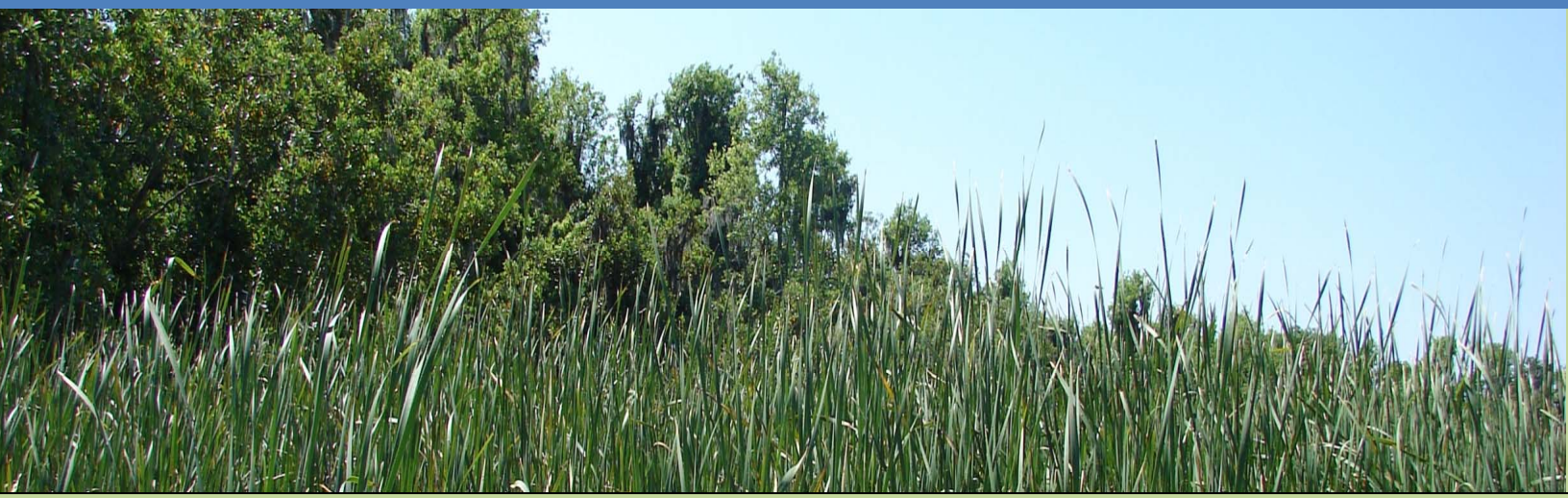
Winter Haven Chain of Lakes
Water Quality Management Plan



Submitted to:

WINTER HAVEN
The Chain of Lakes City

Prepared by:

PBSJ
an Atkins company

Final
December 2010

4030 West Boy Scout Boulevard
Suite 700
Tampa, Florida 33607

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FINAL
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Executive Summary

The Winter Haven Chain of Lakes (WHCL) is at the headwaters of the larger Peace River – Charlotte Harbor watershed. The lakes are located in central Florida, an area of rapid urbanization and commensurate high stormwater runoff and associated nutrient loadings to the lakes. A Water Quality Management Plan (WQMP) was developed for the WHCL to ensure long-term water quality protection and compliance with state and federal water quality regulations. Lakes in the WHCL are shown in Figure ES-1 and lakes for which a TMDL has been adopted are identified.

This WQMP presents a compilation of information relevant to water quality in the 25 lakes, an analysis of water quality and water quality trends, and proposed restoration projects and priorities for the lakes. One of the primary features of this plan is the recommendation of scientifically proven methods for managing lakes as an integrated ecological systems rather than managing based on nutrient inputs alone. Recommendations were also made in consideration of management projects implemented in the past that have had successful results. More specifically, this WQMP:

- Characterizes water quality associated with lakes in the WHCL
- Identifies restoration projects to address water quality issues
- Links restoration projects to lakes based on individual water quality needs
- Provides recommendations for lake restoration priorities

Importantly, 18 of the 25 lakes in the WHCL are designated as impaired by FDEP. Among the impaired lakes, five exhibit improving trends in water quality, while the remaining 13 exhibit declining (or no) trends in water quality. Three of the unimpaired lakes had declining trends in water quality, and none had improving trends. Stormwater treatment projects have been implemented for seven lakes (Howard, May, Lulu, Hartridge, Jessie, Cannon, and Mariana) in the WHCL to reduce nutrient loads to the lakes. Lake Hartridge is the only lake not impaired due to high nutrient levels and all but Cannon and Jessie exhibit improving trends in water quality.

While traditional stormwater treatment projects can successfully reduce external phosphorus loadings to the lakes, historic point and nonpoint source runoff and subsequent sediment accumulation in some lakes resulted in internal phosphorus loads that existing stormwater projects cannot treat. Consequently, both traditional and non-traditional water quality management projects are proposed to address both external and internal phosphorus loading to the WHCL in this WQMP.

In addition to nutrients and chlorophyll *a* (algal growth), factors affecting quality in the WHCL include long-term land use and hydrologic alterations, stormwater runoff, historic point source discharges (particularly phosphorus), extent of submerged aquatic vegetation (SAV) and emergent aquatic vegetation (EAV), lake water levels, and hydrologic connections to forested wetlands and other lakes. A decision key was developed for the WHCL as a means of selecting these projects. These components are therefore included as part of a holistic lake management approach for the WHCL. The link between water quality issues and lake-specific water quality

restoration projects for the WHCL are presented in the context of state and federal regulations, as well as lake management science.

A priority matrix was developed to rank lakes by management needs. Lake priorities were based on water quality (e.g. impairment status and chlorophyll trends), required phosphorus reductions, and lake connections and location. Lakes most likely to benefit from a project were also considered. Lakes were grouped into five tiers based on rank and are summarized below (first tier lakes are the highest priorities).

- **First Tier:** Lakes Mariana, Idyllwild, Little Hamilton, Spring, Haines, and Rochelle are all designated as impaired and were the highest ranked lakes for water quality restoration projects.

- **Second Tier**: Lakes Cannon, Smart, Middle Hamilton, Howard, and Eloise.

- **Third Tier**: These five lakes are designated as impaired and only one of the lakes (Jessie) exhibited a decreasing trend in chlorophyll *a*, while Lakes Mirror, Blue, May, and Lulu all exhibited a decreasing chlorophyll *a* trend.

- **Fourth Tier**: Lakes Summit, Conine, Shipp, Roy, and Hartridge.

- **Fifth Tier**: Lakes Henry, Winterset, Hamilton, and Fannie, none of which are designated impaired or have trends in chlorophyll *a*.

Several projects were proposed as part of the WHCL WQMP, including Stormwater Infiltration Areas (SIAs) that reduce direct runoff and associated external nutrient loads into lakes and redirect surface water flows into ground water. Sediment inactivation/removal projects are proposed to reduce internal phosphorus loading. Other projects, such as planting SAV and EAV provide sustainable means of phosphorus removal and immobilization. Non-native species control, especially for *Hydrilla*, should continue, and maintaining native SAV cover of at least 30 percent is also important. Forested wetland hydration is proposed for valley lakes (historically colored due to forest flooding) in instances in which more color may inhibit the growth of algae. Whole lake aeration in smaller lakes could decrease algae productivity in lakes. Sediment, SIA, and SAV and EAV projects were proposed for all lakes, but not always with the same priority, while forest rehydration, lake aeration, and Floating Treatment Wetlands (FTWs) were proposed for only a few lakes. Projects were ranked lake by lake based on the relative likelihood of improving water quality in a lake. Cost was not a part of the rankings, but relative magnitudes of restoration costs were provided as a means of comparison.

The WQMP is consistent with the Winter Haven Chain of Lakes Surface Water Improvement and Management (SWIM) Plan, state and federal regulations, and a local preference for managing lakes as part of an overall interconnected water resource. This report also relies heavily on previously completed lake studies and reports for the WHCL. The WQMP was developed with cooperative funding from the Southwest Florida Water Management District (SWFWMD) and City of Winter Haven. Restoration projects and planning level cost estimates for the recommended projects are included in this WQMP.

1.0 Introduction

1.1. Project Objective

This report presents a Water Quality Management Plan (WQMP) for the Winter Haven Chain of Lakes (WHCL). The WQMP relies heavily on the results of work performed for three previously completed tasks: a summary and analysis of existing water quality data (WHCL pre-BMAP Assessment, PBS&J 2008), development of criteria for Best Management Practices (BMPs) (WHCL Interim Report, PBS&J 2010), and development of a lake-specific conceptual restoration plan (WHCL Conceptual Restoration Plan, PBS&J 2010). This WQMP was developed with cooperative funding from the Peace River Basin Board of the Southwest Florida Water Management District (SWFWMD) and the City of Winter Haven.

This WQMP describes the link between water quality issues and lake-specific water quality restoration projects in the context of state and federal regulations and documents the process and science by which lake specific restoration projects were selected. More specifically, this WQMP:

- Characterizes water quality issues associated with lakes in the WHCL
- Identifies restoration projects to address specific water quality issues
- Links restoration projects to lakes based on individual water quality needs of each lake
- Provides recommendations for lake restoration priorities

Lake restoration project recommendations were developed to meet the requirements of the federal Clean Water Act and the Florida Department of Environmental Protection's (FDEP) Total Maximum Daily Load (TMDL) program. A TMDL establishes the allowable loadings to a watershed that are necessary for the lake to meet the applicable water quality standards for an identified parameter of concern (e.g. nutrients). Restoration projects and water quality improvements anticipated as a result of the proposed projects, as well as planning level cost estimates for the recommended projects, are included in this WQMP. The WQMP is consistent with the *Winter Haven Chain of Lakes Surface Water Improvement and Management* (SWIM) *Plan*, as well as the *Winter Haven Chain of Lakes Pre-BMAP* (Basin Management Action Plan) *Assessment* (PBS&J 2008) prepared for the FDEP. Lakes in the WHCL are mapped in Figure 1-1 and identified as to whether a TMDL has been developed/adopted (based on Florida's Trophic State Index, TSI) and if the lake is a designated SWIM waterbody. The WQMP is presented in seven sections, listed below.

Section 1. Introduction. The introduction outlines the purpose of the WQMP and presents an overview of the WHCL, including location and physical characteristics.

Section 2. Water Quality Issues Associated with the WHCL. A water quality characterization for the WHCL and the implications of relevant state and federal regulations due to water quality issues are presented in this section.

Section 3.0. Restoration Projects to Address Water Quality Issues. Restoration projects developed to address water quality issues specific to the WHCL and the science on which the projects are based are presented in Section 3.0.

Section 4. Lake-specific Water Quality Improvement Projects. Restoration project recommendations on a lake by lake basis, with more specific details if available (including planning level cost estimates), are presented in this section.

Section 5. Priorities for Lake Restoration Projects. In Section 5, the approach used to develop recommendations and priority restoration projects for lakes are presented.

Section 6. Conclusions and Recommendations. Conclusions and recommendations developed in previous sections of the WHCL WQMP are summarized in Section 6.

Section 7. Literature Cited. Scientific literature and previously prepared reports used to develop this WQMP are documented in the Literature Cited section.

1.2. Project Area

The WHCL is a priority waterbody identified in the SWFWMD SWIM Plan and consists of two "chains" of lakes – the Southern and Northern Chains (Figure 1-1). The watersheds of the Southern and Northern Chains make up approximately 18 and 14 square miles, respectively, of the 32 square mile WHCL watershed (FDEP 2007). The watershed of the WHCL is part of the Peace Creek sub-basin of the Peace River Watershed and is at the headwaters of the 110 mile long Peace River. Water from the Peace River eventually flows into Charlotte Harbor and then the Gulf of Mexico.

The Northern Chain of Lakes includes nine lakes. Water levels in lakes Haines, Rochelle, Conine, and Smart are maintained at the same elevation by a control structure at Lake Smart. Only Lakes Fannie, Henry and Hamilton do not have navigable canals to other lakes. are not connected to other lakes Lake Fannie water level elevations are maintained by water control structures on the canal draining to Lake Fannie from Lake Smart and from Lake Fannie to Lake Hamilton. Water levels in lakes Hamilton, Middle Hamilton, and Little Hamilton are controlled at the same elevations with a structure at the outfall from Lake Hamilton. The outflow from Lake Hamilton begins the Peace Creek Drainage Canal. Lake Henry is also connected to Lake Hamilton via a gated structure, but is not navigable.

The Southern Chain includes lakes Hartridge, Jessie, Idylwild, Cannon, Mirror, Spring, Howard, May, Shipp, Lulu, Roy, Eloise, Little Eloise, Summit, Winterset, and Little Winterset. Lakes Blue and Mariana are connected to the other lakes in the Southern Chain only when seasonal high waters exceed the lake operational levels (i.e. no navigable canals). Little Eloise and Little Winterset lakes were not evaluated separately from Lakes Eloise and Winterset for this report. Sixteen lakes are controlled by one control structure at Lake Lulu. A gated control structure between Lake Blue and Cannon isolates Lake Blue from the Southern Chain. The Southern Chain eventually flows into the Wahneta Farms Drainage Canal and then to the Peace Creek Drainage Canal. However, water discharges infrequently from Lake Lulu, resulting in an extended residence time in the Southern Chain lakes. During periods of discharge, water in the Wahneta Farms Drainage Canal flows to the Peace Creek Drainage Canal and then to the Peace River, although anecdotal evidence indicates that the canal has discharged water from the Southern Chain only three times in the past 25 years.

1.3. Project Area Description

The WHCL watershed is part of the rapidly urbanizing area of central Florida. The City of Winter Haven includes approximately 90 percent of the WHCL watershed. Other cities, including Auburndale, Lake Alfred, Haines City, and Dundee have jurisdiction in the watershed. Prior to urban development, citrus and agriculture (improved pasture) were the predominant land uses in the watershed.

High sandy ridges and lower 'valleys' characterize the WHCL watershed. Historically, virtually all of the rainwater that fell on the sandy ridge areas percolated into the soils that are characterized by high infiltration rates (approximately 6.0 inches/hour, USDA/SCS Polk County Soil Survey 1990), while excess water was stored in the lower valley wetlands. During the dry season, ridge lakes were historically maintained by ground water from the sandy surficial aquifer, which is one of the highest recharge zones for the Floridan aquifer in the Southern West Central Ground Water Basin. Urban development in the WHCL occurred primarily on soils that have high infiltration rates (Figure 1-2). Consequently, rainfall that formerly infiltrated these high recharge areas is now surface water runoff. In contrast, the valley areas were historically characterized by forested and marshy shorelines, the largest of which is Lake Hamilton.

Figure 1-1. TMDL status (adopted or still required) and designated SWIM waterbodies in the WHCL.

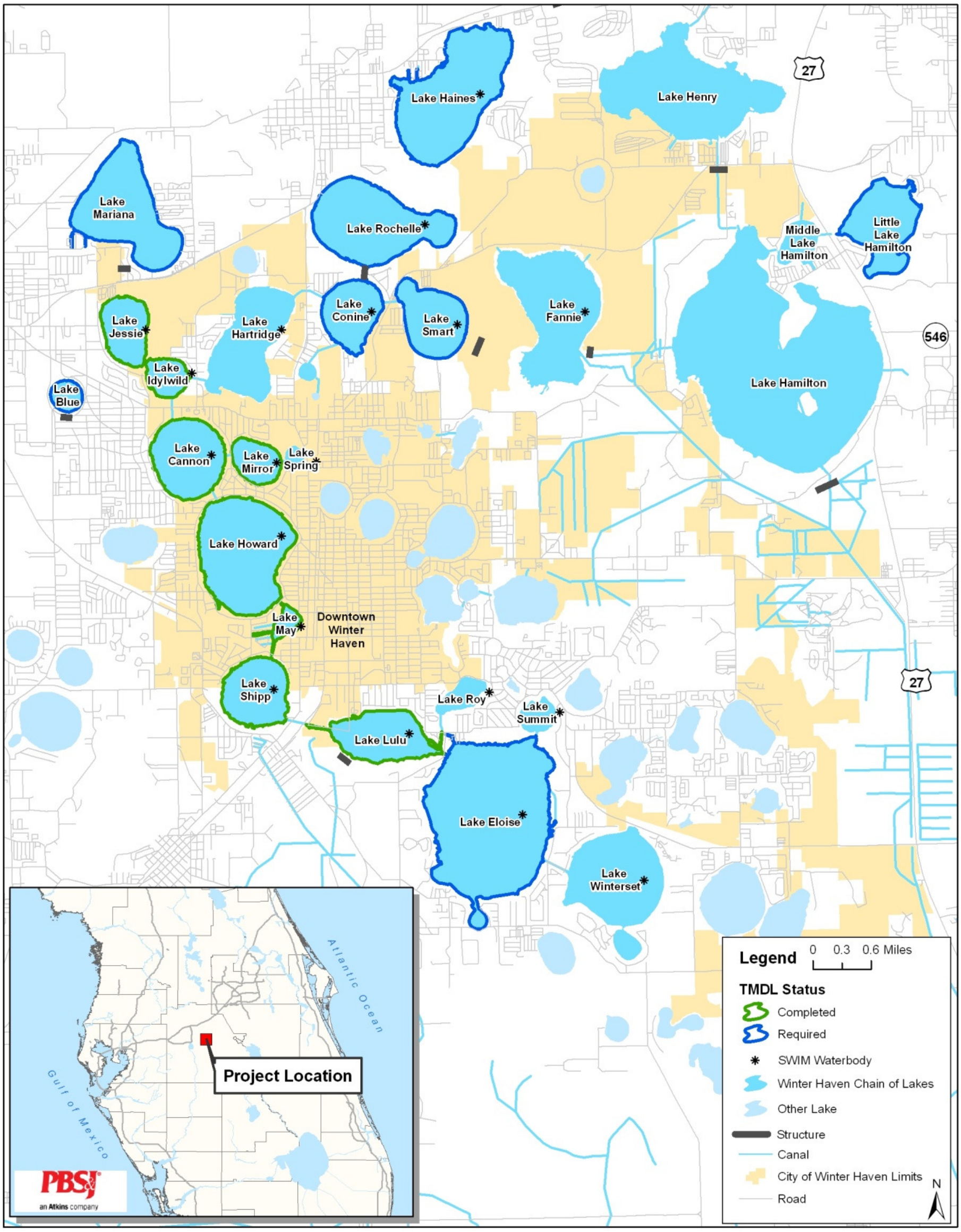
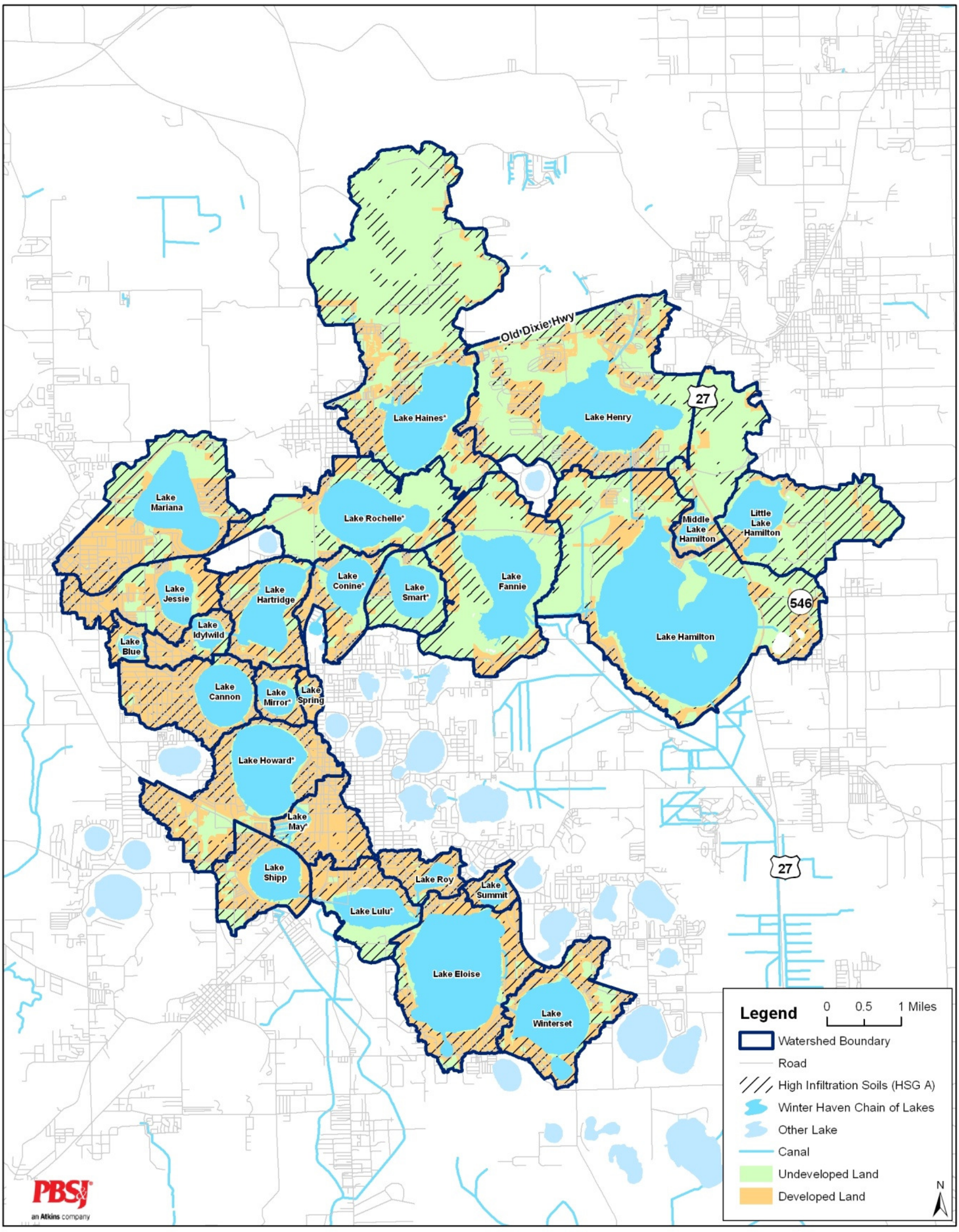


Figure 1-2. Developed and undeveloped areas in the WHCL watershed and high infiltration soils (potential recharge areas).



2.0 Factors Affecting Water Quality in the WHCL

Lake eutrophication is a natural process of increasing nutrient enrichment and biological productivity that can be exacerbated by anthropogenic land uses (Gill *et al*. 2005). The accelerated eutrophication due to human activities is termed "cultural eutrophication". Increased nutrients associated with eutrophication can increase algal growth (algal blooms) (Smith *et al*. 1999), in turn increasing turbidity, particulate organic matter, and dissolved organic particulate matter in lakes.

Historic water quality impacts in the WHCL, the implications of relevant state and federal regulations for water quality restoration, and a characterization of water quality in the WHCL are presented in this section, thereby establishing the need for management projects. In addition to nutrients and chlorophyll *a*, several other factors may influence water quality, including: long-term hydrologic alterations, stormwater runoff, historic point source discharges (particularly phosphorus), extent of submerged aquatic vegetation (SAV) and emergent aquatic vegetation (EAV), and hydrologic connections to forested wetlands. The potential effects of these factors on water quality in the WHCL are discussed here.

2.1. Historic Water Quality Impacts

Historical drainage projects and development patterns throughout the U.S. have altered the hydrologic functions in watersheds and subsequently resulted in long-term impacts to water supply and water quality, flood regimes, and fish and wildlife habitat. The movement and storage of water for human uses such as agriculture, homes, schools, businesses, industry, and roads has relied on drainage and diversion construction projects for many years. In addition, urban development often occurs first in the highest, driest areas with the greatest potential for aquifer recharge. The last areas to be developed are usually those that were historically wet; often these are still prone to flooding.

Hydrologic alterations such as dams, control structures, and drainage canals can adversely affect volumes, locations, and timing of natural stormwater and stream flows, and natural hydrologic functions in the watershed. These changes may be anthropogenic or climate induced. Hydrologic impacts due to urbanization are reported to cause water quality problems such as sedimentation, increased temperatures, habitat changes, and the loss of fish populations and several case studies indicate that these problems are caused by increased runoff volumes and velocities from urbanization and associated increases in watershed imperviousness (EPA 2010). For example, floodplains with substantial hydrologic connection to streamflow may trap (riparian retention) large amounts of sediment and associated nutrients and other contaminants (Brinson 1988, Hupp *et al*. 1993, 2008, Noe and Hupp 2005, 2009). Unfortunately, these water quality functions of floodplains may not apply where there has been widespread alteration of fluvial processes by human activity, e.g. dam construction, channelization, and concentrated land use (Sharitz and Mitsch 1993). In general, these alterations typically disrupt fluvial dynamic equilibrium (Hack 1960) such that the normal floodplain to streamflow connectivity may be decreased or increased (Hupp *et al*. 2009).

Stormwater runoff increases pollutant loads and stormwater collection and conveyance systems. Consequently, pollutants may rapidly wash into downstream receiving waters and adversely impact water quality (Figure 2-1). Pollution from nonpoint sources accounts for most of the water quality problems in the State of Florida. Typically, nonpoint source pollution is associated with stormwater runoff from residential, urban, and agricultural activities and the associated transport of sediments, nutrients, pathogens and pesticides. Urban land uses and activities can also degrade ground water quality and contaminate wells in ground water supply aquifer areas if stormwater with high pollutant loads is directed into the soil without adequate treatment.

Prior to the enactment of Clean Water Act and amendments to the Act in the early 1970s, wastewater discharges to flowing waters were largely unregulated and streams were used to dilute and transport wastes from their sources. While environmental regulations have resulted in substantial improvements in wastewater treatment, wastewater discharges still contribute to increased stream flows and pollutant concentrations in waterbodies.

The Peace Creek watershed has also undergone substantial alteration for the purpose of agricultural and urban development. The higher, drier areas in the headwaters/ridge portion of the watershed were developed first for residential and business use. These high-recharge areas historically helped maintain water levels and water quality in the lakes, streams, and aquifer systems. Historical drainage "improvements" (as opposed to present-day stormwater treatment systems) diverted rainwater that once percolated into the surficial aquifer into the lakes. Regional water withdrawals and commensurate loss of surface water to lower aquifers, and changes in infiltration, flow, and storage have contributed to lowered lake levels and degraded water quality.

Urban development in the WHCL watershed increased the extent of impervious (e.g. pavement, rooftops) surfaces, increased stormwater runoff, decreased infiltration of water into aquifers, and increased pollutant loads to the lakes (stormwater runoff is the third largest cause of lake water quality impairment in the U.S. (EPA 2003)). Navigable canals constructed in the 1920s ultimately decreased water storage. Some lakes were lowered for agricultural or urban uses and wetlands were drained for agricultural uses. Lowering lake levels decreases hydrologic connections between some lakes and forested wetlands and can adversely impact habitat available to fish and wildlife during the wet season.

While point source discharges have been eliminated from those lakes that had them, nutrient issues from non-point and past point source discharges may persist in the lake sediments and extend the time before a lake returns to a steady state, i.e. the rates of sediment phosphorus release are in equilibrium with newly established rates of labile (available to plants) phosphorus deposition (Lewis *et al*. 2007).

Regional water withdrawals from the Floridan aquifer for urban, mining, and agricultural activities have decreased aquifer water levels and lowered the potentiometric surface (water levels in Floridan aquifer wells) by as much as 50 feet (SWFWMD 2007, Figure 2-2). While the center of the drawdown has shifted from Polk County during the period of predevelopment to 1975 to Hillsborough and Manatee counties in 2000, aquifer declines have greater impacts in areas with less developed confining units and leaky lakes as is the case in the Winter Haven area.

Figure 2-1. Impacts to watershed due to conversion from natural landscapes to urban development (PBS&J 2007).

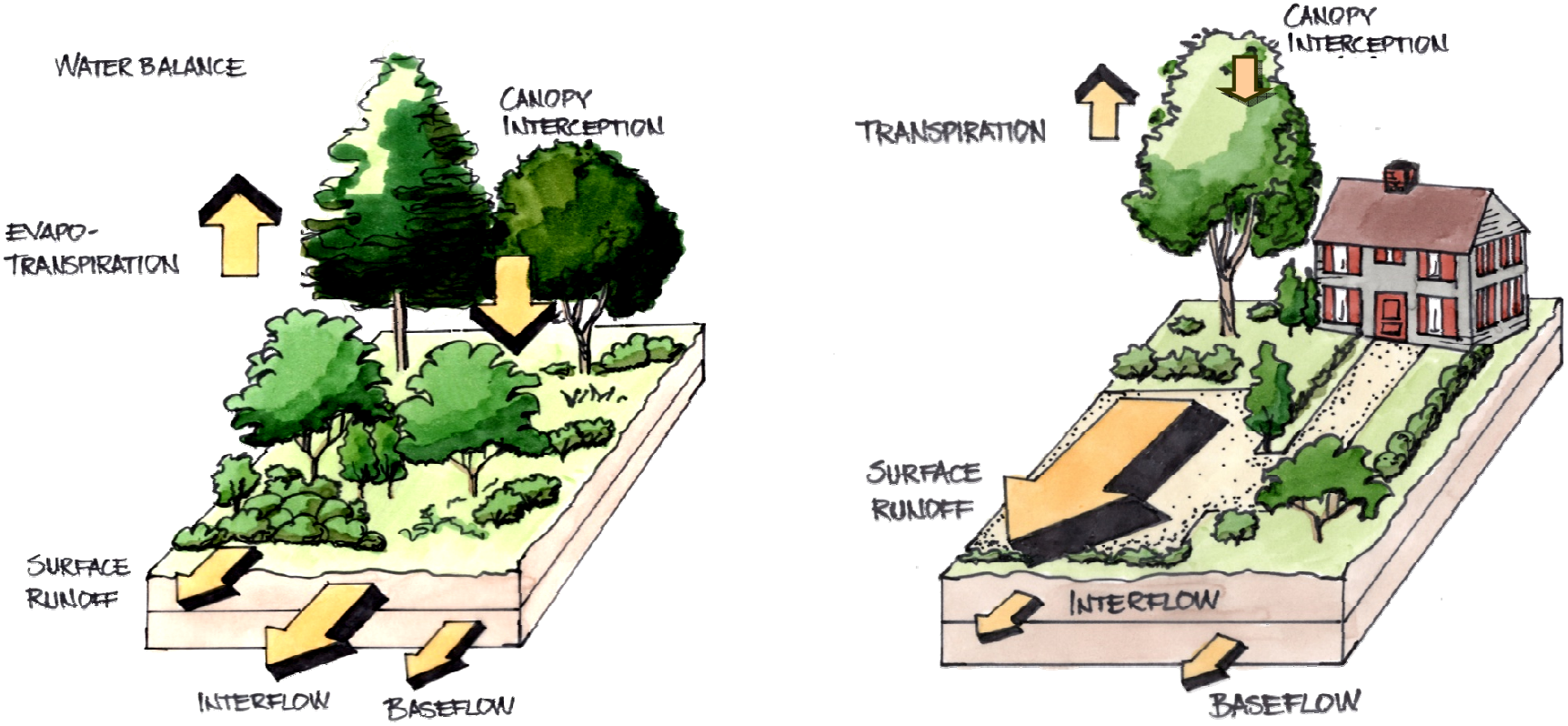
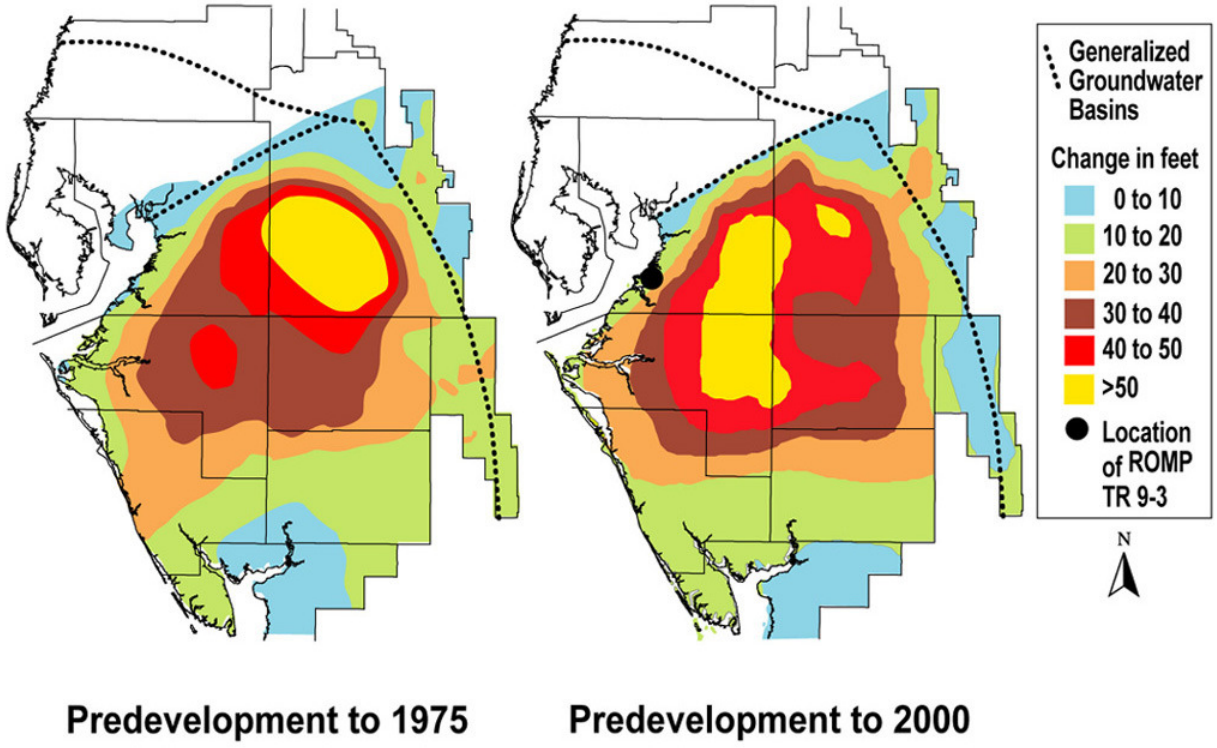


Figure 2-2. Relative, long-term changes in the potentiometric surface of the Floridan aquifer (SWFWMD 2007).



In addition to anthropogenic impacts to water quality, natural, long-term seasonal rainfall patterns and associated hydrologic (ground water and surface water) changes affect water quality. Large rainfall events can increase stormwater and associated pollutant loads into lakes, while low rainfall can result in declining aquifers and low lake levels. In central Florida, the summer wet season accounts for nearly 60 percent of the 52 inches of total average annual precipitation. Streams, wetlands, and surficial ground water levels are typically at their lowest during May (end of dry season) and highest during September and October (end of wet season). Intense El Niño/Southern Oscillation (ENSO) events can result in atypical, extended periods of heavy rainfall during the typically dry season and dramatically alter the annual hydroperiod. Short term extremes of high and low flows influence the watershed budget over periods of years, while larger cyclic periods may cover a number of decades.

The City of Winter Haven is taking a long-term planning approach to addressing water resources, including water supply, water quality, flooding and natural systems, by implementing its recently approved (December 2010) Sustainable Water Resource Management Plan (SWRMP). The SWRMP points to nearly a century of drainage practices that have discharged water during times of need, low water levels in lakes, hydrologic alteration that has affected water quality, and declining aquifer recharge. The SWRMP is also consistent with the SWFWMD Southwest Water Use Caution Area (SWUCA), established in 1992, which includes ensuring sufficient water supply for existing and projected reasonable beneficial uses as one of four recovery goals. The SWRMP is primarily focused on Winter Haven, but incorporates all of

the Peace Creek Watershed, which also includes all or parts of Auburndale, Lake Alfred, Haines City, Lake Hamilton, Dundee, Lake Wales, Alturas, Wahneta, Bartow, Eagle Lake and unincorporated Polk County. The SWRMP focuses on planning principles that will ensure that adequate water is available for people, industry, agriculture, and the environment.

2.2. State and Federal Regulations and Water Quality Impairments: Total Maximum Daily Loads (TMDLs), Numeric Nutrient Criteria (NNC), Pollutant Load Reduction Goals (PLRGs)

Under section 303(d) of the Clean Water Act, Florida (like all states) is required to develop a list of impaired waters (waters that do not meet the water quality standards set by the State of Florida), establish priority rankings for listed waters, and develop TMDLs for these waters. EPA determines if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and various and affiliated EPA regulations. In 2010, EPA proposed and then adopted rules to establish NNC.

The FDEP is responsible for developing and implementing TMDLs for impaired waterbodies in Florida, and therefore in the WHCL. A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet its appropriate water quality standards, which are based on the waterbody type (i.e. lake, stream, estuary) and designated use(s) (e.g. potable water supply, recreation). The WHCL is designated by FDEP as "Class III fresh waterbodies, with a designated use of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife."

Florida's TSI is a measure of the degree of impairment, or eutrophication, of a lake based on total phosphorus (TP), total nitrogen (TN), and chlorophyll *a*. Currently, FDEP uses a TSI value of 60 to establish impairment (and corresponding TMDLs) for the WHCL, consistent with the TSI established previously by the SWFWMD for the WHCL pollutant load reduction goals (PLRG) (USF 2005). However, paleolimnological data used to develop the TSI goal were based on only five of the WHCL, and may be over- or under- protective of individual lakes. In the WHCL, the lakes are managed based on levels of nutrients and chlorophyll *a* combined.

Sixteen lakes in the WHCL are listed as impaired for nutrients based on Florida's TSI. Lakes in the WHCL are listed in Table 2-1 and identified as to impairment, TMDL status (TMDL required or adopted), and other information relevant to meeting a TMDL. For example, Lake Howard is designated as impaired and therefore has a TMDL that identifies load reductions necessary to meet water quality standards (declared in 2005). As part of the TMDL implementation, FDEP develops Basin Management Action Plans (BMAPs) to identify specific BMP projects to achieve the TMDLs, that is, to restore and protect impaired waters. The BMAP implemented for Lake Howard successfully reduced nutrient loading to the lake, however, Lake Howard remains impaired due to factors including legacy phosphorus released from lake sediments.

Table 2-1. WHCL lakes identified by impairment and TMDL status.

Lake	WBID #	Chain	If Impaired, Year Declared	If Delisted, Year of Delisting	TMDL Developed and Adopted	TMDL Needs to be Developed
Fannie	14882	Northern	2005	2005*		
Henry	1504A	Northern				
Hamilton	15041	Northern				
Hartridge	1521I	Southern	2005	2005*		
Winterset	1521A	Southern	2005	2005*		
Roy	1521O	Southern				
Summit	1521M	Southern				
Smart	1488A	Northern	2005			X
Mariana	1521L	Southern	2010			X
Little Hamilton	15001	Northern	2010			X
Eloise	1521B	Southern	2005, 2010	2005*		X
Spring	1521G1	Southern				
Haines	1488C	Northern	2005			X
Mirror	1521G	Southern	2005	2010†	X	
Idylwild	1521J	Southern	2005	2010†	X	
Howard	1521F	Southern	2005	2010†	X**	
Middle Hamilton	15002	Northern				
Cannon	1521H	Southern	2005	2010†	X	
Shipp	1521D	Southern	2005	2010†	X	
Rochelle	1488B	Northern	2005			X
Lulu	1521	Southern	2005	2010†	X**	
May	1521E	Southern	2005	2010†	X**	
Jessie	1521K	Southern	2005	2010†	X	
Conine	1488U	Northern	2005			X
Blue	1521Q	Southern	2010			X

Based on Group 3, Cycles 1 and 2 Verified Impaired and Delist List (FDEP 2010)

Shaded cells- Not Applicable

* Delisted based on paleolimnological data supporting historic eutrophic conditions

† Delisted due to TMDL adoption requiring phosphorus load reduction

**TMDL Required phosphorus load reduction met

2.3. Nutrient Impairments and Criteria for Water Quality Restoration

Annual mean chlorophyll *a* values and TSI values are the primary means for assessing nutrient impairment in a waterbody, pursuant to FDEP's Impaired Waters Rule (IWR), as approved by EPA. Several lakes in the WHCL are designated by FDEP as impaired for nutrients based on elevated annual average TSI values, which is calculated for Florida lakes using TN, TP, and chlorophyll *a* data, as described previously. To better address nutrient impairment from nonpoint (non-regulated) sources, FDEP recently revised the IWR to include numeric nutrient impairment thresholds.

EPA (2010) classified Florida's lakes into three groups: colored (> 40 PCU), clear and alkaline (≤ 40 PCU), clear and acidic (≤40 PCU), and then assigned TN, TP and chlorophyll *a* criteria to each lake group based on the biological response (chlorophyll *a* production) to TN and TP levels in Florida's lakes (Figure 2-3, Figure 2-4). An accompanying approach is also proposed that allows Florida to adjust TN and TP criteria for a particular lake if TN and TP data are sufficient to demonstrate that the chlorophyll *a* criteria will still be met. The EPA NNC are calculated using lake alkalinity in addition to color.

NNC established by EPA are not site-specific and consequently, some criteria thresholds may be inappropriate for particular regions. EPA's proposed NNC distinguishes clear, acidic lakes from clear, alkaline lakes for the WHCL using 20 mg $CaCO_3$/liter alkalinity. This distinction is important because the chlorophyll *a* and nutrient targets for clear acidic lakes are much lower (more stringent) than those for clear alkaline lakes. Alkalinity data are unavailable for the majority of lakes in the WHCL. As such, specific conductivity was used as a surrogate for alkalinity to evaluate the WHCL.

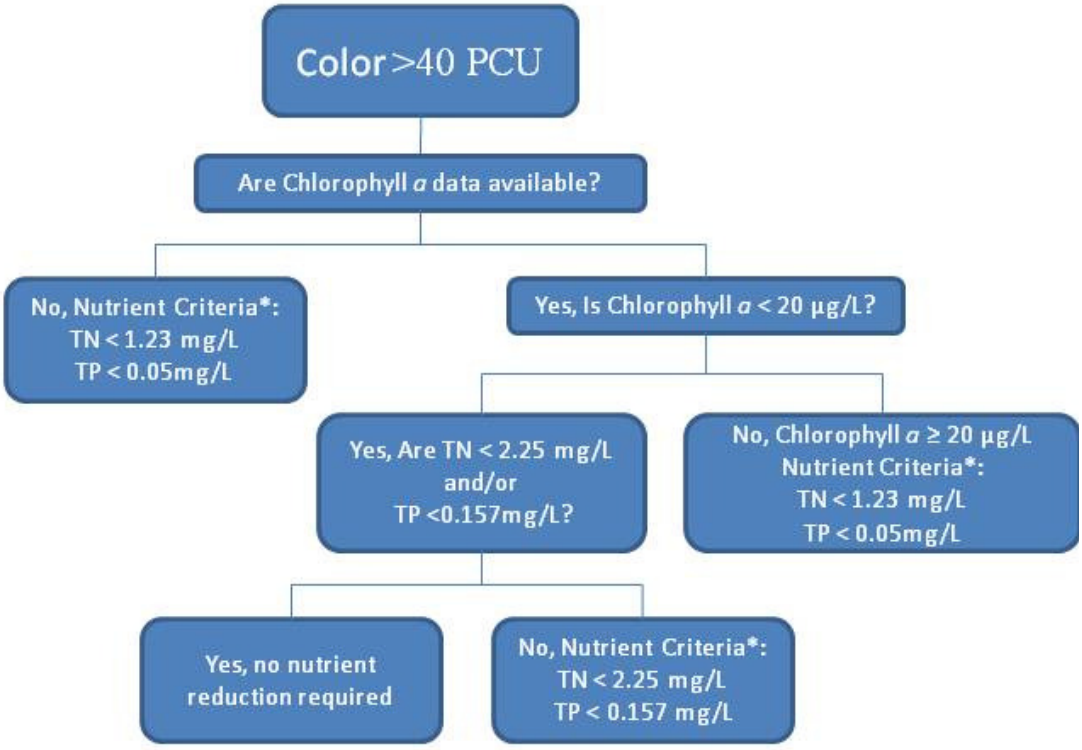
Local lake specific conductivity data indicated that 164 µmhos/cm was an appropriate surrogate for the 20 mg $CaCO_3$/liter alkalinity as the threshold specific conductivity for a lake to be classified as clear and alkaline rather than clear, acidic. In fact, there will be a mechanism/process to have site specific alternative criteria (SSAC) established, contingent upon submittal of scientifically defensible recalculations that meet the requirements of Clean Water Act Section 303(c) and approval by the EPA. Consequently, 164 µmhos/cm was used to classify lakes for identifying lake-specific NNC values in this WQMP. Using this information, lakes in the WHCL were classified as clear and colored, and alkaline and acidic (PBS&J 2008) and lake-specific nitrogen, phosphorus, and chlorophyll *a* values were calculated to provide "targets" for meeting NNC.

EPA chlorophyll *a* NNC values, in-lake geometric mean (1997 to 2007) chlorophyll *a* values, and chlorophyll *a* percent concentration reductions required (if any) to meet NNC chlorophyll *a* values are listed for each of the WHCL (colored and clear, acid and alkaline) in Table 2-2. Similarly, EPA TP and TN NNC values, in-lake geometric mean TP and TN values, and percent concentration reductions in TP and TN necessary to meet NNC are listed in Table 2-3. Annual and long-term (1997-2007) geometric means were calculated for chlorophyll *a*, TN, and TP for each lake as outlined in the EPA NNC. The median percent chlorophyll *a* reduction for the 25 lakes is 27, indicating that a chlorophyll *a* reduction of about 27 percent is needed for lakes in the WHCL to meet the proposed EPA NNC criteria. Lakes Fannie, Hamilton, Hartridge, Henry,

Little Hamilton, Summit, and Winterset have geometric mean chlorophyll *a* levels (1997 to 2007) below their relevant thresholds, although they may exceed the proposed values in some years: impairment is established by failure to meet criteria more than once in three years. Insufficient chlorophyll *a* data are available in Lake Roy for NNC comparison.

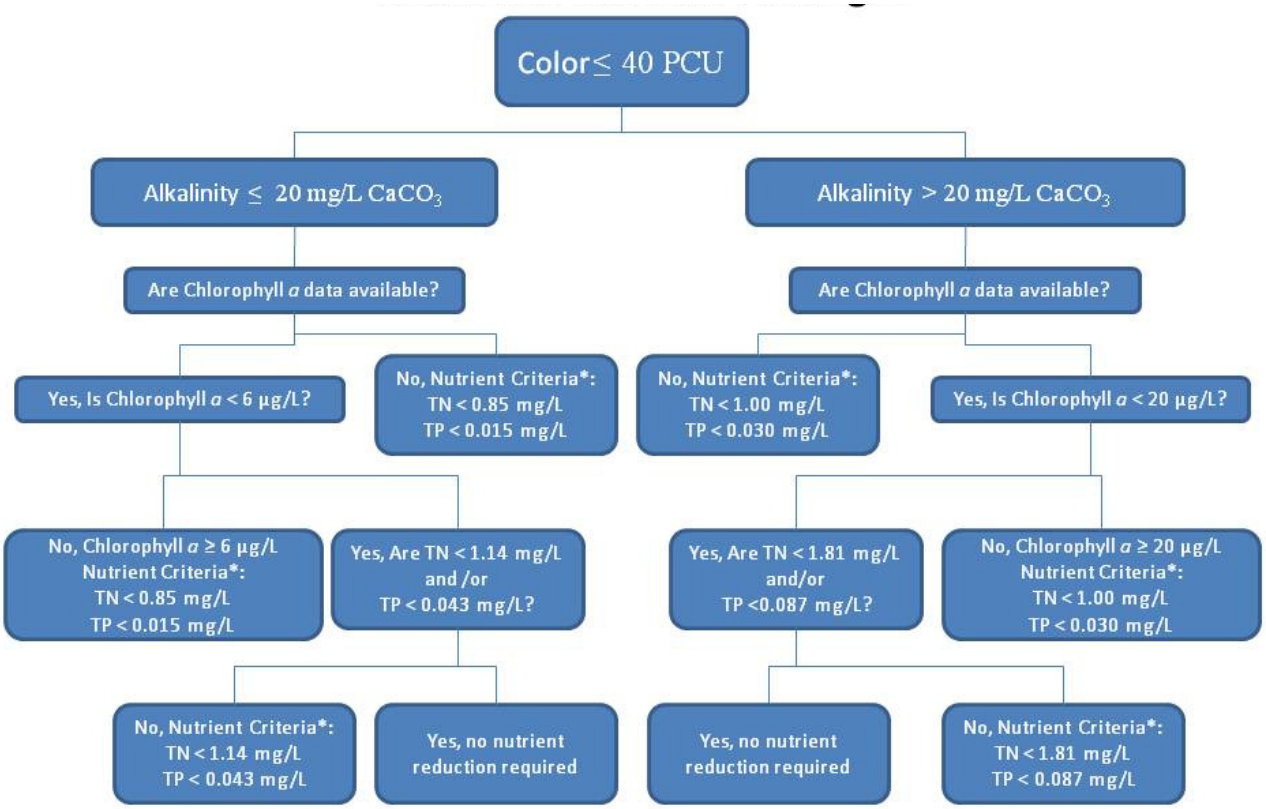
Target and geometric mean TP values and percent TP reductions for lakes in the WHCL are listed in Table 2-3. The mean (geometric) percent TP reduction required for all the lakes combined is 19 percent and represents the reduction needed to meet the EPA NNC. The median TN reduction for the listed values is 10 percent, although phosphorus control is considered more important for water quality in the WHCL when compared with nitrogen (FDEP 2007).

Figure 2-3. EPA numeric nutrient criteria guidance for high color lakes.



*Nutrient criteria are performance based; an exceedance more than once every three years results in non-compliance

Figure 2-4. EPA Numeric nutrient criteria guidance for low color lakes.



*Nutrient criteria are performance based; an exceedance more than once every three years results in non-compliance

Table 2-2. Target and geometric mean chlorophyll *a* values (1997 to 2007) for WHCL using EPA method (2010) modified for locally-derived specific conductivity values for alkalinity.

Lake	Chlorophyll *a* NNC (µg/L)	If >1 Exceedance, then Impaired	In-lake Geometric Mean Chlorophyll *a* (µg/L)	Percent Chlorophyll *a* Reduction Required	Clear or Colored	Locally-derived: Acidic or Alkaline
Blue	6	Impaired	62	90	Clear	Acidic
Cannon	20	Impaired	27	26	Clear	Alkaline
Conine	20	Impaired	32	37	Clear	Alkaline
Eloise	20	Impaired	33	39	Clear	Alkaline
Fannie	20	Unimpaired	12	0	Colored	NA
Haines	20	Impaired	39	49	Colored	NA
Hamilton	20	Unimpaired	9	0	Colored	NA
Hartridge	20	Unimpaired	15	0	Clear	Alkaline
Henry	20	Unimpaired	5	0	Colored	NA
Howard	20	Impaired	34	41	Clear	Alkaline
Idylwild	20	Impaired	26	22	Clear	Alkaline
Jessie	20	Impaired	28	29	Clear	Alkaline
Little Hamilton	20	Impaired	18	0	Clear	Alkaline
Lulu	20	Impaired	39	48	Clear	Alkaline
Mariana	20	Impaired	23	12	Clear	Alkaline
May	20	Impaired	42	53	Clear	Alkaline
Middle Hamilton	20	Impaired	30	33	Colored	NA
Mirror	20	Impaired	38	48	Clear	Alkaline
Rochelle	20	Impaired	26	22	Clear	Alkaline
Roy	20	Unimpaired	ID	ID	Clear	Alkaline
Shipp	20	Impaired	60	67	Clear	Alkaline
Smart	20	Impaired	29	30	Colored	NA
Spring	20	Impaired	22	9	Clear	Alkaline
Summit	20	Unimpaired	15	0	Clear	Alkaline
Winterset	20	Unimpaired	15	0	Clear	Alkaline

NA=not applicable
ID= Insufficient data

Table 2-3. Target and geometric mean values (1997 to 2007) for TP and TN for WHCL using EPA (2010) method and modified using locally-derived specific conductance threshold values for alkalinity.

Lake	TP NNC (mg/L)	Geometric Mean TP (mg/L)	TP Reduction Required (percent)	TN NNC (mg/L)	Geometric Mean TN (mg/L)	TN Reduction Required (percent)
Blue	0.015	0.102	85	0.85	2.22	62
Cannon	0.030	0.036	17	1.00	1.12	11
Conine	0.030	0.057	48	1.00	1.28	22
Eloise	0.030	0.036	17	1.00	1.22	18
Fannie	0.157	0.035	0	2.25	0.93	0
Haines	0.050	0.063	20	1.23	1.35	9
Hamilton	0.157	0.094	0	2.25	1.18	0
Hartridge	0.030	0.030	0	1.00	0.73	0
Henry	0.157	0.111	0	2.25	1.06	0
Howard	0.030	0.039	23	1.00	1.27	22
Idylwild	0.030	0.045	33	1.00	0.90	0
Jessie	0.030	0.054	44	1.00	0.94	0
Little Hamilton	0.030	0.035	15	1.00	1.15	13
Lulu	0.030	0.049	39	1.00	1.24	19
Mariana	0.030	0.031	3	1.00	1.10	9
May	0.030	0.057	47	1.00	1.35	26
Middle Hamilton	0.050	ID	ID	1.23	1.51	18
Mirror	0.030	0.054	44	1.00	1.32	24
Rochelle	0.030	0.047	37	1.00	1.07	7
Roy	0.030	ID	ID	1.00	ID	ID
Shipp	0.030	0.052	42	1.00	1.76	43
Smart	0.050	0.056	10	1.23	1.42	13
Spring	0.030	ID	ID	1.00	0.93	0
Summit	0.030	0.027	0	1.00	0.89	0
Winterset	0.087	0.019	0	1.81	0.77	0

ID= Insufficient Data

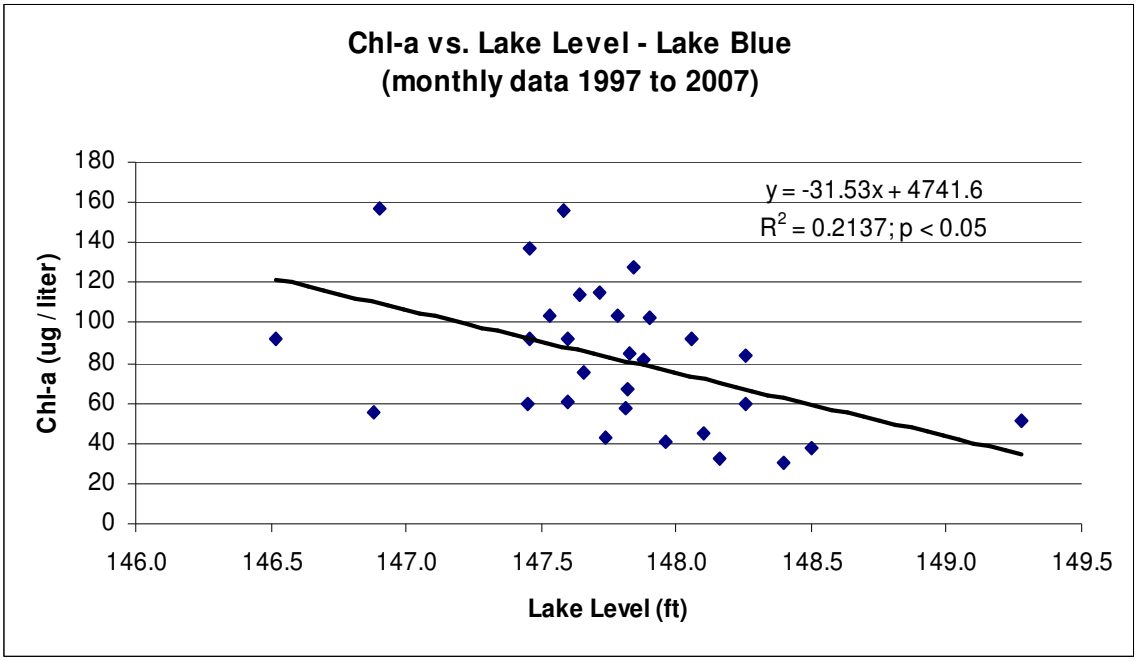
2.4. Lake Water Levels

2.4.1. Present Day Levels

Present relationships and long term trends in the WHCL and water quality were evaluated for lakes with at least 10 continuous years of both lake level and water quality data to be consistent with water quality analyses described in the Pre-BMAP Report (PBS&J 2008) and Interim Report (PBS&J 2010). The relationships between lake levels and chlorophyll *a*, TN, and TP were examined for all lakes with adequate data (Table 2-4). Data were tested for statistically significant relationships using linear regression ($p < 0.05$). For example, the relationship between

lake water level and chlorophyll in Lake Blue (Figure 2-5) indicates a significant, albeit weak, inverse relationship: higher chlorophyll *a* levels correspond to lower lake levels.

Figure 2-5. Relationship between lake level (feet NGVD) and chlorophyll *a* for Lake Blue.



Data were inadequate to evaluate potential relationships in five of the lakes and relationships were inconsistent among the remaining lakes. While many relationships were significant ($p < 0.05$), correlations (r^2 values) between lake levels and nutrient and chlorophyll *a* values were not strong. For example, chlorophyll *a* and lake levels had no relationship in 12 lakes, but correlations were negative in four lakes, and positive in four lakes. The highest r^2 value for a chlorophyll *a* and lake level relationship was 0.35 for Lake Shipp, i.e. 35 percent of the variation in chlorophyll *a* levels in Lake Shipp could be explained by variation in lake levels. The relationships between lake levels and water quality should therefore be considered as guidance rather than rules per se.

Four lakes exhibited positive chlorophyll *a* - lake levels relationships, suggesting that higher runoff volumes increase both lake water levels and nutrient and chlorophyll *a* levels. In contrast, lakes Blue, Henry, Howard and Shipp had negative chlorophyll *a* – lake level relationship, suggesting that internal processes such as sediment re-suspension and re-mineralization may influence chlorophyll *a* more than external nutrient loads from stormwater runoff. At least two lakes (Shipp and Howard) previously received point source discharges (Table 2-5) and many of the lakes have received effluent from domestic and/or industrial discharges, sometimes for many decades (Table 2-5).

Table 2-4. Regression analysis of lake levels and chlorophyll *a*, TN, and TP using closest lake with adequate lake level data (data from PBS&J 2008).

