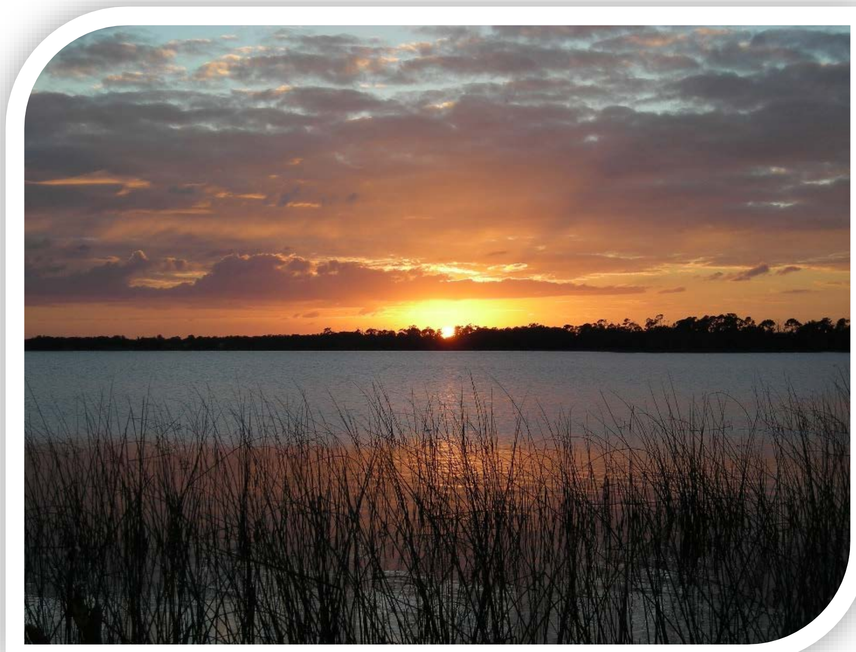
WINTER HAVEN
The Chain of Lakes City

2016

Annual Lakes Report

Presented by the Lakes Advisory Committee



CITY OF WINTER HAVEN
Public Works Department
Natural Resources Division

Executive Summary

The residents of Winter Haven have continually recognized the significant role lakes play in the social, economic, and ecologic fabric of the community. This report is presented by the Lakes Advisory Committee which is comprised of members representing a variety of local interests, serving the community by:

- Receiving input on the state of local lakes.
- Advising on the direction of management strategies.
- Communicating that information with the City Commission.

This report strives to achieve that through three main sections:

1.) An introduction
   - Providing a brief background on the ecological processes that drive the health of local waterbodies and the metrics that are applied to asses them.

2.) A presentation and analysis of the data.
   - Serving as a snapshot in time of the current local trends in lake health.

3.) An overview of major management strategies.
   - Outlining the action taken by the City to improve lake health.

Due to the strong relationships between water quality and hydrology in the area, and the fact that 2016 had some of the highest sustained water levels in recent history, the overall outlook for lakes in the area is very positive. High lake levels have alleviated the ecological stress on local systems, but levels can change rapidly, and it is important to also address the other factors that influence long term lake health. The management strategies outlined in this document provide a clear pathway forward for doing just that.

As a community that identifies so closely with its natural resources, it is important that the City continue to have an advantageous understanding of the function of these systems, the regulations that surround them, and an ability to apply management strategies to secure their health. Many of the lake health challenges we face today, created over generations, will not be overcome with quick fix solutions, but with long term management strategy.

The Natural Resources Division, under the advice of the Lakes Advisory Committee, and in cooperation with various community partners and other City of Winter Haven staff, continuously strive to be good stewards of the community's natural resources. We live in a unique community and I hope you find this report informational and enjoyable. If this peaks your interest, I invite you to reach out to us with any additional questions, thoughts, or comments you may have.

M.J. Carnevale, Natural Resources Manager

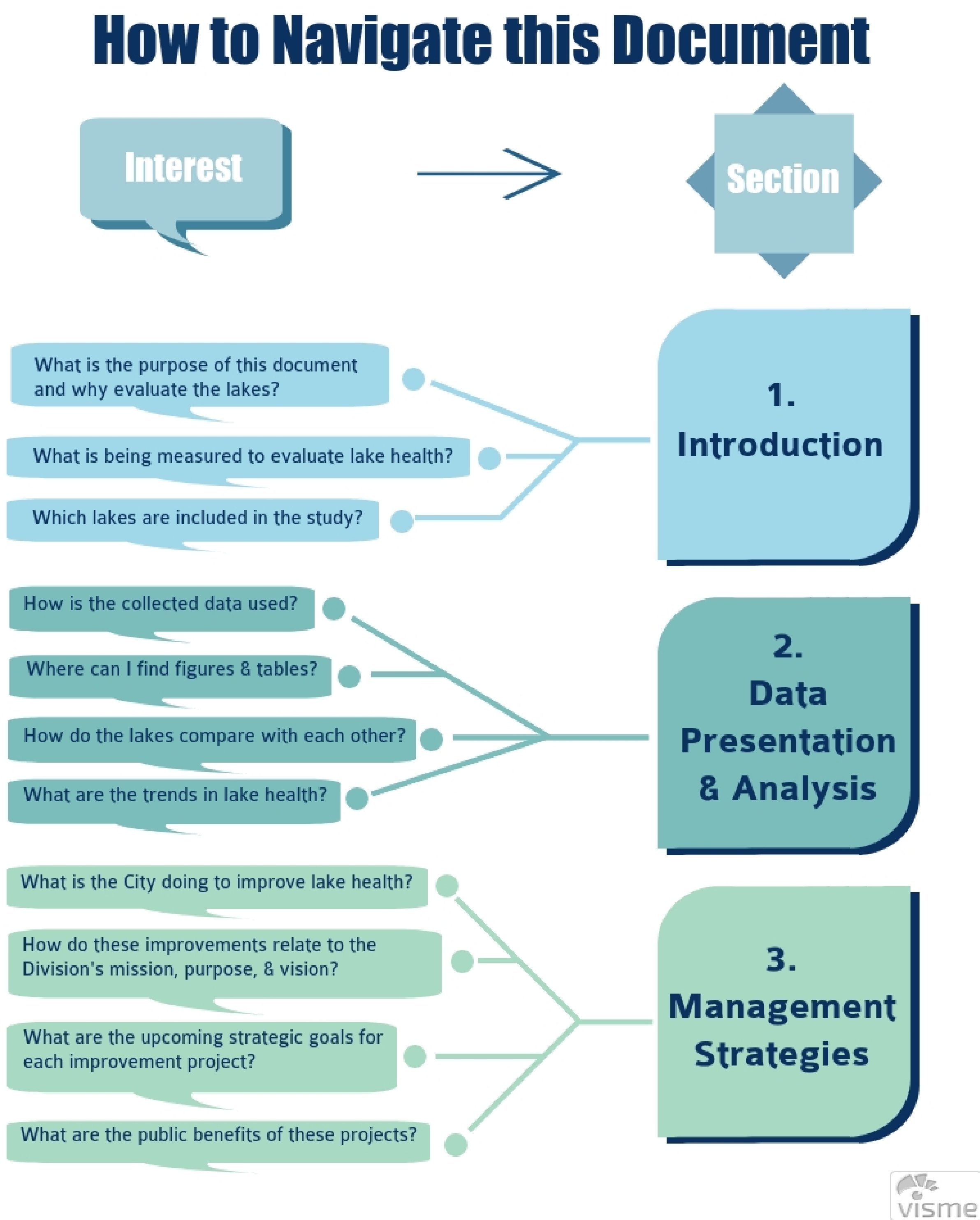


Figure-A How to Navigate the Annual Lakes Report

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1. Introduction

1.1 Purpose

The lakes of the greater Winter Haven area are considered some of its most important assets—ecologically, recreationally, and economically. This report was drafted as part of the City's mission to preserve the wellness of these natural commodities for future use by its citizens. Ultimately, the goal was to incorporate data from various sources and metrics into a comprehensive, annual status report in a format that is technically sound, yet accessible. The selection of lakes studied, while not all-encompassing, are representative of the various lake types found in the Winter Haven Ridge and Polk Uplands geographic regions; including the greater part of the Winter Haven Chain of Lakes as well as several waterbodies independent of the chain. The metrics chosen for this report represent the various facets of limnology (the study of lakes) and help to demonstrate the dynamic nature of lake systems; the interaction between and amongst water chemistry, biology, and hydrology. Finally, this report details the developing management strategies that the City's Natural Resources Division as well as Federal, State and Regional agencies employ to help improve and maintain the health of Winter Haven's lakes.

1.2 Background on the Waterbodies

The 33 lakes included in this study area all possess improved public access and are located within or adjacent to Winter Haven's city limits or share a connection with a lake that is. These lakes were categorized into three groups: the Northern Chain comprised of lakes Conine, Fannie, Haines, Hamilton, Rochelle, and Smart; the Southern Chain comprised of lakes Cannon, Eloise, Hartridge, Howard, Idylwild, Jessie, Lulu, May, Mirror, Roy, Shipp, Spring, Summit, and Winterset; and the Interior lakes comprised of lakes Blue, Buckeye, Deer, Elbert, Idyl, Link, Mariam, Mariana, Martha, Maude, Otis, Pansy, and Silver. Lakes Henry, Little Hamilton, and Middle Hamilton were not included in this study due to a lack of improved public access such as navigable pathways or boat ramps.

Winter Haven's lakes are part of the Peace Creek sub-basin of the Peace River watershed. Figure 1-1 details the lakes in the study area as well as the flow pathways through the watershed. The lakes of the Southern Chain are maintained at a roughly equalized level, but collectively sit at a higher elevation than the Northern Chain. A lock structure, operated and maintained by the Lakes Region Lakes Management District, connects

Lake Hartridge to Lake Conine and regulates flow from the Southern Chain to the Northern Chain. Lakes Conine, Haines, Rochelle, and Smart operate at an equalized level and flow downstream to Lake Fannie, Lake Hamilton, and eventually drain via the Peace Creek Drainage Canal—a major outfall on the south side of Lake Hamilton. The Southern Chain primarily drains to the Northern Chain, but can also flow out of a major outfall on the south side of Lake Lulu via the Wahneta Farms Drainage Canal when surface level rises to minimum flood level (132 ft NGVD). Several of the Interior Lakes share connections with Winter Haven's Chain of Lakes via drainage ditches or pipes. However, these flow-ways typically only convey water during periods of higher than average surface level.

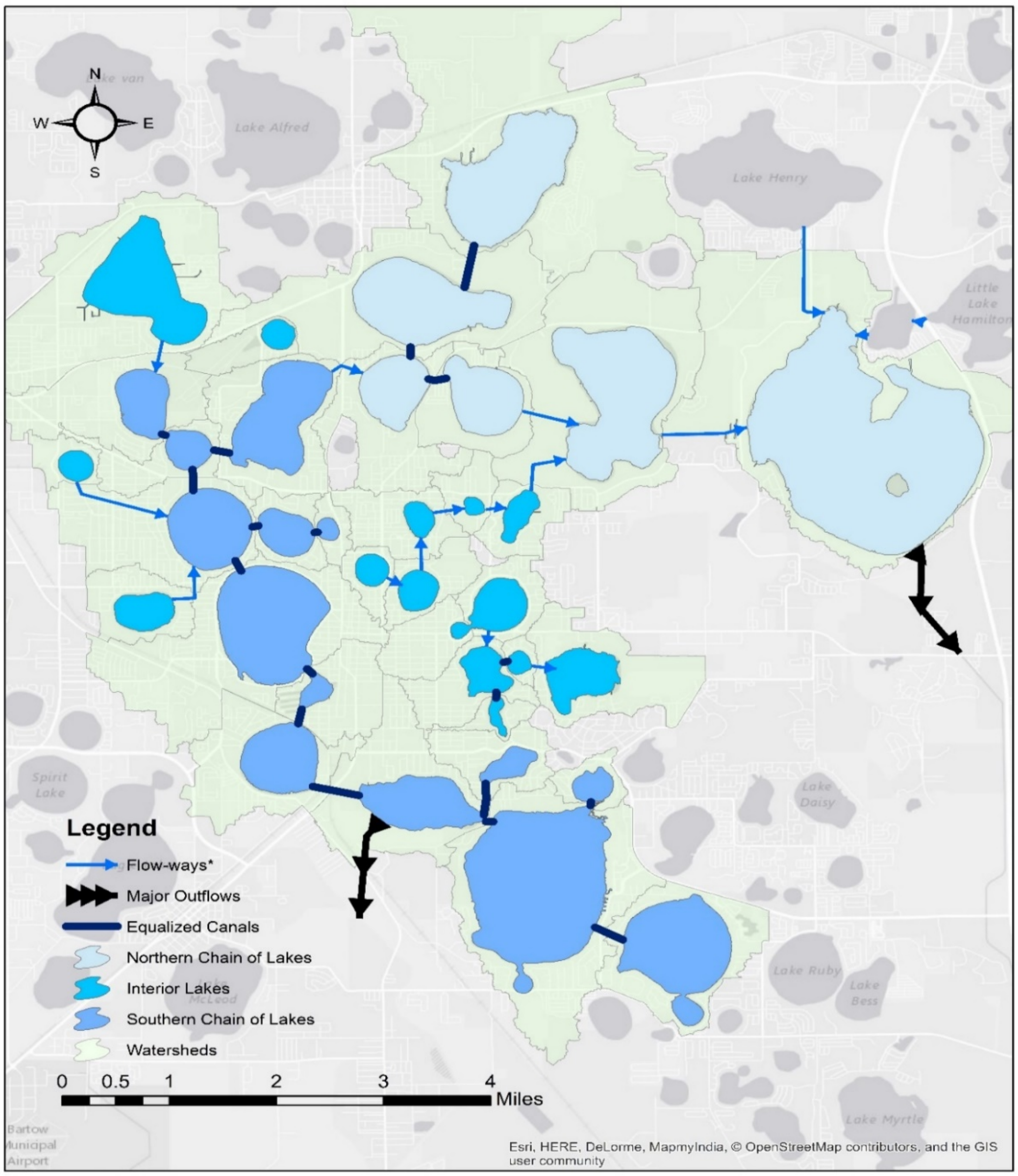

Figure 1-1 Winter Haven lakes with improved public access: major outflows, equalized canals, and flow-ways indicating water pathways through the watershed

1.3 Background on the Metrics

Water Quality/NNC[3]:

In 2010, the US Environmental Protection Agency (EPA) and Florida Department of Environmental Protection (FDEP) mutually agreed to adopt a system to assess the status of Florida's waterbodies under section 303(d) of the Clean Water Act. Numeric Nutrient Criteria (NNC), as part of this system, aims to establish impairment thresholds for chlorophyll a (Chla), total phosphorus (TP) and total nitrogen (TN). Nitrogen and phosphorus are nutrients present in all natural waterbodies and have been determined to have a strong relationship with Chla production—a measurement of phytoplankton (algae) concentration.

Chlorophyll and nutrient concentrations are indicative of the trophic state or productivity of waterbodies where low, medium, and high productivity correspond with oligotrophic, mesotrophic, and eutrophic classifications respectively. The increase in productivity is a process known as eutrophication which occurs naturally as lakes age. However, increasing anthropogenic influence expedites eutrophication and can yield adverse effects including algal blooms, fish kills resulting from hypoxic (low oxygen) conditions, and growth of nuisance macrophytes[1].

Secchi depth, an additional parameter that represents water clarity, is a measure of the depth of light penetration in the water column. Although Chla concentration has since replaced Secchi depth as a primary trophic state metric, clarity still remains a useful means of determining the amount of suspended solids and phytoplankton in a waterbody. While clarity is often associated with lake cleanliness by the public, this perception can be misleading as naturally eutrophic lakes are, by definition, less clear relative to naturally oligotrophic waterbodies. Over time, sediment and detritus (decaying organic matter) are deposited in lake basins via surface-water flow. This natural process reduces clarity of lake water as more and more material becomes suspended in the water column. Similarly to the eutrophication process, water clarity naturally decreases as a lake ages.

Since water chemistry plays a major role in the response of nutrients in a system, thresholds are calculated on a per-lake basis using color (measured in platinum-cobalt units [PCU]) and alkalinity (measured in milligrams per liter calcium carbonate [mg/L $CaCO_3$]). Color is present due to dissolved tannic and humic acids in a waterbody and can be observed as a brown tint or staining. Lake color, as well as clarity, affect light penetration in the water column and subsequently Chla production. Algae requires light to photosynthesize, therefore reduced light penetration in the water column limits phytoplankton growth[2]. Color represents the concentration of dissolved matter while clarity measures the amount of undissolved (particulate) matter in the water column. Despite their shared effects on light penetration, care should be taken not to confuse water color and clarity.

