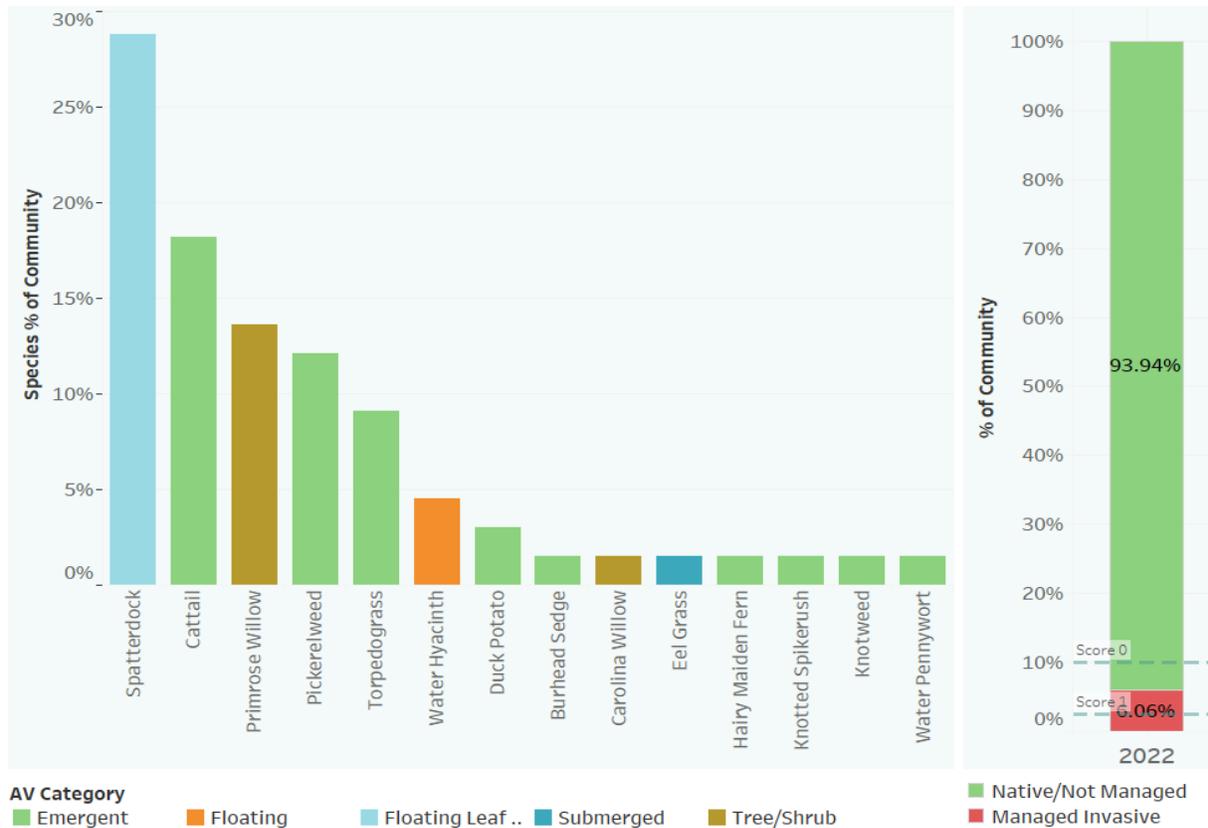

Figure 3-200. Chart depicting species frequency and invasive species percentage of Lake Ned during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, all three of Lake Ned's diversity indices met or exceeded their respective median values (Figure 3-201). This equates to a diversity criterion score of 3. Unsurprisingly, the recovery of additional submerged species led to an overall increase in diversity; not just from the increase in number of unique species, but also due to the improved distribution of the community.

Figure 3-201. Chart depicting 2022 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 2022 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. Since TN exhibited as close to a null trend as possible, it often switches between a positive and negative direction. The majority of the score fluctuation has occurred from the biological criteria. As stated, vegetation abundance is recovering. After a reduction of water hyacinth in 2019, the invasive presence was undetectable until the hydrilla observed in 2022. The diversity has also improved as the vegetation community recovered. Overall, Lake Ned is in the middle of 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

Figure 3-202. Chart depicting a comparison of Lake Ned's Lake Health Index scores from 2018 to 2022.

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 there is some recovery of submerged plants, there is a new presence of hydrilla that will likely need to be treated. It can take a single growing season for this plant to expand exponentially.

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	2	2	1	2	2	2	2	**2.0**

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).
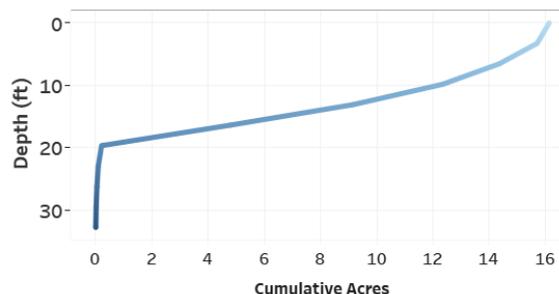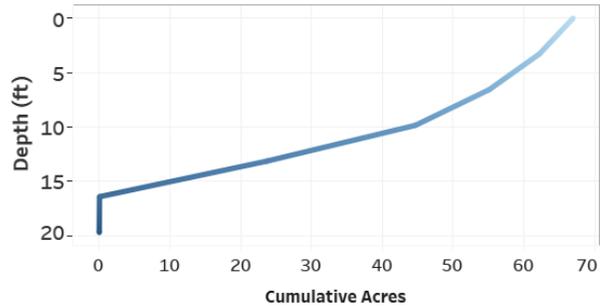

Figure 3-203. Hypsograph of Lake Otis depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

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.
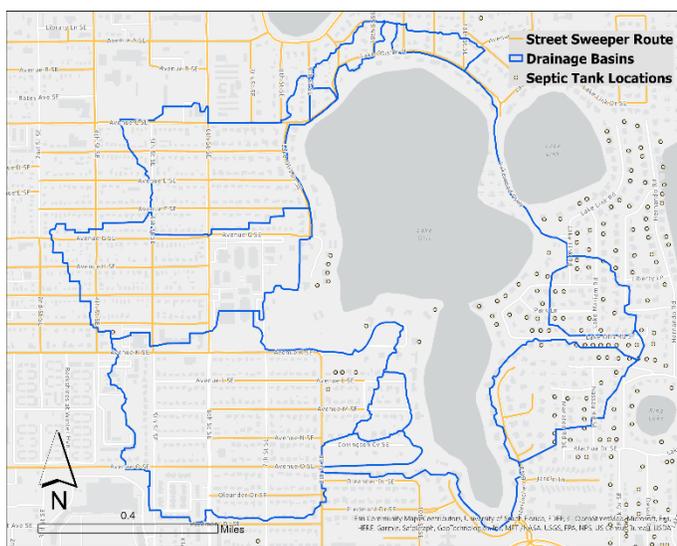
Figure 3-204. Map of Lake Otis' drainage basin, City street sweeper routes, and nearby septic systems.

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 3-205). During 2022, Lake Otis reached a wet season peak of 128.2 feet in October and a dry season low of 126.9 feet in March. The surface level ended the year at 127.9 feet—above the high end of the normal range. According to linear regression analysis, changes in Lake Otis' surface level are correlated with Chla, TN, and Secchi depth (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.
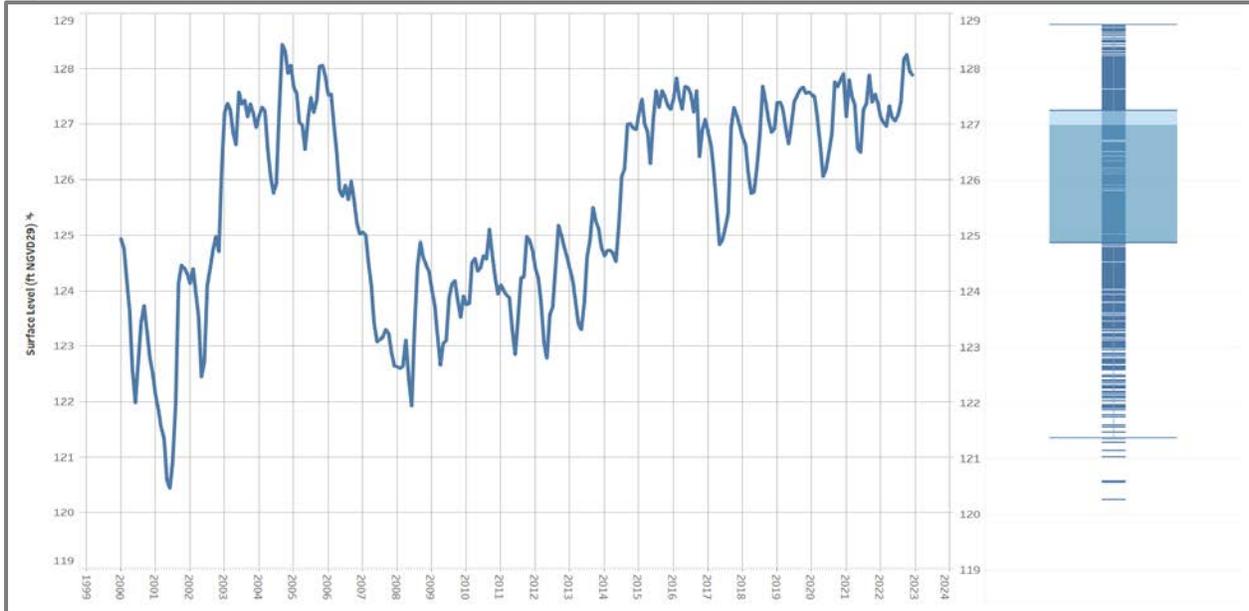
Figure 3-205. Hydrograph of Lake Otis depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

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 2015 – 2022 assessment period, Lake Otis is considered un-impaired (Figure 3-206). This equates to an impairment criterion score of 3. Lake Otis did exhibit Chla impairment as late as 2019, but has since improved to the point of being delisted.

Parameter	Impaired	Index Score
Chla	N	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Lake Otis exhibits no statistically significant trends. However, Chla, TN, and Secchi depth trends are in an improving direction. Each of these earns a trend criterion score of 2. On the other hand, the direction of the TP trend is deteriorating—resulting in a criterion score of 1. 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	Increasing	Not Significant	1
Secchi	Increasing	Not Significant	2
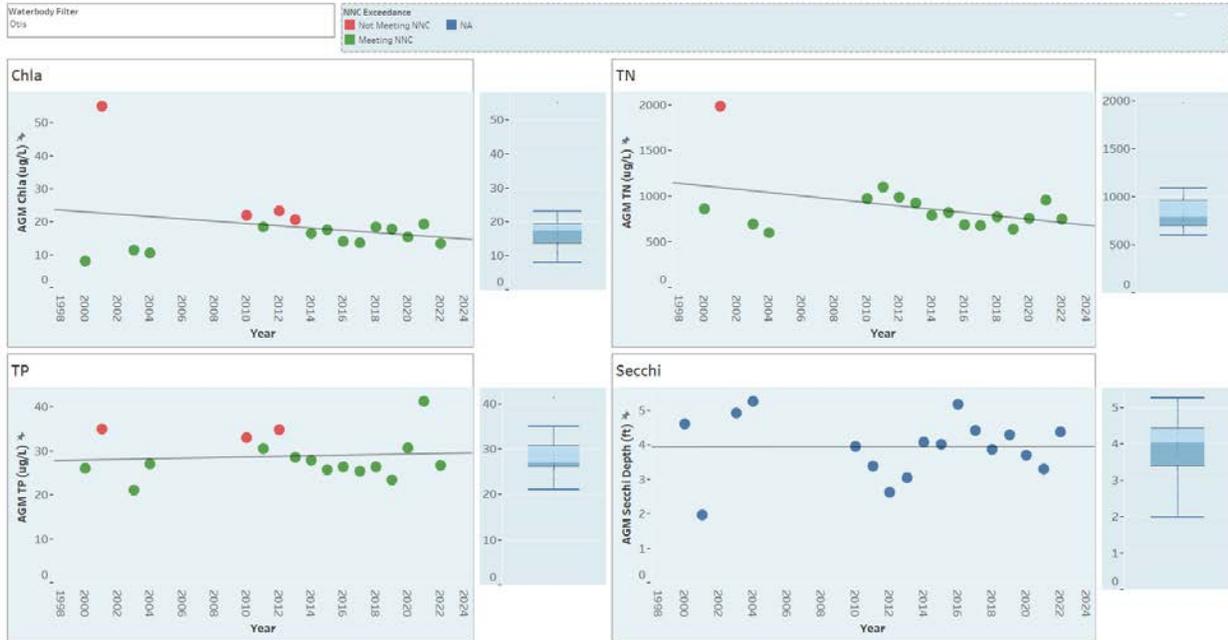
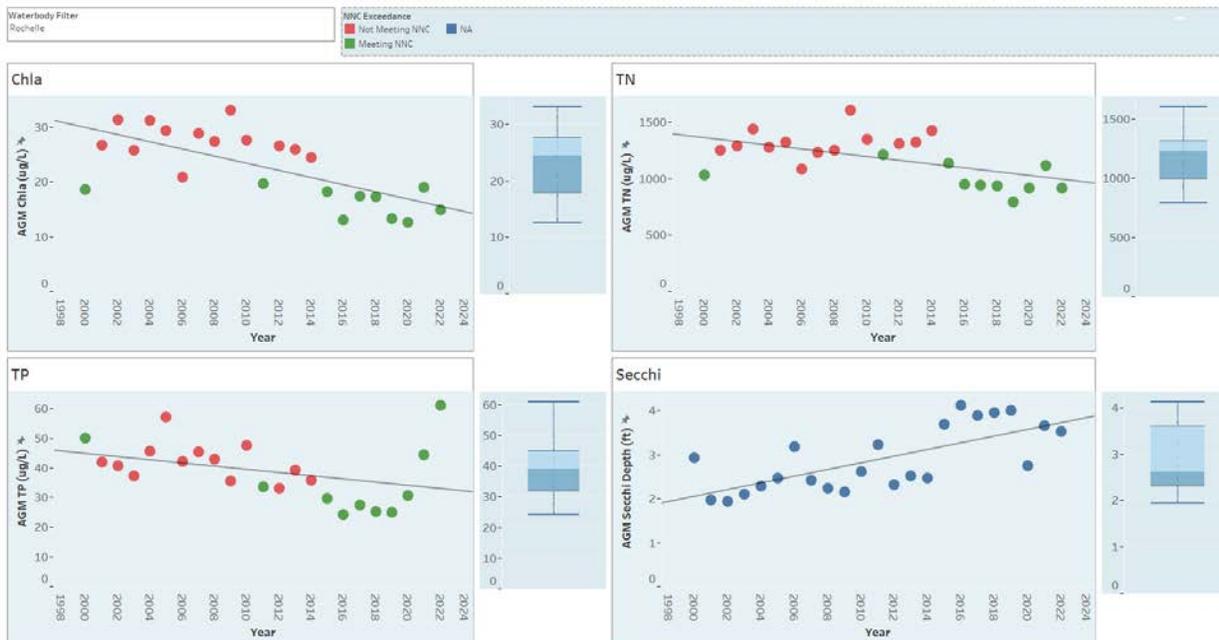*Figure 3-207. Lake Otis AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.*

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Otis on August 2nd, 2022. The PAC during this survey was 19.6% and the total BV was 15.4% (Figure 3-207). Exceeding the 15% PAC threshold results in an abundance criteria of 2. A comparison of abundance records from 2018 to the present shows that Lake Otis' coverage is typically between 15% and 30%. This middling vegetation abundance may be the result of hydrilla control measures—specifically, the stocking of grass carp.
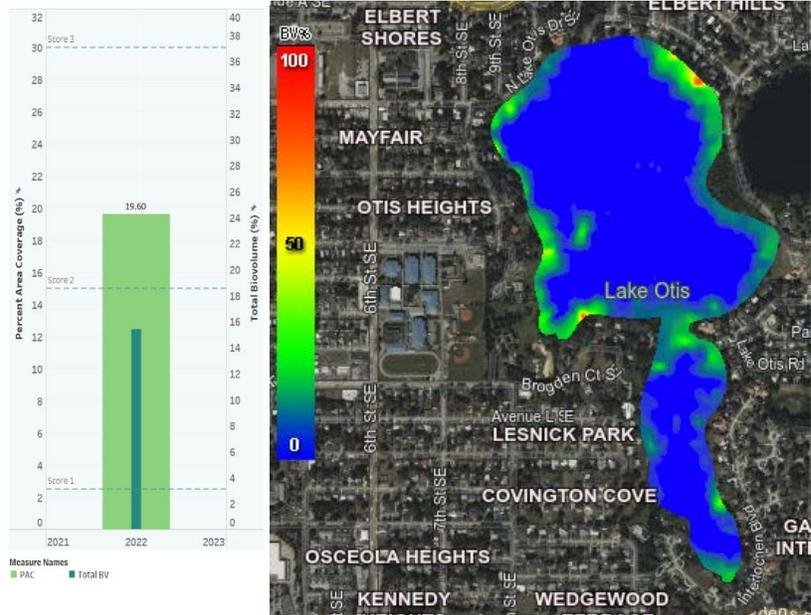
Figure 3-206. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Otis; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2022 survey data, Lake Otis maintains a health mix of vegetation types. The most dominant species present are fragrant water lily, eel grass, and torpedograss at 17%, 14%, and 13% of the community, respectively (Figure 3-208). Regarding invasive species, water hyacinth was present at just over 2% of the community. This equates to an invasive criterion score of 2. Prior to 2018, hydrilla was the primary invasive species to be controlled. This is likely

the reason why grass carp were stocked in 2018 and 2019. However, this seems to have had a negative impact on the overall abundance of submerged plants in the lake.
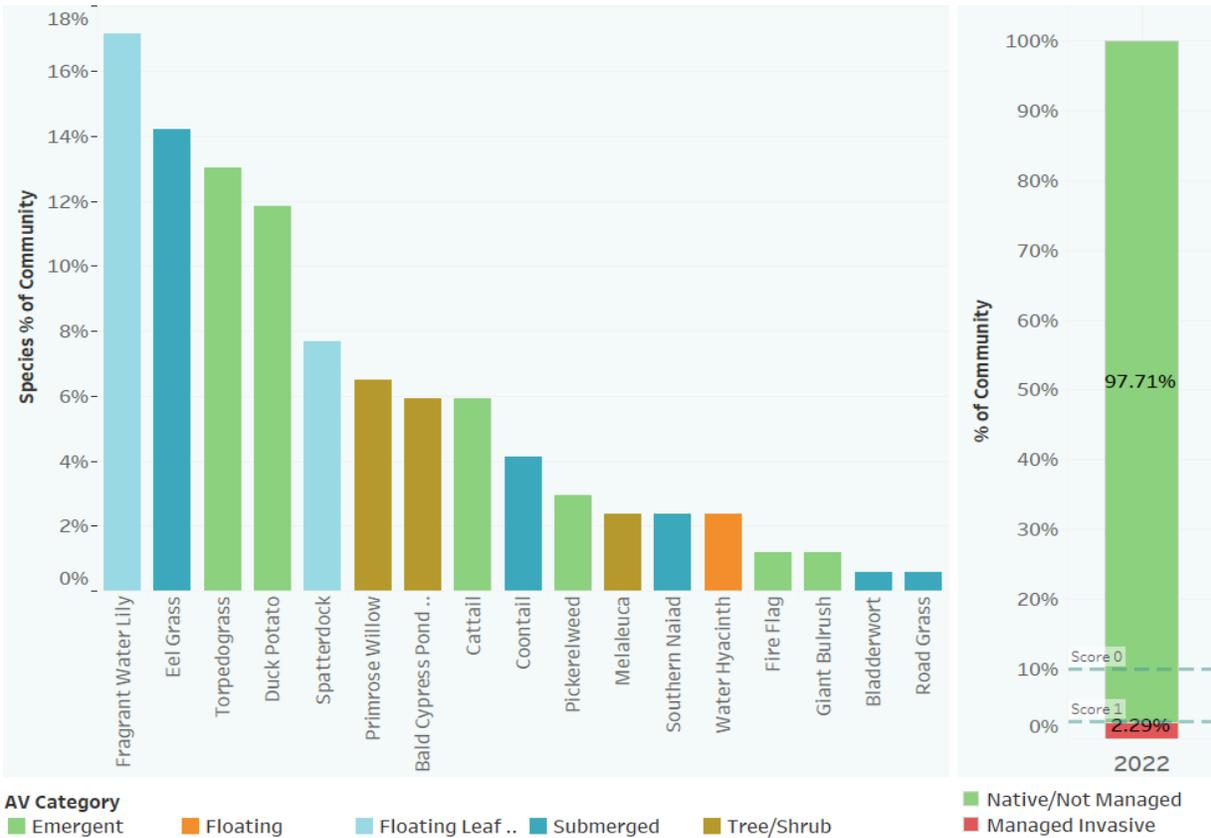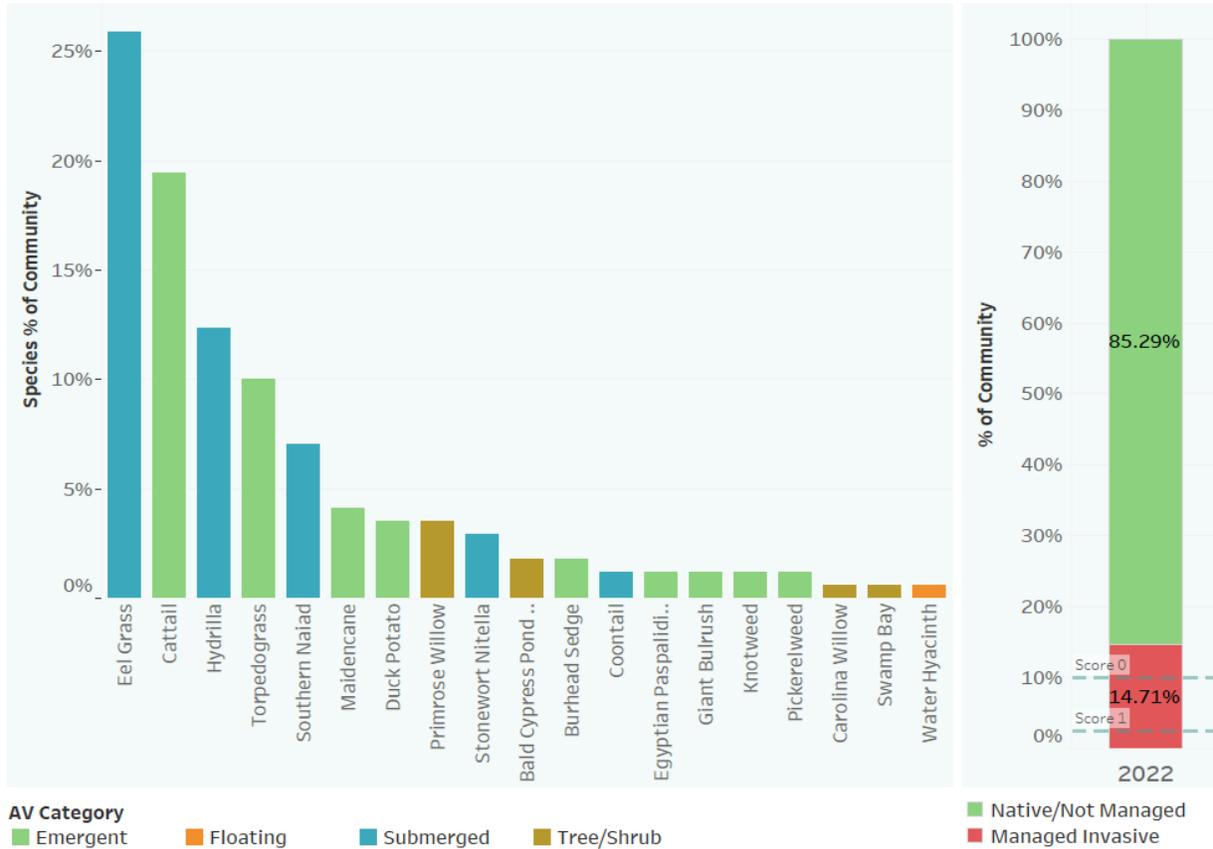

Figure 3-208. Chart depicting species frequency and invasive species percentage of Lake Otis during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on 2022 species data, Lake Otis' richness and evenness indices met their respective median values (Figure 3-209). This equates to a diversity criterion score of 2. A comparison of diversity values from 2018 to 2022 shows that species richness and overall diversity were slightly higher prior to 2020. Again, this is indicative that invasive species treatment has impacted the vegetation community.