Lake	Chlorophyll *a*	TP	TN	Stage Data Source
Blue	Neg	None	Neg*	Blue
Cannon	Pos	Pos	Pos	Howard
Conine	Pos	Pos	None	Conine
Eloise	None	None	None	Shipp
Fannie	ID	ID	ID	ID
Haines	None	Pos	Pos	Haines
Hamilton	None	None	None	Hamilton
Hartridge	Pos	Pos	Pos	Howard
Henry	Neg	Pos	None	Henry
Howard	Neg	None	Neg*	Howard
Idylwild	Pos	Pos	Neg	Howard
Jessie	None	Pos	None	Howard
Little Hamilton	ID	ID	ID	ID
Lulu	None	Neg	Neg	Shipp
Mariana	ID	ID	ID	ID
May	None	Neg	Neg	Shipp
Middle Hamilton	ID	ID	ID	ID
Mirror	None	None	None	Mirror
Rochelle	None	None	None	Rochelle
Roy	ID	ID	ID	ID
Smart	None	None	None	Smart
Shipp	Neg	Neg	Neg	Shipp
Spring	None	None	None	Mirror
Summit	None	Pos	Neg	Shipp
Winterset	None	None	None	Shipp

"NEG" = inverse relationship found. "NEG*" = inverse relationship found with evidence of nitrogen fixation. "POS" = positive relationship found. "NONE" = no significant relationship found.
"ID" = insufficient data for analysis.

Table 2-5. Summary of available information on point source discharge history of various WHCL lakes (compiled from various sources).

Lake	Status	Discharge Source	Comments
Eloise	diverted in June 1975	Cypress Gardens WWTP	9.5 m^3/d, 30kg P/year; 85 kg TN/year
Haines	ended in 1992	Lake Alfred WWTP	77 percent lake TP load; 1,515 kg P/year; 2,230 kg TN/year, 0.3 million gallons/day (MGD)
Howard	discharge until 1977, capable of overflow until 1980	Jan-Phyl Village WWTP	~1,500 lbs TP/year
Conine	discharges ended	Birds Eye	
Conine	discharges ended	Pipping Packing Co.	
Conine	discharges ended	Florida Citrus Salads	
Conine	ended in 1992	City of Winter Haven (CWH) WWTP	
Lulu	ended in 1977	CWH WWTP	90 percent lake TP load, domestic secondary effluent, 1.8 MGD in 1976
Lulu	discharges ended	Bordo's citrus processing plant	
Lulu	discharges ended	Snively plant	
Lulu	discharges ended	Swift Fertilizer plant	
Shipp	discharges ended	Robert Brothers vegetable processing	Sewer discharge until connected to the City, then sludge from tankers
Shipp	discharges ended	Bordo's citrus processing plant	
May	closed in 1949	Imhoff Plant	
May	discharges ended	Citrus	
May	discharges ended	Velda	
Jessie	discharges ended	Wastewater treatment plant effluent	

Shaded cells represent no available data. Data on total period of operation unavailable.

2.4.2. Historical Trends in Lake Levels

Longer term patterns in lake level changes were examined using lake level data from available sources, including SWFWMD and the U.S. Geological Survey (USGS) over a period of record (POR) that, in some cases, went back to the 1940s. Lake level data for lakes Cannon, Eloise, Hamilton, Howard, Lulu, and Smart suggest that these lakes are lower than they were 50 to 60 years ago. Heath (1961) also noted that Polk County lake levels had likely been affected by drainage as well as water withdrawals for public supply, agriculture, and/or phosphate mining and concluded that "…The construction of a canal to remove water from what previously had been a landlocked lake, for example, would change the stage characteristics…" Further, Kaufman (1967) concluded that "Pumpage from the Floridan aquifer has increased the hydraulic gradient between the lake surfaces and the piezometric surface and may be responsible in part for lowered lake levels in this area." These conclusions, and the data for several of the lakes, contrast with conclusions of Spechler and Kroening (2006), who found little evidence of recent

declines in lake levels in Polk County (see Table 2-6). For example, Lake Clinch exhibited a significant decline in water levels from 1960 to 2003, while Scott Lake exhibited a significant incline, and both had relatively weak correlations (28 percent).

Spechler and Kroening (2006) found that only half of the 14 lakes they examined in Polk County exhibited evidence of a change in lake levels over the period of 1960 to 2003, and two (Scott Lake and Lake Mariana) had significant increases in lake levels during that time. However, with the exception of Lake Smart, lake level trends suggest lake level declines mostly during the 1940s and the 1950s. Consistent with the Spechler and Kroenig (2006) work, data for lakes Cannon, Eloise, Hamilton, Howard, Lulu, and Smart exhibit a wide range of lake levels over the past 20 to 30 years, however, there is no apparent continued decline in water levels over the past two to three decades.

Table 2-6. Summary of lake level trends in Polk County (Spechler and Kroening 2006).

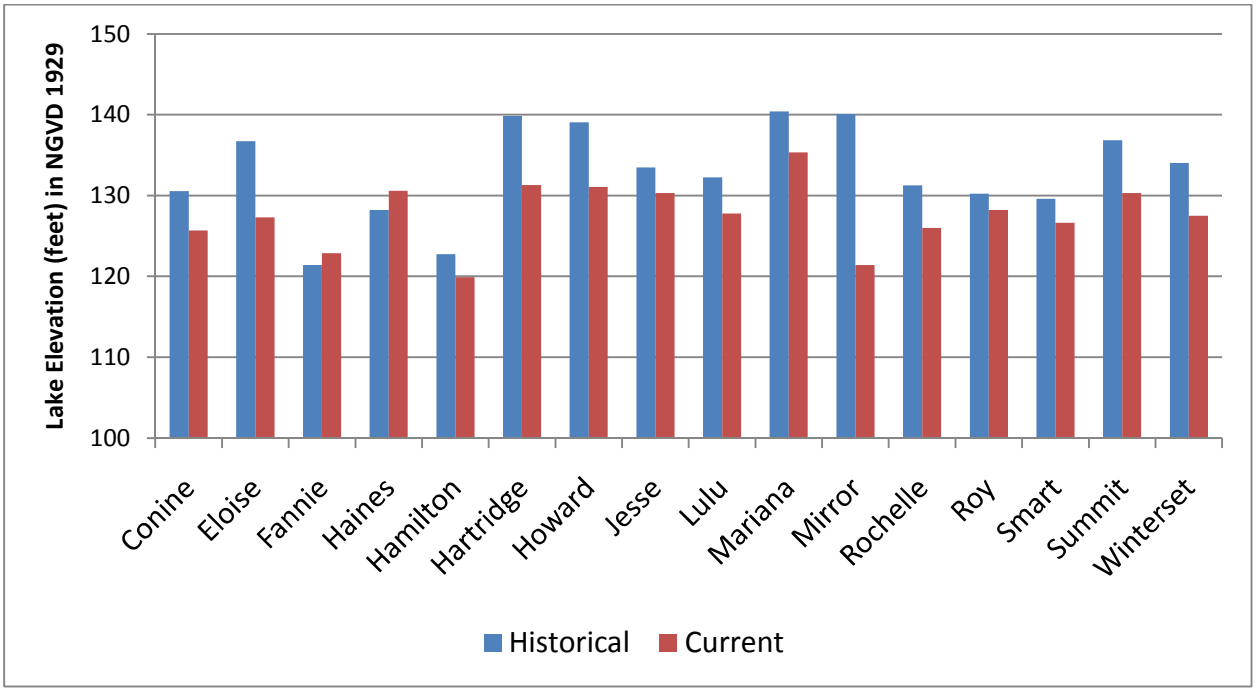
Lake Name	POR Analyzed	Kendall's tau (correlation)
Lake Clinch	1960-2003	-.28*
Lake Parker	1960-2003	.15
Crooked Lake	1960-2003	-.40*
Lake Hamilton	1960-2002	.01
Scott Lake	1960-2002	.29*
Mountain Lake	1960-1986, 1989-1999,2000-2003	-.53*
Lake Hancock	1960-2002	.08
Lake Howard	1960-2003	.11
Lake Mariana	1960-2003	.98*
Lake Deeson	1960, 1965-2003	.17
Lake Otis	1960-2003	-.08
Reedy Lake	1960-2003	.09
Lake Marion	1960-1993, 1998, 2001-2003	-.23*
Lake Wales	1960-2003	-.29*

*Indicates results of seasonal Kendall-Tau test is statistically significant ($p<0.05$)

Further analysis of lake level trends was completed using Geographic Information System techniques (GIS) to integrate elevation data and historic photography and existing lake edges. Historic lake edges were identified using General Land Office Survey (GLOS) maps (circa 1850) and data obtained from FDEP Bureau of Survey and Mapping (BSM), Land Boundary Information System (LABINS) website. Present day lake edges were established by referencing SWFWMD 2006 land use data and 2008 aerial photographs. Historic and present day lake level elevations for the lakes with adequate data are graphed in Figure 2-6.

Analyses indicate that most of lakes in the WHCL system (14 of 16 in Table 2-4) are at lower elevations than in the 1850s or earlier. This finding is supported by anecdotal observations from various sources (e.g. Stokes 1999). The average reduction in lake level elevations, from estimated historical conditions, is approximately five feet.

Figure 2-6. Comparison of lake level elevations (feet NGVD) for historical (1850s) and current (2005) conditions.

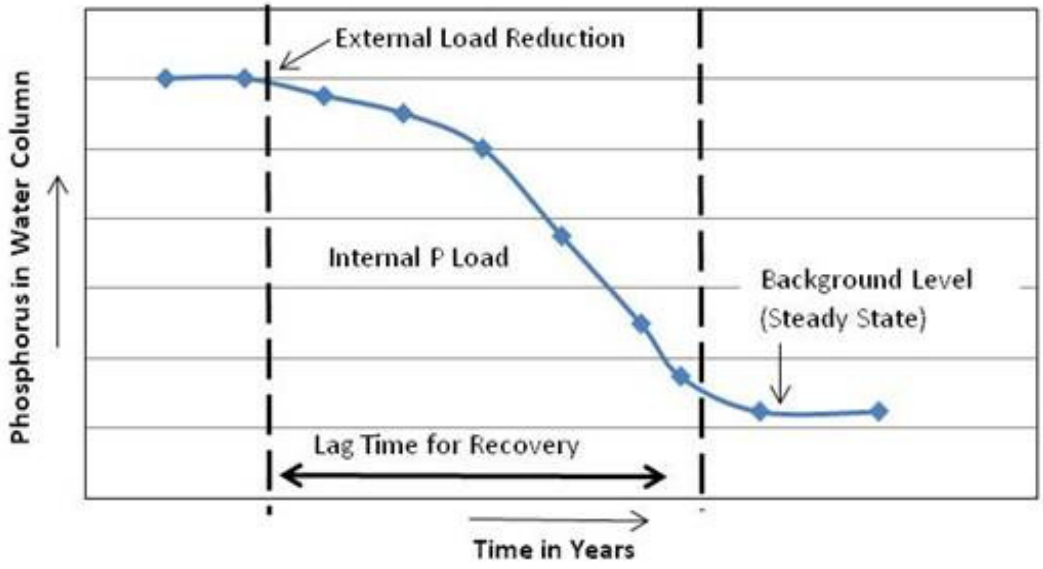


2.5. Historic Point Source Discharges and Legacy Sediments

Although the WHCL TMDL report (FDEP 2007) reports no current wastewater discharges to lakes in the WHCL, "legacy effects" of these prior discharges could delay or preclude improvements in water quality until and unless accumulated sediments are appropriately addressed. The impact of phosphorus inputs from lake sediments on water quality was not examined in the WHCL TMDL (FDEP 2007), but should be part of the development of lake restoration strategies.

Phosphorus inputs into lakes include external sources from the watershed and internal sources from the lake sediments. Phosphorus flux from sediments is sometimes sufficient to maintain anthropogenic eutrophication of a lake even when external phosphorus loads have been reduced or eliminated (Larsen *et al*. 1979, Ryding 1981). Consequently, after watershed management strategies reduce external phosphorus flux (e.g. stormwater treatment), recovery to a steady state (no net efflux of phosphorus from sediments into the water column) can be delayed many years if mechanisms controlling internal phosphorus flux due to sediments are not included in restoration plans (Haggard *et al*. 2005, Hullebusch *et al*. 2005) (Figure 2-7). Phosphorus from sediments occurs via two mechanisms: 1) diffusion of dissolved phosphate into the water column, and 2) the release of sediment pore water phosphorus or release of phosphorus adsorbed to sediment particles into the water column. Seasonal variation in phosphorus release into the water column has been attributed to changes in redox status and phosphorus concentration gradients at the sediment-water interface (Penn *et al*. 2000).

Figure 2-7. Influence of reduced external phosphorus reductions on phosphorus in water column (after Reddy *et al.* 1999).



The type of lake may also influence the effect of legacy phosphorus on water quality in the WHCL. Lakes in the WHCL watershed can be characterized as ridge or valley lakes, as described in section 1.0 of this WQMP. Ridge lakes are typically associated with sandy areas with high ground water recharge at higher elevations when compared with valley lakes, which are often dominated by surface water flows and located at lower elevations. Ridge lakes typically have marsh-dominated shorelines compared with forested wetlands that often characterize valley lakes. Ridge lakes, particularly those with a history of point source discharges, can be more susceptible to impacts from nutrient-enriched bottom sediments when compared with valley lakes (i.e. see Bachman *et al.* 2000). Sediments disturbed by wind or wave action can re-introduce nutrients into the water column and cause phytoplankton blooms. For valley lakes, lower lake levels can "disconnect" the lake from historical swamp shorelines, reducing the benefits of wetland-derived tannins that buffer the effects of increased nutrients (PBS&J 2008).

Phosphorus release into the water column can result from less dilution of internal nutrient loads due to lower water volumes and greater potential for wind-induced sediment resuspension with shallower water depths. For example, the Lake Dynamic Ratio concept for Florida lakes (Bachman *et al.* 2000) was used to predict decreases in sediment resuspension frequency (from once/week to once/two weeks) due to a 4 ½ feet increase in water levels in Lake Hancock (Tomasko *et al.* 2009). The study concluded that "…increases in effective water depth of Lake Hancock would likely bring about an improvement in water quality, due in part to conditions being less favorable for resuspension of bottom sediments." For Lakes May, Shipp, and Lulu, ERD (2010) reported that "… windy conditions increased total suspended solids (TSS) by approximately 37 percent in Lake May, 33 percent in Lake Shipp, and 53 percent in Lake Lulu."

Decisions regarding management and restoration of wetlands and aquatic systems are often difficult and controversial because they involve regulating phosphorus loads from external

sources. Implementation of phosphorus reduction goals can have significant costs and economic impacts and therefore an understanding of the physical, chemical, and biological processes that regulate water quality in the system is paramount. The effectiveness of phosphorus management can be measured by knowing: 1) the baseline phosphorus concentration of surface water, sediments, and biota, and 2) the mass phosphorus imports and export (budget) in the system.

Results from the ERD (2010) sediment study were used to calculate the length of time expected before the internal phosphorus loading reaches background conditions (i.e. steady state) for Lakes May, Shipp, and Lulu. Phosphorus decay to time of labile phosphorus depletion from sediments is expected to take more than twenty years in all three lakes (May- 403 years; Shipp- 76.3 years, Lulu- 142.4 years) (see individual lake descriptions in Section 4.0 for greater detail).

2.6. Rainfall and Lake Levels

Monthly average total rainfall data in Polk County for the 1915-2008 POR obtained from SWFWMD were used to evaluate monthly, annual, total wet season, and total dry season rainfall, as well as five-year moving averages for the POR. Wetter and drier periods of rainfall were apparent from trends in annual, but not monthly, total rainfall. During the 1950s, there were extended periods of wetter than average conditions, while two of the driest periods in the last 70 years occurred during the years 1999 to 2001 and 2006 to 2008. Both droughts corresponded with low rainfall during both wet and dry seasons. Dry season rainfall totals in 2001 and 2002 were the two lowest total recorded during the last 70 years (PBS&J 2010). In contrast, wet season rainfall in 2004 was the highest recorded over the POR, the same year central Florida was affected by hurricanes Charley, Frances, and Jeanne during the same six weeks.

Historic lake level data from SWFWMD and USGS were sufficient to examine long term water levels trends in lakes Fannie, Hamilton, Howard, and Smart. Data were graphed and smoothed using appropriate statistical and graphing software. Differences between rainfall and lake levels varied among lakes and time lags between rainfall events and lake levels were also apparent (for example, in Lake Hamilton, Figure 2-8). The maximum lake level response to increased rainfall is limited by outflow from the lake.

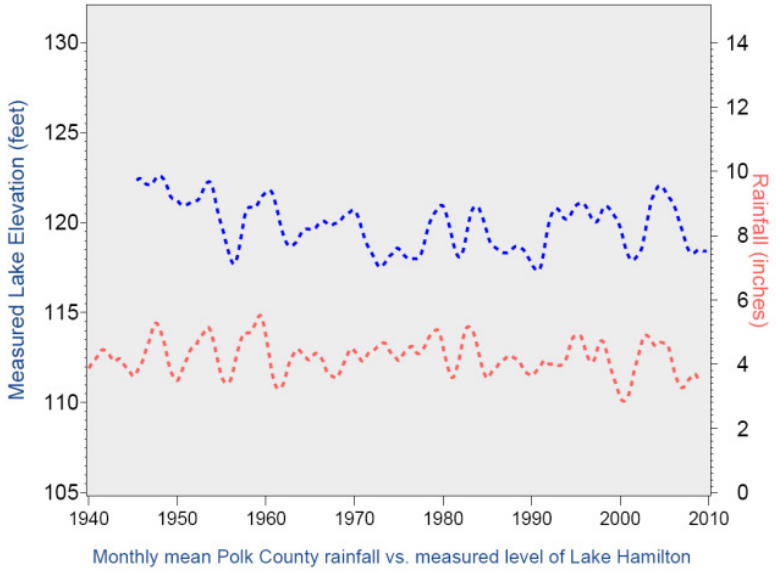
The relationship between measured lake levels and antecedent rainfall was evaluated for lakes using analyses of correlation between lake levels and antecedent rainfall, regressions for quantifying a predictive relationship and testing whether the relationship was significant ($p < 0.05$). The analyses were performed using SAS statistical software (Cary, NC 2009).

Results of analyses are graphed for lakes Fannie, Hamilton, Howard, and Smart in Figure 2-9. The “fit” of the relationships is illustrated by the 95 percent prediction lines, which include nearly all the observations. The regression models use the generalized form presented below.

Lake level = $\beta\alpha + (\beta_1 \times rain_1) + (\beta_2 \times rain_2) + (\beta_3 \times rain_3)$, where:

β_α = line intercept
β_1 = slope for "short-term (i.e. 3 months)" rainfall (linear and/or non-linear)
β_2 = slope "long-term (i.e. 12 months)" rainfall (linear and/or non-linear)
β_3 = slope "longer-term (i.e. 21 to 24 months)" rainfall (linear and/or non-linear)

Figure 2-8. Comparisons of lake levels and rainfall for Lake Hamilton.



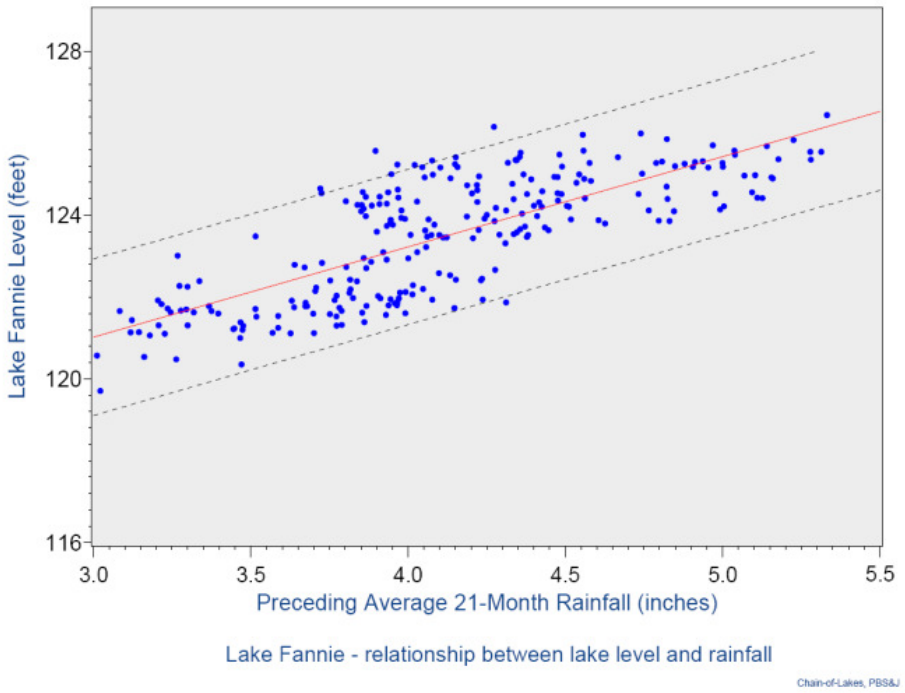
Approximately 60 percent (r^2 = 0.60) of the observed variation in monthly lake levels in Lake Fannie and Lake Hamilton can be explained by rainfall during previous three and 12 months (Table 2-7). Similar r^2 values resulted from regression models for Lakes Howard and Smart by also accounting for rainfall during the previous 12 months. The positive relationship between antecedent rainfall conditions and water levels is illustrated for the four lakes (Figure 2-9).

These results indicate that lake levels reflect longer term rainfall conditions rather than only recent rain events. Therefore, ground water from the surficial aquifer may influence lake water levels more than recent rainfall, particularly during the dry season. Restoration activities that increase recharge to the surficial aquifer would, then, also improve water quality.

Table 2-7. Summary of model results for lake levels and antecedent rainfall.

Lake Level	Intervals for Rainfall			r^2 Value
Lake Fannie	3 month	21 month	Not significant	0.60
Lake Hamilton	3 month	24 month	Not significant	0.57
Lake Howard	3 month	12 month	24 month	0.58
Lake Smart	3 month	12 month	24 month	0.61

Figure 2-9. Comparisons of lake levels and rainfall patterns in lakes Fannie, Hamilton, Howard, and Smart, for selected model terms.



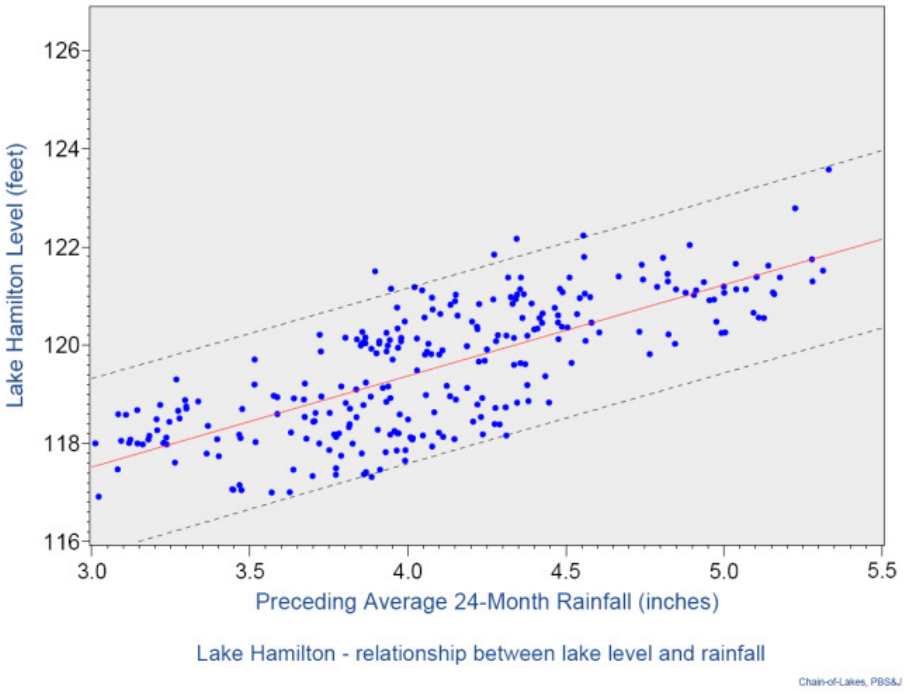
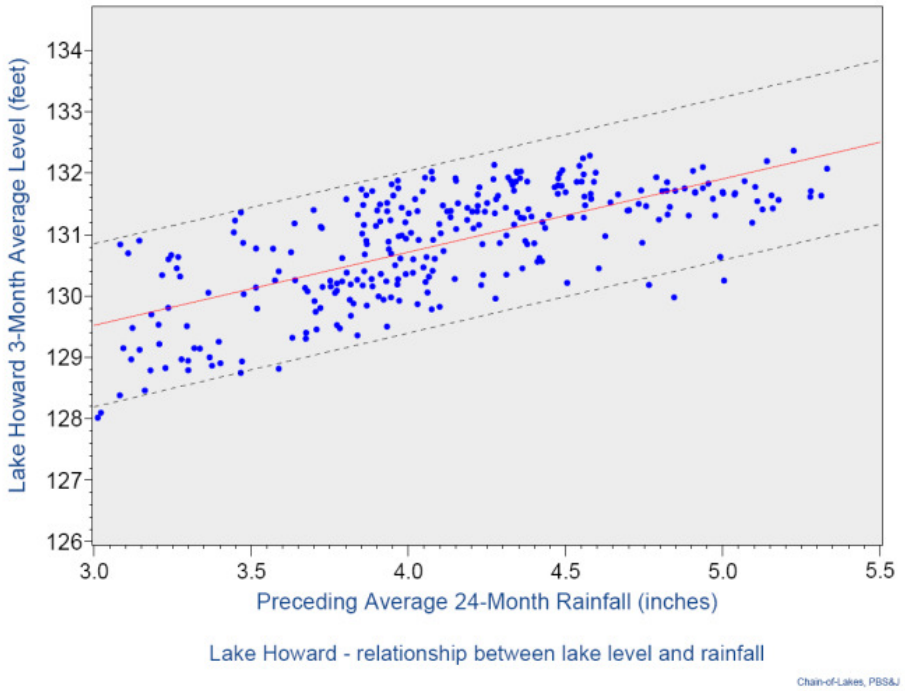
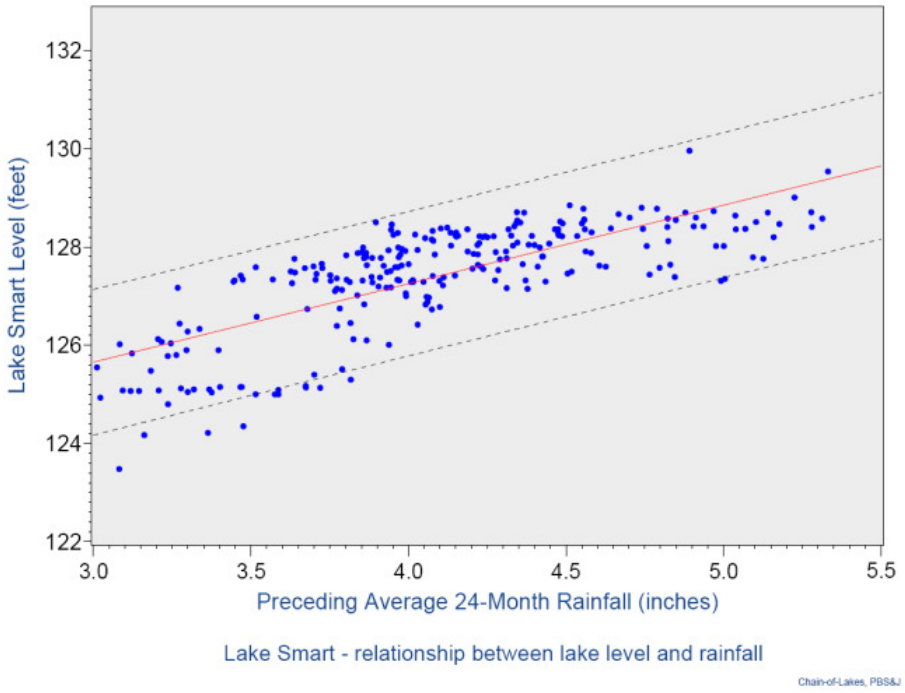


Figure 2-9 (continued)
Comparisons of lake levels and rainfall patterns for selected model terms.





2.7. Lake Color: Valley Lakes and Forested Wetlands

Lake color, nutrients and chlorophyll *a* (as a measure of algae abundance) data for the WHCL were examined to evaluate the effect of lake color on the relationship between increased nutrients on algae abundance in a lake (Table 2-8). As an example, lakes with median color levels less than or equal to 50 PCU (ridge lakes) and greater than 50 PCU (valley lakes) were compared. The 50 PCU threshold was based on the relationship between color and nutrients for the WHCL (PBSJ 2010). That is, lakes in the WHCL with color less than or equal to 50 PCU had elevated phytoplankton biomass, but lower TP levels ($p = 0.05$), although TN levels were no different between low and high color lakes. These results are evidence that in the higher color valley lakes, phytoplankton biomass is more strongly influenced by color than phosphorus.

A graph of phosphorus and chlorophyll *a* for colored lakes Henry and Lulu (Figure 2-10) further illustrates the effect of color on nutrients: higher TP in Lake Henry does not correspond to higher levels of chlorophyll *a*. Similarly, low color in Lake Lulu corresponds to high chlorophyll *a*, while high color in Lake Henry corresponds to low chlorophyll *a*, (Figure 2-11) indicating that the most likely factor moderating chlorophyll *a* concentrations in Lake Henry is the elevated color.

Table 2-8. Mean and median values of water quality parameters for lakes with color ≤ 50 PCU and color > 50 PCU (1997 to 2007).

Statistic	Chlorophyll *a* (µg/L)		TP (mg/L)		TN (mg/L)	
	PCU ≤ 50	PCU > 50	PCU ≤ 50	PCU > 50	PCU ≤ 50	PCU > 50
Mean	31.0	20.2	0.046	0.076	1.201	1.161
Median	28.0	13.6	0.041	0.070	1.103	1.089

Figure 2-10. Relationship between in lakes Henry and Lulu.

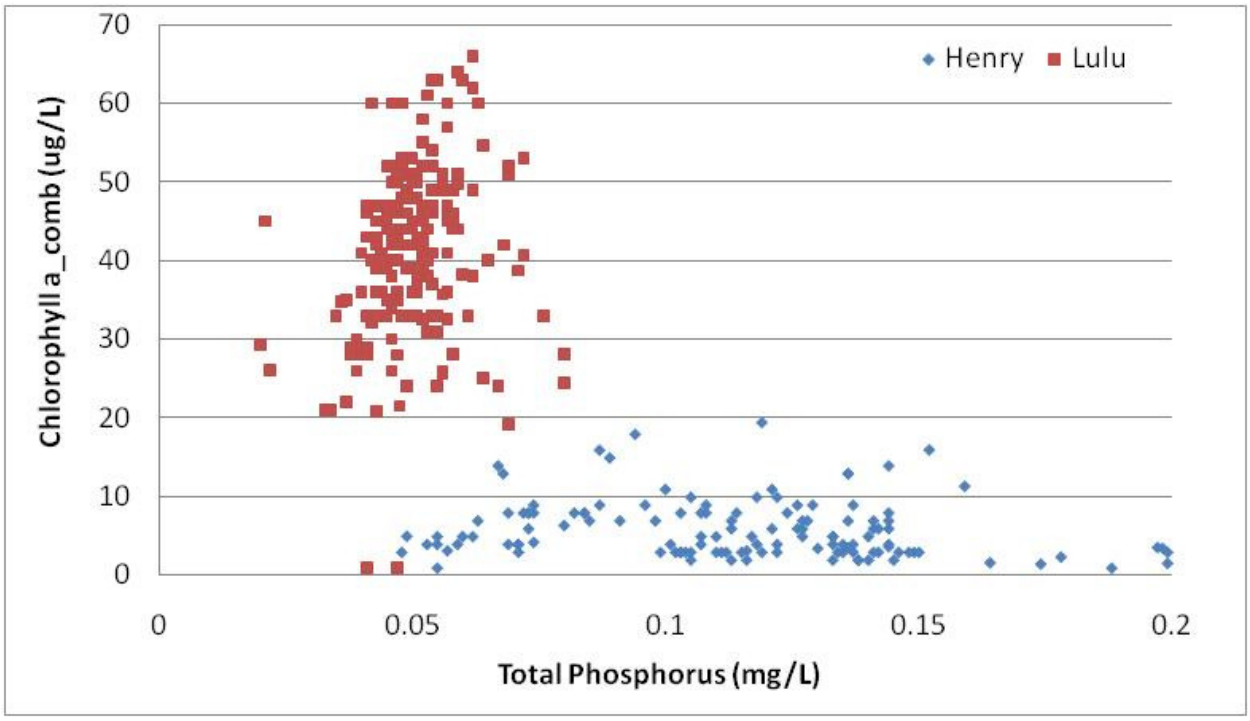
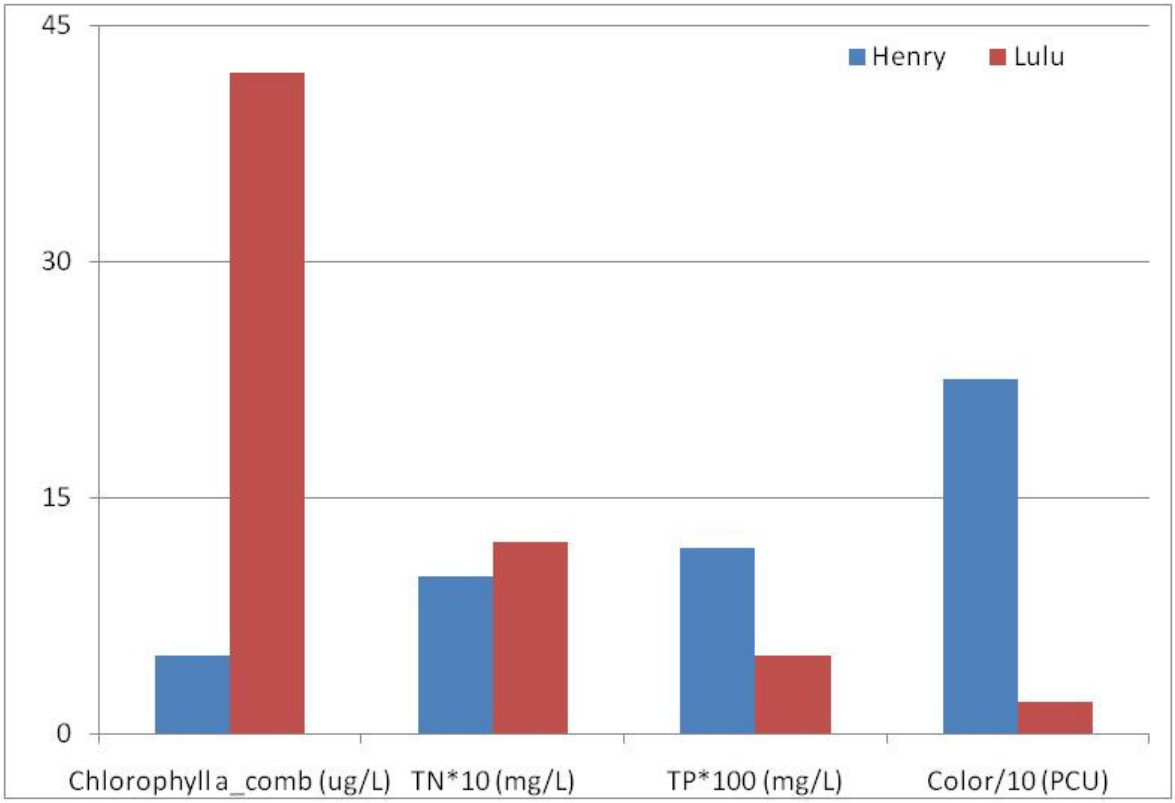


Figure 2-11. Median concentrations of chlorophyll *a*, TN, TP and color in Lakes Henry and Lulu (1997 to 2007).



Sources of color for lakes in the WHCL system (PBS&J 2008) were examined by evaluating relationships between lake chemistry and landscape features. Results indicated that the presence of forested wetlands on the immediate shoreline (within 500 feet of the lake edge) explained the greatest amount of variability in levels of color: the greater the extent of forested wetlands, the greater the color (i.e. tannins) in the lake. In addition, a shoreline of about 10 to 20 percent forested wetlands appears necessary to meet or exceed 50 PCU color. Using this information, the following targets are proposed for color and forested wetlands:

- A preliminary and minimum target of 50 PCU or higher for high color valley lakes in the WHCL to maintain water color at a level that moderates the effect of increased nutrients on phytoplankton.

- Restore or maintain a minimum 10 to 20 percent of nearshore habitat as forested wetland. This management goal may be important in controlling phytoplankton levels.

2.8. Submerged Aquatic Vegetation (SAV)

Removal of nutrients from the water column by SAV communities is well documented (Kadlec and Wallace 2009, Knight *et al*. 2003, Blindow *et al*. 2002, Canfield *et al*. 1984, Havens 2003, Shireman *et al*. 1985) and, as such, SAV is an important consideration for improving water quality in the WHCL. Unfortunately, the results of water quality improvements and non-native invasive species control sometimes conflict.

Quantifying the relationship between SAV and nutrients in the WHCL is impossible in the absence of SAV abundance data. However, there is information regarding the impact of SAV eradication on water quality in other lakes in central Florida, as well as anecdotal information from various lakes in the WHCL. In the WHCL, for example, herbicide treatments to eradicate non-native invasive SAV are an important component of lake management because of the negative impacts of these species in the lakes, including replacement of native plant species and habitat and adverse impacts to recreation and fishing. *Hydrilla* (*H. verticillata*) is the primary target of herbicide treatments in the WHCL. However, eradication of SAV also removes a nutrient reduction mechanism and can result in a decline in water quality. For example, TP levels in Lake Howard increased in the months after the completion of an extensive *Hydrilla* eradication implemented over approximately half of Lake Howard. The eradication efforts in Lake Howard may have compromised some of the benefits of the prior regional stormwater treatment projects.

Similarly, Lake Hartridge chlorophyll *a* values from 1997 to 2007 were highest in 1998, following *Hydrilla* treatment over at least 30 percent of the lake each year from 1994 to 1998 and may be due to *Hydrilla* eradications in prior years. In contrast, chlorophyll *a* values during the period 1997 to 2007 were lowest in 2002 to 2004, following two previous years of *Hydrilla* treatments limited to 10 percent of the lake. Fourteen of the lakes in the WHCL with treatment data (70 percent of the lakes) had more than 50 percent of their surface areas treated on at least one occasion. Replacing *Hydrilla* with native SAV would restore the water quality benefits provided by SAV and restore native habitat for fish and wildlife as well.

3.0 Restoration Projects to Address Water Quality Issues

Restoration project concepts were developed to address water quality issues specific to the WHCL as part of this WQMP. Some projects are proposed to address issues that have persisted despite previously implemented stormwater quality improvement projects. The projects and the science on which they are based are described in this section and rely heavily on the water quality characterization presented previously in Section 2. Where possible, the water quality in lakes with these types of management actions were compared to reference lakes, i.e. similar lakes in the same general region without the management action. Finally, a decision key used to identify projects appropriate for each lake is presented.

Lakes in the WHCL are typically shallow (mean depth less than three meters) and restoration projects proposed as part of the WQMP are consistent with general characteristics of these shallow lakes, as opposed to deeper, stratified lakes and reservoirs outside the southeastern United States. For example, shallow lakes are less sensitive to significant reductions in external nutrient loading because interactions at the sediment-water interface tend to maintain high nutrient levels (Cooke *et al*. 2005). Therefore, diverting external nutrient loads, although necessary, may not be sufficient to reduce nutrient loads to the lake and sediment treatment may be necessary. Cooke *et al*. (2005) describe two alternative and often stable states of shallow lakes: algae-dominated turbid state at high nutrient concentrations or clear water with macrophytes (aquatic submergent, emergent, or floating plants). Therefore, projects that increase the cover of macrophytes are proposed for most lakes in the WHCL.

3.1. Previously Implemented Restoration Projects

The conventional approach to lake management in the WHCL system is based on the premise that treating stormwater will reduce nutrient loads to the level necessary to meet or exceed state and federal water quality regulations. Consistent with this approach, the City of Winter Haven, Polk County, and funding partners have completed a series of regional stormwater treatment projects for lakes Howard, May, Lulu, and Hartridge, as well as county projects on Lakes Jessie, Cannon, and Mariana, to reduce external phosphorus loads to the lakes. Construction of a stormwater project for the south side of Lake Conine to reduce external nutrient loading to the lake is also planned. Lake Hartridge is the only one of the lakes not verified impaired due to high nutrient levels. While stormwater projects successfully reduce external nutrient loads to lakes, internal nutrient loads may be large enough to delay the water quality effects of reduced external loads.

WHCL treatment projects were designed to meet or exceed the TP load reduction called for by the TMDL for eight lakes in the WHCL (FDEP 2007). Project expectations are that water quality in the lakes would improve with the implemented load reductions and the lakes would no longer be impaired. Water clarity, chlorophyll *a*, and TP data from lakes Howard, May and Lulu ("clear" lakes) were examined for trends over time in response to load reductions. Data were not normally distributed and comparisons were made using the non-parametric Kruskal-Wallis test ($p < 0.05$) for the three lakes.

There were no significant improvements in water clarity, chlorophyll *a*, or TP during the post-stormwater project implementation period when compared with the pre- project period. Data graphed over time, in relation to pre-and post-project implementation are presented for water clarity (Figures 3-1, 3-2, 3-3), chlorophyll *a* (Figures 3-4, 3-5, 3-6) and TP (Figures 3-7, 3-8, 3-9) for lakes Howard, May, and Lulu. There was, however, evidence of increased levels of chlorophyll *a* in both Lake May and Lake Lulu during the post-project period and an initial reduction in TP in Lake Howard (detailed later in text).

These results suggest that regional stormwater retrofit projects, while able to exceed required TP load reductions, may not be adequate for managing water quality in the WHCL system. As described previously (section 2.5), internal phosphorus loads from sediments may be responsible for excessive phosphorus loads even when external phosphorus sources have been reduced and water quality recovery can be delayed many years if internal phosphorus flux is not addressed as part of a watershed management strategy. In this context, additional water quality improvement projects, including sediment removal or inactivation and/or submersed aquatic plant restoration, are proposed as part of this WQMP.

Figure 3-1. Water clarity in Lake Howard, pre- and post project construction (line is three-point moving average, orange and purple shading denote approximate times of the stormwater project and *Hydrilla* treatment, respectively).

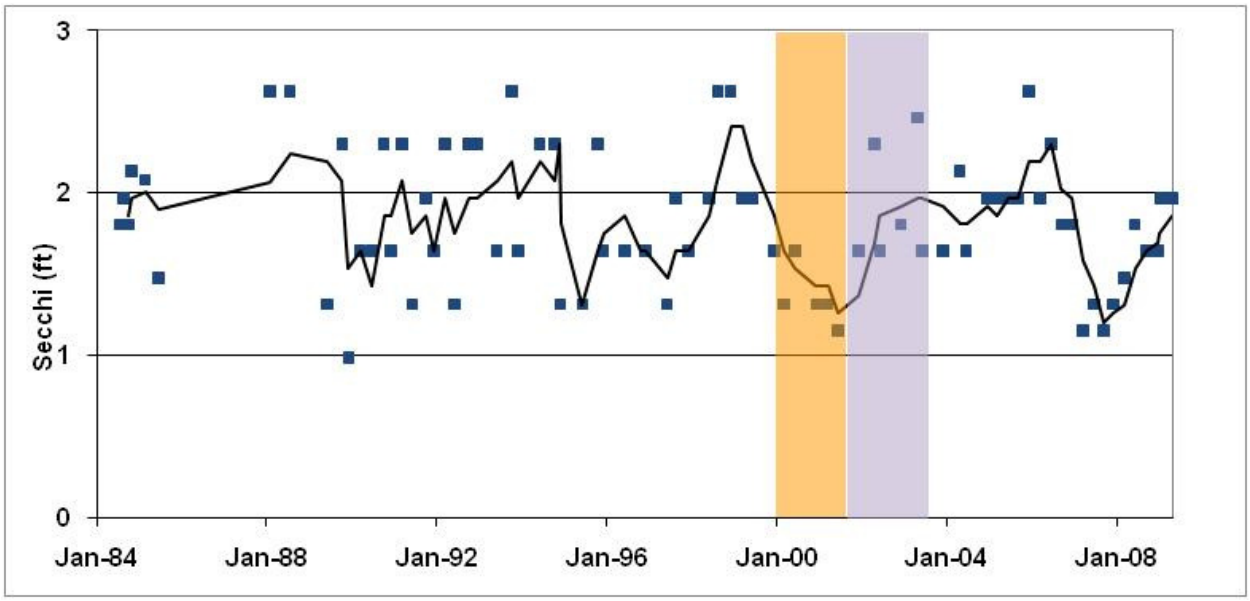


Figure 3-2. Water clarity in Lake May, pre- and post project construction (line is three-point moving average and shaded area denotes approximate time of stormwater project).

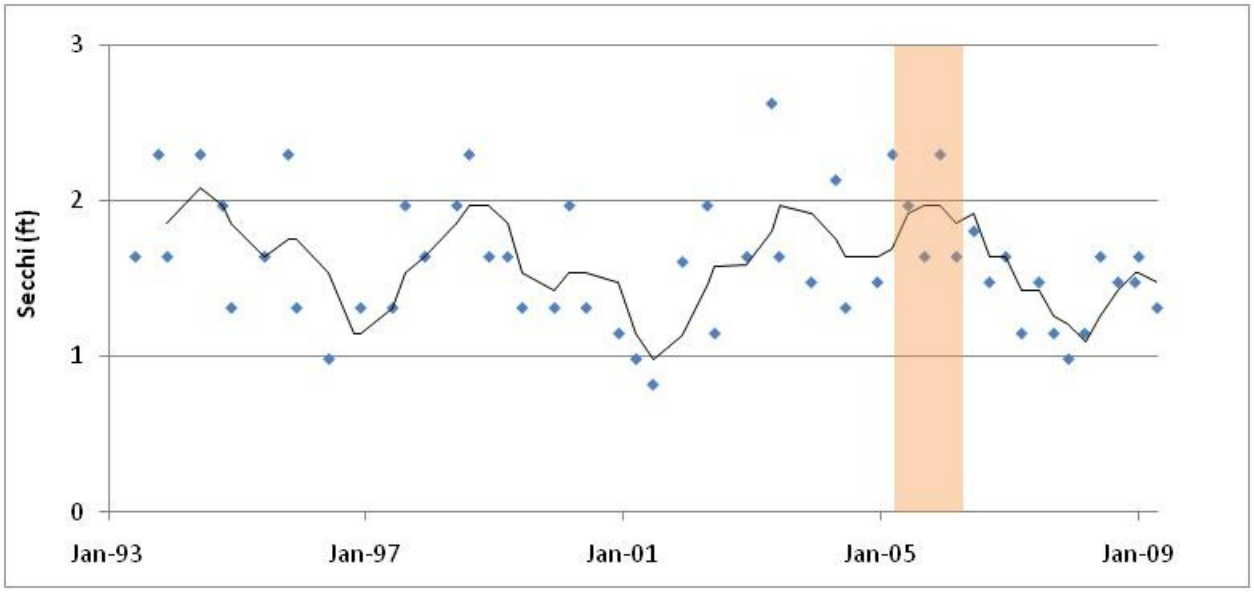


Figure 3-3. Water clarity in Lake Lulu, pre- and post project construction (line is three-point moving average and shaded area denotes approximate time of stormwater project).

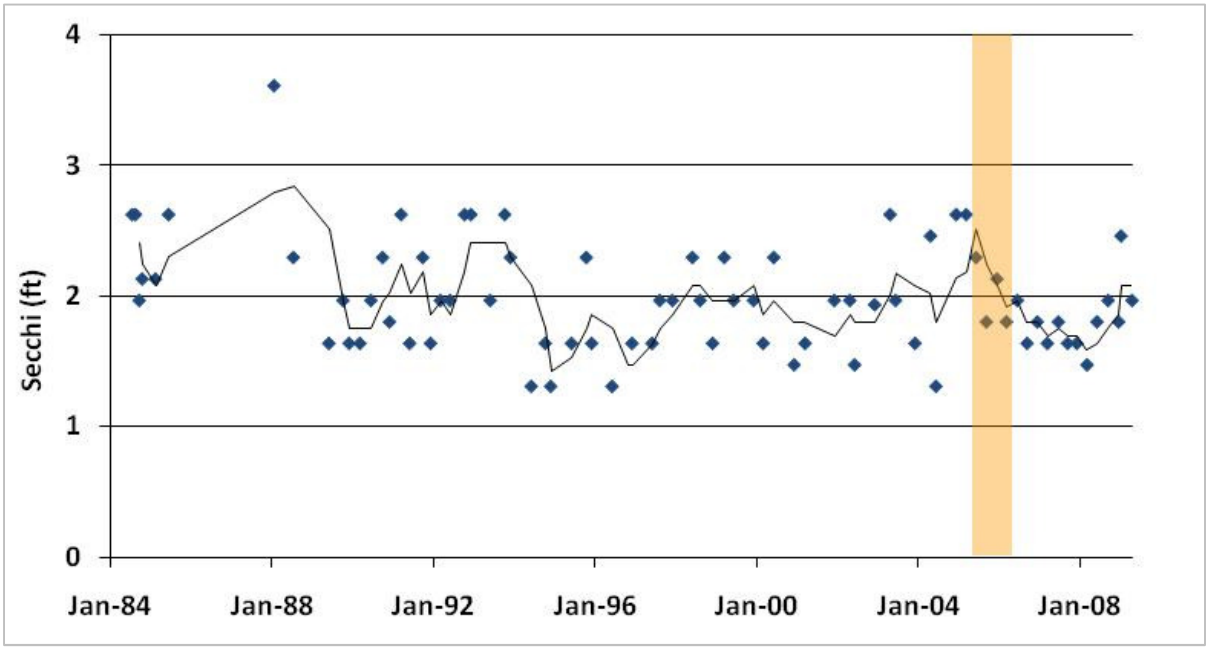


Figure 3-4. Chlorophyll *a* levels in Lake Howard, pre- and post- project (line is three-point moving average, orange and purple shading denote approximate times of the stormwater project and *Hydrilla* treatment, respectively).

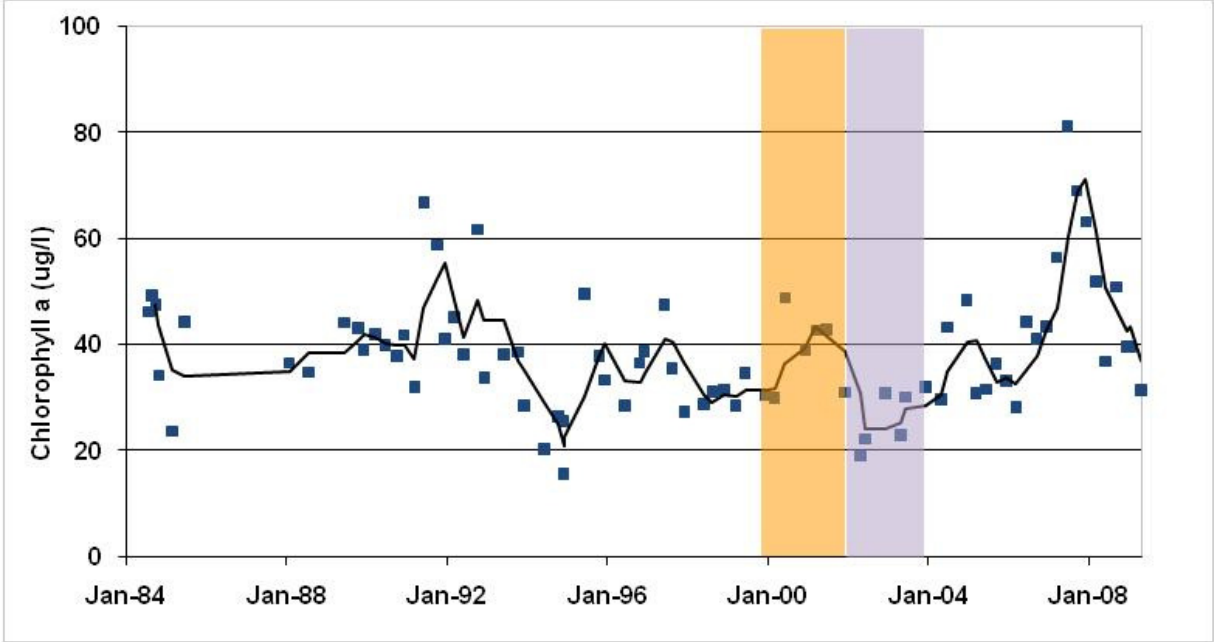


Figure 3-5. Chlorophyll *a* levels for Lake May, pre- and post- project (line is three-point moving average and shading denotes approximate time of stormwater project).

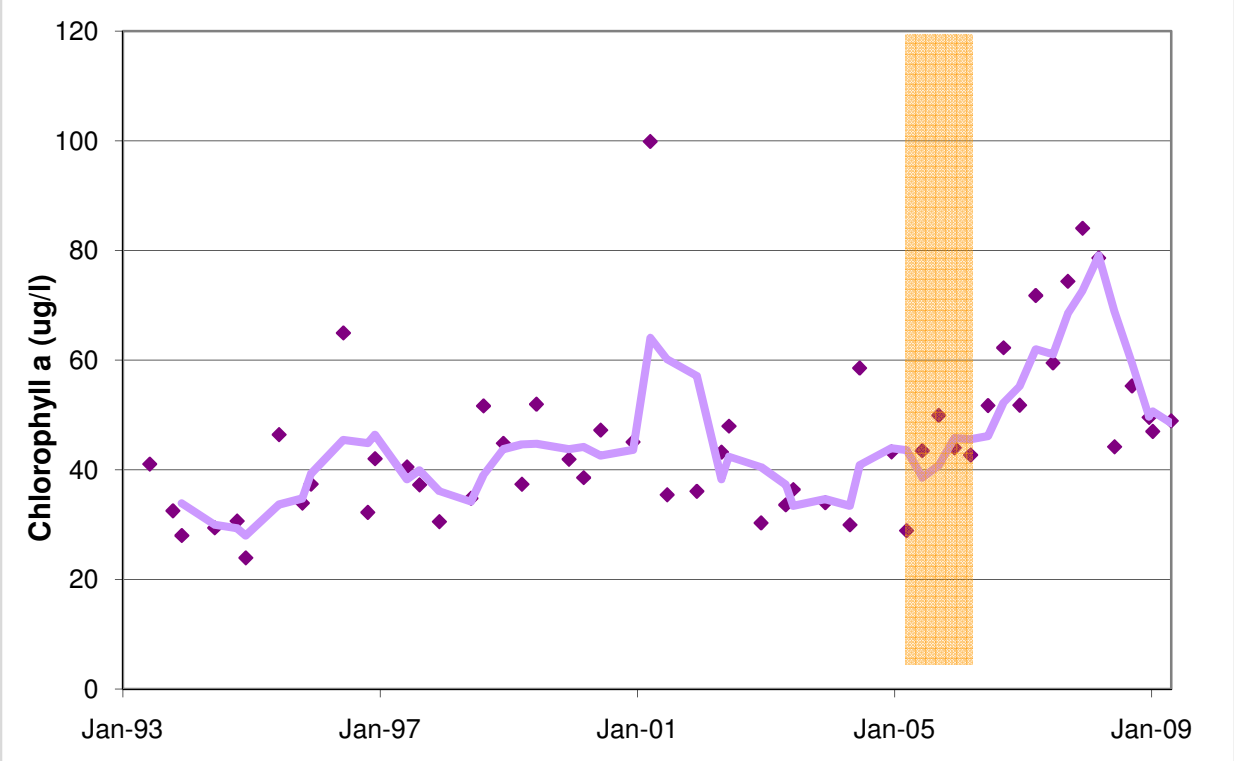


Figure 3-6. Chlorophyll *a* levels in Lulu, pre- and post project construction (line is three-point moving average and shaded area denotes approximate time of stormwater project).

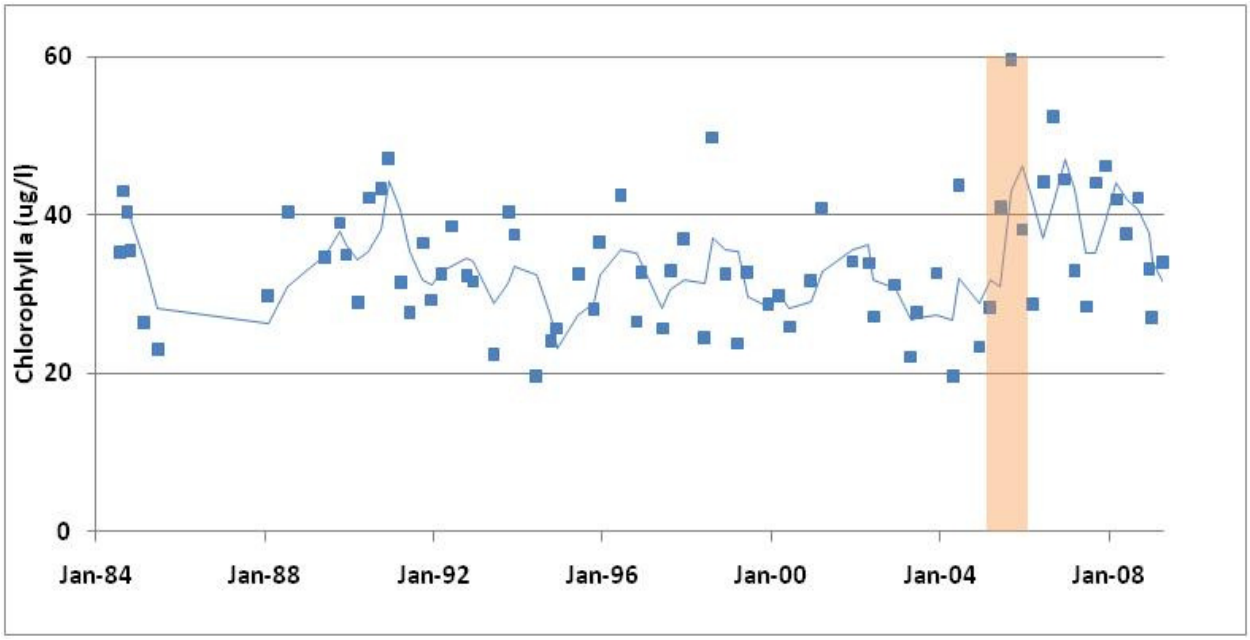


Figure 3-7. TP in Lake Howard, pre- and post- project (line is three-point moving average, orange and purple shading denote approximate times of the stormwater project and *Hydrilla* treatment, respectively).