Alkalinity is the measure of the buffering capacity (ability to neutralize an acid) or strength of the dissolved bases in a waterbody. In short, an alkaline waterbody will maintain a relatively stable pH over time. Due to the karst geology (limestone/carbonate rock) underlying Central Florida, most of Winter Haven's lakes are naturally alkaline. As such, the lakes in the study area fall into two categories: Colored lakes (> 40 PCU) and Clear, alkaline lakes (≤ 40 PCU and >20 mg/L $CaCO_3$)—derived from measured long-term geometric mean (average) values of color and alkalinity. Long-term refers to a minimum of ten data points over at least three years with at least one data point in each year[8].

Impairment for each NNC parameter is determined when annual geometric mean values exceed the threshold numeric interpretation more than once in a consecutive three year period. Determination of impairment for each parameter follows a specific progression tree beginning with classification of lake type based on color and alkalinity. After lake type is established, Chla impairment it determined. Waterbodies above and below the Chla threshold utilize different nutrient thresholds to determine TN and TP impairment. Figure 1-2 depicts a flowchart that explains the numeric criteria interpretation based on thresholds determined by the FDEP[3]. Since lakes can be impaired for one, two or all three parameters, lakes are given a score from 0 to 3 with 0 indicating a waterbody with no NNC impairments.

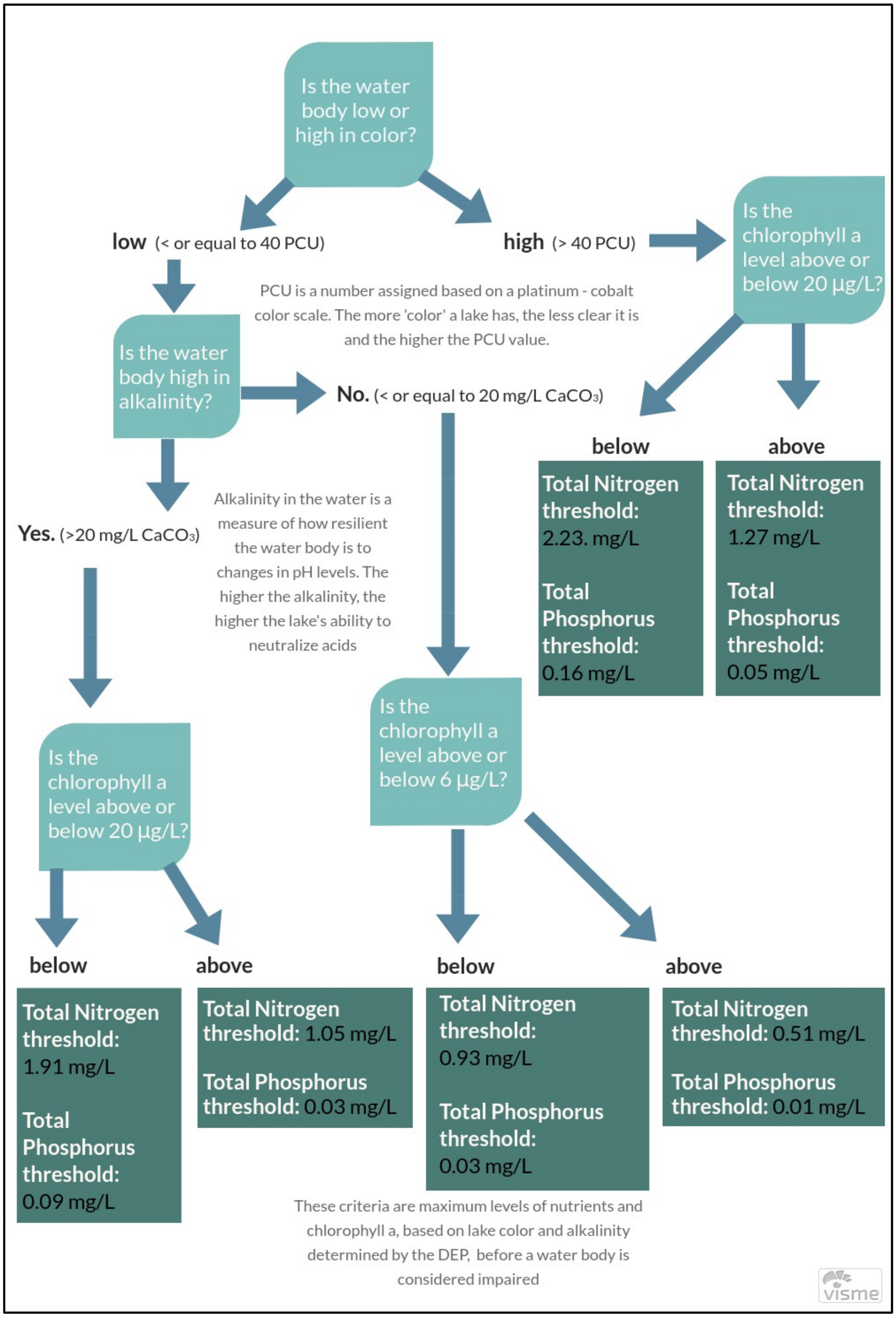

Figure 1-2 FDEP Numeric Nutrient Interpretation flowchart

Total Maximum Daily Load (TMDL)[4]:

A TMDL is the maximum rate of loading of a pollutant that can be assimilated by a waterbody and still meet water quality standards based on the designated use classification of that waterbody. Florida's surface waters are classified into five designated use categories and Winter Haven's lakes fall into Class III: Recreation; propagation, and maintenance of a healthy, well balanced population of fish and wildlife. TMDLs are used to develop restoration goals for impaired waterbodies by setting a baseline for the necessary reduction in nutrient loading in order to meet water quality standards. The TMDL metric is recorded in kilograms per year (kg/yr) of the limiting nutrient(s) for each lake. A limiting nutrient is one that limits plant and algal growth if not in sufficient concentrations. For example: plants need many nutrients in varying amounts in order to grow. The first nutrient that is depleted or becomes inaccessible, causing plant growth to cease, is known as the limiting nutrient. Most of Winter Haven's lakes are phosphorus limited, but several are co-limited by nitrogen and phosphorus[4]. It is for this reason that management practices are focused on reducing TN or TP inputs to the lakes.

Nutrient loading and reduction values can be determined through the modeling of surface water flow, groundwater interaction, nutrient assimilation by plants and algae as well as sediment processes. Point and non-point sources of pollution are taken into consideration in the loading allocation modelling. Since all point source (wastewater) inputs to Winter Haven's lakes were removed early in 1992, loading allocations are calculated based on the modelling of non-point (stormwater and internal) sources. Despite the removal of point source inputs, legacy nutrients still remain within lake sediments from historic discharge—contributing to internal pollutant loading. Once TMDLs are established for a waterbody, the FDEP typically develops basin management action plans (BMAPs) to detail protocols for reducing the nutrient load in a waterbody. These protocols range from sediment removal to planting aquatic vegetation in order to drive nutrient concentrations toward acceptable levels. Due to Florida's incredible abundance of waterbodies, the FDEP follows a cyclical schedule to assess the impairment of each major Floridian watershed once every five years. Modelling nutrient inputs to a waterbody is a very extensive and laborious process with priority given to more severe cases of pollution. As a result, TMDLs and BMAPs cannot always be established for each waterbody. Despite these limitations, TMDLs are especially useful in the development of lake management strategies when available.

According to the FDEP's 2007 TMDL report, eight lakes of the Southern Chain exceeded impairment thresholds and require reductions in phosphorus loading: Cannon, Howard, Idylwild, Jessie, Lulu, May, Mirror, and Shipp. Table 1-1 indicates the TP load reductions required as of this report. TMDLs have not yet been established for the Northern Chain of Lakes as well as most of the Interior Lakes. Therefore, in order to supplement the lack of TMDL information the City must employ alternate metrics to assess lake health for these waterbodies.

Table 1-1 TMDL Values for the Southern Chain of Lakes: existing TP loading and required TP load reductions

Waterbody	Existing TP Load (kg/yr)	TP Reduction Required (kg/yr)	TP % Reduction Required
Cannon	280.2	142.9	49.0
Howard	336.4	143.0	57.5
Idylwild	103.9	64.4	38.0
Jessie	254.1	139.8	45.0
Lulu	167.3	83.7	50.0
May	184.8	87.8	52.5
Mirror	70.6	54.7	22.5
Shipp	241.4	96.6	60.0

Biology:

The metrics in this section are representative of the interactions between aquatic vegetation and the physical characteristics of waterbodies. Vegetative biological volume and abundance quantify macrophyte (plant) growth in a given waterbody. Abundance measures the number of individual organisms while volume is a calculation of the amount of space in the water column taken up by vegetation. The amount of vegetation in lakes affects habitat area, water color, and nutrient concentrations as they cycle through the aquatic system.

Nitrogen (N) and phosphorus (P) go through natural cycles in aquatic environments. Biologically available N and P enter aquatic systems through external loading (surface runoff, stormwater discharge, and atmospheric deposition) as well as internal loading (sediments). Aquatic plants and algae assimilate these dissolved nutrients in their cellular tissue, are consumed or die, and decompose. This detritus settles on lake floors, eventually depositing N and P in the sediment. Certain types of bacteria are able to convert bioavailable nitrogen into atmospheric nitrogen (N_2) which makes up 78% of the air we breathe—essentially removing a portion of it from the aquatic system. Unfortunately, there is no similar process of P removal. The only way to practically extract large amounts of P from lake systems is through the physical removal of nutrients bound in fauna, vegetation, or sediments. This process is exceedingly expensive which is why limiting anthropogenic sources of P loading to the lakes is more fiscally responsible. It should be noted that promoting healthy aquatic plant communities provides a temporary sink for both of these nutrients and limits the available N and P for phytoplankton growth. Aquatic vegetation can act as a buffer against changing nutrient levels and provide a measurable amount of stability to lake systems. Moreover, monitoring vegetation abundance and biovolume can help quantify the amount of nutrients bound in plant tissues and strengthen the calculation of nutrient budgets for each waterbody.

Species richness and evenness are metrics that describe the diversity of aquatic plant communities. A lake with high abundance values may not necessarily be healthy from an ecological standpoint if diversity is low. In order to remain qualified as a Class III waterbody, lakes must promote *healthy* communities of flora and fauna. Competition of invasive macrophytes, such as hydrilla, with native species can minimize spawning and hunting habitat for fauna and choke the water column to the detriment of recreational use. Additionally, a vegetative community with low diversity is more susceptible to decimation by disease, climate change or pests. Limiting competition between native and invasive species is essential in ensuring a robust, healthy aquatic plant community. Herbicide application can be an effective management strategy that requires careful planning to prevent native casualties. An early detection and rapid response system is essential to eliminate invasives before they are able to outcompete native species.

Hydrology:

The observation of the physical characteristics of water and the way it interacts with the land is known as the study of hydrology. Rainfall, groundwater, topography, and lake surface elevation are all part of a dynamic system that affects lake health. For example: rainfall directly contributes to the surface flow in a watershed, increasing lake level as well as recharging groundwater reservoirs. Precipitation can also significantly impact nutrient discharge to the lakes via surface runoff from agricultural, urban, and other land uses. Finally, monitoring rainfall is necessary in the development of a watershed water budget as well as forecasting system responses for potential drought and flooding scenarios.

Groundwater in Florida is stored in different layers: the upper layer known as the surficial aquifer or water table and the deeper, confined Floridan aquifer. Piezometric or potentiometric level represents the static head pressure of the aquifer and can be measured as the height above sea level that water rises inside a well pipe (Figure 1-3). Consequently, surface level in some lakes is impacted significantly by the potentiometric surface level. When the potentiometric surface is low, water drains from lakes more quickly through breaks in the confining layer—causing surface elevation to drop. The opposite occurs when aquifer levels are high: lakes drain more slowly, allowing for rainfall and surface water flow to raise surface level.

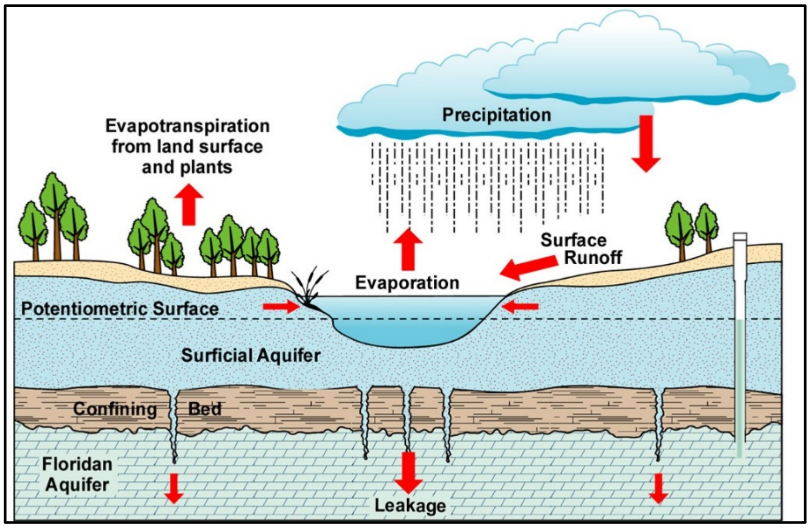

Figure 1-3 Diagram of the water table and the potentiometric surface of a confined aquifer

Topography also significantly impacts how groundwater interacts with each waterbody. Winter Haven's lakes are generally categorized into two groups: ridge lakes and valley lakes[12]. Ridge lakes are characterized by their locations at higher elevation with more pronounced groundwater interaction, steeper slopes, deeper bottoms, modest wetland areas, and narrow littoral zones. Valley lakes, on the other hand, are defined by their lower elevation, large areas of surrounding marshy and forested wetlands, broad littoral zones, and flatter, shallower lake bottoms. Lake elevation determines position relative to the potentiometric surface. Ridge lake surface elevations are typically located above the piezometric level and quickly drain to the aquifer through underlying limestone—this quality denotes these lakes as areas of good aquifer recharge. On the other hand, valley lakes are often known as water storage and treatment areas. These large, shallow lakes drain to the Floridan aquifer much more slowly. This equates to longer retention times which allow for more treatment via the surrounding wetlands.

It has been established that lake surface level is dependent on the combined interactions of rainfall, groundwater level, and topography. Worth noting, is that surface level plays a major role in the cycling of nutrients in lake systems. As surface elevation fluctuates, wetlands and littoral zones can be drained or inundated—affecting the amount of nutrient uptake by aquatic vegetation. Nutrients bound within lake sediments behave differently dependent on surface level as well. A changing volume of water in a reservoir can create gradients that dissolved nitrogen and phosphorus move along to reach equilibrium. This process of nutrients moving back and forth between the water column and sediments is known as nutrient flux. Fluctuations in surface level can transform lake sediments into a massive nutrient sink or source depending on the gradient direction while resuspension of settled bottom sediments can pull additional nutrients out into the water column as more surface area comes in contact with the nutrient gradient. Resuspension of sediments can be exacerbated by lower surface levels as wind and wave action has a greater opportunity to stir up the lake bottom. In conclusion, these cumulative sediment interactions account for what is known as internal nutrient loading in lakes.

2. Data Presentation and Analysis

The information in this section presents analytical and inferential viewpoints that take into account all applicable metrics mentioned in the previous section. While the focus of this report is to provide an annual update on lake health, some long-term data is included in order to gain a broader perspective on the overall trends. Numeric Nutrient Criteria (NNC) and Total Maximum Daily Load (TMDL) metrics exist to determine minimum water quality requirements set forth by the US Environmental Protection Agency (EPA) and the Florida Department of Environmental Protection (FDEP). The City of Winter Haven seeks to improve lake health beyond these minimum requirements. To that end, a comprehensive and systemic approach that involves analyzing the impacts of the other metrics on the overall well-being of the lakes is required to present the whole narrative. Utilizing the results from this section allows for informed decisions to be made when selecting the most effective management strategies for improving lake health. The data employed in the following analysis is taken from the Polk County Water Atlas database[11].

2.1 Northern Chain of Lakes

The Northern Chain of Lakes mostly consist of large, shallow waterbodies that are fringed with dense emergent vegetation and some forested wetland. These lakes are located at the edge of the Winter Haven Ridge—putting them at a lower collective elevation relative to the other lake groups. It can be inferred that the characteristics that designate the majority of the Northern Chain as valley lakes also play a role in their impact to water quality. The following water quality data and trends are explained with references to the hydrologic and biological processes that take place in these waterbodies.