Figure 3-209. Chart depicting 2022 diversity indices for Lake Otis. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Otis' health index scores from 2018 to 2022 shows values ranging from 1.6 to 2.2 (Figure 3-210). Over this five year span, the impairment criterion has seen improvement as Chla 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 has remained below the ideal threshold. However, invasive species presence has improved 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

Figure 3-210. Chart depicting a comparison of Lake Otis' Lake Health Index scores from 2018 to 2022.

Lake Health Impacts/Challenges:

- Stormwater pollutant loading from the western portion of the basin is a concern. Additionally, the presence of OSTDs in 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. Even though its presence was minimal in 2022, other invasive species have been detected. 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. The 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 indentified 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 Score
3	0	1	1	2	2	1	0	1.3

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 2022, Lake Pansy reached a wet season peak of 129.1 feet in November and a dry season low of 127.45 feet in both March and
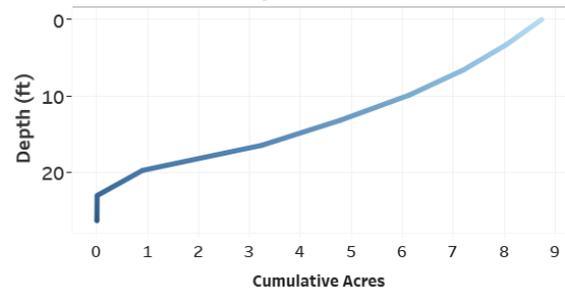

Figure 3-211. Hypsograph of Lake Pansy depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.
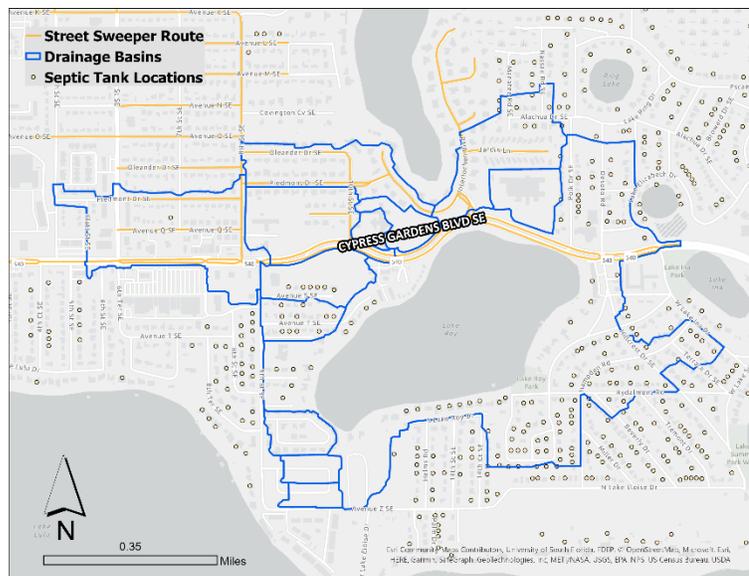

Figure 3-212. Map of Lake Pansy's drainage basin and nearby septic systems.

July. The surface level ended the year above the normal range at 128.8 feet. According to linear regression analysis, 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.
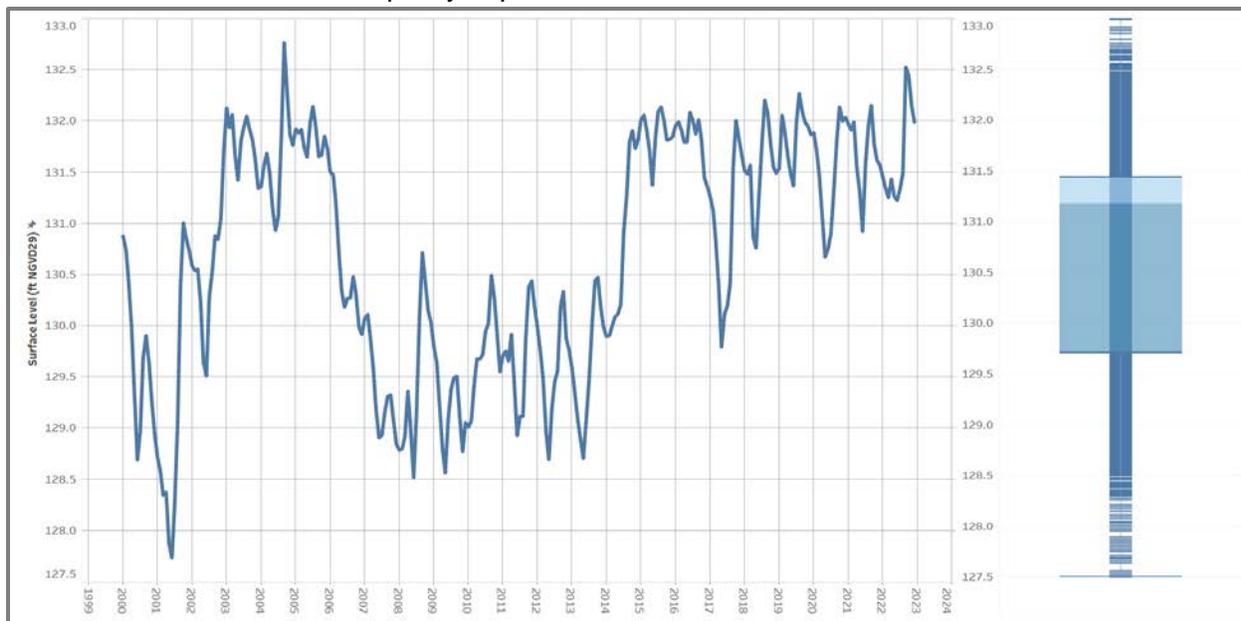

Figure 3-213. Hydrograph of Lake Pansy depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 Chla during the 2015 – 2022 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	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. During this time frame, Chla exhibits a significant deteriorating trend; for a trend criterion score of 0. The TN and TP trends were non-significant, but in deteriorating direction; for criterion scores of 1. Secchi depth exhibited a non-significant improving trend; for a criterion score of 2. Individual AGM values and trend statistics can be found in the appendix.

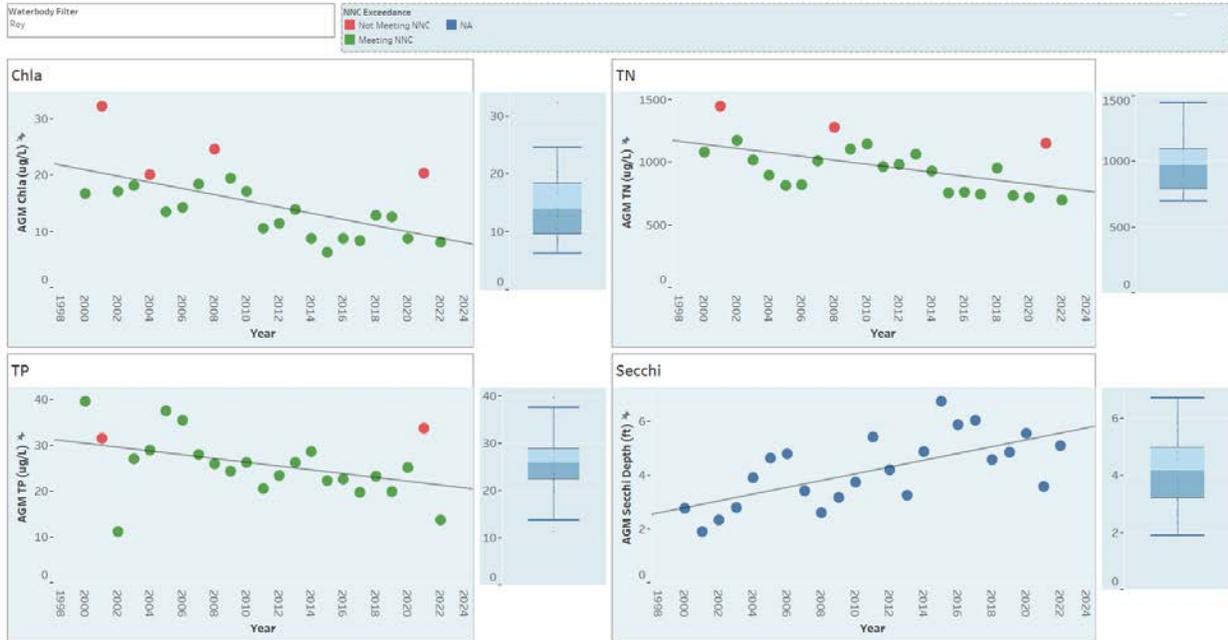| Parameter	Trend Direction	Significance	Index Score
Chla	Increasing (Deteriorating)	Significant	0
TN	Increasing	Not Significant	1
TP	Increasing	Not Significant	1
Secchi	Increasing	Not Significant	2
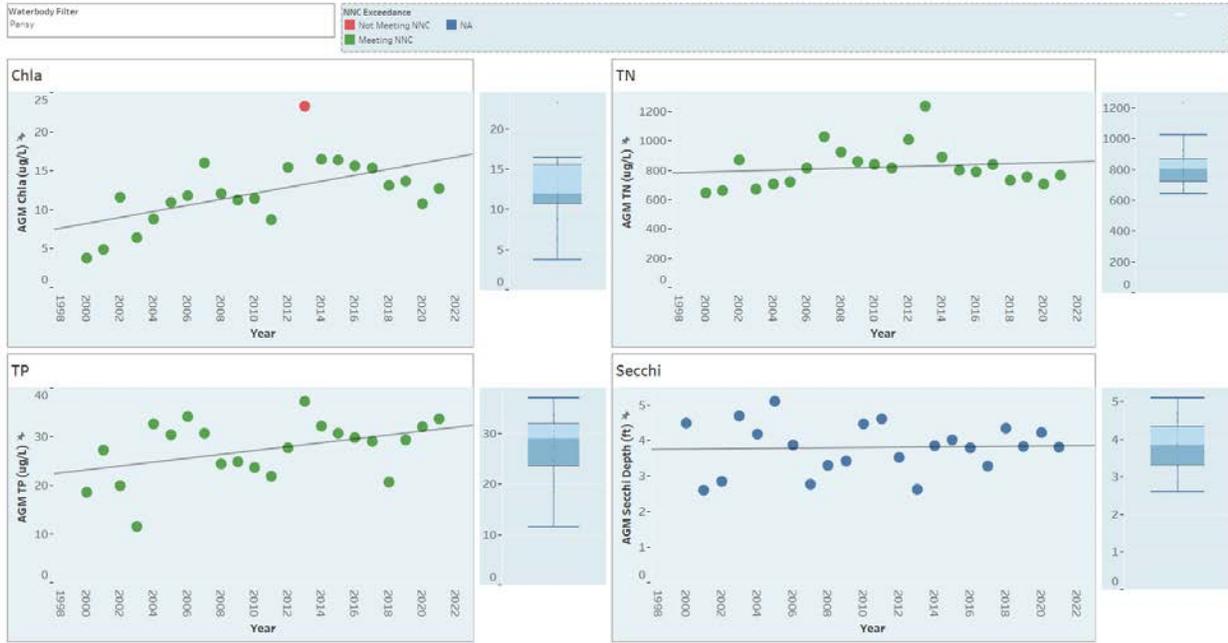
Figure 3-214. Lake Pansy AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Pansy on September 2nd, 2022. The PAC during this survey was 15.1% and the total BV was 1.15% (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 2022 indicates that its coverage often fluctuates between 15% and 45%. This may be the result of consistent invasive species treatments.

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept
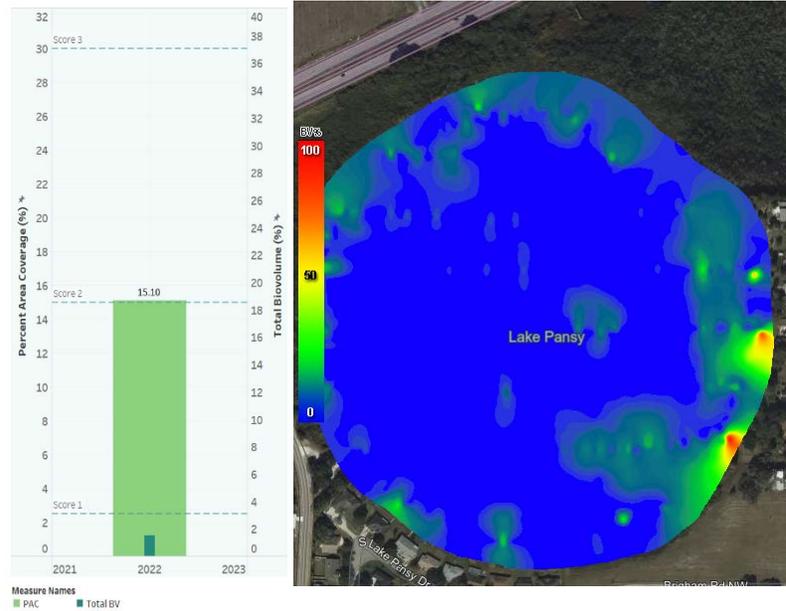
Figure 3-215. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Pansy; biovolume values range from green (lowest) to red (highest).

sampling methods. Based on the 2022 survey, Lake Pansy is dominated by spatterdock at 29% of the community (Figure 3-216). The remaining species were mostly comprised of emergent plant types, with submerged plants at only 1.5%. Managed invasive species made up just over 6% of the community and were comprised of water hyacinth and burhead sedge. This equates to an invasive criterion score of 1. In previous years, hydrilla was the primary invasive species;

present in perecentages over 10% of the community. Recent invasive management efforts, including herbicide and grass carp stocking, have effectively controlled this population.
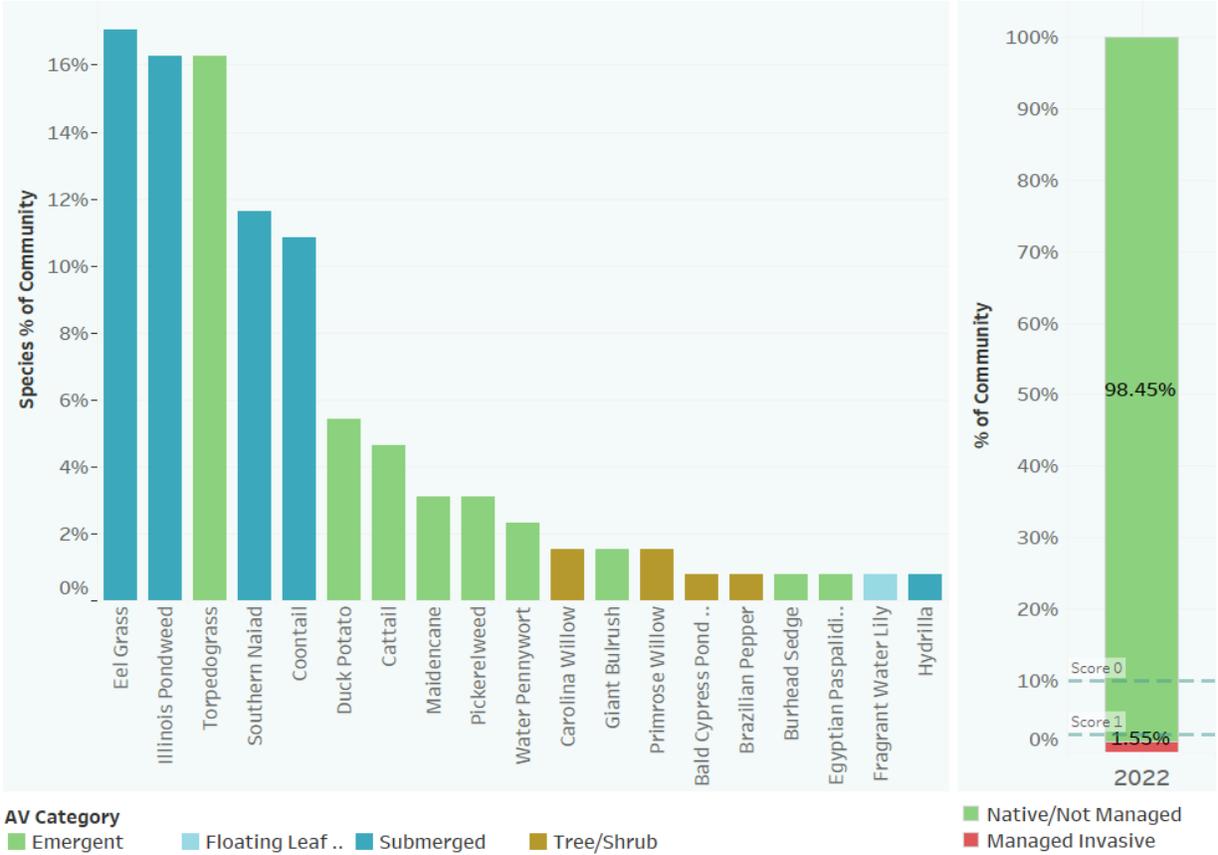

Figure 3-216. Chart depicting species frequency and invasive species percentage of Lake Pansy during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, none of Lake Pany's diversity indices met or exceeded their respective median values (Figure 3-217). This equates to a diversity criterion score of 0. The most logical explanation for these low diversity values is impacts from invasive species treatment. Not only did these efforts reduce overall vegetation abundance, but the presence of several submerged aquatic species were lost in the most recent survey. Future management efforts must take into account these impacts in order to reach better balance.
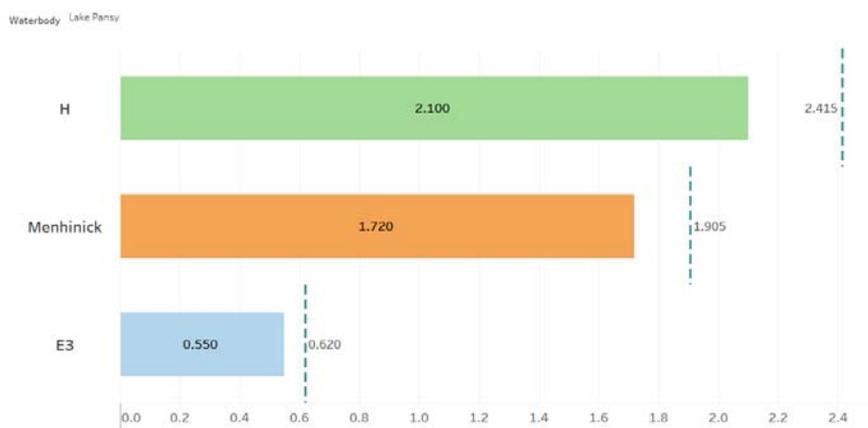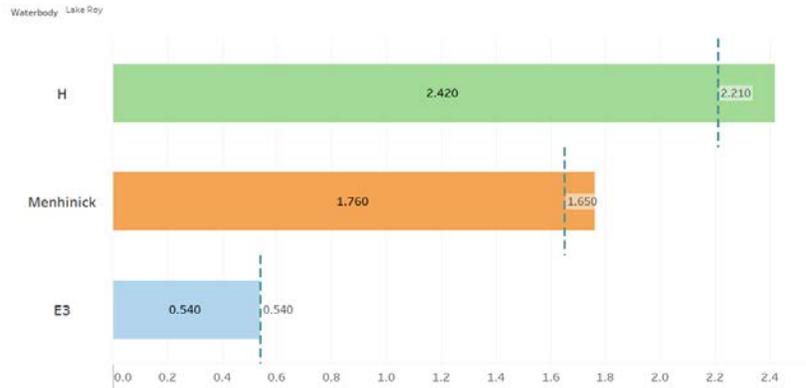

Figure 3-217. Chart depicting 2022 diversity indices for Lake Pansy. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Pansy's health index scores from 2018 to 2022 shows some fluctuation between 1.1 and 1.6 (Figure 3-218). The majority of these changes have been the result of the biological criteria. Impairment has remained static over the past five 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	1	3	1.6
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

Figure 3-218. Chart depicting a comparison of Lake Pansy's Lake Health Index scores from 2018 to 2022.

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. The means that drought conditions could result in water quality declines.

Lake Management Strategy:

- The City can explore expanding street sweeping services to 21st Street in order 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
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	3	0	2	**2.4**

Location, Characteristics, & Hydrology:

Lake Rochelle is located to the 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 1670 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 3002 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 on a monthly basis along US Highway 17.