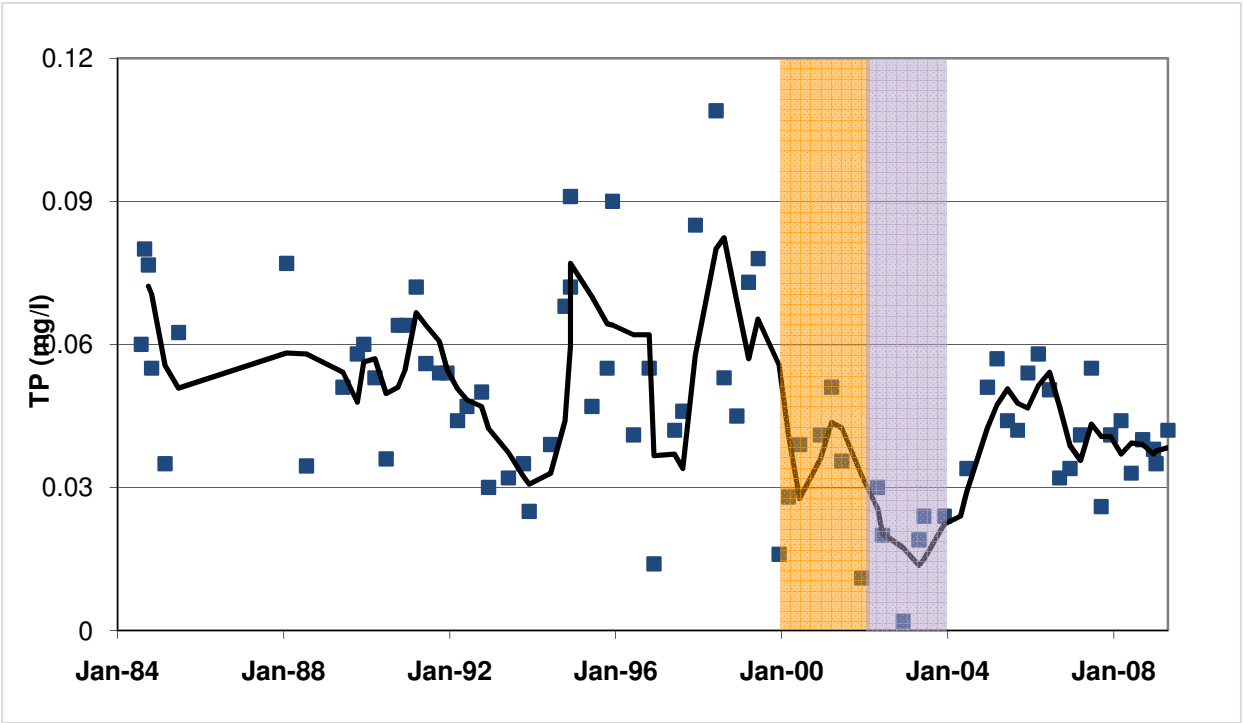


Figure 3-8. TP in Lake May, pre- and post- project (line is three-point moving average and shading denotes approximate time of stormwater project).

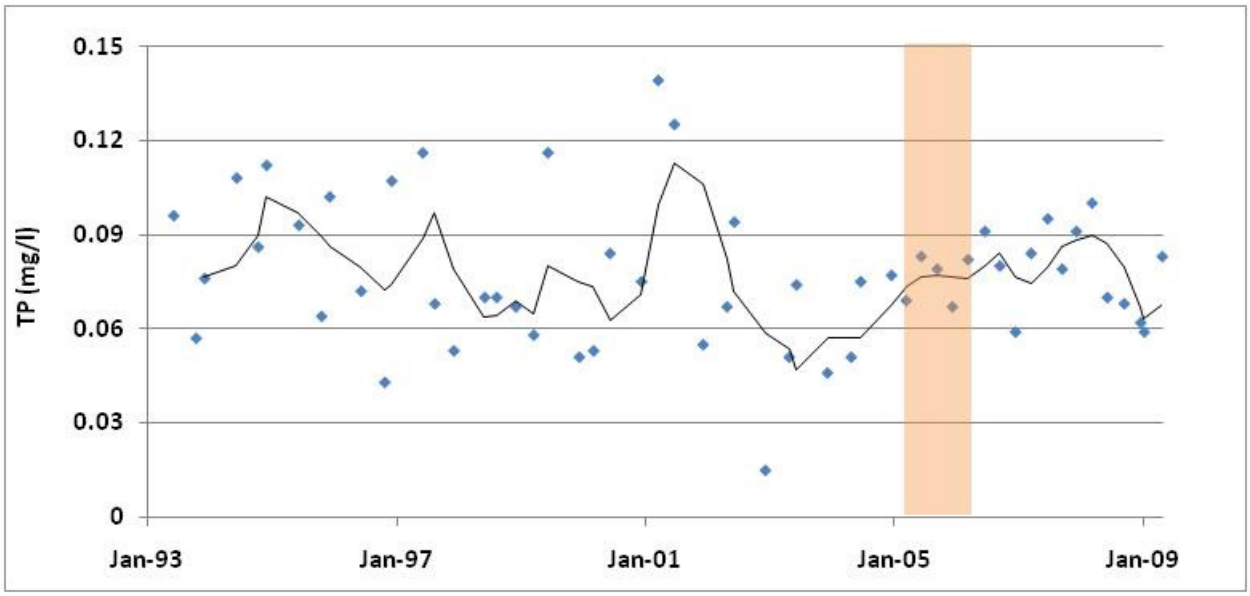
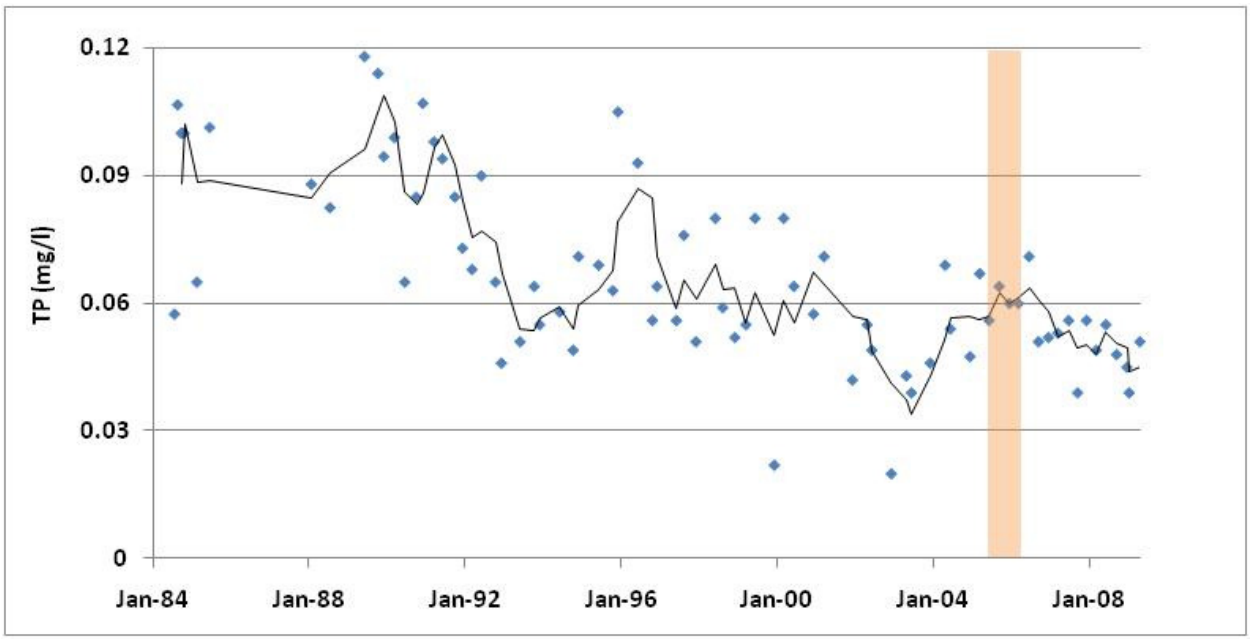


Figure 3-9. TP in Lake Lulu, pre- and post- project (line is three-point moving average and shading denotes approximate time of stormwater project).



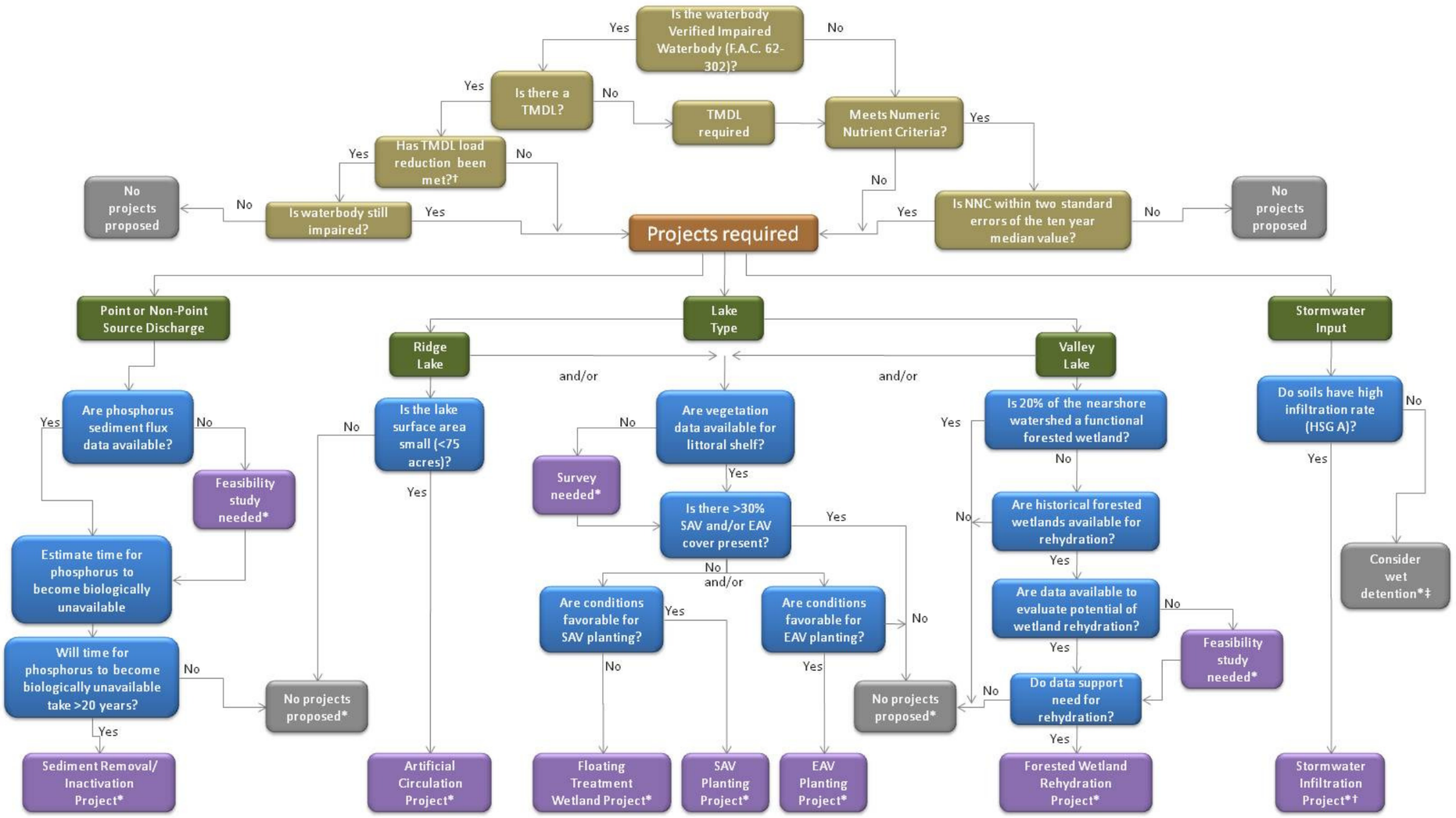
These results also indicate that "traditional" large regional stormwater retrofit projects have not proven successful at improving water quality in the WHCL system, even though these projects were sufficient to exceed required TP load reductions called for in the WHCL TMDL report (FDEP 2007) and reduce phosphorus loading to the lake. In contrast, whole-lake alum application clearly improved water quality in Lake Conine (Figures 3-11, 3-12, and 3-13), as well as having downstream benefits to Lake Smart (PBS&J 2008). Sediment removal appears to

have benefited water quality in Lake Hollingsworth, as well as in Collier County's Lake Trafford. However, while TP levels decreased in response to sediment removal in Banana Lake, there was no concurrent improvement in either chlorophyll *a* or water clarity. Based on results in Lake Persimmon, whole-lake aeration appears to be capable of improving water quality, although lake aeration is appropriate only for smaller lakes (refer to section 3.9, below) in the WHCL.

3.2. Project Selection and Decision Key

A decision key was developed specifically for the WHCL WQMP to select restoration projects (Figure 3-10). To apply the key, series of yes/no decisions were made for each lake, first pertaining to water quality regulations to decide whether a project is "required". For example, if a TMDL has been established for a lake and the lake is no longer designated as impaired, the decision key leads to "no projects proposed" and the decision process terminates. However, if a lake is verified impaired and a TMDL is required for the waterbody, but the TMDL load reduction has not been accomplished, the decision key leads to "projects required" within the context of this WQMP.

Figure 3-10. WHCL WQMP decision key.



•Consider alternative projects

‡Wet detention may also be required if sufficient area is unavailable for dry retention

† Stormwater Infiltration projects could satisfy required TMDL Load reduction

If a project is required, water quality issues such as those described in Section 2, e.g. stormwater inputs, lake color (ridge and valley), and sediment phosphorus, become part of the decision making process. The next level of the decision key addresses the presence of SAV and EAV, forested wetlands, and soil infiltration. Ultimately, a specific project(s) is selected, or, if data are insufficient, a feasibility study to gather the data necessary to select a project is recommended. In response to these findings, alternative lake water quality restoration approaches were examined. The decision key leads to seven potential projects, listed below, and described in this section.

- Sediment removal/inactivation
- Stormwater infiltration areas (SIAs)
- Forested wetland rehydration
- SAV planting
- Floating treatment wetland
- EAV planting
- Artificial circulation (aeration)

3.3. Sediment Removal/Inactivation

Internal phosphorus loading originates from phosphorus accumulated in sediment under high external loading. Removing or inactivating the phosphorus-laden sediments reduces or eliminates the phosphorus that can be released into the water column of the lake and result in increased nutrient availability to algae and subsequently, increased chlorophyll *a* in the lake. The time for the lake to recover to a steady state between sediment and water column phosphorus can be calculated using phosphorus flux rates from sediments, sediment depth, sediment organic matter, and sediment bulk density (Reddy *et al*. 2011). The internal loading can be reduced significantly by various restoration methods, such as removal of phosphorus-rich surface layers or by the addition of iron or alum to increase the sediment's sorption capacity.

Sediment removal and inactivation are a means of reducing available nutrients in a lake and have been successful in Florida and the WHCL, as documented in this section of the WQMP. Sediment removal physically removes the source of internal nutrient cycling, while phosphorus inactivation lowers lake phosphorus by inhibiting the release of mobile phosphorus from lake sediments.

Significant amounts of phosphorus in lake sediments may be bound to redox-sensitive iron compounds or fixed in labile organic forms and may eventually be released to the lake water. Many factors influence the release of phosphorus. Redox sensitive mobilization from the anoxic zone just below the sediment surface and microbial processes are considered important, but the phosphorus release mechanisms are to a certain extent lake specific (Sondergaard *et al*. 2002). Phosphorus inactivation is an in-lake technique designed to lower phosphorus content in a lake by removal of phosphorus from the water column (phosphorus precipitation) and retarding the release of mobile phosphorus from lake sediments (phosphorus inactivation). Phosphorus inactivation is generally accomplished via addition of an aluminum salt to the lake that forms aluminum phosphate and an aluminum floc to which certain phosphorus fractions are bound. The floc settles to the lake bottom and continues to adsorb and retain phosphorus. Phosphorus

inactivation is considered more economical and effective, while sediment removal has the long term benefit of nutrient source removal (Cooke *et al*. 2005). In contrast to iron, low or zero dissolved oxygen (DO) concentrations in lake sediments do not solubilize the floc and allow phosphorus release, although phosphorus may be released if the pH is high (Cooke *et al*. 2005). Sediment phosphorus inactivation treatments must reduce sediment phosphorus release for at least several years, lower the phosphorus concentration in the lake photic zone, and be non-toxic.

Phosphorus inactivation provides long-term control of algal biomass by reducing the availability of nutrients (phosphorus), in contrast with algaecides that are directly toxic to algae and are effective for only brief periods. The primary objective of in-lake alum treatment is to cover the sediment with aluminum hydroxide. Mobile phosphorus is sorbed and internal loading is reduced. The formation of aluminum hydroxide may also remove particulate organic and inorganic matter with phosphorus from the water column. Phosphorus inactivation is an attempt to permanently and extensively bind phosphorus in lake sediments and essentially eliminate sediments as a phosphorus source to the water column. The potential use of sediment removal and inactivation for reducing TP in the WHCL was examined by evaluating other Florida lakes where removal or inactivation projects have been implemented. For sediment removal, water quality in Banana Lake and Lake Hollingsworth were compared to Lake Parker. Lake Parker was selected as the "reference" site for comparison because it is a similarly eutrophic lake that has not had a removal project. In-lake water quality responses to sediment removal were also examined for Lake Trafford in Collier County.

Sediment removal has become an established fisheries management technique for lakes throughout Florida (Aresco and Gunzburger 2004) based on studies in which immediate positive fisheries response followed a water level drawdown and sediment removal in Lake Tohopekaliga, Florida (e.g. Moyer *et al*. 1995). However, sediment removal may negatively impact herpetofauna (Aresco and Gunzburger 2004). Sediment inactivation via alum treatment requires periodic maintenance and treatment if hydrologically connected, may affect downstream waters.

Sediment Inactivation

Water quality data for Lake Conine demonstrate that a properly designed and implemented whole-lake alum treatment can improve water quality in lakes in the WHCL. Water clarity, chlorophyll *a*, and TP data were graphed for Lakes Parker and Conine relative to the occurrence of whole-lake alum treatment in Lake Conine in the mid-1990s (Figures 3-11, 3-12, 3-13) and compared between the lakes (Kruskal-Wallis test, $p < 0.05$). Water clarity increased, TP decreased, and chlorophyll *a* subsequently decreased in Lake Conine following treatment. In contrast, there was no change in water clarity and chlorophyll *a* and TP increased in Lake Parker during the same time. The graph for Lake Conine also illustrates a TP reduction in the lake associated with a 1980s diversion of a domestic waste water treatment facility (WWTF) point source diversion.

Figure 3-11. Water clarity in lakes Conine and Parker (line is three-point moving average and shading denotes time of whole-lake alum treatment in Lake Conine).

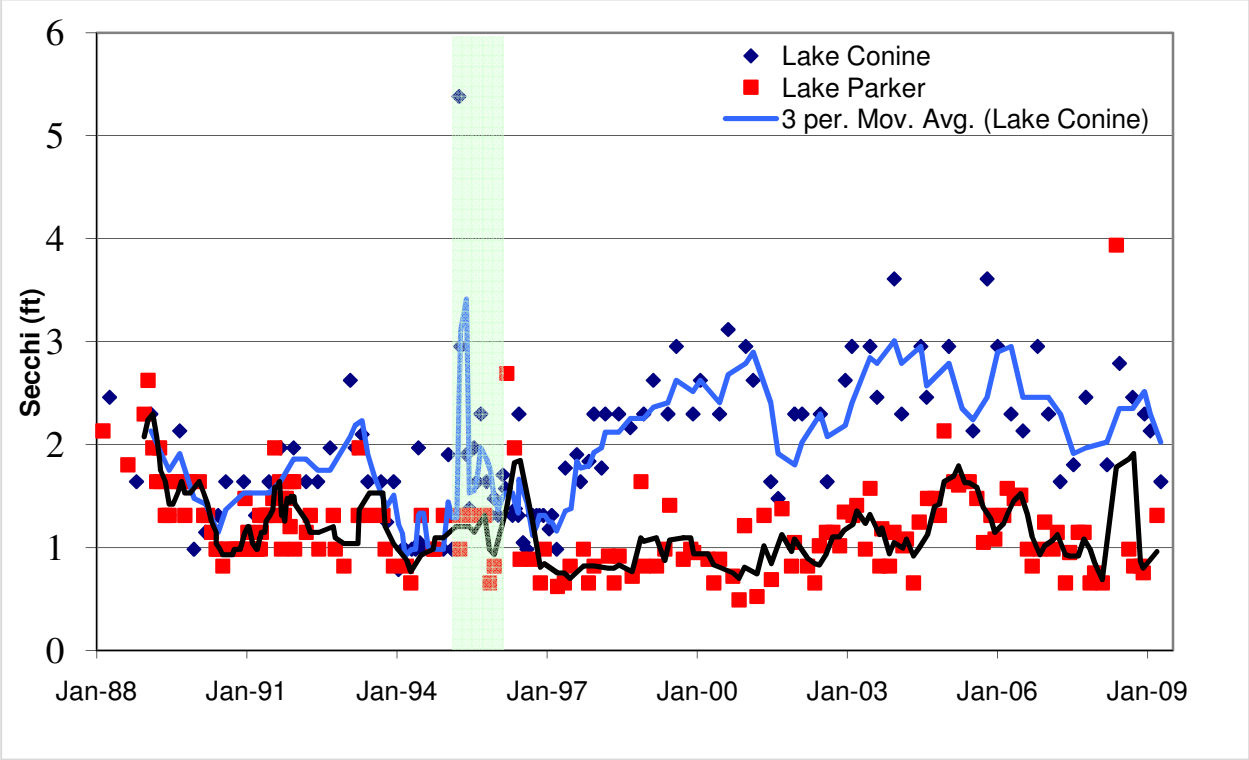


Figure 3-12. Chlorophyll *a* in lakes Conine and Parker (line is three-point moving average and shading denotes approximate time of whole-lake alum treatment in Lake Conine).

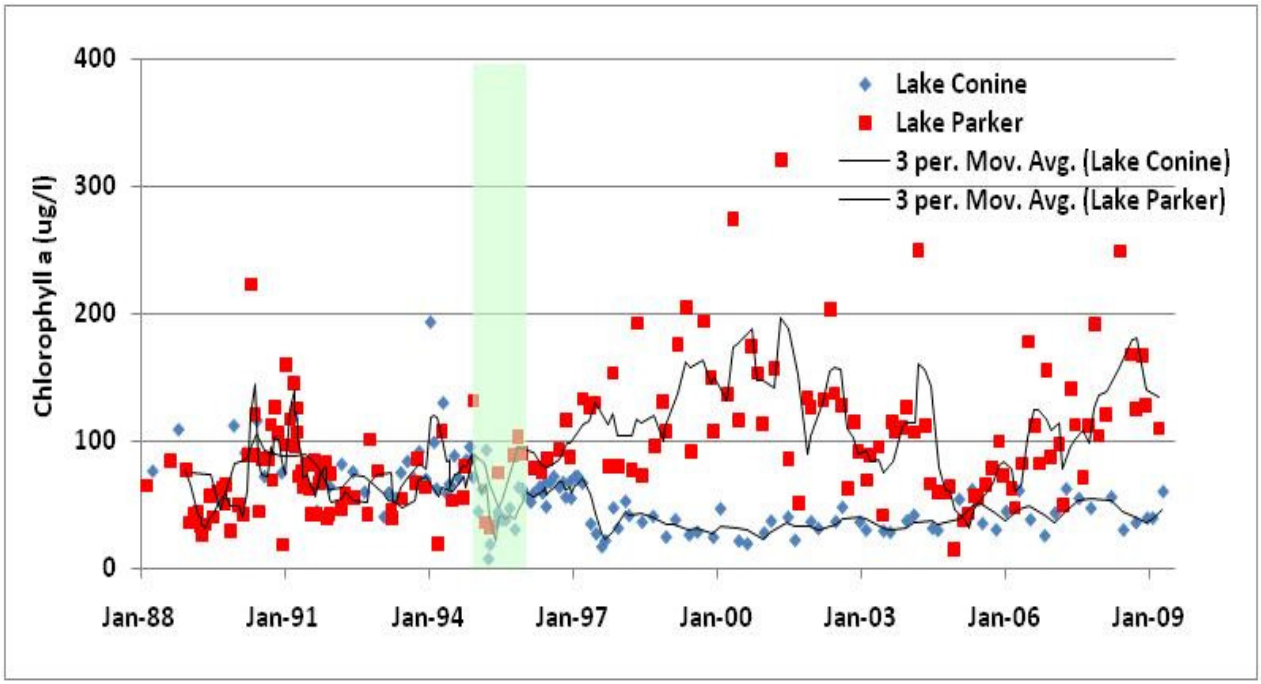
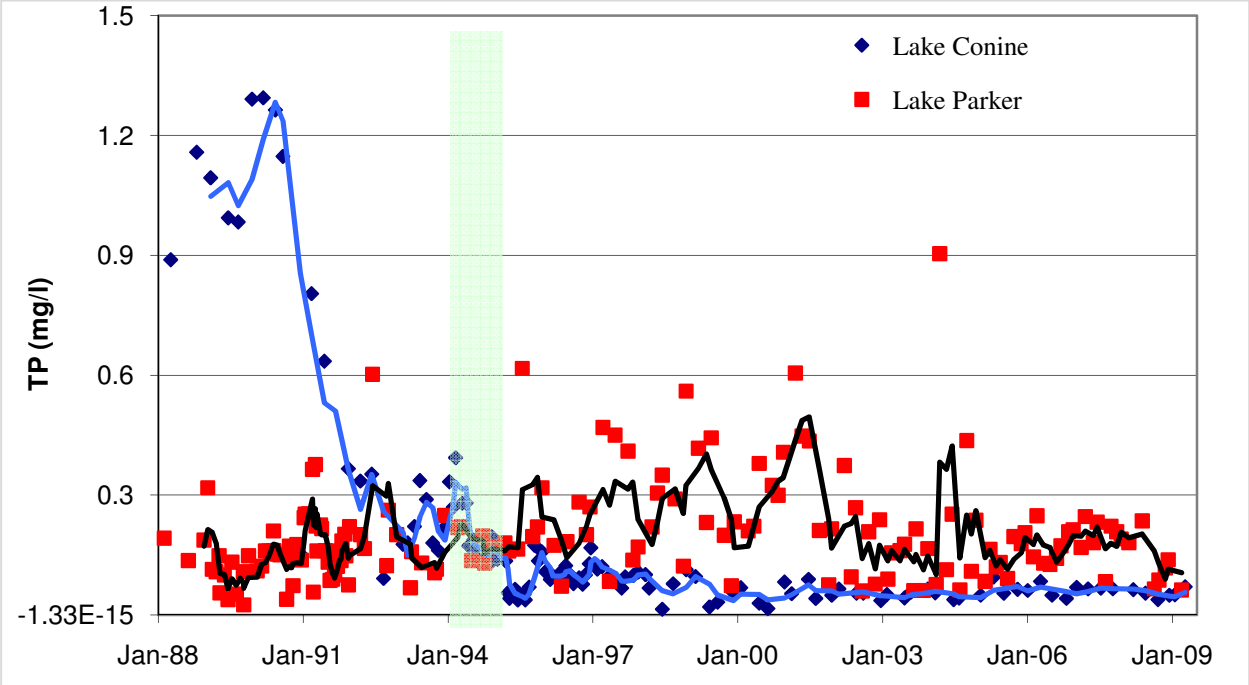


Figure 3-13. TP in lakes Conine and Parker (line is three-point moving average and shading denotes approximate time of whole-lake alum treatment in Lake Conine).



Sediment Removal

The effectiveness of sediment removal as a water quality improvement mechanism in the WHCL was examined by comparing water quality trends in similarly eutrophic lakes that have (Banana Lake and Lake Hollingsworth) and have not (Lake Parker, a nearby and similarly hypereutrophic lake) undergone sediment removal projects. Trends in water clarity, chlorophyll *a*, and TP were examined using Kruskal-Wallis tests ($p < 0.05$) to compare water quality between pre- and post-project periods. Water clarity (Figures 3-14 and 3-15), chlorophyll *a* (Figures 3-16 and 3-18) and TP (Figures 3-18 and 3-19) data were graphed for pre- and post-sediment removal and whole lake alum projects for the treated (Hollingsworth and Banana) and untreated (Parker) lakes. Water clarity improved in Lake Hollingsworth, but not in Banana Lake following the sediment removal. A later short term increase in water clarity in Lake Hollingsworth also occurred following a corresponding alum treatment. Even prior to the alum treatment, water clarity had already improved in Lake Hollingsworth. While water quality improvements can be affected by numerous factors, the opportunity to compare lakes with and without sediment removal projects provides a means of evaluating the success of the projects. However, the influence of internal loads on these water quality changes has not been evaluated yet.

Chlorophyll *a* and TP concentrations also improved in Lake Hollingsworth after sediment removal. An initial increase in TP levels after sediment removal, followed by a later decline after whole-lake alum treatment, was also evident in Lake Hollingsworth. No changes in water quality occurred over the same time period in Lake Parker, suggesting that sediment projects were responsible for the water clarity differences. Water quality trends in all lakes are summarized individually in Section 4.0 of this report.

The relationship between sediment removal projects and water quality was less consistent in Banana Lake. TP decreased in Banana Lake following sediment removal but increased during the same time period in Lake Parker. There was no evidence of improved water clarity or chlorophyll *a* in Banana Lake following sediment removal. Sediment removal may have reduced TP in Banana Lake, but the reduction may have been inadequate to reduce phytoplankton biomass, and thus not enough to improve water clarity. For example, results of one sediment removal project (Pitt *et al*. 1997) indicated that most of the soft sediment was removed, but that rapid decomposition of remaining sediment increased internal loading immediately after dredging.

Water quality in Lake Trafford (Collier County) was also examined to evaluate the effects of large scale sediment removal on lakes. Similar to Lake Hollingsworth, but in contrast to Banana Lake, Lake Trafford exhibited evidence of reduced chlorophyll *a* levels following sediment removal (Figure 3-20). However, the POR following sediment removal in Lake Trafford is relatively short and there is no similar, but untreated, lake in the vicinity to provide a reference lake. Therefore, the conclusion that sediment removal improved water quality in Lake Trafford is a tentative one. In their assessment of the water quality responses of Lake Tohopekaliga to sediment removal efforts, Hoyer *et al*. (2008) similarly concluded that sediment removal improved water quality, at least in the short term.

Figure 3-14. Water clarity in Banana Lake and Lake Parker (shading denotes approximate time of sediment removal project).

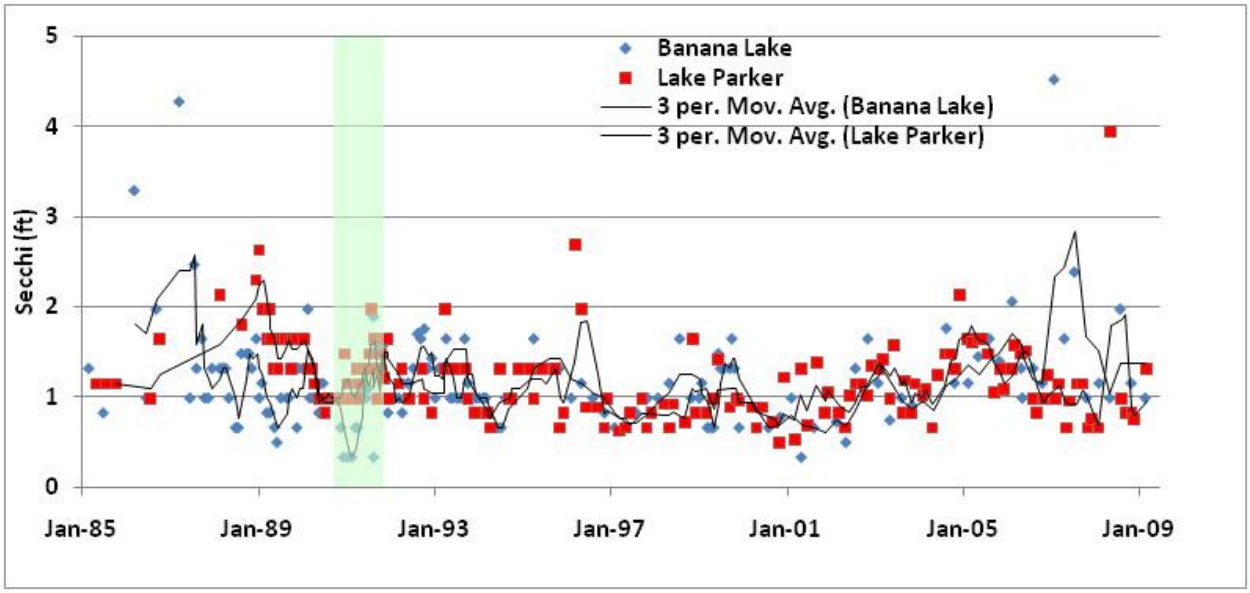


Figure 3-15. Water clarity in lakes Hollingsworth and Parker (green and orange shading denote approximate time of sediment removal alum projects, respectively, in Lake Hollingsworth).

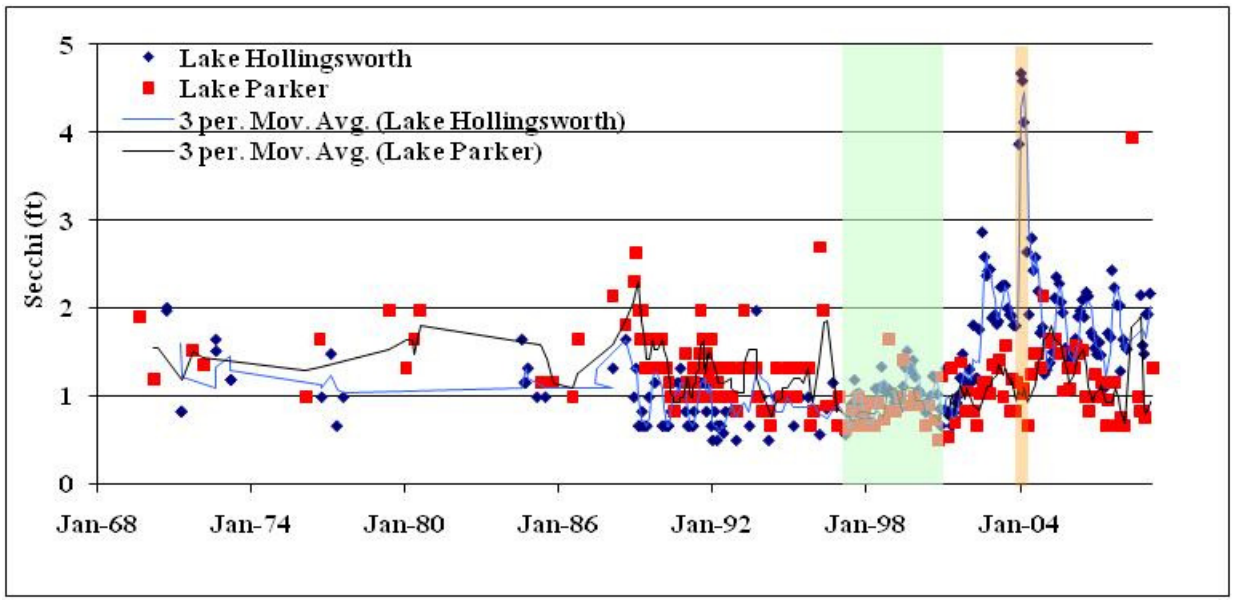


Figure 3-16. Chlorophyll *a* in Banana Lake and Lake Parker (shading denotes approximate time of sediment removal project in Banana Lake).

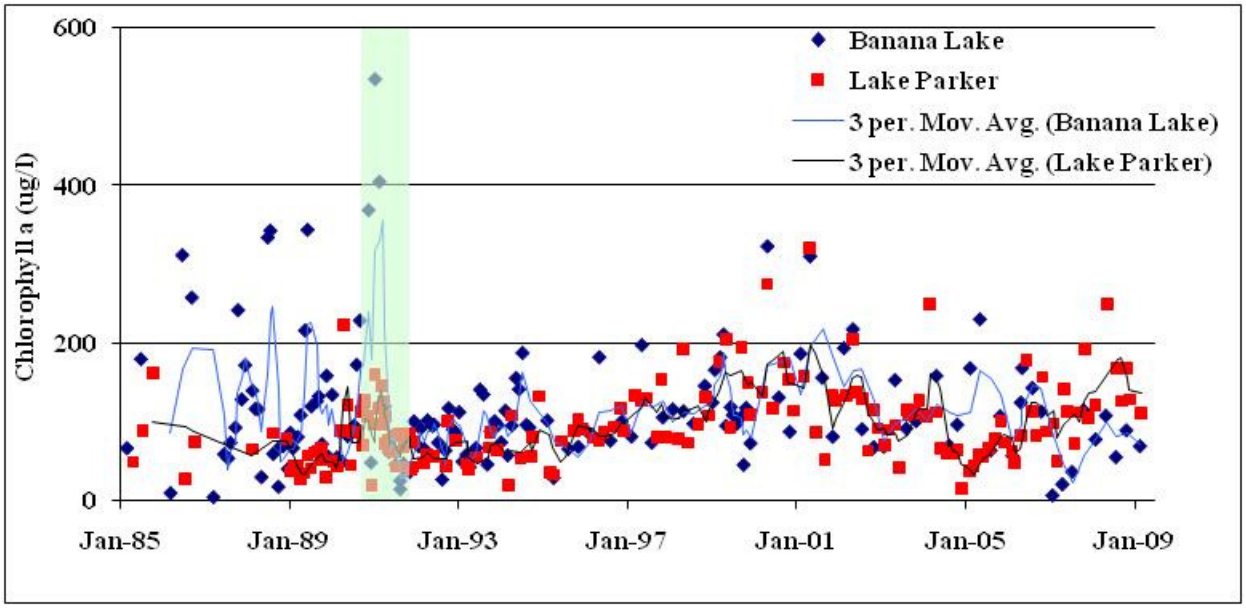


Figure 3-17. Chlorophyll *a* in lakes Hollingsworth and Parker (line is three-point moving average and green and orange shading denote approximate time of sediment removal and alum projects, respectively, in Lake Hollingsworth).

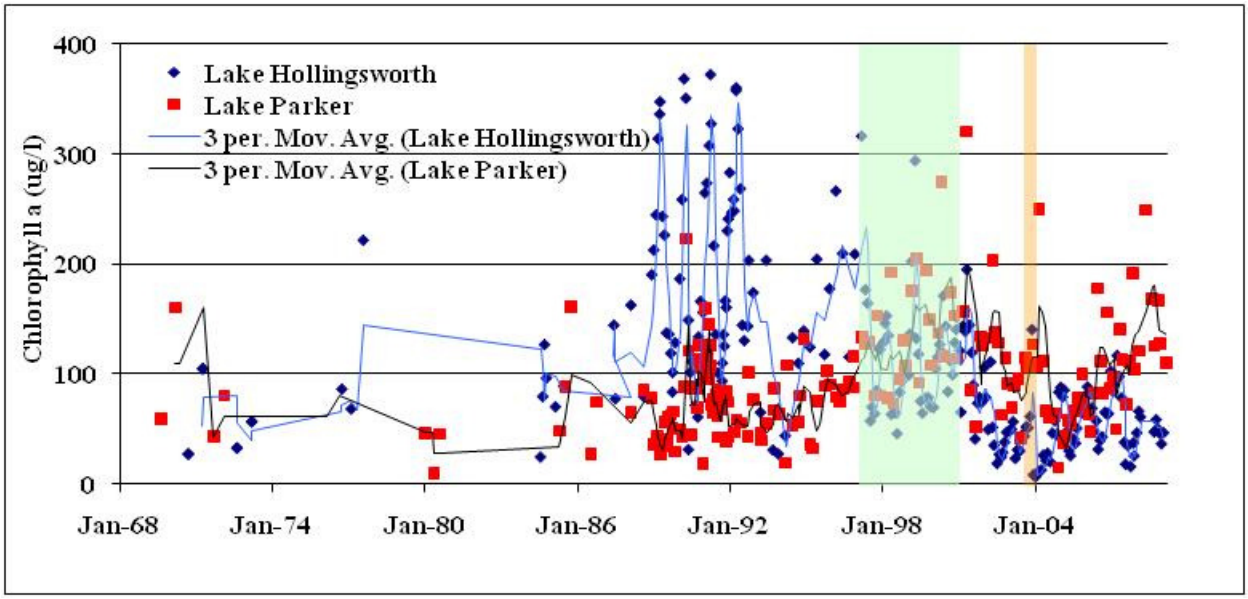


Figure 3-18. TP in Banana Lake and Lake Parker (line is three-point moving average and shading denotes approximate time of sediment removal project in Banana Lake).

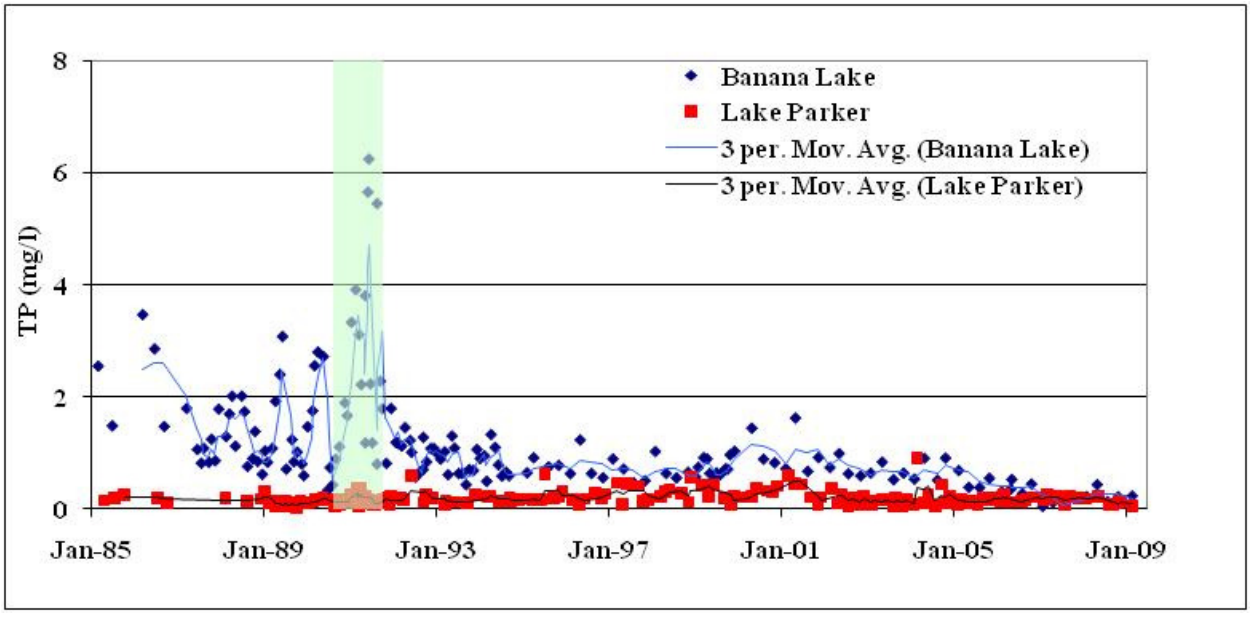


Figure 3-19. TP in lake Hollingsworth and Parker (line is three-point moving average and green and orange shading denote approximate time of sediment removal and alum projects, respectively, in Lake Hollingsworth).

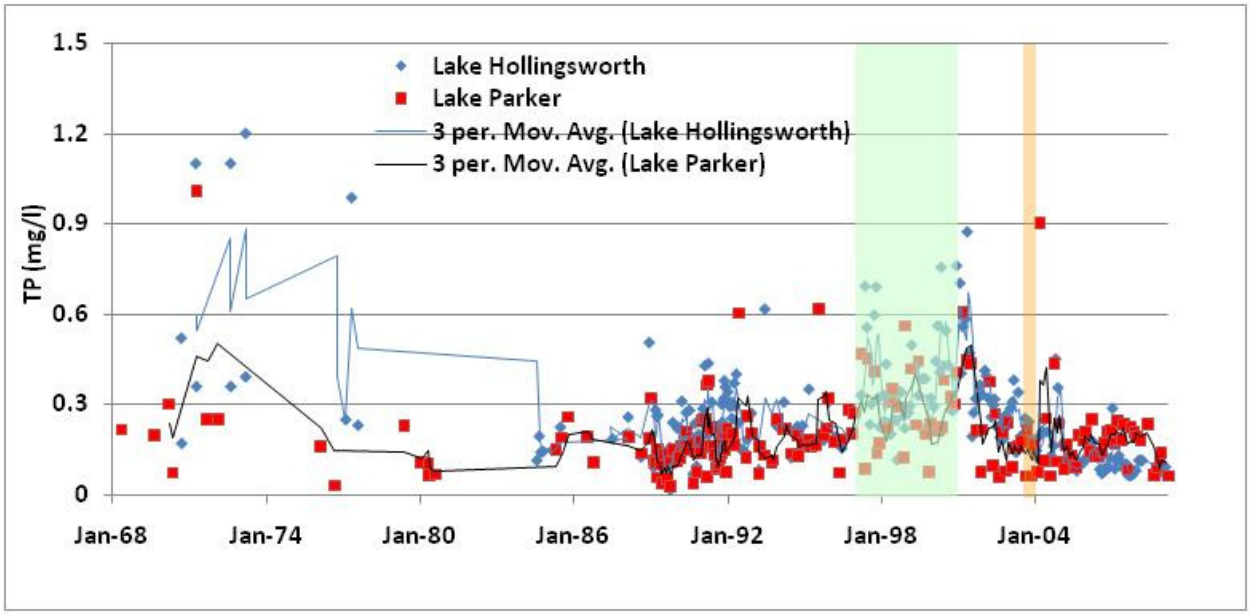
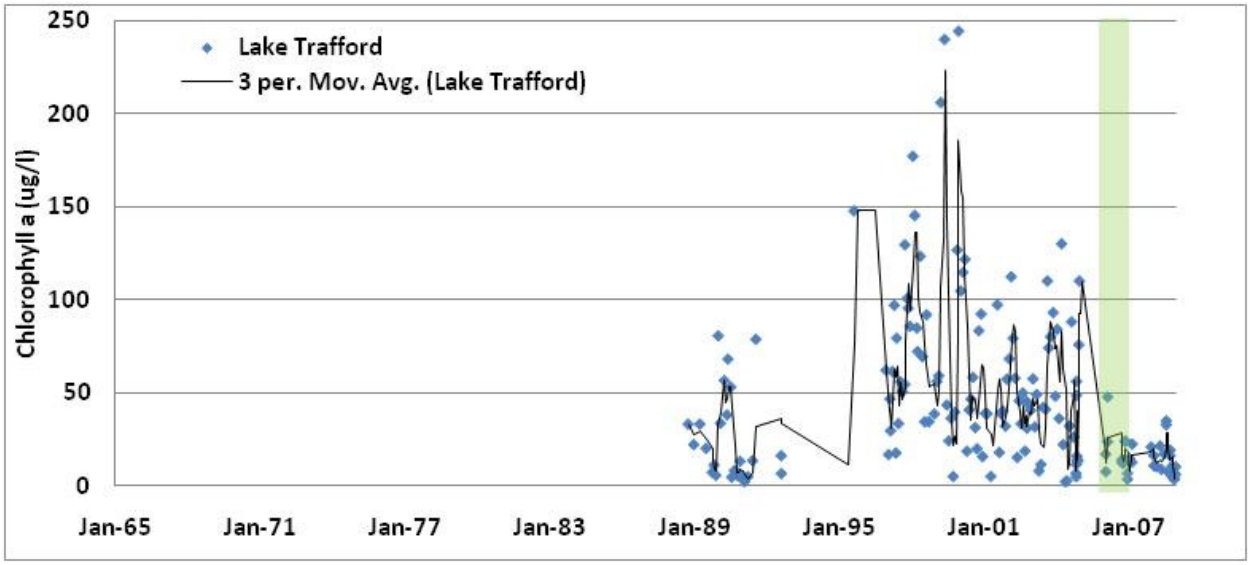


Figure 3-20. Chlorophyll *a* in Lake Trafford (shading denotes approximate time of sediment removal project).



Sediment removal entails either the partial or full removal of organic sediments. Sediments are removed using a hydraulic dredge and transported to a shoreline dewatering facility (if possible). Dredged material can then be used as an agricultural soil amendment if recipient sites can be identified. The location of an appropriate dewatering area within close proximity to the dredge location can assist in reducing project costs. In contrast, chemical inactivation relies on the properties of the water and sediment. Two potential methods are available for chemical inactivation: Alum or Phoslock®.

- Alum Treatment. Alum (aluminum sulphate) is typically applied to lake water with a pH of 6 to 8. Due to the alkalinity of the water, hydrolysis of the alum ion occurs resulting in the formation of aluminum hydroxide which binds to the available phosphorus creating aluminum phosphate. Aluminum phosphate is an insoluble compound which settles to the lake bottom creating a barrier restricting phosphorus release from the sediments. Due to the initial hydrolysis of alum, fluctuations in the pH concentration of the lake can result in acidification of the waterbody depending on the initial alkalinity and alum dose applied. When required, a buffering agent is applied in concert with alum or the required dosage is spread over several applications to minimize the fluctuations in pH. Lake acidification can result in aluminum toxicity within the waterbody. Alum has been shown to be effective in binding phosphorus for 2 to 20 years. The resuspension or accumulation of organic material can shorten the longevity of alum treatment. Alum has been used to bind phosphorus in both lakes and stormwater management facilities in Florida since at least the 1980's.

- Phoslock® Treatment. Phoslock® (lanthanum modified bentonite clay) binds with phosphate most successfully when pH conditions are within the range of 6 to 9. However, the application of Phoslock® does not rely on the pH nor does it alter the pH of the waterbody. Rhabdophane, a stable mineral, is formed from the adsorption of phosphate to the lanthanum portion of Phoslock®. Rhabdophane is an insoluble clay structure which settles to the lake bottom creating a barrier restricting phosphorus release from the sediments. Ambient concentrations of lanthanum in the waterbody remain low due to structure of the bentonite clay. Presently, the longevity of Phoslock® to bind phosphorus is unknown. The first application of Phoslock® in the U.S. should be completed in California in the near future.

Legacy Sediment Phosphorus

The estimated time required for legacy phosphorus in sediments to become biologically unavailable is especially important for those lakes that received historic point source discharges or still receive nonpoint source inputs and can be estimated using sediment phosphorus flux data. If sufficient data are unavailable for phosphorus flux or sediment volume, a feasibility study is necessary and should include the components listed below.

- Quantification of the sediment nutrient release to the overlying water column
- Quantification of the depth and volume of organic (labile) material
- Sediment characteristic profiles
- Assessment of available sites for dredging operation facility once extent of internal phosphorus load is evaluated

Once external nutrient loads to lakes are eliminated or reduced to the extent possible, a reasonable time frame could be selected that balances the expense of a project with the long-term benefit of the project. For example, if it takes less than 20 years for the phosphorus enriched sediment in a particular lake to become biologically unavailable, alternative water quality restoration projects should be considered. However, if the time frame for phosphorus to become unavailable is greater than 20 years, sediment removal or inactivation could be recommended may be more cost effective.

3.4. Stormwater Infiltration Areas (SIAs)

SIAs are dry retention basins intended, in this case, to reduce direct stormwater runoff (and associated nutrients) to lakes by increasing surface water infiltration into ground water via permeable soils. SIAs are also referred to as rain gardens, dry retention ponds, French drains, infiltration pipes, and bio-infiltration basins (Photo 3-1). SIAs differ from traditional stormwater treatment projects in that they direct surface water to ground water and have the benefit of increasing aquifer recharge due to greater surface water infiltration. In addition, SIAs require can be constructed with minimal to no infrastructure and can be very small and located throughout urban settings.

Photo 3-1. Example of implemented SIAs.

Historic surface water runoff in the WHCL may have been negligible due to high infiltration rates of the natural landscape. The pollutant loading model for the WHCL (USF 2005) is the basis of the TMDL for the WHCL (FDEP 2007) and in it, the authors reported that "In general, pervious runoff was negligible due to … the sands that are predominant in the Winter Haven area". Under present developed conditions, however, surface water runoff in the WHCL watershed is substantial.

Therefore, the volume of "lost" storage in the surficial aquifer, i.e. the volume of rainfall that no longer percolates into the surficial aquifer, can be estimated by comparing nearly 100 percent infiltration under pre-development conditions (USF 2005) with the volume of stormwater that now enters the lakes in the WHCL. The water budget developed for the WHCL (USF 2005) included estimates of rainfall, seepage into the aquifer, lake-to-lake water transfers (via canals), evaporation, and direct stormwater runoff. These results indicate that the average lake in the WHCL receives approximately 329 million gallons of direct stormwater runoff per year, ranging from 61 million gallons per year into Lake Summit to 895 million gallons per year into Lake Mariana. Lake Howard receives approximately 548 million gallons of direct stormwater runoff per year. The high runoff volumes into Lakes May, Blue, and Spring reflect the "export" of surface water flows to adjacent lakes via canals.

Water budget estimates for the WHCL (USF 2005) indicate that approximately five times more water enters the lakes via ground water when compared to surface water. Although the Northern Chain of the WHCL (Haines, Rochelle, Conine, Smart, and Fannie) may receive substantial ground water inflows, data are insufficient to develop an estimate of ground water inputs (USF 2005) and FDEP did not develop TMDLs for the Northern Chain (FDEP 2007). Consequently, a conservative approach was applied here and only the southern lakes were included in an estimate of "lost infiltration" volumes in the WHCL.

Total surface water runoff entering the Southern Chain is an estimated 4.3 billion gallons per year (Table 3-1). Therefore, an estimated 4.3 billion gallons per year (11.8 million gallons per day) no longer percolates into the surficial aquifer, but is instead diverted to the lakes via direct stormwater runoff. If the water was re-directed into ground water infiltration, stormwater runoff and associated nutrient into the lakes would be reduced. Increased ground water recharge could contribute to ground water levels in the surficial aquifer and possibly increase recharge to adjacent lakes via seepage and/or contribute to deeper aquifer recharge. Re-establishing soil infiltration and surficial aquifer recharge as a water source in the WHCL could decrease the variability, or "flashiness", in water levels, while dry season lake levels could be held higher due to increased ground water seepage during periods of reduced rainfall.

Table 3-1. Water budget summary for the lakes in the Southern Chain of the WHCL (from USF 2005).

Lake	Lake Surface Area (acres)	Contributing Watershed (acres)	Runoff Volume from Watershed (acre-feet)	Runoff Volume from Watershed (MG)
Cannon	328	746	1,455	474
Blue*	54	116	939	306
May*	52	610	7,233	2,357
Spring*	23	93	515	168
Eloise	1,163	843	386	126
Hartridge	415	508	652	212
Howard	625	1,153	1,681	548
Idylwild	93	267	665	217
Jessie	186	783	2,192	714
Lulu	307	547	834	272
Mariana	511	1,445	2,745	895
Mirror	126	163	227	74
Roy	74	297	697	227
Shipp	277	534	1,126	367
Summit	64	122	188	61
Winterset	548	694	260	85
Average	363	623	1,008	329
Total	4,717	8,102	13,109	4,272

*Lakes with enough runoff that they "export" surface flows to adjacent lakes via interconnected canals

Data from the PLRG study (USF 2005) for the Southern Chain and TMDLs (if adopted) were used to estimate SIA treatment areas. The SIA treatment areas for lakes with adopted TMDLs represent the phosphorus load reduction required to meet the TMDL. While half of the lakes in the Southern Chain do not have adopted TMDLs, phosphorus reduction estimates can provide "ballpark" figures of reductions needed to meet the PLRGs and/or NNC. Therefore, estimates of SIA acres necessary for lakes without adopted TMDLs were made to provide management guidelines for the WHCL based on the PLRG and NNC (if applicable). The acres (and percent of total acres in watershed) of SIAs needed to meet the PLRG/TMDL requirements and NNC (if applicable) were therefore calculated for each lake (Table 3-2). The USF report (2005) calculated PLRGs based on the phosphorus reduction needed for a TSI value of 60. For the concentration reduction needed to meet the NNC, the reduction was simply the difference between the NNC for a lake and its geometric mean for phosphorus divided by the geometric mean.

Acres of SIA necessary to address TMDLs in the WHCL watershed range from 5.2 acres to meet a 28 percent phosphorus reduction in Mirror Lake to approximately 133.3 acres to meet 50 percent reduction for Lake Jessie. Acres of SIA estimated to meet NNC were 5.2 acres for a 44 percent phosphorus reduction in Lake Mirror to meet its NNC and 133.3 acres for the same 44 percent reduction in Lake Jessie to meet its NNC.