The Northern Chain of Lakes group showed moderate overall improvement in all NNC parameters from 2015 to 2016 with reductions to mean algae or chlorophyll a (Chla), total phosphorus (TP), and total nitrogen (TN) concentrations [Chla: -0.4ug/L; TP: -0.2ug/L; TN: -83.5ug/L] (Table 2-1). Of the six lakes within this group, five surpassed impairment thresholds in some manner in 2015. Lakes Conine, Hamilton and Smart exhibited impairment for Chla, TP and TN while lakes Rochelle and Haines exceeded thresholds for Chla and TN. In 2016, only Lakes Hamilton and Smart maintained concentrations of all NNC parameters above impairment thresholds. Reduction of nitrogen in lakes Conine and Haines was sufficient to decrease TN below impairment levels while Lake Rochelle showed improvement in all parameters with concentrations below impaired levels. Figure 2-1 depicts 2016 mean Chla concentrations of individual lakes relative to the impairment threshold as well as to each of the other lakes within this group. Only lakes Fannie and Rochelle exhibited below-threshold Chla concentrations; possibly related to the considerable density of emergent vegetation fringing these lakes.

Figure 2-2 displays the annual mean NNC concentrations of the Northern Chain of Lakes from 2010 – 2016. It is evident that Chla, TP and TN concentrations continue to exhibit declining trends over the course of the last five years. TN maintained a relatively stable rate of reduction since 2011 while Chla and TP reduction both began to slow between 2014 and 2016. This strong positive correlation between Chla and TP is most likely attributable to phosphorus being the limiting nutrient in these lakes—with changes in TP concentrations eliciting similar fluctuations in Chla levels.

Of particular note is the considerable reduction in all NNC parameters in Lake Rochelle. Biovolume and diversity data suggests that a tremendous abundance of hydrilla in this lake may be responsible for the reduced NNC concentrations from 2015 – 2016. While prior biovolume and diversity data does not yet exist to compare annual changes in plant abundance, an aquatic vegetation monitoring project was recently adopted by the City to record these changes in the future. As an invasive species, hydrilla is targeted for elimination through routine herbicide applications. The NNC data, in this case, is misleading as it shows significant water quality improvement, but does not account for cause. After plant bodies are killed, they will decompose on the lake bottom—releasing nitrogen and phosphorus back into the water column. Future management strategies may need to include the physical removal of hydrilla or staggered herbicide applications to prevent large scale die-offs of nuisance vegetation.

It has been observed that the relationship between lake surface level and water quality varies considerably from lake to lake[2]. Similarly, changes in lake level may carry greater impacts to water quality in some lake groups than in others. In cases where this relationship is strong, it is logical that greater emphasis should be placed on the management of lake surface level as a means of improving and maintaining lake health. The mean surface level of the Northern Chain has exhibited a considerable increase from 2010 – 2016. Figures 2-3, 2-4, and 2-5 display the effects of surface level on nutrients and clarity (secchi depth) with a marked improvement in secchi depth, Chla, TP, and TN. The rapid increase in surface level between 2013 and 2014 corresponds with a sharp reduction of Chla, TP, and TN. From 2014 – 2016, the rate of lake level rise slowed as it reached its peak in 2015 then began to recede. This rate of lake level change was mirrored by a similar, yet inverse change in Chla and TN concentrations—indicated by the slopes of the plotted lines. The inverse correlation between TP and surface level during this period was fairly strong as well [$R^2 = 0.7$; $p < 0.01$]. The large, shallow basins of the Northern Chain allow more contact between bottom sediments and the water column as well as a greater chance for re-suspension of sediments due to wind and wave action. These factors may equate to an increased incidence of inorganic phosphorus flux from sediments to the water column and a greater impact of surface level on TP concentrations in these lakes. Additionally, higher surface levels in these lakes provide the benefit of greater wetland connectivity through a decrease in nutrient concentrations via vegetative assimilation as well as an increase in water color. Therefore, maintaining beneficially high surface levels on these lakes can be an effective strategy to manage water quality.

Table 2-1 Northern Chain of Lakes NNC impairment scores for 2015 and 2016 (including change in annual mean NNC concentrations from 2015-2016)

	2015 Impairment				2016 Impairment				Δ NNC (ug/L)		
Waterbody	Chla	TP	TN	Total	Chla	TP	TN	Total	Chla	TP	TN
Lake Conine	1	1	1	3	1	1	0	2	-3.3	0.9	-95.3
Lake Hamilton	1	1	1	3	1	1	1	3	-0.6	-5.1	86.0
Lake Rochelle	1	0	1	2	0	0	0	0	-4.6	-4.5	-187.5
Lake Smart	1	1	1	3	1	1	1	3	-1.7	-1.1	-159.1
Lake Fannie	0	0	0	0	0	0	0	0	0.2	-0.7	-72.1
Lake Haines	1	0	1	2	1	0	0	1	7.6	9.1	-73.4
					Mean Δ NNC				-0.4	-0.2	-83.5

Legend				
Impairment Score	0	1	2	3
Color Rating				

Δ NNC Trend	Improvement	Decline
Color Code		

∗ Each NNC variable receives a 1 for impaired or 0 for unimpaired; Total score is sum of all impairments. ∗ Δ NNC column derived from difference in NNC concentration from 2015-2016.

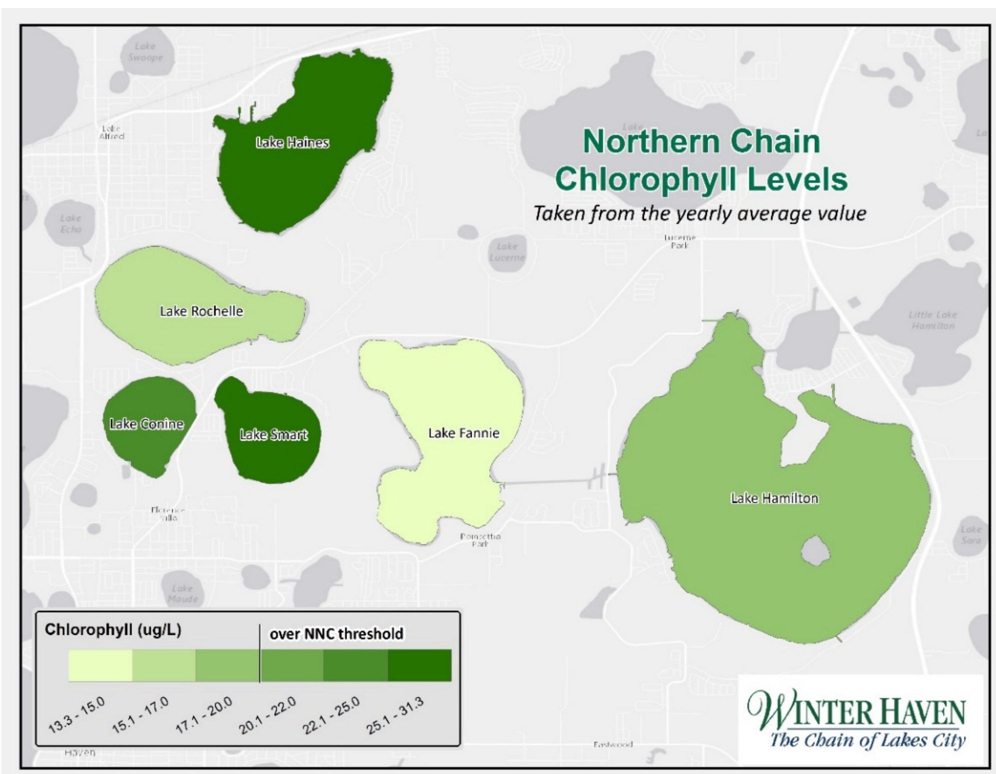

Figure 2-1 Map of Northern Chain of Lakes mean 2016 chlorophyll a concentrations

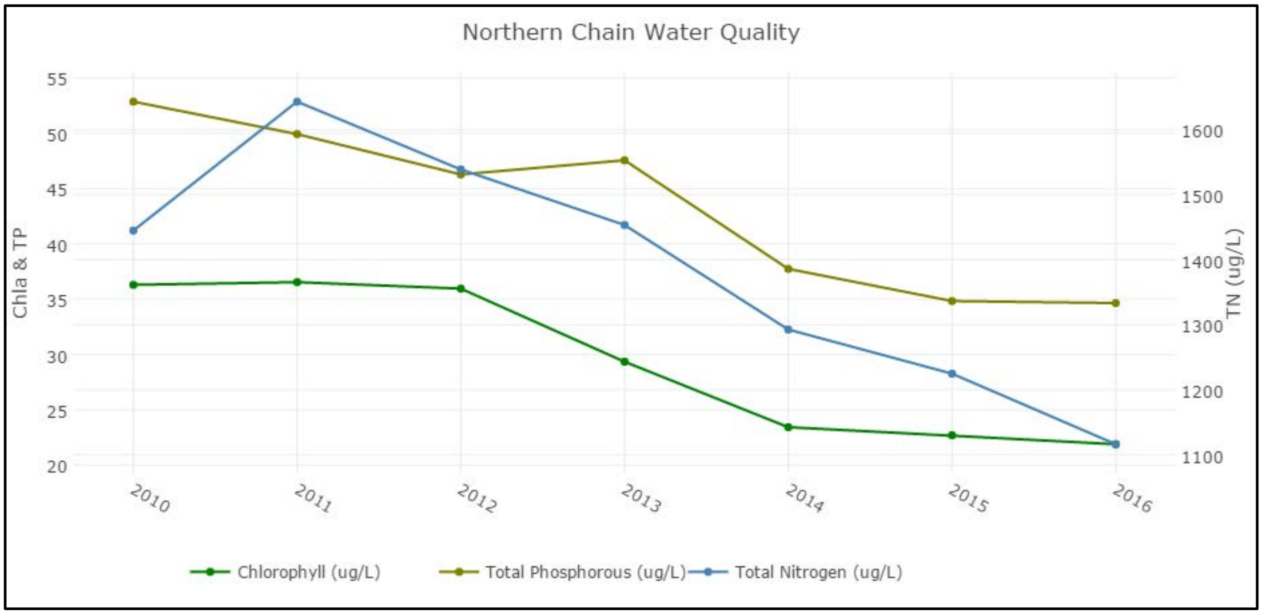

Figure 2-2 Trends of annual mean NNC concentrations for the Northern Chain of Lakes from 2010-2016

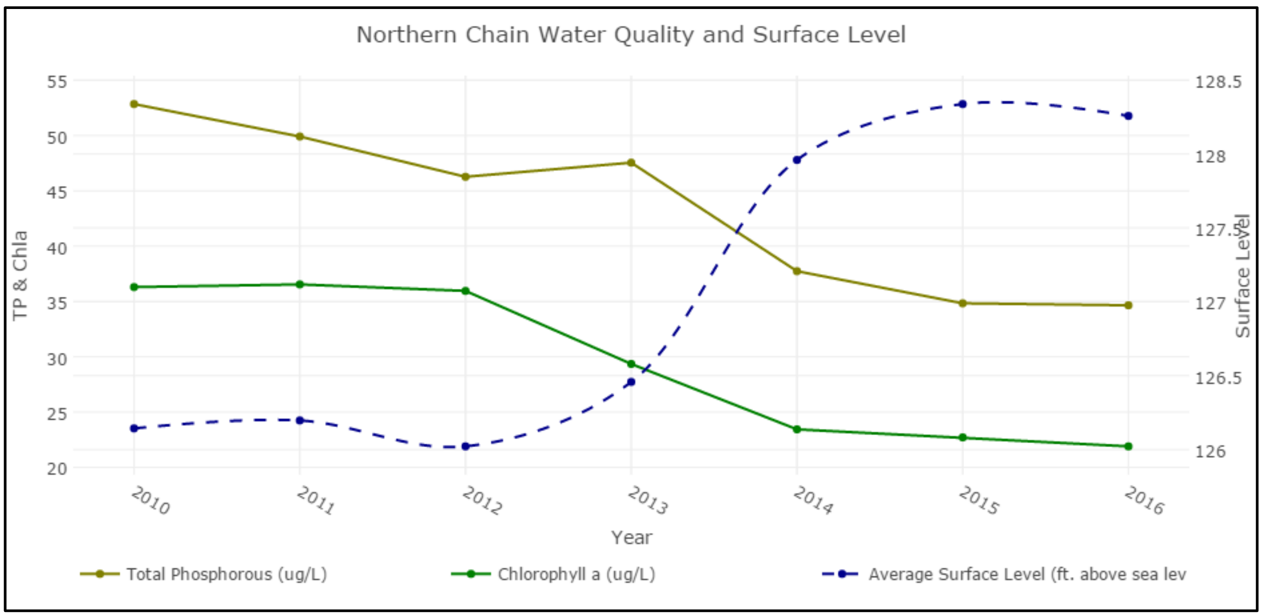

Figure 2-3 Comparison of annual mean chlorophyll a, total phosphorus, and surface level for the Northern Chain of Lakes from 2010-2016

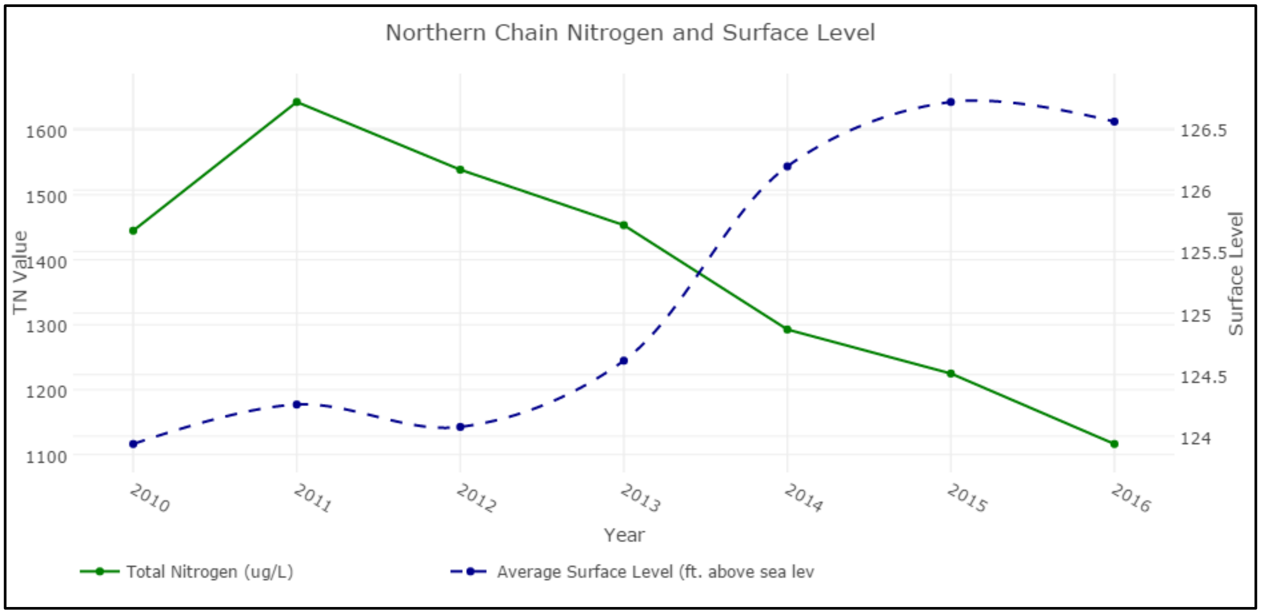

Figure 2-4 Comparison of annual mean total nitrogen and surface level for the Northern Chain of Lakes from 2010-2016

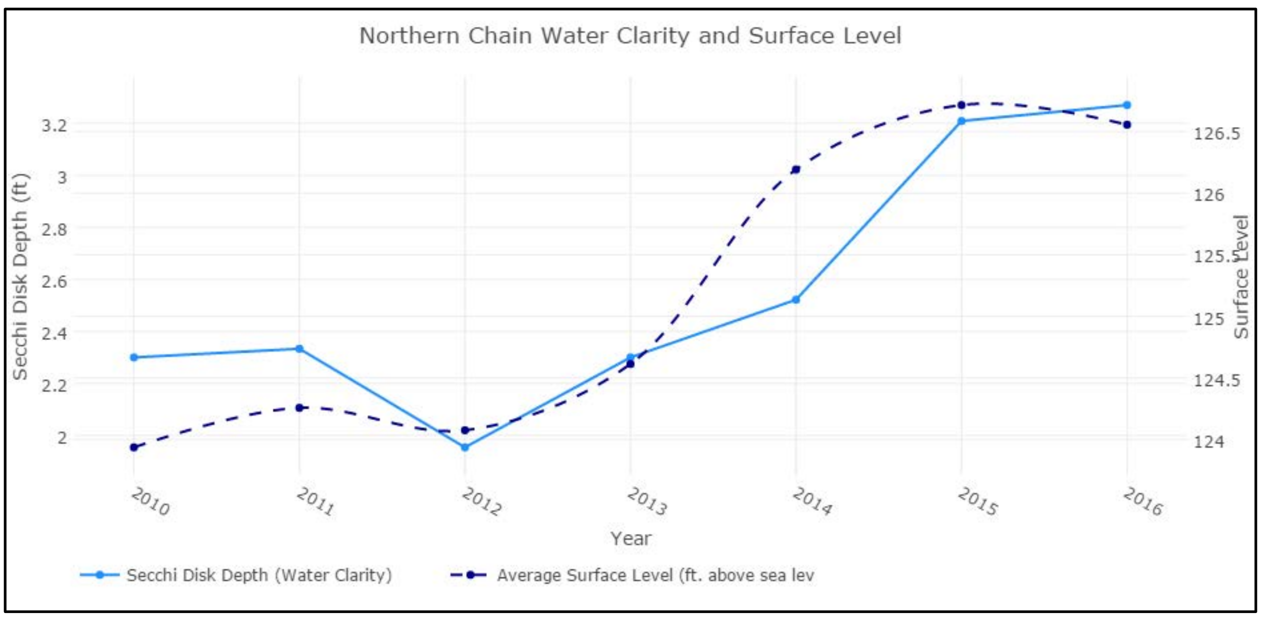

Figure 2-5 Comparison of annual mean secchi depth and surface level for the Northern Chain of Lakes from 2010-2016

2.2 Southern Chain of Lakes

The vast majority of the Southern Chain are considered ridge lakes. Their qualities consist of steeper slopes, deeper bottoms, and smaller littoral zones. In addition, most of these lakes are located closer to Winter Haven's city center—with a greater concentration of stormwater infrastructure and higher density land use. These factors impact water quality in a different manner than the Northern Chain. The following data and trends seek to explain these interactions in greater detail.