Figure 3-220. Hypsograph of Lake Rochelle depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Over its 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 3-221). During 2022, Lake Rochelle reached a wet season peak of 129 feet in September and a dry season
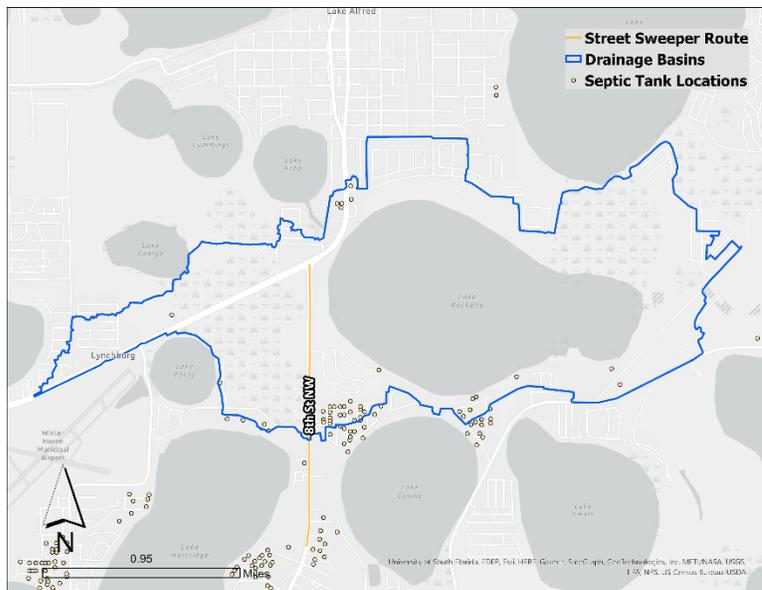
Figure 3-219. Map of Lake Rochelle's drainage basin, City street sweeper routes, and nearby septic systems.

low of 128 feet in June. The surface level ended the year above the high end of the normal range at 128.47 feet. Changes in Lake Rochelle's surface level are directly correlated with water clarity and indirectly correlated with Chla and TN (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.
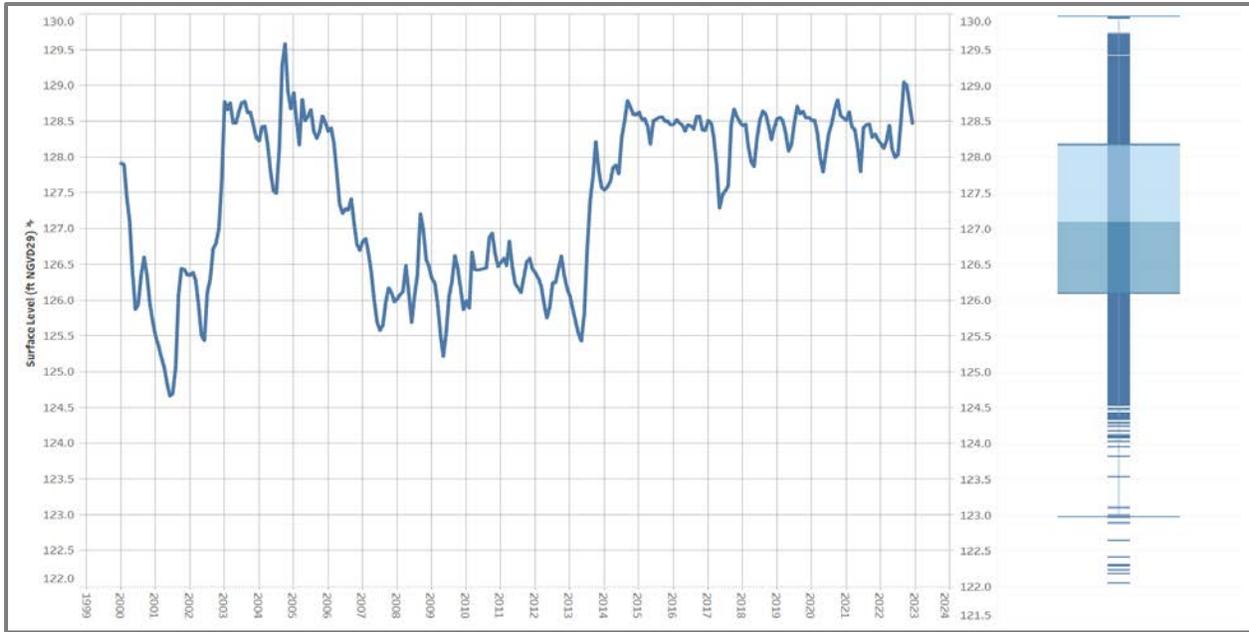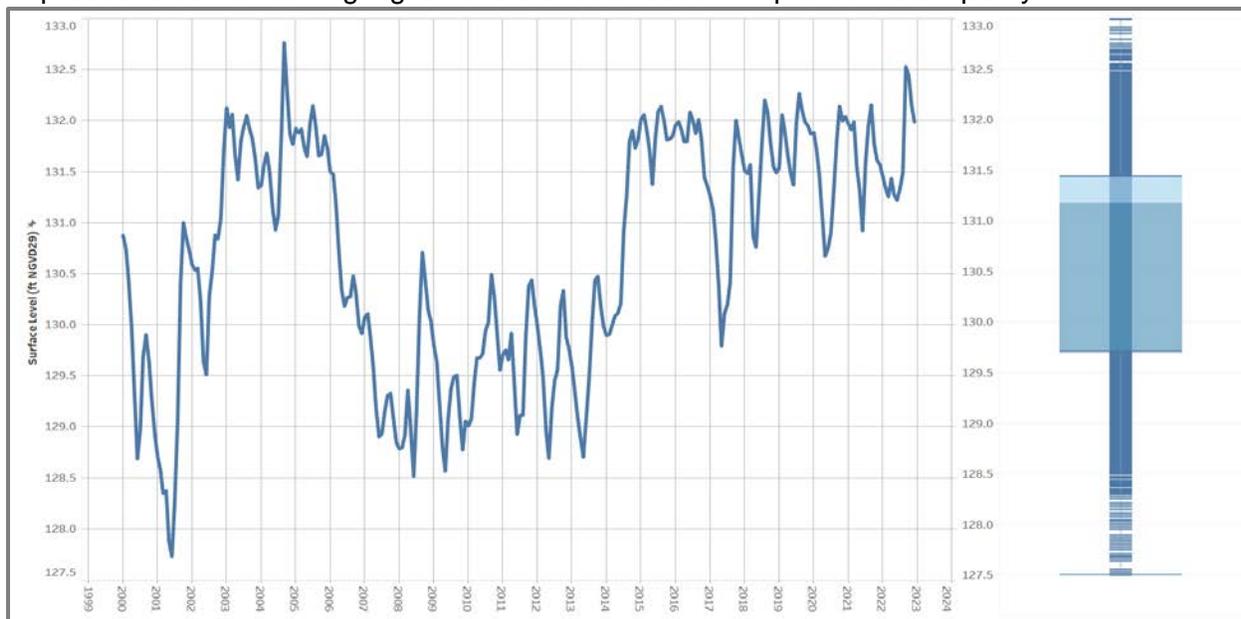

Figure 3-221. Hydrograph of Lake Rochelle depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 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 in order to meeting NNC guidelines. Lake Rochelle has been meeting all NNC thresholds since 2015.

Parameter	Impaired	Index Score
Chla	N	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. During the most recent analysis, Chla, 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 3-222. Lake Rochelle AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. 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 March 3rd, 2022. The PAC during this survey was 43.8% and the total BV was 5.8% (Figure 3-223). This equates to an abundance criterion score of 3. Lake Rochelle has consistently maintained vegetation coverage above 30% in the five years since monitoring began.The coverage observed during 2022 was a substantial increase from the previous year and the highest on record.
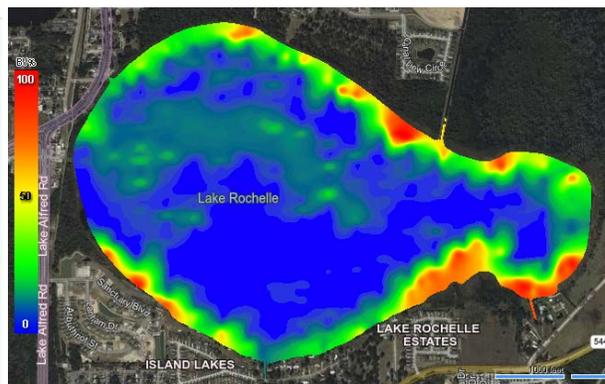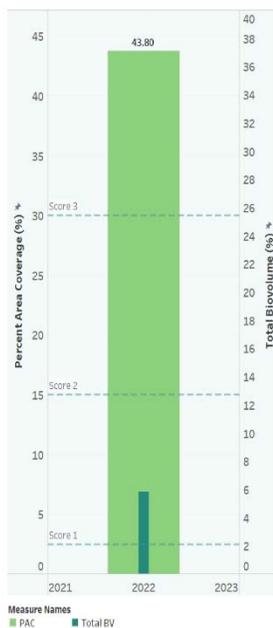
Figure 3-223. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Rochelle; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, Lake Rochelle boasts a healthy mix of both submerged and emergent vegetation—with eel grass dominating the community at 26% (Figure 3-224). Hydrilla, burhead sedge, and water hyacinth comprised the managed invasive

species present; at 14.7% of the community. Exceeding the 10% threshold equates to an invasive presence criterion score of 0. 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.
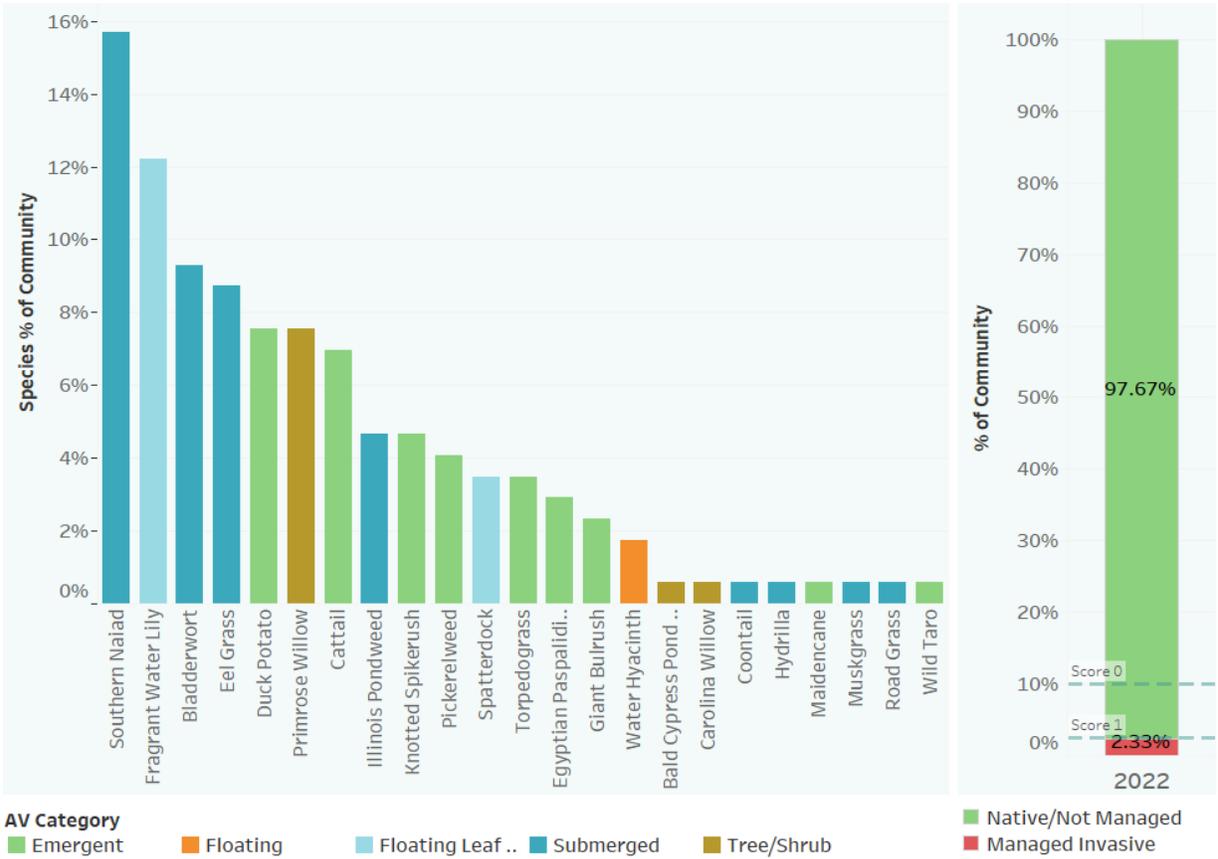

Figure 3-224. Chart depicting species frequency and invasive species percentage of Lake Rochelle during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, Lake Rochelle's richness and overall diversity indices met or exceeded their respective median values (Figure 3-225). This equates to a diversity criterion score of 2. Comparing 2022 to the previous year shows an increase in these two indices, but a slight decrease in evenness. This change is likely due to an increase in the number of unique species detected, but at the cost of the more equal distribution. Overall, Lake Rochelle exhibits moderate diversity for one of the North Chain lakes.
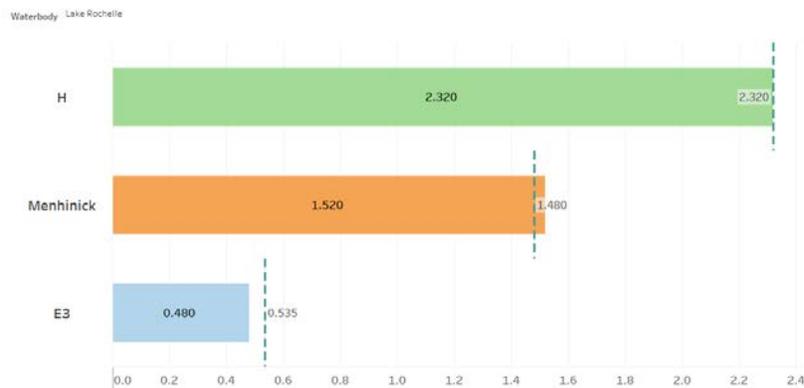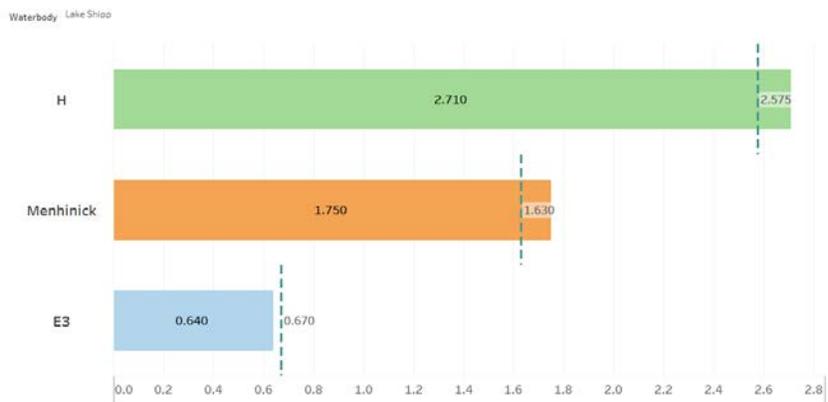

Figure 3-225. Chart depicting 2022 diversity indices for Lake Rochelle. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Rochelle's health index scores from 2018 to 2022 shows relative stability—with values ranging from 1.9 to 2.4 (Figure 3-226). Over this five year span, Rochelle's water quality has improved considerably; both exhibiting improving trends and meeting NNC guidelines after 2020. Its vegetation abundance has remained high as well. The primary areas of score fluctuation have been the invasive species presence and diversity criteria. No doubt, these are linked as invasive species treatment likely impacts the vegetation community and its diversity. Overall, Lake Rochelle ranks lower on the priority list since its water quality is now meeting standards and continues to improve. 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	0	1.9
2021	3	3	3	3	3	3	1	0	2.4
2022	3	3	3	2	3	3	0	2	2.4

Figure 3-226. Chart depicting a comparison of Lake Rochelle's Lake Health Index scores from 2018 to 2022.

Lake Health Impact/Challenges:

- Lake Rochelle currently exhibits good water quality and improving trends. However, stormwater pollutant loadings 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. The 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 residential housing 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 get the lake into a controlled state.

Lake Roy

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	3	2	3	2.8

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 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).

Figure 3-227. Hypsograph of Lake Roy depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

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 1448 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 the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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 3-229). That said, wetter and drier periods often result in more

Figure 3-228. Map of Lake Roy's drainage basin, City street sweeper routes, and nearby septic systems.

extreme peaks and troughs, respectively. During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period (Figure 3-230). As a result, Roy is considered un-impaired and earns an impairment criterion score of 3. Despite the high Chla and nutrient concentrations in 2021, Lake Roy exhibited much better water quality than typical during 2022.

Parameter	Impaired	Index Score
Chla	N	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. During this period, Chla, TN, and Secchi depth exhibited significant improving trends. This equates to trend criteria score of 3 for these parameters. TP exhibited a non-significant improving trend; for a criterion 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 3-230. Lake Roy AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. 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 April 15th, 2022. The PAC during this survey was 34.8% and the total BV was 3.9% (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 since then.
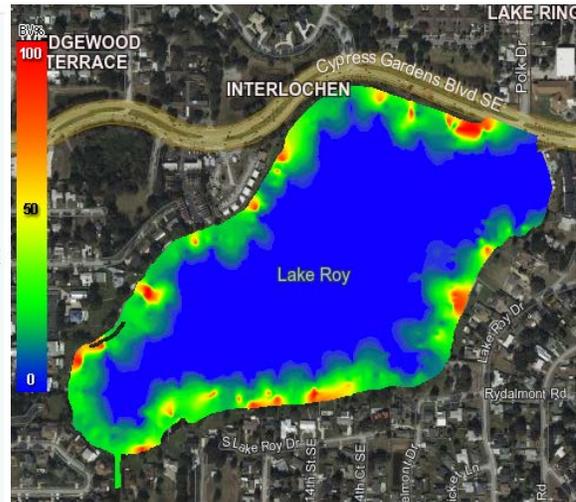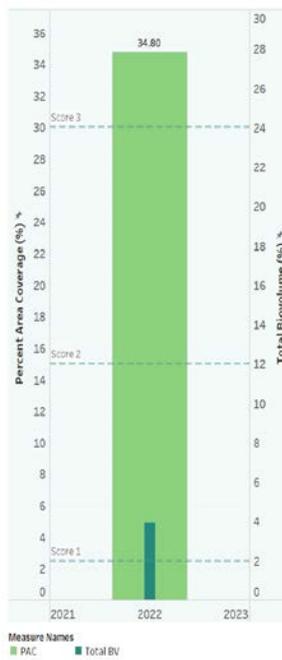
Figure 3-231. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Roy; biovolume values range from green (lowest) and red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, Lake Roy is very clearly dominated by submerged plants. The native eel grass and Illinois pondweed made up over 33% of the community (Figure 3-232). Managed invasives made up only 1.5% of the community; comprised

of small populations of burhead sedge and 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 is back up without a high invasive presence in 2022.

Figure 3-232. Chart depicting species frequency and invasive species percentage of Lake Roy during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2022 species data, all three of Lake Roy's diversity indices met or exceeded their respective median values (Figure 3-233). This equates to a diversity criterion score of 3. 2022 exhibited more unique species identified and a more even distribution of the top five species compared to previous years. This indicates that Lake Roy's vegetation management program has been successful at maintaining a robust and healthy plant community.

Figure 3-233. Chart depicting 2022 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 2022 shows consistently high lake health—with values ranging from 2.4 to 2.8 (Figure 3-234). Over this five year span, the water quality criteria scores have changed very little. Lake Roy has excellent water quality and continues to exhibit improving trends. Vegetatation abundance exhibited a decline in 2019 and 2020, but has since recovered. Aside from 2018 and 2021, the invasive presence has remained controlled. Species diversity has been the main source of lake health fluctuation. 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	2	1	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

Figure 3-234. Chart depicting a comparison of Lake Roy's Lake Health Index scores from 2018 to 2022.

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. The 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 Score
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 maximum depth of over 13 feet (Figure 3-235).
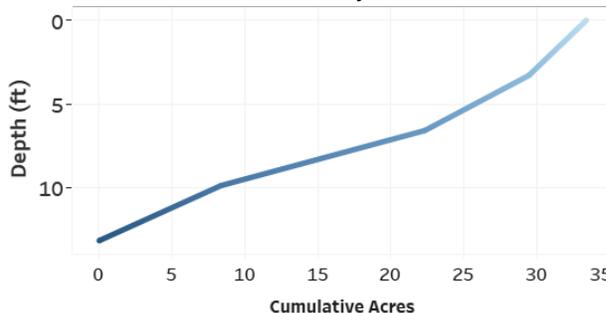
Figure 3-235. Hypsograph of Lake Shipp depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

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 modelling, this drainage area contributes 3614 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.
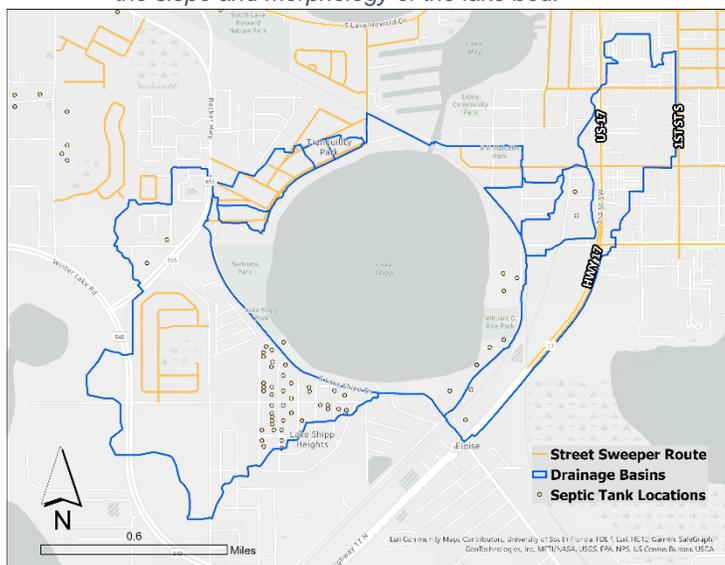
Figure 3-236. Map of Lake Shipp's drainage basin, City street sweeper routes, and nearby septic systems.

Due to the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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 3-237). That said, wetter and drier periods

often result in more extreme peaks and troughs, respectively. During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period, Lake Shipp is considered impaired for Chla, 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	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Each of Lake Shipp's water quality parameters exhibited significant improving trends during this period. This equates to trend criteria scores of 3 for Chla, 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
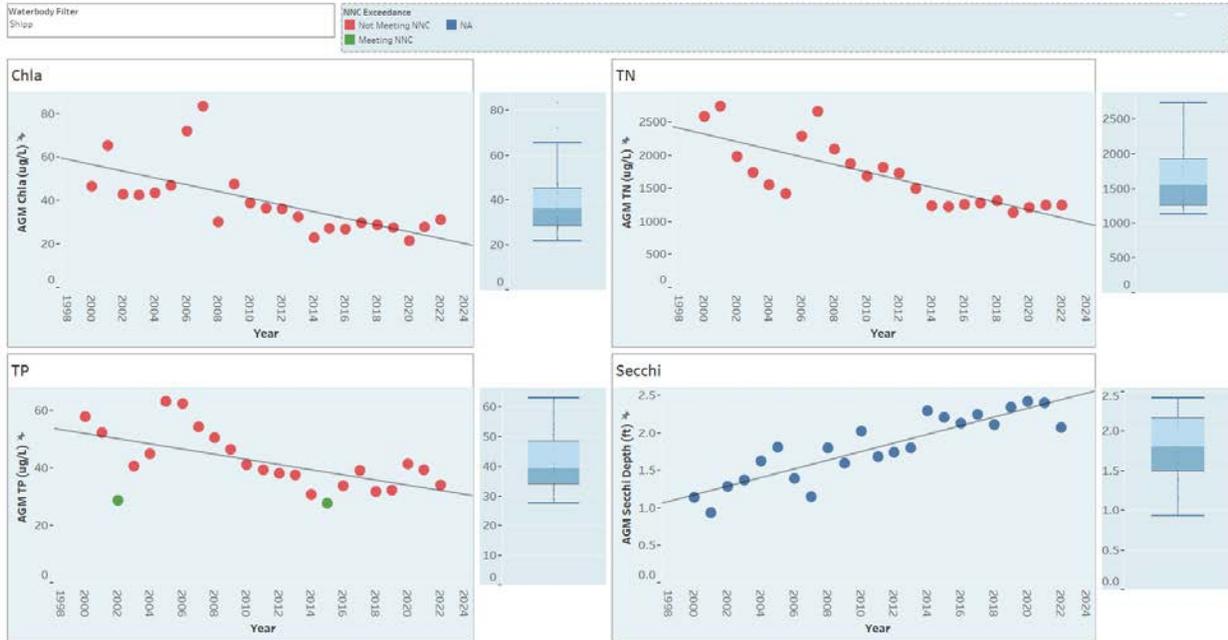
Figure 3-238. Lake Shipp AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Shipp on September 16th, 2022. The PAC during this survey was 51.8% and the total BV was 8.53% (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 shallow depth and gradually sloping bed.
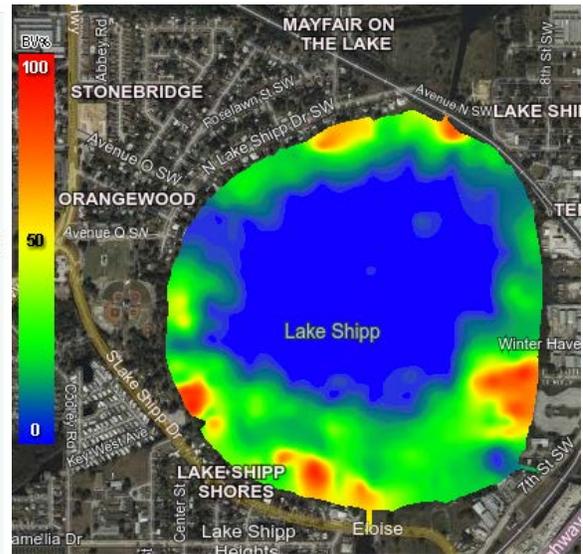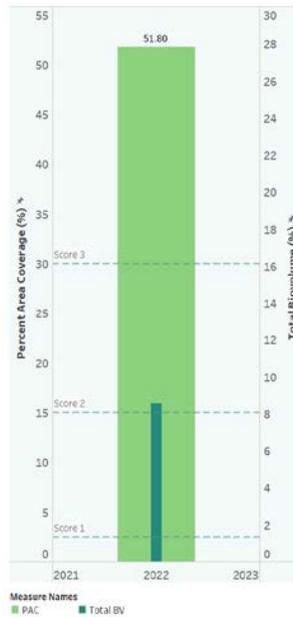
Figure 3-239. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Shipp; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2022 survey data, Lake Shipp has a healthy mix of vegetation types. It is currently dominated by the native southern naiad at over 15% of the community (Figure 3-240). Managed invasive species made up just 2.3% of the community; mostly comprised of water hyacinth 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 during the last two years.