Table 3-2. Acres of SIAs needed to treat stormwater volumes that meet phosphorus reduction goals for TMDLs/PLRGs and/or NNC in the Southern Chain of the WHCL

Lake	Runoff (inches/year)	Total P (kg/year)	Percent Reduction for PLRG/TMDL	Area to be treated by SIA to meet PLRG/TMDL (and percent)	Percent TP Concentration Reduction for NNC	Area to be treated by SIA to meet NNC (and percent)
Blue	97.4	155	90	70.0 (60)	85	77.7 (67)
Cannon*	23.4	280	54	64.9 (9)	17	24.0 (3)
Eloise	5.5	192	31	9.9 (1)	17	6.4 (1)
Hartridge	15.4	224	19	10.2 (2)	NA	NA
Howard*	17.5	336	63	86.8 (8)	23	37.5 (3)
Idylwild*	29.9	104	43	23.6 (9)	33	21.4 (8)
Jessie*	33.6	254	50	133.3 (12)	44	138.6 (12)
Lulu*	18.3	167	55	37.9 (7)	39	31.7 (6)
Mariana	22.8	457	17	30.5 (3)	3	7.2 (1)
May*	142.3	185	58	34.3 (6)	47	33.4 (5)
Mirror*	16.7	71	28	5.2 (3)	44	9.7 (6)
Roy	28.2	73	21	11.8 (4)	ID	ID
Shipp*	25.3	241	65	60.4 (11)	42	46.5 (9)
Spring	66.6	38	NA	NA	ID	ID
Summit	18.4	42	11	1.7 (1)	NA	NA
Winterset	4.5	95	NA	NA	NA	NA

* TMDL adopted; ID= Insufficient data; NA= Not Applicable

Among lakes without TMDLs, estimates of acres of SIAs that may be necessary to address estimated PLRGs ranged from 1.7 acres (approximately one percent of the watershed) in Lake Summit to meet an 11 percent PLRG to 70 acres (60 percent of watershed) in Lake Blue to meet a 90 percent PLRG. Numbers were similar for reductions required and SIA acres necessary to meet NNC. For example, Lake Blue requires an 85 percent reduction in phosphorus to meet its NNC target, which translates to 77.7 acres (67 percent of the watershed) in SIAs.

The average percent reduction required for lakes with an adopted TMDL was 52 percent and the corresponding average number of SIA acres was 56. Percent phosphorus reductions required to meet NNC for lakes with TMDLS averaged 66 percent, and acres of corresponding SIAs averaged 71. In contrast with the lakes with TMDLs, the average percent reduction required for lakes without an adopted TMDL was 23 percent and the average number of acres in SIA required to meet that reduction was 17. Percent phosphorus reductions required to meet NNC averaged 33 percent, and acres of corresponding SIAs averaged 30, for lakes without TMDLs.

The methods used to calculate SIA for phosphorus load reductions are presented here. The watershed boundaries for each lake were identified using 2008 digital orthophoto quarter quadrangle (DOQQ) aerials, known hydraulic structure connectivity (e.g. pipes, channels, and structural weirs) as well as topographic slope from the Peace Creek Digital Terrain Model. Those sub-basins contributing to each lake were grouped to delineate the contributing drainage area. An effort was made to identify hydraulically closed sub-basins, however, due to ground water connectivity any questionable areas were determined to contribute to the lake. This is a conservative approach for the purpose of this delineation.

SIAs have a documented phosphorus removal efficiency of 85 percent (Harper 2008), i.e. 85 percent of phosphorus in the stormwater runoff captured by the SIAs will be removed. The location and sizing of SIAs vary, but the SIAs are designed to capture the total treatment volume (from the contributing watershed) and be conducive to infiltration of the treatment volume within two hours. The areas calculated were generated for each lake watershed, not for specific projects. Assumptions applied toward the calculation of the area of SIAs necessary to treat the stormwater runoff volumes to meet a lake's TMDL are list below.

- Significant rain events are defined as those with more than 1.0 inch or more of rain, plus half of the rain events with 0.1 to 1.0 inches of rain.

- Rainfall analyses for stormwater frequency completed for Orange County Stormwater Management Annual Report are appropriate for the WHCL watershed (http://www.orangecountyfl.net/Portals/0/Resources/Internet/DEPARTMENTS/Public_Works/ Docs_2010/2009RainfallReport.pdf).

- The phosphorus treatment efficiency of the SIAs is 85 percent removal rate.

- The treatment capacity of the SIAs is based on an average depth of 3.0 inches and a soil infiltration rate of 6.0 inches/hour and a depth of at least 6.0 feet to the aquifer.

- SIAs do not include landscape buffers or access easements.

- SIA size is designed to capture the treatment volume of the watershed during any significant rainfall event.

- A design safety factor of 2.0 was used provide an additional conservative estimate of area needed to treat the necessary stormwater volume.

Prior work has indicated that ridge lakes in the WHCL would benefit from higher water levels during the dry season (PBS&J 2008). Increased surface water infiltration would provide additional stormwater treatment via particle filtration, phosphorus absorption to carbonate sediments, and (potentially) nitrogen reduction via dentrification. In addition, recent studies have demonstrated that in-situ practices such as bio-swales, bio-infiltration, engineered soil media systems or engineered permeable pavement that receive runoff from impervious urban areas can greatly reduce runoff and help restore the pre-development hydrology (University of Florida 2009). A recent study showed that water level fluctuations in Lake Haines were correlated with

the level of the surficial aquifer, but only when the surficial aquifer was at a higher elevation than the lake itself (PBS&J 2009).

Together, these findings indicate that maintaining higher water table levels in the WHCL watershed may be a useful lake management strategy for improving water quality. An estimated two billion gallons a year of stormwater runoff could be diverted from lakes, helping to improve water quality and restore hydrology.

3.5. Aquatic and Wetland Vegetation

Aquatic and wetland vegetation, including forested wetlands, submerged aquatic vegetation (SAV), emergent aquatic vegetation (EAV), and floating treatment wetlands (FTWs) have been proven effective for improving water quality. Rehydrating forested wetlands along a lake can increase the color of a lake and reduce the light available to algae, while EAV and SAV communities provide sustainable means of removing phosphorus from the water column and making it permanently unavailable. FTWs are an alternative form of water quality treatment wetland that floats, rather than being rooted, in a lake or water body.

The removal or diversion of phosphorus from lakes via more traditional sediment removal/inactivation and stormwater treatment wetlands and SIAs can be quantified, as described in previous sections, because a known quantity of sediment or water is captured, diverted, detained, removed, or inactivated. However, while it can be "treated", stormwater runoff that is not captured or diverted before it flows into a lake directly or through a wetland cannot be quantified. Phosphorus removal by EAV and SAV systems have been quantified using measured inflow and outflow concentrations and flow (e.g. the Orlando Easterly Wetlands at Iron Bridge and the SFWMD stormwater treatment systems). In the absence of these data, phosphorus removal via aquatic and wetland vegetation in the WHCL cannot be estimated.

Wetland and aquatic vegetation projects for water quality improvement are described, and the mechanisms by which the projects improve water quality are documented, in the following sections.

3.5.1. Forested Wetland Rehydration

Restoring forested wetlands to hydrologically reconnect a lake with the adjacent floodplain can improve water quality by reducing nutrients and sediment delivery to the lake (Richardson and Pahl 2005) and restoring former color levels to the lake. Both herbaceous (marshes) and forested (swamps) wetlands have been used extensively for water quality improvement (Mitsch and Gosselink 2000). Flooded forests receive a large sediment load during the wet season from surface runoff, providing the substrate for phosphorus adsorption and subsequent burial when waters subside during the dry season. Nitrogen and phosphorus reductions in the soils of a restored floodplain will occur via nitrification/denitrification and sedimentation and soil sorption. During wet periods, the ground water hydraulic gradient is from land to lake.

Depth and duration of water are important to the maintenance of forested wetlands by excluding upland species. Based on physiological tolerances of wetland vegetation, two-year with 14- and

21- day inundation periods and five-year with 14- and 21- day inundation periods are important in that these periods of inundation limit the invasion of wetlands by upland species (Demaree 1932, Hosner 1960, Harms 1973, Brown 1984, Fowells 1965, Conner and Askew 1993, after Light *et al*. 2002). At a depth of approximately one meter, previously established seedlings of upland species will die and faster growing wetlands species will remain.

The purpose of reconnecting or re-establishing forested wetlands associated with the valley lakes is to improve lake water quality (i.e. reduce chlorophyll *a*). In addition to nitrogen and phosphorus reductions, tannic and humic acids from the forested wetlands can reduce chlorophyll *a* concentrations in waterbodies (Terrell *et al*. 2000). The color in valley lakes appears to moderate the transformation of nutrients in the water column, thereby allowing a colored lake to tolerate more nutrients than a clear ridge lake before exhibiting an increase in chlorophyll *a*. While the benefit of improved water quality due to color increases has not been quantified, significant improvements to water quality due to restored forested wetlands is well documented.

The effect of color on water quality is explained by the organic matter exported from forested wetlands into the valley lakes and the subsequent reductions in available sunlight in the water column. Leaves decay on forest floor and may form peat soils or partially decay into loose organic matter. These humic and tannic substances leach from decaying leaves and are transported by stormwater runoff into the lake and can color the water. Color can reduce the amount of sunlight available in the water column and decrease algal and plant growth. In some waterbodies, color is the limiting environmental factor. For example, high color concentrations (> 50 PCU) may limit both the quantity and types of algae in a waterbody (IFAS 2003). Even most blue-green algae are obligate phototrophs and those that grow heterotrophically in the dark have extremely low growth rates (VanBaalen et al. 1971). Consequently, the location of a waterbody in relation to associated forested wetlands has a strong influence on its color (Richardson and Pahl 2005).

Valley lakes typically have greater color than ridge lakes, due at least in part to forested wetland inputs. Valley lakes with less than 20 percent of the shoreline characterized by functional forested wetlands were evaluated to determine if historical forested wetlands are available for rehydration. Historical forested wetlands that are hydrologically disconnected from an adjacent lake were proposed as areas for wetland rehydration. In some instances, the former wetlands may now be cropland/pastureland. A feasibility study is required to evaluate current soils conditions, develop design plans, and identify constraints to inundation. The feasibility study should include the components listed below.

- Review of existing aerials, elevation, vegetation, and soils GIS data
- Ecological and engineering site evaluation.
- Detail analysis of existing hydraulic system
- Identification/Analysis of necessary hydraulic modifications to existing system
- Soil boring and biochemical and geotechnical evaluation of site conditions
- Supplemental topographic survey of project area
- Proposed project area property ownership evaluation
- Review of required utility service to pumping station

- Monthly surficial aquifer water level monitoring for one year
- Evaluation of environmental permitting issues
- Preliminary project design and construction cost estimate

Based on the results of the feasibility study, a cost:benefit analysis could be completed to ascertain if rehydration is possible and cost-effective. One conceptual design for each proposed project area would require the construction of one pump station to convey water from the lake into the constructed containment area as well as a water level/discharge structure. The pumping schedule would be developed based on the soils/surficial aquifer data acquired during the feasibility study. The identified project areas would be kept saturated throughout the year and flooded during the wet season if possible. For approximately one month in the wet season, at least six inches of water would be sustained above the surface in order to reduce encroachment of upland vegetation species.

There are other means of restoring forested wetland hydrology that do not include pumping structures. One includes raising lake levels via the use of control structures and purchase of adjacent lands that may be part of the forested wetland. Another method includes the use of control structures to detain water in the wetland for a long period of time before releasing the water back into the lake. In addition, restoring hydrology in a former forested wetland will result in a pulse of phosphorus to the receiving lake and should be considered as part of a feasibility study.

3.5.2. SAV Planting

Planting and restoring native SAV where appropriate in the WHCL is expected to improve water quality via assimilation of nutrients from the water column and the soil-pore water. SAV can reduce nutrient and chlorophyll *a* concentrations in a lake and subsequently increase transparency in the water column (Blindow *et al*. 2002, Canfield *et al*. 1984, Havens 2003, Shireman *et al*. 1985) and provide fish and wildlife habitat (Canfield *et al*. 1996). Water quality improvements due to SAV can be attributed to direct uptake and nutrient assimilation, sediment stabilization that reduces sediment resuspension (Vermaat *et al*. 2000), as well as associated nutrient sequestration by epiphytes. Canfield *et al*. (1984) reported that SAV abundance is inversely related to phytoplankton levels for Florida lakes. In Lake Okeechobee, chlorophyll *a* concentrations were two to three times lower at locations with high submerged aquatic vegetaion biomass compared with locations without aquatic vegetation (Havens 2003). Increased levels of TP and chlorophyll *a*, and decreased water clarity, occurred in Lake Baldwin (near Orlando) in response to *Hydrilla* eradication efforts (Shireman *et al*. 1985).

At a minimum, *Hydrilla* control efforts should be coordinated with other lake management efforts such that the benefits of one project (i.e. *Hydrilla* control) do not offset the benefits of other projects (i.e. water quality improvement projects). An optimal course of action would be to focus *Hydrilla* control physical removal and replanting efforts as a means of substituting the water quality benefits of "non-native" SAV with the water quality benefits of "native" SAV. A reasonable lake restoration goal for the WHCL system is the threshold value of 30 to 50 percent recommended by Canfield and Hoyer (1992). In lakes with native SAV, invasive species management is recommended to eliminate competition and allow the expansion of existing SAV,

thereby reducing the costs associated with planting. However, if SAV is absent from a lake but conditions in the lake are conducive to SAV, planting is recommended.

Aquatic vegetation distribution is affected by multiple factors: sediment type, water depth and clarity, bottom slope, wave disturbance, and benthic algae (as cited in Havens 2003). An SAV survey is recommended for each lake to calculate the percent of the lake surface area covered by SAV. The SAV cover data would be assessed to determine if present SAV cover exceeds the targeted 30 to 50 percent proposed by the Florida Fish and Wildlife Conservation Commission (FFWCC) (Canfield and Hoyer 1992) and represents desirable aquatic plants. SAV planting is not recommended for those lakes with greater than 30 percent cover. For those lakes with insufficient SAV cover, an evaluation of the sediment type, water depth, water column transparency, bottom slope, wave disturbance, and benthic algae is recommended to determine if conditions are favorable for aquatic vegetation planting. If conditions are favorable, desirable plants would be planted to the maximum allowable water depth.

Twenty-one of the lakes in the WHCL have SAV projects proposed as part of their restoration strategy. In the absence of light measurements, secchi depth is used as an indicator of available light for photosynthesis. Plants would not be planted in water depths greater than the median secchi depth to ensure light penetration. The maximum possible area for planting is calculated for each lake based upon current two foot contour bathymetry data. If additional water quality improvement projects are performed, which may alter the bottom geometry of the lake (e.g. sediment removal), updated bathymetry information would be required to quantify the maximum allowable area for planting based on water depth. Nursery grown *Vallisneria*, a desirable freshwater SAV species, could be planted using a three foot center grid pattern. Planting would occur in early spring to allow sufficient time for the plants to establish during the growing season.

Maintenance is required for SAV plantings in the first year to reduce herbivory and remove encroaching plants. As part of a feasibility study, a Lake Vegetation Index – water quality relationship may be established if data are available. In addition, for individual lakes, an SAV survey and an evaluation of the anticipated water quality improvement if less than 30 percent of the lake is planted should be completed.

3.5.3. Emergent Aquatic Vegetation (EAV) Planting

Both EAV and SAV are critical to the removal and permanent burial of available phosphorus from the water column. Treatment wetlands are constructed based on the phosphorus removal facilitated by emergent and aquatic vegetation. While the plants themselves may assimilate less than 10 percent of the phosphorus from the water column into plant biomass, the plants facilitate the microbial activity and chemical sorption processes (Richardson and Marshall 1986) that account for most of the phosphorus removal (Pietro *et al.* 2006a, Noe *et al*. 2003). Importantly, phosphorus is released back into the water column following plant senescence and decay and herbaceous vegetation provides only a temporary nutrient sink to ameliorate eutrophic conditions. Freeze events (e.g. winter 2010) may increase the amount of dead EAV and therefore result in a temporary increase in phosphorus release following the freeze. It is the nutrient transformations among the plants, soils, and water that can make the phosphorus permanently

unavailable. Phosphorus removal is a function of inflow phosphorus loadings (Kadlec and Wallace 2009), water levels, microorganism populations, seasonal phosphorus adsorption, and phosphorus soil adsorption capacity (Richardson and Marshall 1986).

The accretion and permanent burial of phosphorus into the sediments via EAV and SAV is the only sustainable removal mechanism for phosphorus in these lake systems. Organic, adsorbed, and mineral phosphorus are unavailable to plants and adsorption and precipitation are major mechanisms of phosphorus retention. Sediment characteristics affecting phosphorus availability are briefly outlined below.

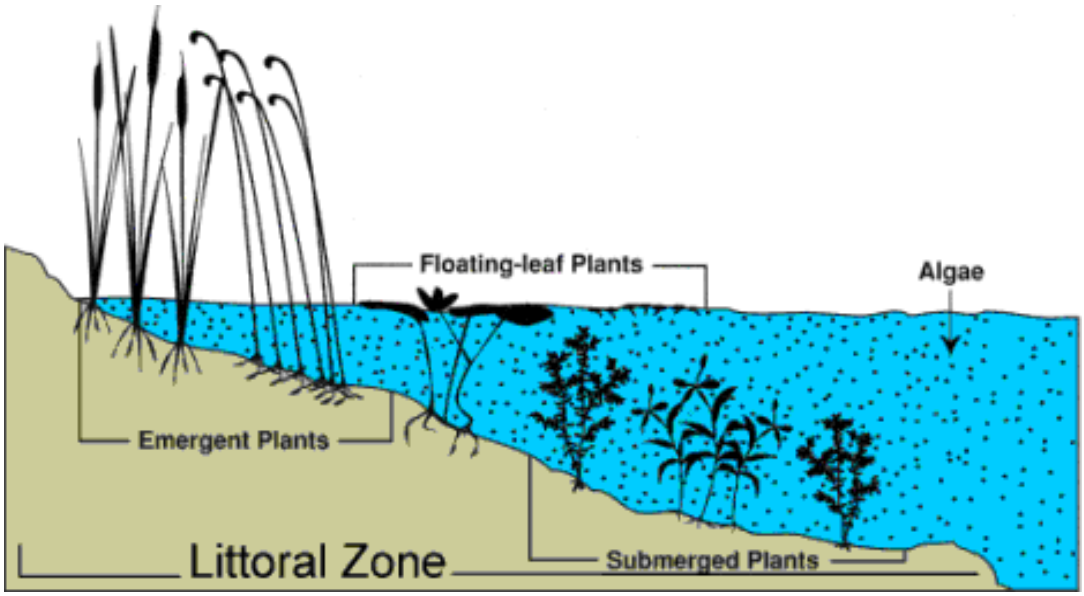
- Adsorption/desorption. Adsorption is the chemical binding of plant available phosphorus to soil particles, making the phosphorus unavailable to plants. Desorption is the release of adsorbed phosphorus from its bound state into the soil solution. Higher iron and/or aluminum content of the sediment increases adsorption.

- Precipitation/dissolution. Phosphorus can become unavailable via precipitation of plant available inorganic phosphorus with dissolved iron, aluminum, manganese (in acid soils), or calcium (in alkaline soils) to form phosphate minerals. Precipitation is more permanent when compared with adsorption (see previous discussion of sediment inactivation). High concentrations of calcium, aluminum, or iron can also precipitate phosphorus into water column. The presence of redox-insensitive phosphorus binding systems such as $Al(OH)_3$ and unreducible Fe(III) minerals can enhance the phosphorus retention and completely prevent phosphorus release even in case of anoxic conditions (Hupfer and Lewandowski 2008).

- Immobilization/mineralization. Mineralization is the microbial conversion of organic phosphorus to plant available orthophosphates. Immobilization occurs when the plant available phosphorus is consumed by microbes and thereby converted unavailable organic phosphorus.

The littoral zones of lakes are typically less than three meters in depth, thereby allowing sunlight penetration adequate for plant growth. The littoral zone includes EAV and SAV at different depths, but typically overlapping (Figure 3-23). The width of the littoral zone will vary in a lake and among lakes and where the slope of the lake bottom is steep, the littoral area may be narrow, extending several feet from the shoreline. In contrast, if the lake is shallow and has a gradual slope, the littoral area may extend hundreds of feet into the lake or may even cover it entirely. EAV includes aquatic plants that are rooted in the lake bottom but protrude above the water surface, e.g. floating water lilies (*Nuphar* spp. and *Nymphaea* spp.), bulrushes (*Scirpus validus*), wild rice (*Zizaniopsis miliaceae*), duck potato (*Sagittaria* spp.), and cattails (*Typha latifolia*).

Figure 3-21. EAV and SAV distribution in the lake littoral zone (after MDNR 2010).



A vegetated wetland buffer between land development and the water intercepts nutrients and sediments and can improve or restore biodiversity (Wall *et al*. 2001, Dosskey 2001, Brinson *et al*. 2002, Fiener and Auerswald 2003). Vegetated buffer zones decrease nutrient and sediment transport by detaining water, allowing particle sedimentation, and increasing soil infiltration capacity (Cooke *et al*. 2005, Lee *et al*. 2003). Wetzel (1992, 2001) refers to this EAV dominated portion of the littoral zone as the riparian zone and describes it as a gradient community between the lake and the upland. The riparian zone reduces nonpoint nutrient loading (Cooke *et al*. 2005, Dosskey 2001) and restoration of this zone is an important part of lake rehabilitation (Cooke *et al*. 2005). VanNess (2002) also reports that the re-establishment and conservation of aquatic plants within shallow lakes is a vital component for successful restoration of shallow lakes (van Ness *et al*. 2002).

Consequently, re-establishing native EAV vegetation, where appropriate, is expected to improve water quality in the WHCL. The WHCL Education/Action Drive (Lakes LE/ADer) recommends shoreline aquascaping for lake residents and includes a short description of the benefits of the practice and a list of several desirable EAV species (e.g. duck potato, bulrush, maidencane, and pickerel weed) that can be planted along shorelines for aquascaping (Selser 2010). Lakescaping is another common term used to describe the establishment of EAV along lake edges and is typically designed to return 50 to 75 percent of the shoreline to a vegetated condition, without obscuring views (Cooke *et al*. 2005). Costs range from $46,200 to $6,200 per hectare (Henderson *et al*. 1999). This proposed project differs from forested wetland rehydration in that it includes planting vegetation only along the shoreline and does not rely on restored hydrologic connects. SAV planting projects are limited to deeper portions of the littoral zone. Examples of marsh, shrub, and forested shorelines are illustrated in Figure 3-24.

A good example of the effectiveness of vegetated wetland buffers (compared with no EAV or SAV) is illustrated in a comparison of a control site with a seven meter wide switchgrass (*Panicum virgatum*) wetland buffer, and the same buffer with an additional 13 meter wide forested buffer (Zaimes *et al*. 2004). The switchgrass buffer alone removed more than 90 percent of sediments and 80 percent of TP over the 18 month study period. The combined buffer zone reduced TP from 200 g/hectare to 19 g/hectare and sediments from 587 g/kg to 16 kg/hectare (Lee *et al*. 2003). Wider vegetated zones promote more water infiltration and nutrient retention (Schmitt *et al*. 1999). Wetland species other than switchgrass would also be effective buffers.

In addition to EAV and SAV, forested lake edges (wetlands) also remove nutrients from the water column. Effective nutrient reduction of secondarily treated effluent in forested wetlands in Louisiana has been successfully demonstrated (Hunter *et al*. 2009). Removal efficiencies for total nitrogen and phosphorus are typical of other forested wetlands receiving treated effluent in Louisiana, ranging between 65 and 90 percent (Hunter *et al*. 2009a). Wetland trees cannot germinate under water and EAV has a limited tolerance to inundation, consequently, the most important component of shoreline vegetation is water level (elevation). Vegetation must be planted at appropriate inundation intervals. If water levels are too high, the vegetation will shift landward if space is available, while water levels that are too low will result in invasion by upland species and loss of wetland species and commensurate water quality functions. Success of a shoreline planting is also strongly affected by other plant species as well and invasion by upland or non-native invasive species can eliminate the desirable wetland plant species.

An evaluation of shoreline and littoral vegetation data should be completed for each lake. For those lakes without shoreline vegetation, an evaluation of the sediment type, water level and inundation frequency, slope, wave disturbance, is recommended to determine if conditions are favorable for shoreline planting. Plants appropriate for typical water levels and water level variation should be selected and planted. Non-native and invasive plants should be removed prior to planting and controlled post-planning for a minimum of one year. If conditions are favorable, desirable plants should be identified for shoreline vegetation planting (Table 3-3, Figure 3-25).

Figure 3-22. Conceptual diagram of EAV and SAV (top) and forested (bottom) wetlands lake restoration projects.

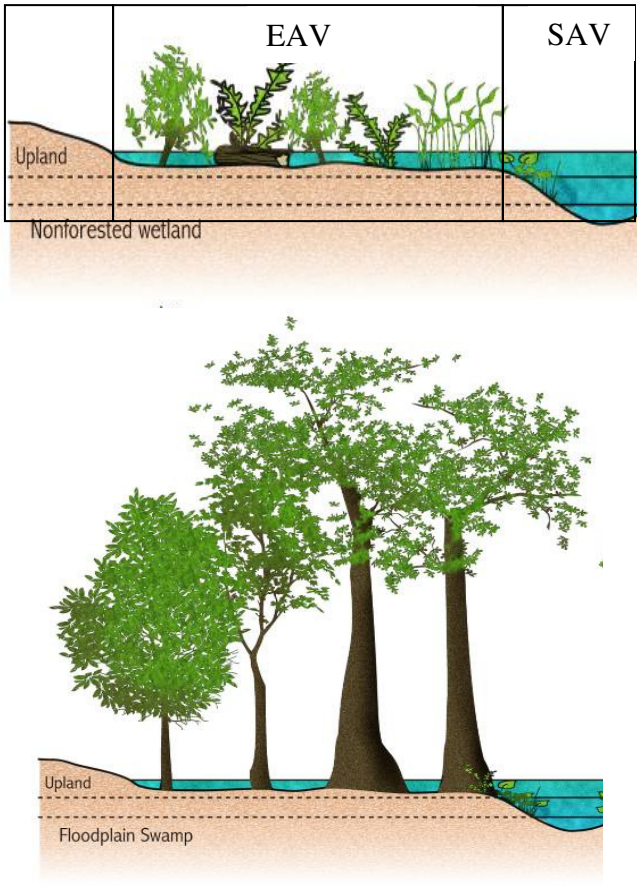


Table 3-3. List of potential plant species for EAV planting project.

Common Name	Scientific Name	Elevation based on Mean High Water Level (feet)
Softstem bulrush	*Scirpus validus*	-2.0 to -3.0
Pickerel weed	*Pontedaria cordata*	-1.0 to -2.0
Maidencane	*Panicum hemitomon*	-1.0 to -1.5
Arrowhead	*Sagittaria lancifolia*	-1.0 to -1.5
Spikerush	*Eleocharis interstincta*	-0.5 to -1.0
Sand Cord Grass	*Spartina bakeri*	0 to +2.0
Muhly grass	*Muhlenbergia capillaris*	0 to +2.0

The first step in planting a shoreline is site preparation to remove undesirable species that may be non-native, invasive, or both. Sod can be removed in a number of ways: through herbicide application, removal with a sod cutter, or by smothering sod with black plastic or other materials.

An advantage of herbicides or smothering techniques is erosion prevention. Appropriate permits should be obtained. Bare-root or larger transplants should be planted rather than seeding so that no additional soil preparation, fertilizer, or soil supplements will be needed. Plants should be selected to be compatible with existing elevation and soils.

One planting technique on shallow slopes is to cover existing vegetation with a four-inch thick layer of mulch. However, mulch must be retained in the planting area. Biodegradable erosion control blankets can be used to retain the exposed disturbed soil. In areas subject to wave action, temporary wave breaks may need to be installed to prevent erosion. Protective fencing might need to be installed to protect the sapling plants from birds. Install the container plants using a three foot on center pattern and water thoroughly. Plants should be installed in the late fall/early winter to encourage below ground biomass and successful plant establishment.

3.5.4. Floating Treatment Wetlands

Floating treatment wetlands (FTWs) can provide an alternate means of reducing nutrients in the water column and improving water quality in the WHCL. Water quality improvements in water that flows through wetlands have been documented extensively (Kadlec and Wallace 2009, DeBusk *et al*. 2005, Kadlec and Knight 1996) and the South Florida Water Management District has constructed over 40,000 acres of stormwater treatment wetlands to treat surface water runoff in the Everglades. Water leaving a wetland has lower dissolved and organic nutrient loads (via multiple pathways, e.g. plant assimilation, denitrification, immobilization, physical settling) when compared with the water flowing into the wetland. Even though FTWs are not specific to stormwater treatment or flow-through systems, they are anticipated to provide this same function.

A FTW is composed of emergent wetland vegetation suspended on the water surface by a buoyant raft. In contrast to wetland systems, research on FTWs is limited and they rely primarily on plant assimilation of nutrients (Hubbard 2010, Hubbard *et al*. 2004), and therefore must be harvested or nutrients will be returned to the water column following plant senescence. The nutrient removal efficiency is related to the amount of biomass produced by the selected vegetation (Hubbard 2010) and can therefore be maintenance intensive. Biomass harvesting can also be required of naturally floating vegetation (water hyacinths and duckweed). It is anticipated that the aesthetic vegetation islands also provide food and habitat for wildlife, including waterfowl, songbirds, frogs, and turtles (Floating Island International 2010). FTWs would only be used in situations where other options are not available and can be located so as not to impede navigation or shade SAV.

The raft systems and plant species are the most important considerations for a FTW (Headley and Tanner 2006). Design criteria to establish the size and distribution of FTWs required to treat a waterbody is presently unavailable (Headley and Tanner 2006). Three scenarios for FTW deployment in a stormwater pond are illustrated in Figure 3-22. Reduced dissolved oxygen levels in the water column below FTWs have been reported (Headley and Tanner 2006) and FTWs should not, therefore, extend across an entire lake. Several small FTWs throughout a lake are recommended for water quality restoration. Annual maintenance including plant harvesting is required. Plant biomass is a short term sink and annual harvesting of the plant biomass is

required to permanently sequester the nutrient uptake and should occur in late fall/ early winter before the plants senesce and decay. Both cattails (*Typha latifolia)* and maidencane (*Panicum hemitomon)* were successfully documented to perform well in a FTW constructed in Georgia (Hubbard *et al*. 2004).

Figure 3-23. Cross-section of a typical FTW and pond showing main structural elements (from Headley and Tanner 2006).

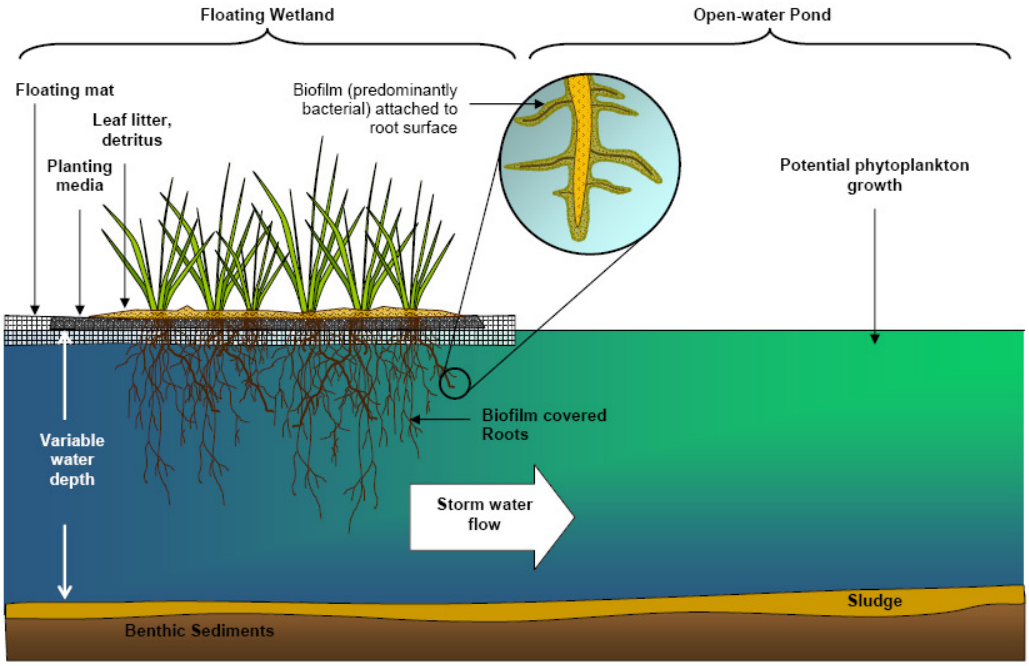


Figure 3-24. Plan view of three design approaches for FTW in a stormwater detention basin (cross-hatching represents FTWs) (after Headley and Tanner 2006).

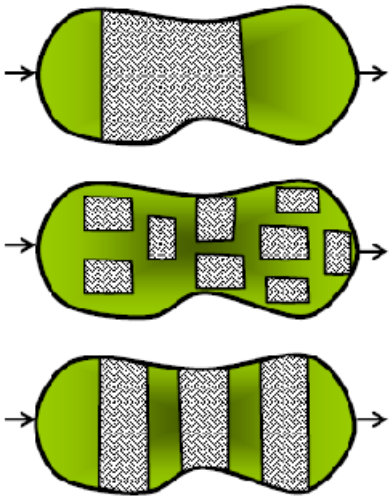


Figure 3-25. Potential plant species for shoreline vegetation planting project Top: soft stem bulrush. Middle: pickerel weed. Bottom: water lily and spikerush.

3.6. Artificial Circulation

Whole lake aeration via artificial circulation is another lake management activity examined as a potential water quality improvement project for the WHCL. Artificial circulation is designed to pump deeper water to the lake surface where the water becomes aerated (Pastorak *et al*. 1981, 1982). The technique was originally developed to prevent winter fish kills but its primary application is now treating eutrophication. Artificial circulation also transports phytoplankton biomass to the deeper, light limited portion of the water column, thereby reducing the light available for photosynthesis and phytoplankton productivity (Cooke *et al*. 1993). Associated changes in CO_2 and pH, buoyant cell (blue-green algae) distribution, and zooplankton grazing have also been reported to alter phytoplankton composition. Finally, reduced internal phosphorus loading is possible if iron is the factor controlling sediment phosphorus release. The aeration of the sediment-water interface can result in phosphorus adsorption to ferric-hydroxy complexes

resulting in a decrease in phosphorus release to the overlying water column (Stumm and Leckie 1971). However, colloidal organic matter can retard the formation of the nonreactive iron (Fe^{+3}) and allow phosphorus to remain free in solution and therefore biologically available (Koenings and Hooper 1976).

There are examples in the literature of improved water quality following lake aeration, but many appear to be insufficient in terms of experimental design. However, results of a whole-lake aeration system installed in the Lake Persimmon, a hypereutrophic lake in Highlands County, were documented by SWFWMD scientists. Kolasa and Kang (2005) concluded that "…several parameters have shown improvements including the reduction of ammonia and also chlorophyll" in Lake Persimmon. While nitrate loads to the lake did not decline, local homeowners have noted the improvements. The aeration system was taken offline due to maintenance problems. Grochowska and Gawronska (2004) also documented water quality improvements as a result of lake aeration in a eutrophic lake in Poland. Lake water quality improved substantially but was not sufficient to reduce phytoplankton production or improve the trophic state.

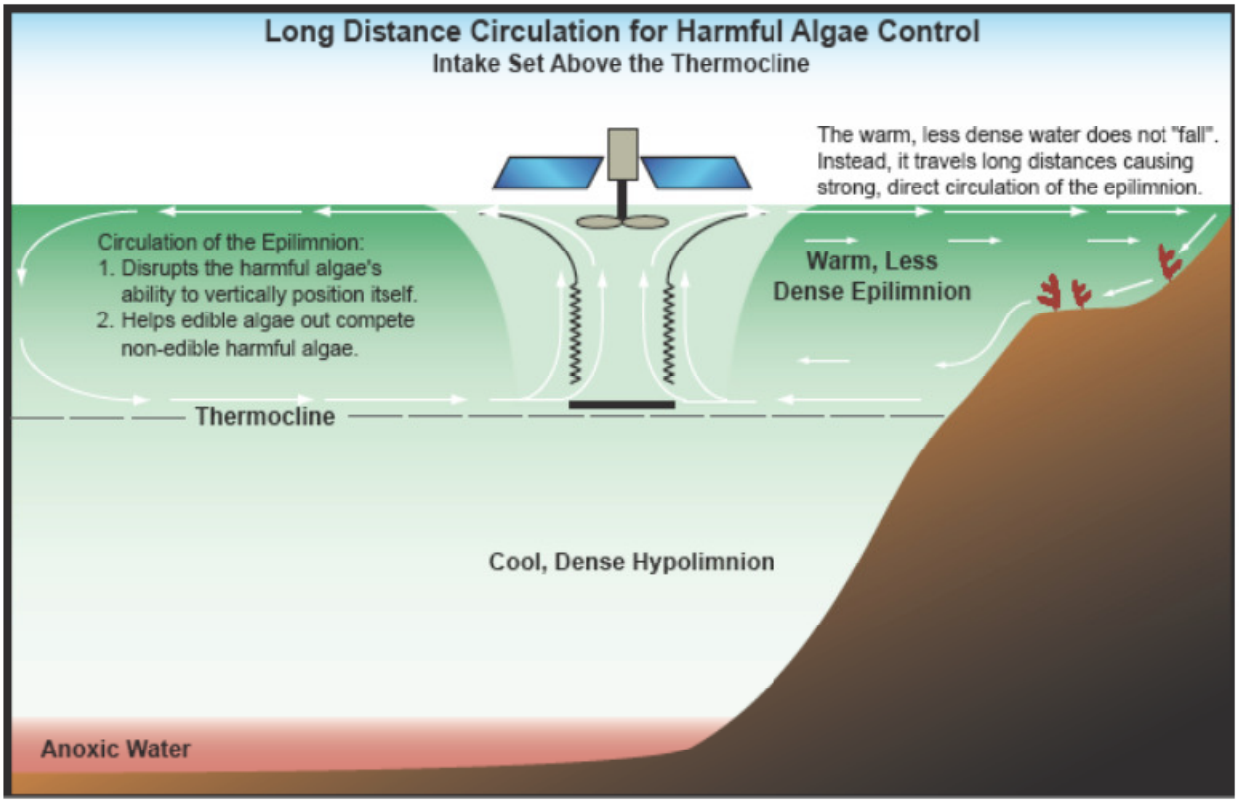
Artificial circulation is accomplished using electric powered pumps to pull water from the lower water depths to the water surface (Figure 3-26). The water intake system can be positioned in the water column based upon the unique water depth and sediment quality characteristics of the lake. Solar powered pumps (e.g. SolarBee®) have been developed to reduce operation costs. The number and size of the pumps for an individual lake depend on water quality and depth, lake size, and non-point source inputs. Artificial circulation is only recommended for small lakes (< 75 acres) with poor water quality, and costs for WHCL ranged from $55,000 (Lake Spring) to $215,000 for Lake Summit.

Operations and maintenance costs were difficult to examine. However, estimates for the Township of Wiconisco in Dauphin County, PA, indicated savings of approximately $251,000 in operations costs over 20 years by replacing seven mechanical aerators with SolarBee solar aerators. Total installation and operation of mechanical aerators totaled approximately $404,000, compared with $182,000 for the solar powered aerators (SolarBee.com).

3.7. Summary

There are several lake management approaches and techniques that can be used to address water quality issues and concerns in the WHCL. Even if external loads to lakes are reduced or eliminated, internal nutrient loads should be managed. In addition to documented successes of sediment removal and inactivation and wetlands treatment, water quality improvements may also be accomplished using less traditional methods, including artificial circulation, SAV planting, forested wetland rehydration, stormwater infiltration areas, and shoreline vegetation establishment. Water quality improvements expected as a result of projects such as forested wetland rehydration and SIAs will occur as a result of the water quality/hydrologic restoration benefits. Applications of these methods to individual lakes in the WHCL are presented in Section 4: *Lake-Specific Restoration Projects*.

Figure 3-26. Schematic of proposed artificial circulation system using SolarBee system.



4.0 Lake-Specific Restoration Projects

Lakes in the WHCL for which restoration projects are proposed are individually characterized in this section of the WQMP (in alphabetical order). Physical, chemical, and regulatory characteristics are presented in table format and maps illustrating land use and topography are provided for each lake. Watershed boundaries for each lake were identified using 2008 DOQQs, hydraulic structure connectivity, and topography from the Peace Creek Digital Terrain Model, as described in Section 3.4. Those sub-basins contributing to each lake were grouped to delineate the contributing drainage area. The decision key presented earlier is included for each lake, with the path to projects highlighted for that particular lake. Finally, proposed restoration projects specific to each lake are listed and described.

Developed and undeveloped lands and high and low infiltration soils are identified for each lake watershed in each of the lake sections to illustrate that development has occurred primarily on high infiltration soils into which rainfall historically percolated. Consequently, much of the former ground water infiltration is now surface water runoff due to developed, impervious surfaces. However, all developed areas are not necessarily impervious (e.g. orange groves and pasture) and all undeveloped areas are not necessarily "natural areas" (e.g. orange groves and pasture). Land use cover data were obtained from the SWFWMD (2006) and may not be consistent with more recent 2010 aerial photography.

4.1. Lake Blue

Background

Physical and chemical characteristics specific to Lake Blue are presented here in the context of relevant regulatory criteria and requirements (Table 4-1). Lake Blue (WBID 1521Q) contributes to the WHCL Southern Chain and connects to Lake Cannon via a constructed canal and a gated structure that restricts flow between lakes (Photo 4-1, Figure 4-1). In 2010, Lake Blue was declared verified impaired based on elevated TSI values (> 60), indicating a nutrient impairment. A TMDL is required for Lake Blue to calculate load reductions necessary to satisfy the TSI criteria. The TP, TN, and chlorophyll *a* geometric mean for Lake Blue for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-1. To comply with the NNC, concentration reductions of 85 percent for TP, 62 percent for TN, and 90 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Blue is presented in Table 4-2. The minimum recorded chlorophyll *a*, TN, and TP concentrations exceed the NNC targets provided by EPA for Lake Blue. Chlorophyll *a* concentrations in Lake Blue have fluctuated but have remained consistently elevated above 6 µg/L (Figure 4-2). A statistically significant trend in chlorophyll *a* concentrations from 1987 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). An inverse relationship between lake levels and chlorophyll *a* concentrations may suggest sediment resuspension resulting in a decline in water quality. No water quality improvement projects have been implemented in Lake Blue to restore water quality. Due to the hydrologic isolation of Lake

Blue from the Southern Chain by a gated structure, improvements in water quality of the lake would result in little benefit farther downstream.

The Lake Blue watershed is 116 acres in size and includes 94 acres (81 percent) of developed lands compared to 22 acres (19 percent) of undeveloped lands. The 2000-2007 median color value (30 PCU) was below 40 PCU indicating it is a clear (non-colored) lake and specific conductivity data indicate the lake is acidic. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 149 feet in May 2006. Bathymetry data are available for Lake Blue for the May 2006 water level elevation (Figure 4-3). A water level of 148 feet was reported in August 2010, reflecting a 1.0 foot decrease in water elevation when compared to 2006. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Blue water quality and the surrounding watershed characteristics, five potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-4). The highlighted path in the decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management
- Project 5: Artificial Circulation

Table 4-1. Physical, chemical, and regulatory characteristics of Lake Blue.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	55 (47 percent)
Relation to other lakes	Isolated	**Developed land (acres)**	94 (81 percent)
Watershed area (acres)	116	**Undeveloped land (acres)**	22 (19 percent)
Lake area (acres)*	54	**Median water depth (feet)***	5.6
Perimeter (feet)*	5,800	**Maximum water depth (feet)***	10.5
Surface area: lake volume ratio*	0.13	**Volume (acre-feet)***	401
Watershed to surface area ratio*	2.15		
Water Chemistry			
Locally-derived: acidic or alkaline	Acidic	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	62	**NNC chlorophyll *a* target (µg/L)**	6
Geometric mean TN (mg/L)	2.22	**NNC TN target (mg/L)**	0.85
Geometric mean TP (mg/L)	0.102	**NNC TP target (mg/L)**	0.015
Regulatory Data			
Impaired	Yes	**TMDL status**	Required
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	85 percent

*at a water level elevation of 149 feet
**presented in section 5.0

Table 4-2. Lake Blue water quality characteristics over the period of 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	32	29	79	153
Color (PCU)	25	20	30	38
Conductivity (µmhos/cm)	39	127	145	294
Dissolved oxygen (mg/L)	39	1.4	7.88	13.06
pH	39	5.6	7.6	9.3
Secchi depth (feet)	32	0.6	1.0	2.0
Total nitrogen (mg/L)	43	1.16	2.35	4.03
Total phosphorus (mg/L)	39	0.047	0.101	0.189

Photo 4-1. Water control structure at southern end of Lake Blue.

Figure 4-1. Lake Blue and associated watershed.

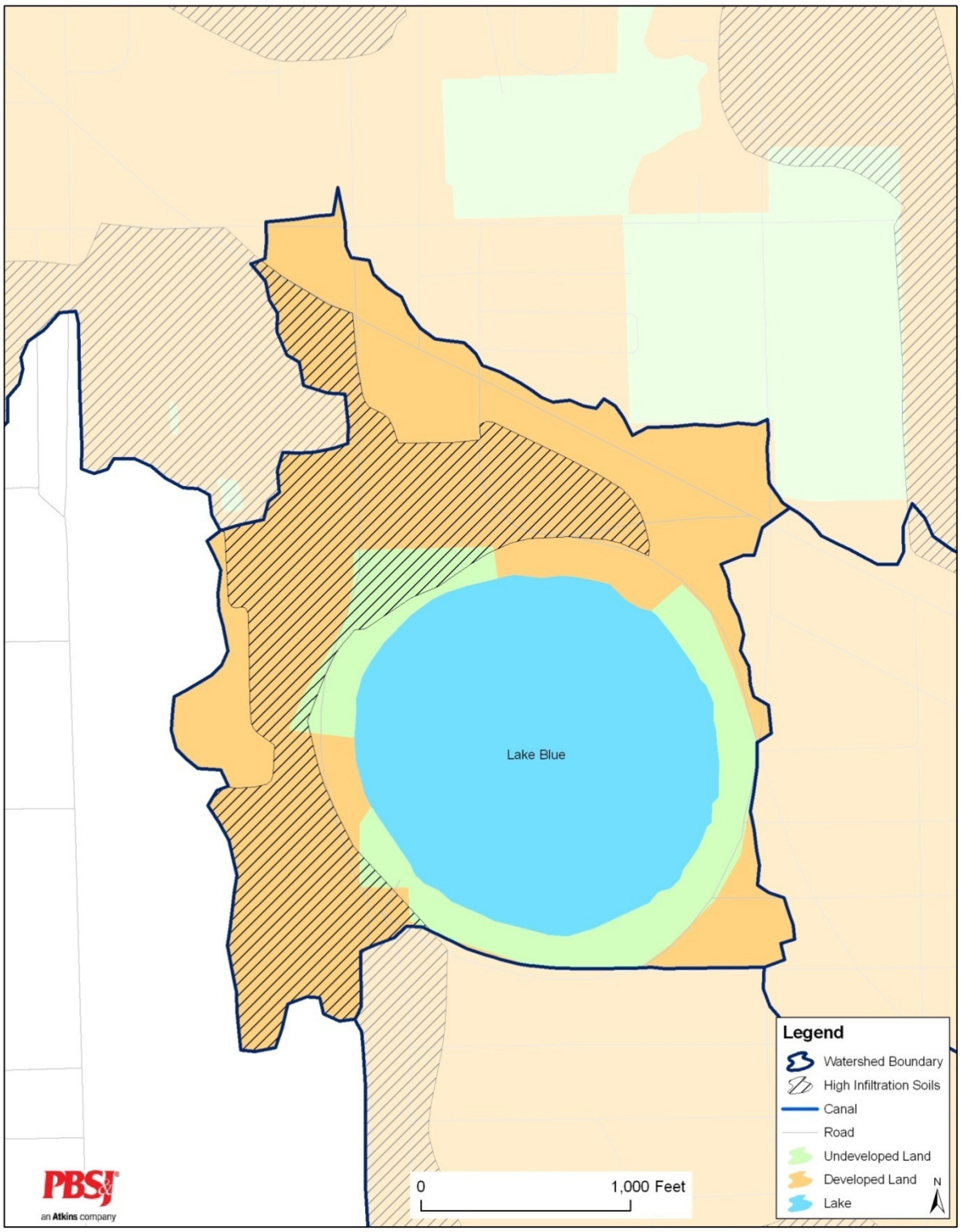


Figure 4-2. Lake Blue chlorophyll *a* concentrations with available data from 1987 to 2007.

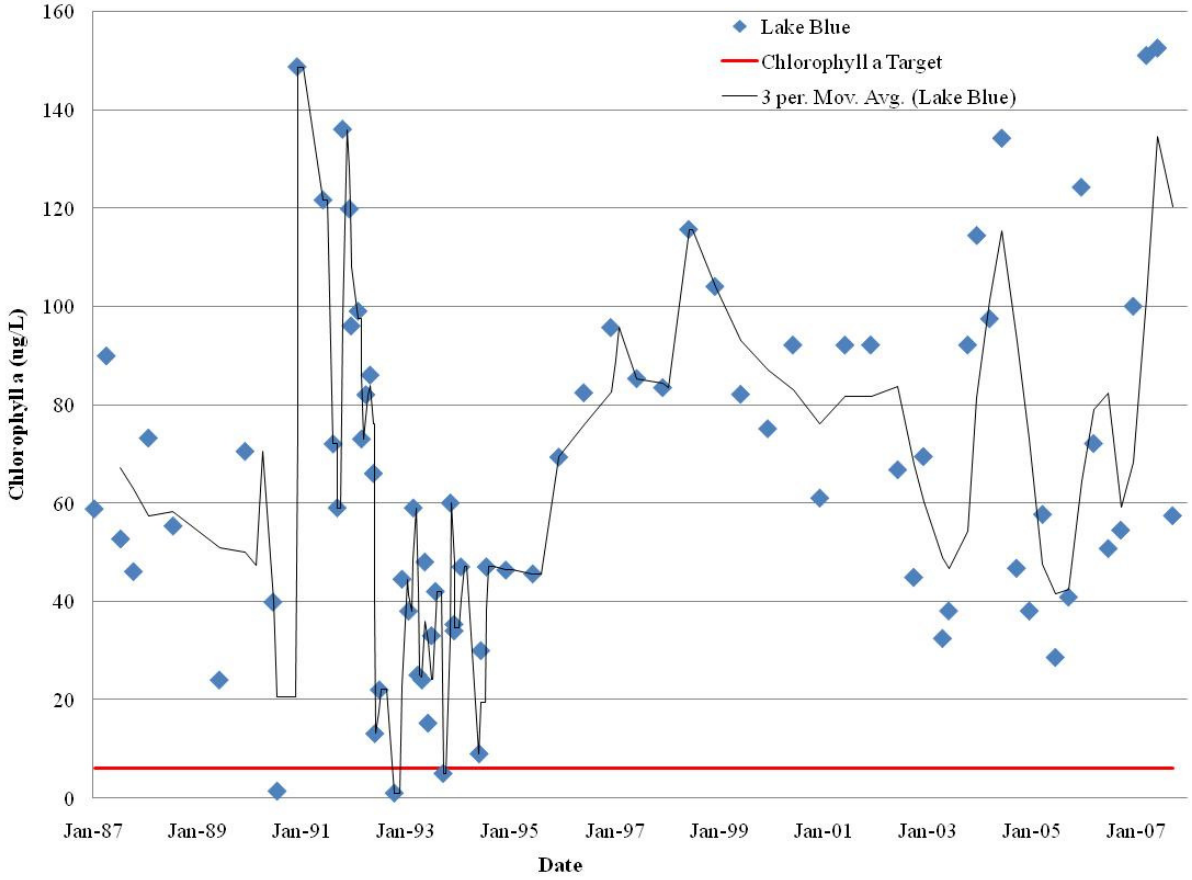


Figure 4-3. Lake Blue bathymetry (May 2006) at water level elevation = 149 feet (Polk County Water Atlas).

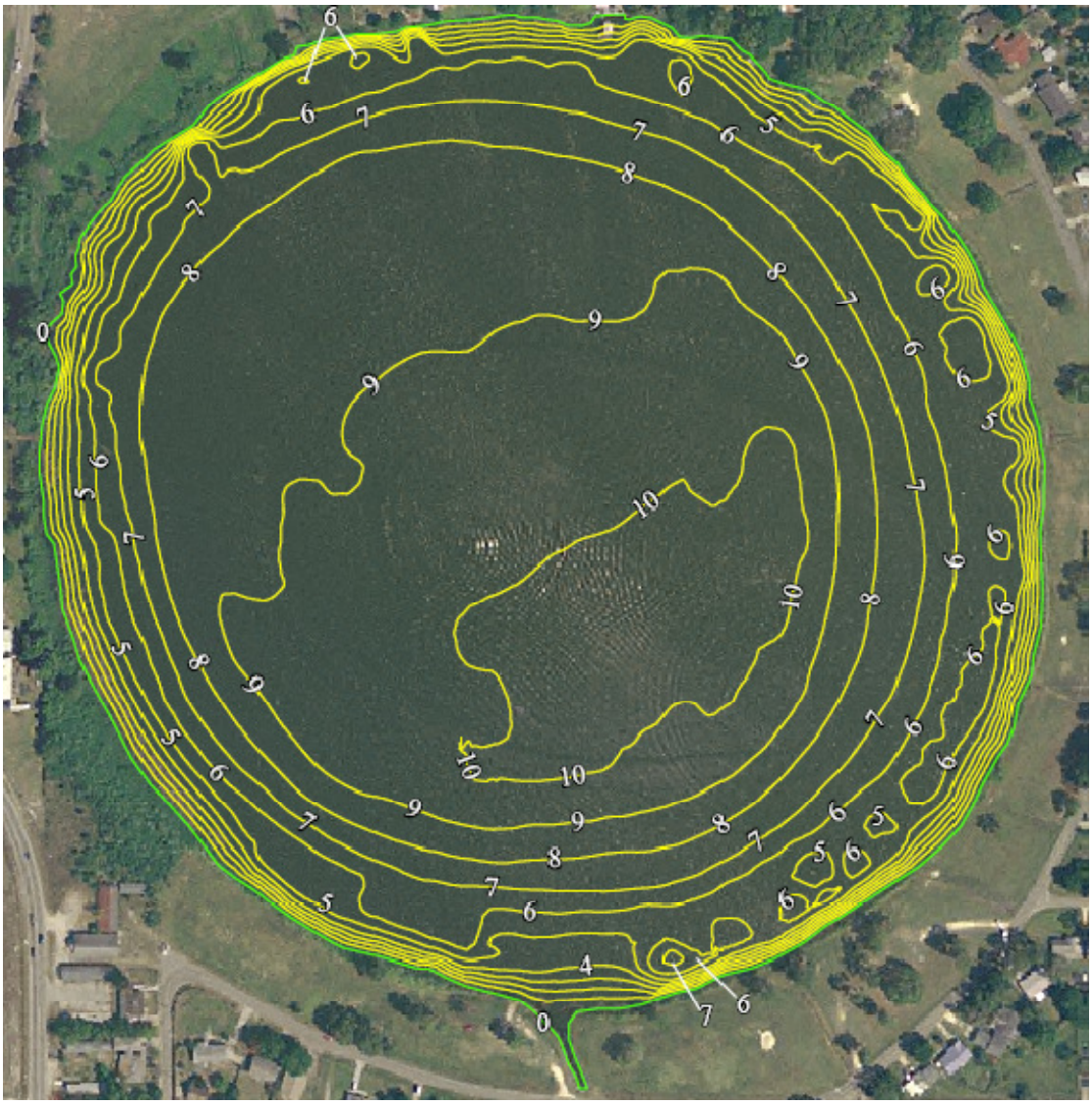
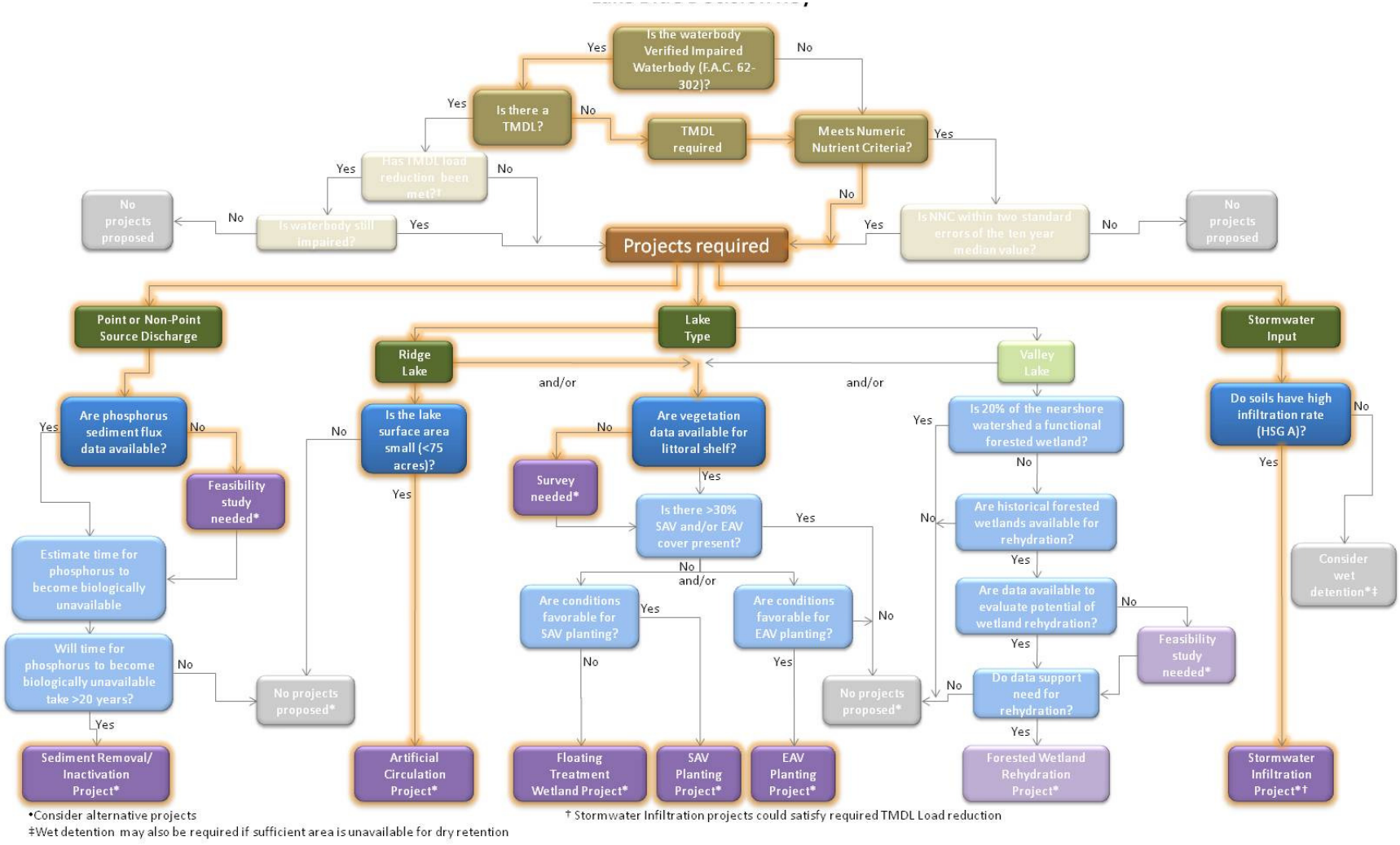


Figure 4-4. Lake Blue decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Blue watershed has approximately 55 acres (47 percent of the watershed) classified as high infiltration soils. Lake Blue does not have a TMDL, therefore, SIA acres estimates were calculated using data from the PLRG (USF 2005). The SIA estimate for Lake Blue was 70 acres (approximately 60 percent of the watershed) to meet a 90 percent PLRG. Acres of SIA estimated to meet the TP NNC was 78 (67 percent of the watershed) for an 85 percent phosphorus reduction in Lake Blue to meet its NNC. Forty-seven percent of the watershed is characterized by high infiltration soils; therefore, it may not be feasible to satisfy the load reductions through SIA implementation.