While a few lakes exhibited some form of improvement in individual parameters from 2015 to 2016, the Southern Chain saw an overall increase in mean NNC concentrations [Chla: +0.5ug/L; TP: +3.7ug/L; TN: +62.6ug/L] which equates to a general decline in water quality. (Table 2-2). The 2016 mean Chla levels of each lake in relation to the impairment threshold can be seen in Figure 2-6. Lakes Jessie and Spring showed improvement in Chla levels, sufficiently pushing all NNC parameters below impairment thresholds in 2016. However, Chla and TN concentrations in Lake Cannon increased beyond the impairment thresholds while lakes Eloise and Shipp exceeded TP impairment levels.

Despite the sweeping increase in NNC concentrations from 2015 to 2016, the Southern Chain still exhibits a downward overall trend for the last five years (Figure 2-7). The considerable increases in TP and TN did not appear to greatly impact Chla concentration in 2016 which, anecdotally, may be due to an increase in macrophyte abundance. The city is currently building a biovolume and biodiversity dataset to lend significance to this information.

The Southern Chain of Lakes exhibited a dramatic increase in surface level from 2010 – 2016, followed by a slight decrease from 2015 – 2016 which was congruent with level fluctuations in the Northern Chain. Figures 2-8, 2-9, and 2-10 compare surface level with mean NNC concentrations and Secchi depth. Nutrient concentrations closely mirrored lake surface level until 2016 when both TP and TN concentrations dramatically increased. The result of the sudden change in TP and TN concentrations was a display of weak to moderate inverse correlation between lake surface level and each nutrient respectively [TP: $R^2 = 0.30$; TN: $R^2 = 0.48$]. Although it is evident that the impact surface level has on nutrient concentrations is greater on the Northern Chain than the Southern Chain, lake levels still play a role in the overall water quality narrative and should not be dismissed. It is plausible that internal nutrient loading via sediment flux coupled with a greater input of external loading via surface and stormwater runoff compared to the Northern Chain has caused the nutrient increases. The Southern Chain also appears to have less dense emergent vegetation communities in comparison to the Northern Chain—a factor that impacts the potential for nutrient absorption and can create a somewhat less stable environment. It is important to consider the dynamic aspects of lake systems when determining cause and effect. A change in surface level may not immediately elicit a direct effect, but over time indirect impacts may be observable. Understanding the effects of these changes is where the value in the monitoring program is realized.

Table 2-2 Southern Chain of Lakes NNC impairment scores for 2015 and 2016 (including change in annual mean NNC concentrations from 2015-2016)

	2015 Impairment				2016 Impairment				Δ NNC (ug/L)		
Waterbody	Chla	TP	TN	Total	Chla	TP	TN	Total	Chla	TP	TN
Lake Cannon	0	0	0	0	1	0	1	2	2.6	4.3	128.0
Lake Eloise	1	0	1	2	1	1	1	3	4.7	8.3	183.1
Lake Hartridge	1	0	1	2	1	0	1	2	-2.0	1.2	69.6
Lake Howard	1	0	1	2	1	0	1	2	1.9	3.7	174.6
Lake Idylwild	0	0	0	0	0	0	0	0	-3.5	5.7	17.5
Lake Jessie	1	0	0	1	0	0	0	0	-5.0	1.0	-47.8
Lake Lulu	1	1	1	3	1	1	1	3	5.4	7.1	135.0
Lake May	1	1	1	3	1	1	1	3	10.1	13.1	185.7
Lake Mirror	0	0	0	0	0	0	0	0	3.9	4.4	147.0
Lake Roy	0	0	0	0	0	0	0	0	1.6	-0.8	-10.6
Lake Shipp	1	0	1	2	1	1	1	3	1.9	7.5	115.9
Lake Spring	1	0	0	1	0	0	0	0	-15.1	-6.4	-127.4
Lake Summit	0	0	0	0	0	0	0	0	0.2	1.4	-66.0
Lake Winterset	0	0	0	0	0	0	0	0	0.0	1.0	-28.8
					Mean Δ NNC				0.5	3.7	62.6

Legend				
Impairment Score	0	1	2	3
Color Rating				

Δ NNC Trend	Improvement	Decline
Color Code		

∗ Each NNC variable receives a 1 for impaired or 0 for unimpaired; Total score is sum of all impairments.
∗ Δ NNC column derived from difference in NNC concentration from 2015-2016.

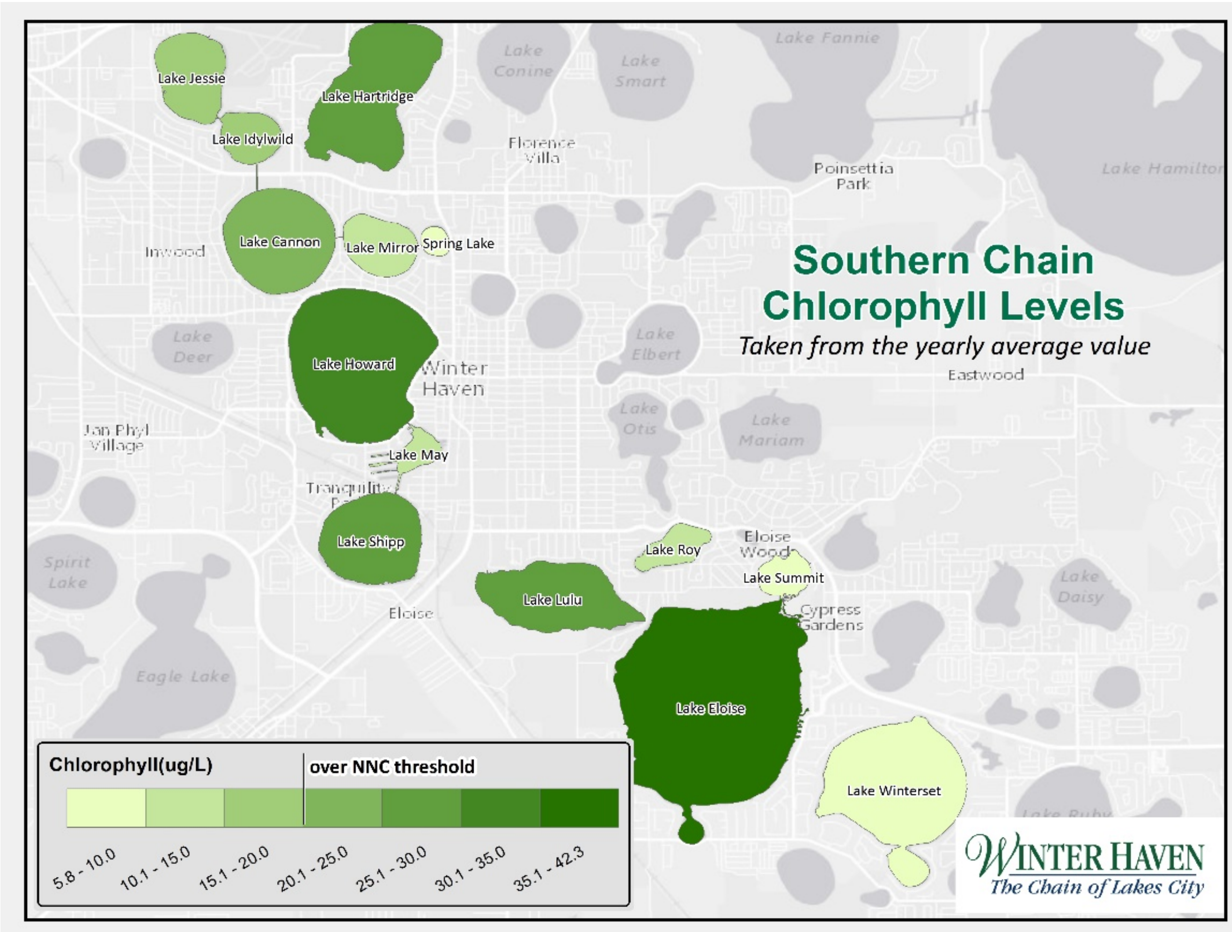

Figure 2-7 Map of Southern Chain of Lakes mean 2016 chlorophyll a concentrations

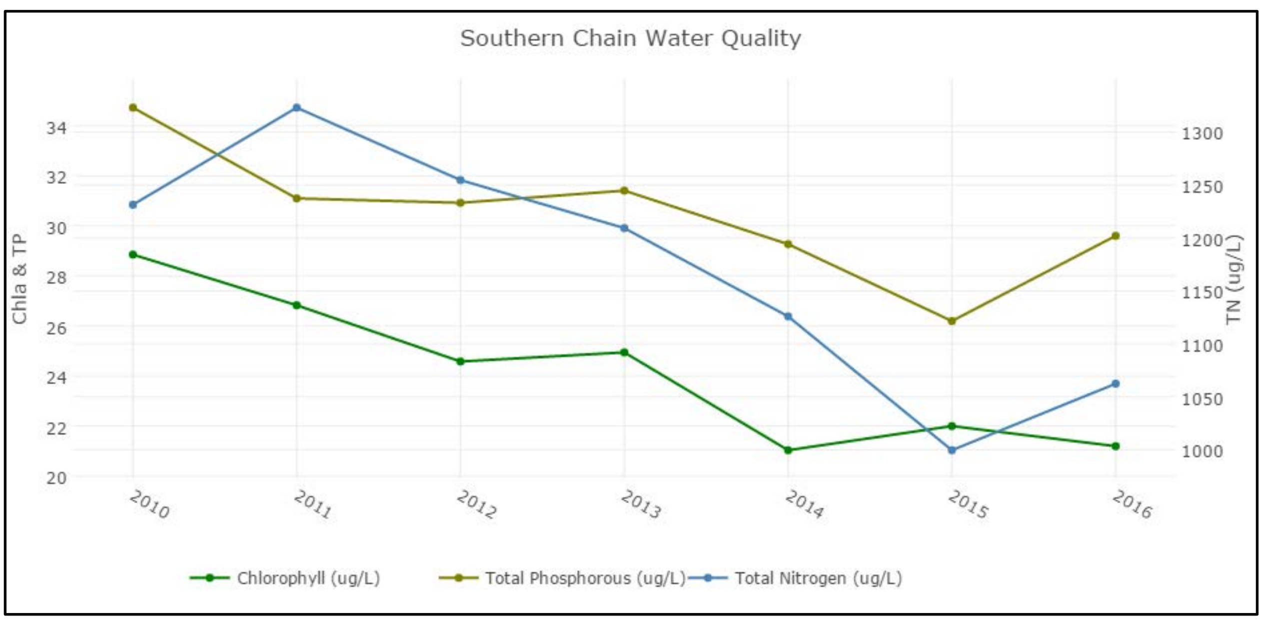

Figure 2-6 Trends of annual mean NNC concentrations for the Southern Chain of Lakes from 2010-2016

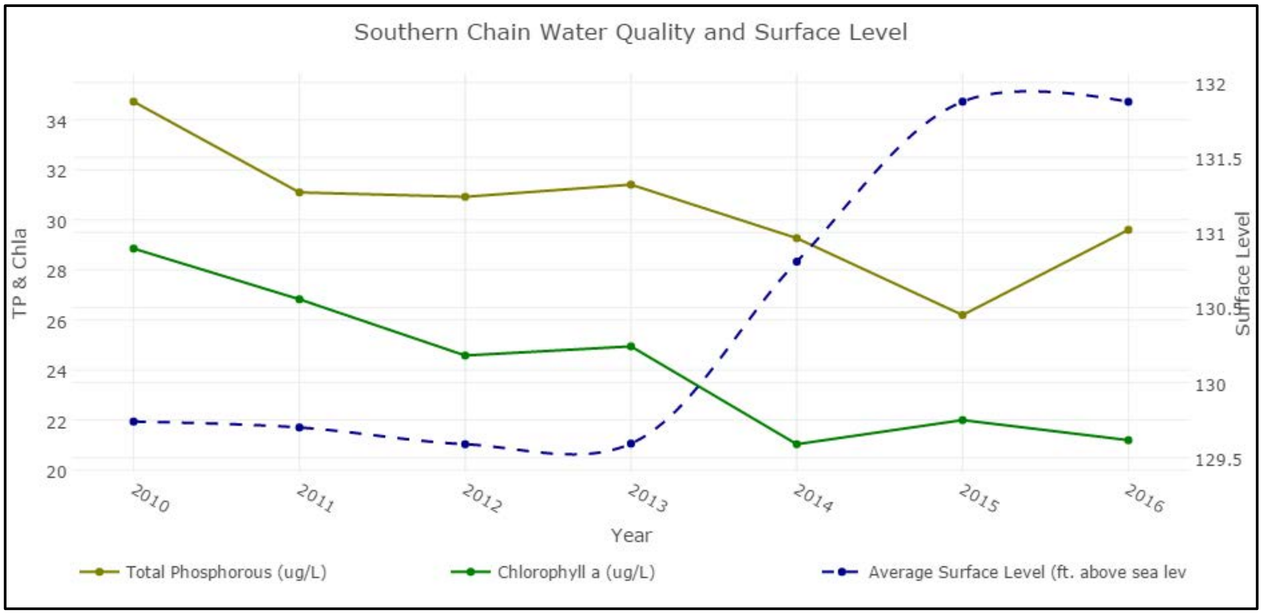

Figure 2-8 Comparison of annual mean chlorophyll a, total phosphorus, and surface level for the Southern Chain of Lakes from 2010-2016

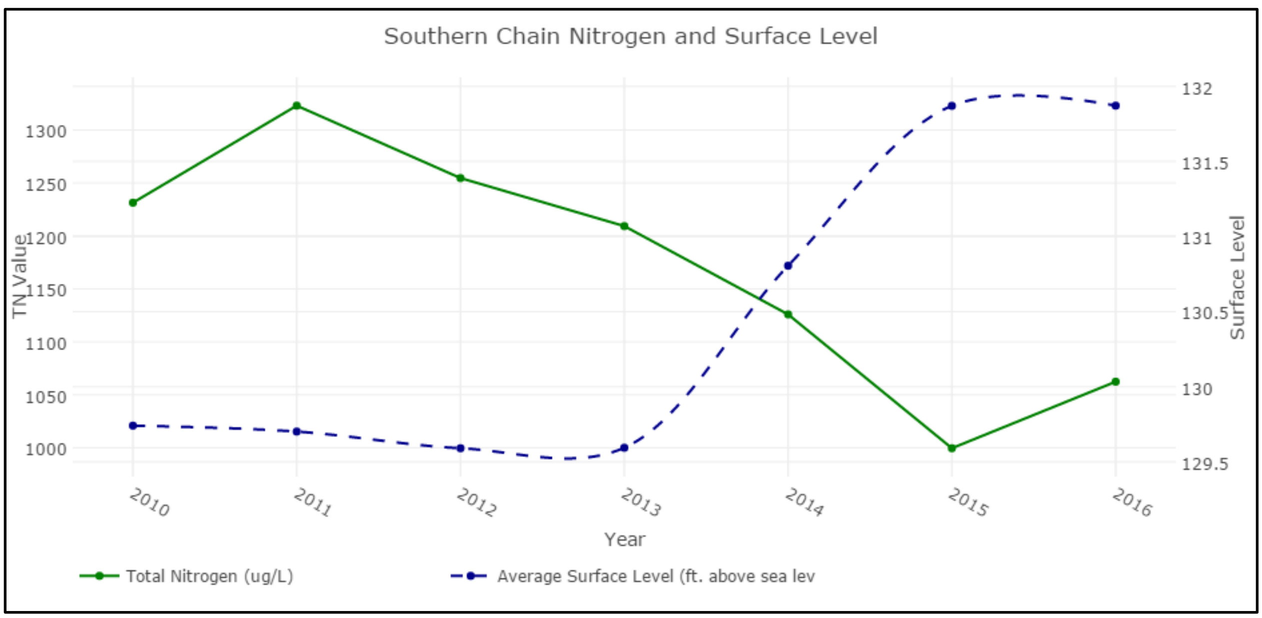

Figure 2-9 Comparison of annual mean total nitrogen and surface level for the Southern Chain of Lakes from 2010-2016