Figure 3-240. Chart depicting species frequency and invasive species percentage of Lake Shipp during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2022 species data, Lake Shipp's richness and overall diversity indices met or exceeded their respective median values (Figure 3-241). This equates to a diversity criterion score of 2. While the number of unique species identified in 2022 was higher than previous years, the distribution of the plants in the middle frequency ranks (5-10) was less even than during previous years. Despite the lower evenness index score, Lake Shipp does boast relatively high overall diversity.

Figure 3-241. Chart depicting 2022 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 2022 shows relative consistency—with values ranging from 2.1 to 2.4 (Figure 3-242). Throughout this five 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 in 2021 and 2022. 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

Figure 3-242. Chart depicting a comparison of Lake Shipp's Lake Health Index scores from 2018 to 2022.

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

Location, Characteristics, & Hydrology:

Lake Silver is centrally located within the heart of Winter Haven's downtown area. It's 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).

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 modelling, 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.

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 2022, Lake Silver reached a wet season peak of 146.5 feet in October and a dry season low of 144.9 feet in July. The surface level ended the year

Figure 3-243. Hypsograph of Lake Silver depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Figure 3-244. Map of Lake Silver's drainage basin, City street sweeper routes, and nearby septic systems.

well above the normal range, at 146.3 feet. Changes in Lake Silver's surface level are not significantly correlated with any of its water quality metrics (see appendix).
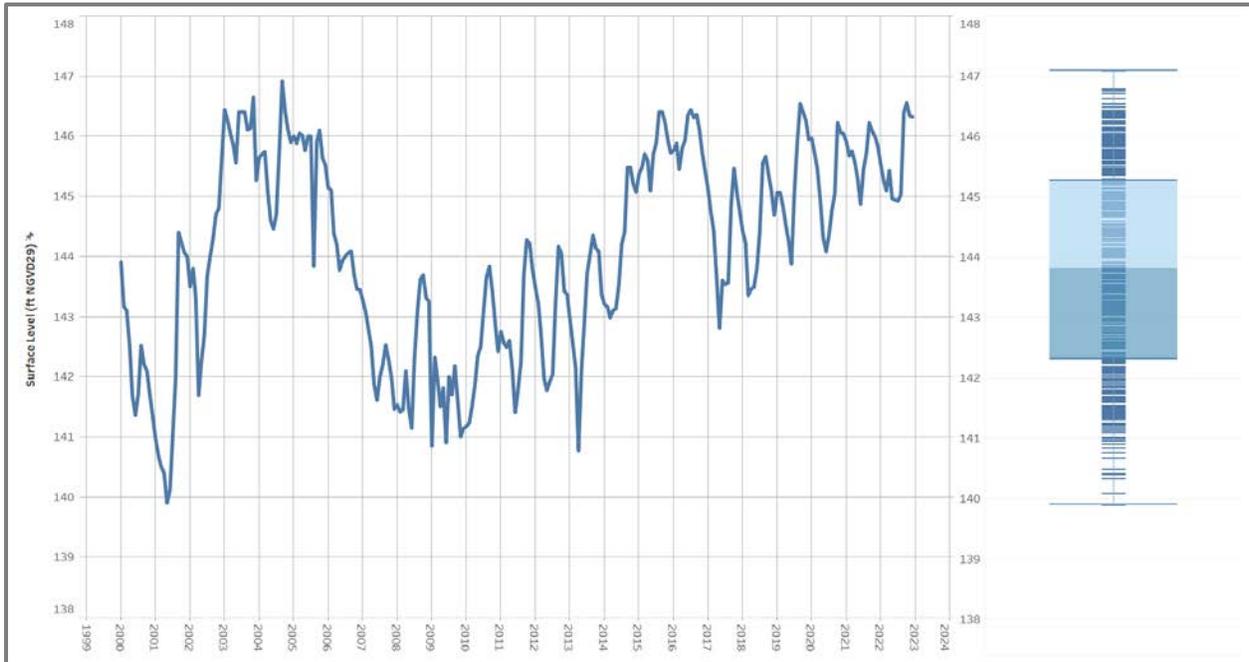
Figure 3-245. Hydrograph of Lake Silver depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining water quality impairment based on the Numeric Nutrient Criteria, Lake Silver is categorized as a clear, alkaline waterbody. Aside from an exceedance of the Chla threshold in 2017, Lake Silver has not exhibited any other NNC exceedances during the 2015 – 2022 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 2022 Chla, TN, and TP concentrations were well below the normal range—indicating better water quality than normal.

Parameter	Impaired	Index Score
Chla	N	
TN	N	3
TP	N	

Water Quality Trends

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. During this period, Chla, TN, and TP exhibited non-significant improving trends; equating to trend criteria scores of 2. Secchi depth, on the other hand, exhibited a non-significant deteriorating trend; for a score of 1. 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	Decreasing	Not Significant	1
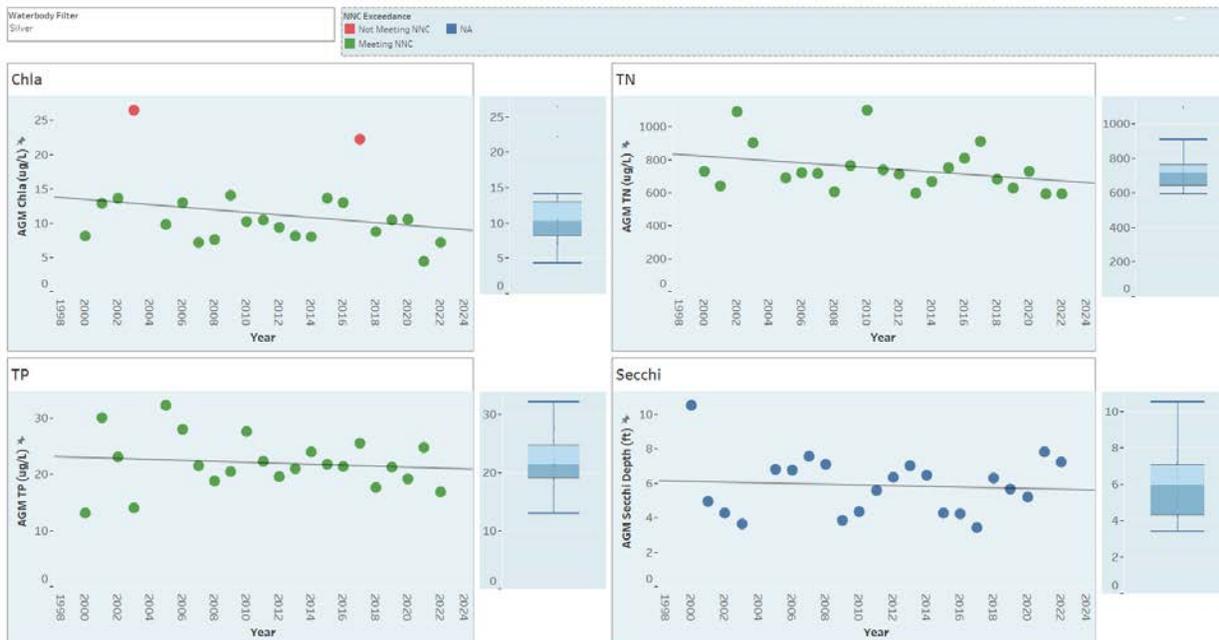
Figure 3-246. Lake Silver AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Silver on August 19th, 2022. The PAC during this survey was 2.3% and the total BV was 0.26% (Figure 3-247). PAC below the 2.5% threshold earns a vegetation abundance score of 0. Since monitoring began, Lake Silver has displayed very low vegetation abundance. 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 wave action that prevents most plants from rooting and expanding into deeper water.
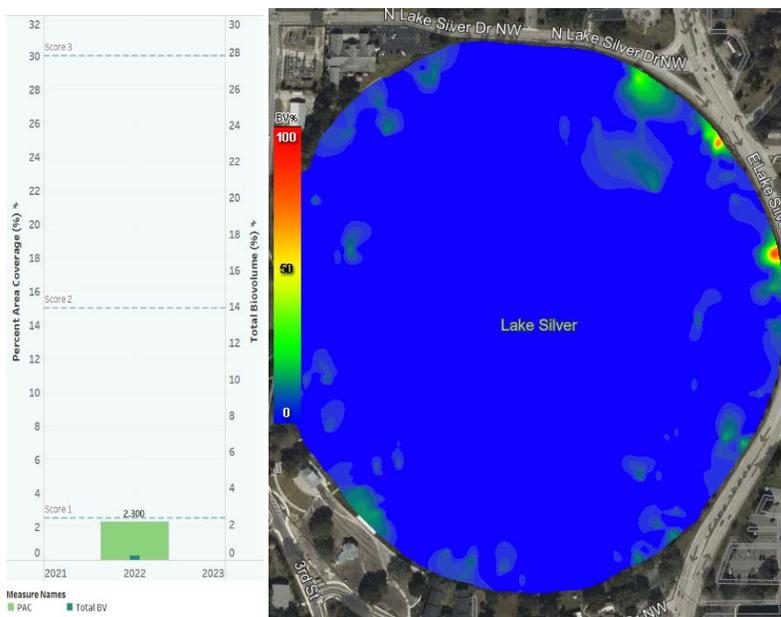
Figure 3-247. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Silver; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, Lake Silver lacked any appreciable presence of submerged vegetation. Emergent plants like cattail and torpedograss made up over

95% of the community (Figure 3-248). 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. What hasn't been consistent is the presence of submerged eel grass in the lake. Eel grass appears to be detected in moderate frequencies every other year. Considering that staff monitor the same

Figure 3-248. Chart depicting species frequency and invasive species percentage of Lake Silver during 2022.

sampling points each year, this alternating presence/absence of eel grass could be deliberate vegetation management by a non-governmental organization or natural shifts in the vegetation community. Additional study is required to draw definitive conclusions.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2022 species data, none of Lake Silver's diversity indices met their respective median values (Figure 3-249). This equates to a diversity criterion score of 0. A comparison of species data from the previous year shows fewer unique species identified and a less even distribution of the community in 2022.
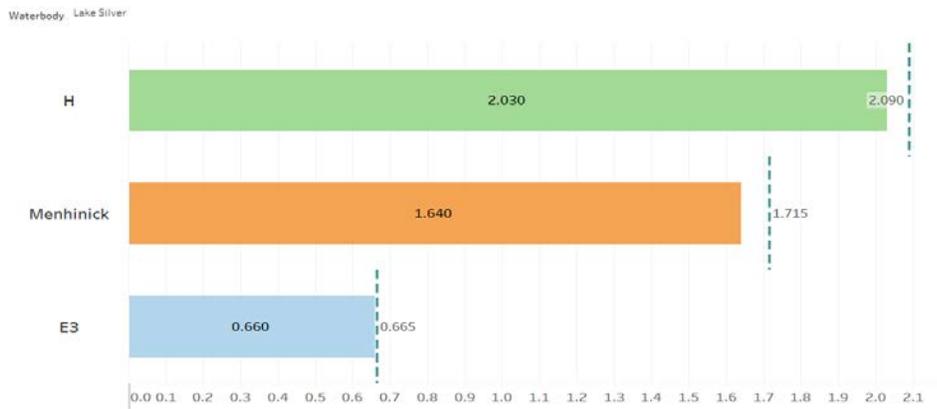
Figure 3-249. Chart depicting 2022 diversity indices for Lake Silver. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Silver's health index scores from 2018 to 2022 shows some variability, with values ranging from 1.6 to 2.1 (Figure 3-250). Over this five year 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 amongst 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	1	3	0	1.8
2021	3	2	2	2	1	0	3	3	2.0
2022	3	2	2	2	1	0	3	0	1.6

Figure 3-250. Chart depicting a comparison of Lake Silver's Lake Health Index scores from 2018 to 2022.

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 Score
0	2	2	2	3	3	1	2	1.9

Location, Characteristics, & Hydrology:

Lake Smart is located to the 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).

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 1673 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 currenlty conduct street sweeping services in Lake Smart's drainage basin.

Over its 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 3-253). During 2022, Lake
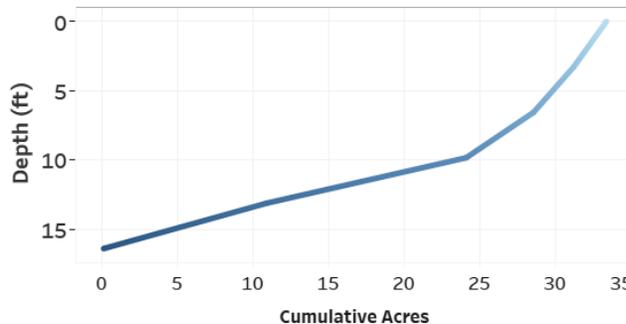
Figure 3-251. Hypsograph of Lake Smart depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.
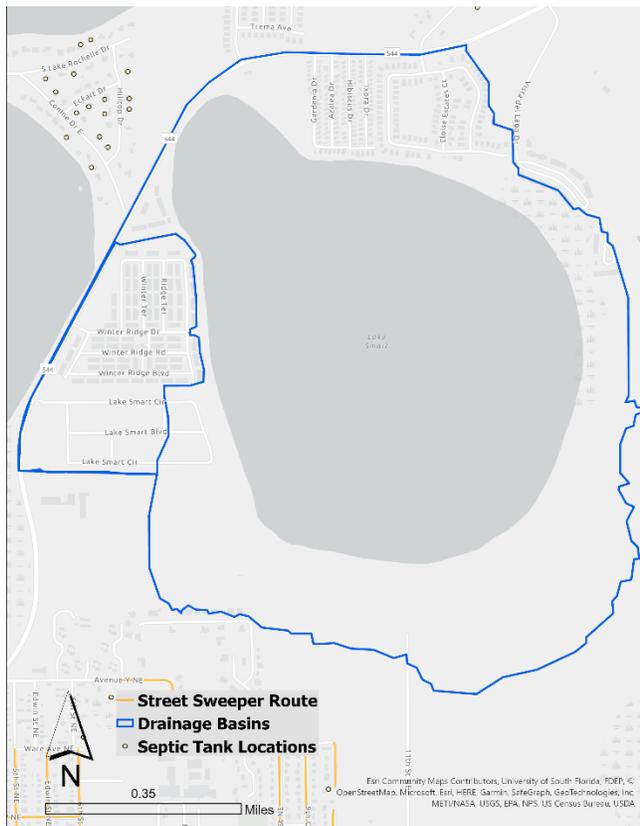
Figure 3-252. Map of Lake Smart's drainage basin and nearby septic systems.

Smart reached a wet season peak of 129 feet in September and a dry season low of 128 feet in June. The surface level ended the year above the high end of the normal range at 128.47 feet. Changes in Lake Smart's surface level are directly correlated with water clarity and indirectly correlated with Chla and TN (see appendix). This carries management implications as maintaining higher levels should result water quality improvements.
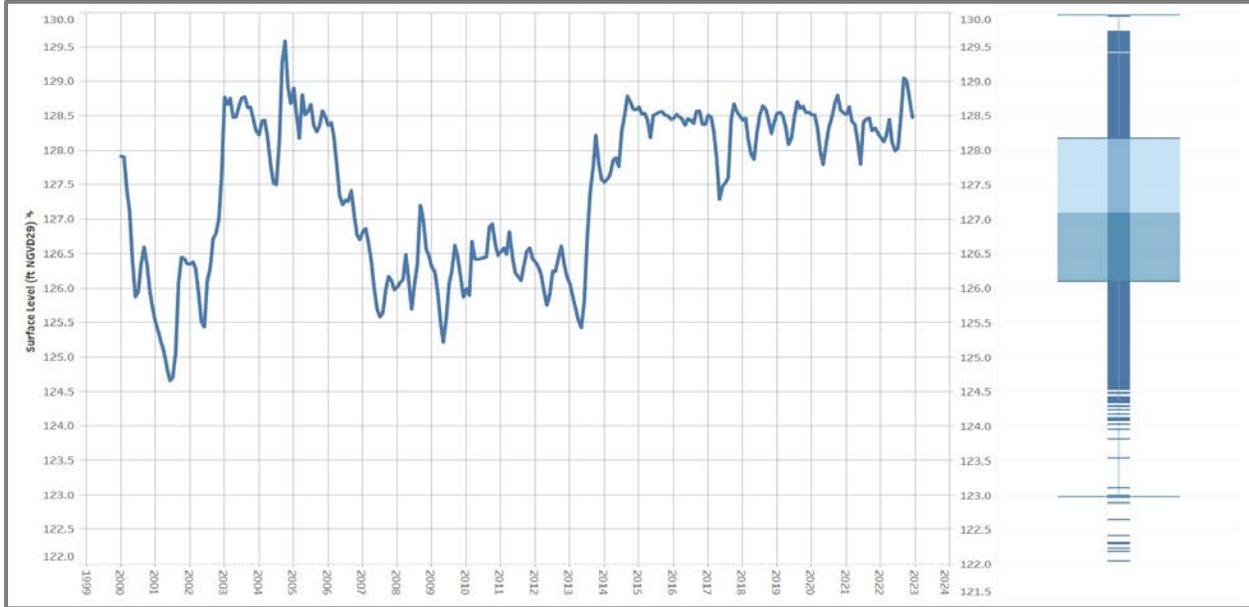
Figure 3-253. Hydrograph of Lake Smart depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period, Lake Smart is considered impaired for Chla, TN, and TP (Figure 3-254). This equates to an impairment criterion score of 0. As of 2022, the FDEP has begun 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	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. All four of these parameters exhibited non-significant improving trends during this period. Secchi depth exhibited significant improving trends in previous years—indicating that water quality is beginning to decline. The result is that each parameters receives a trend criterion score of 2. Individual AGM values and trend statistics can be found in 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
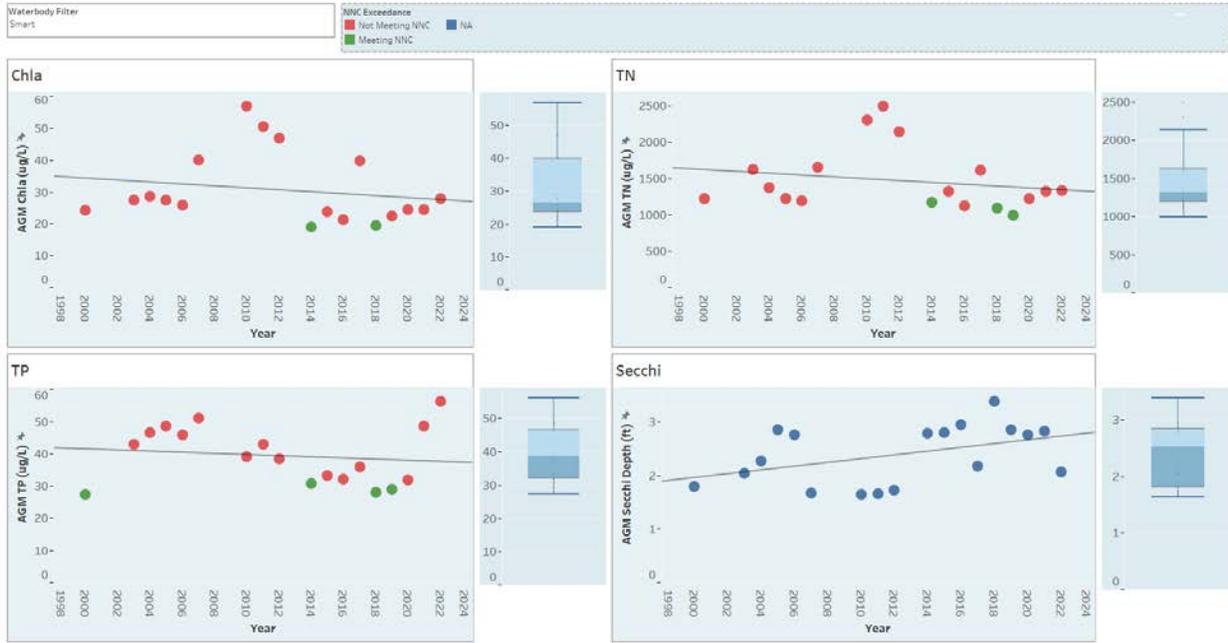
Figure 3-254. Lake Smart AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Smart on April 5th, 2022. The PAC during this survey was 61.9% and the total BV was 7% (Figure 3-255). A PAC value above the 30% threshold equates to an abundance criterion score of 3. Coverage during 2022 was the highest recording in the five years that monitoring has been conducted. PAC ranged between 13% and 30% in previous years. This indicates a substantial improvement in vegetation abundance.
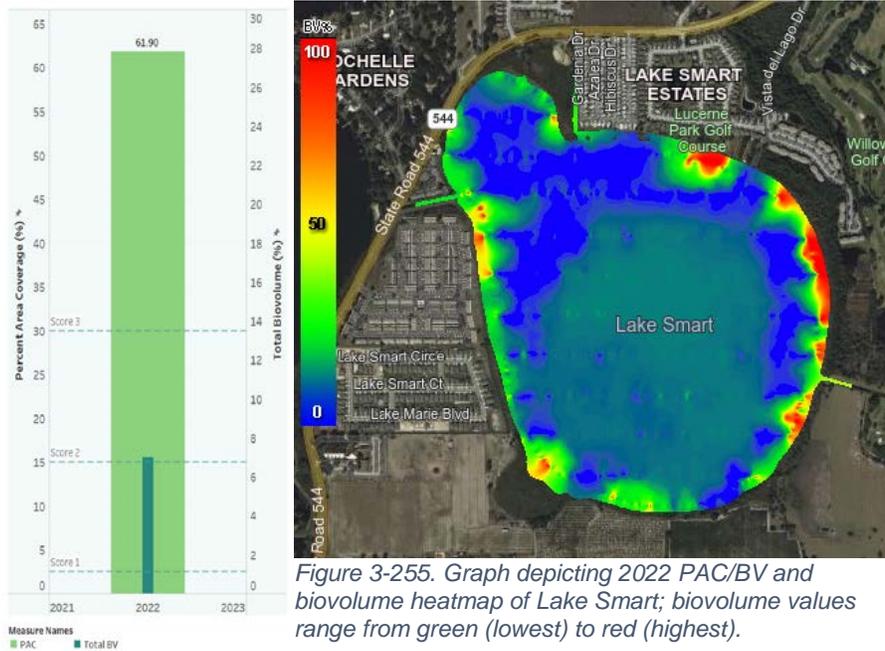
Figure 3-255. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Smart; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, Lake Smart supports a healthy mix of vegetation types. Eel grass and cattail were the most dominant species, at 17.8% and 16.9% respectively (Figure 3-256). The invasive hydrilla made up 3.4% 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 4% after treatment that same year.
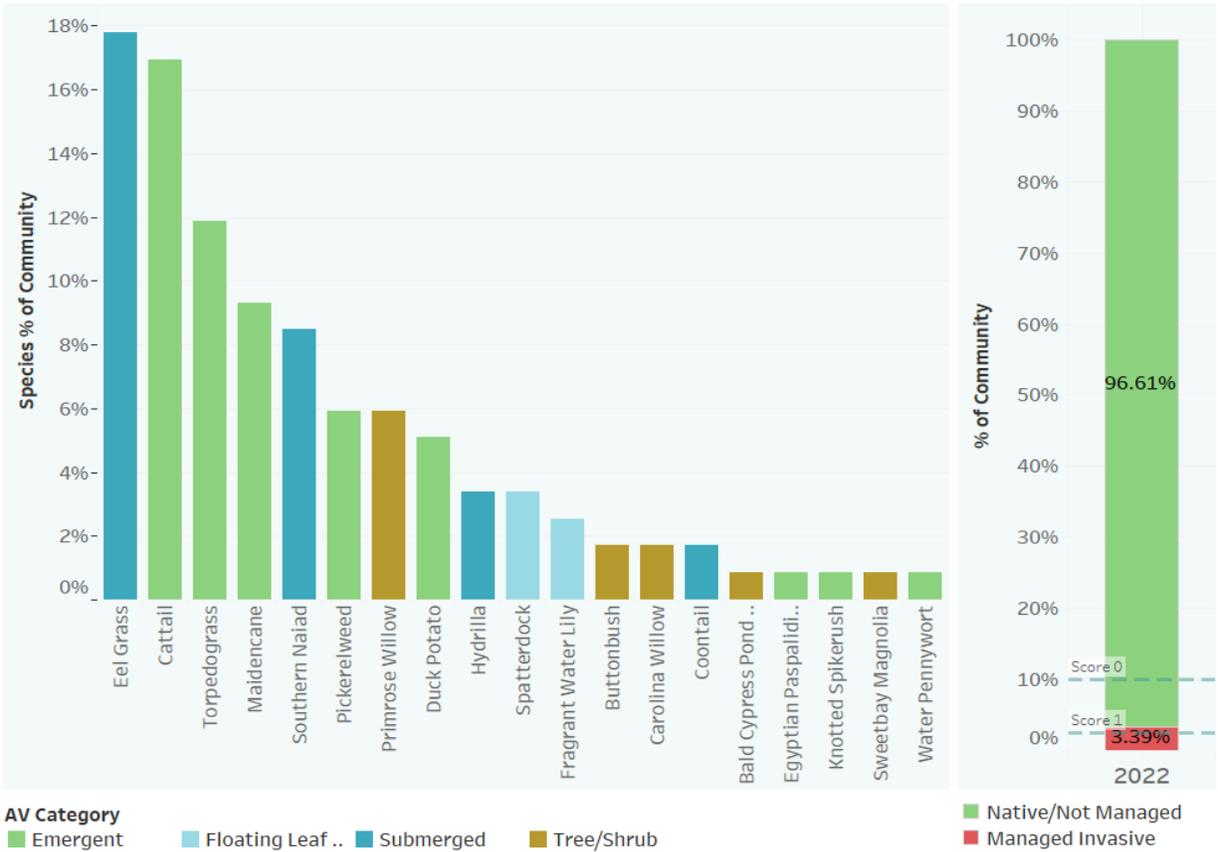
Figure 3-256. Chart depicting species frequency and invasive species percentage of Lake Smart during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2022 species data, Lake Smart's richness and overall diversity indices met or exceeded their respective median values (Figure 3-257). This equates to a diversity score of 2. An increase in the number of unique species identified was the primary factor for the increase in these two diversity indices. While the evenness index was slightly below the median, it has historically not shifted much in the five years that monitoring has been conducted. The species distribution has remained relatively static during this period.
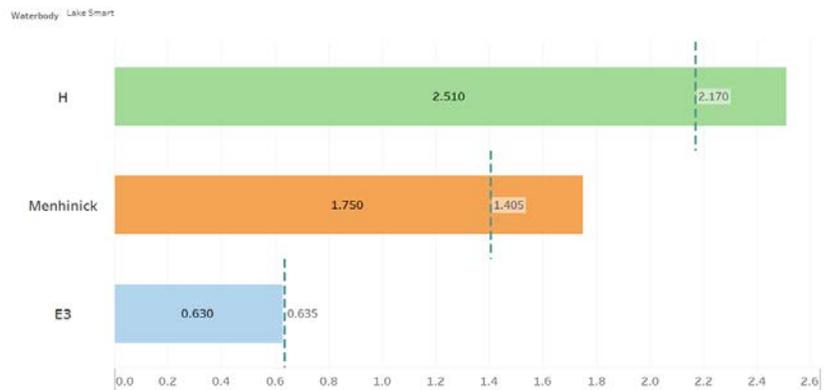
Figure 3-257. Chart depicting 2022 diversity indices for Lake Smart. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Smart's health index scores from 2018 to 2022 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 has 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	2	3	1	2	1.8