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Lake Blue may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

Hydrilla infestations have not been a chronic problem in Lake Blue. A survey of existing SAV cover in Lake Blue is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth.

The 1997-2007 median secchi depth for Lake Blue was 1.0 feet indicating that SAV plants should not be planted in water depths greater than 2 feet. The maximum planting effort could result in vegetation cover of approximately 4 percent of the lake bottom (2 acres).

Cost Estimate: $20,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance).

FTWs

If the feasibility study indicates that more than 30 percent of Lake Blue has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing EAV surrounding Lake Blue is recommended due to the lack of sufficient data at this time. Based on the results of the survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited EAV is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

Project 5: Artificial Circulation

The project design is based the system configuration developed by SolarBee®. Each circulation pump is assumed to effectively circulate 16 to 20 acres. The surface area of Lake Blue is 54 acres requiring the purchase and installation of three SB10000 v 18 machines.

Cost Estimate: $160,000 (estimate by Solar Bee®).

4.2. Lake Cannon

Background

Physical and chemical characteristics specific to Lake Cannon are presented here in the context of relevant regulatory criteria and requirements (Table 4-3). Lake Cannon (WBID 1521H) is located in the Southern Chain of the WHCL and is hydrologically connected to lakes Idylwild, and Howard via constructed navigable canals and fixed structures to Lake Blue (Photo 4-2, Figure 4-5) and Deer. In 2005, Lake Cannon was declared verified impaired based on elevated TSI values (>60), indicating a nutrient impairment. A TMDL was adopted for the Southern Chain of the WHCL, including Lake Cannon (FDEP 2007), and Lake Cannon was subsequently delisted from impairment by FDEP in 2010. Based on the modeled external TP load to Lake Cannon, a 54 percent reduction in TP load (137 kg TP/year) is required to comply with the TSI criteria of 60 (FDEP 2007). The TP, TN, and chlorophyll *a* geometric mean for Lake Cannon for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-3. To comply with the NNC, concentration reductions of 17 percent for TP, 11 percent for TN, and 26 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Cannon is presented in Table 4-4. The median chlorophyll *a*, TN and TP concentrations exceed the NNC targets provided by EPA for Lake Cannon. Chlorophyll *a* concentrations in Lake Cannon have fluctuated but have remained consistently elevated above 20 µg/L (Figure 4-6). However, a statistically significant decline in chlorophyll *a* concentrations from 1983 to 2007 was observed (seasonal Kendall-Tau, p=0.0037). Abundant *Hydrilla* populations are commonly found on Lake Cannon resulting in frequent eradication efforts (greater than 60 percent of the lake surface area was treated in 2005). A stormwater alum treatment improvement projects has been implemented in Lake Cannon to restore water quality. Lake Cannon is located in the middle of the southern chain of lakes; therefore, improvements in water quality of the lake could result in benefit farther downstream.

The Lake Cannon watershed is 746 acres in size and includes 712 acres (95 percent) of developed lands compared to 35 acres (5 percent) of undeveloped lands. The 2000-2007 median color value (17 PCU) was below 40 PCU, indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 129 feet in June 2007. Bathymetry data are available for Lake Cannon for the June 2007 water level elevation (Figure 4-7). A water level of 130 feet was reported in July 2010, reflecting a 1.0 foot increase in water elevation when compared to 2007. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Cannon water quality and the surrounding watershed characteristics, four potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-8). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in

order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/ Management

Table 4-3. Physical, chemical, and regulatory characteristics of Lake Cannon.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	501 (67 percent)
Relation to other lakes	Intermediate	**Developed land (acres)**	712 (95 percent)
Watershed area (acres)	746	**Undeveloped land (acres)**	35 (5 percent)
Lake area (acres)*	335	**Median water depth (feet)***	9.9
Perimeter (feet)*	16,440	**Maximum water depth (feet)***	16.6
Surface area to lake volume ratio*	0.10	**Volume (acre-feet)***	3,486
Watershed to surface area ratio*	2.23		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (ug/L)	27	**NNC chlorophyll *a* target (ug/L)**	20
Geometric mean TN (mg/L)	1.12	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.036	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required†
Chlorophyll *a* trend	Decreasing	**TP concentration reduction required**	17 percent

*at a water level elevation of 129 feet
**presented in section 5.0
† TMDL adopted

Photo 4-2. View from western shoreline of Lake Cannon.

Table 4-4. Lake Cannon water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	287	6	28	73
Color (PCU)	158	5	17	35
Conductivity (µmhos/cm)	98	190	217	285
Dissolved oxygen (mg/L)	98	5.25	8.35	11.46
pH	98	6.2	8.06	9.43
Secchi depth (feet)	321	1.2	2.1	6.4
Total nitrogen (mg/L)	314	0.53	1.08	1.92
Total phosphorus (mg/L)	307	0.003	0.043	1.82

Figure 4-5. Lake Cannon and associated watershed.

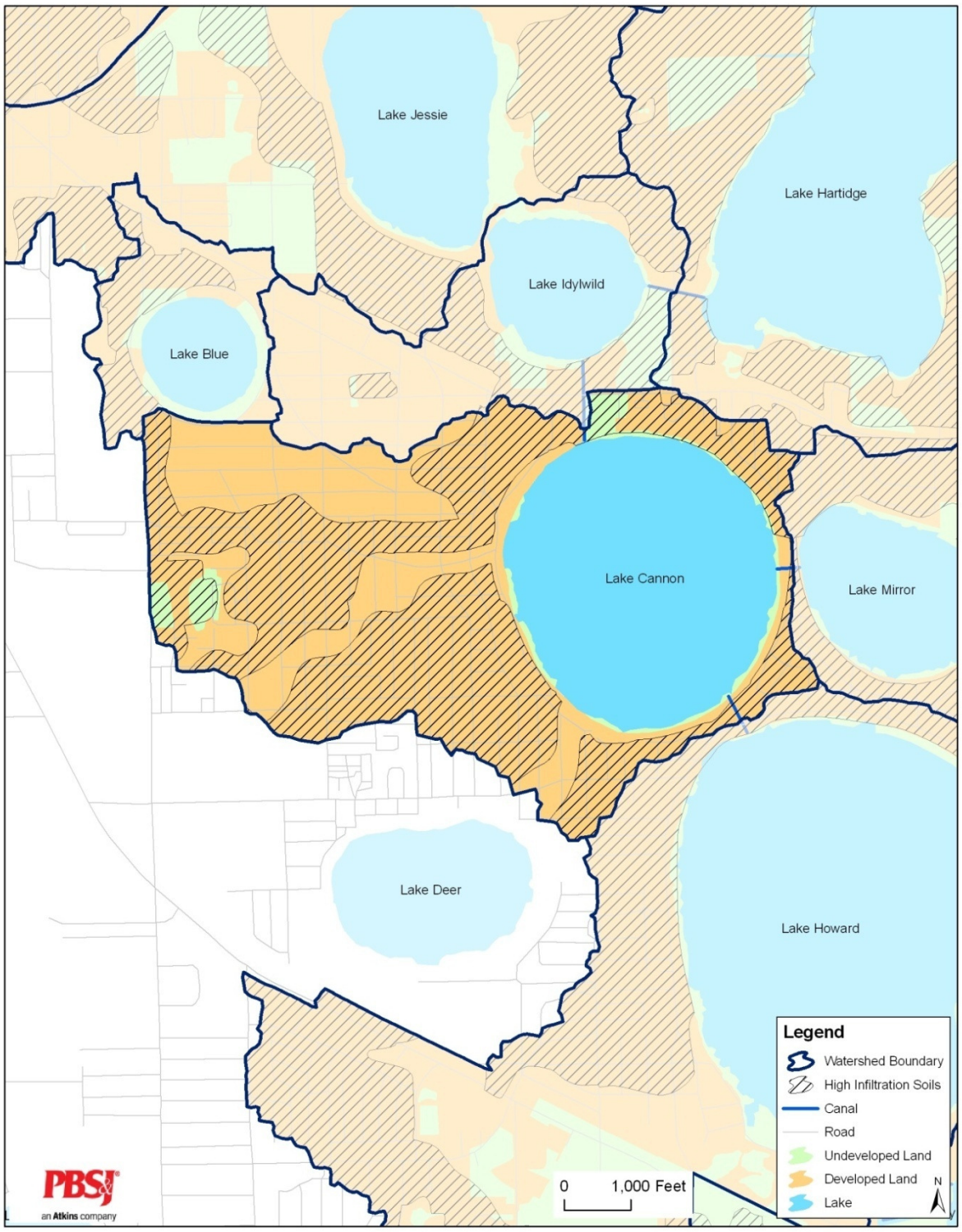


Figure 4-6. Lake Cannon chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

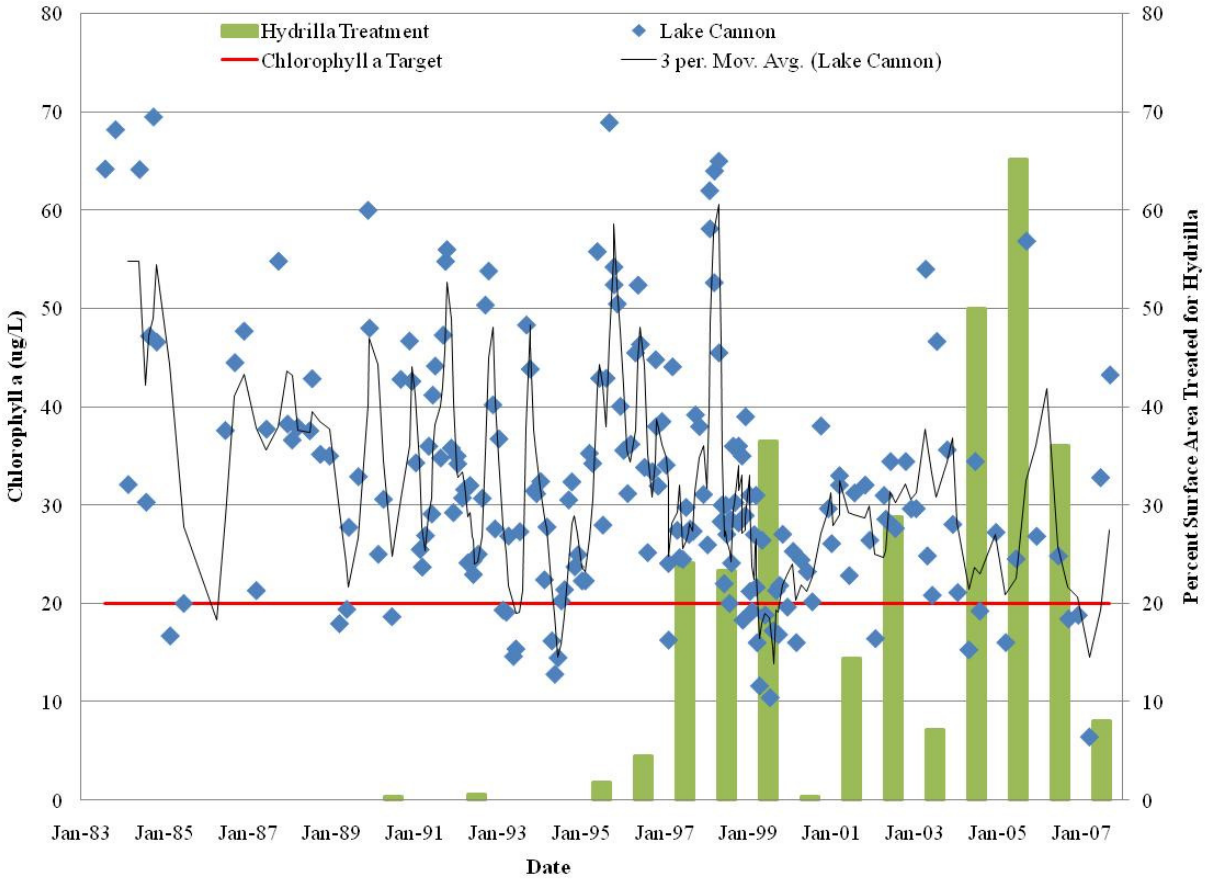


Figure 4-7. Lake Cannon bathymetry (June 2007) at water level elevation = 129 feet (Polk County Water Atlas).

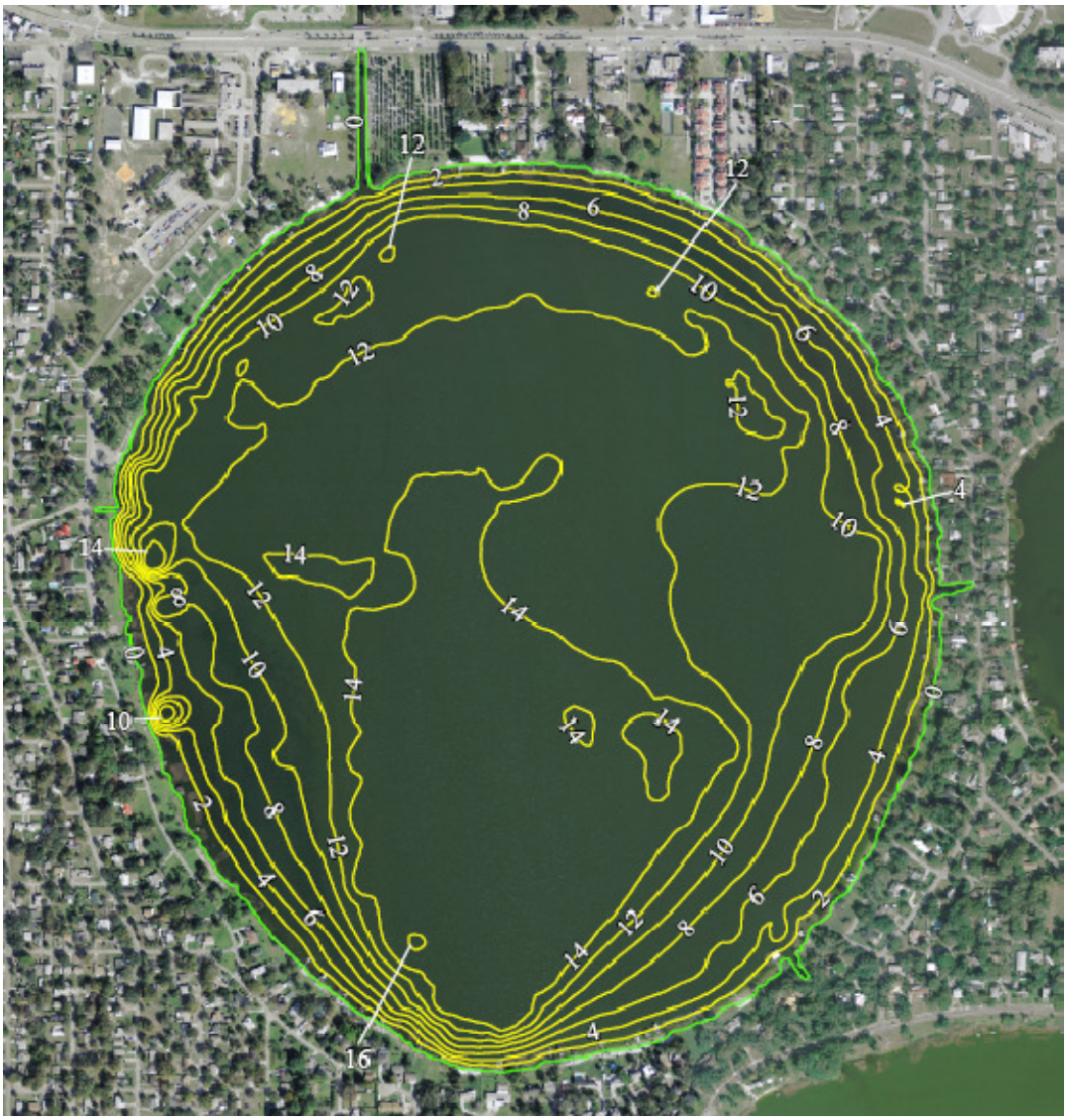
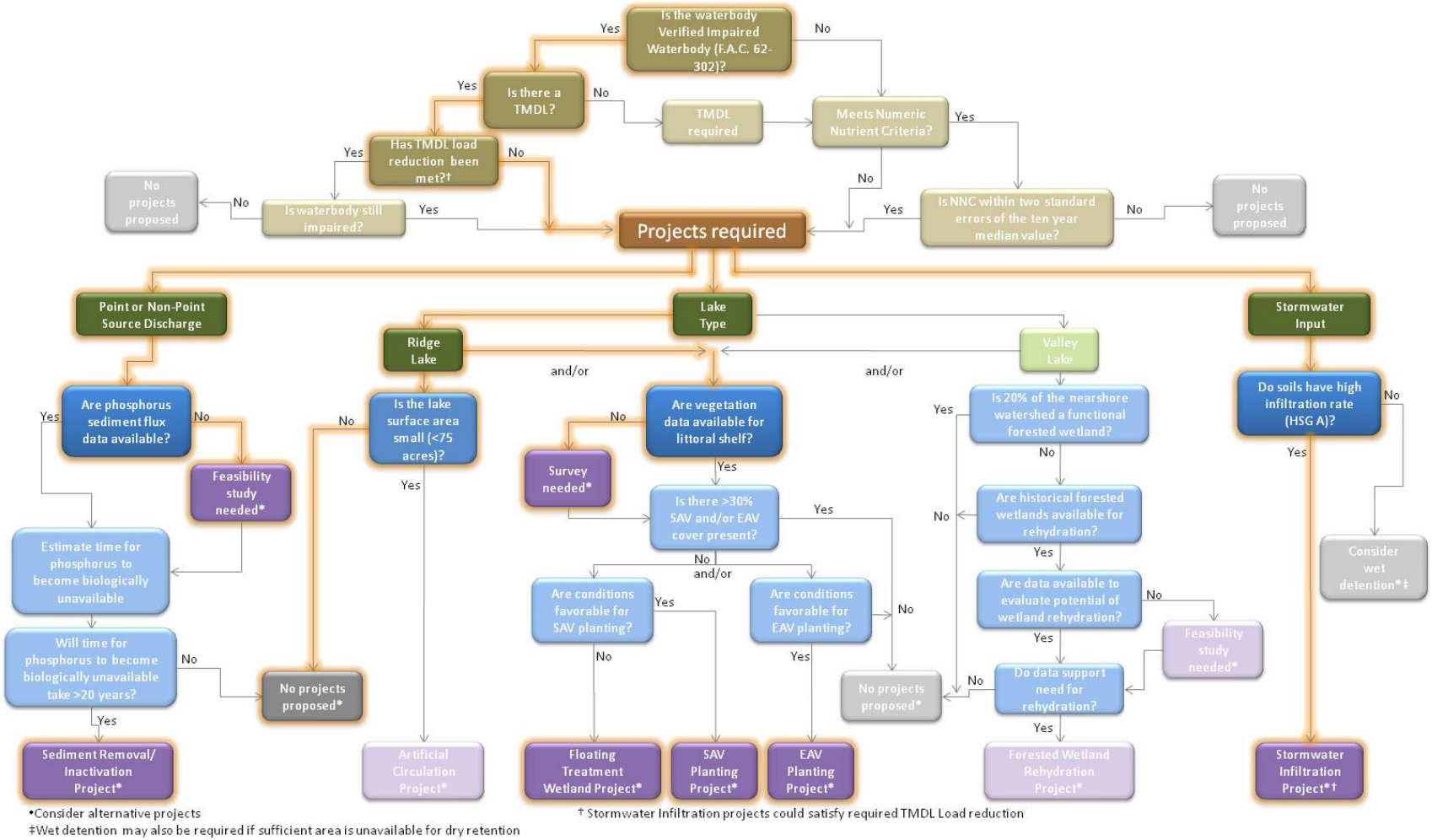


Figure 4-8. Lake Cannon decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Cannon watershed has approximately 501 acres (67 percent of the watershed) classified as high infiltration soils. A TMDL has been established for Lake Cannon, and as such, the SIA design should be focused on satisfying the TMDL requirements. SIA projects would need to encompass approximately 9 percent (65 acres) of the watershed in order to accomplish an annual 137 kg reduction in TP loads to Lake Cannon. Acres of SIA estimated to meet the TP NNC was 24 (3 percent of the watershed) for a 17 percent phosphorus reduction in Lake Cannon to meet its NNC. Sixty-seven percent of the watershed is characterized by high infiltration soils; therefore, it may be feasible to satisfy the TMDL or NNC load reductions through SIA implementation.

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Lake Cannon may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

In Lake Cannon, as much as 65 percent of the lake surface has been treated for *Hydrilla* eradication. A survey of existing SAV cover in Lake Cannon is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

The median secchi depth from 1997-2007 in Lake Cannon was 2.1 feet so SAV should not be planted in water depths greater than 2 feet. The maximum planting effort could result in vegetation cover of approximately 5 percent of the lake bottom (18 acres).

Cost Estimate: $100,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance)

FTWs

If the feasibility study indicates that more than 30 percent of Lake Cannon has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing EAV surrounding Lake Cannon is recommended due to the lack of sufficient data at this time. Based on the results of the EAV survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited EAV is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.3. Lake Conine

Background

Physical and chemical characteristics specific to Lake Conine are presented here in the context of relevant regulatory criteria and requirements (Table 4-5). Lake Conine (WBID 1488U), a lake in the WHCL Northern Chain, is hydrologically connected to lakes Rochelle and Smart via constructed navigable canals (Photo 4-3, Figure 4-9). In 2005, Lake Conine was declared verified impaired based on elevated TSI values (>60). A TMDL is required for Lake Conine to calculate load reductions necessary to satisfy the TSI criteria. The TP, TN, and chlorophyll a geometric mean for Lake Cannon for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-5. To comply with the NNC, concentration reductions of 48 percent for TP, 22 percent for TN, and 37 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Conine is presented in Table 4-6. Lake Conine historically received point source discharges from four WWTF (Birds Eye, Pipping Packing Company, Florida Citrus Salads, and the City of Winter Haven). In 1992, the City of Winter Haven WWTF terminated discharges to the lake. While the effluent discharges have been eliminated, the discharges resulted in nutrient and sediment accumulation in the lake bottom. Sediment inactivation in Lake Conine was completed in the mid-1990's to address the legacy internal phosphorus loads. While water quality improvements were observed, nutrient concentrations continue to be elevated. Since 1998, *Hydrilla* eradication projects have been completed annually treating over 40 percent of the lake surface area in some years. The median chlorophyll *a*, TN and TP concentrations continue to exceed the NNC targets provided by EPA for Lake Conine. Chlorophyll *a* concentrations in Lake Conine are elevated above 20 µg/L but improvements in water quality have been observed due to previous water quality restoration projects (Figure 4-10). A statistically significant decline in chlorophyll *a* concentrations from 1987 to 2007 was observed (seasonal Kendall-Tau, $p<0.001$). The combination of the elimination of point source discharges and alum treatment (completed in 1995) has improved water quality when compared to the previous water quality conditions. Additionally, the City of Winter Haven acquired a large parcel of undeveloped land along the southeastern rim of the lake for the construction of a wetland treatment project designed to improve lake water quality. Improvements in water quality of the lake Conine as a headwater lake could result in benefit farther downstream.

Consistent with reducing external nutrient loads, the City has an approved grant from SWFWMD and FDEP to design and construct a project on the south side of Lake Conine on approximately 34 acres of City property to treat stormwater from the Lake Conine watershed, as well as provide a new nature park. The project is in the design and permitting phase and should be under construction in the spring of 2011. The project will be similar to the recently completed Lake Hartridge Nature Park Project which also received funds from the 319 program.

The Lake Conine watershed is 447 acres in size and includes 316 acres (71 percent) of developed lands compared to 131 acres (29 percent) of undeveloped lands. The 2000-2007 median color value (30 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume

statistics are based on a water level elevation of 125 feet in June 2007. Bathymetry data are available for Lake Conine for the June 2007 water level elevation (Figure 4-11). A water level of 126 feet was reported in August 2010, reflecting a 1.0 foot increase in water elevation when compared to 2006. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Conine water quality and the surrounding watershed characteristics, four potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-12). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. In addition to the approved stormwater treatment project (described above), projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management

Table 4-5. Physical, chemical, and regulatory characteristics of Lake Conine.

Physical			
Location in chain	Northern	**High infiltration soils (acres)**	288 (65 percent)
Relation to other lakes	Immediate	**Developed land (acres)**	316 (71 percent)
Watershed area (acres)	447	**Undeveloped land (acres)**	131 (29 percent)
Lake area (acres)*	231	**Median water depth (feet)***	9.9
Perimeter (feet)*	16,458	**Maximum water depth (feet)***	20.0
Surface area to lake volume ratio*	0.12	**Volume (acre-feet)***	1,928
Watershed to surface area ratio*	1.94		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (ug/L)	32	**NNC chlorophyll *a* target (ug/L)**	20
Geometric mean TN (mg/L)	1.28	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.057	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required
Chlorophyll *a* trend	Decreasing	**TP concentration reduction required**	48 percent

*at a water level elevation of 125 feet
**presented in section 5.0

Photo 4-3. View from western shoreline of Lake Conine.

Table 4-6. Lake Conine water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	84	3	39	79
Color (PCU)	70	5	30	70
Conductivity (µmhos/cm)	31	198	229	275
Dissolved oxygen (mg/L)	31	5.95	8.82	13.88
pH	31	7.32	8.22	9.21
Secchi depth (feet)	87	0.9	1.8	3.3
Total nitrogen (mg/L)	89	0.62	1.33	2.62
Total phosphorus (mg/L)	85	0.014	0.073	0.163

Figure 4-9. Lake Conine and associated watershed.

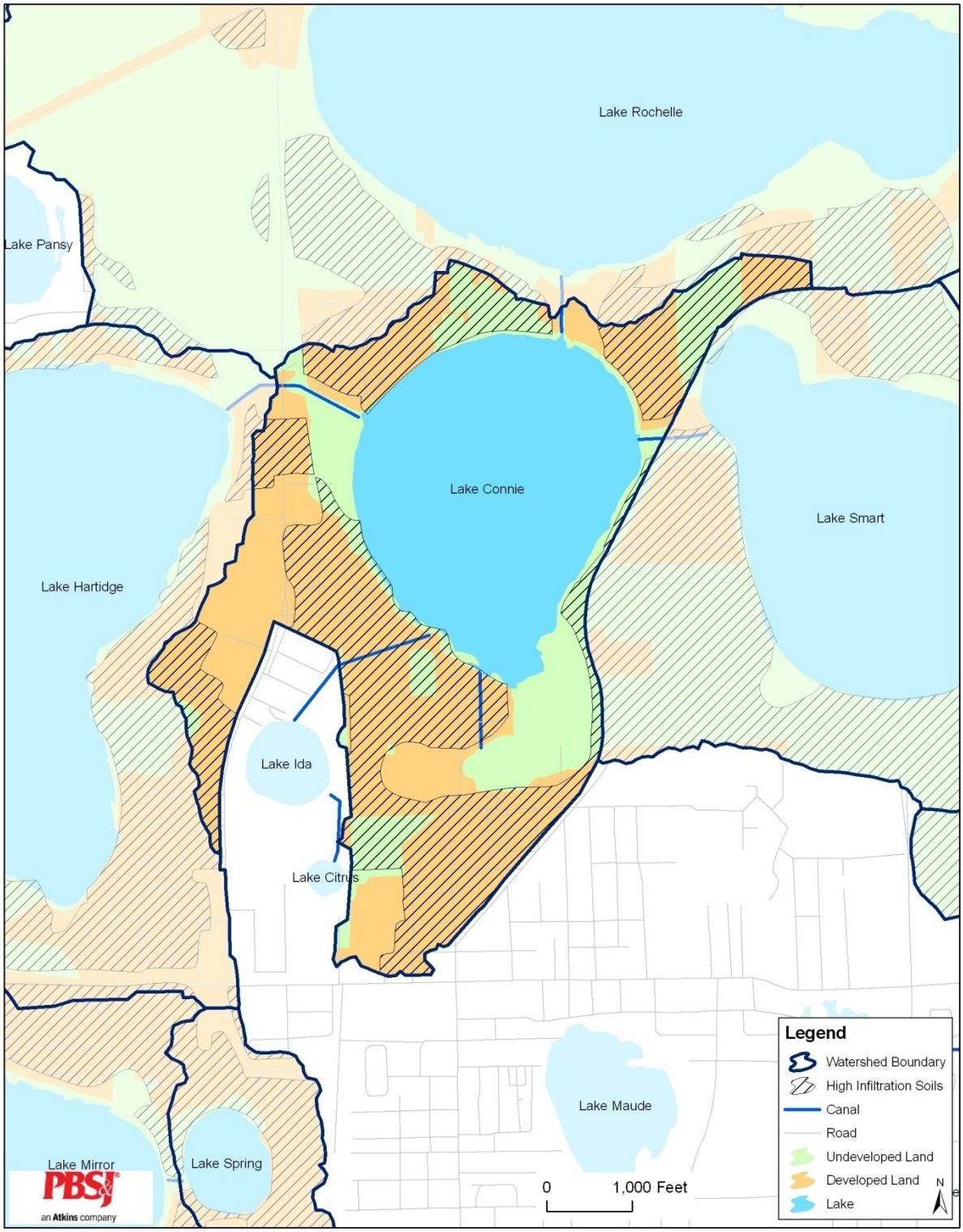


Figure 4-10. Lake Conine chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007. Previous water quality improvement projects are identified.

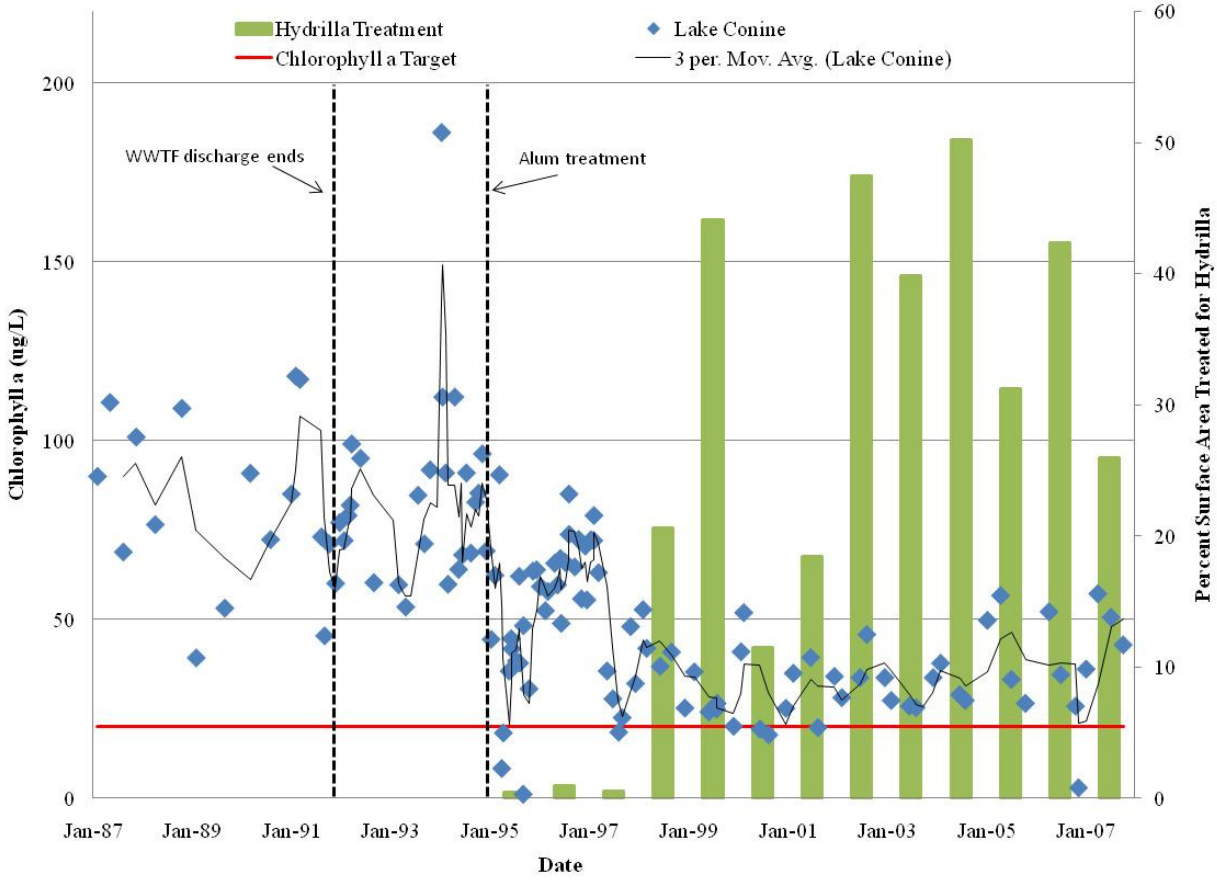
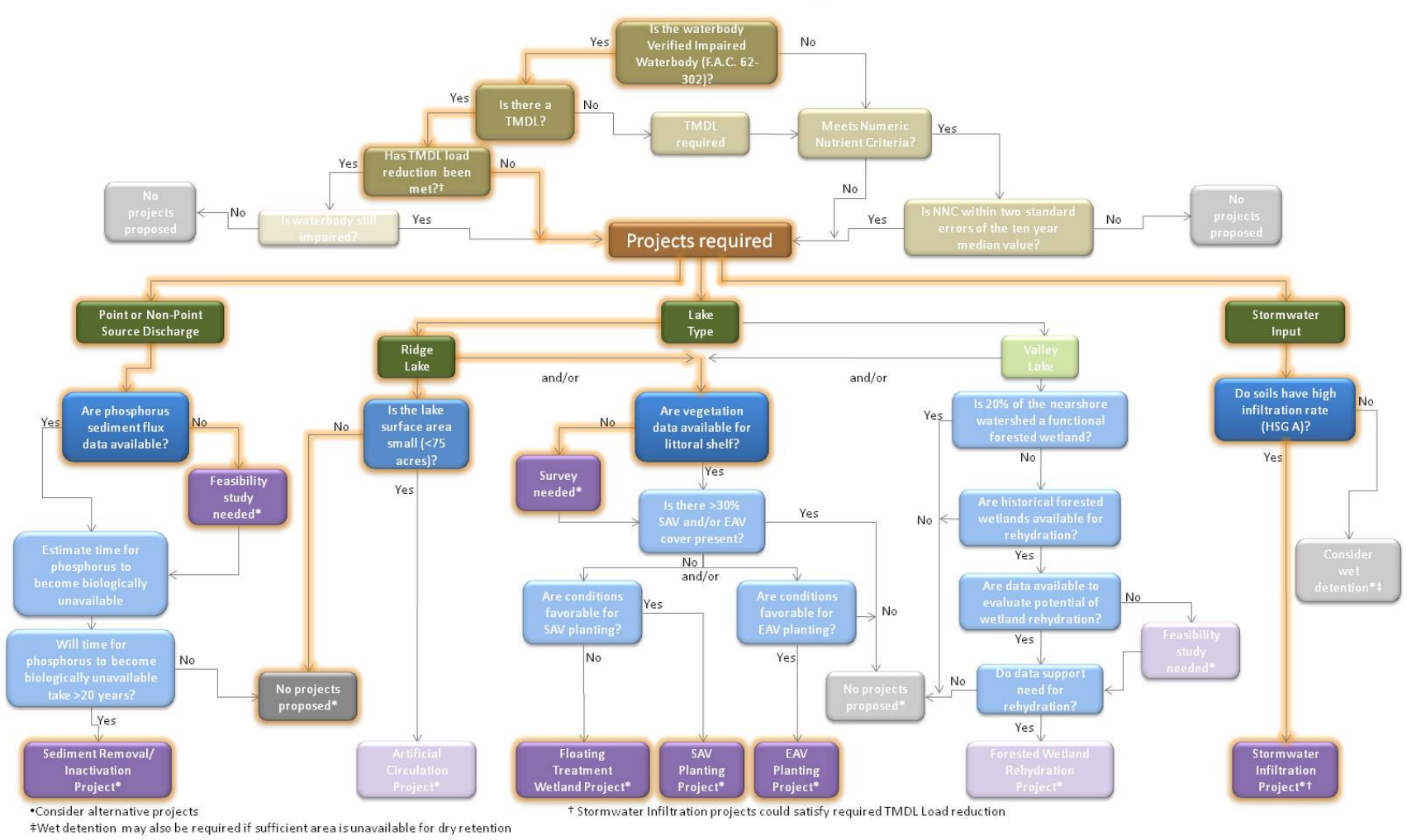


Figure 4-11. Lake Conine bathymetry (June 2007) at water level elevation = 125 feet (Polk County Water Atlas).

Figure 4-12. Lake Conine decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Conine watershed has approximately 288 acres (65 percent of the watershed) classified as high infiltration soils. The Northern Chain was not included in the PLRG study (USF 2005), therefore a TMDL has not been completed for Lake Conine and data to estimate SIA acres for TP load reduction are not available at this time. SIA implementation could have the additional benefit of increasing storage to supplement dry season lake levels and a reduction in stormwater loads that can be later applied to the required TMDL TP load reduction. As such, SIA design should be focused on recharging the surficial aquifer. The City of Winter Haven and SWFWMD have already purchased land along the southern rim of Lake Conine for the construction of a wetland treatment project designed to reduce external nutrient loads entering the lake via stormwater.

Project 2: Sediment Removal/Inactivation

Historical point source discharges to Lake Conine from the multiple WWTFs require further evaluation of the potential internal phosphorus load from the lake bottom sediments. Sediment inactivation in Lake Conine was previously completed in the mid-1990's to address the legacy internal phosphorus loads. While water quality improvements were observed, nutrient concentrations continue to be elevated. Alum treatment has been shown to control phosphorus loading from sediments for approximately two to twenty years; therefore, subsequent restoration actions may be required. Presently, sufficient data are not available to calculate the phosphorus decay rate and the time at which the phosphorus will become biologically unavailable in the lake sediments. The recommended feasibility study is required to determine whether sediment removal/inactivation is necessary.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

In Lake Conine, *Hydrilla* eradication occurs frequently attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Conine is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

The 1997-2007 median secchi depth in Lake Conine (1.8 feet) indicated that SAV planting should not occur in water depths greater than 2 feet. The maximum planting effort could result in vegetation cover of approximately 7 percent of the lake bottom (16 acres). Due to the extensive organic material located in Lake Conine, it is recommended that SAV planting be performed after sediment removal/inactivation, if completed. If sediment removal is completed, the planting area would need to be recalculated using updated bathymetry data.

Cost Estimate: $100,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance).

FTWs

If the feasibility study indicates that more than 30 percent of Lake Conine has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing EAV surrounding Lake Conine is recommended due to the lack of sufficient data at this time. Based on the results of the EAV survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited EAV is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.4. Lake Eloise

Background

Physical and chemical characteristics specific to Lake Eloise are presented here in the context of relevant regulatory criteria and requirements (Photo 4-4). Lake Eloise (WBID 1521B) is located in the WHCL Southern Chain and is hydrologically connected to lakes Lulu, Summit, Winterset and Little Lake Eloise via constructed canals (Figure 4-13). Canals to lakes Winterset and Lulu are naviagable. Lake Eloise was initially declared verified impaired based on elevated TSI values (>40), indicating a nutrient impairment in 2005. Later in 2005, a paleolimnological review of Lake Eloise supported the decision to remove the lake from the impaired list based on the evidence that the lake was historically eutrophic and assigned a revised TSI threshold of 60. In 2010, Lake Eloise was again declared verified impaired based on elevated TSI values (>60), indicating a nutrient impairment. A TMDL is required for Lake Eloise to calculate load reductions necessary to satisfy the TSI criteria. The TP, TN, and chlorophyll *a* geometric mean for Lake Eloise for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-7. To comply with the NNC, concentration reductions of 17 percent for TP, 18 percent for TN, and 39 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Eloise is presented in Table 4-8. In June 1975, point source discharges to Lake Eloise from Cypress Gardens WWTF were eliminated. The point source discharge resulted in the annual addition of approximately 30 kg TP and 85 kg TN to the lake. Recently, *Hydrilla* eradication treatment projects have been completed within the lake. In 2007, 100 percent of the lake surface area was reported to have been treated for *Hydrilla* infestation. The median chlorophyll *a*, TN and TP concentrations exceed the NNC targets provided by EPA for Lake Eloise. Chlorophyll *a* concentrations in Lake Eloise have fluctuated but have remained consistently elevated above 20 µg/L (Figure 4-14). A statistically significant trend in chlorophyll *a* concentrations from 1983 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). No water quality improvement projects have been implemented in Lake Eloise to restore water quality. Lake Eloise is located adjacent to Lake Lulu which discharges water directly to the Wahneta Farms Drain Canal. Therefore, water quality improvements in the lake would result in benefits to one lake farther downstream.

The Lake Eloise watershed is 843 acres in size and includes 711 acres (84 percent) of developed lands compared to 132 acres (16 percent) of undeveloped lands (Table 4-7). The 2000-2007 median color value (15 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 129 feet in June 2007. Bathymetry data are available for Lake Eloise for the June 2007 water level elevation (Figure 4-15). A water level of 130 feet was reported in July 2010, reflecting a 1.0 foot increase in water elevation when compared to 2007. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Eloise water quality and the surrounding watershed characteristics, four potential water quality restoration projects were identified using the WHCL WQMP (Figure 4-16). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management

Table 4-7. Physical, chemical, and regulatory characteristics of Lake Eloise.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	683 (81 percent)
Relation to other lakes	Adjacent to Terminal	**Developed land (acres)**	711 (84 percent)
Watershed area (acres)	843	**Undeveloped land (acres)**	132 (16 percent)
Lake area (acres)*	1,170	**Median water depth (feet)***	9.9
Perimeter (feet)*	42,551	**Maximum water depth (feet)***	17.8
Surface area to lake volume ratio*	0.09	**Volume (acre-feet)***	12,645
Watershed to surface area ratio*	0.72		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (ug/L)	33	**NNC chlorophyll *a* target (ug/L)**	20
Geometric mean TN (mg/L)	1.23	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.036	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	17 percent

*at a water level elevation of 129 feet
**presented in section 5.0

Photo 4-4. Lake Eloise

Table 4-8. Lake Eloise water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	47	12	31	83
Color (PCU)	35	5	15	50
Conductivity (µmhos/cm)	30	230	267	346
Dissolved oxygen (mg/L)	30	6.7	9.04	13.45
pH	30	7.27	8.18	9.47
Secchi depth (feet)	50	1.3	2.2	5.3
Total nitrogen (mg/L)	50	0.38	1.32	1.78
Total phosphorus (mg/L)	44	0.004	0.038	0.108

Figure 4-13. Lake Eloise and associated watershed.

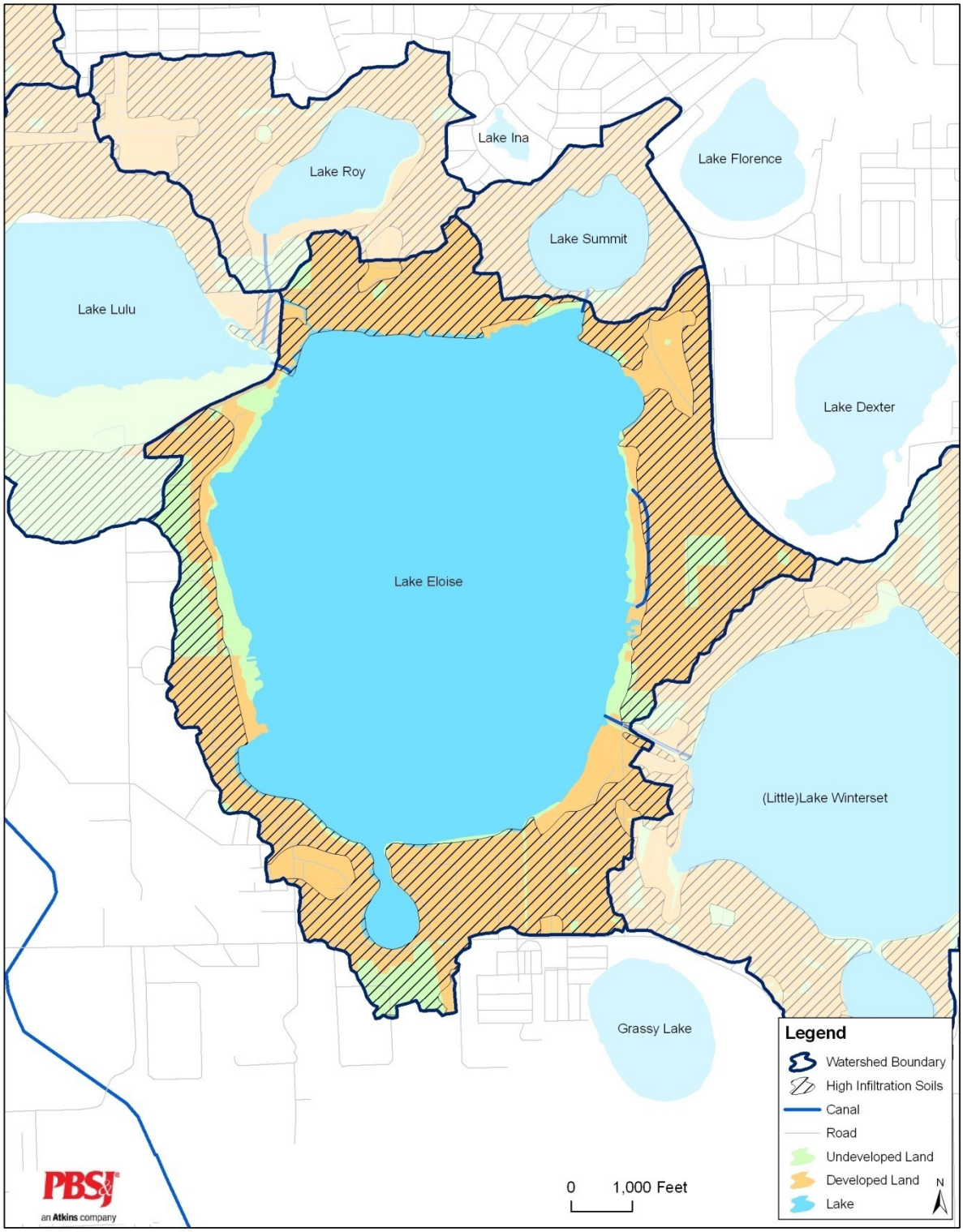


Figure 4-14. Lake Eloise chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

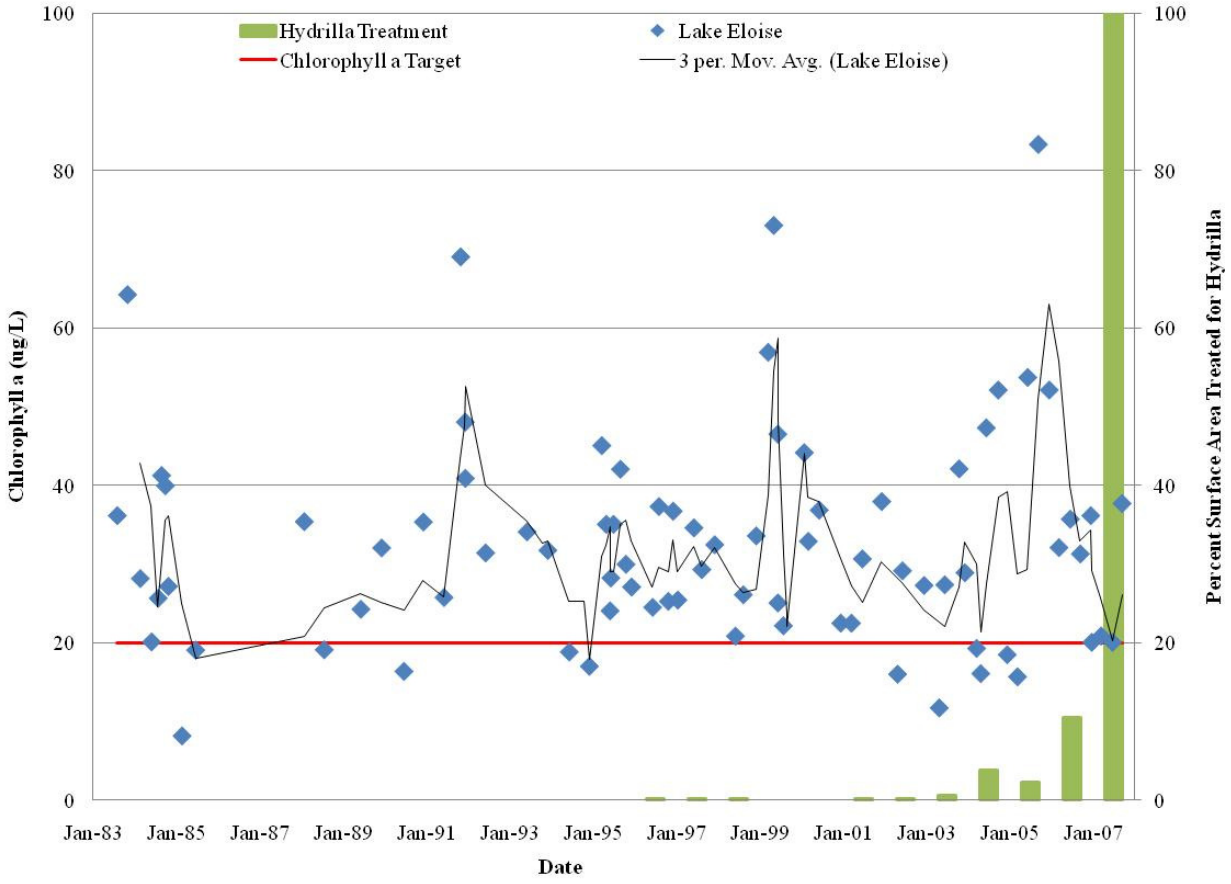
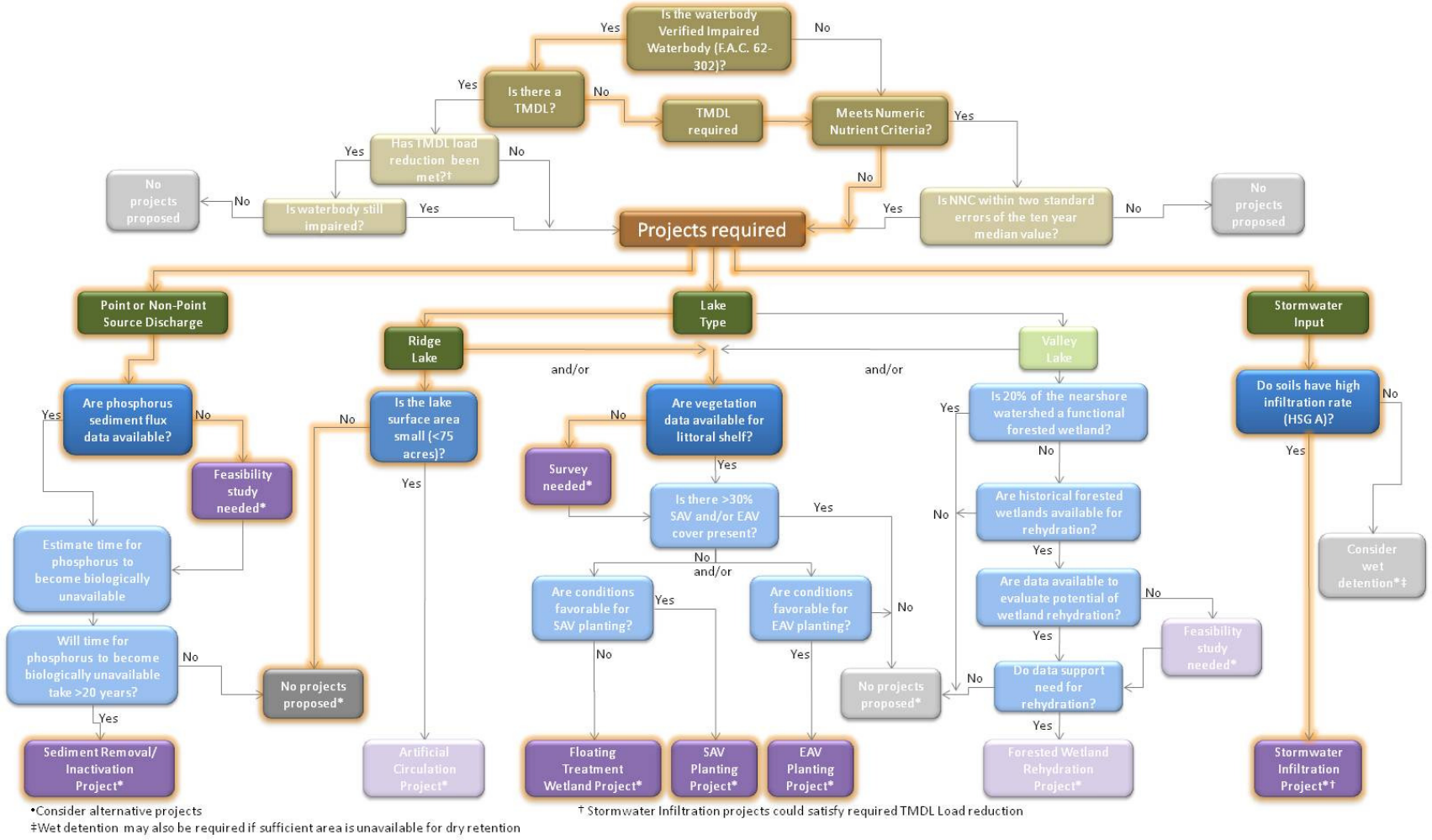


Figure 4-15. Lake Eloise bathymetry (June 2007) at water level elevation = 129 feet (Polk County Water Atlas).

Figure 4-16. Lake Eloise decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Eloise watershed has approximately 683 acres (81 percent of the watershed) classified as high infiltration soils. Lake Eloise does not have a TMDL, therefore, SIA acres estimates were calculated using data from the PLRG (USF 2005). The SIA estimate for Lake Eloise was 10 acres (approximately one percent of the watershed) to meet a 31 percent PLRG. Acres of SIA estimated to meet the TP NNC were 6.4 (one percent of the watershed) for a 17 percent phosphorus reduction in Lake Eloise to meet its NNC. Eighty-one percent of the watershed is characterized by high infiltration soils; therefore, it may be feasible to satisfy the load reductions through SIA implementation.

Project 2: Sediment Removal/Inactivation

Historical point source discharges to Lake Eloise from the Cypress Gardens WWTF will require further evaluation of the potential internal phosphorus load from the lake bottom sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

In Lake Eloise, *Hydrilla* eradication has been completed over as much as 100 percent of the lake surface area attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Eloise is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

SAV plants should not be planted in water depths greater than 2 feet based on the median secchi depth values. The median secchi depth from 1997-2007 in Lake Eloise was 2.2 feet. The maximum planting effort could result in vegetation cover of approximately 5 percent of the lake bottom (57 acres). Due to the extensive organic material located in Lake Eloise, it is recommended that SAV planting be performed after sediment removal/inactivation, if completed. If sediment removal is completed, the planting area would need to be recalculated using updated bathymetry data.

Cost Estimate: $275,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance).

FTWs

If the feasibility study indicates that more than 30 percent of Lake Eloise has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Eloise is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level inundation frequency and wave disturbance.

4.5. Lake Fannie

Background

Physical and chemical characteristics specific to Lake Fannie are presented here in the context of relevant regulatory criteria and requirements (Table 4-9). Lake Fannie (WBID 14882) is located in the Northern Chain of the WHCL and is hydrologically connected to Lakes Smart and Hamilton via constructed canals, however, water control structures regulate the passage of water through the canals (Photo 4-5, Figure 4-17) and the canals are not navigable. Initially, Lake Fannie was declared verified impaired based on elevated TSI values (>40). Later in 2005, a paleolimnological review of Lake Fannie supported the decision to remove the lake from the impaired list based on the evidence that the lake was historically eutrophic and assigned a revised TSI threshold of 60. No TMDL is required for Lake Fannie because it is not identified as an impaired waterbody. The TP, TN, and chlorophyll *a* geometric mean for Lake Fannie for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-9. Concentrations reductions in chlorophyll *a*, TN, or TP are not required to comply with the NNC.

A summary of water quality statistics for Lake Fannie is presented in Table 4-10. Median chlorophyll *a*, TN and TP concentrations do not exceed the NNC targets provided by EPA for Lake Fannie. Chlorophyll *a* concentrations in Lake Fannie have fluctuated substantially however, values have remained below 20 µg/L sufficiently to maintain an unimpaired status (Figure 4-18). A statistically significant trend in chlorophyll *a* concentrations from 1986 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). No water quality improvement projects have been implemented in Lake Fannie to restore water quality. However, several *Hydrilla* infestation eradication projects have been performed in the last ten years. Due to the hydrologic isolation of Lake Fannie from the Northern Chain by gated structures, improvements in water quality of the lake would result in little benefit farther downstream.