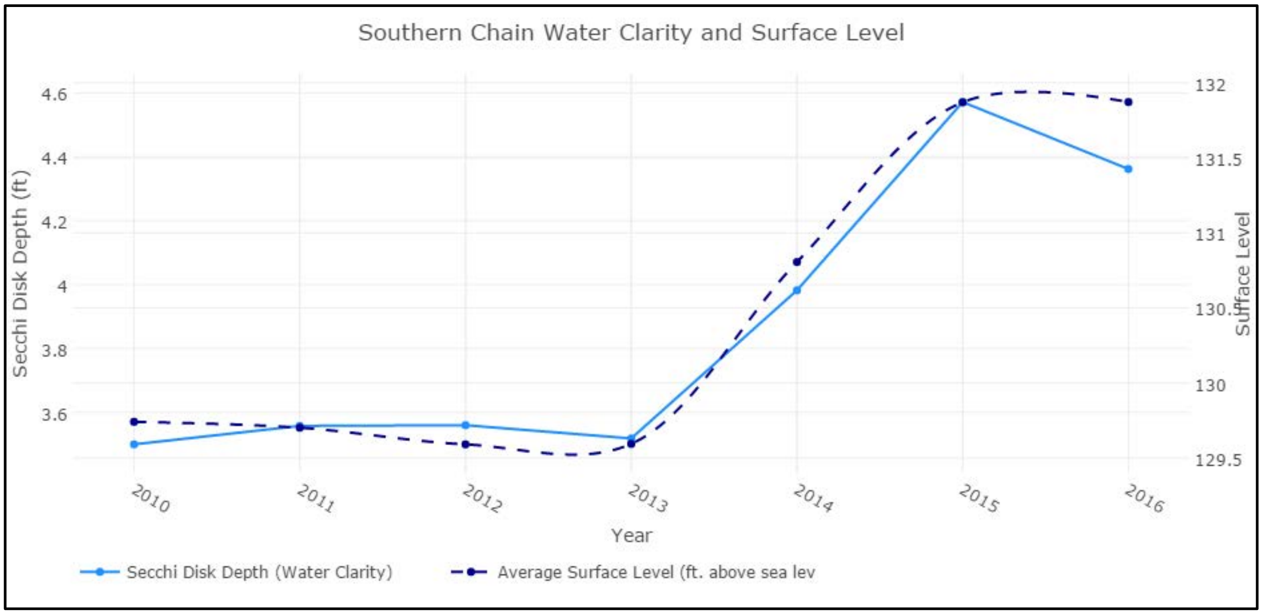

Figure 2-10 Comparison of annual mean secchi depth and surface level for the Southern Chain of Lakes from 2010-2016

2.3 Interior Lakes

As a miscellaneous collection of waterbodies disconnected from the chain, it is difficult to lump all the Interior Lakes under one banner. The majority of this group are considered ridge lakes, but the hydrologic, topographic, and biological qualities vary wildly due to their diverse range of locations. Due to these factors, most of the Interior Lakes must be considered independently when developing management strategies. The collective data and trends for this lake group clearly emphasizes the independent nature of each waterbody.

The grouping of independent waterbodies known as the Interior Lakes exhibited moderate overall improvement in Chla and TN, along with a slight collective increase in TP concentrations from 2015 to 2016 [Chla: -1.0ug/L; TP: +0.9ug/L; TN: -42.0ug/L] (Table 2-3). Figure 2-11 displays the annual mean Chla levels for each lake in relation to the impairment threshold. In 2016 Lake Blue NNC concentrations remained above impairment threshold levels with increases in TP and TN, while Lake Mariana saw declines in Chla and TN—yet both still exceeded impairment thresholds. An overall increase in TP concentration for the Interior Lakes indicates a need to focus on reducing phosphorus loading moving forward. While lakes Blue and Mariana possess NNC concentrations above impairment thresholds, the majority of the Interior Lakes remain unimpaired for TP, TN, and Chla. Although many of the lakes in this group exhibit favorable water quality conditions, the City is still committed to maintaining and improving the Interior Lakes. It is important to closely monitor trends so that swift action can be taken if water quality conditions begin to deteriorate. Maintaining healthy lake ecosystems is more economical than attempting to restore impacted and declining systems.

The overall seven-year trend in Chla within this lake group has remained relatively stable with a slight decrease from 2010 – 2016. TP has exhibited an overall decreasing trend, albeit with a spike in 2013 in addition to the latest increase in 2016. On the other hand, TN continues to maintain its trend of moderate decline from 2011 – 2016 (Figure 2-12). Due to their isolated nature, it is difficult to pinpoint universal drivers of NNC concentrations for the Interior lakes. Some lakes are surrounded by urban development and high density residential areas, while others are bordered by some agricultural land. Additionally, topography and bathymetry varies significantly from lake to lake in this group. Therefore, a site-specific approach must be utilized to manage these waterbodies. The City is currently working toward a similar approach for all lakes within the study area including a comprehensive Stormwater Assessment and Improvement Plan (SAIP) as well as incorporating an aquatic vegetation monitoring (AVM) program to improve nutrient modelling. Many of the projects that the Winter Haven NRD is engaged in provide valuable data that help in the process of selecting the correct treatment strategy and prioritization of each lake.

The surface level of the Interior Lakes exhibited a significant decrease from 2010 to 2012, followed by a dramatic increase from 2012 to 2016. Figures 2-13, 2-14, and 2-15 show the interactions between surface level and mean Chla, TP, TN, and Secchi depth amongst the lakes in this group. Similar to the Southern Chain, TP increased slightly from 2015 – 2016 during a period where surface level fluctuation decreased. Once again, this may possibly be due to phosphorus flux from lake sediments to the water column as concentrations attempt to reach equilibrium.

Table 2-3 Interior Lakes NNC impairment scores for 2015 and 2016 (including change in annual mean NNC concentrations from 2015-2016)

	2015 Impairment				2016 Impairment				Δ NNC (ug/L)		
Waterbody	Chla	TP	TN	Total	Chla	TP	TN	Total	Chla	TP	TN
Lake Blue	1	1	1	3	1	1	1	3	-0.1	1.7	156.9
Lake Buckeye	0	0	0	0	0	0	0	0	1.4	0.6	-51.4
Lake Deer	0	0	0	0	0	0	0	0	-4.2	-1.2	-208.3
Lake Elbert	0	0	0	0	0	0	0	0	-0.6	0.9	-15.8
Lake Idyl	0	0	0	0	0	0	0	0	0.2	10.3	21.6
Lake Link	0	0	0	0	0	0	0	0	-3.1	-3.5	-154.2
Lake Mariana	1	0	1	2	1	0	1	2	-8.3	1.0	-254.1
Lake Martha	0	0	0	0	0	0	0	0	1.0	2.0	-26.3
Lake Maude	0	0	0	0	0	0	0	0	-1.1	-2.2	-36.4
Lake Otis	0	0	0	0	0	0	0	0	-3.7	0.5	-131.7
Lake Silver	0	0	0	0	0	0	0	0	0.9	-0.4	56.3
Lake Mariam	0	0	0	0	0	0	0	0	4.4	2.3	105.5
Lake Pansy	0	0	0	0	0	0	0	0	-0.2	-1.0	-7.3
					Mean Δ NNC				-1.0	0.9	-42.0

Legend				
Impairment Score	0	1	2	3
Color Rating				

Δ NNC Trend	Improvement	Decline
Color Code		

∗ Each NNC variable receives a 1 for impaired or 0 for unimpaired; Total score is sum of all impairments.

∗ Δ NNC column derived from difference in NNC concentration from 2015-2016.

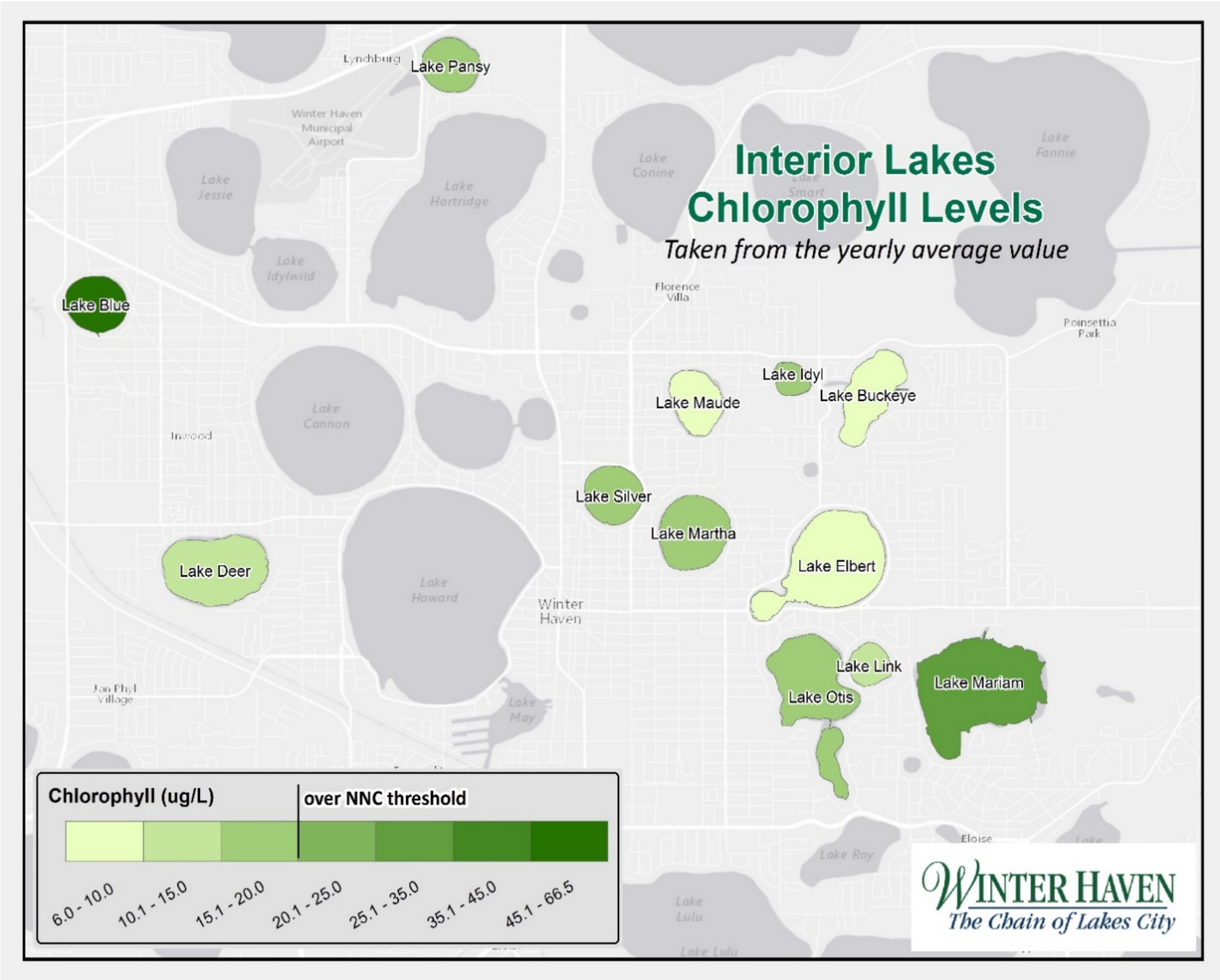

Figure 2-11 Map of Interior Lakes mean 2016 chlorophyll a concentrations

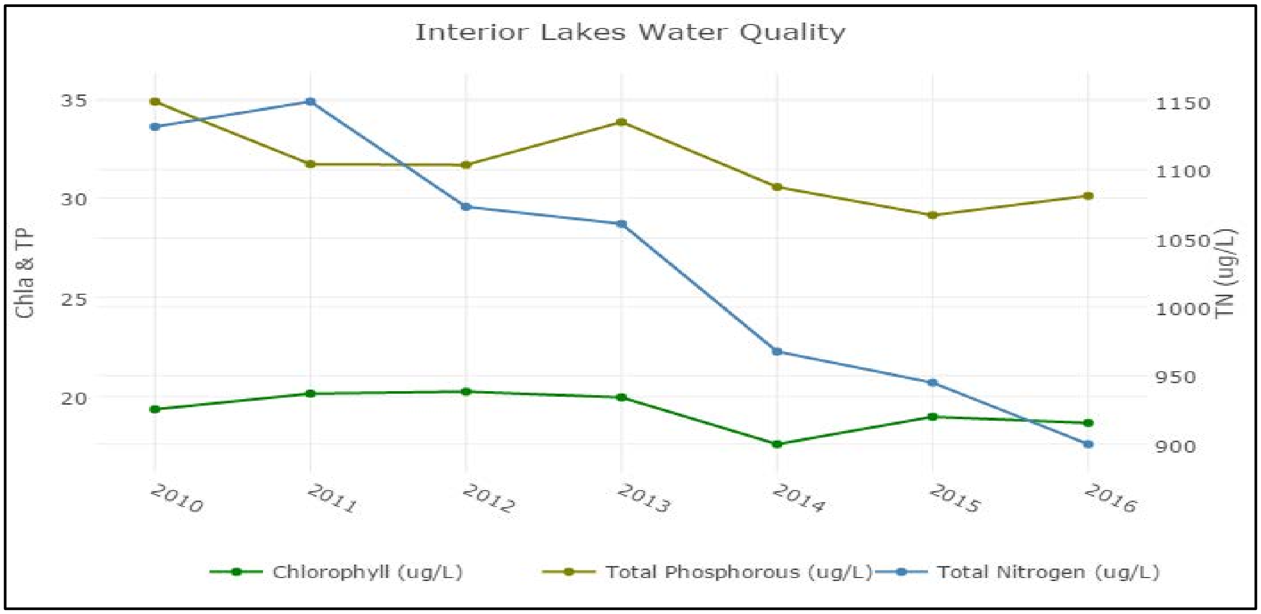

Figure 2-12 Trends of annual mean NNC concentrations for the Interior Lakes from 2010-2016

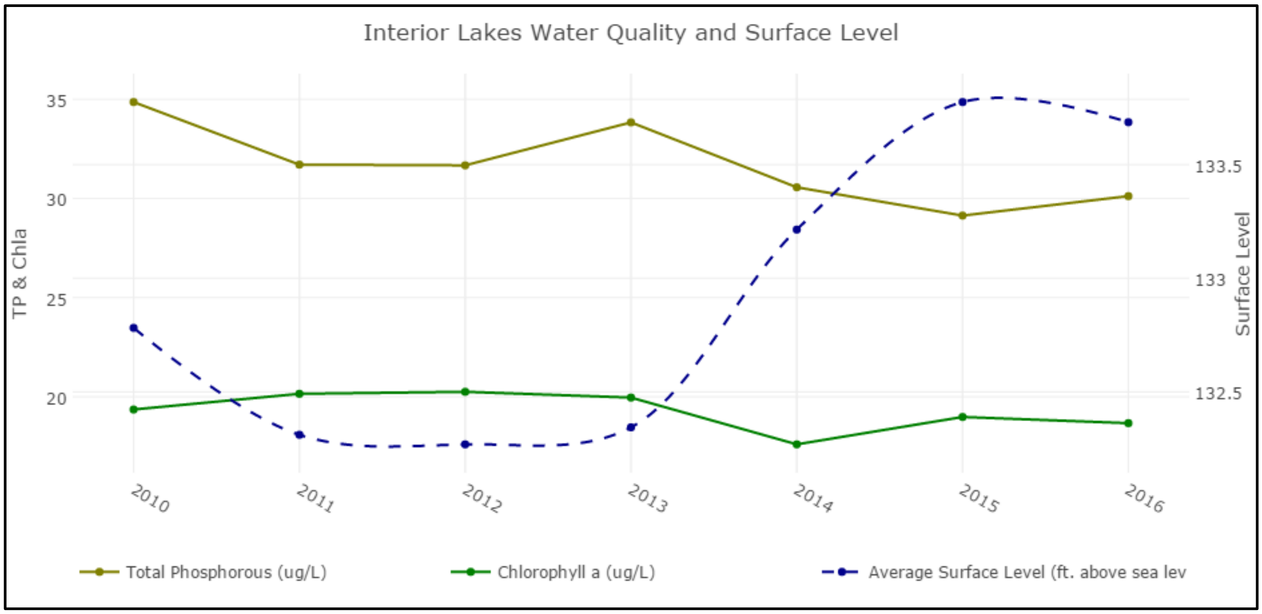

Figure 2-13 Comparison of annual mean chlorophyll a, total phosphorus, and surface level for the Interior Lakes from 2010-2016