Figure 3-258. Chart depicting a comparison of Lake Smart's Lake Health Index scores from 2018 to 2022.

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 and the City of Winter Haven are currently partnering to develop a pollutant reduction plan for Lake Smart. This process explores the possible pollution sources within the basin and proposes management practices to reduce them. Once this process is completed, it will be submitted to the FDEP for review.

- 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 Score**
3	3	3	3	3	3	1	2	**2.6**

Location, Characteristics, & Hydrology:

Lake Spring (aka Spring Lake) is located near to 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 Wahneta 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.

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 modelling, 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 stormater loading, the City conducts 7.4 miles of street sweeping in this basin on a monthly basis.

Due to the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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

Figure 3-259. Hypsograph of Lake Spring depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

Figure 3-260. Map of Lake Spring's drainage basin and City street sweeper routes.

129.7 and 131.4 feet (Figure 3-261). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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).
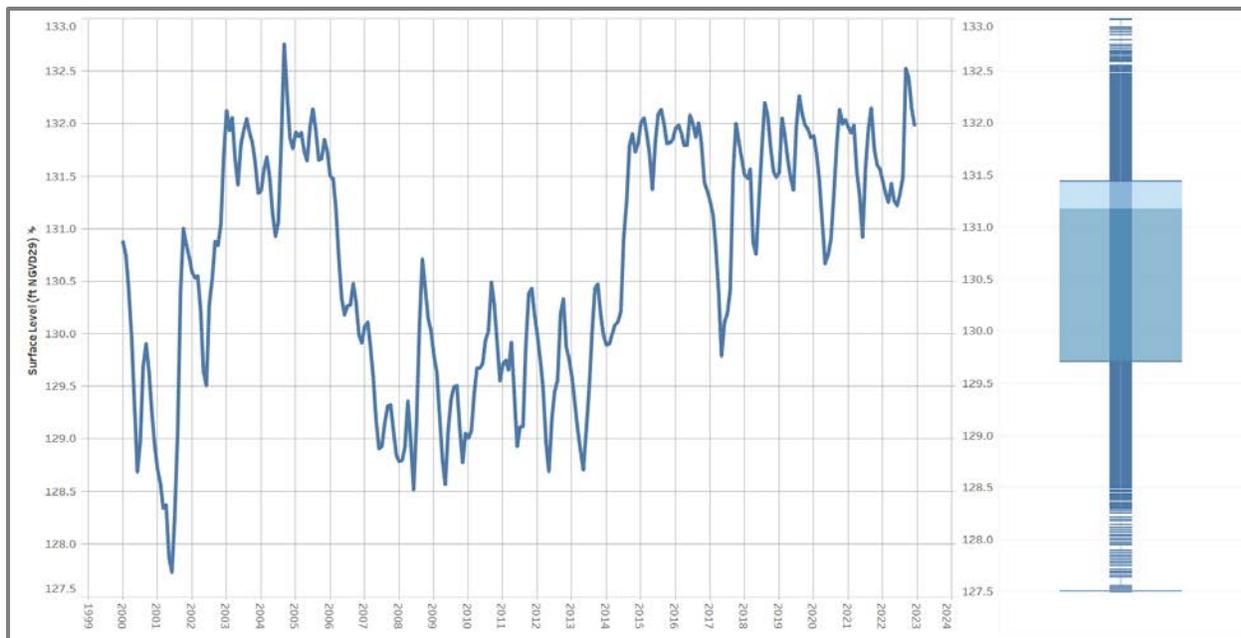
Figure 3-261. Hydrograph of Lake Spring depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Spring is categorized as a clear, alkaline waterbody. Despite an exceedance of Chla in 2015, Lake Spring has exhibited no other NNC exceedances during the 2015 – 2022 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	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. All four of these parameters exhibited significant improving trends during this period. This equates to trend criteria scores of 3 for Chla, 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 3-262. Lake Spring AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. 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 January 7th, 2022. The PAC during this survey was 56.3% and the total BV was 8% (Figure 3-263). A PAC over the 30% threshold equates to a vegetation abundance criterion score of 3. Over the last five 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.
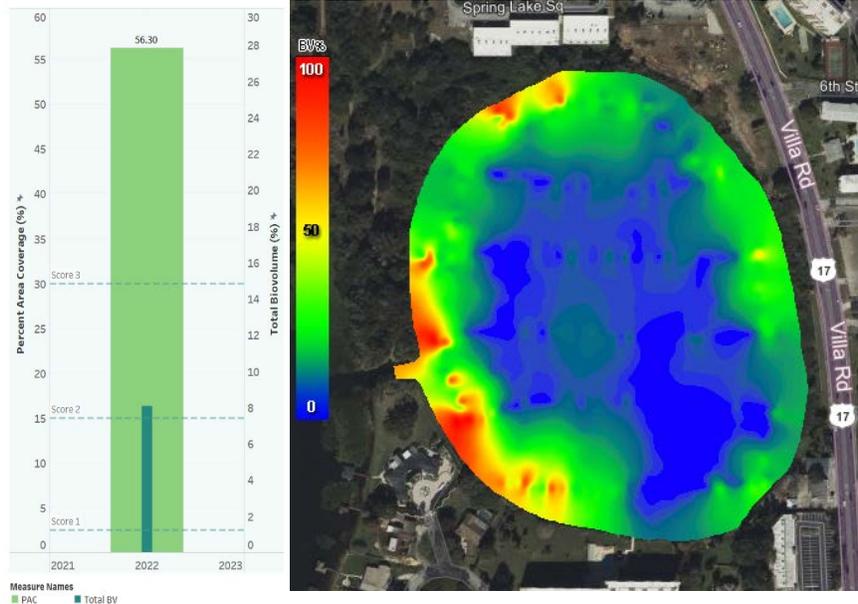
Figure 3-263. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Spring: biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, Lake Spring possesses a mix of vegetation types. Eel grass was the most dominant at 17.4%, followed closely by the floating leaf plants, fragrant water lily and spatterdock (Figure 3-264). Invasive species were represented solely by burhead sedge—at 5.8% of the community. This equates to an invasive criterion score

of 1. Historically, hydrilla has been the primary invasive species present. However, recent invasive management efforts were able to reduce hydrilla below detectable levels. The invasive percentage in 2022 was the lowest on record.
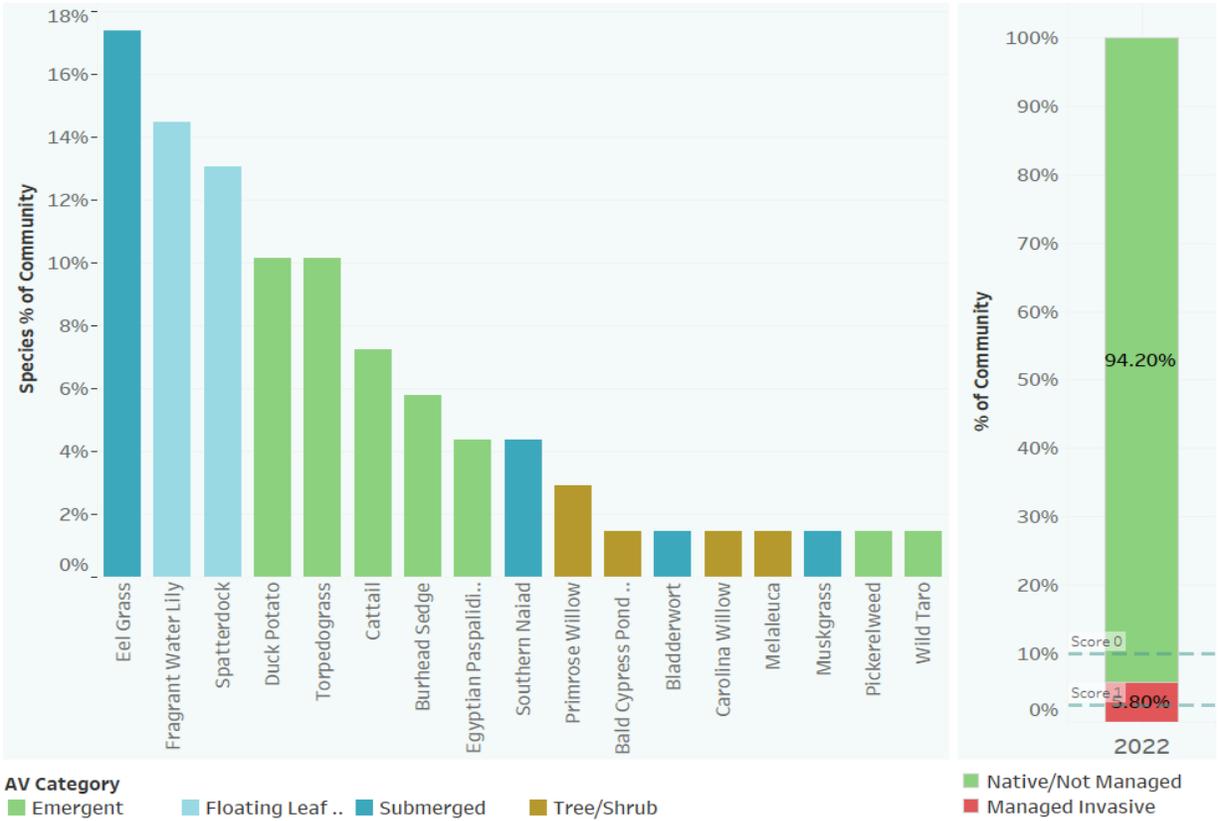
Figure 3-264. Chart depicting species frequency and invasive species percentage of Lake Spring during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2022 species data, Lake Spring's richness and overall diversity indices were above median values (Figure 3-265). There was an increase in all three indices from 2021 to 2022. This was primarily due to an increase in the number of unique species detected. While evenness did increase slightly, it was not sufficient to meet the median index value.
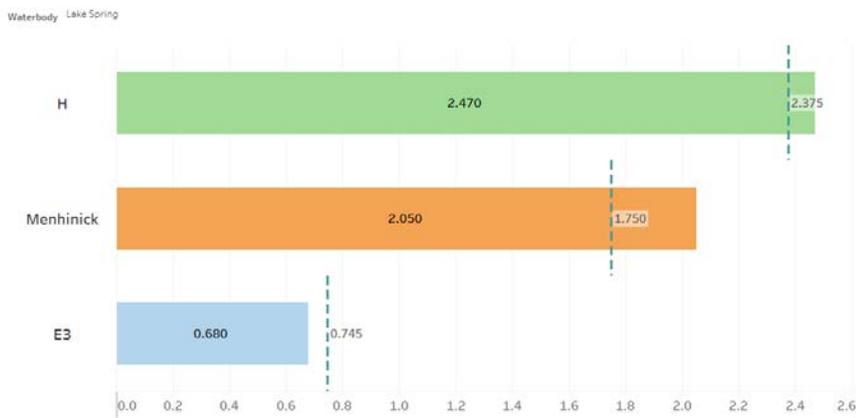
Figure 3-265. Chart depicting 2022 diversity indices for Lake Spring. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Spring's health index scores from 2018 to 2022 shows consistently good values ranging from 2.3 to 2.6 (Figure 3-266). During this five year span, there have been no changes in the impairment, trend, and vegetation abundance criteria scores. The presence of invasive species was reduced somewhat in 2022 after several years of low scores. The diversity score provided the majority of variance, but no major changes were observed. 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

Figure 3-266. Chart depicting a comparison of Lake Spring's Lake Health Index scores from 2018 to 2022.

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 2022, it can take only a single growing season for a small population to take over large areas of a waterbody.

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 sclae 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 Score
3	3	3	2	3	3	1	3	2.6

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 Wahneta 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, and average depth of 12.7 feet, and a maximum depth of over 26 feet (Figure 3-267).
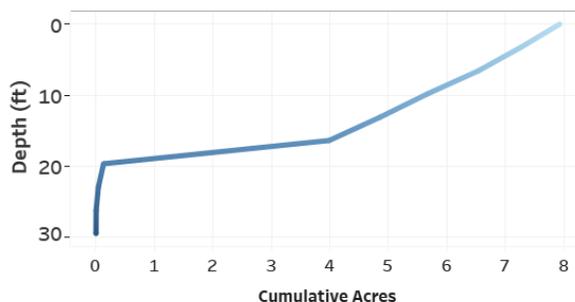
Figure 3-268. Hypsograph of Lake Summit depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake

Stormwater is conveyed to this waterbody from a 166 acre drainage basin (Figure 3-268). The basin is dominanted 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 the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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 3-269). That said, wetter and drier periods

often result in more extreme peaks and troughs, respectively. During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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 is correlated with Chla, TN, and water clarity (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.
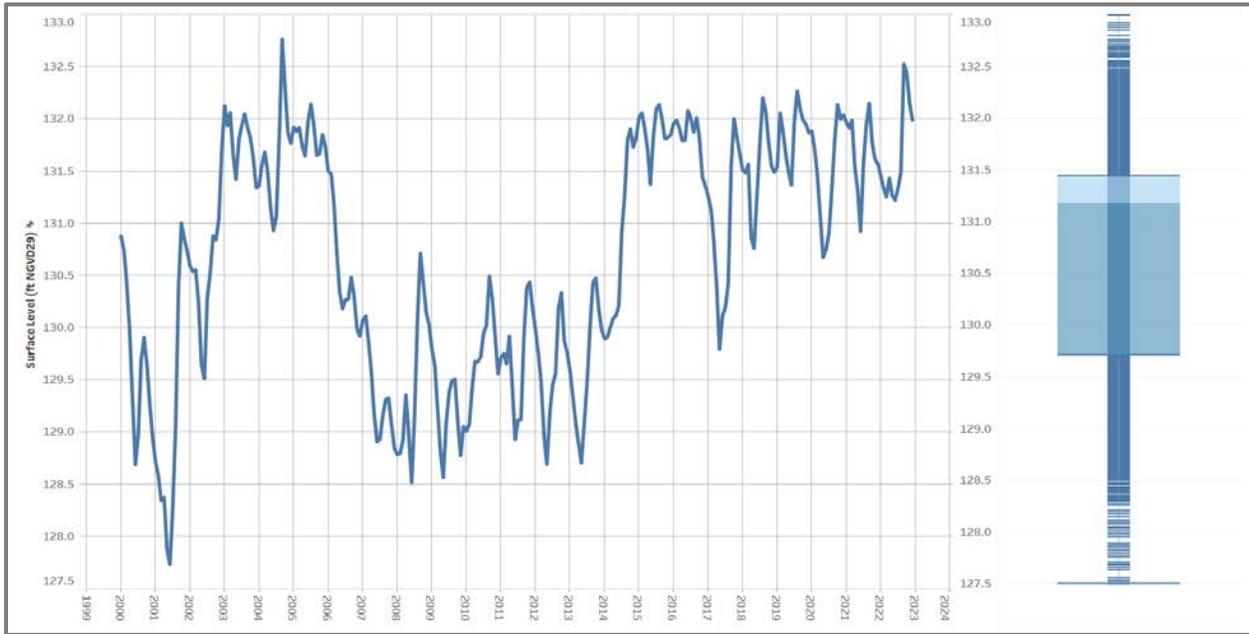
Figure 3-269. Hydrograph of Lake Summit depicting monthly surface level readings from 2000 to 2022. A box and whisker plot detail total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 - 2022 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	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. During this period, Chla, TN, and Secchi depth exhibited significant improving trends; earning trend criteria score of 3 for these parameters. 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	Decreasing (Improving)	Significant	3
TN	Decreasing (Improving)	Significant	3
TP	Decreasing	Not Significant	2
Secchi	Increasing (Improving)	Significant	3

Figure 3-270. Lake Summit AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. 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 March 18th, 2022. The PAC during this survey was 63% and the total BV was 9.3% (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.
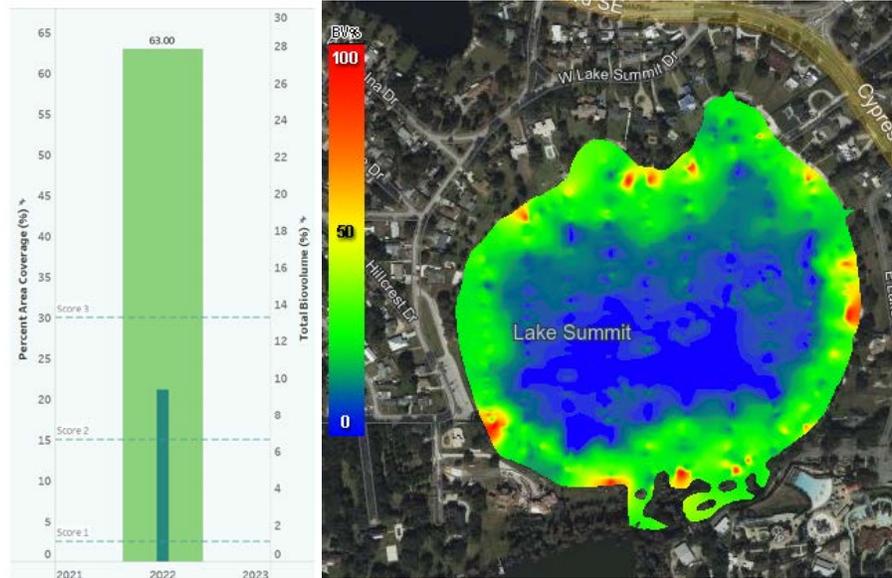
Figure 3-271. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Summit; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2022 data, Lake Summit is dominated by submerged aquatic vegetation. The top four most abundant species, making up over 55% of the community, are eel grass, southern naiad, coontail, and Illinois pondweed (Figure 3-272). Hydrilla was the only managed invasive species present; at 4.96% 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%.
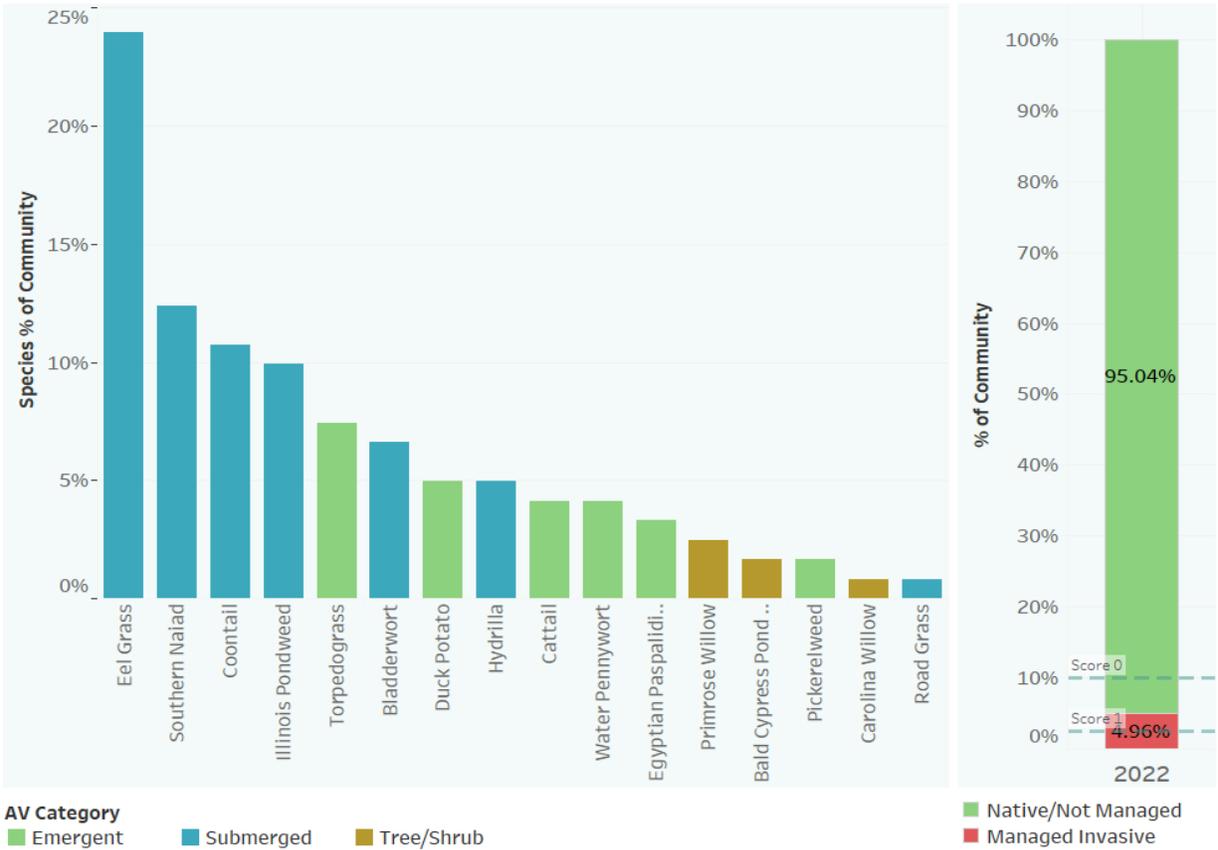
Figure 3-272. Chart depicting species frequency and invasive species percentage of Lake Summit during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2022 species data, all three of Lake Summit's diversity indices met or 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 2022, compared with previous years.
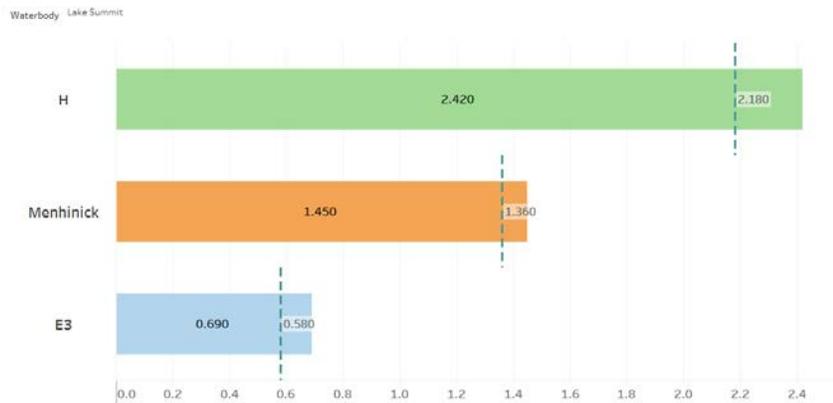
Figure 3-273. Chart depicting 2022 diversity indices for Lake Summit. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Summit's health index scores from 2018 to 2022 shows consistently good values ranging from 2.4 to 2.6 (Figure 3-274). Throughout the five year span, the primary source of score fluctuation has been from the diversity criterion. This likely changes in response to natural factors as well as invasive species treatment efforts. It should be noted that the TP trend criterion did shift from statistically significant, to non-significant in 2019. 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

Figure 3-274. Chart depicting a comparison of Lake Summit's Lake Health Index scores from 2018 to 2022.