The Lake Fannie watershed is 1,534 acres in size and includes 443 acres (29 percent) of developed lands compared to 1,091 acres (71 percent) of undeveloped lands. Approximately 46 percent of the land cover within the 500 foot buffer surrounding Lake Fannie is classified as wetlands using the 2006 FLUCS data. Forested wetlands encompass ten percent of the total wetland area, which satisfies the recommended forested wetland cover required to maintain color levels above 50 PCU. The hydrologic connection between Lake Fannie and adjacent forested wetlands should be maintained to preserve the elevated color levels and resulting beneficial attributes. The 2000-2007 median color value (55 PCU) was above 40 PCU indicating the lake is a colored lake. Using the adopted EPA NNC for Florida lakes, characterization of alkalinity or acidity is not necessary based on the colored classification of Lake Fannie. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 122 feet in July 2007. Bathymetry data are available for Lake Fannie for the July 2007 water level elevation (Figure 4-19). A water level of 121 feet was reported in August 2010, reflecting a 1.0 feet decrease in water elevation when compared to 2007.

Water Quality Restoration Project Selection and Priorities

Based on Lake Fannie water quality and the surrounding watershed characteristics, no water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-20). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Continued water quality monitoring is recommended for the ongoing evaluation of water quality status and trends.

Table 4-9. Physical, chemical, and regulatory characteristics of Lake Fannie.

Physical			
Location in chain	Northern	**High infiltration soils (acres)**	823 (54 percent)
Relation to other lakes	Isolated	**Developed land (acres)**	443 (29 percent)
Watershed area (acres)	1,534	**Undeveloped land (acres)**	1,091 (71 percent)
Lake area (acres)*	805	**Median water depth (feet)***	5.2
Perimeter (feet)*	35,750	**Maximum water depth (feet)***	14.1
Surface area to lake volume ratio*	0.23	**Volume (acre-feet)***	3,486
Watershed to surface area ratio*	1.9		
Water Chemistry			
Locally-derived: acidic or alkaline	NA	**Clear or colored**	Colored
Geometric mean chlorophyll *a* (ug/L)	12	**NNC chlorophyll *a* target (ug/L)**	20
Geometric mean TN (mg/L)	0.93	**NNC TN target (mg/L)**	2.25
Geometric mean TP (mg/L)	0.035	**NNC TP target (mg/L)**	0.157
Regulatory Data			
Impaired	No	**TMDL status**	NA
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	NA

*at a water level elevation of 122 feet
**presented in section 5.0
NA= not applicable

Photo 4-5. North view of Lake Fannie.

Table 4-10. Lake Fannie water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	87	1	14	46
Color (PCU)	12	5	55	80
Conductivity (µmhos/cm)	19	202	239	368
Dissolved oxygen (mg/L)	19	3.84	7.67	10.3
pH	19	6.59	7.5	8.37
Secchi depth (feet)	80	0.9	2.8	5.5
Total nitrogen (mg/L)	91	0.37	0.84	1.75
Total phosphorus (mg/L)	89	0.01	0.029	0.121

Figure 4-17. Lake Fannie and associated watershed.

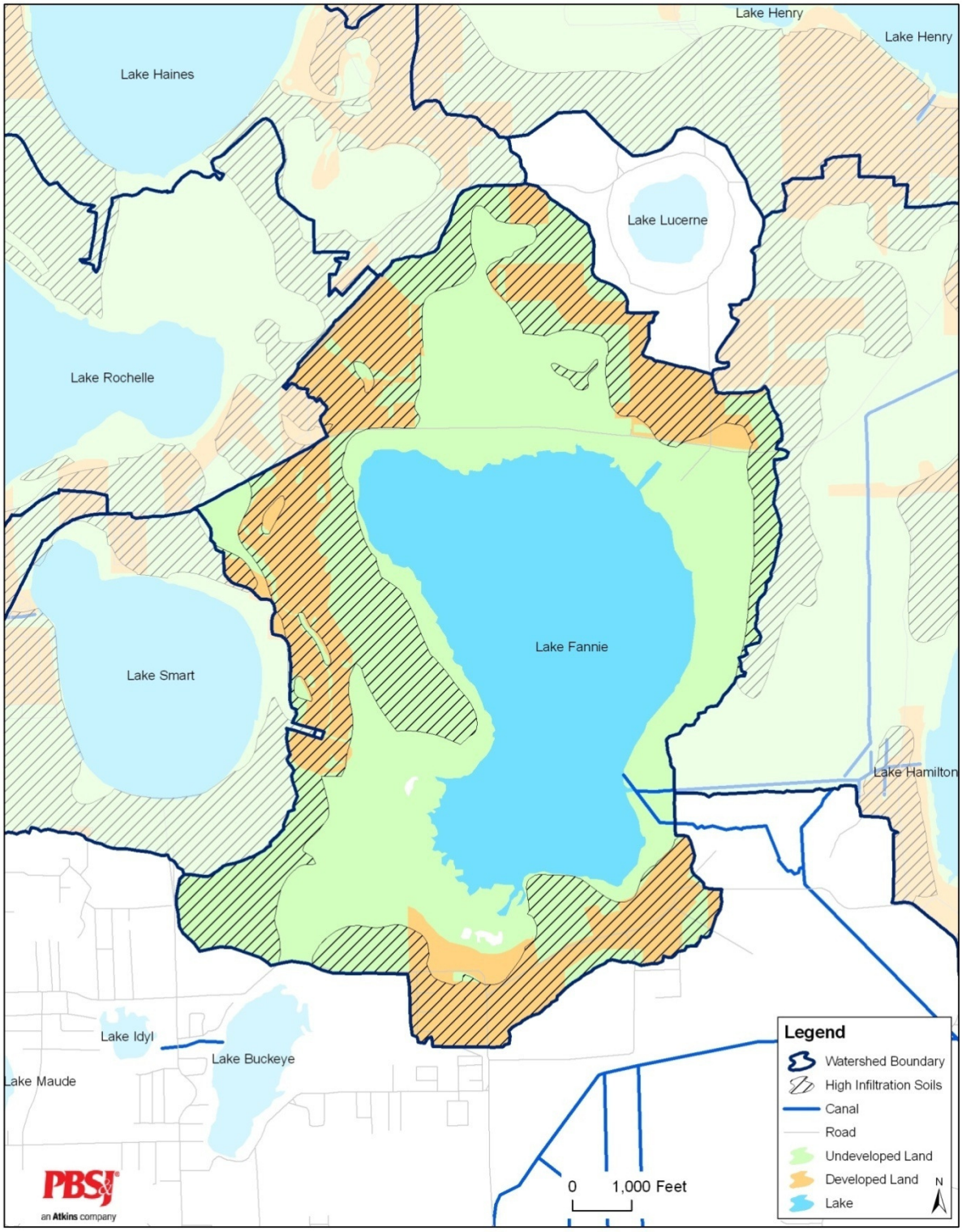


Figure 4-18. Lake Fannie chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1986 to 2007.

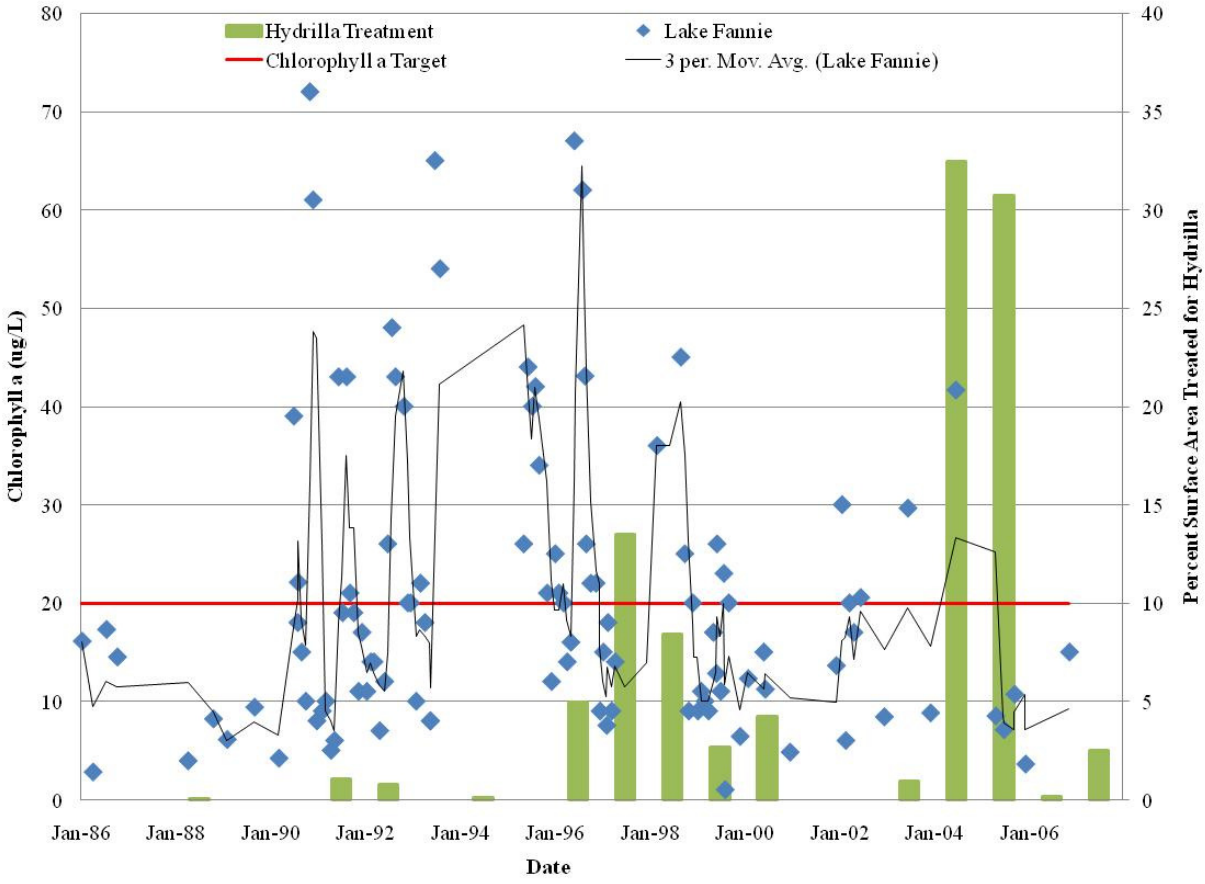


Figure 4-19. Lake Fannie bathymetry (July 2007) at water level elevation = 122 feet (Polk County Water Atlas).

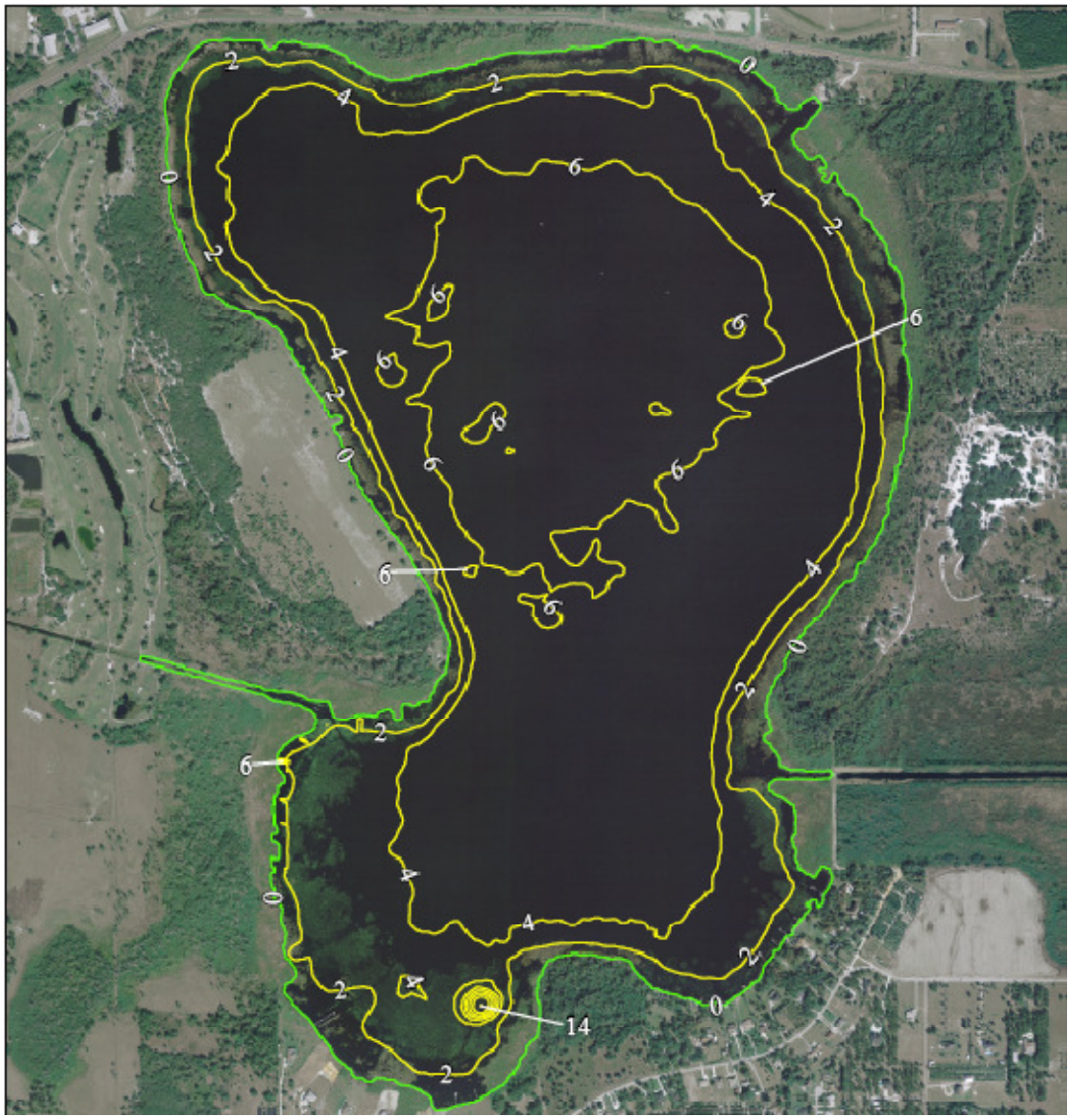
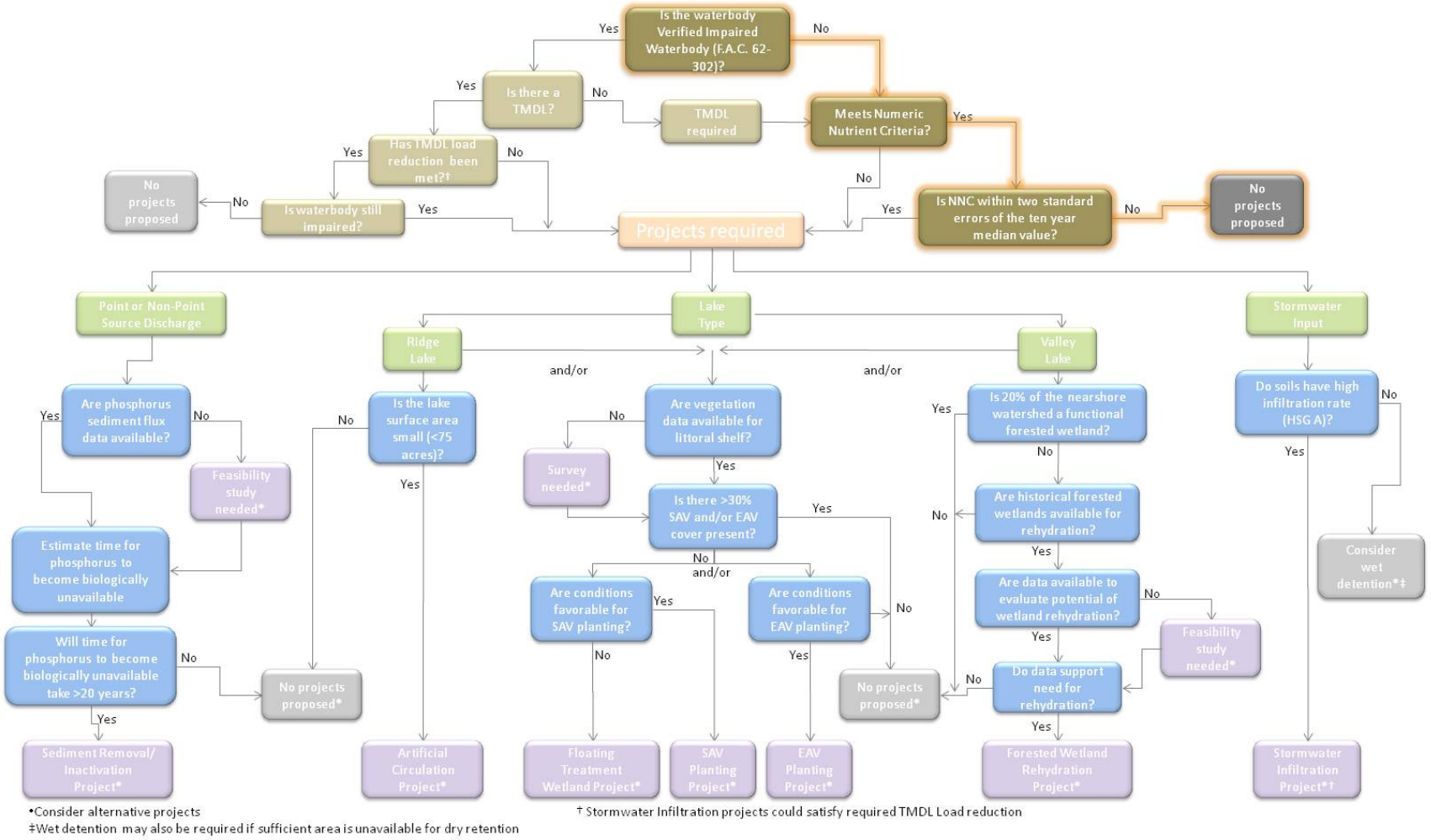


Figure 4-20. Lake Fannie decision key: highlighted path shows decision process.



4.6. Lake Haines

Background

Physical and chemical characteristics specific to Lake Haines are presented here in the context of relevant regulatory criteria and requirements (Table 4-11). Lake Haines (WBID 1488C), the headwaters of the WHCL Northern Chain, is hydrologically connected to Lake Rochelle via a constructed navigable canal and to Lake Henry via a flow-through wetland (Photo 4-6, Figure 4-21). In 2005, Lake Haines was declared verified impaired based on elevated TSI values (>60), indicating a nutrient impairment. A TMDL is required for Lake Haines to calculate load reductions necessary to satisfy the TSI criteria. The TP, TN, and chlorophyll *a* geometric means for Lake Haines for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-11. To comply with the NNC, concentration reductions of 20 percent for TP, 9 percent for TN, and 49 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Haines is presented in Table 4-12. In 1992, point source discharges to Lake Haines from the Lake Alfred WWTF were eliminated. These point source discharges resulted in the annual addition of approximately 1,515 kg TP and 2,230 kg TN to the lake. Median chlorophyll *a*, TN and TP concentrations exceed the NNC targets provided by EPA for Lake Haines. Chlorophyll *a* concentrations in Lake Haines have fluctuated but have remained consistently elevated above 20 µg/L (Figure 4-22). A statistically significant decline in chlorophyll *a* concentrations from 1985 to 2007 was observed (seasonal Kendall-Tau, p=0.009), indicating improving water quality conditions. Multiple *Hydrilla* eradication projects have been completed in the past several years, with greater than 70 percent of the lake being treated in 2002 and 2003. Beyond the termination of the WWTF discharges in 1992, no water quality improvement projects have been implemented in Lake Haines to restore water quality. Lake Haines is a headwater lake; therefore, improvements in water quality of the lake could result in benefits farther downstream.

The Lake Haines watershed is 4,120 acres in size and includes 767 acres (19 percent) of developed lands compared to 3,353 acres (81 percent) of undeveloped lands. The 2000-2007 median color value (100 PCU) was below 40 PCU indicating the lake is a colored lake. Using the adopted EPA NNC for Florida lakes, characterization of alkalinity or acidity is not necessary based on the colored classification of Lake Haines. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 127 feet in October 2006. Bathymetry data are available for Lake Haines for the October 2006 water level elevation (Figure 4-23). A water level of 127 feet was reported in August 2010, indicating a similar water elevation when compared to 2007. Changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects

Water Quality Restoration Project Selection and Priorities

Based on Lake Haines water quality and the surrounding watershed characteristics, five potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-24). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient

and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: Forested Wetland Rehydration
- Project 4: SAV Planting/Management or FTWs
- Project 5: EAV Planting/Management

Table 4-11. Physical, chemical, and regulatory characteristics of Lake Haines.

Physical			
Location in chain	Northern	**High infiltration soils (acres)**	1,846 (45 percent)
Relation to other lakes	Headwater	**Developed land (acres)**	767 (19 percent)
Watershed area (acres)	4,120	**Undeveloped land (acres)**	3,353 (81 percent)
Lake area (acres)*	736	**Median water depth (feet)***	7.8
Perimeter (feet)*	30,662	**Maximum water depth (feet)***	19.2
Surface area to lake volume ratio*	0.10	**Volume (acre-feet)***	7,104
Watershed to surface area ratio*	5.60		
Water Chemistry			
Locally-derived: acidic or alkaline	NA	**Clear or colored**	Colored
Geometric mean chlorophyll *a* (ug/L)	39	**NNC chlorophyll *a* target (ug/L)**	20
Geometric mean TN (mg/L)	1.35	**NNC TN target (mg/L)**	1.23
Geometric mean TP (mg/L)	0.063	**NNC TP target (mg/L)**	0.05
Regulatory Data			
Impaired	Yes	**TMDL status**	Required
Chlorophyll *a* trend	Decreasing**	**TP concentration reduction required**	20 percent

*at a water level elevation of 127 feet
**presented in section 5.0

Photo 4-6. View of northwestern shoreline of Lake Haines.

Table 4-12. Lake Haines water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	269	2.29	50	130
Color (PCU)	53	20	100	280
Conductivity (µmhos/cm)	55	175	218	276
Dissolved oxygen (mg/L)	55	5.47	9.11	12.91
pH	56	6	7.79	9.32
Secchi depth (feet)	266	0.9	1.8	3.6
Total nitrogen (mg/L)	273	0	1.32	2.60
Total phosphorus (mg/L)	267	0.032	0.066	0.144

Figure 4-21. Lake Haines and associated watershed.

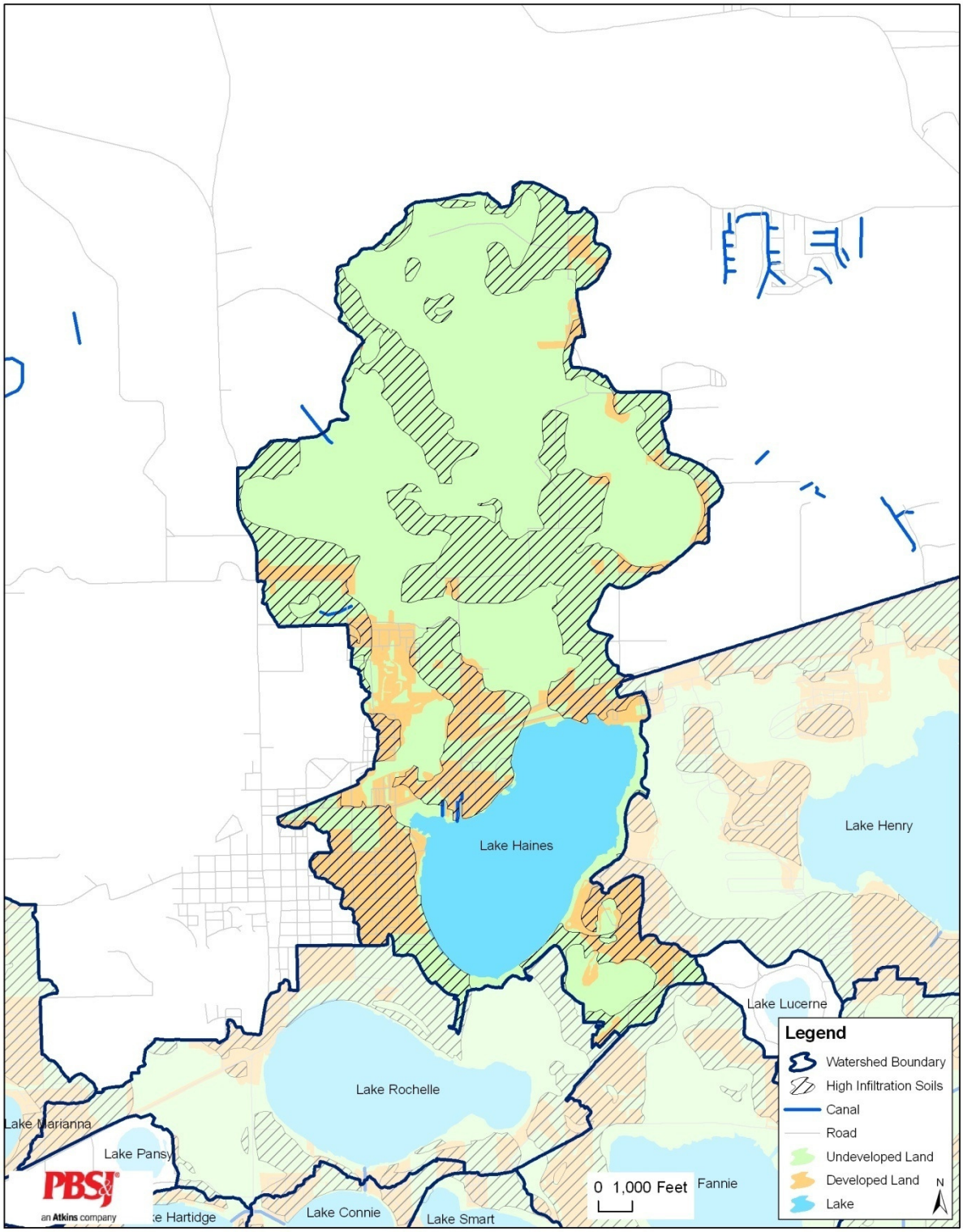


Figure 4-22. Lake Haines chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1985 to 2007.

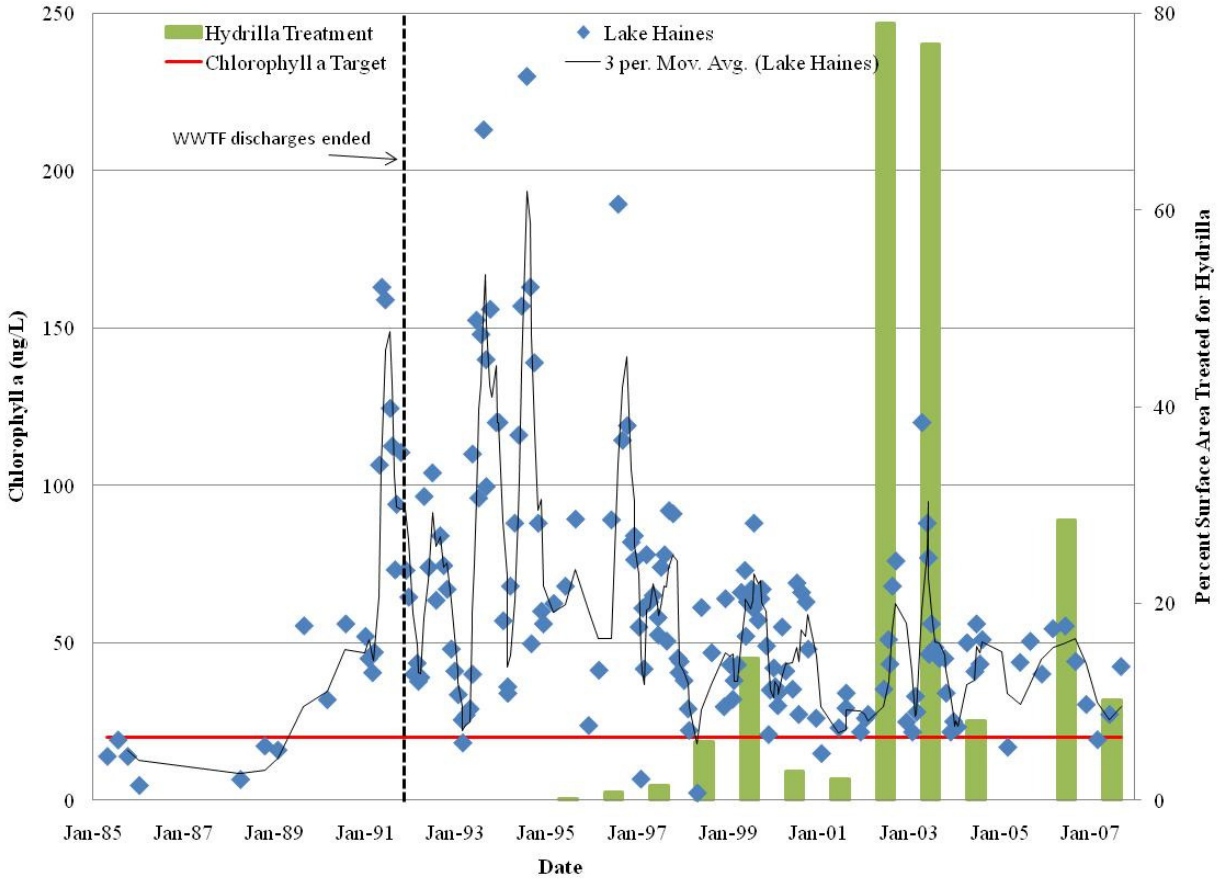


Figure 4-23. Lake Haines bathymetry (October 2006) at water level elevation = 127 feet (Polk County Water Atlas).

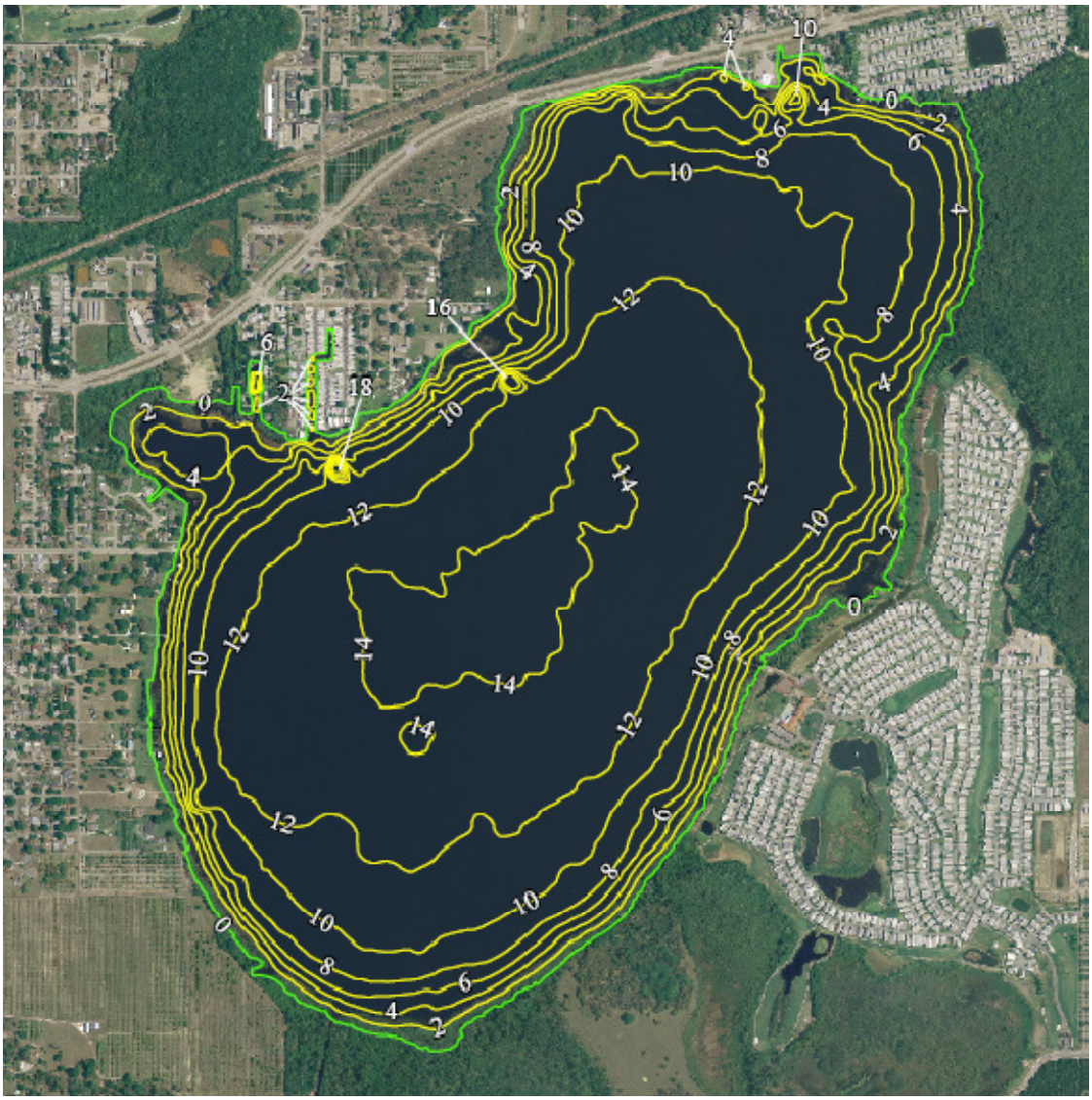
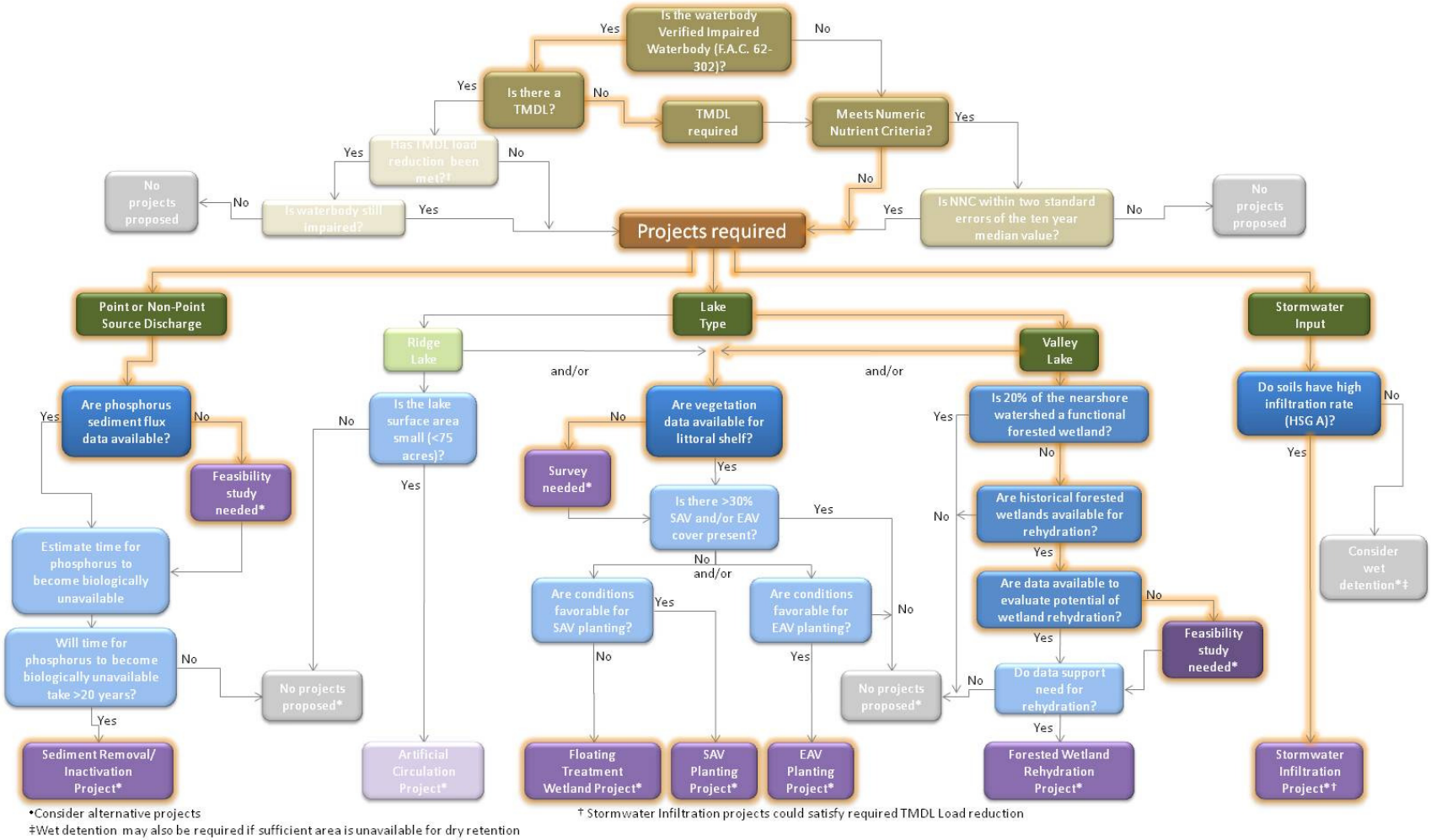


Figure 4-24. Lake Haines decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Haines watershed has approximately 1,846 acres (45 percent of the watershed) classified as high infiltration soils. The Northern Chain was not included in the PLRG study (USF 2005), therefore a TMDL has not been completed for Lake Haines and data to estimate SIA acres for TP load reduction are not available at this time. SIA implementation could have the additional benefit of increasing storage to supplement dry season lake levels and a reduction in stormwater loads that can be later applied to the required TMDL TP load reduction. As such, SIA design should be focused on recharging the surficial aquifer.

Project 2: Sediment Removal/Inactivation

Historical point source discharges to Lake Haines from the WWTF will require further evaluation of the potential internal phosphorus load from the lake bottom sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

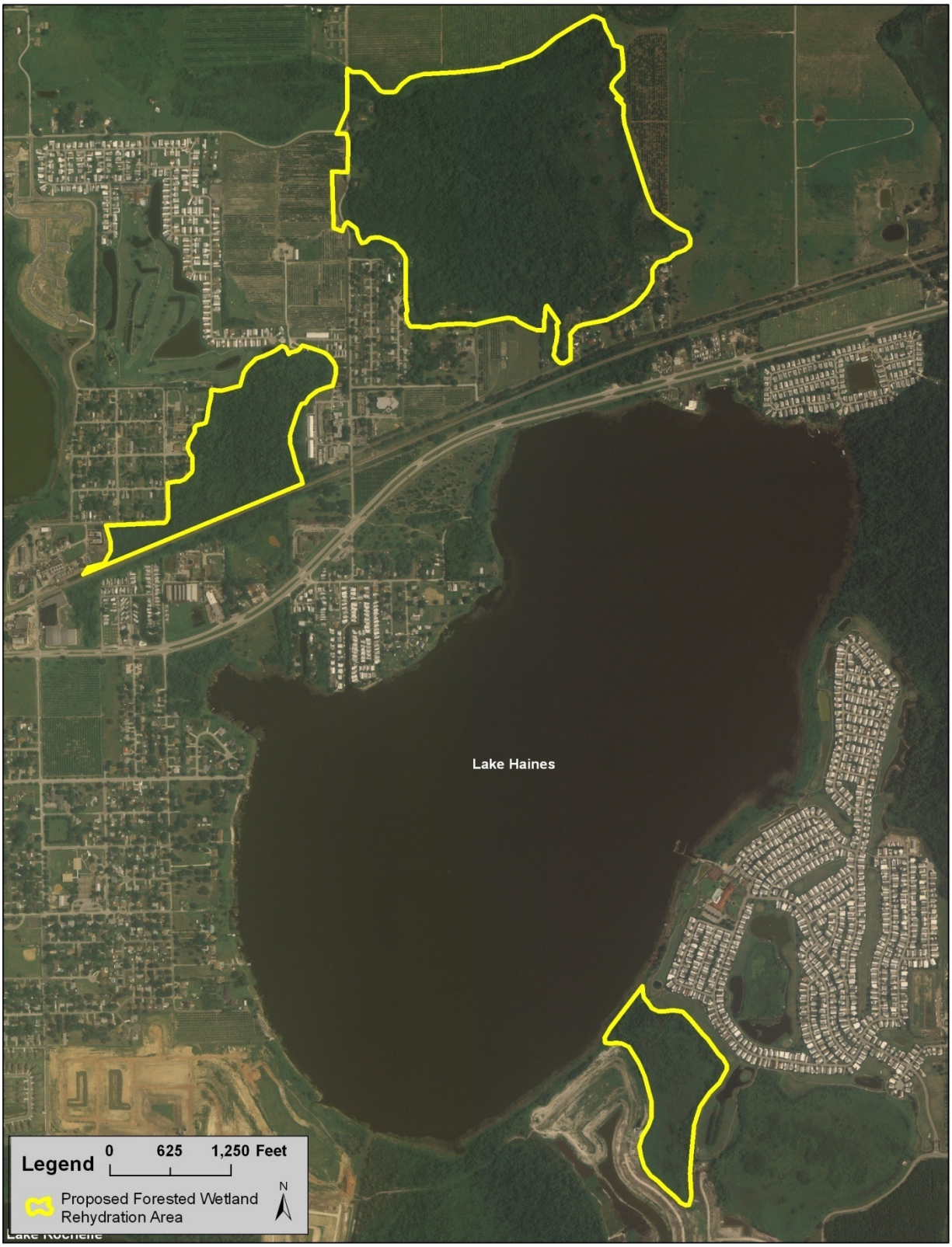
Project 3: Forested Wetland Rehydration

Approximately 27 percent of the land cover within the 500 foot buffer surrounding Lake Haines is classified as wetlands using the 2006 FLUCS data. Forested wetlands encompass 17 percent of the total wetland area, which is within the 10 to 20 percent recommended forested wetland cover required to maintain color levels above 50 PCU. While FLUCS classifies the land cover as forested wetland, the hydrologic connection between the lake and adjacent land might not be present as is observed along the southern rim of the Lake.

Three proposed project areas were identified adjacent to Lake Haines expected to rehydrate approximately 235 acres (Figure 4-25). The feasibility study is recommended in order to evaluate the proposed project areas for inundation.

Feasibility study cost estimate: $100,000.

Figure 4-25. Proposed forested wetland rehydration project areas for Lake Haines.



Project 4: SAV Planting or FTWs

SAV Planting

In Lake Haines, *Hydrilla* eradication in the lake has contributed to the continued degradation in water quality. A survey of existing SAV cover in Lake Haines is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

SAV plants should not be planted in water depths greater than 2 feet based on the median secchi depth values (1.8 feet). The maximum planting effort could result in vegetation cover of approximately 7 percent of the lake bottom (51 acres). Due to the organic material located in Lake Haines, it is recommended that SAV planting be performed after sediment removal/inactivation, if completed. If sediment removal is completed, the planting area would need to be recalculated using updated bathymetry data.

Cost Estimate: $240,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance).

FTWs

If the feasibility study indicates that more than 30 percent of Lake Haines has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 5: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Haines is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.7. Lake Hamilton

Background

Physical and chemical characteristics specific to Lake Hamilton are presented here in the context of relevant regulatory criteria and requirements (Table 4-13). Lake Hamilton (WBID 15041), is the terminal lake in the Northern Chain of the WHCL and is hydrologically connected to Lakes Henry and Middle Lake Hamilton via non-navigable constructed canals along the northern shoreline and to Lake Fannie along the western shoreline via a gated constructed canal (Photo 4-7, Figure 4-26). Lake Hamilton has not been identified as impaired; therefore, no TMDL is required. The TP, TN, and chlorophyll *a* geometric mean for Lake Hamilton for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-13. Reductions in concentrations of chlorophyll *a*, TN, or TP are not required to comply with the NNC.

A summary of water quality statistics for Lake Hamilton is presented in Table 4-14. Median chlorophyll *a*, TN and TP concentrations do not exceed the NNC targets provided by EPA for Lake Hamilton. Chlorophyll *a* concentrations in Lake Hamilton fluctuate remaining consistently below 20 µg/L (Figure 4-27). A statistically significant trend in chlorophyll *a* concentrations from 1985 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). No water quality improvement projects have been implemented in Lake Hamilton to restore water quality. A few *Hydrilla* infestation eradication projects have been performed in the last ten years, however, treatment occurred to less than one percent of the lake surface area. Lake Hamilton discharges via a gated structure to the Peace Creek Drainage Canal; therefore, improvements in water quality of the lake would result in little benefit farther downstream.

The Lake Hamilton watershed is 2,651 acres in size and includes 909 acres (34 percent) of developed lands compared to 1,742 acres (66 percent) of undeveloped lands. Approximately 21 percent of the land cover within the 500 foot buffer surrounding Lake Hamilton is classified as wetlands using the 2006 FLUCS data. Forested wetlands encompass five percent of the total wetland area, which does not satisfy the recommended forested wetland cover required to maintain color levels above 50 PCU. Lake Henry discharges highly colored water into Lake Hamilton which could explain the elevated colored values recorded in the lake due to the reduced forested wetlands found adjacent to the Lake Hamilton. The hydrologic connection between the forested wetlands and Lake Henry should be preserved to maintain elevated color values. The 2000-2007 median color value (80 PCU) was above 40 PCU indicating the lake is a colored lake. Using the adopted EPA NNC for Florida lakes, characterization of alkalinity or acidity is not necessary based on the colored classification of Lake Hamilton. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 121 feet in September 2005. Bathymetry data are available for Lake Hamilton for the September 2005 water level elevation (Figure 4-28). A water level of 119 feet was reported in July 2010, reflecting a 2.0 feet decrease in water elevation when compared to 2005.

Water Quality Restoration Project Selection and Priorities

Based on Lake Hamilton water quality and the surrounding watershed characteristics, no water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-29).

The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Continued water quality monitoring is recommended for the ongoing evaluation of water quality status and trends.

Table 4-13. Physical, chemical, and regulatory characteristics of Lake Hamilton.

Physical			
Location in chain	Northern	**High infiltration soils (acres)**	1,324 (50 percent)
Relation to other lakes	Terminal	**Developed land (acres)**	909 (34 percent)
Watershed area (acres)	2,651	**Undeveloped land (acres)**	1,742 (66 percent)
Lake area (acres)*	2,248	**Median water depth (feet)***	7.4
Perimeter (feet)*	57,274	**Maximum water depth (feet)***	23.4
Surface area: lake volume ratio*	0.12	**Volume (acre-feet)***	17,846
Watershed to surface area ratio*	1.18		
Water Chemistry			
Locally-derived: acidic or alkaline	NA	**Clear or colored**	Colored
Geometric mean chlorophyll *a* (µg/L)	9	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.18	**NNC TN target (mg/L)**	2.25
Geometric mean TP (mg/L)	0.094	**NNC TP target (mg/L)**	0.157
Regulatory Data			
Impaired	No	**TMDL status**	NA
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	NA

*at a water level elevation of 121 feet
**presented in section 5.0
NA=Not applicable

Photo 4-7. View of Lake Hamilton.

Table 4-14. Lake Hamilton water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	30	1	5	31
Color (PCU)	22	30	80	150
Conductivity (µmhos/cm)	27	133	204	341
Dissolved oxygen (mg/L)	27	5.96	7.96	9.93
pH	27	6.31	7.30	8.00
Secchi depth (feet)	30	0.9	2.2	4.2
Total nitrogen (mg/L)	30	0.29	1.09	1.54
Total phosphorus (mg/L)	26	0.054	0.100	0.888

Figure 4-26. Lake Hamilton and associated watershed.

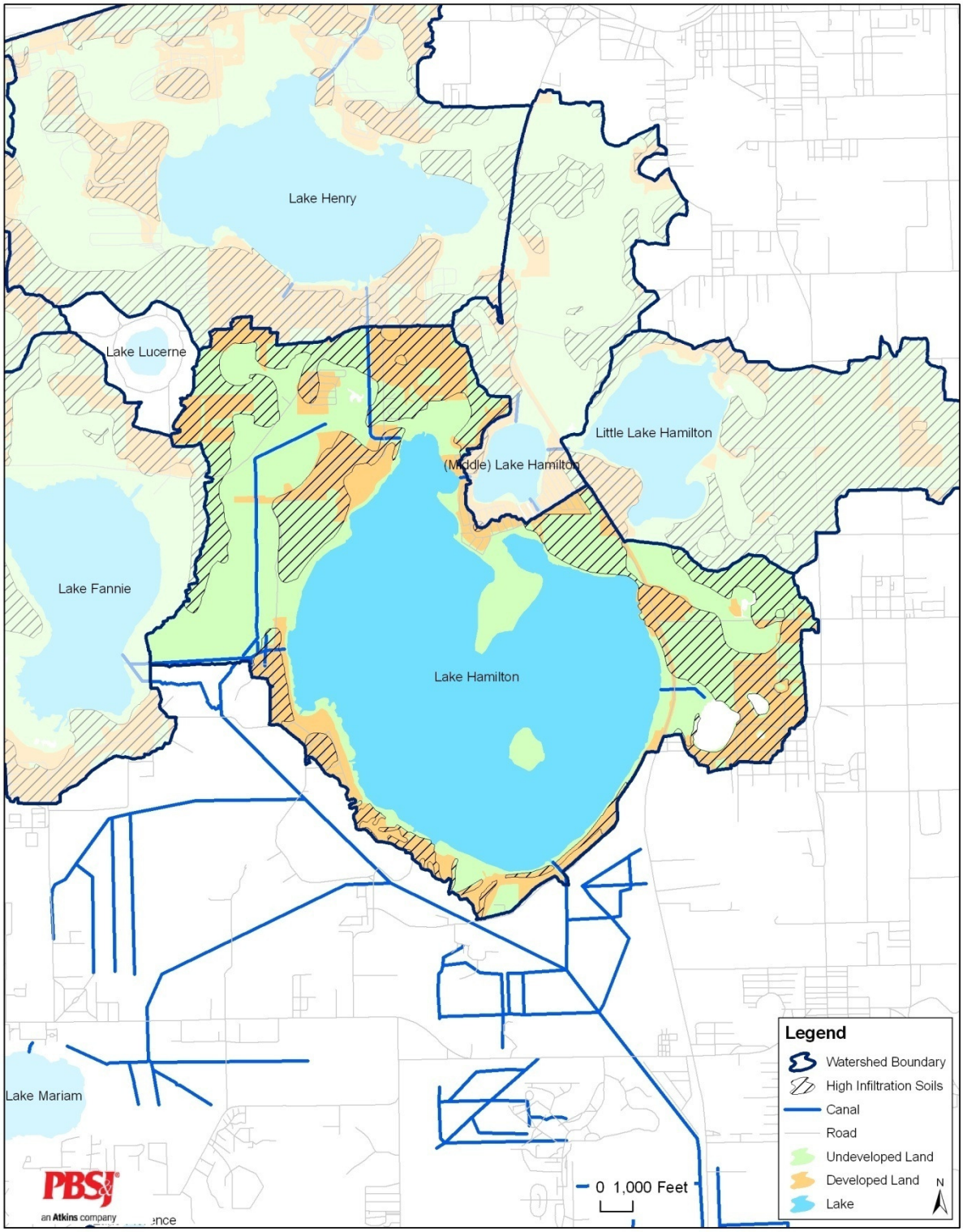


Figure 4-27. Lake Hamilton chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1985 to 2007.

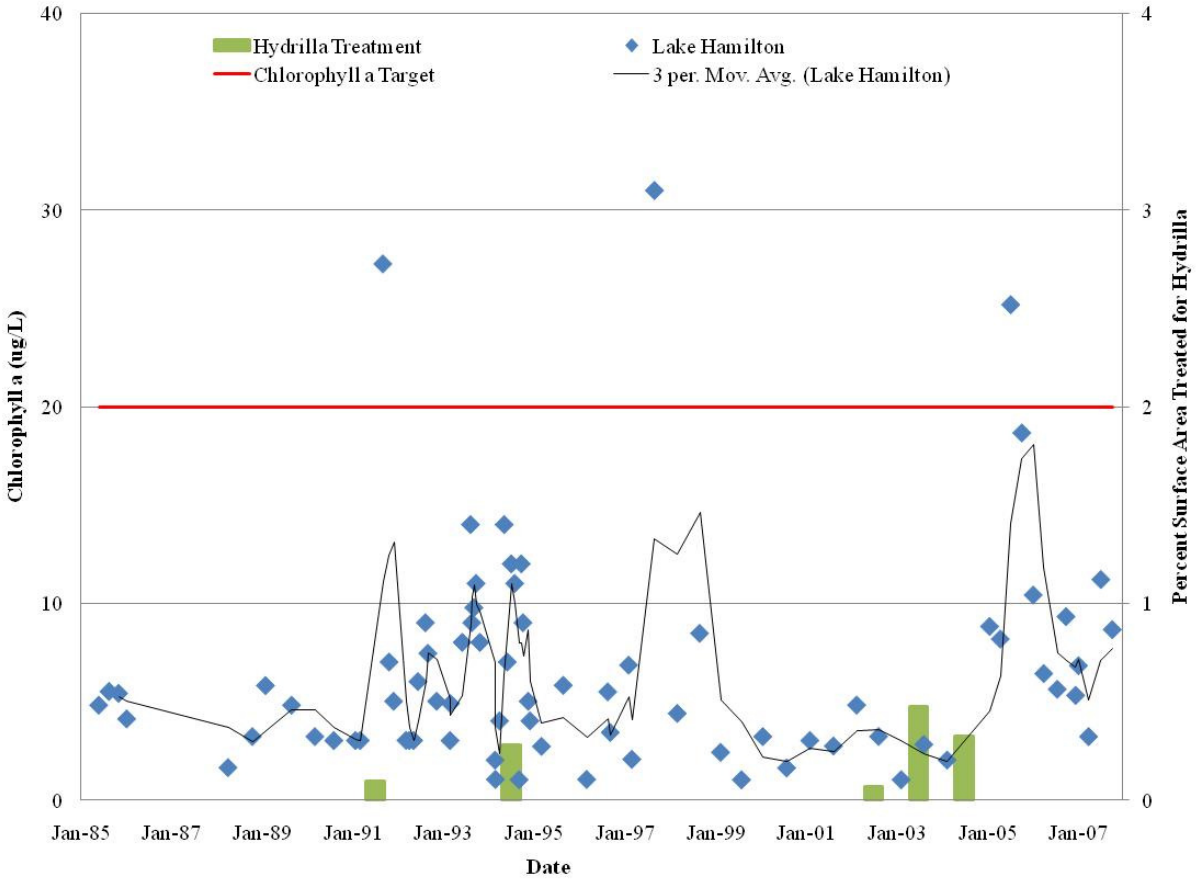


Figure 4-28. Lake Hamilton bathymetry (September 2005) at water level elevation = 121 feet (Polk County Water Atlas).