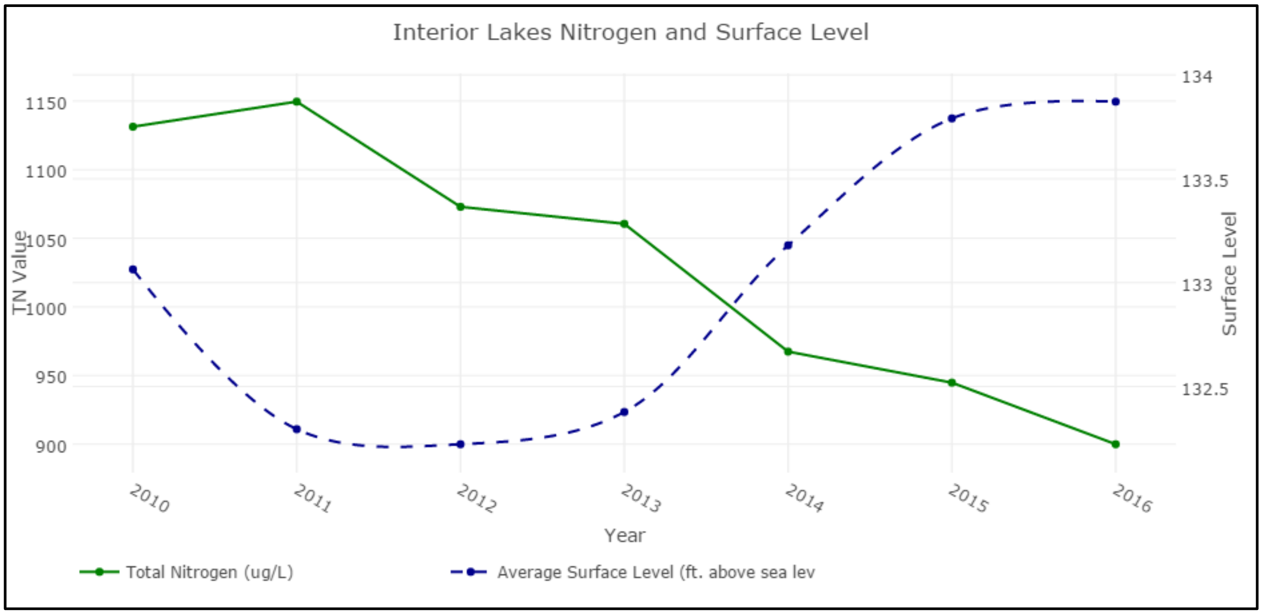

Figure 2-14 Comparison of annual mean total nitrogen and surface level for the Interior Lakes from 2010-2016

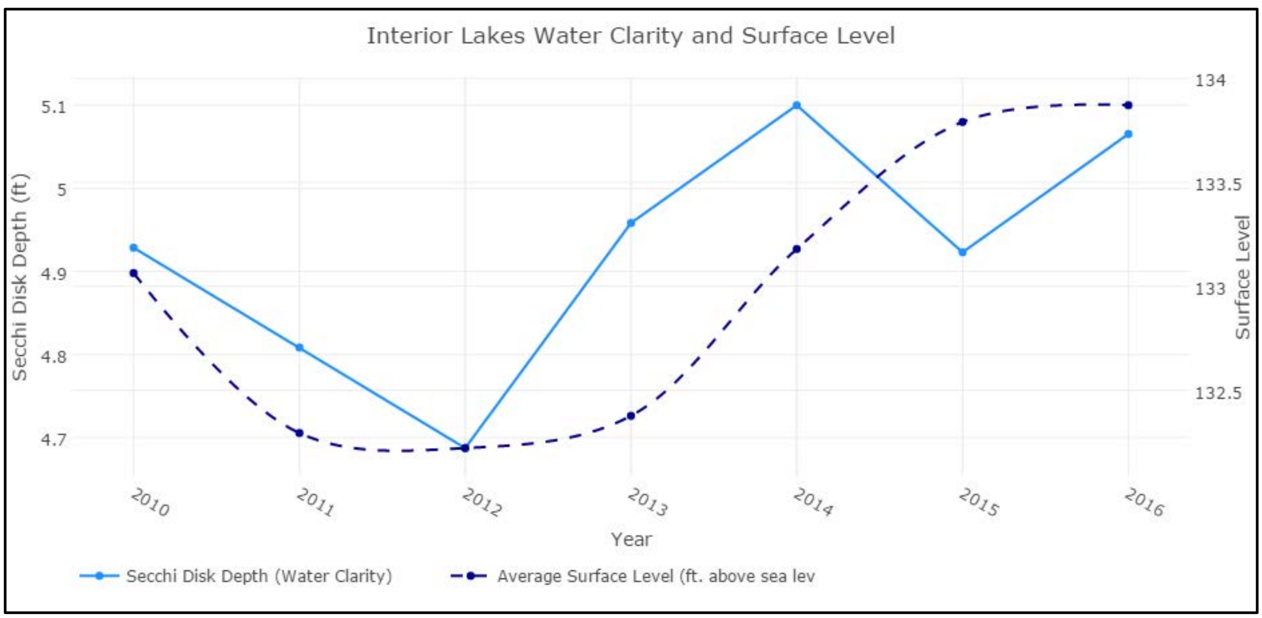

Figure 2-15 Comparison of annual mean secchi depth and surface level for the Interior Lakes from 2010-2016

3. Management Strategies

Winter Haven's lakes are beneficial resources enjoyed by various groups in many different ways. Features of the lakes that are desirable by one group may not be considered attractive to another. A robust vegetative community, for example, may be considered favorable for fishing, but not for swimmers, skiers and those enjoying watersports. On the other hand, clear and uncolored water may be desirable despite it conflicting with the natural state of these waterbodies. Consequently, a balance must be struck to maintain the designated use classification of the lakes in all categories—water quality, ecology, recreational use, etc. Therefore, a systematic management approach is necessary to ensure lake health on all fronts. This section presents background information on some of the management practices employed by the City as well as reinforces how each strategy provides public benefit and supports the Mission, Purpose, and Vision (MPV) of the Division.

Mission:

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

Purpose:

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

Vision:

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

Values:

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

3.1 Watershed Initiatives

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 improve existing stormwater infrastructure as well as to better plan additions to this network. This project 100% funded by a legislative appropriation administered by the Florida Department of Environmental Protection (FDEP) involves 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. The engineering firm, Chastain Skillman, has been employed by the City to update the currently outdated and fragmented inventory map to one that is more cohesive. Additionally, this updated database will include a standardized procedure for entering new stormwater information.

2. Ground truthing existing and previously unidentified stormwater infrastructure: Chastain Skillman is scheduled to work closely with the City to evaluate the current condition of the various pipes, drains, and other conveyances. Factors such as pipe and drain size, material type (e.g. concrete, steel, etc…), flow capacity as well as code compliance. This evaluation will allow the City to more efficiently prioritize management and repairs to the existing stormwater infrastructure.

3. Collection and compilation of LiDAR data to develop a high resolution digital topographic map of the City: Light Detection And Ranging (LiDAR) users lasers to measure variable distances to earth from a known point—usually from an airplane or drone. This data is then compiled to form a highly detailed topographic map of the area studied. The City of Winter Haven has piggybacked onto an existing contract between the Sanborn Map Company and the Southwest Florida Water Management District (SWFWMD). This cooperation with the District provides the City with services and data it could not have achieved alone with a limited budget. Ultimately, the topographic information will allow for more precise modelling of surface water flow and pollutant loading to the lakes.

4. Identification and prioritization of targets for improvement: Incorporating all of the previously mentioned methods of this approach will allow the City to prioritize areas of necessary stormwater improvement. This prioritization process includes the creation and refinement of a comprehensive, city-wide diagram of stormwater connections, pipe sizes, pathways, and existing conditions as well as a high resolution topographic map. a more detailed surface flow modelling can highlight the pathways that receive greater stormwater volume and heavier nutrient loading. The former will help users to understand where potential drainage issues may occur, while the latter will provide more detailed stormwater modelling; highlighting waterbodies that receive heavier surface flow which could lead to greater nutrient loading and propensity for water quality issues. This suite of information will allow 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 in limited supply. Moreover, the SAIP will greatly enhance the speed and efficiency of repairs, maintenance, and improvements to Winter Haven's stormwater systems.

Public Benefit:

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

Support of Mission, Purpose, and Vision:

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.

Strategic Goals:

- By the end of 2017 conduct a complete inventory of the City's stormwater system.
- By the end of 2017 collect new LiDAR data for the entire City to be used in stormwater modeling.
- By the end of 2017 initiate a modeling exercise to identify areas with potential for stormwater quality and quantity improvements.

Alum Treatment:

Summary:

Aluminum sulfate (Al_2SO_4) aka 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 especially 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 that rapidly binds to nutrients and suspended matter, after which it settles out of the water column (Figure 3-1)[9]. The efficiency of pollutant removal via alum treatment varies dependent upon dosage and nutrient type. Total phosphorus (TP) removal is considered to be the most efficient with estimated ranges from 85-95%, while total nitrogen (TN) removal is much less efficient at 35-70%[5]. After nutrient adsorption to the alum floc, it falls out of solution and can be collected in settling reservoirs or allowed to settle in the treated waterbody. This alum floc is stable in a pH range of 5.5 – 7.5[5]. Since Winter Haven's lakes are generally alkaline with stable pH levels, they make good candidates for alum treatment as there is little risk of the precipitate re-dissolving into the water column.

The City of Winter Haven currently operates three alum treatment facilities located at major stormwater outfall positions on the Southern Chain. One is located on the eastern shore of Lake Howard at Heritage Park, one on the northern shore of Lake Lulu at the Chain of Lakes Complex and one on the eastern shore of Lake May near 6th Street SW. Preliminary alum project evaluation reports were drafted prior to the construction of the alum treatment systems which modelled estimated pollutant reductions at each potential outfall location (published in 1998 for Lake Howard and 2002 for lakes Lulu and May). According to the reports, the alum treatment was anticipated to reduce annual stormwater pollutant loading of TP by 92%, TN by 45%, and TSS by 87% on the eastern side of Lake Howard[6]; a reduction of TP by 73%, TN by 37%, and TSS by 69% on the northern side of Lake Lulu; and a reduction of

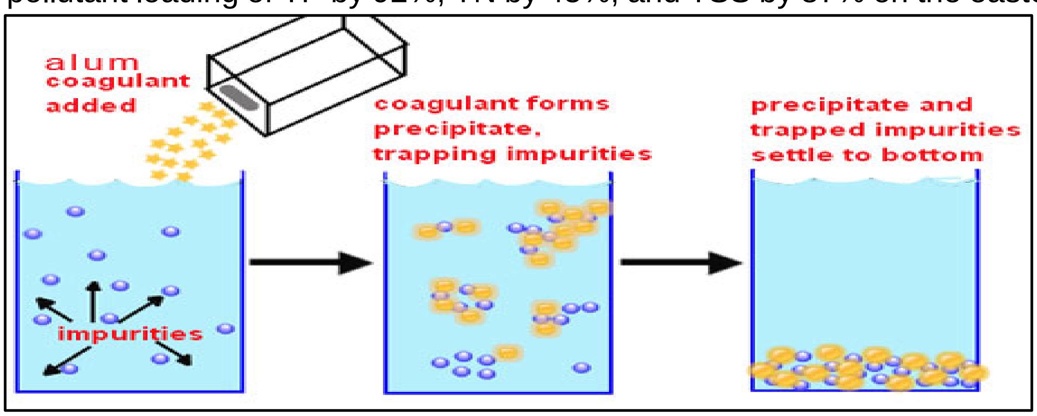

Figure 3-1 Conceptual diagram of alum binding to aquatic pollutants (alum floc production)

TP by 95%, TN by 44%, and TSS by 97% on the eastern side of Lake May[7]. These reduction estimates only account for the stormwater basins leading directly to their respective alum treatment locations and not reductions in total stormwater loading for each lake. Refer to Table 3-1 for estimated total stormwater pollutant loading reduction for each lake via alum treatment. It is worth noting that Polk County manages one additional alum injection site that treats incoming stormwater on the western side of Lake Cannon. The City works closely with the County to monitor pollutant loading at this site.

Table 3-1 Estimated reductions in total phosphorus, total nitrogen, and total suspended solids via alum treatment at Lakes Howard, Lulu, and May

	Total Stormwater Pollutant Loading (kg/yr)*			Estimated Reduction at Alum Outfall (kg/yr)†			Total Stormwater Reduction via Alum Treatment		
Waterbody	TP	TN	TSS	TP	TN	TSS	TP	TN	TSS
Lake Howard	2703	22,481	433,279	400	921	65,957	15%	4%	15%
Lake Lulu	448	2906	86,726	94	222	17,832	21%	8%	21%
Lake May	328	2036	71,523	147	205	29,171	45%	10%	41%

Public Benefit:

Making TP and TN biologically unavailable means it cannot be used for excessive growth of vegetation or algae in lakes. These are the main pollutants of concern in local systems and limiting their availability in the system helps to prevent further decline in lake water quality.

Support of Mission, Purpose, and Vision:

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 group" 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.

Strategic Goals:

- By the end of 2017 establish an internal understanding of the system's operation.
- By the October 1, 2017 devise a strategy to evaluate the effectiveness of the systems.
- By FY18-19 budget preparations include any improvements needed in FY 19.

Street Sweeping:

Summary:

One significant source of pollutant loading to lakes comes from sedimentation accumulated in streets and drained to lakes via stormwater runoff. Street sweeping is what is referred to as a non-structural best management practice (BMP). In 2013, the City entered into a three year contract with USA Services to sweep curbed streets in specified areas to mitigate this pollutant loading source. Areas swept included downtown and much of Winter Haven's residential areas. Specifically, areas including downtown and major Department of Transportation (DOT) roads were prioritized for sweeping on a bi-weekly basis. The remaining residential areas were covered on a semi-annual basis. These sweeping areas encompass a significant portion of the major outfall basins that drain stormwater run-off into Winter Haven's lakes. Sweeping these areas on a regular basis provided the service of reducing nutrient loading into the lakes via sedimentation on streets running into stormwater drains. In 2016, the City renewed a service contract and issued an updated task order that improved upon these benefits by increasing residential sweeping to monthly and expanding sweeping coverage (Figure 3-2).

Public Benefit:

This non-structural BMP provides a physical removal of potential pollutants that is exponentially more efficient then dealing with them once they enter a waterbody. It also limits debris from blocking the stormwater conveyance system which can be problematic and expensive to address. This is a true maintenance practice that strives to deal with issues by attentively and routinely managing them rather than allowing the issue to reach the end of the line where they are more expensive and difficult to manage. Removing this debris from roadways also prevents situations that undermine the quality of the roadway. There is an ancillary aesthetic benefit as well.

Support of Mission, Purpose, and Vision:

Street sweeping is a true 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 is 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.