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. The 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 Score
3	3	3	3	3	3	0	1	2.4

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).

Figure 3-276. Hypsograph of Lake Winterset depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.

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 2259 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 3-275. Map of Lake Winterset's drainage basin and nearby septic systems.

Due to the navigable canals connecting the South Chain waterbodies, surface levels fluctuate consistently across the 14 lakes in this group. 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 3-277). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2022, the South Chain reached a wet season peak of 132.5 ft and a dry season low of 131.2 ft, but ended the year at 131.99 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).
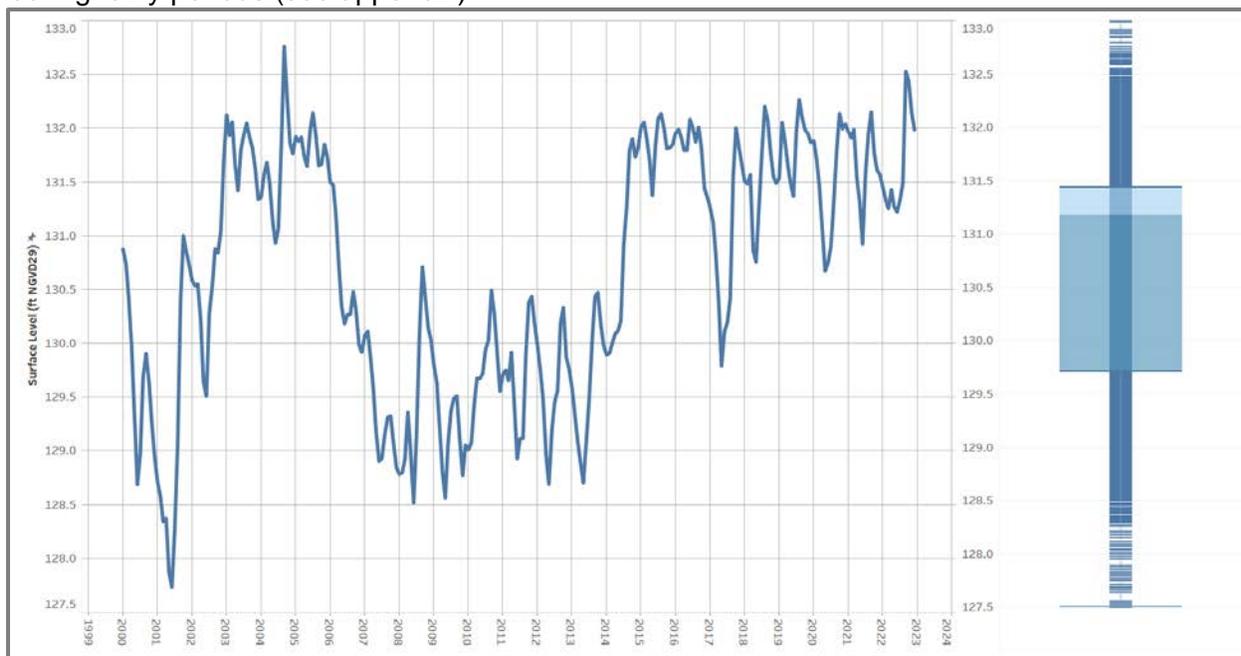
Figure 3-277. Hydrograph of Lake Winterset depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 Chla, TN, or TP during the 2015 – 2022 assessment period, Lake Winterset is considered un-impaired (Figure 3-278). This equates to an impairment criterion score of 3. It should be noted that 2022 Chla and TN concentrations were the lowest; and Secchi depth was the highest value on record.

Parameter	Impaired	Index Score
Chla	N	
TN	N	3
TP	N	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. 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

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

trend statistics can be found in the appendix.
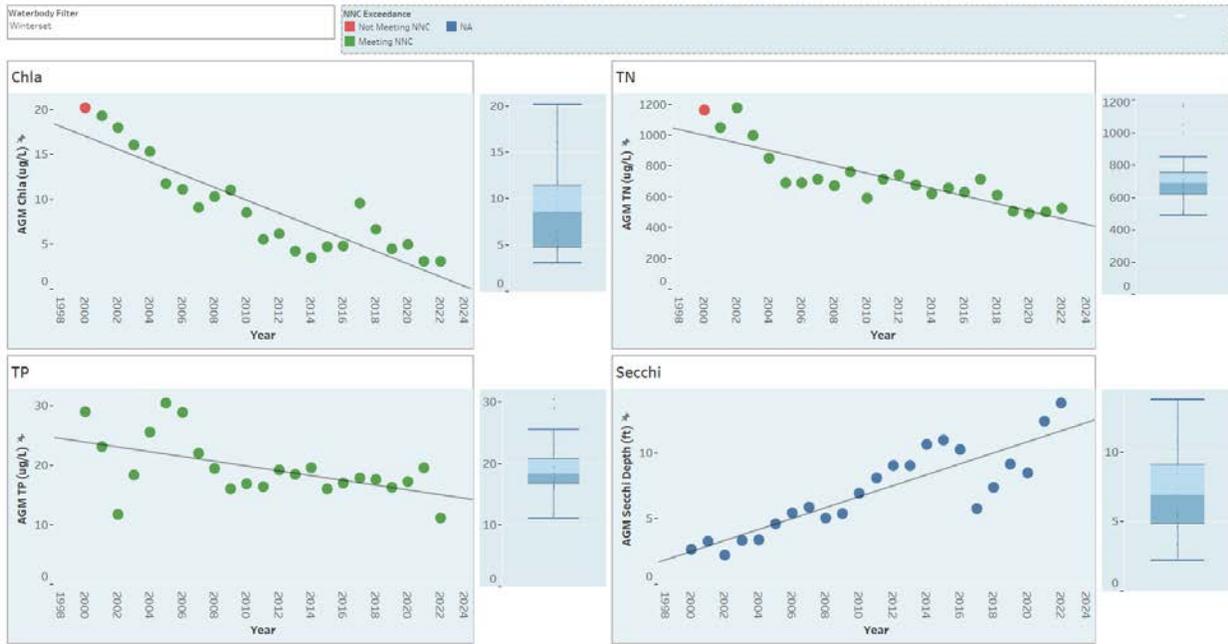
Figure 3-279. Lake Winterset AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Winterset on February 23rd, 2022. The PAC during this survey was 56% and the total BV was 6.6% (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 steadily increased from 28% to its current value. This robust vegetaiton community is likey the result of and contributor of Winterset's excellent water clarity and improving water quality trends.
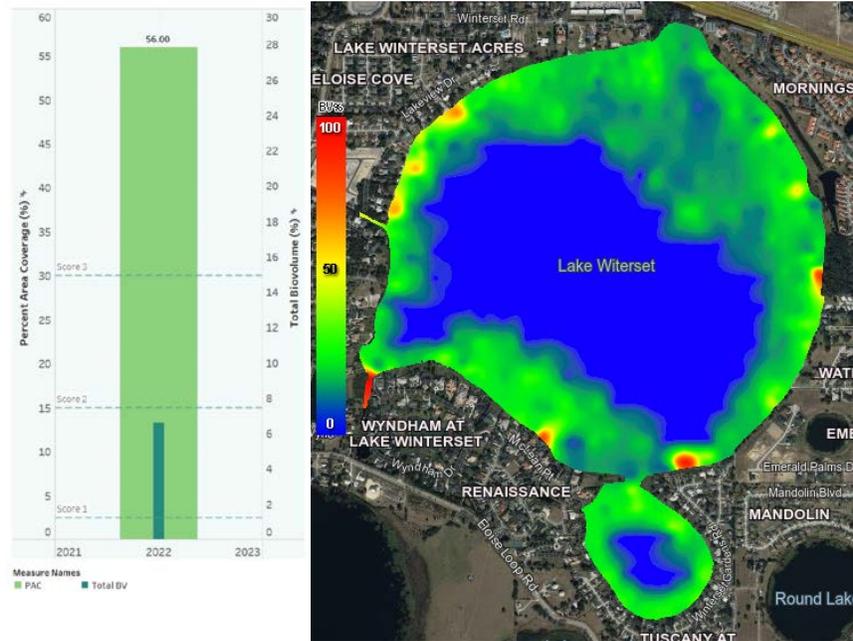
Figure 3-278. Graph depicting 2022 PAC/BV and biovolume heatmap of Lake Winterset; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, Lake Winterset is dominated by submerged

species. Eel grass, hydrilla, and southern naiad made up close to 50% of the vegetation community (Figure 3-280). While this robust SAV community is good for water quality, invasives like hydrilla and burhead sedge constituted 17% of it. This equates to an invasive percentage score of 0. Similar to the vegetation abundance trend, invasive percentage has exhibited a gradual increase from 3% in 2018 to the current percentage. It is likely that some of the increase in coverage was due to hydrilla expansion.
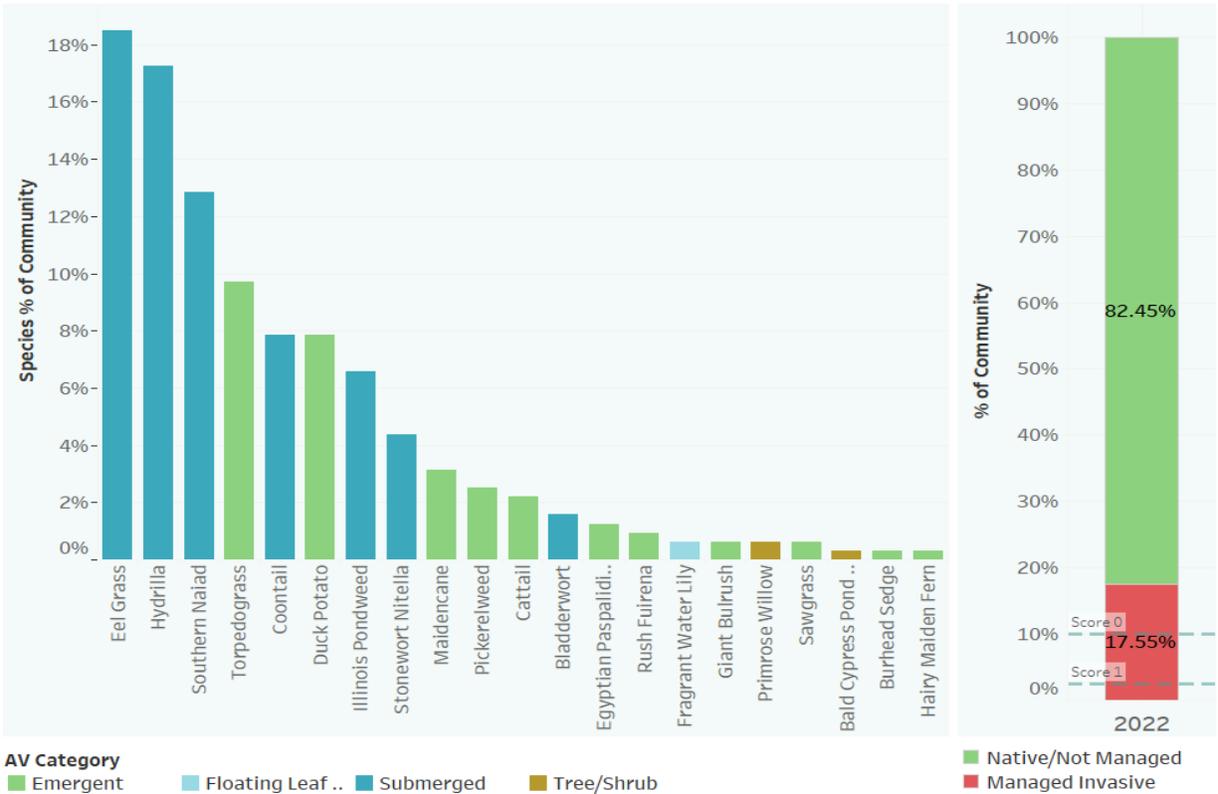
Figure 3-280. Chart depicting species frequency and invasive species presence of Lake Winterset during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity. According to the 2022 species data, only Winterset's overall diversity index met or exceeded its median value—resulting in a diversity criterion score of 1. The richness and evenness indices fell just short of their median values. This was due to the absence of a single low-frequency species as well as a less even distribution of hydrilla, naiad, and coontail from the previous year. However, Lake Winterset does boast a high diversity of aquatic vegetation compared with other lakes in the area.
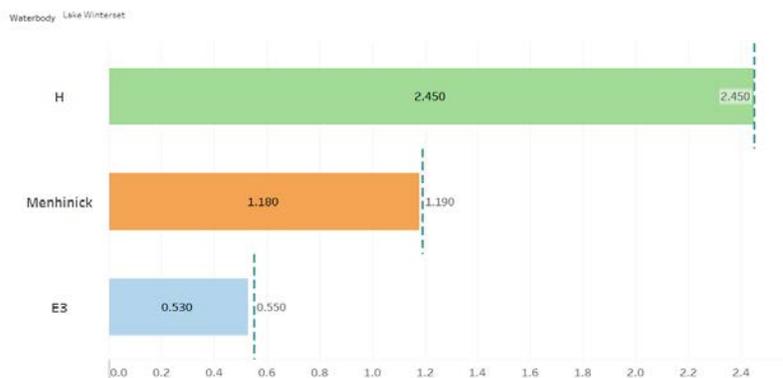
Figure 3-281. Chart depicting 2022 diversity indices for Lake Winterset. Dashed lines represent median values.

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 Score
0	1	1	2	1	2	3	3	1.6

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 1016 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 1472 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.

Figure 3-284. Hypsograph of Little Lake Hamilton depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.
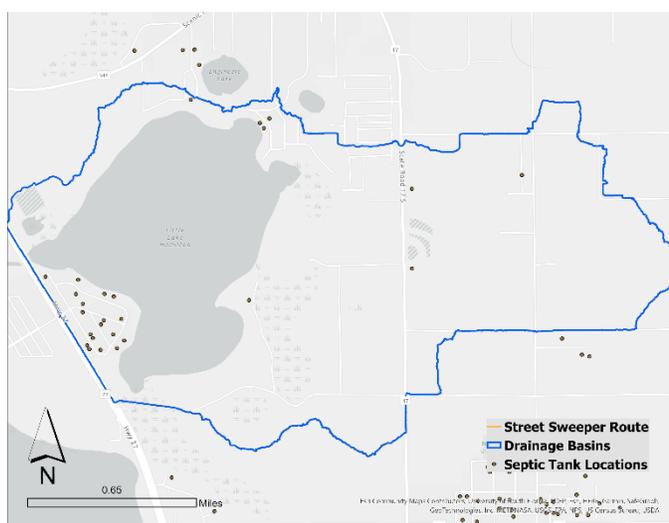
Figure 3-283. Map of Little Lake Hamilton's drainage basin and nearby septic systems.

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 2022, its surface level reached a wet season peak of 121.8 feet in October and a dry season low of 120.25 feet in March. The Hamilton Chain ended the year well above the normal range, at 121.5 feet. According to linear regression analysis, changes in Little Hamilton's surface level are strongly correlated with Chla, TN, TP, and water clarity (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.
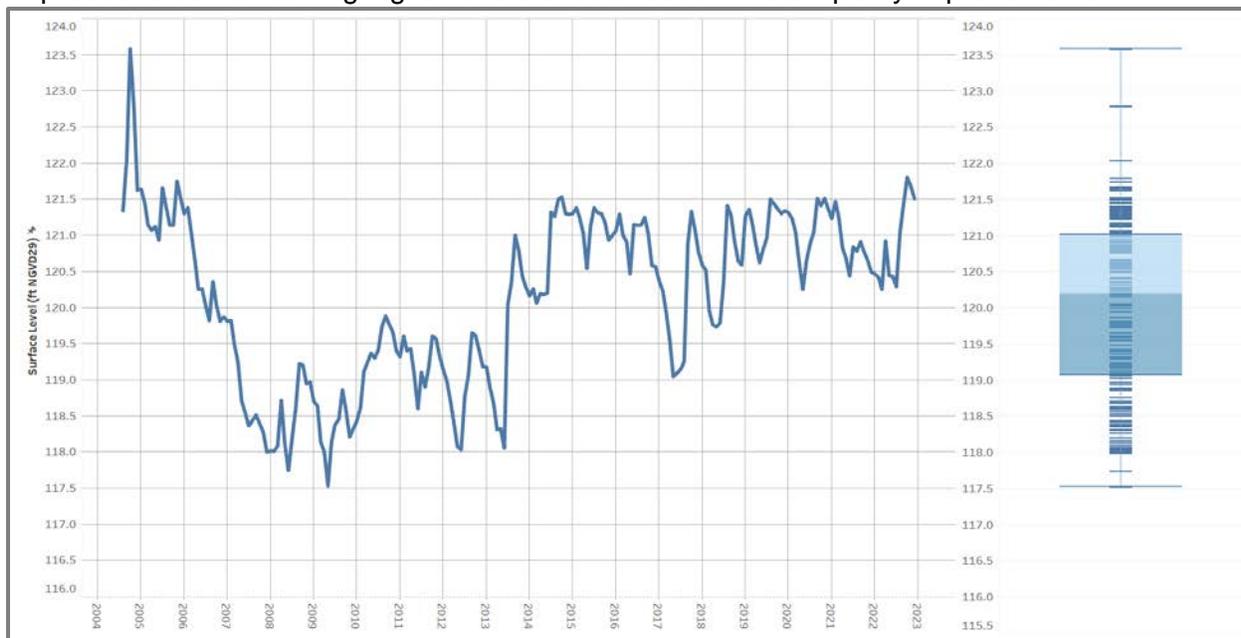
Figure 3-285. Hydrograph of Little Lake Hamilton depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 Chla, TN, and TP based on exceedances in 2022, 2020, and 2018 (Figure 3-286). This equates to an impairement 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	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. During this period, Chla, TN, and Secchi depth exhibited non-significant deteriorating trends— equating to trend criteria scores of 1. TP exhibited a non-signficant improving