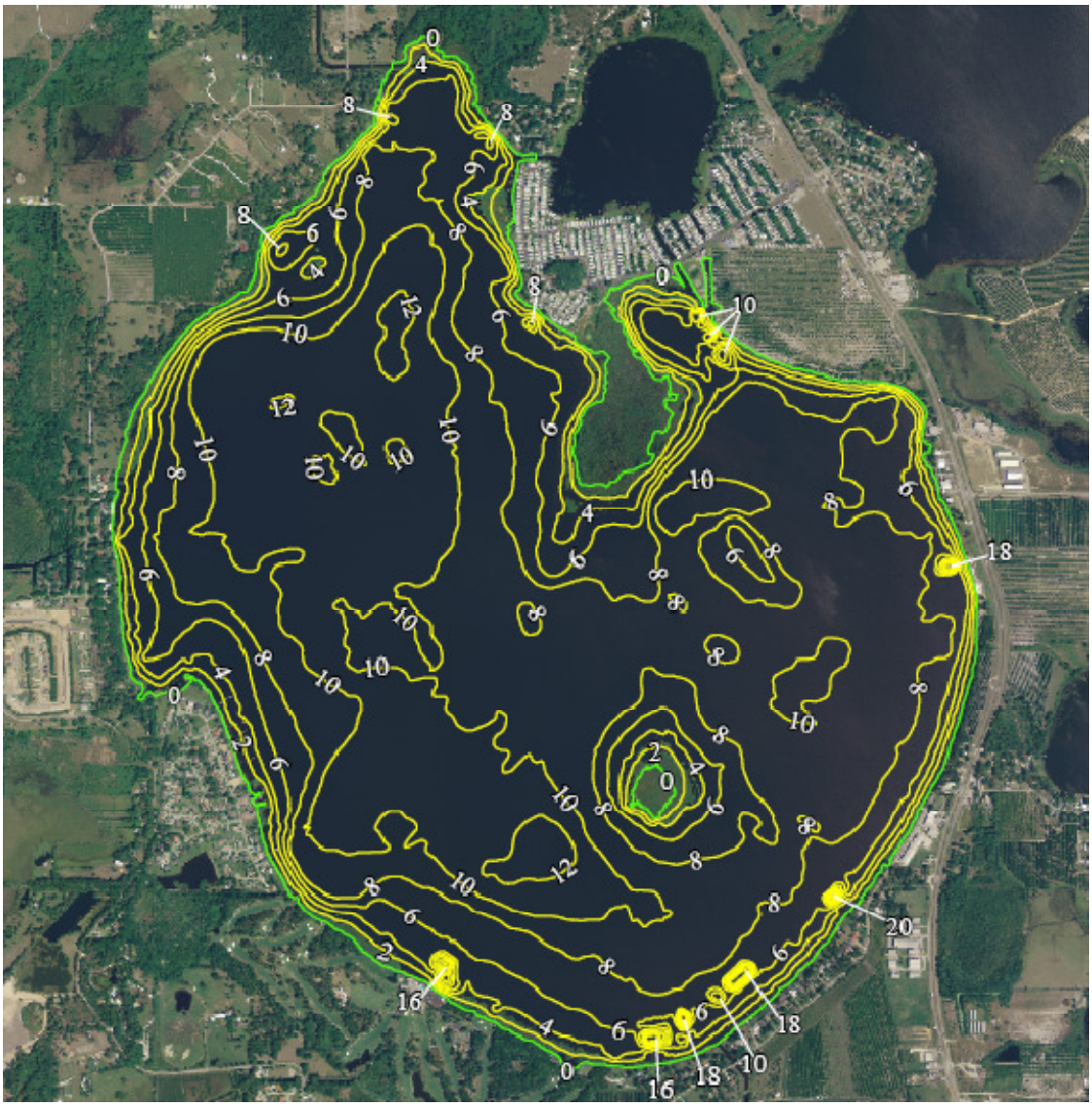
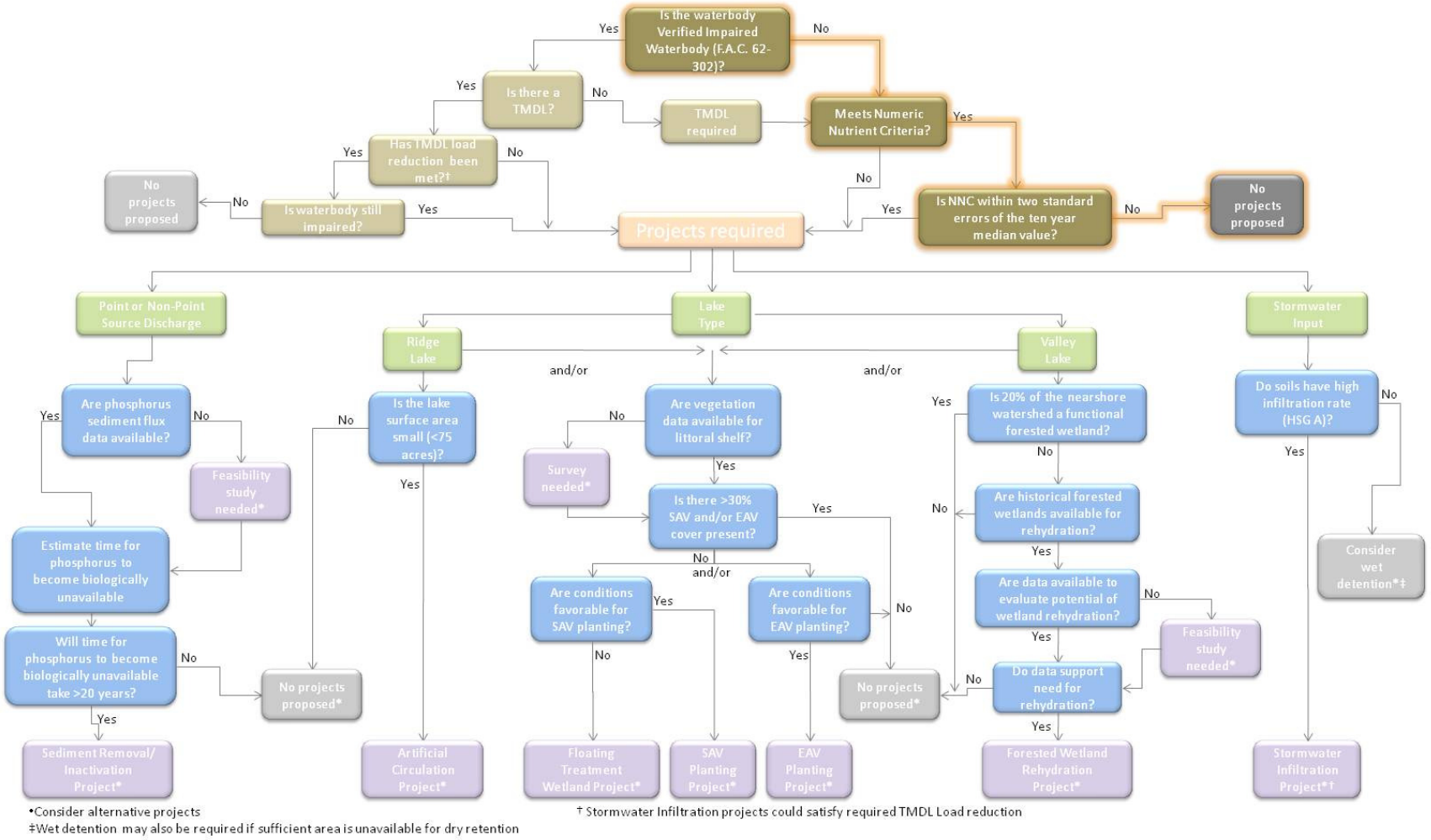


Figure 4-29. Lake Hamilton decision key: highlighted path shows decision process.



4.8. Lake Hartridge

Background

Physical and chemical characteristics specific to Lake Hartridge are presented here in the context of relevant regulatory criteria and requirements (Table 4-15). Lake Hartridge (WBID 1521I), a lake in the WHCL Southern Chain, is hydrologically connected to Lake Idylwild via a constructed navigable canal (Photo 4-8, Figure 4-30. Initially, Lake Hartridge was declared verified impaired based on elevated TSI values (>40). Later in 2005, a paleolimnological review of Lake Hartridge resulted in the removal of the lake from the impaired list based on the evidence that the lake was historically eutrophic and assigned a revised TSI threshold of 60. No TMDL is required for Lake Hartridge because it is not identified as an impaired waterbody. However, the NNC are performance based, an exceedance more than once every three years results in non-compliance. The annual geometric chlorophyll *a* mean in 2006 (21µg/L) was above the NNC; however, TN and TP values are below the NNC. Therefore, no concentration reductions are required. The results of this comparison indicate that a slight degradation in water quality in Lake Hartridge could result in an impairment designation. Therefore, water quality restoration projects are recommended for Lake Hartridge as a preventative action. The TP, TN, and chlorophyll *a* geometric mean for Lake Hartridge for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-15.

A summary of water quality statistics for Lake Hartridge is presented in Table 4-16. The median recorded chlorophyll a, TN, and TP concentrations are below the NNC targets provided by EPA for Lake Hartridge. However, the TP NNC is within twice the standard error of the ten year median indicating that water quality restoration projects are necessary to maintain unimpaired water quality. Chlorophyll *a* concentrations in Lake Hartridge have fluctuated with values peaking in the mid-1990s. Values have remained below 20 µg/L sufficiently to avoid an impairment designation by FDEP (Figure 4-31). However, a statistically significant increase in chlorophyll *a* concentrations from 1983 to 2007 was observed (seasonal Kendall-Tau, p=0.006). In 2007, the City of Winter Haven and the District implemented a stormwater treatment project on the southern rim of Lake Hartridge (Photo 4-9). The estimate TP load reduction from the stormwater treatment project is 39 kg/year. *Hydrilla* eradication projects have been completed on Lake Hartridge over at least the past 20 years. Most recently, 100 percent of the lake surface area was treated for *Hydrilla*. Lake Hartridge is a headwater lake and, as such, improvements in water quality of the lake could result in benefit farther downstream.

The Lake Hartridge watershed is 508 acres in size and includes 404 acres (79 percent) of developed lands compared to 105 acres (21 percent) of undeveloped lands. The 2000-2007 median color value (15 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 131 feet in October 2006. Bathymetry data are available for Lake Hartridge for the October 2006 water level elevation (Figure 4-32). A water level of 130 feet was reported in August 2010, reflecting a 1.0 foot decrease in water elevation when compared to 2006. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Hartridge water quality and the surrounding watershed characteristics, four potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-33). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management

Table 4-15. Physical, chemical, and regulatory characteristics of Lake Hartridge.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	391 (77 percent)
Relation to other lakes	Headwater	**Developed land (acres)**	404 (79 percent)
Watershed area (acres)	508	**Undeveloped land (acres)**	105 (21 percent)
Lake area (acres)*	454	**Median water depth (feet)***	2.5
Perimeter (feet)*	23,542	**Maximum water depth (feet)***	21.5
Surface area: lake volume ratio*	0.11	**Volume (acre-feet)***	4,114
Watershed to surface area ratio*	1.12		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	15	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	0.73	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.030	**NNC TP target (mg/L)**	0.3
Regulatory Data			
Impaired	No	**TMDL status**	NA
Chlorophyll *a* trend	Increasing**	**TP concentration reduction required**	NA

*at a water level elevation of 131 feet
**presented in section 5.0
NA=not applicable

Photo 4-8. Lake Hartridge.

Table 4-16. Lake Hartridge water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	81	4	16	54
Color (PCU)	29	5	15	30
Conductivity (µmhos/cm)	26	149	188	240
Dissolved oxygen (mg/L)	26	6.51	8.27	9.74
pH	26	6.8	7.61	8.74
Secchi depth (feet)	82	1.8	3.3	9.4
Total nitrogen (mg/L)	86	0.07	0.75	1.3
Total phosphorus (mg/L)	83	0.009	0.027	0.073

Figure 4-30. Lake Hartridge and associated watershed.

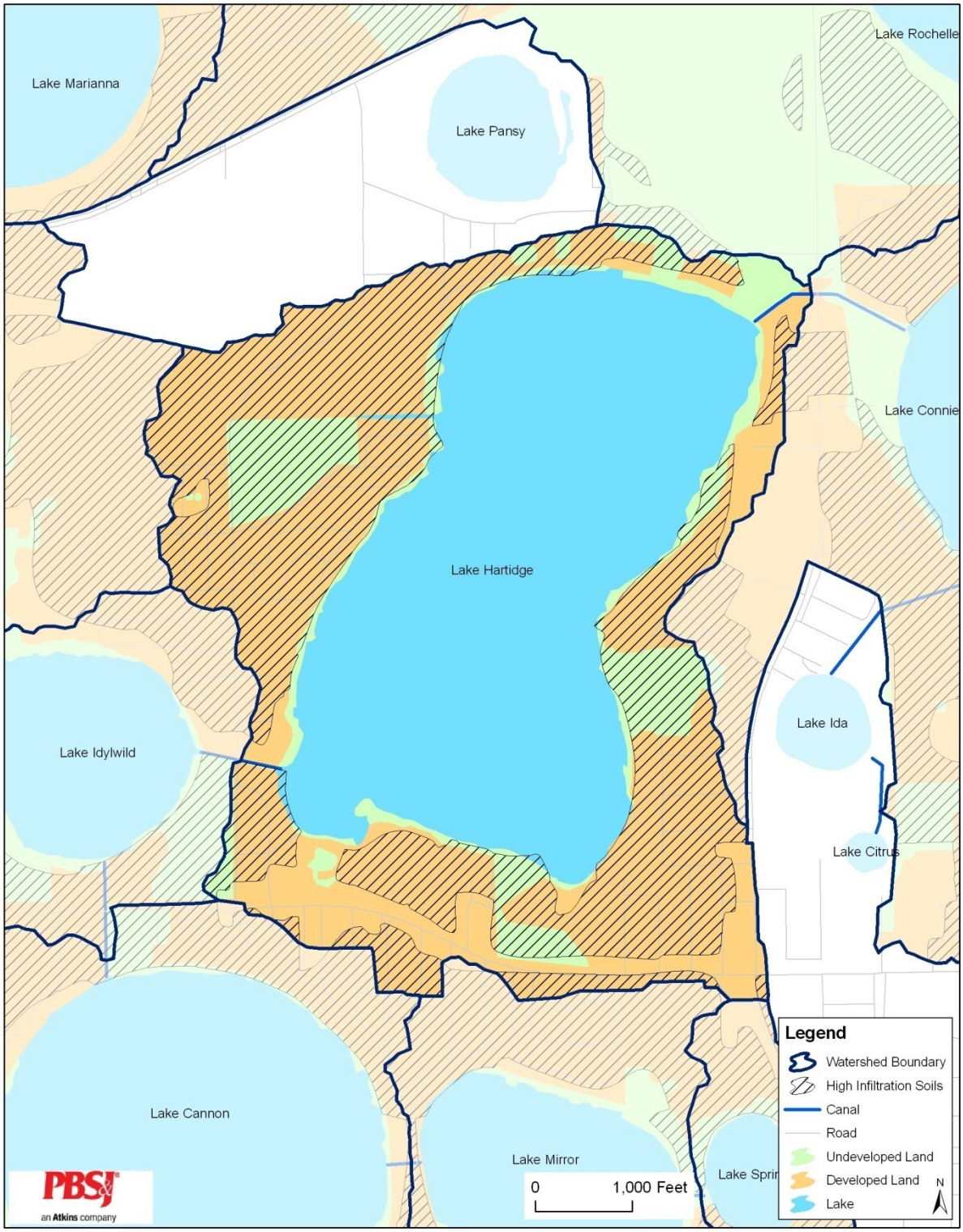


Photo 4-9. Lake Hartridge Stormwater Treatment Project.

Figure 4-31. Lake Hartridge chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

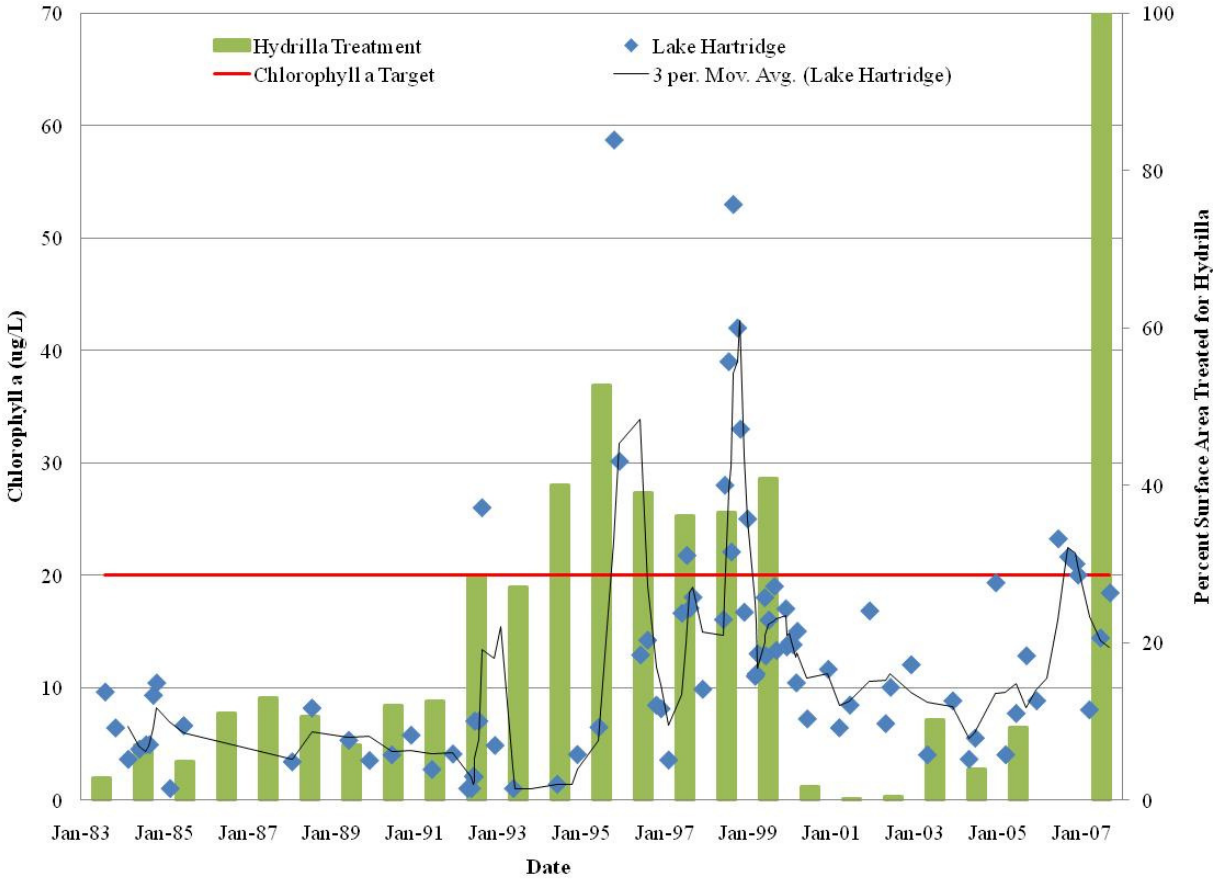


Figure 4-32. Lake Hartridge bathymetry (October 2006) at water level elevation = 131 feet (Polk County Water Atlas).

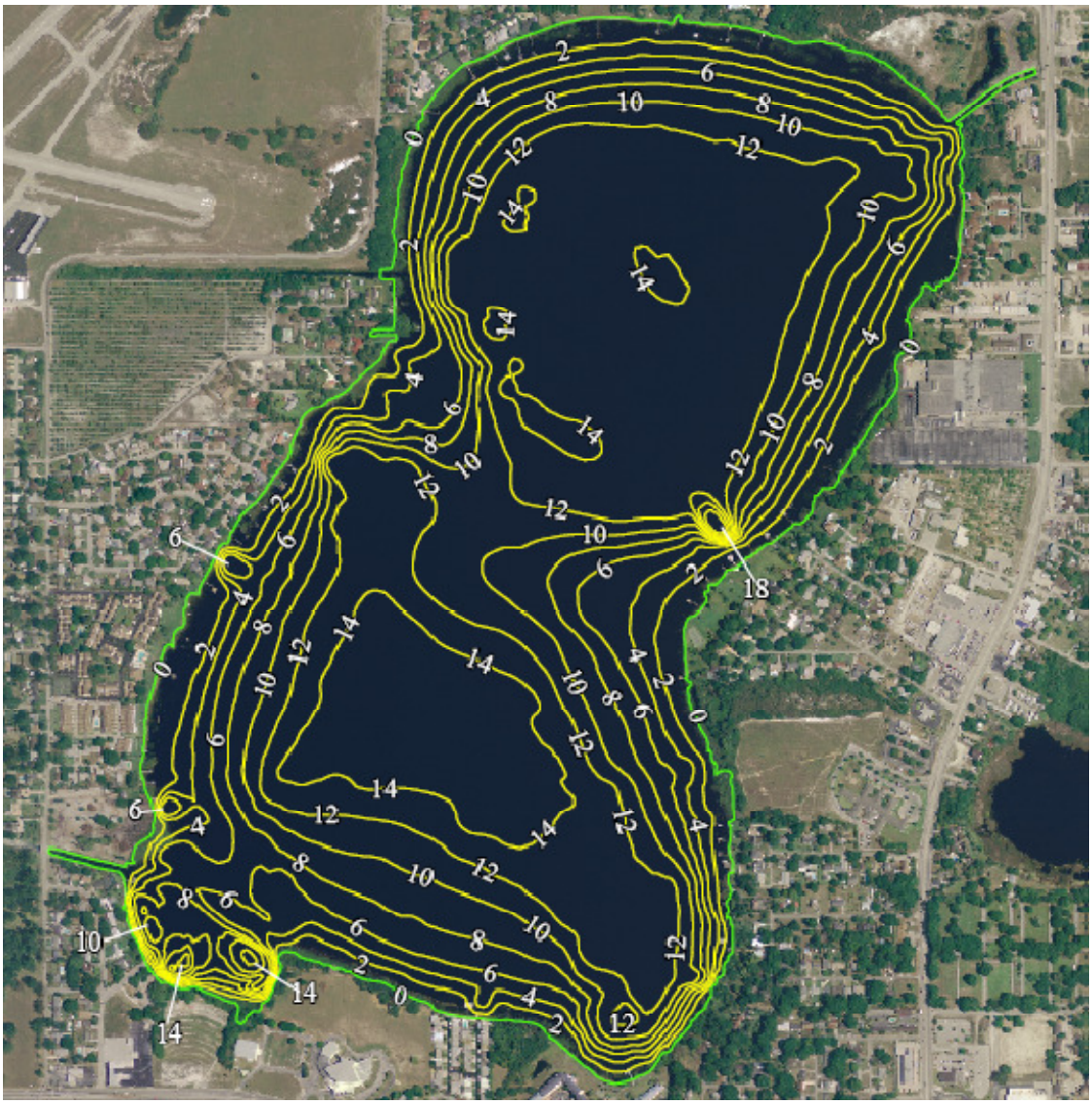
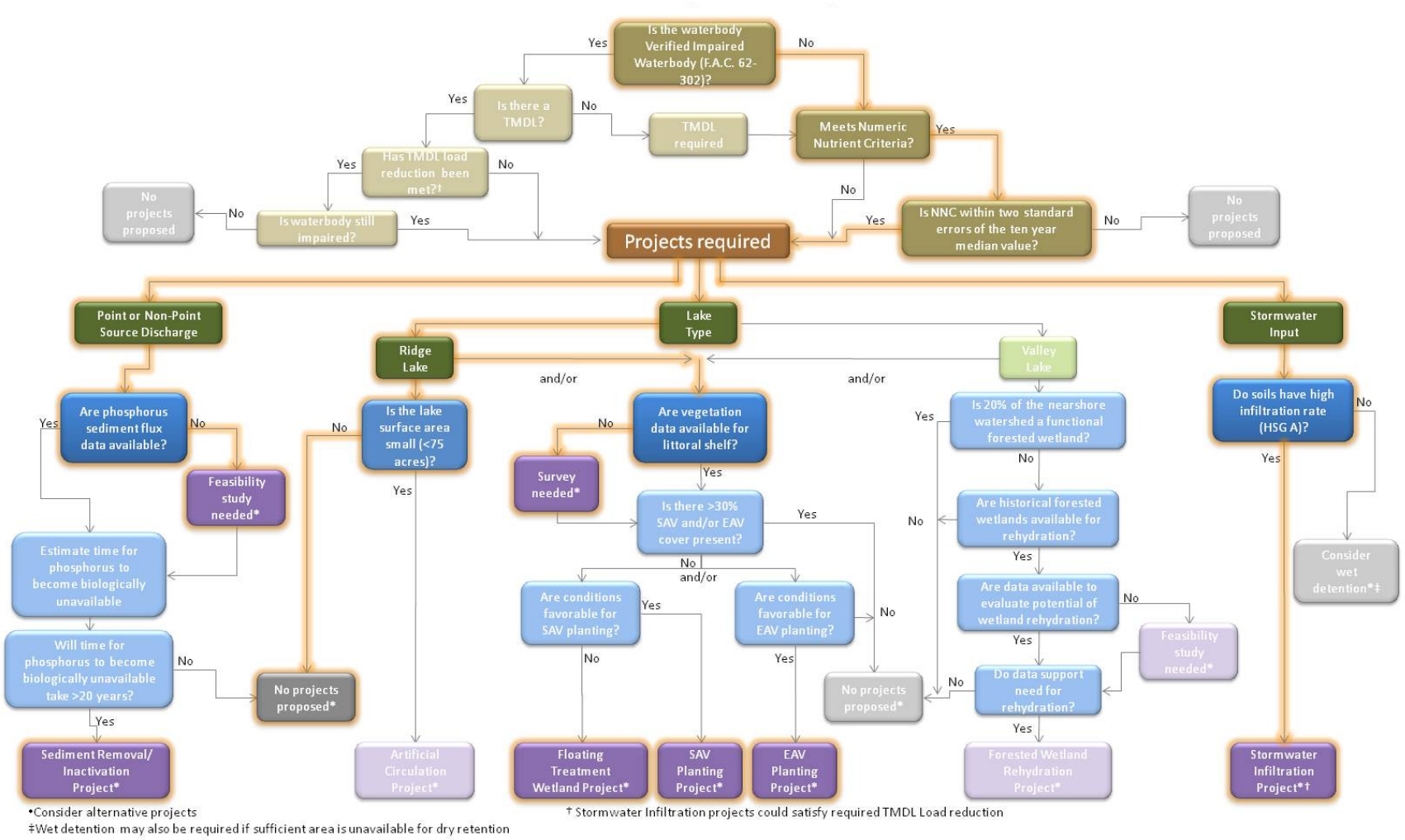


Figure 4-33. Lake Hartridge decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Hartridge watershed has approximately 391 acres (77 percent of the watershed) classified as high infiltration soils. A TMDL is not required for Lake Hartridge due to the unimpaired status; therefore; SIA acres estimates were calculated using data from the PLRG (USF 2005). The SIA estimate for Lake Hartridge was 10 acres (approximately two percent of the watershed) to meet a 19 percent PLRG. The TP geometric mean for Lake Hartridge is below the NNC; therefore, acres of SIA estimated to meet the TP NNC were not calculated.

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Lake Hartridge may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

Hydrilla infestations have been a chronic problem in Lake Hartridge. A survey of existing SAV cover in Lake Hartridge is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth.

The 1997-2007 median secchi depth for Lake Hartridge was 3.3 feet indicating that SAV plants should not be planted in water depths greater than 4 feet. The maximum planting effort could result in vegetation cover of approximately 18 percent of the lake bottom (83 acres).

Cost Estimate: $400,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance).

FTWs

If the feasibility study indicates that more than 30 percent of Lake Hartridge has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing EAV surrounding Lake Hartridge is recommended due to the lack of sufficient data at this time. Based on the results of the survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited EAV is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.9. Lake Henry

Background

Physical and chemical characteristics specific to Lake Henry are presented here in the context of relevant regulatory criteria and requirements (Table 4-17). Lake Henry (WBID 1504A) is located in the Northern Chain of the WHCL and is hydrologically connected to Lake Hamilton via a constructed non-navigable canal and control structure along the southern shoreline, however water control structures regulate the passage of water through the canals and Lake Henry receives water from Lake Haines through a flow through wetland (Photo 4-10, Figure 4-34). Lake Henry has not been identified as impaired, therefore, no TMDL is required. The TP, TN, and chlorophyll *a* geometric mean for Lake Henry for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-17. Reductions in concentrations for chlorophyll *a*, TN, or TP are not required to comply with the NNC.

A summary of water quality statistics for Lake Henry is presented in Table 4-18. Median chlorophyll *a*, TN and TP concentrations do not exceed the NNC targets provided by EPA for Lake Henry. Chlorophyll *a* concentrations in Lake Henry have consistently remained below 20 µg/L (Figure 4-35). However, a statistically significant increase in chlorophyll *a* concentrations from 1990 to 2007 was observed (seasonal Kendall-Tau, p=0.06). No water quality improvement projects have been implemented in Lake Henry to restore water quality and *Hydrilla* infestations have not been problematic. Lake Henry is adjacent to a terminal lake; therefore, improvements in water quality within the Lake could result in benefits to one downstream lake (Lake Hamilton).

The Lake Henry watershed is 2,810 acres in size and includes 1,124 acres (40 percent) of developed lands compared to 1,686 acres (60 percent) of undeveloped lands. The 2000-2007 median color value (200 PCU) was above 40 PCU indicating the lake is a colored lake. Using the adopted EPA NNC for Florida lakes, characterization of alkalinity or acidity is not necessary based on the colored classification of Lake Fannie. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 125 feet in October 2006. Bathymetry data are available for Lake Fannie for the October 2006 water level elevation (Figure 4-36). A water level of 130 feet was reported in August 2010, reflecting a 5.0 foot increase in water elevation when compared to 2006.

The water level elevations throughout the WHCL are monitored and managed by the Lake Region Lakes Management District (LRLMD). In October 2010, the SWFWMD requested that the LRLMD reduce water levels in Lake Henry to 125.5 feet, 6 inches below the 126 feet maximum desirable level established in 1981. The request was initiated by the Sweetwater community residents based on the flooding of an adjacent golf course. An extensive portion of Lake Henry's shoreline is comprised of healthy forested wetlands. Approximately 42 percent of the land cover within the 500 foot buffer surrounding Lake Henry is classified as wetlands using the 2006 FLUCS data. Forested wetlands encompass 30 percent of the total wetland area which satisfies the recommended forested wetland cover required to maintain color levels above 50 PCU. Due to the inundation of the adjacent forested wetlands, increased tannin levels are observed throughout the lake which inhibits phytoplankton production. Effort should be taken to maintain sufficient inundation frequency and duration within the Lake Henry forested wetlands

to maintain elevated color levels to avoid adverse impacts to water quality within the lake. Therefore, changes to the management in water levels in Lake Henry should be evaluated based on the impact to the forested wetlands.

Water Quality Restoration Project Selection and Priorities

Based on Lake Henry water quality and the surrounding watershed characteristics, no water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-37). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Because Lake Henry has displayed increasing trends in chlorophyll *a* concentrations and its water quality depends on high color resulting from the hydrologic connection with the forested wetland shoreline, continued monitoring of water quality, lake levels and wetland connections is recommended for the ongoing evaluation of water quality status and trends. It may be that future projects for wetland reconnections would be necessary if chlorophyll *a* trends continue to increase.

Table 4-17. Physical, chemical, and regulatory characteristics of Lake Henry.

Physical			
Location in chain	Northern	**High infiltration soils (acres)**	1,360 (48 percent)
Relation to other lakes	Adjacent to Terminal	**Developed land (acres)**	1,124 (40 percent)
Watershed area (acres)	2,810	**Undeveloped land (acres)**	1,686 (60 percent)
Lake area (acres)*	861	**Median water depth (feet)***	3.0
Perimeter (feet)*	33,051	**Maximum water depth (feet)***	78.4
Surface area: lake volume ratio*	0.16	**Volume (acre-feet)***	5,546
Watershed to surface area ratio*	3.26		
Water Chemistry			
Locally-derived: acidic or alkaline	NA	**Clear or colored**	Colored
Geometric mean chlorophyll *a* (µg/L)	5	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.06	**NNC TN target (mg/L)**	2.25
Geometric mean TP (mg/L)	0.111	**NNC TP target (mg/L)**	0.157
Regulatory Data			
Impaired	No	**TMDL status**	NA
Chlorophyll *a* trend	Increasing**	**TP concentration reduction required**	NA

*at a water level elevation of 125 feet
**presented in section 5.0
NA= not applicable

Photo 4-10. View of northwestern portion of Lake Henry.

Table 4-18. Lake Henry water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	129	1	5	19.5
Color (PCU)	19	20	200	350
Conductivity (µmhos/cm)	21	128	162	262
Dissolved oxygen (mg/L)	21	5.5	8.3	10.2
pH	21	5.71	6.88	7.71
Secchi depth (feet)	135	0.65	1.7	2.7
Total nitrogen (mg/L)	135	0.70	1.00	1.65
Total phosphorus (mg/L)	134	0.048	0.116	0.208

Figure 4-34. Lake Henry and associated watershed.

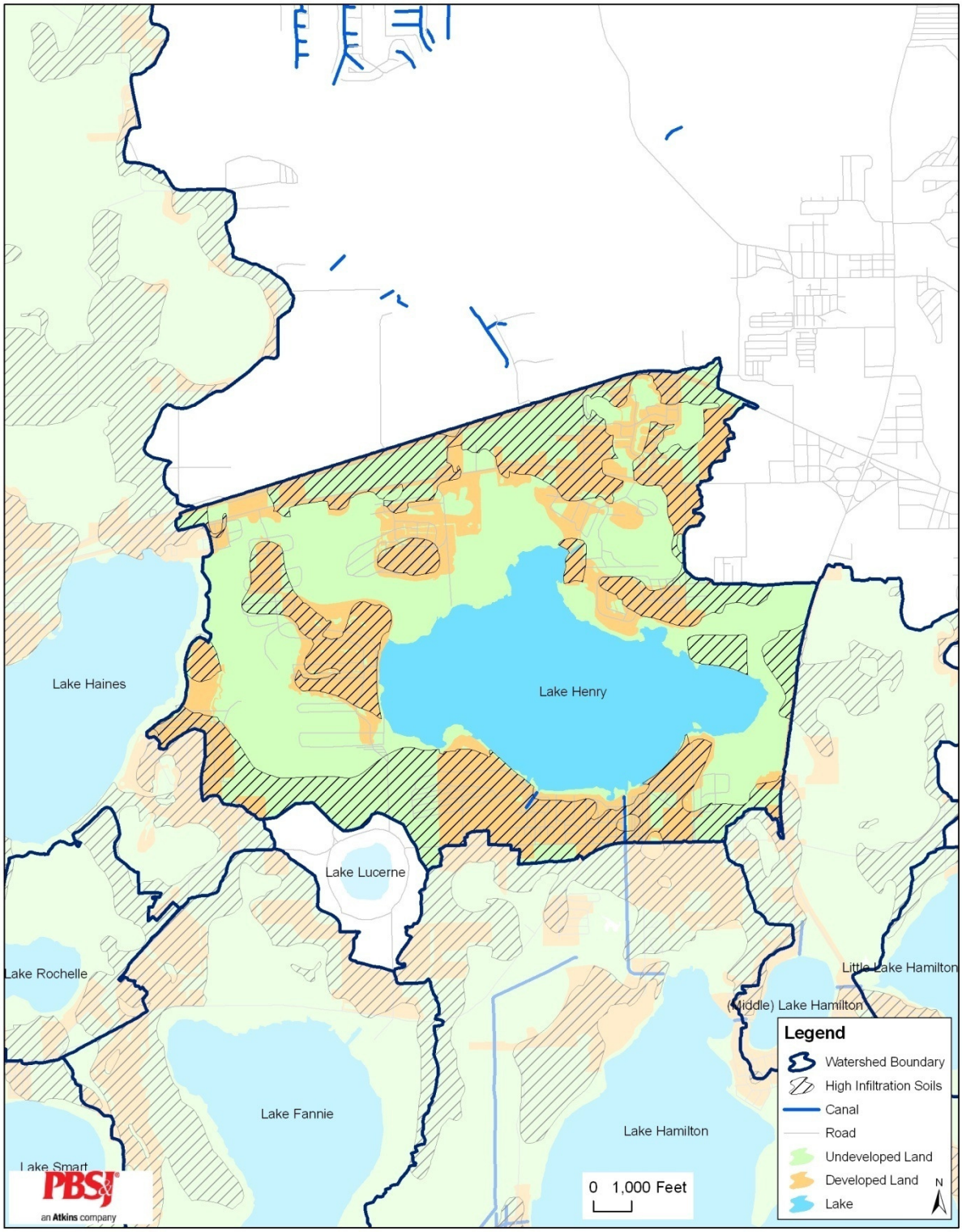


Figure 4-35. Lake Henry chlorophyll *a* concentrations with available data from 1990 to 2007.

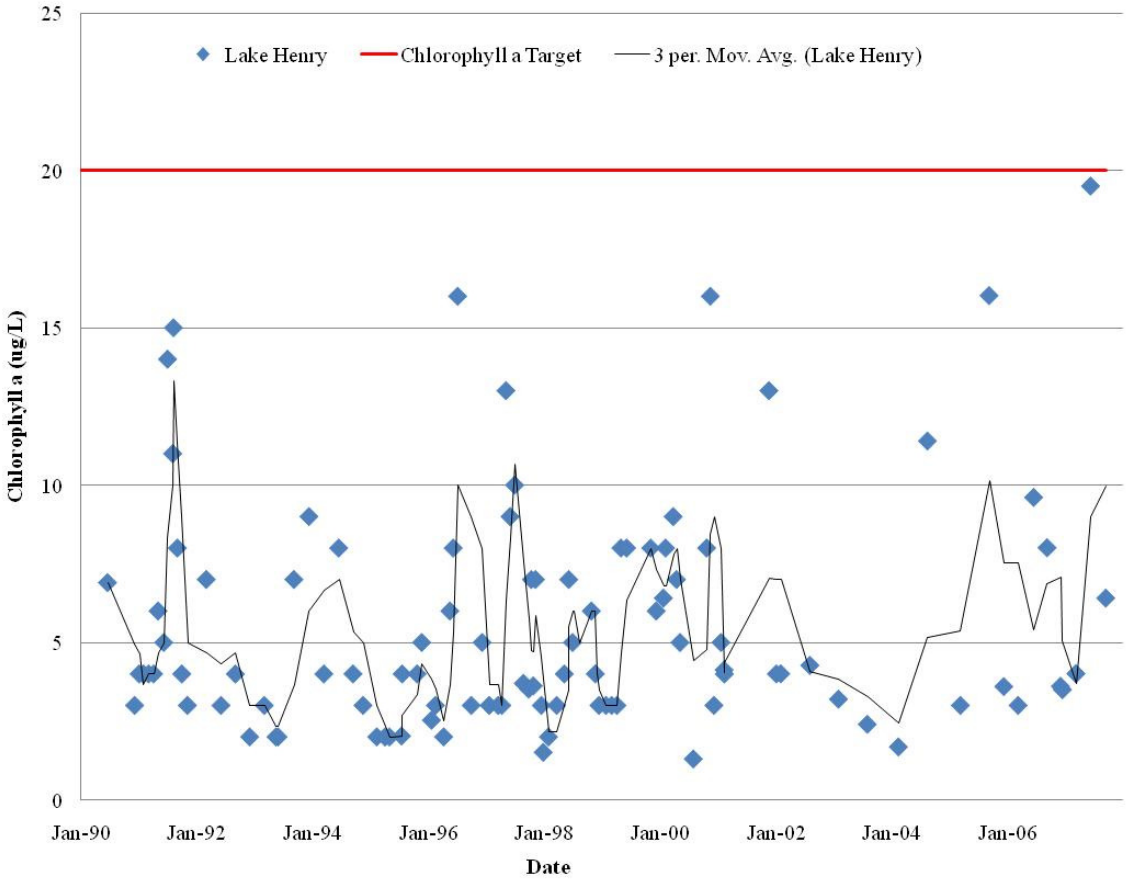


Figure 4-36. Lake Henry bathymetry (October 2006) at water level elevation = 125 feet (Polk County Water Atlas).

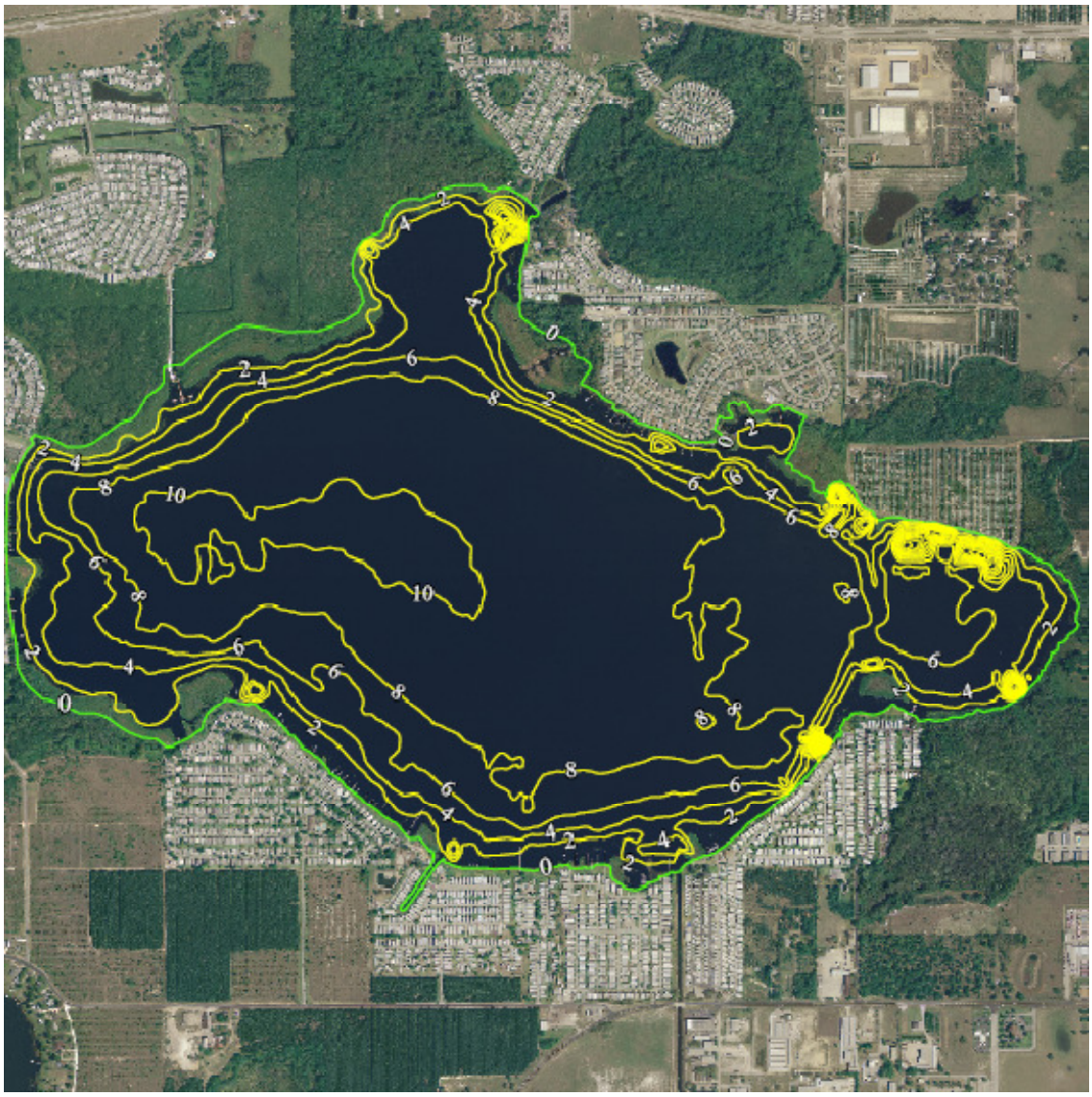
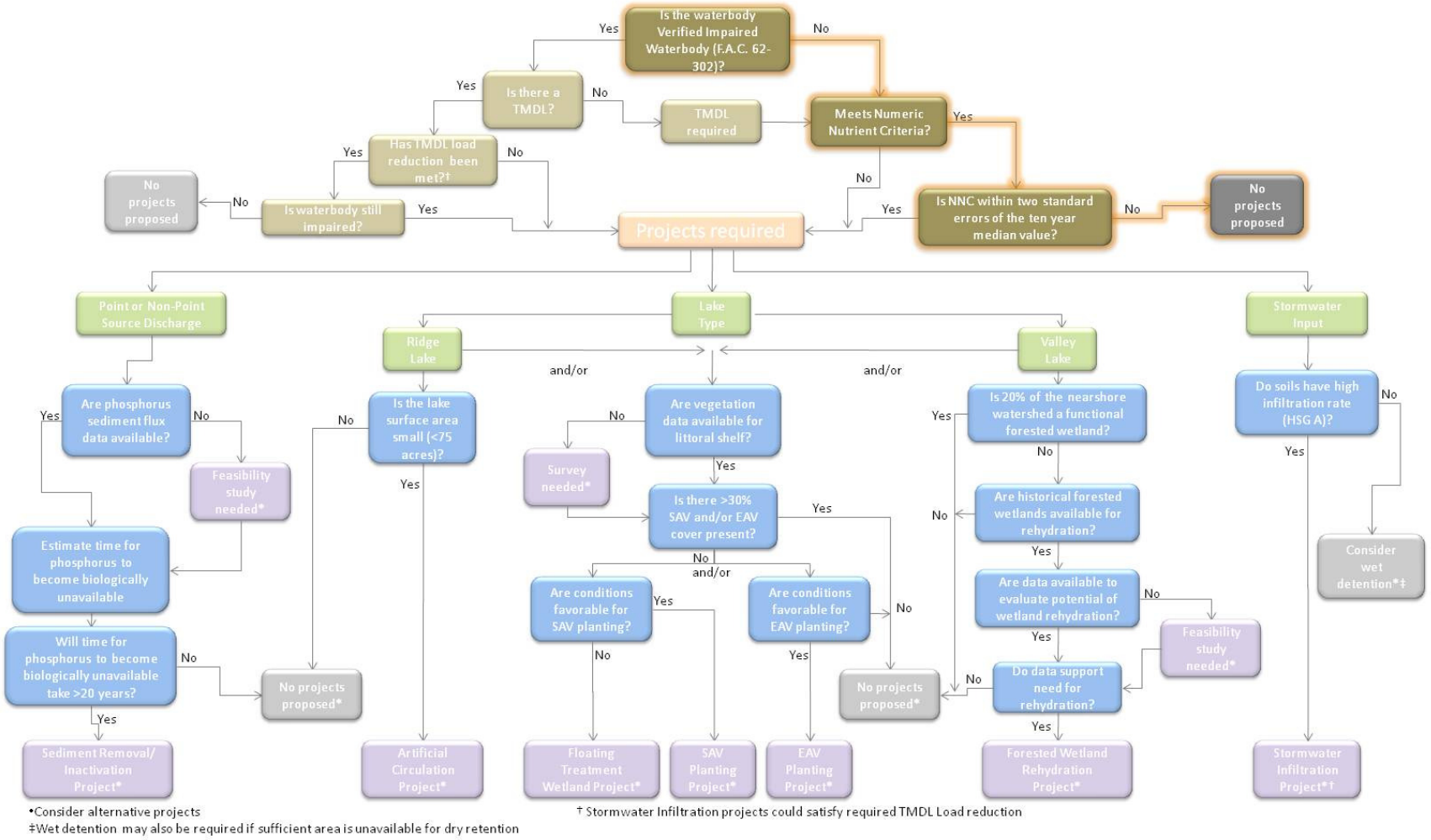


Figure 4-37. Lake Henry decision key: highlighted path shows decision process.



4.10. Lake Howard

Background

Physical and chemical characteristics specific to Lake Howard are presented here in the context of relevant regulatory criteria and requirements (Table 4-19). Lake Howard (WBID 1521F) is located in the Southern Chain of the WHCL and is hydrologically connected to lakes Cannon and May via constructed navigable canals (Photo 4-11, Figure 4-38). In 2005, Lake Howard was declared verified impaired based on elevated TSI values (>60). A TMDL was adopted for the Southern Chain of the WHCL, including Lake Howard (FDEP 2007), and Lake Howard was subsequently delisted from impairment by FDEP in 2010. Based on the modeled external TP load to Lake Howard, a 62.5 percent reduction in TP load (193 kg TP/year) is required to comply with the TSI criteria of 60 (FDEP 2007). The TP, TN, and chlorophyll *a* geometric mean for Lake Howard for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-19. To comply with the NNC, concentration reductions of 23 percent for TP, 22 percent for TN, and 41 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Howard is presented in Table 4-20. In 1977, point source discharges to Lake Howard from the Jan-Phyl Village WWTF were eliminated followed by overflow discharge termination in 1980. These point source discharges resulted in the annual addition of approximately 689 kg TP to the lake as well as lake sediment accumulation. While the effluent discharges have been eliminated, the discharges resulted in nutrient and sediment accumulation in the lake bottom. An inverse relationship between lake levels and chlorophyll *a* concentrations may suggest sediment resuspension resulting in a decline in water quality. Recognizing water quality problems for the lake, the City of Winter Haven and the District implemented a habitat/stormwater retrofit project and alum injection (Photo 4-12). Projects and predicted load reductions are summarized in Table 4-21. Based on TP load reduction estimates for projects constructed on Lake Howard (263 kg/year), it appears that required TP load reductions (193 kg/year) have already been accomplished (Figure 4-40). Unfortunately, chlorophyll *a* levels in the lake following completion of stormwater retrofits in 2000 and 2001 provided no clear evidence of improvement in water quality. Chlorophyll *a* levels in Lake Howard seem to reflect a delayed, but real, response to point source load eliminations in the 1980s, but not after the 2000 and 2001 stormwater retrofits. The lowest chlorophyll *a* values exceed 20 µg/liter, indicating that TSI_{CHLA} values less than or equal to 60 (which would require chlorophyll *a* levels to be below 20 µg/L) were not reached. An increase in TP levels in Lake Howard after an initial decrease during the months after completion of the large regional stormwater treatment projects was also observed. This increase in TP coincided with herbicide applications for *Hydrilla* eradication over approximately half of Lake Howard (Polk County, personal communication). *Hydrilla* eradication efforts in Lake Howard appear to have compromised or offset some of the benefits, at least to chlorophyll *a* concentrations and TP levels, of the prior stormwater treatment projects.

The median chlorophyll *a*, TN and TP concentrations continue to exceed the NNC targets provided by EPA for Lake Howard. Chlorophyll *a* concentrations in Lake Howard fluctuate but remain elevated above 20 µg/L (Figure 4-41). A statistically significant decline in chlorophyll *a* concentrations from 1983 to 2007 was observed (seasonal Kendall-Tau, p=0.092). The

combination of the elimination of point source discharges and stormwater treatment projects has resulted in improved water quality when compared to the previous water quality conditions. Improvements in water quality within Lake Howard could result in benefit farther downstream.

The Lake Howard watershed is 1,153 acres in size and includes 948 acres (82 percent) of developed lands compared to 205 acres (18 percent) of undeveloped lands. The 2000-2007 median color value (15 PCU) was below 40 PCU indicating the lake is a clear (non colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 132 feet in August 2005. Bathymetry data are available for Lake Howard for the August 2005 water level elevation (Figure 4-39). A water level of 130.0 feet was reported in August 2010, reflecting a 2.0 feet decrease in water elevation when compared to 2005. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Howard water quality and the surrounding watershed characteristics, four potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-42). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Sediment Removal/Inactivation
- Project 2: Stormwater Infiltration Areas (SIAs)
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management

Table 4-19. Physical, chemical, and regulatory characteristics of Lake Haines.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	655 (57 percent)
Relation to other lakes	Intermediate	**Developed land (acres)**	948 (82 percent)
Watershed area (acres)	1,153	**Undeveloped land (acres)**	205 (18 percent)
Lake area (acres)*	641	**Median water depth (feet)***	11.5
Perimeter (feet)*	21,459	**Maximum water depth (feet)***	18.7
Surface area: lake volume ratio*	0.16	**Volume (acre-feet)***	6,968
Watershed to surface area ratio*	1.80		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	34	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.27	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.039	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required†
Chlorophyll *a* trend	Decreasing**	**TP concentration reduction required**	23 percent

*at a water level elevation of 132 feet
**presented in section 5.0
† TMDL adopted

Photo 4-11. View of Lake Howard from southwestern rim.

Table 4-20. Lake Howard water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	44	1	32	78
Color (PCU)	28	5	15	52
Conductivity (µmhos/cm)	26	188	215	300
Dissolved oxygen (mg/L)	26	6.97	8.85	11.6
pH	26	6.87	8.18	9.07
Secchi depth (feet)	47	1.0	2	2.7
Total nitrogen (mg/L)	46	0.48	1.41	2.67
Total phosphorus (mg/L)	42	0.002	0.041	0.109

Figure 4-38. Lake Howard and associated watershed.

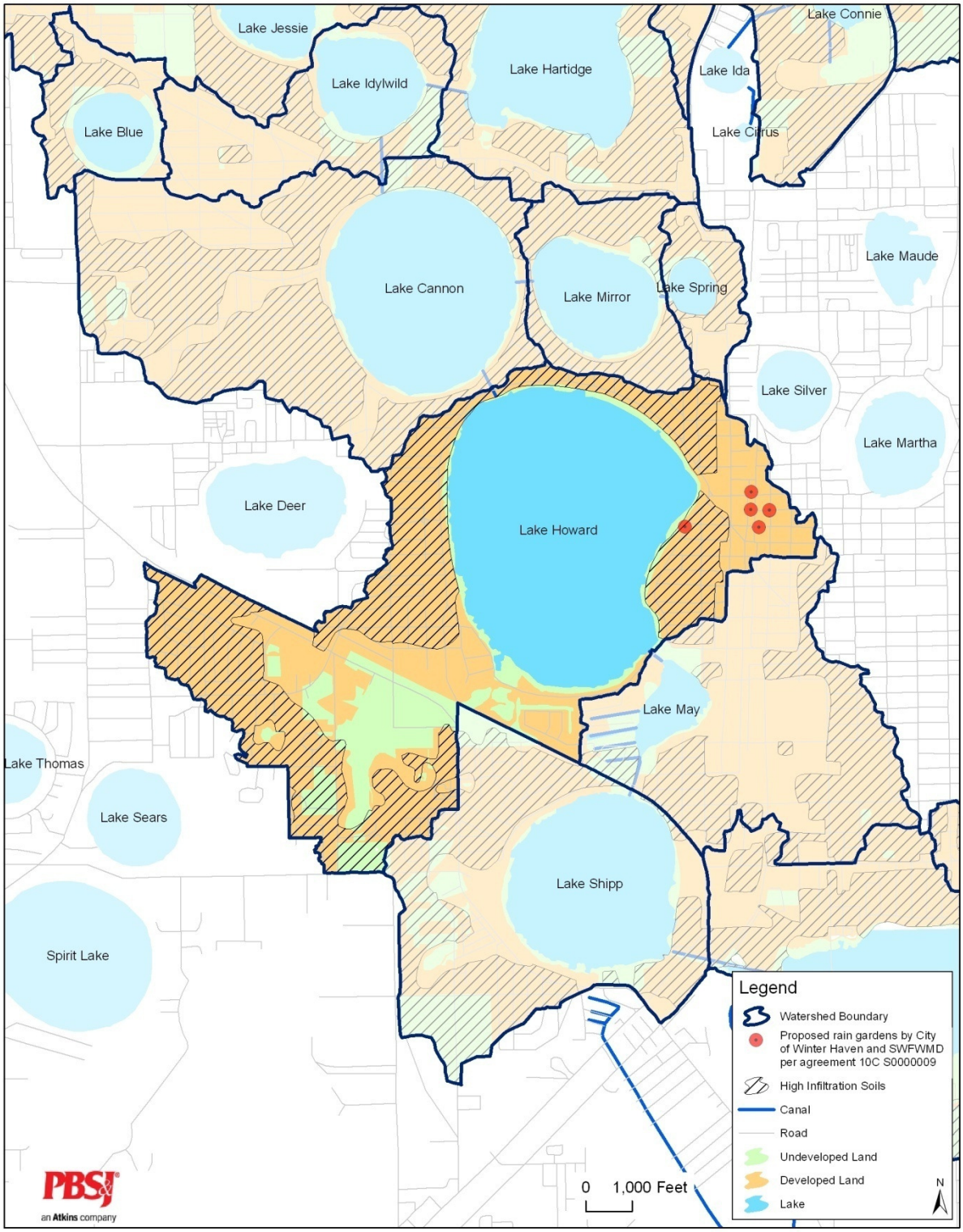


Photo 4-12. South Lake Howard wet detention stormwater treatment project.

Table 4-21. Estimated Lake Howard TP reductions due to projects and required under the TMDL.

Project	Year Completed	Contributing Drainage Area (acres)	Projects	TP Reduction (kg/year)
Lake Howard Habitat/Stormwater Retrofit Project	2001	578	Wetland treatment/wet detention	181
Lake Howard Alum Injection Project	2000	175	Alum injection	82
Total		753	NA	263 (estimated)
TMDL TP Reduction Required (kg/year)				193 (required)

NA=not applicable

Figure 4-39. Lake Howard bathymetry (August 2005) at water level elevation = 132 feet (Polk County Water Atlas).