Strategic Goals:

- Increase the analysis of the street sweeping program to refine the Work Plan by the start of FY17-18
- Conduct monthly surveys of street sweeping activities to gauge effectiveness and communicate deficiencies with contractor
- By the end of 2017 begin to explore options for further increasing the efficiency of this program

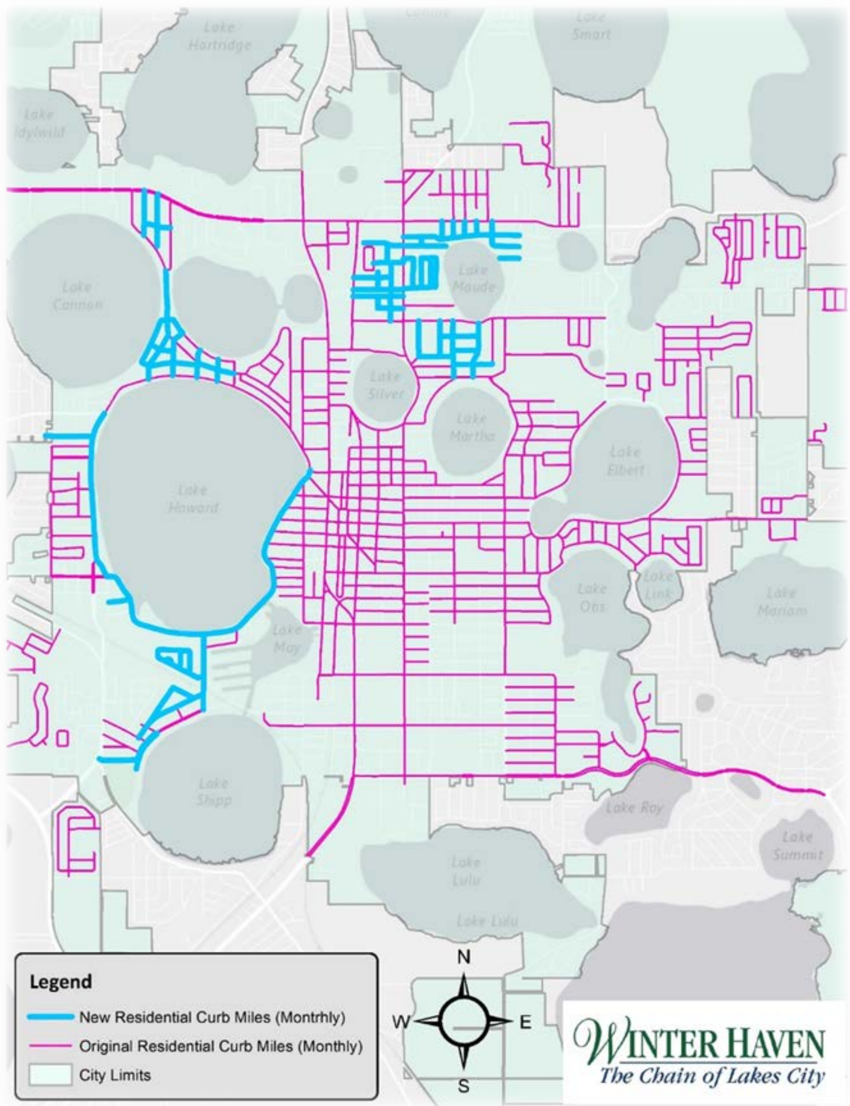

Figure 3-2 Map of street sweeping routes prior to and after sweeping contract re-newal

Low Impact Development Projects:

Summary:

The United States Environmental Protection Agency defines Low Impact Developments (LIDs) as systems and practices that use or mimic natural processes that result in the infiltration, evapotranspiration or use of stormwater in order to protect water quality and associated aquatic habitat by managing stormwater as close to the source as possible. By engineering infrastructure that implements vegetation and porous soils, polluted runoff can be treated before it reaches traditional stormwater systems and ultimately lakes and canals. Traditional or “gray” stormwater infrastructure relies on impervious materials, gutters, pipes, and ponds and only transfers runoff from one area to another. Winter Haven is in the process of moving to more “green” development projects such as raingardens, bioswales, exfiltration structures (e.g. french drains), and pervious pavement. While nutrient loading benefits are localized, there are ancillary benefits imparted through the use of “green” engineering. Instead of stormwater running over impervious surfaces, LIDs provide an inlet for surface runoff to percolate directly into the water table or surficial aquifer. If placed in the direct pathway to an existing stormwater drain, LIDs are able to capture sediments, heavy metals, and solid refuse during the first flush of a rainfall event before it can drain directly to the lakes. Using proper xeric soils, flooding along roadways during 1 to 10 year storm events can be reduced, while utilizing xerophilic plants in the construction of LIDs also helps to beautify the urban landscape. In some cases, LIDs can be utilized in lieu of traditional stormwater ponds in city planning. If engineered correctly, low impact storm systems can occupy smaller footprints while still mitigating a similar volume of stormwater—benefitting developers by allowing more area for construction while still promoting the above mentioned services.

Currently, the City has constructed 71 raingardens and French drains in and around Winter Haven’s urban center. Plans are in place to construct 45 to 60 more in the next two years. Table 3-2 highlights the estimated nutrient load reduction capabilities of LIDs in each lake group. While nutrient removal capabilities are minimal on an individual basis, LIDs can collectively have a greater impact in larger numbers. 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.

Table 3-2 Estimated total phosphorus and total nitrogen load reductions via low impact development projects for the Southern Chain and Interior Lakes

Estimated Reductions			
Lake Group	# of LIDs	TN (kg/yr)	TP (kg/yr)
Southern Chain of Lakes	25	6.82	1.05
Interior Lakes	46	17.87	2.74

Public Benefit:

LID's provide stormwater treatment above and beyond what was historically constructed in the City. By replicating natural systems in the management of stormwater, pretreatment of pollutants is achieved along with hydrologic restoration. Both of these have direct benefits to lake water quality. Furthermore, these projects can provide social and economic benefits by improving the aesthetics of an area either through improved landscaping, reduced puddling, or both.

Support of Mission, Purpose, and Vision:

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

Strategic Goals:

- By October 1, 2017 apply for SWFWMD funding to construct Raingardens in FY 2019.
- By the end of 2017 design an improved maintenance strategy for LID's.
- By the end of 2017 construct 16 FDEP funded Raingardens.
- By the end of 2017 construct 10 SWFWMD funded Raingardens in house.
- By the end of 2017 design 20 SWFWMD funded Raingardens to be contracted out.
- Be prepared to implement an in house construction program by the start of the FY18-19 Budget Development.

Stormwater Treatment Parks:

Summary:

Stormwater treatment parks (aka nature parks) are engineered wetlands that perform similar functions as other forms of low impact development as well as provide additional benefits to the surrounding community. 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 refuse, 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. In essence, nature parks exemplify how "green" engineering can easily solve human problems with natural solutions as well as seamlessly integrate beneficial ecology and urban development.

Maintenance to these nature parks is vital to their ability to effectively treat the incoming stormwater and involves clearing overgrown or nuisance vegetation from the periphery of the lakes and ponds. The benefits of proper landscaping include the opening of clogged stormwater pathways, curtailment of invasive species growth, aesthetic improvement, and a reduction in the available nutrients that would otherwise enter the adjoining waterbody. The latter of these benefits is especially important. The decomposition of plant matter releases nutrients the plant has sequestered over its lifetime back into the environment.

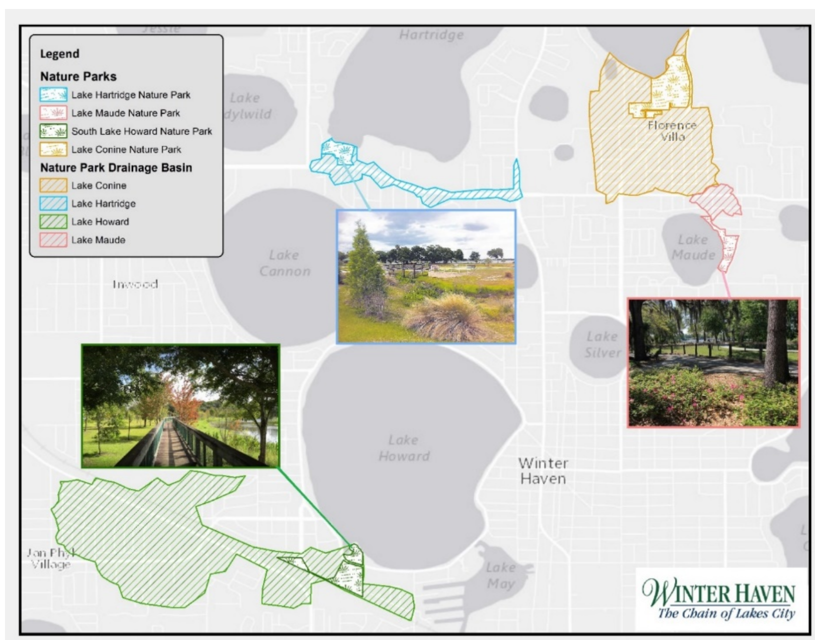

Figure 3-3 Map of Winter Haven Nature Park locations

Therefore, removing excess vegetation assists in reducing the total nutrient load to our waterbodies.

There are currently three stormwater treatment parks located in Winter Haven: South Lake Howard Nature Park (15.9 acres), Lake Hartridge Nature Park (9.4 acres), and Lake Maude Nature Park (6.4 acres). In addition to providing the above-mentioned services, each park was constructed with walking trails and boardwalks, picnic pavilions, and fishing piers. Plans are underway to construct a fourth stormwater treatment park on the south shore of Lake Conine which will be Winter Haven's largest nature park constructed to date (32.9 acres). As one of the recipient waterbodies of point-source (wastewater discharge) prior to 1992, Lake Conine is considered a high priority for water quality improvement. This proposed wetland park is expected treat the stormwater runoff from an approximate 330 acres of residential area and considerably reduce pollutant loading to Lake Conine. Figure 3-3 depicts the locations of each of the current nature parks as well as the proposed Lake Conine project.

Public Benefit:

These parks provide treatment of stormwater prior to it entering local lakes providing a centralized location for debris and pollutants to be actively managed. These parks keep significant pollution from entering local waterbodies. Additionally there is a recreational component that these parks provide supporting social and economic wellbeing in the community.

Support of Mission, Purpose, and Vision:

These project are similar to LIDs 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 is the "premier knowledge base for local natural resources".

Strategic Goals:

- By the end of 2017 increase restoration activities to include all 3 of the existing nature parks.
- By the end of 2017 secure funding for construction of the Lake Conine Treatment Wetland.
- Be prepared to budget for Vicennial maintenance of Lake Howard Nature Park by FY18-19

NPDES:

Summary:

The National Pollutant Discharge Elimination System (NPDES) was created in 1972 under the U.S. Clean Water Act. The U.S. Environmental Protection Agency (EPA) is responsible for the permit but works with the Florida Department of Environmental Protection (FDEP) to administer it within the state. Polk County holds a permit for the region and the City serves as a Co-permittee within that permit. The permit addresses water pollution by regulating point sources that discharge pollutants to water of the United States. In Winter Haven that would mainly be the lakes.

The major component of the NPDES permit the City participates in relates to stormwater management. Specifically, to the functional maintenance of the infrastructure, educating the community about ways to reduce impacts, designing an active approach to reduce pollutant loading into local water bodies, and tracking lake health to look for a measurable impact.

Public Benefit:

The NPDES permit provides accountability and transparency to residents that every precaution is being taken by the organization to protect natural resources in all operations. The permit also requires the City to constantly improve their understanding of the potential local impacts and create plans for addressing those impacts.

Support of Mission, Purpose, and Vision:

By requiring the City to continually improve its understanding of the potential impacts 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.

Strategic Goals:

- Submit the Cycle 3 year 5 permit by the end of January 2017 to allow focus to return to process improvement.
- Create a repository of Standard Operating Procedures for all sections of the permit that require it
- Distribute cycle 4 year 1 permit data requests by November 1, 2017

- Receive all data from majority of providers by the Thanksgiving Holiday
- Have a final draft of the permit prepared by the 2nd week in January 2018
- Work with data providers to better understand the challenges in efficiently providing their portion of the permit data and develop strategies by the start of Cycle 4 Year 3 to increase efficiency.

319 Grey to Green:

Summary:

In response to findings that a number of lakes in Winter Haven had impaired water quality, the City adopted a Sustainable Water Resource Management Plan, lake water quality restoration and management goals, and amended its comprehensive land development code to protect the health of its surface water and groundwater resources. Through these efforts the City identified the need to develop and implement a public education program to help the community transition from a conventional “pipe and pond” (gray) stormwater management system to a green stormwater system designed to slow, spread, and soak stormwater, and help restore the natural flow-way of runoff and the water balance. Managing water in this way also allows for more robust and sustainable development in the future. This project will design and implement an education program targeted at City staff, local engineers, and developers, and provide them with the tools they need to bring about this philosophical shift in stormwater management.

Financial assistance was applied for and received to offset the cost of this program. The funding source is in the form of a 319 Clean Water Act Grant from the United States Environmental Protection Agency (USEPA) administered by the Florida Department of Environmental Protection (FDEP) through “DEP AGREEMENT N0. NF015”.

The agreement identifies four main tasks, to be completed by April 2018, and is summarized as follows:

1. Solicit community guidance and institutional support in developing and implementing the education program
    a) Green Education and Green Transition teams will be comprised of City staff and technical members of the community to better understand the challenges green stormwater system development poses.
2. Develop education and marketing materials
    a) Based on the lessons learned in the first task and through previous efforts, materials will be created to stimulate public and private sector awareness, involvement, and action in developing green infrastructure projects.
3. Implementation of the education program
    a) The education program will be implemented through a series of community workshops and land planning development reviews. The effectiveness of which

will be tracked through participation surveys conducted at the beginning and end of all project activities.

4. Final report

a) A final report summarizing the results of the effort will be produced and submitted to the EPA.

Public Benefit:

Changing land uses come with changes in the way water moves in the landscape. The goal of this program is to make sure the City is providing education and options to customers on how to develop using tools Like Low Impact Developments and Best Management Practices (BMPs) to minimize impacts to the functions of the natural system.

Support of Mission, Purpose, and Vision:

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

Strategic Goals:

- By the end of 2017 solicit stakeholder input and use it to develop education materials and tools to provide to the development community of ruse in planning.

Floating Treatment Wetland:

Summary:

It has been established that emergent vegetation acts as a temporary nutrient sink within an aquatic environment. Additionally, the physical removal of vegetation is necessary to eliminate the eventual nutrient source that arises as plants decompose in a waterbody. Unfortunately, the time and effort required to extract this vegetation becomes progressively expensive and impractical in larger volumes. Implementing floating treatment wetlands (FTWs) is a solution for the assimilation of nutrients by macrophytes (plants), bacterial conversion of nitrogen into atmospheric form, and relatively simple plant removal. Figure 3-4 depicts a diagram of a floating wetland. Instead of planting emergent aquatic vegetation in the substrates of lake shores, wetlands, and stormwater detention ponds, plants can be placed on floating foam rafts and allowed to grow and assimilate nutrients without rooting into aquatic sediments. After a defined period of time (typically 3, 6, or 12 month increments), these plants can be removed with considerably less effort than if they were planted traditionally.

A study performed by the University of Central Florida's Stormwater Management Academy in 2012 sought to evaluate the efficacy of FTWs in the removal of nutrients from stormwater detention ponds. Using rafts covering 5% of pond surface area, the floating wetland treatment reduced total nitrogen (TN) by 16% and total phosphorus (TP) by 44% on average as well as significantly inhibited the growth the algae and duckweed in the stormwater ponds[10]. The removal efficiencies determined by this study also prompted the FDEP to grant a 12% credit to the reduction of TN and TP in the calculation of TMDLs for a waterbody where a FTW is used[10]. Due to this information, the City of Winter Haven plans to implement a trial FTW in a stormwater pond that discharges to Lake Martha. This trial period is to begin in 2017 at the start of the Florida rainy season in late Spring and conclude when precipitation rates drop off in Fall. The data collected will determine the efficacy of expanding the use of FTWs to more ponds in the Winter Haven area.

Public Benefit:

This project has a fourfold potential for benefits. The first being potential for reduction in the stormwater pond where it is deployed helping to stabilize that system by limiting swings in nutrient and oxygen concentrations that lead to undesirable conditions. Second is an opportunity to provide desirable aquatic vegetation to lake front homeowners at no cost. Third is an opportunity to communicate with the public about why such a management strategy is effective and how the same theories apply to lakes. Lastly, is a learning opportunity for the City to determine the worthwhileness of this pilot project and the value in expansion.

Support of Mission, Purpose, and Vision:

This pilot project is an implantation of the Mission as it is derived from an understanding of the “social, economic, and ecological systems” that govern the existing stormwater pond and the impacts that can be felt by the community and the adjacent lake. Currently this pond can reach conditions deemed undesirable by the local stakeholders, this project is designed to alleviate those conditions restoring “natural resources the community can be proud of” as is part of the Division’s Purpose. By engaging in this pilot project the City will deepen it’s understanding of how local systems function further supporting its position as “the premier knowledge base for local natural resources” and creating an opportunity to engage the public in conversations about management strategy which works to achieve the Vision.