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

trend—for a trend criterion score of 2. Individual AGM values and trend statistics can be found in the appendix.
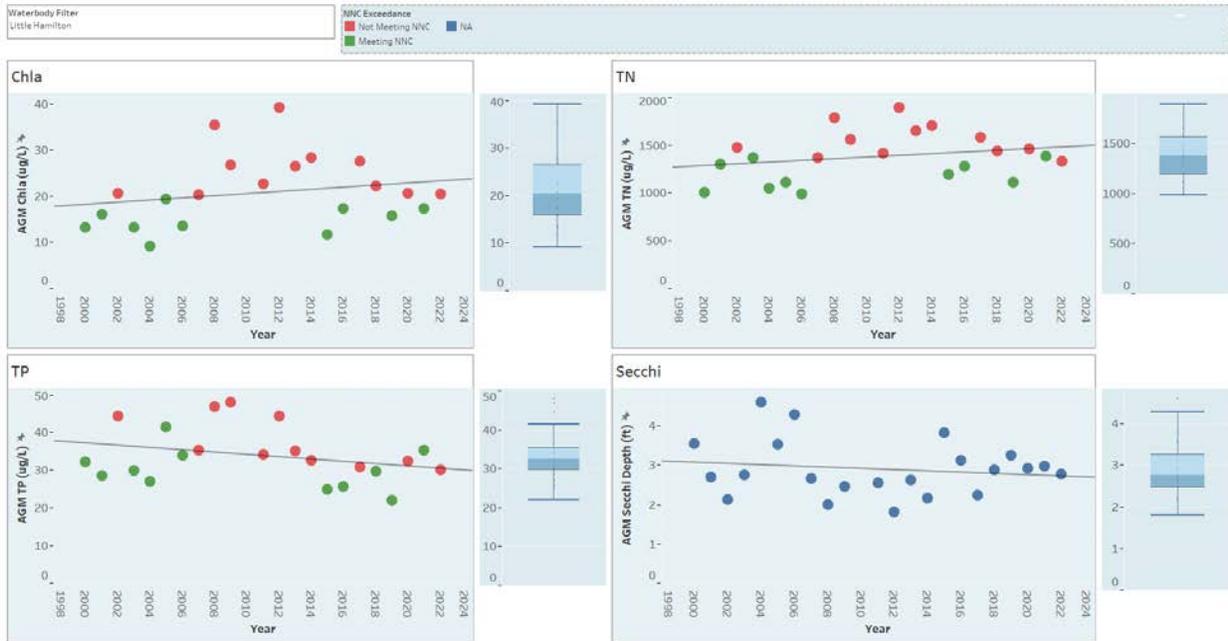
Figure 3-286. Little Lake Hamilton AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Little Lake Hamilton on June 24th, 2022. The PAC during this survey was 21.3% and the total BV was 1.2% (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%. The PAC during 2022 was the highest on record—indicating an expansion of the vegetation community.
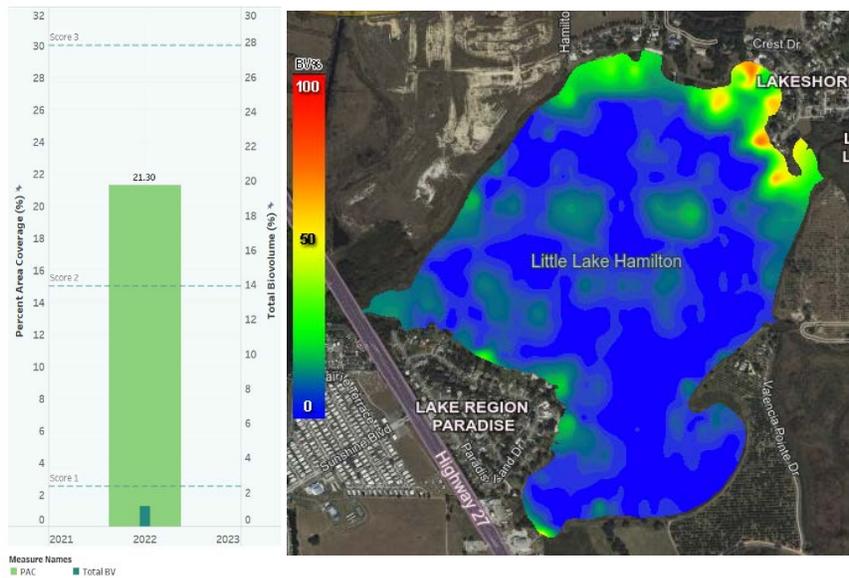
Figure 3-287. Graph depicting 2022 PAC/BV and biovolume heatmap of Little Lake Hamilton; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on the 2022 survey data, Little Lake Hamilton is dominated by floating

leaf plants. The native banana lily, spatterdock, and fragrant water lily made up over 38% of the community (Figure 3-288). Fortunately, there were no managed invasive species detected during the 2022 survey. 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.
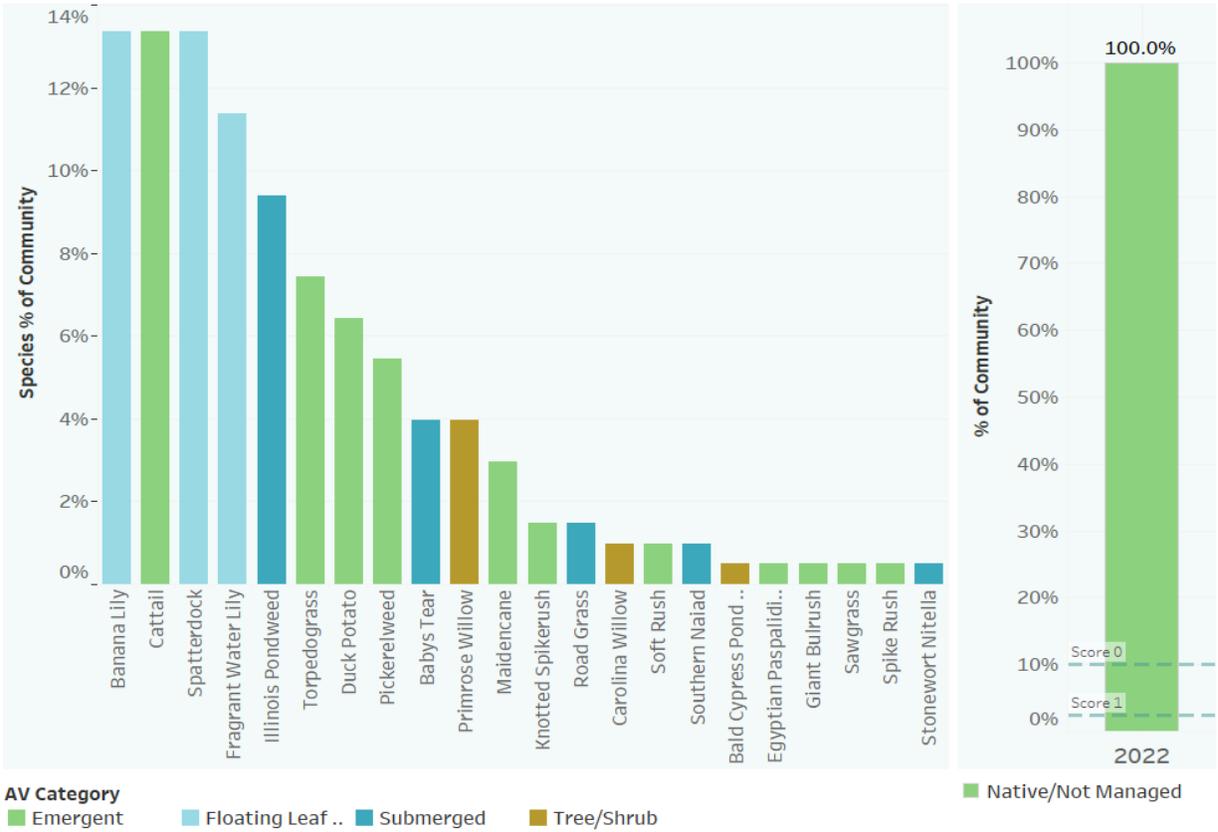
Figure 3-288. Chart depicting species frequency and invasive species percentage of Little Lake Hamilton during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2022 species data, all three of Little Hamilton's diversity indices met or exceeded their respective median values (Figure 3-289). This equates to a diversity criterion score of 3. Even with the elimination of invasive species, there were slightly more unique species indified in 2022 than in previous years. Additionally, the distribution of the top 4 most frequent species was much more even.
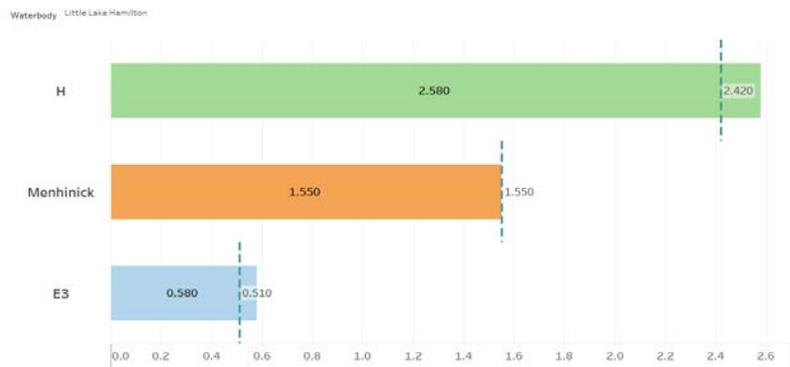
Figure 3-289. Chart depicting 2022 diversity indices for Little Lake Hamilton. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Little Lake Hamilton's health index scores from 2018 to 2022 shows slight improvement—with values ranging from 1.3 to 1.6 (Figure 3-290). During this five year span, 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 has exhibited the most improvement; with consistently high scores the last three years despite the lower scores in 2018 and 2019. 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

Figure 3-290. Chart depicting a comparison of Little Lake Hamilton's Lake Health Index scores from 2018 to 2022.

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 capactity 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. The 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 2022, 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 Score
0	1	2	3	3	2	1	3	1.9

Location, Characteristics, & Hydrology:

Middle Lake Hamilton is located to the 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).

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 11621 lbs of TN and 1072 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.

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

Figure 3-291. Hypsograph of Middle Lake Hamilton depicting cumulative area at regular depth intervals. Demonstrates the slope and morphology of the lake bed.
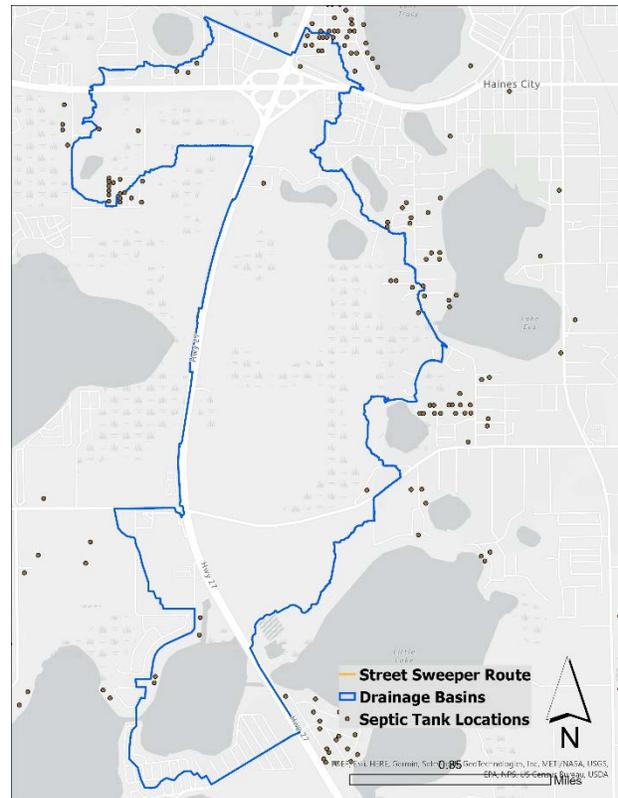
Figure 3-292. Map of Middle Lake Hamilton's drainage basin and nearby septic systems.

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 2022, its surface level reached a wet season peak of 121.8 feet in October and a dry season low of 120.25 feet in March. The Hamilton Chain ended the year well above the normal range, at 121.5 feet. According to linear regression analysis, changes in Middle Hamilton's surface level are strongly correlated with Chla, TN, TP, and water clarity (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.
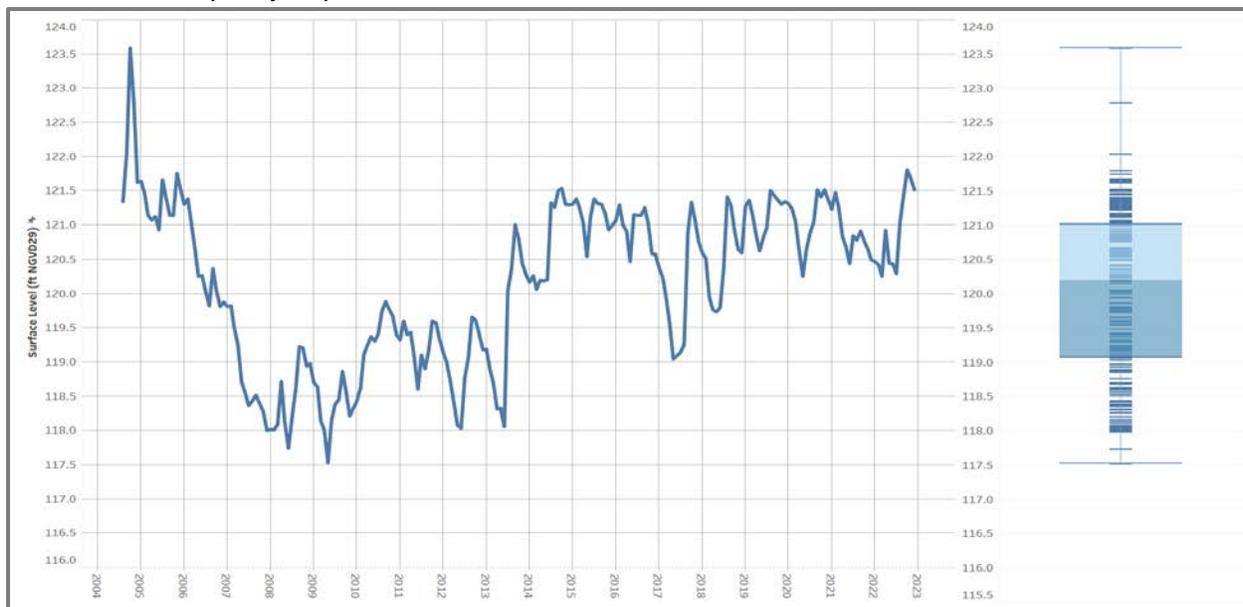
Figure 3-293. Hydrograph of Middle Lake Hamilton depicting monthly surface level readings from 2000 to 2022. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining 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 2015 – 2022 assessment period, Middle Hamilton is considered impaired for Chla, TN, and TP (Figure 3-294). Like with Lakes Hamilton and Little Hamilton, the FDEP has adoped a Polk County-developed pollutant reduction plan in lieu of a total maximum daily load.

Parameter	Impaired	Index Score
Chla	Y	
TN	Y	0
TP	Y	

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. 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 Chla exhibited a non-

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

significant deteriorating trend; for a trend criterion score of 1. Individual AGM values and trend statistics can be found in the appendix.
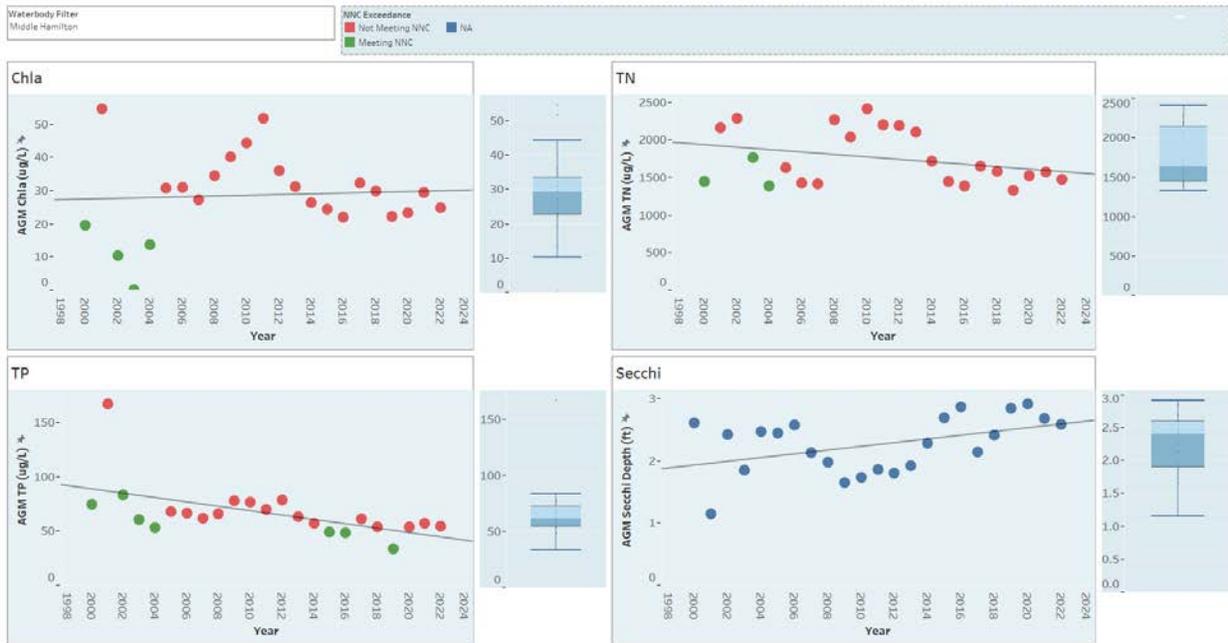
Figure 3-294. Middle Lake Hamilton AGM Chla, TN, TP, and Secchi depth values from 2000 to 2022. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Middle Lake Hamilton on June 12th, 2022. The PAC during this survey was 21.8% and the total BV was 5.4% (Figure 3-295). A PAC between 15% and 30% equates to an abundance criterion score of 2. Middle Hamilton's vegetation abundance has previousy been low. Values have ranged from 8.6% in 2021 to the current highest value in 2022. This record high is indicative of an expanding vegetatation community.
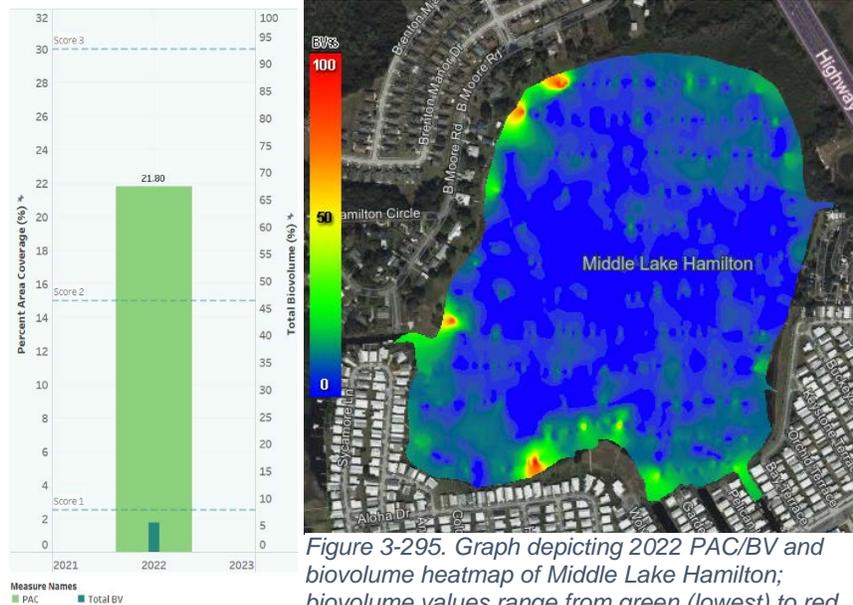
Figure 3-295. Graph depicting 2022 PAC/BV and biovolume heatmap of Middle Lake Hamilton; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Species composition is collected as part of the annual vegetation surveys using point-intercept sampling methods. Based on data from the 2022 survey, Middle Hamilton is dominated by

floating-leaf vegetation. Spatterdock and banana lily made up over 30% of the community (Figure 3-296). The remaining plants are a mix of mostly emergent and submerged species. Invasive species like hydrilla, water hyacinth, and burhead sedge made up 6.3% of the community. This equates to an invasive criterion score of 1. This invasive presence is consistent with previous years' data and indicates that more management action may be required to keep these invasives under control.
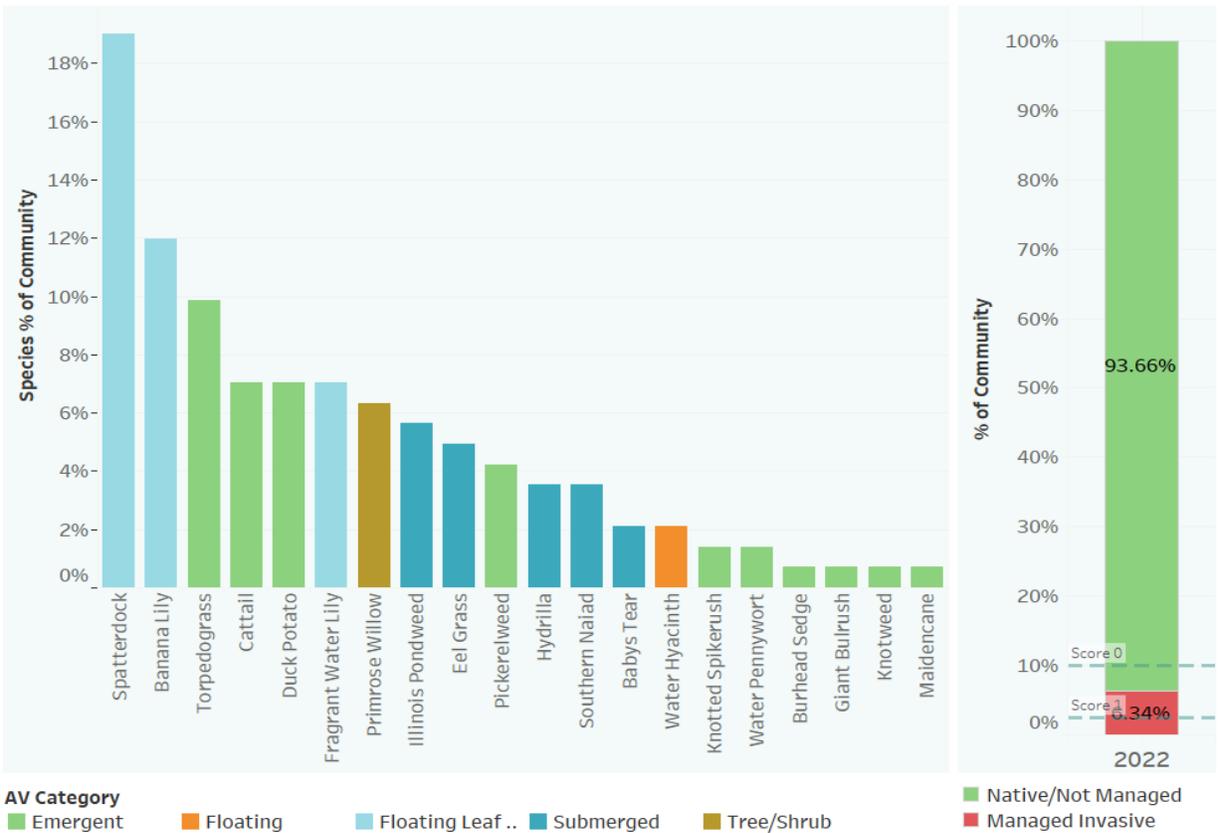
Figure 3-296. Chart depicting species frequency and invasive species percentage of Middle Lake Hamilton during 2022.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to 2022 species data, all three of Middle Hamilton's diversity indices exceeded their respective median values (Figure 3-297). This equates to diversity criterion score of 3. This result is easily explained as 2022 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.
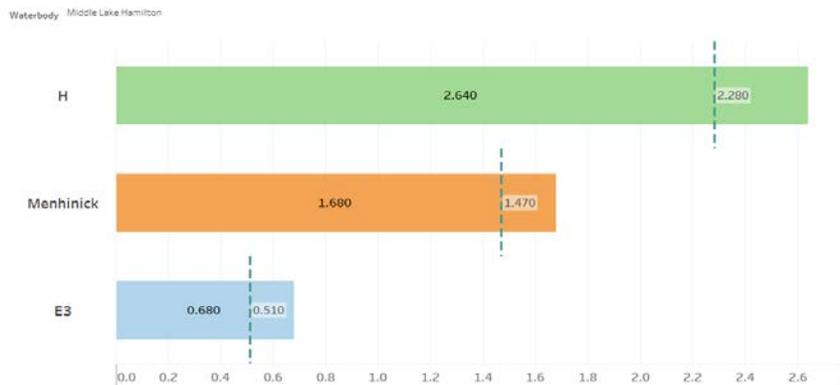
Figure 3-297. Chart depicting 2022 diversity indices for Middle Lake Hamilton. Dashed lines represent median values.

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 2022 (Figure 3-298). While impairment has not changed in this five 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 Chla 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

Figure 3-298. Chart depicting a comparison of Middle Lake Hamilton's Lake Health Index scores from 2018 to 2022.

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. The 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 2022 Lake Health Index scores (Table 3-1).