Strategic Goals:

- By the start of the 2017 rainy season acquire outside funding to supplement the cost of the pilot program
- By the October 1, 2017 develop a baseline dataset for water quality parameters in the pond
- By the end of 2017 install floating treatment wetland and begin tracking status of program

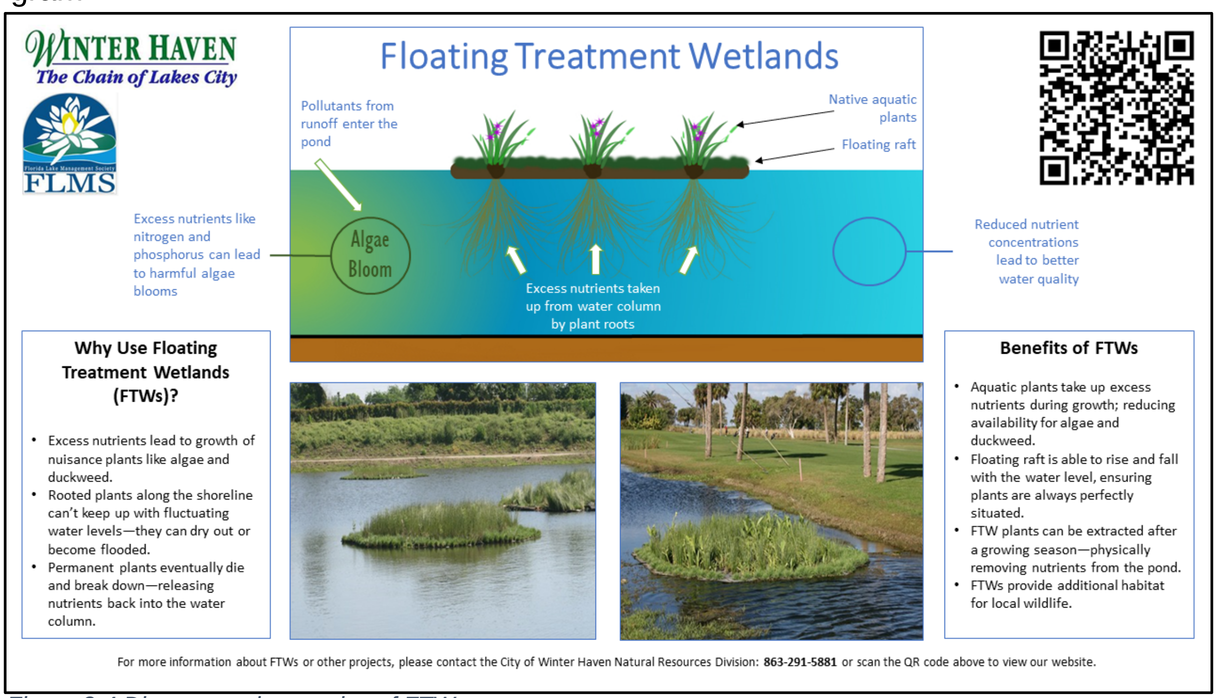

Figure 3-4 Diagram and examples of FTW processes

3.2 In-Lake Initiatives

Aquatic Vegetation Monitoring:

Summary:

The importance of aquatic vegetation on the health of a waterbody has been discussed previously in this report, however the City's role in managing the aquatic plant community must be demonstrated as well. Winter Haven's Natural Resources Division is currently engaged in a long-term data collection project that involves sonar mapping each navigable lake to determine macrophyte abundance while simultaneously collecting samples of each lake's vegetative community in order to ascertain species diversity and evenness. The aim is to collect individual lake data at least once per year to monitor annual and possibly even seasonal changes in the species composition and density of vegetative communities.

The Aquatic Vegetation Monitoring (AVM) process starts with the creation of transect grids with sampling points in ArcGIS (Figure 3-5). Once created, transects and sampling points are uploaded to a sonar/GPS receiver aboard a City vessel. Sonar, which is an acronym for SOund Navigation And Ranging, uses sonic pulses to determine distance to objects underwater. A receiver measures sediment density and depth to the bottom as well as the percentage of the water column occupied by aquatic flora (biovolume). This sonar data is logged as City employees drive along the transect lines while simultaneously collecting vegetation samples at each point, until the entire lake has been covered. Vegetation sampling provides information on species composition and density while the sonar data is used to create a heat-map representation of biological volume—indicating areas of high or low aquatic vegetation abundance. Overlaying the species data on top of the biovolume heat-map creates a graphic that allows users to determine areas that require management such as the elimination of invasive species. A map of Lake Rochelle biovolume and species frequency has been created as an example (Figure 3-6). Furthermore, by making this data available to other agencies, the City helps foster cooperation and incentivize future assistance and funding. This project, for example, provides assistance to the Polk County Natural Resources Division by expediting the process of evaluating areas that require management of invasive species via herbicide application.

Public Benefit:

Aquatic vegetation is a significant component of lake health and understanding it provides multiple benefits to the community. Most visible is the early detection and early response to invasive species identified in the summary. But major changes in plant communities are an early indicator that something negative may be happening in a lake and can serve as a red flag for a pending lake issue allowing time for corrective action to be taken. By understanding the vegetative community staff can help guide the management of species on local lakes towards the types of communities that create stability and health in lake systems.

Support of Mission, Purpose, and Vision:

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 at the table for discussions about management of the resource.

Strategic Goals:

- By the end of 2017 develop baseline data for all Priority 1 & 2 Lakes in the Winter Haven Area
- By the start of the 2018 growing season re-establish the Polk Aquatic vegetation working group

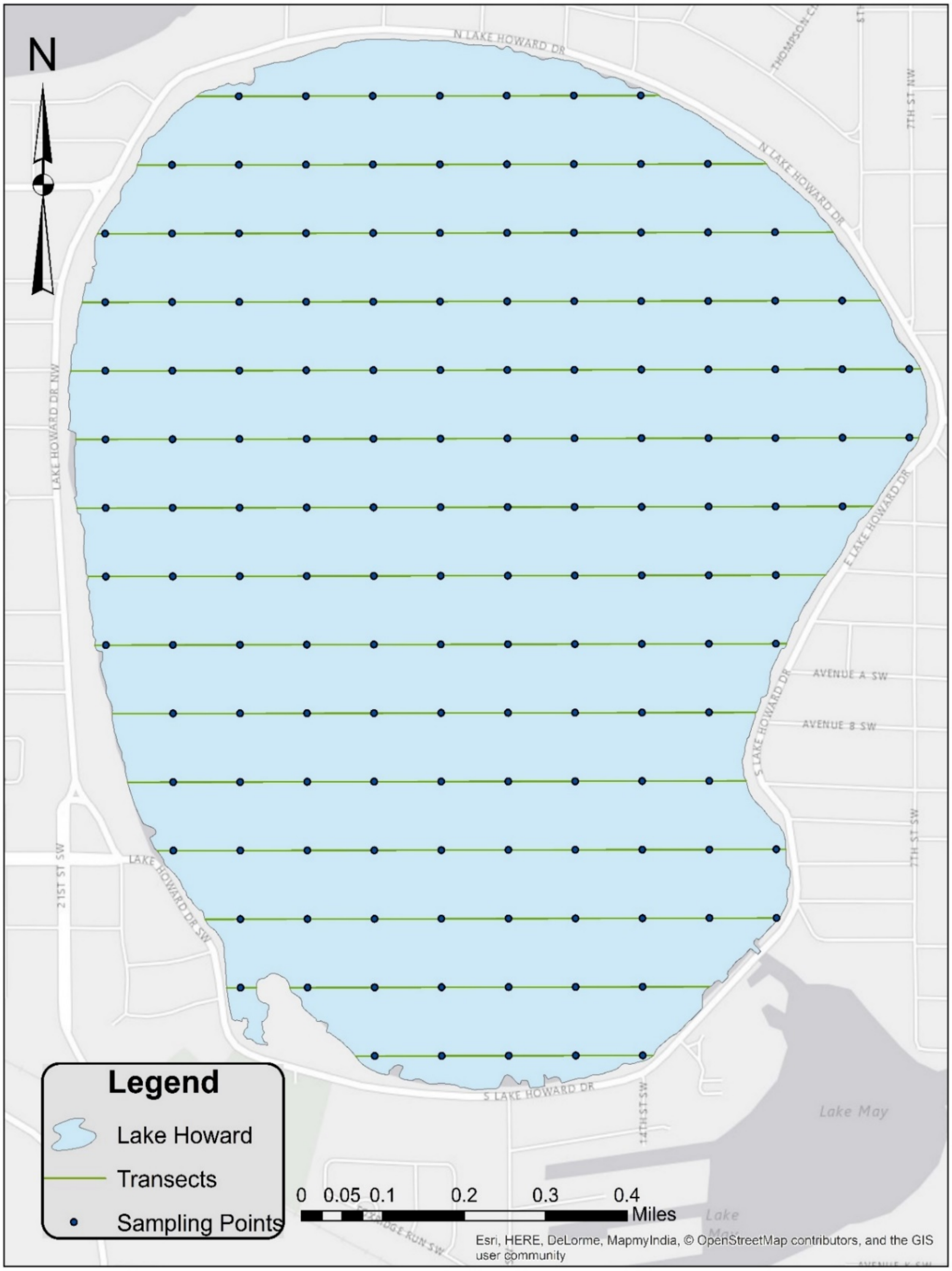

Figure 3-5 Lake Howard transects and sampling points created in ArcGIS

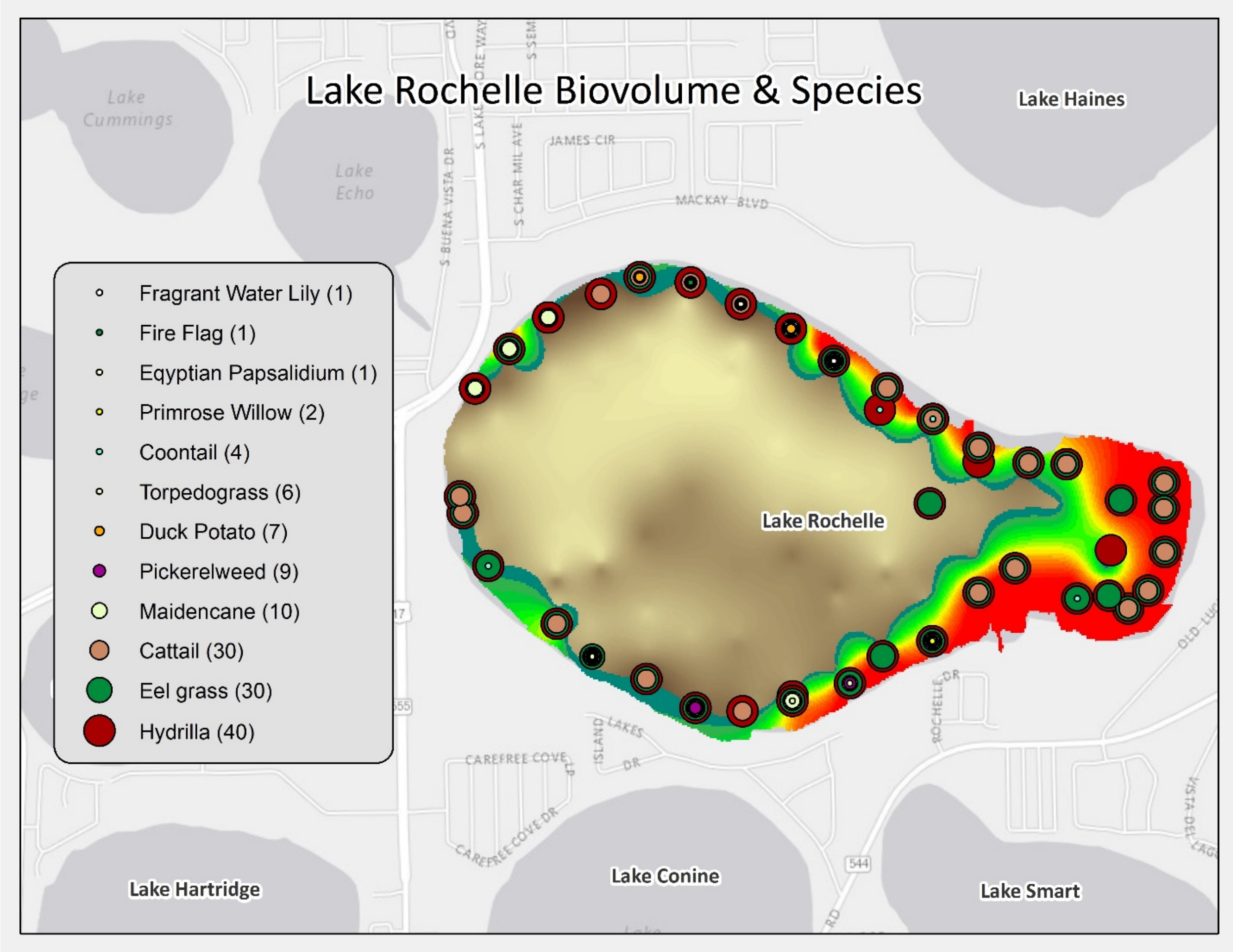

Figure 3-6 Lake Rochelle biovolume heat-map including species identification and density

Hydrologic Monitoring:

Summary:

Hydrologic monitoring looks at the processes relating to water quantity in the area and is critical in understanding the relationships amongst rainfall, surface level changes, and groundwater interactions. Changes is water quality often share a strong relationship with hydrologic fluctuations as well.

The City is currently engaged in monitoring programs that track rainfall accumulation, lake surface level and groundwater fluctuations. Utilizing radar stations and a growing network of atmospheric sensors, the Natural Resources Division collects precipitation data to understand how much water enters the Winter Haven area. Additionally, the observation of surface level and groundwater fluctuations at several Environmental Monitoring Protocol (EMP) sites provide insight into the effects of rainfall and municipal groundwater usage on the numerous waterbodies across the City. All of these metrics are integral in the calculation of the water budget—ensuring the most efficient use of our limited supply.

Public Benefit:

Surface water hydrology is a critical element of water quality management as can be seen by the relationships to water level fluctuations in this report. Understanding this element is necessary to design effective management strategy. This information is immediately useful for things like assessing flood potential prior to a hurricane, but also will prove invaluable for posterity managing the resource.

Support of Mission, Purpose, and Vision:

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 the utmost important to the “diverse user groups” 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.

Strategic Goals:

- By the end of 2017 overhaul existing system for monitoring surface water hydrology.
- By the start of the 2018 rainy season increase coverage of rainfall monitoring stations to better understand localized impacts of rainfall.
- By FY18-19 budget preparations have plan for network expansion laid out.

Nutrient Budgeting:

Summary:

A nutrient budget utilizes external pollutant load modelling data, internal load modelling data, as well as biovolume and species composition data to estimate the amount of nutrients entering and leaving a lake system. External loading, briefly discussed earlier in this report, includes stormwater and surface runoff, atmospheric deposition of nitrogen and phosphorus, and groundwater seepage. Total Maximum Daily Loads (TMDLs) are calculated by modelling for these external inputs. Internal loading accounts for the nutrient cycling or flux from lake sediments and is calculated by evaluating the physical and chemical properties of these sediments. The biological component of a nutrient budget, which will be explained in greater detail in this section, is determined by calculating the amount of nutrients interred by lake aquatic vegetation.

The vegetative portion of the nutrient budget is calculated by linking the average nutrient concentrations of plant tissues with species density values obtained during the vegetative sampling process explained previously. Plant tissue nutrient concentrations, which are determined through laboratory testing, vary from species to species. By virtue of this, average tissue concentrations per unit of dry mass need to be determined for each species found in the lakes studied. In order to relate the biomass variable with sample density, the average dry weight of each density rank is recorded for every species encountered. This process allows scientists to assign a nutrient concentration value to each sample point for a given waterbody. Extrapolating the point data to relate to the biovolume component is the next logical step in this process—allowing the City to estimate the nutrient content of aquatic vegetation in each lake on an annual or seasonal basis.

Public Benefit:

Nutrients bound in vegetation account for a significant portion of nutrient in lakes and understanding this content enables better management decisions. For example if a lake has a significant population of *Potamogeton Illinoensis* knowing it will die back and release its nutrients once it gets cold. A management plan could be devised to remove a known volume of Phosphorus prior to the first cold snap of the year. There is also potential to receive management credit with State and Federal agencies using this type of approach. This is one example of how this data can be used to drive management strategy.

Support of Mission, Purpose, and Vision:

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 at the table for discussions about management of the resource.

Strategic Goals:

- By the end of 2017 develop a plan for creating nutrient budgets for Priority 1 Lakes

Figures

Tables

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