Lake Health Index								
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health Score
Lake Elbert	3	0	0	0	0	3	0	2	1.0
Lake Hartridge	1	0	0	1	0	3	2	2	1.1
Lake Idyl	0	1	1	0	1	3	1	2	1.1
Lake Mariana	0	0	0	3	0	2	3	1	1.1
Lake Hamilton	0	0	0	3	0	1	3	3	1.3
Lake Martha	3	0	1	0	0	1	3	2	1.3
Lake Pansy	3	0	1	1	2	2	1	0	1.3
Lake Jessie	0	1	1	2	2	3	1	1	1.4
Lake Ned	3	0	1	0	0	2	2	3	1.4
Lake Haines	1	2	3	1	3	1	1	1	1.6
Lake Silver	3	2	2	2	1	0	3	0	1.6
Little Lake Hamilton	0	1	1	2	1	2	3	3	1.6
Lake Conine	0	3	2	2	3	2	1	1	1.8
Lake Eloise	0	2	2	2	3	2	2	1	1.8
Lake Smart	0	2	2	2	3	3	1	2	1.9
Middle Lake Hamilton	0	1	2	3	3	2	1	3	1.9
Lake Link	3	2	3	2	2	2	1	1	2.0
Lake Mariam	3	1	2	1	2	3	2	2	2.0
Lake Otis	3	2	2	1	2	2	2	2	2.0
Lake Deer	3	2	3	2	3	3	0	1	2.1
Lake Fannie	3	2	2	2	3	2	0	3	2.1
Lake Idylwild	2	2	2	2	3	3	1	2	2.1
Lake May	0	3	3	3	3	3	0	2	2.1
Lake Blue	0	2	2	3	2	3	3	3	2.3
Lake Buckeye	3	3	3	3	3	3	1	0	2.4
Lake Cannon	2	2	2	2	3	3	2	3	2.4
Lake Howard	1	3	3	2	3	2	3	2	2.4
Lake Lulu	0	3	3	3	3	3	1	3	2.4
Lake Shipp	0	3	3	3	3	3	2	2	2.4
Lake Winterset	3	3	3	3	3	3	0	1	2.4
Lake Rochelle	3	3	3	3	3	3	0	2	2.5
Lake Spring	3	3	3	3	3	3	1	2	2.6
Lake Summit	3	3	3	2	3	3	1	3	2.6
Lake Daisy	3	3	3	3	3	3	2	2	2.8
Lake Maude	3	3	3	2	3	3	2	3	2.8
Lake Mirror	3	3	3	3	3	3	1	3	2.8
Lake Roy	3	3	3	2	3	3	2	3	2.8

Table 3-1. 2022 Lake Health Index scores ranking the Winter Haven study area lakes from highest to lowest

Among the highest ranked waterbodies are similar qualities—exhibiting multiple 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 2022 Lake Health Index, the top five highest priority waterbodies are Lake Elbert (p. 108), Lake Hartridge (p. 133), Lake Idyl (p. 144), Lake Mariana (p. 174), and Lake Hamilton (p. 128), 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:

- Implementation of additional green infrastructure around Lakes Elbert and Idyl. Some parts of these drainage basins still discharge stormwater runoff directly to the lakes. Redevelopment of these areas does require the addition of conventional stormwater BMPs. However, relying on the private sector to remedy the lack of treatment in these areas is slow and ineffective. The City has multiple opportunities to retrofit green stormwater infrastructure in these areas as part of street improvement projects. The most recent are the trail construction project planned along Lake Elbert's north shoreline a proposed retrofit of the basin north of Lake Idyl.

- Studying the impacts of septic on the water quality of Lakes Hartridge, Mariana, and Hamilton. While it is unclear how much impact OSTDs have on waterbodies in their vicinity, there are ways to verify and quantify these pollutant loads. A groundwater seepage study is a process that examines the flow of groundwater into a lake or stream; evaluating the presence of septic compounds and the concentration of pollutants present in this flow. The City and Polk County have opportunities to conduct seepage studies in waterbodies suspected to have higher OSTD influence. This information can then be used to leverage State and Federal funding for septic-to-sewer conversion programs.

Comparing the Lake Health Index scores through time provides insights into how successful these management strategies have been. Taking the mean of Lake Health criteria values from 2018 to 2022 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**

Table 3-2. Mean Lake Health Index scores for all Winter Haven area lakes from 2018 to 2022.

- 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 poorer total phosphorus trends. This indicates a need to focus on TP reduction strategies for these waterbodies.

- Vegetation abundance and invasive presence scores have reached an all-time high in 2022. 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.

- Lastly, aquatic plant diversity is at the second highest it has been over the last five years. Diversity increases with invasive species decreases indicate an improvement in overall biological health.

While these scores show general improvement, there are many individual waterbodies that 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

4.1 References

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4.2 Data Sources:

Water Quality Data

Collected from: https://polk.wateratlas.usf.edu/datadownload/; Surface Water Quality

Parameters:

- Akalinity, 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 Automtated 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 2001 – 2022 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
Lake Blue	92.1	59.2	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
Lake Buckeye	13.6	17.6	18.3	14.3	24.2	12.1	13.6	10.6	10.2	7.4	6.0	4.9	7.1	7.1	5.3	5.4	4.9	6.5	9.5	3.4	3.6	9.3
Lake Cannon	24.0	31.9	24.2	30.6	27.8	18.5	22.9	23.7	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	
Lake Conine	28.8	35.8	26.2	32.0	39.6	36.8	45.9	34.0	36.1	44.1	34.5	30.1	23.3	22.7	19.0	19.0	22.3	17.5	17.6	24.0	15.1	
Lake Daisy	5.7	8.2	6.7	3.6	4.8	9.0	8.5	5.7	5.7	4.8	3.7	4.9	4.8	3.8	4.5	4.5	3.9	3.0	3.0	3.0		
Lake Deer	25.8	11.3	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
Lake Elbert	1.6	1.4	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
Lake Eloise	32.9	28.1	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
Lake Fannie	10.6	11.9	13.0	21.3	13.4	14.7	16.9	22.6	22.0	25.6	19.1	17.1	13.7	10.5	11.3	11.5	12.0	11.6	13.6	12.4		
Lake Haines	18.6	34.3	26.1	31.7	34.9	44.8	28.3	29.8	25.8	22.8	35.2	28.7	18.7	16.8	26.0	23.8	34.4	23.7	23.1	23.0	18.5	
Lake Hamilton	0.0	3.9	1.5	2.0	13.6	7.7	6.8	16.0	28.9	26.5	29.0	29.2	22.5	21.3	24.9	45.8	40.5	32.8	34.7	37.1	48.2	
Lake Hartridge	10.6	10.6	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
Lake Howard	37.3	25.1	28.8	42.9	31.0	37.4	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	
Lake Idyl	41.0	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	38.9	17.4			
Lake Idylwild	30.2	17.3	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
Lake Jessie	23.1	15.6	25.0	26.4	28.1	27.8	24.0	25.4	30.9	31.9	25.0	24.0	26.8	18.3	15.4	33.0	24.3	23.0	25.2	23.3	27.0	
Lake Link	29.6	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
Lake Lulu	32.0	26.6	28.0	39.0	38.6	35.0	34.8	30.9	29.6	25.2	23.1	17.2	21.2	25.4	25.7	30.2	22.3	20.8	21.3	19.8		
Lake Mariam	5.8	12.6	4.2	3.8	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	
Lake Mariana	35.7	15.1	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	38.2	31.5	35.1	26.3	35.6	35.6	
Lake Martha	1.9	5.0	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
Lake Maude	14.5	10.6	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
Lake May	32.4	35.1	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
Lake Mirror	36.9	37.2	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
Lake Ned	1.8	2.3	10.7	4.8	8.0	5.4	4.9	6.2	7.9	3.6	10.7	13.9	13.9	13.2	15.2	14.3	14.8	13.7	13.5	10.8	11.9	
Lake Otis	55.0	11.2	10.4							21.9	18.3	23.2	20.4	16.3	17.3	18.3	13.5	18.3	17.7	15.1	19.3	13.3
Lake Pansy	4.8	11.6	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	13.0	13.7	17.7	15.1	12.7	13.1
Lake Rochelle	26.7	31.3	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
Lake Roy	32.2	17.0	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
Lake Shipp	65.3	42.7	42.5	43.6	46.9	71.7	83.2	30.0	47.5	38.8	36.4	32.5	22.7	27.2	26.6	29.6	28.9	27.4	21.5	27.7	30.9	
Lake Silver	12.8	13.6	26.4		9.8	12.9	7.1	7.6	14.0	10.2	10.4	9.4	8.1	13.6	12.9	22.2	8.7	10.4	10.5	4.3	7.2	
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		
Lake Spring	24.8	16.8	33.1	17.2	22.1	21.6	19.7	22.9	12.6	9.2	9.7	8.0	5.7	5.5	6.3	7.4	11.4	14.8	9.1	9.9	9.2	13.1
Lake Summit	14.9	16.7	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	5.0
Lake Winterset	19.2	18.0	16.0	15.2	11.7	11.1	9.1	10.3	11.0	8.5	5.5	6.2	4.2	3.5	5.0	4.8	4.8	9.5	6.6	4.9	4.5	3.0
Little Lake Hamilton	16.0	20.6	13.2	9.1	19.4	13.6	20.4	35.4	26.8	22.6	39.2	26.4	28.3	26.3	11.6	17.3	27.5	22.2	15.8	20.6	17.3	20.5
Middle Lake Hamilton	54.5	10.3	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

Table 4-2. Annual geometric mean total nitrogen concentrations from 2001 – 2022 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
Lake Blue	3548.9	2521.3	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
Lake Buckeye	805.0	1045.4	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
Lake Cannon	1248.9	1535.7	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
Lake Conine	1214.9	1388.9	1251.1	1289.9	1460.6	1278.6	1378.7	1464.4	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	
Lake Daisy	407.4	709.7	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
Lake Deer	1912.9	1172.8	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
Lake Elbert	273.3	391.3	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
Lake Eloise	1615.6	1416.1	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
Lake Fannie	851.7	1239.8	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
Lake Haines	1328.7	1518.4	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
Lake Hamilton	933.4	997.5	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
Lake Hartridge	812.9	801.5	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
Lake Howard	1882.3	1364.6	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
Lake Idyl	1400.0		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
Lake Idylwild	1256.7	949.0	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
Lake Jessie	1302.7	909.3	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
Lake Link	1770.0	660.0	920.0						764.9	1036.5	1043.3	816.5	855.2	829.0	688.3	734.2	862.4	701.6	1060.7	769.6		
Lake Lulu	1177.0	1404.8	1308.6	1087.4	1226.5	1373.9	1587.7	1643.1	1495.6	1482.5	1327.1	1164.7	1037.9	1084.1	1219.6	1204.9	1047.5	1132.2	1228.9	1051.3		
Lake Mariam	913.9	1429.1	927.7	976.3	947.5	1036.9	1147.3	1070.5	1042.3	897.1	915.7	878.2	836.4	867.3	891.0	996.5	1078.0	1092.6	939.9	893.2	945.7	1012.2
Lake Mariana	1256.4	1016.1	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
Lake Martha	495.8	644.6	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
Lake Maude	996.3	876.1	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	488.4	512.1	760.5	
Lake May	1787.7	1616.6	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
Lake Mirror	1500.0	1748.6	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
Lake Ned	794.3	712.2	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
Lake Otis	1980.0		690.0	600.0					970.0	1095.3	985.8	921.0	788.0	819.8	681.1	673.0	769.7	634.2	753.1	953.5	750.9	
Lake Pansy	659.9	865.1	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	726.1	753.4	703.4	761.4	739.2
Lake Rochelle	1251.8	1289.0	1434.1	1274.2	1322.9	1084.7	1228.4	1249.6	1603.5	1346.9	1208.9	1306.6	1319.5	1426.7	1134.0	946.5	942.1	934.6	792.8	914.3	1114.2	916.4
Lake Roy	1441.9	1168.8	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
Lake Shipp	2728.9	1970.7	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
Lake Silver	640.0	1090.0	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
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
Lake Spring	1130.0	1230.2	1811.1	793.6	809.7	1052.9	867.8	741.2		707.8	613.3	665.3	580.0		680.5	721.0	593.7	666.1	712.8	643.3	615.5	611.5
Lake Summit	1149.8	1038.8	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
Lake Winterset	1049.0	1174.3	995.6	851.0	688.9	686.6	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
Little Lake Hamilton	1297.6	1476.6	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	
Middle Lake Hamilton	2160.0	2284.1	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

Table 4-3. Annual geometric mean total phosphorus concentrations from 2001 – 2022 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
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
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
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
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
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
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
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
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
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
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
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
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	29.4	28.6	29.8	26.3	23.5	23.0	27.4	30.1	18.1
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	22.6	29.9	29.4	28.1
Lake Idyl	62.0	20.0	31.0	34.7	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
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
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
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
Lake Mariam	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
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
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
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
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
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
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
Lake Otis	35.0	21.0	27.0								33.0	30.5	34.8	28.5	27.8	25.6	26.3	25.4	23.3	30.6	41.2	26.7
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
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
Lake Roy	31.5	11.2	26.9	28.9	37.5	28.0	25.8	20.4	26.2	20.4	23.3	26.3	28.6	22.2	29.6	22.6	19.7	23.2	19.9	25.0	33.7	13.7
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	26.3	30.7	27.5	33.7	39.0	31.6	32.2	41.2	39.2	34.0
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
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
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
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
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
Little Lake Hamilton	28.5	44.4	29.9	27.0	41.4	33.9	35.2	46.9	48.0	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
Middle Lake Hamilton	167.0	83.5	60.5	53.0	67.4	66.5	61.4	66.0	78.0	76.6												

Table 4-4. Annual geometric mean Secchi depth from 2001 – 2022 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
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
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
Lake Cannon	2.08	1.56	1.67	2.46	2.64	3.49	3.07	2.70	2.29	2.60	2.51	2.65	2.13	2.23	3.89	3.14	3.45	3.14	2.36	3.24	3.00	2.22
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
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
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
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
Lake Eloise	1.86	1.84	1.90	2.36	2.16	2.31	2.21	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	
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
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
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
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
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	1.95	1.92	2.25	1.93	2.47	2.66	2.39	2.13	2.09	1.82
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
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
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
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	
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
Lake Mariam	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	1.67	1.67	2.24
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
Lake Martha	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
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
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
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
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
Lake Otis	1.97		4.92	5.25					3.94	3.38	2.62	3.03	3.95	4.00	4.00	5.17	4.41	3.85	4.28	3.69	3.30	4.37
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
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
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
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
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
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	
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
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	6.02	5.93	8.02
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
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
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

Linear Regression Statistics

Table 4-5. Trendline statistics for linear regressions of chl-a, TN, TP, and Secchi depth from 2000 - 2022. 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	-	0.0959	0.150	+	0.0067	0.711	-	0.0110	0.634	-	0.3855	0.002
Lake Buckeye	-	0.5524	0.000	+	0.6971	0.000	-	0.6126	0.000	-	0.3405	0.004
Lake Cannon	-	0.0482	0.314	+	0.2060	0.030	-	0.1671	0.053	-	0.0109	0.636
Lake Conine	-	0.3639	0.002	+	0.5767	0.000	-	0.2281	0.021	-	0.0318	0.415
Lake Daisy	-	0.4181	0.001	+	0.2704	0.011	-	0.2209	0.024	-	0.1751	0.047
Lake Deer	-	0.1352	0.084	+	0.1768	0.046	-	0.2699	0.011	-	0.1449	0.073
Lake Elbert	+	0.5579	0.000	-	0.4000	0.001	+	0.4735	0.000	+	0.1858	0.040
Lake Eloise	-	0.1243	0.099	+	0.4047	0.001	-	0.1527	0.065	-	0.1609	0.058
Lake Fannie	-	0.0457	0.327	+	0.2772	0.010	-	0.0646	0.242	-	0.0624	0.250
Lake Haines	-	0.1597	0.059	+	0.6102	0.000	-	0.4519	0.000	+	0.0340	0.400
Lake Hamilton	+	0.8439	0.000	-	0.4823	0.000	+	0.8132	0.000	-	0.4358	0.001
Lake Hartridge	+	0.6131	0.000	-	0.6772	0.000	+	0.5642	0.000	+	0.0000	0.992
Lake Howard	-	0.2533	0.014	+	0.3542	0.003	-	0.4381	0.001	-	0.0557	0.278
Lake Idyl	+	0.1107	0.141	-	0.0506	0.327	+	0.1734	0.060	+	0.3026	0.010
Lake Idylwild	-	0.1033	0.135	+	0.3178	0.005	-	0.0059	0.728	-	0.1063	0.129
Lake Jessie	+	0.0007	0.902	+	0.0757	0.204	+	0.0115	0.626	-	0.0561	0.276
Lake Link	-	0.0758	0.285	+	0.0271	0.528	-	0.2951	0.024	-	0.0266	0.532
Lake Lulu	-	0.3831	0.002	+	0.5824	0.000	-	0.2691	0.011	-	0.3011	0.007
Lake Mariam	+	0.1178	0.109	+	0.1387	0.080	-	0.0705	0.221	+	0.0184	0.537
Lake Mariana	+	0.1772	0.045	-	0.3290	0.004	+	0.1877	0.039	-	0.1752	0.047
Lake Martha	+	0.5452	0.000	-	0.4419	0.001	+	0.1208	0.104	+	0.2158	0.026
Lake Maude	-	0.3713	0.002	+	0.4695	0.000	-	0.4737	0.003	-	0.0400	0.360
Lake May	-	0.3362	0.004	+	0.6353	0.000	-	0.5144	0.000	-	0.4184	0.001
Lake Mirror	-	0.6961	0.000	+	0.5319	0.000	-	0.7129	0.000	-	0.2298	0.021
Lake Ned	+	0.5431	0.000	-	0.3831	0.002	-	0.0001	0.966	+	0.3492	0.003
Lake Otis	-	0.0578	0.353	+	0.0000	0.989	-	0.1654	0.105	+	0.0093	0.713
Lake Pansy	+	0.3336	0.005	+	0.0016	0.858	+	0.0220	0.510	+	0.1780	0.051
Lake Rochelle	-	0.4793	0.000	+	0.5066	0.000	-	0.3078	0.006	-	0.1369	0.082
Lake Roy	-	0.3687	0.002	+	0.4341	0.001	-	0.2972	0.007	-	0.1670	0.053
Lake Shipp	-	0.4440	0.001	+	0.7871	0.000	-	0.6103	0.000	-	0.3468	0.003
Lake Silver	-	0.0655	0.250	-	0.0065	0.721	-	0.1035	0.144	-	0.0149	0.588
Lake Smart	-	0.0343	0.462	+	0.1857	0.074	-	0.0396	0.429	-	0.0187	0.588
Lake Spring	-	0.3524	0.003	+	0.4110	0.001	-	0.4301	0.001	-	0.2578	0.013
Lake Summit	-	0.6157	0.000	+	0.6926	0.000	-	0.3482	0.003	-	0.0057	0.732
Lake Winterset	-	0.7983	0.000	+	0.7631	0.000	-	0.7189	0.000	-	0.2936	0.008
Little Lake Hamilton	+	0.0455	0.341	-	0.0237	0.494	+	0.0605	0.270	-	0.0879	0.180
Middle Lake Hamilton	+	0.0039	0.777	+	0.1986	0.033	-	0.0956	0.151	-	0.3035	0.006

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 hispidula		
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		
Pickerelweed	Pontederia cordata		
Primrose Willow	Ludwigia spp.		

Table 4-10. Percent area coverage values from 2018 – 2022 for all study area lakes.

Waterbody	2018	2019	2020	2021	2022
Lake Blue	19.5	6.5		17.6	46.9
Lake Buckeye	98	99.7	99.1	98.9	98.8
Lake Cannon	64.8	34.9	33.6	37.1	31.8
Lake Conine	29	38.8	36.5	24.2	25.7
Lake Daisy	3.4	14.3	9	21.7	31.1
Lake Deer	83.6	91	57.6	80.3	71.9
Lake Elbert	59.7	58.9	54.9	48.4	46.4
Lake Eloise	12.2	17.1	36.7	29	17.6
Lake Fannie	26.9	26.2	13.3	21.4	26.6
Lake Haines	24.1	26	34.7	10.4	7.5
Lake Hamilton	7.7	8.8	9.5	9.6	10.2
Lake Hartridge	35.6	39.7	63.1	36.4	37.9
Lake Howard	56.7	29	30	39.2	27.1
Lake Idyl	52.9	3.6	35.2	52.9	53
Lake Idylwild	49.1	52.5	54	66.7	58.9
Lake Jessie	35.7	51.6	36.1	34.7	43.5
Lake Link	53.5		47.7	26.5	24.6
Lake Lulu	37.5	40	38.2	38.9	45.7
Lake Mariam	5.8	20	13.5	45.7	34.9
Lake Mariana	22.4	26.1	27.3	24.5	27.8
Lake Martha	0.7	3.1	4.1	4.3	7.8
Lake Maude	96.2	99.1	99.1	96.3	71.6
Lake May	56	69.7	71	78	63.2
Lake Mirror	42.9	43.6	39.9	41.7	49.3
Lake Ned	7	13.6	4.8	10.1	16
Lake Otis	21.2	23.3	27.7	11.4	19.6
Lake Pansy	20.4	45	24.1	31	15.1
Lake Rochelle	34.3	33.9	34.1	31.5	43.8
Lake Roy	53.5	17	29.9	32.9	34.8
Lake Sears	56	53.8		47.3	50.5
Lake Shipp	49.3	52.3	56.4	50.7	51.8
Lake Silver	1	7.3	2.4	1.7	2.3
Lake Smart	13.1	30.6	16.6	28.9	61.9
Lake Spring	56.7	57.8	60.4	53.9	56.3
Lake Summit	59.5	48.4	61.2	54.8	63
Lake Thomas	77.8	85.8		35	56.7
Lake Winterset	28.1	36.3	37.5	44.7	56
Little Lake Hamilton	18.2	17.4	15.9	14.9	21.3
Middle Lake Hamilton	12.3	19	12.2	8.6	21.8

Table 4-11. Invasive species percentage values from 2018 to 2022 for all study area lakes.

Waterbody	2018	2019	2020	2021	2022
Lake Blue	0	0	0	0	0
Lake Buckeye	14.18	11.32	13.14	6.8	2.98
Lake Cannon	1.89	1.47	3.1	7.04	1.17
Lake Conine	13.29	25.24	16.87	10.84	6.02
Lake Daisy	0	0	0.94	0.65	0.66
Lake Deer	8.13	26.33	15.33	28.39	19.05
Lake Elbert	9.31	11.83	15.48	20.22	38.32
Lake Eloise	1.26	2.3	1.61	1.03	1.13
Lake Fannie	16.41	17.79	11.81	14.37	16.97
Lake Haines	24.07	28.99	25.76	4.29	5.19
Lake Hamilton	1.39	0.74	3.73	3.6	0
Lake Hartridge	0	1.81	0.43	0	0.97
Lake Howard	0.96	0	0	0	0
Lake Idyl	4.35	16.67	13.33	24	6.06
Lake Idylwild	1.76	3.76	3.14	5.94	3.65
Lake Jessie	1.27	6.33	4.65	11.84	2.55
Lake Link	10.71	0	0	5.66	5.45
Lake Lulu	4.07	1.55	0	1.63	3.55
Lake Mariam	30.65	23.6	3.03	0	2
Lake Mariana	1.63	0	0	0.57	0
Lake Martha	0	2.33	0	0	0
Lake Maude	2.86	4.38	2.23	5.69	1.63
Lake May	7.37	11.32	11.32	13.83	18.33
Lake Mirror	0.65	3.36	3.68	1.23	7.14
Lake Ned	5.81	5.48	0	0	1.27
Lake Otis	3.96	11.16	0	1.18	2.29
Lake Pansy	13.16	12.5	16	21.28	6.06
Lake Rochelle	8	22.5	20.11	15.48	14.71
Lake Roy	17.69	4.76	1.08	7.81	1.55
Lake Shipp	3.68	6.25	6.63	1.8	2.33
Lake Silver	0	0	0	0	0
Lake Smart	1.33	12.9	2.25	3.16	3.39
Lake Spring	17.81	18.64	17.65	11.86	5.8
Lake Summit	4.4	3.45	4.21	2.86	4.96
Lake Winterset	3.09	7.93	6.49	13.82	17.55
Little Lake Hamilton	1.27	0	1.86	3.43	0
Middle Lake Hamilton	3.85	3.29	0	2.61	6.34

4.3 List of Figures

4.4 List of Tables