Figure 4-40. Lake Howard chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

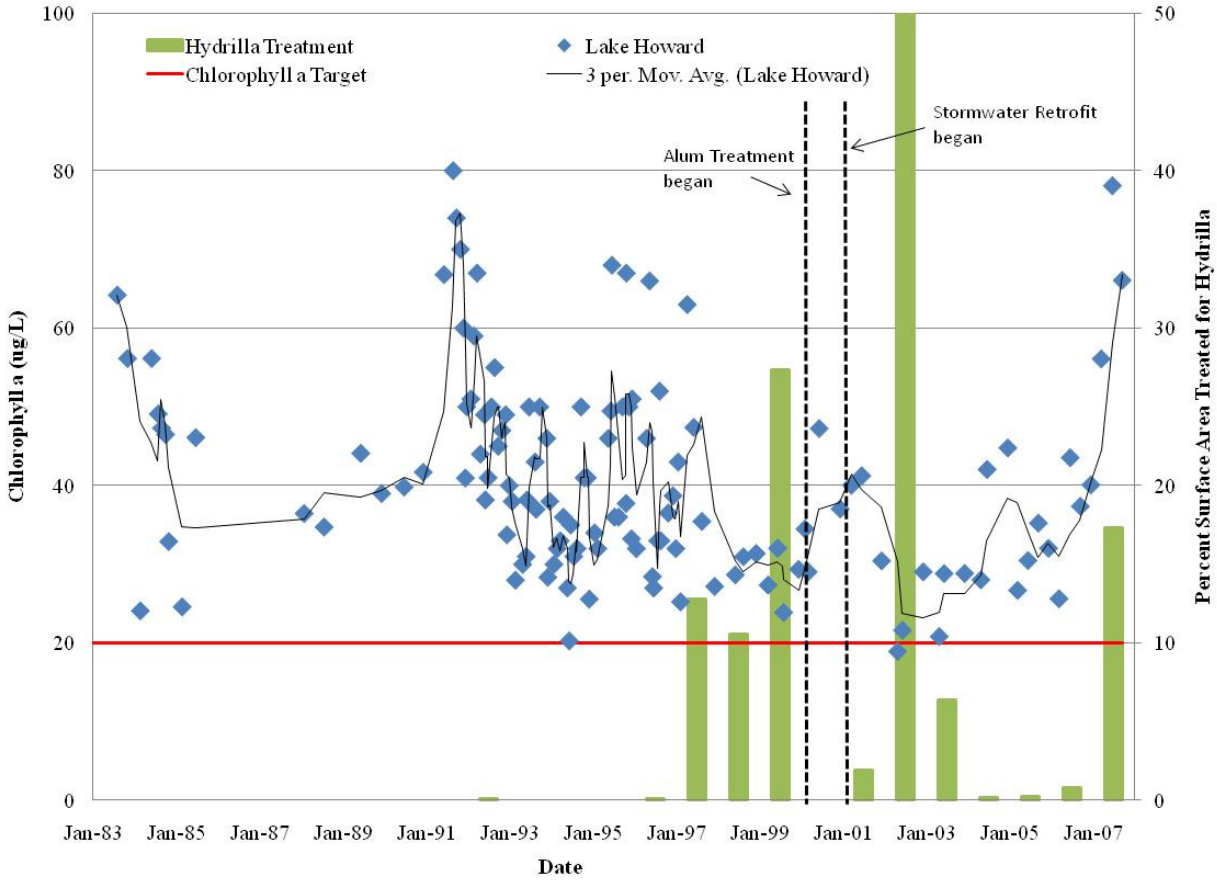


Figure 4-41. Lake Howard total phosphorus concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

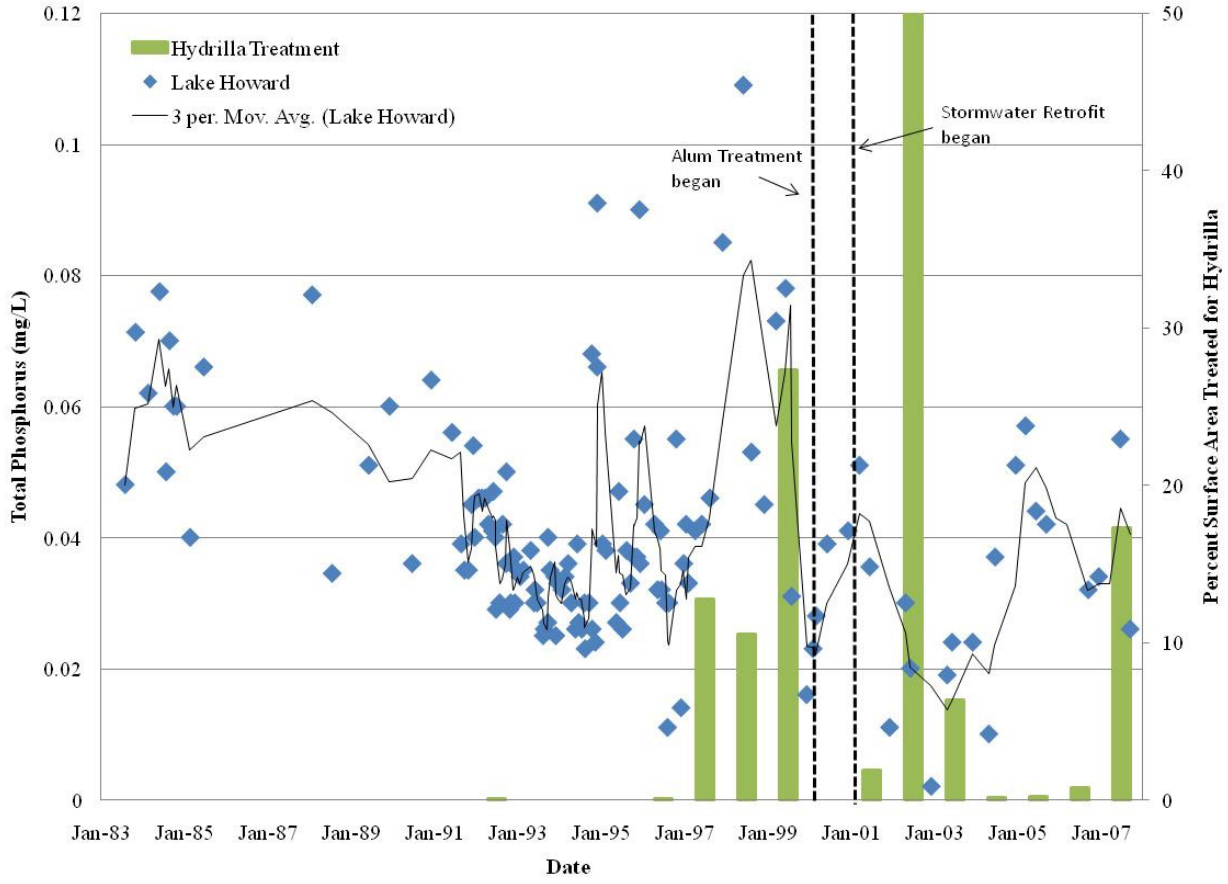
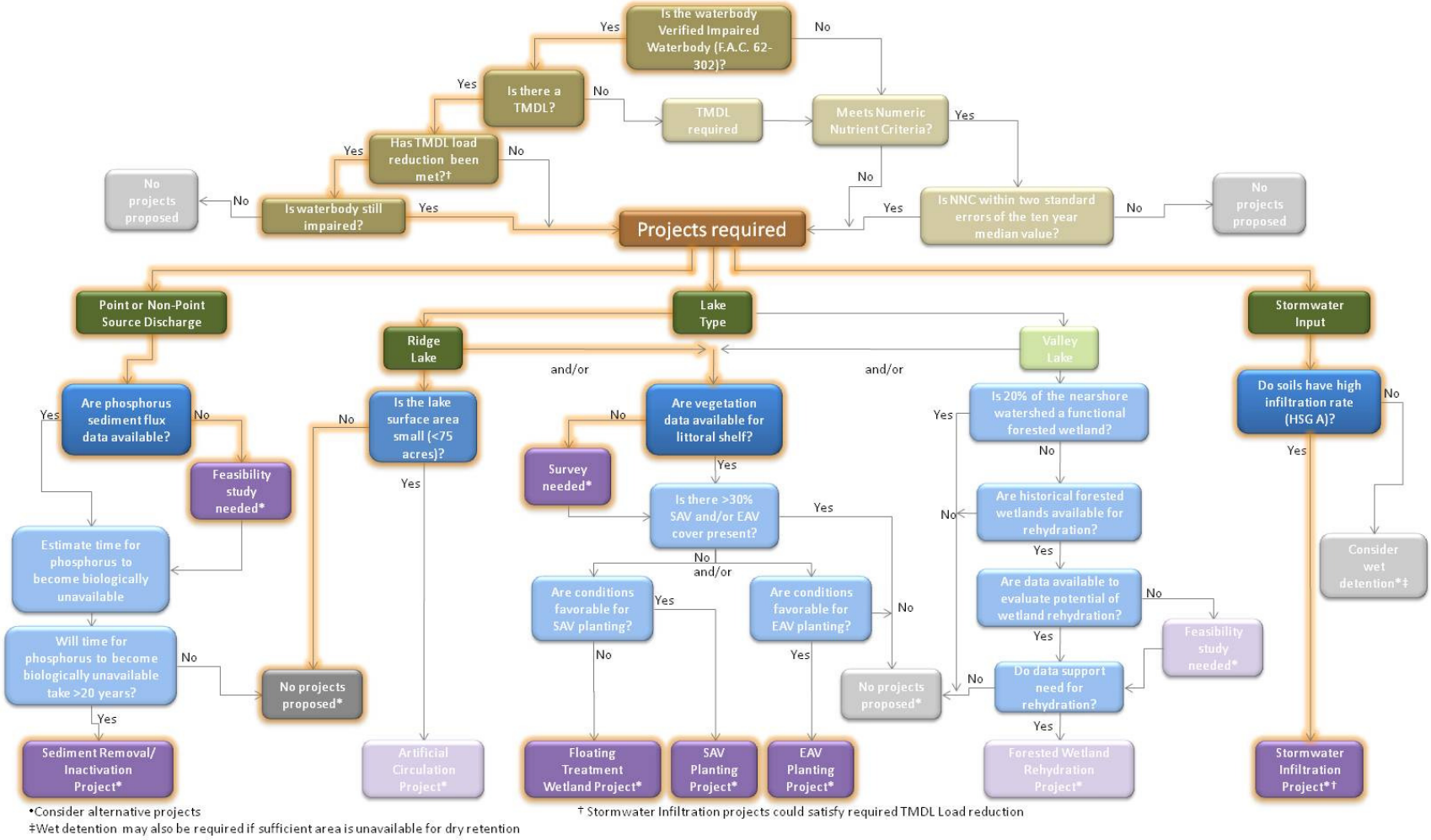


Figure 4-42. Lake Howard decision key: highlighted path shows decision process.



Project 1: Sediment Removal/inactivation

Historical point source discharges to Lake Howard from the Jan Phyl Village WWTF will require further evaluation of the potential internal phosphorus load from the lake bottom sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 2: Stormwater Infiltration Areas (SIAs)

The Lake Howard watershed has approximately 655 acres (57 percent of the watershed) classified as high infiltration soils. A TMDL has been established for Lake Howard, and as such, the SIA design should be focused on satisfying the TMDL requirements. SIA projects would need to encompass approximately 8 percent (87 acres) of the watershed in order to accomplish an annual 193 kg reduction in TP loads to Lake Howard. Acres of SIA estimated to meet the TP NNC was 38 (3 percent of the watershed) for a 23 percent phosphorus reduction in Lake Howard to meet its NNC. Fifty-seven percent of the watershed is characterized by high infiltration soils; therefore, it may be feasible to satisfy the TMDL load reductions through SIA implementation.

Presently, the City of Winter Haven has preliminarily identified six rain garden projects within the contributing drainage basin for Lake Howard as part of SWFWMD funded agreement. The rain gardens' sizes range from 200 to 2,500 feet^2 providing treatment to 5,200 to 15,000 feet^2. A brief description of each project is identified below as provided by the City of Winter Haven.

Site 1: Southeast corner of 3rd Street NW and Ave. C NW:

Type of Project:	Storm Inlet and perforated pipe (French Drain)
Objective:	To capture and percolate the runoff coming down the south side of Ave. C NW before crossing 3rd Street. This would help to reduce the ponding that occurs along Ave. C NW west of 3rd Street NW.
Drainage Area:	11,000 SF
Perforated Pipe:	55 L.F. of 18 inch pipe surrounded by 1 foot thick stone layer.
Treatment Volume:	530 CF (Provided)
Cost Estimate:	$ 7,600

Site 2: Southeast corner of 3rd Street NW and Ave. C NW:

Type of Project:	Storm Inlet and perforated pipe (French Drain)
Objective:	To capture and percolate the runoff coming down the south side of Ave. C NW before crossing 3rd Street. This will help to reduce the ponding that occurs along Ave. C NW west of 3rd Street NW.
Drainage Area:	11,000 SF
Perforated Pipe:	55 L.F. of 18 inch pipe surrounded by 1 foot thick stone layer.
Treatment Volume:	530 CF (Provided)
Cost Estimate:	$ 7,600

Site 3: West of 4th Street NW, southeast corner of Patterson Park:

Type of Project:	Rain Garden
Objective:	To capture and percolate the runoff coming down the west side of 4th Street NW. The runoff from the road can be easily diverted into the depressional area/rain garden at this location as the general area is lower than the edge of pavement elevation.
Drainage Area:	5200 SF
Rain Garden:	750 SF
Treatment Volume:	540 CF (Provided)
Cost Estimate:	$ 4,175

Site 4: West of 4th Street NW and Ave. C NW at Joyce Davis Park:

Type of Project:	Rain Garden
Objective:	To capture and percolate the runoff coming down Ave. C NW and the west side of 4th Street NW. The runoff from the adjacent roads can be easily diverted into the depressional area/rain garden at this location as the general area is lower than the edge of pavement elevation.
Drainage Area:	9,600 SF
Rain Garden:	1,200 SF
Treatment Volume:	860 CF (Provided)
Cost Estimate:	$ 6,550

Site 5: Winter Haven Public Library parking lot along Ave. B NW:

Type of Project:	Rain Garden
Objective:	To capture and percolate the runoff coming down the roof of the building and the adjacent parking area. The runoff can be easily diverted into the depressional area/rain garden at this location by providing curb cuts and concrete flumes at several locations along the existing Type “D” curb.
Drainage Area:	15,000 SF

Rain Garden:	2,500 SF
Treatment Volume:	625 CF (Provided)
Cost Estimate:	$ 5,800

Site 17: Southeast corner of Lake Howard Dr. NW and Ave. B NW:

Type of Project:	Storm Inlet and perforated pipe (French Drain)
Objective:	To capture and percolate the runoff coming down the south side of Ave. B NW before flowing down the road to Lake Howard. In addition to increasing the percolation/infiltration into the ground, this would provide treatment of the runoff thus improving the water quality of the lake.
Drainage Area:	6,000 SF
Perforated Pipe:	100 L.F. of 18 inch pipe surrounded by 1 foot thick stone layer.
Treatment Volume:	950 CF (Provided)
Cost Estimate:	$ 7,450

Cost Estimate: The City of Winter Haven has preliminarily identified 45 locations throughout the City to implement rain garden or perforated pipe systems. The cost estimate for these projects ranged from $2,200 to $20,000. The treatment volume ranged from 150 to 3,200 feet^3.

Project 3: SAV Planting or FTWs

SAV Planting

In Lake Howard, *Hydrilla* eradication occurs frequently attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Howard is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

The 1997-2007 median secchi depth in Lake Howard (2.0 feet) indicated that SAV planting should not occur in water depths greater than 2 feet. The maximum planting effort could result in vegetation cover of approximately 3 percent of the lake bottom (20 acres).

The calculated area for planting is based upon current bathymetry data. Due to the extensive organic material located in Lake Howard, it is recommended that SAV planting be performed after sediment removal/inactivation, if completed. If sediment removal is completed, the planting area would need to be recalculated using updated bathymetry data.

Cost Estimate: $105,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance)

FTWs

If the feasibility study indicates that more than 30 percent of Lake Howard has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Howard is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.11. Lake Idylwild

Background

Physical and chemical characteristics specific to Lake Idylwild are presented here in the context of relevant regulatory criteria and requirements (Table 4-22). Lake Idylwild (WBID 1521J) is located in the Southern Chain of the WHCL and is hydrologically connected to lakes Hartridge, Cannon, and Jessie via constructed navigable canals (Photo 4-13, Figure 4-43). In 2005, Lake Idylwild was declared verified impaired based on elevated TSI values (>60). A TMDL was adopted for the Southern Chain of the WHCL, including Lake Idylwild (FDEP 2007), and Lake Idylwild was subsequently delisted from impairment by FDEP in 2010. Based on the modeled external TP load to Lake Idylwild, a 43 percent reduction in TP load (39.5kg TP/year) is required to comply with the TSI criteria of 60 (FDEP 2007). The TP, TN, and chlorophyll *a* geometric mean for Lake Idylwild for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-22. To comply with the NNC, concentration reductions of 33 percent for TP and 22 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Idylwild is presented in Table 4-23. The chlorophyll *a* and TP concentrations exceed the NNC targets provided by EPA for Lake Idylwild. Chlorophyll *a* concentrations in Lake Idylwild fluctuate with values regularly elevated above 20 µg/L (Figure 4-44). A statistically significant trend in chlorophyll *a* concentrations from 1983 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). *Hydrilla* eradication projects have been implemented in Lake Idylwild consistently over the last 20 years with treatment over 40 percent of the lake surface areas on several occasions. No water quality improvement projects have been implemented in Lake Idylwild to restore water quality. Lake Idylwild is an intermediate lake; therefore, improvements in water quality of the lake could result in some benefit farther downstream.

The Lake Idylwild watershed is 267 acres in size and includes 227 acres (85 percent) of developed lands compared to 40 acres (15 percent) of undeveloped lands. The 2000-2007 median color value (20 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 130 feet in October 2006. Bathymetry data are available for Lake Idylwild for the October 2006 water level elevation (Figure 4-45). A water level of 130 feet was reported in August 2010, indicating similar water elevations compared to 2009. Changes in overall surface area, water depth, and volume of the lake due to water elevation fluctuations should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Idylwild water quality and the surrounding watershed characteristics, four potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-46). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in

order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management

Table 4-22. Physical, chemical, and regulatory characteristics of Lake Idylwild.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	106 (40 percent)
Relation to other lakes	Intermediate	**Developed land (acres)**	227 (85 percent)
Watershed area (acres)	267	**Undeveloped land (acres)**	40 (15 percent)
Lake area (acres)*	102	**Median water depth (feet)***	3.1
Perimeter (feet)*	8,807	**Maximum water depth (feet)***	17.7
Surface area: lake volume ratio*	0.14	**Volume (acre-feet)***	747
Watershed to surface area ratio*	2.62		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	26	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	0.90	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.045	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required†
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	33 percent

*at a water level elevation of 130 feet
**presented in section 5.0
†TMDL adopted

Photo 4-13. Lake Idylwild.

Table 4-23. Lake Idylwild water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	90	11	28	76
Color (PCU)	27	5	20	30
Conductivity (µmhos/cm)	35	179	205	256
Dissolved oxygen (mg/L)	35	5.06	8.47	11.35
pH	35	7.05	7.94	9.3
Secchi depth (feet)	115	1.5	2.3	3.9
Total nitrogen (mg/L)	91	0.48	0.93	1.57
Total phosphorus (mg/L)	87	0.01	0.041	0.09

Figure 4-43. Lake Idylwild and associated watershed.

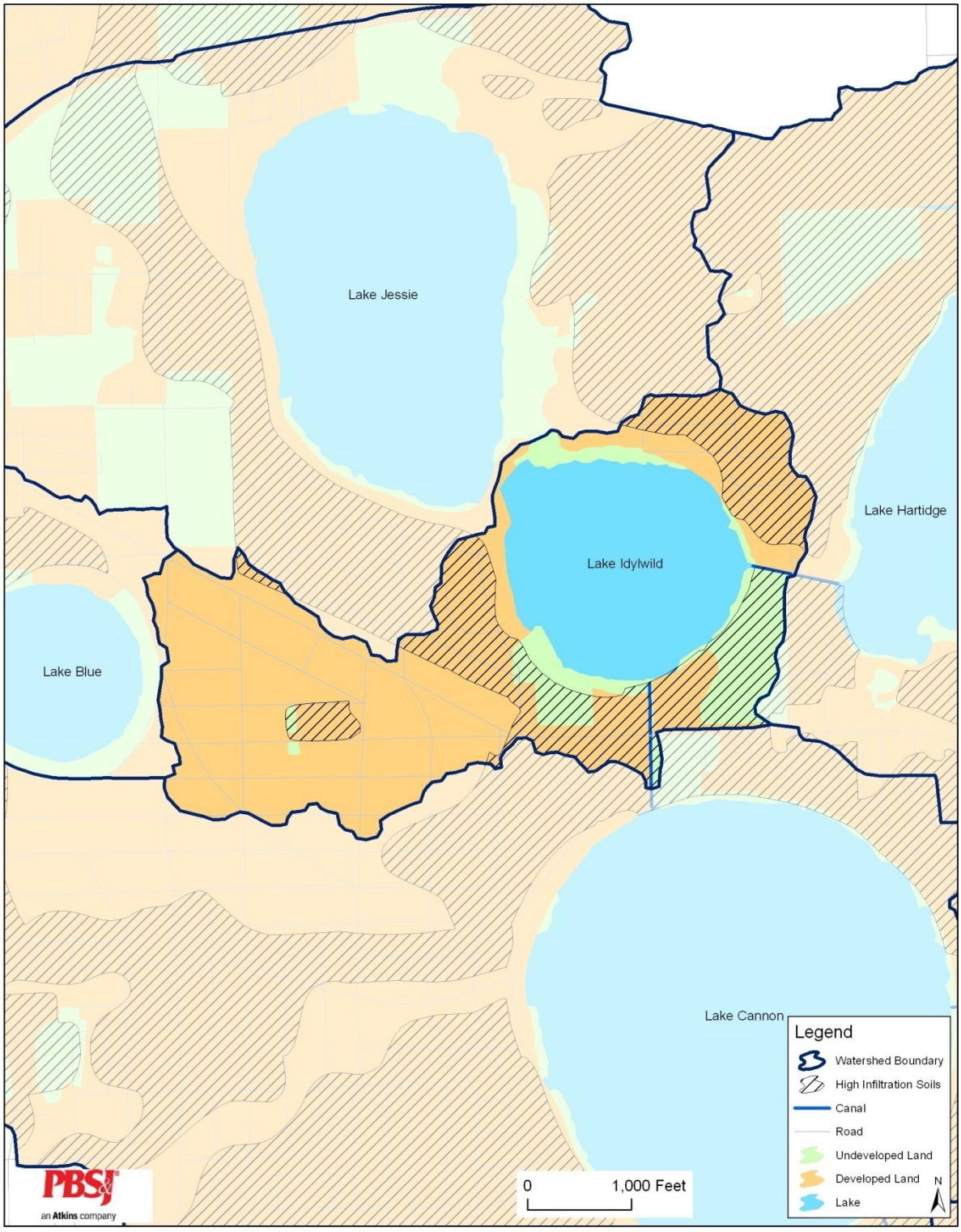


Figure 4-44. Lake Idylwild chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

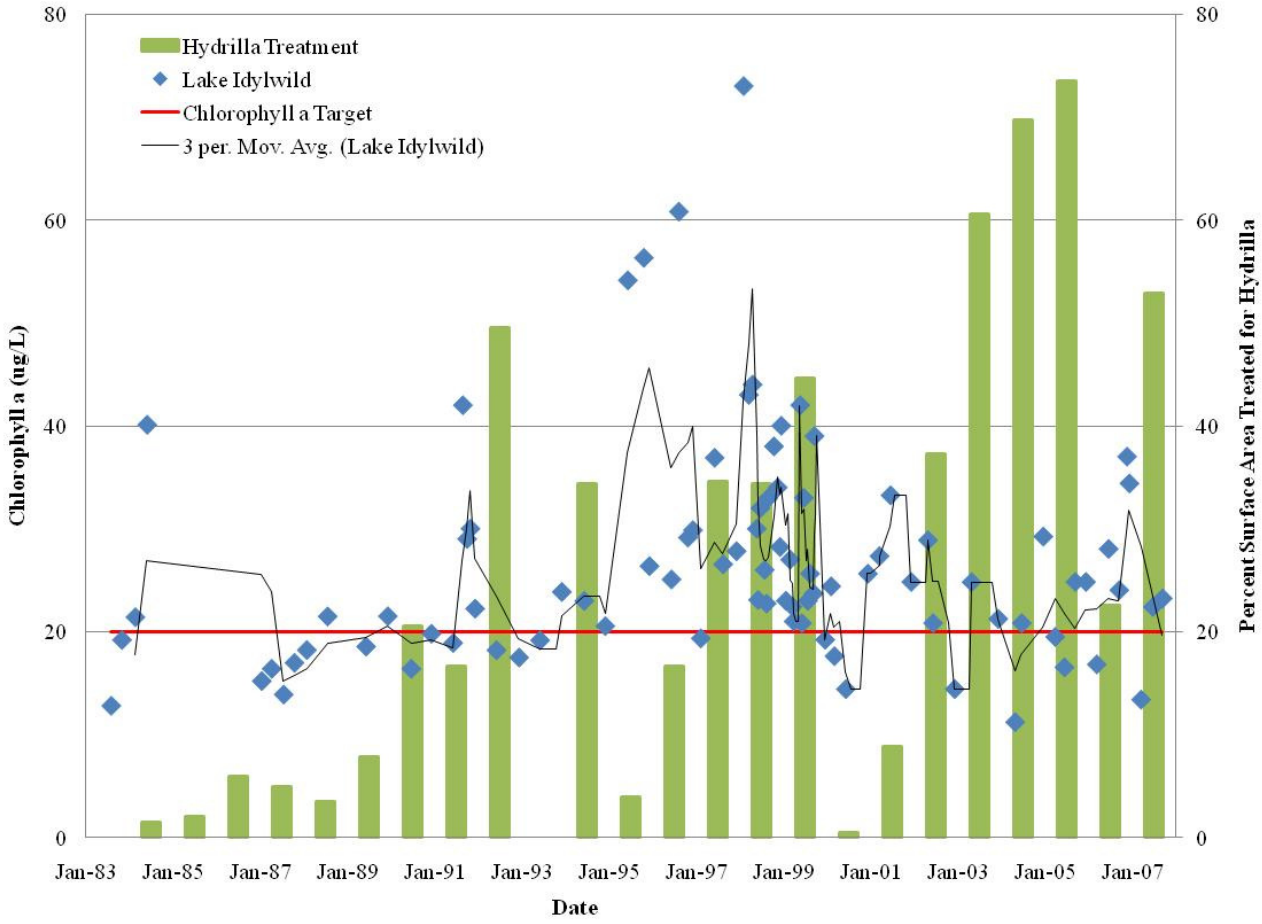
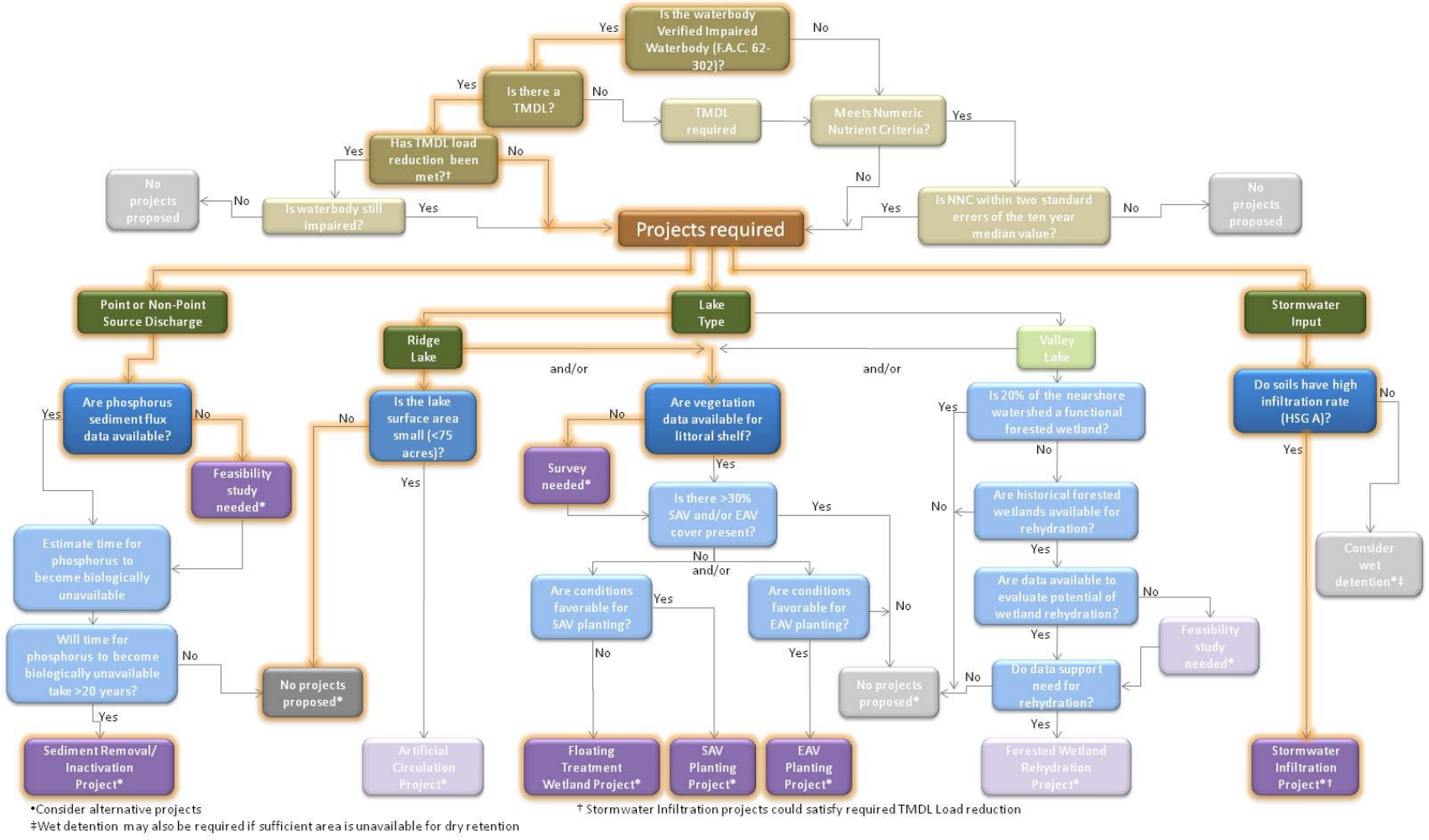


Figure 4-45. Lake Idylwild bathymetry (October 2006) at water level elevation = 130 feet (Polk County Water Atlas).

Figure 4-46. Lake Idylwild decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Idylwild watershed has approximately 106 acres (40 percent of the watershed) classified as high infiltration soils. A TMDL has been established for Lake Idylwild, and as such, the SIA design should be focused on satisfying the TMDL requirements. SIA projects would need to encompass approximately 9 percent (24 acres) of the watershed in order to accomplish an annual 39.5 kg in TP loads to Lake Idylwild. Acres of SIA estimated to meet the TP NNC was 21 (8 percent of the watershed) for a 33 percent phosphorus reduction in Lake Idylwild to meet its NNC. Forty percent of the watershed is characterized by high infiltration soils; therefore, it may be feasible to satisfy the TMDL load reductions through SIA implementation.

Project 3: Sediment Removal/Inactivation

Non-point source discharges to Lake Idylwild may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 2: SAV Planting or FTWs

SAV Planting

In Lake Idylwild, *Hydrilla* eradication occurs frequently attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Idylwild is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

The 1997-2007 median secchi depth in Lake Idylwild (2.3 feet) indicated that SAV planting should not occur in water depths greater than 2 feet. The maximum planting effort could result in vegetation cover of approximately 13 percent of the lake bottom (13 acres).

Cost Estimate: $85,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance)

FTWs

If the feasibility study indicates that more than 30 percent of Lake Idylwild has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 3: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Idylwild is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.12. Lake Jessie

Background

Physical and chemical characteristics specific to Lake Jessie are presented here in the context of relevant regulatory criteria and requirements (Table 4-24). Lake Jessie (WBID 1521K), a lake in the WHCL Southern Chain, is hydrologically connected to lakes Mariana and Idylwild via constructed canals (Photo 4-14, Figure 4-47). In 2005, Lake Jessie was declared verified impaired based on elevated TSI values (>60). A TMDL was adopted for the Southern Chain of the WHCL, including Lake Jessie (FDEP 2007), and Lake Jessie was subsequently delisted from impairment by FDEP in 2010. Based on the modeled external TP load to Lake Jessie, a 50 percent reduction in TP load (114 kg TP/year) is required to comply with the TSI criteria of 60 (FDEP 2007). The TP, TN, and chlorophyll *a* geometric mean for Lake Cannon for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-24. To comply with the NNC, concentration reductions of 44 percent for TP and 29 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Jessie is presented in Table 4-25. Lake Jessie historically received point source discharges from a WWTF. While the effluent discharges have been eliminated, the discharges resulted in nutrient and sediment accumulation in the lake bottom. In response to the TMDL, Polk County District implemented a stormwater treatment area at Derby Avenue (Photo 4-14). The median chlorophyll *a*, TN and TP concentrations continue to exceed the NNC targets provided by EPA for Lake Jessie. Chlorophyll *a* concentrations in Lake Jessie fluctuate but are elevated above 20 µg/L the majority of the time (Figure 4-48). However, a statistically significant decline in chlorophyll *a* concentrations from 1983 to 2007 was observed (seasonal Kendall-Tau, $p<0.001$). Since 1983, *Hydrilla* eradication projects have been completed treating over 40 percent of the lake surface area in some years. Improvements in water quality of the lake Jessie, which is located adjacent to a headwater lake, could result in benefit farther downstream.

The Lake Jessie watershed is 783 acres in size and includes 617 acres (79 percent) of developed lands compared to 166 acres (21 percent) of undeveloped lands. The 2000-2007 median color value (20 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 130 feet in October 2006. Bathymetry data are available for Lake Jessie for the October 2006 water level elevation (Figure 4-49). A water level of 130 feet was reported in August 2010, indicating similar water level conditions when compared to 2006. Changes in overall surface area, water depth, and volume of the lake due to water elevation fluctuations should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Jessie water quality and the surrounding watershed characteristics, four potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-50). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient

and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management

Table 4-24. Physical, chemical, and regulatory characteristics of Lake Jessie.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	408 (52 percent)
Relation to other lakes	Adjacent to Headwater	**Developed land (acres)**	617 (79 percent)
Watershed area (acres)	783	**Undeveloped land (acres)**	166 (21 percent)
Lake area (acres)*	194	**Median water depth (feet)***	3.1
Perimeter (feet)*	11,621	**Maximum water depth (feet)***	12.2
Surface area: lake volume ratio*	0.12	**Volume (acre-feet)***	1,546
Watershed to surface area ratio*	4.04		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	28	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	0.94	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.54	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required†
Chlorophyll *a* trend	Decreasing**	**TP concentration reduction required**	44 percent

*at a water level elevation of 130 feet
**presented in section 5.0
†TMDL adopted

Photo 4-14. Lake Jessie.

Table 4-25. Lake Jessie water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	103	11	27	61
Color (PCU)	27	10	20	64
Conductivity (µmhos/cm)	25	187	207	238
Dissolved oxygen (mg/L)	25	6.9	8.67	11.83
pH	25	6.84	7.76	8.75
Secchi depth (feet)	104	1.7	2.3	4.2
Total nitrogen (mg/L)	105	0.53	1.02	1.88
Total phosphorus (mg/L)	101	0.01	0.061	0.279

Figure 4-47. Lake Jessie and associated watershed.

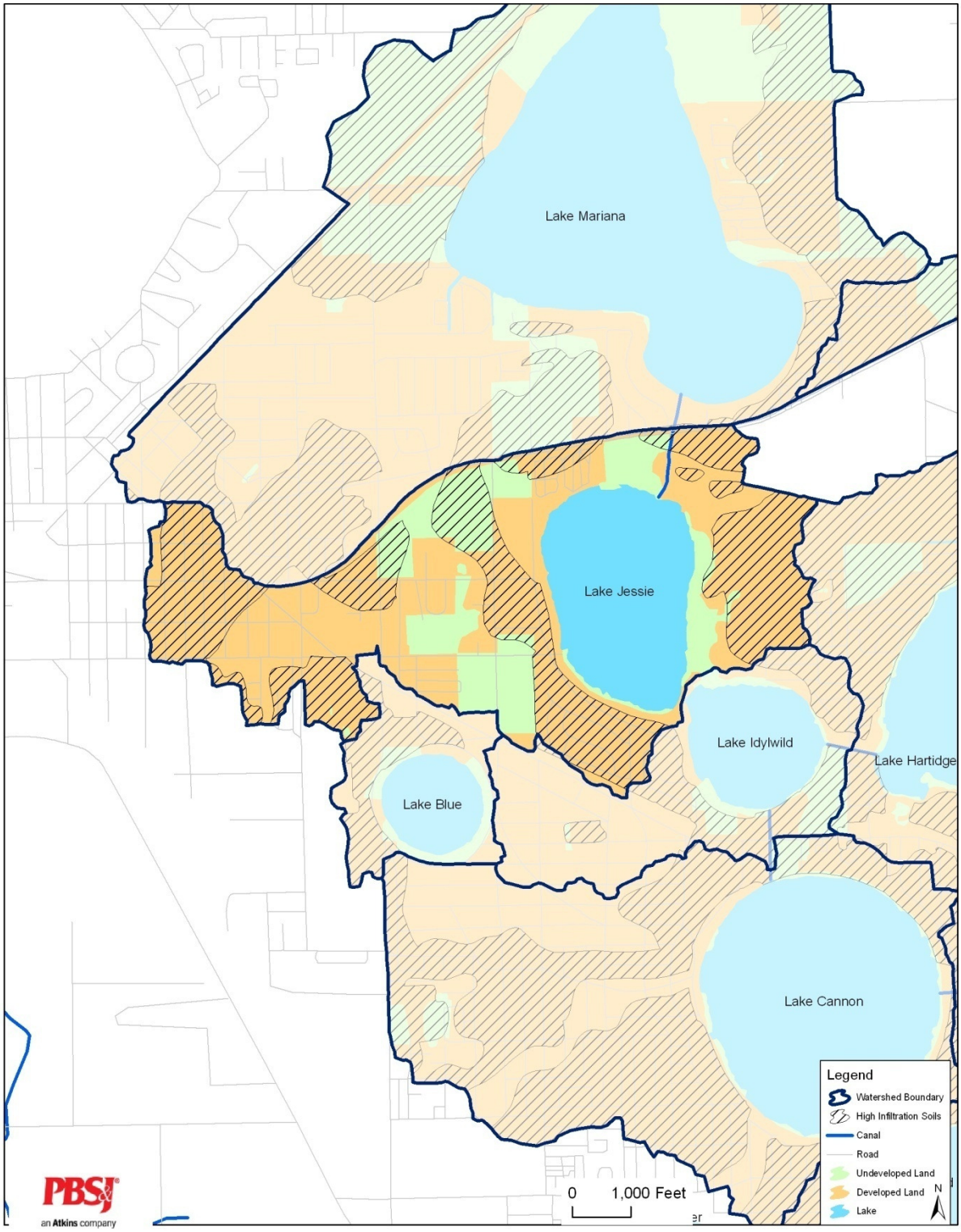


Figure 4-48. Lake Jessie chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

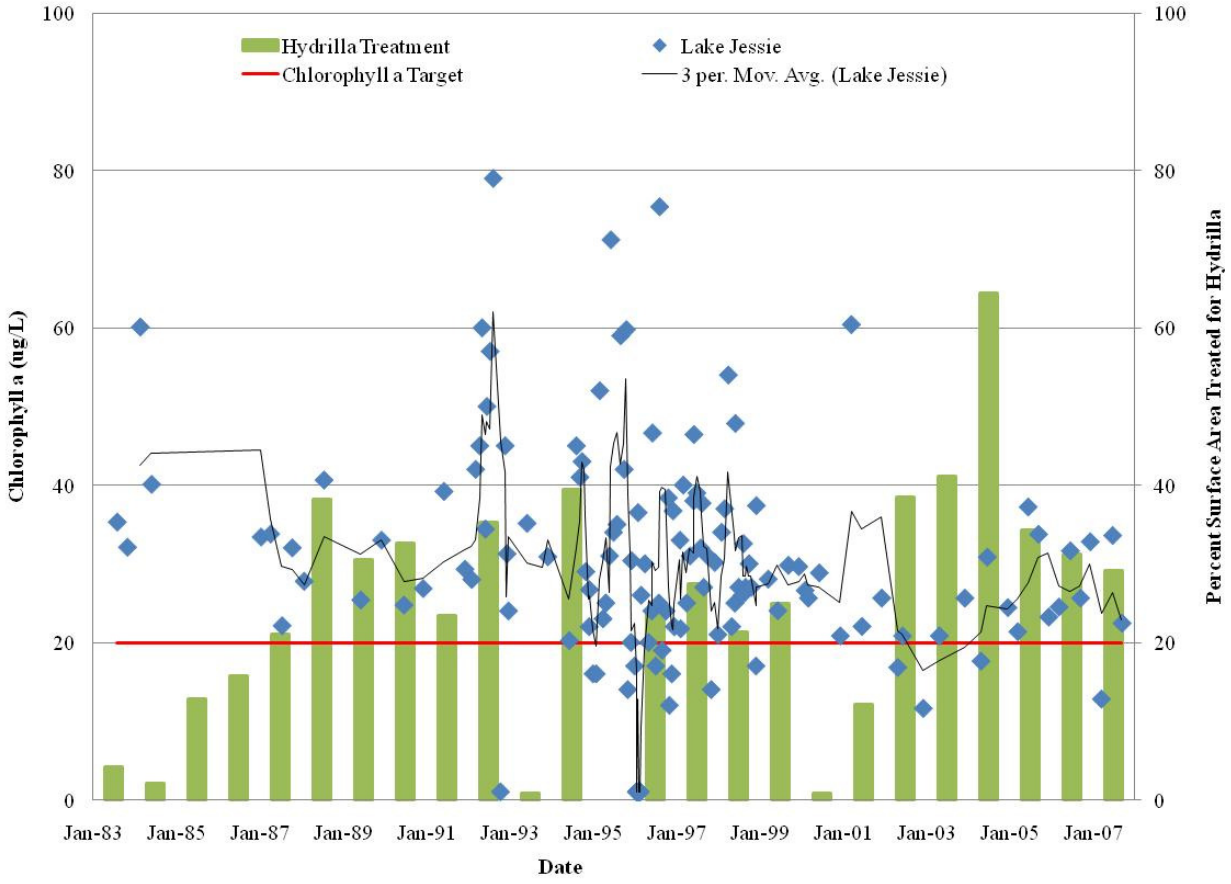


Figure 4-49. Lake Jessie bathymetry (October 2006) at water level elevation = 130 feet (Polk County Water Atlas).

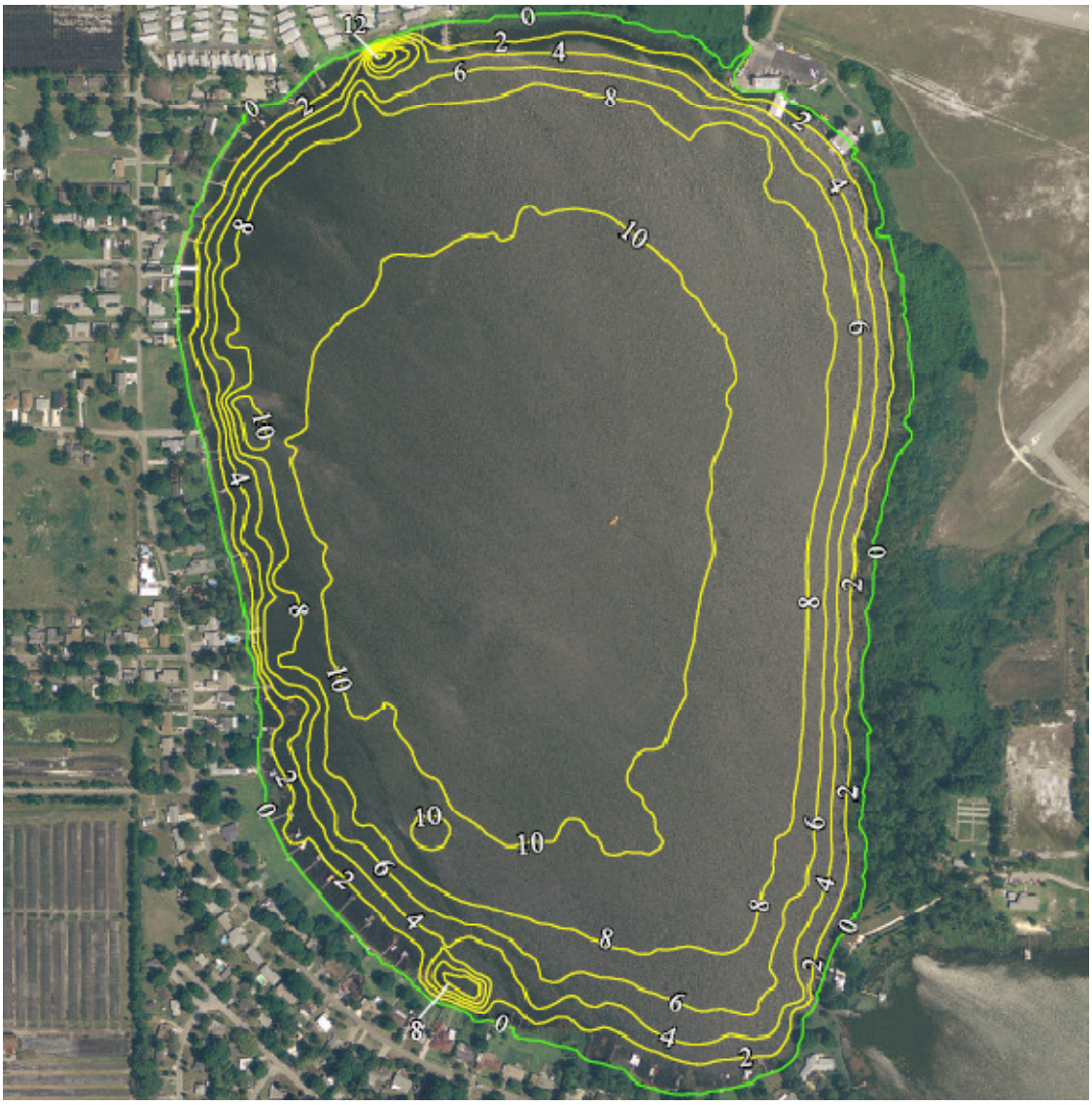
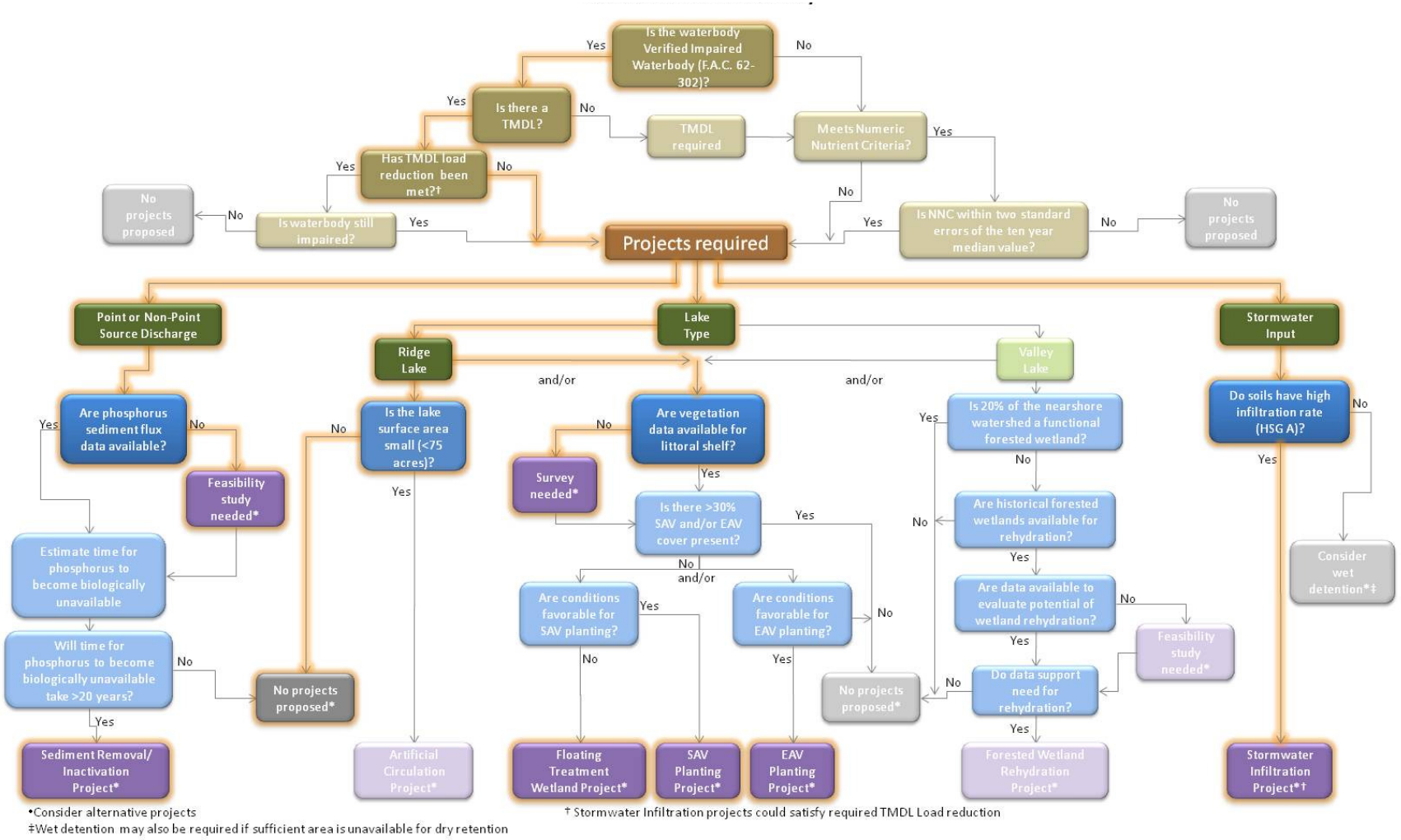


Photo 4-15. Lake Jessie stormwater treatment project at Derby Avenue.

Figure 4-50. Lake Jessie decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Jessie watershed has approximately 408 acres (52 percent of the watershed) classified as high infiltration soils. A TMDL has been established for Lake Jessie, and as such, the SIA design should be focused on satisfying the TMDL requirements. SIA projects would need to encompass approximately 12 percent (133 acres) of the watershed in order to accomplish an annual 114 kg reduction in TP loads to Lake Jessie. Acres of SIA estimated to meet the TP NNC was 139 (12 percent of the watershed) for a 44 percent phosphorus reduction in Lake Jessie to meet its NNC. Fifty-two percent of the watershed is characterized by high infiltration soils, therefore, it may be feasible to satisfy the load reductions through SIA implementation.

Project 2: Sediment Removal/Inactivation

Historical point source discharges to Lake Jessie from the WWTF will require further evaluation of the potential internal phosphorus load from the lake bottom sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

In Lake Jessie, *Hydrilla* eradication occurs frequently attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Jessie is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

The 1997-2007 median secchi depth in Lake Jessie (2.3 feet) indicated that SAV planting should not occur in water depths greater than 2 feet. The maximum planting effort could result in vegetation cover of approximately 9 percent of the lake bottom (17 acres). Due to the extensive organic material located in Lake Jessie, it is recommended that SAV planting be performed after sediment removal/inactivation, if completed. If sediment removal is completed, the planting area would need to be recalculated using updated bathymetry data.

Cost Estimate: $100,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance).

FTWs

If the feasibility study indicates that more than 30 percent of Lake Jessie has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Jessie is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.13. Little Lake Hamilton

Background

Physical and chemical characteristics specific to Little Lake Hamilton are presented here in the context of relevant regulatory criteria and requirements (Table 4-26). Little Lake Hamilton (WBID 15001) is located in the Northern Chain of the WHCL and is hydrologically connected to Lake Hamilton via a constructed navigable canal (Photo 4-16, Figure 4-51). In 2010, Little Lake Hamilton was declared verified impaired based on elevated TSI values (>40). A TMDL is required for Little Lake Hamilton to calculate load reductions necessary to satisfy the TSI criteria. The TP, TN, and chlorophyll *a* geometric mean for Little Lake Hamilton for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-26. To comply with the NNC, concentration reductions a 15 percent for TP and 13 percent for TN are required.

A summary of water quality statistics for Little Lake Hamilton is presented in Table 4-27. The median TN and TP concentrations exceed the NNC targets provided by EPA but not chlorophyll *a*. Chlorophyll *a* concentrations in Little Lake Hamilton have fluctuated and values exceeded 20 µg/L intermittently (Figure 4-52). A statistically significant trend in chlorophyll *a* concentrations from 1991 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). No water quality improvement projects have been implemented in Little Lake Hamilton to restore water quality and *Hydrilla* infestations have not been problematic. Little Lake Hamilton is located adjacent to Lake Hamilton, which discharges water from the Northern Chain to the Peace Creek Drainage Canal and, as such, improvements in water quality of the lake would result in little benefit farther downstream.

The Little Lake Hamilton watershed is 1,148 acres in size and includes 199 acres (seven percent) of developed lands compared to 949 acres (83 percent) undeveloped lands (Table 4-26). The 2000-2007 median color value (38 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 118 feet in February 2010. Bathymetry data are available for Little Lake Hamilton for the February 2010 water level elevation (Figure 4-53). Changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Little Lake Hamilton water quality and the surrounding watershed characteristics, four potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-54). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management

Table 4-26. Physical, chemical, and regulatory characteristics of Little Lake Hamilton.

Physical			
Location in chain	Northern	**High infiltration soils (acres)**	938 (82 percent)
Relation to other lakes	Adjacent to Terminal	**Developed land (acres)**	199 (7 percent)
Watershed area (acres)	1,148	**Undeveloped land (acres)**	949 (83 percent)
Lake area (acres)*	351	**Median water depth (feet)***	7.0
Perimeter (feet)*	20,922	**Maximum water depth (feet)***	22.1
Surface area: lake volume ratio*	0.15	**Volume (acre-feet)***	2,336
Watershed to surface area ratio*	3.27		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	18	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.15	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.035	**NNC TP target (mg/L)**	0.03
Regulatory Data			
Impaired	Yes	**TMDL status**	Required
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	15 percent

*at a water level elevation of 118 feet
**presented in section 5.0

Photo 4-16. View of Little Lake Hamilton.

Table 4-27. Little Lake Hamilton water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	27	8	15	32
Color (PCU)	19	15	38	80
Conductivity (µmhos/cm)	20	222	241	280
Dissolved oxygen (mg/L)	20	5.75	8.31	10.21
pH	20	6.49	7.84	8.93
Secchi depth (feet)	27	1.8	3.2	5.8
Total nitrogen (mg/L)	27	0.86	1.11	1.74
Total phosphorus (mg/L)	24	0.011	0.035	0.070

Figure 4-51. Little Lake Hamilton and associated watershed.

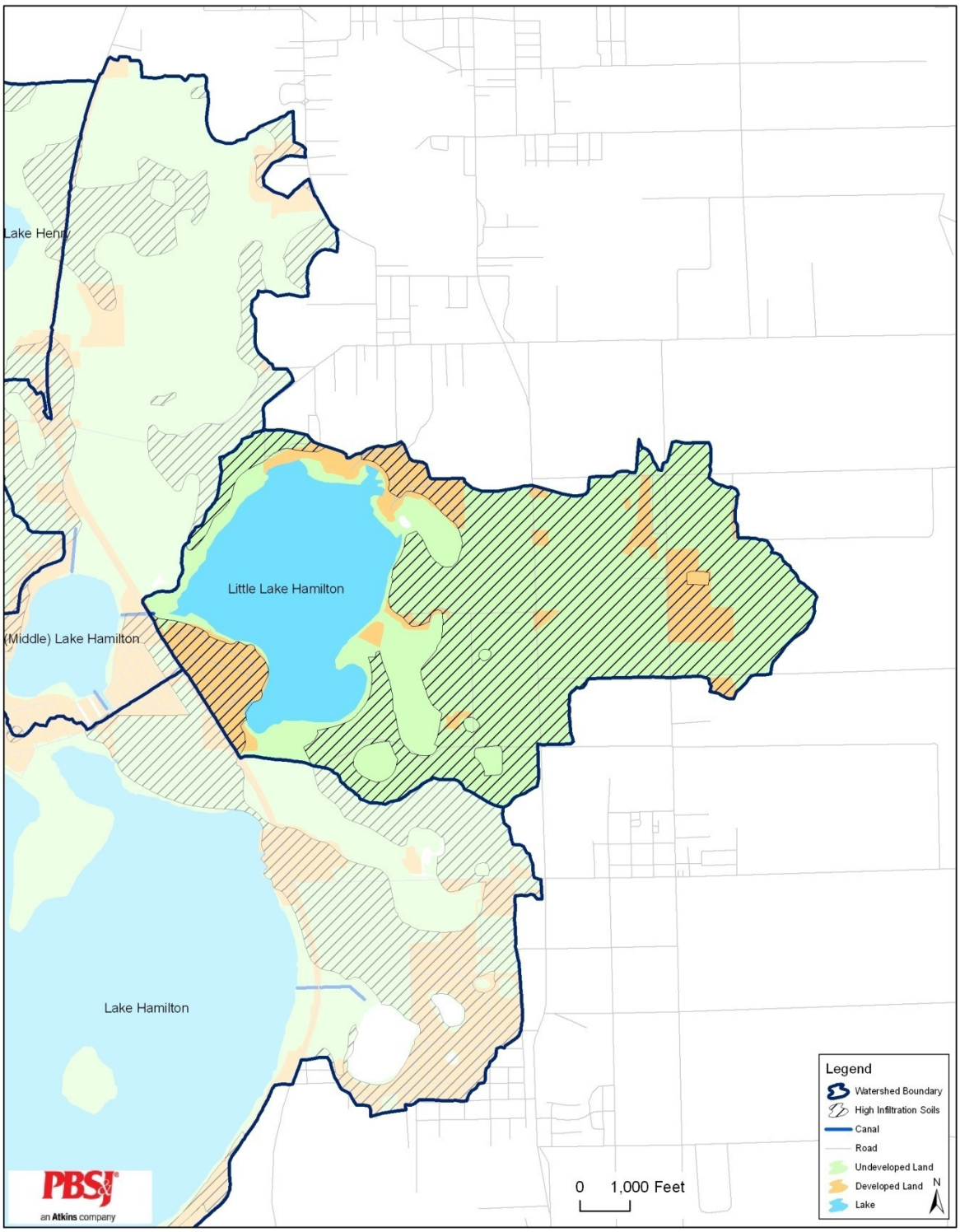


Figure 4-52. Little Lake Hamilton chlorophyll *a* concentrations using available data from 1990 to 2007.

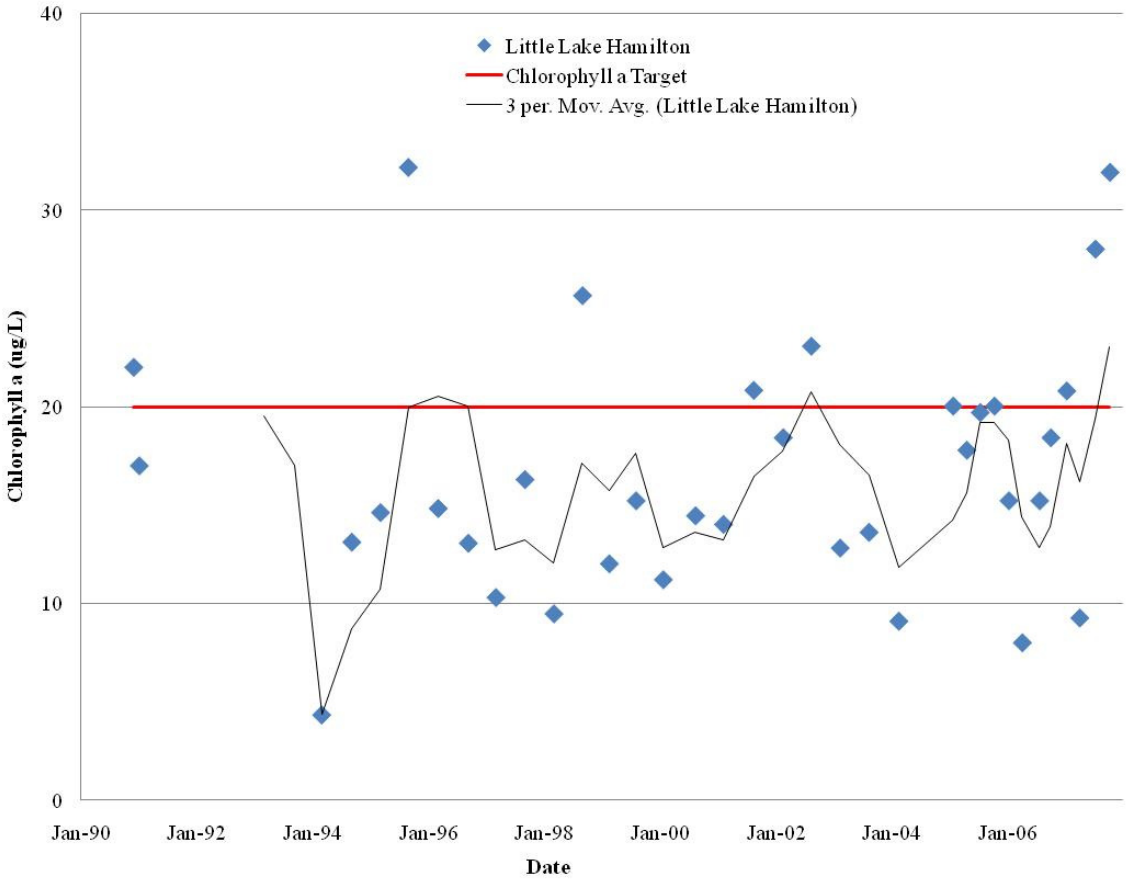


Figure 4-53. Little Lake Hamilton bathymetry (February 2010) at water level elevation = 118 feet (Polk County Water Atlas).

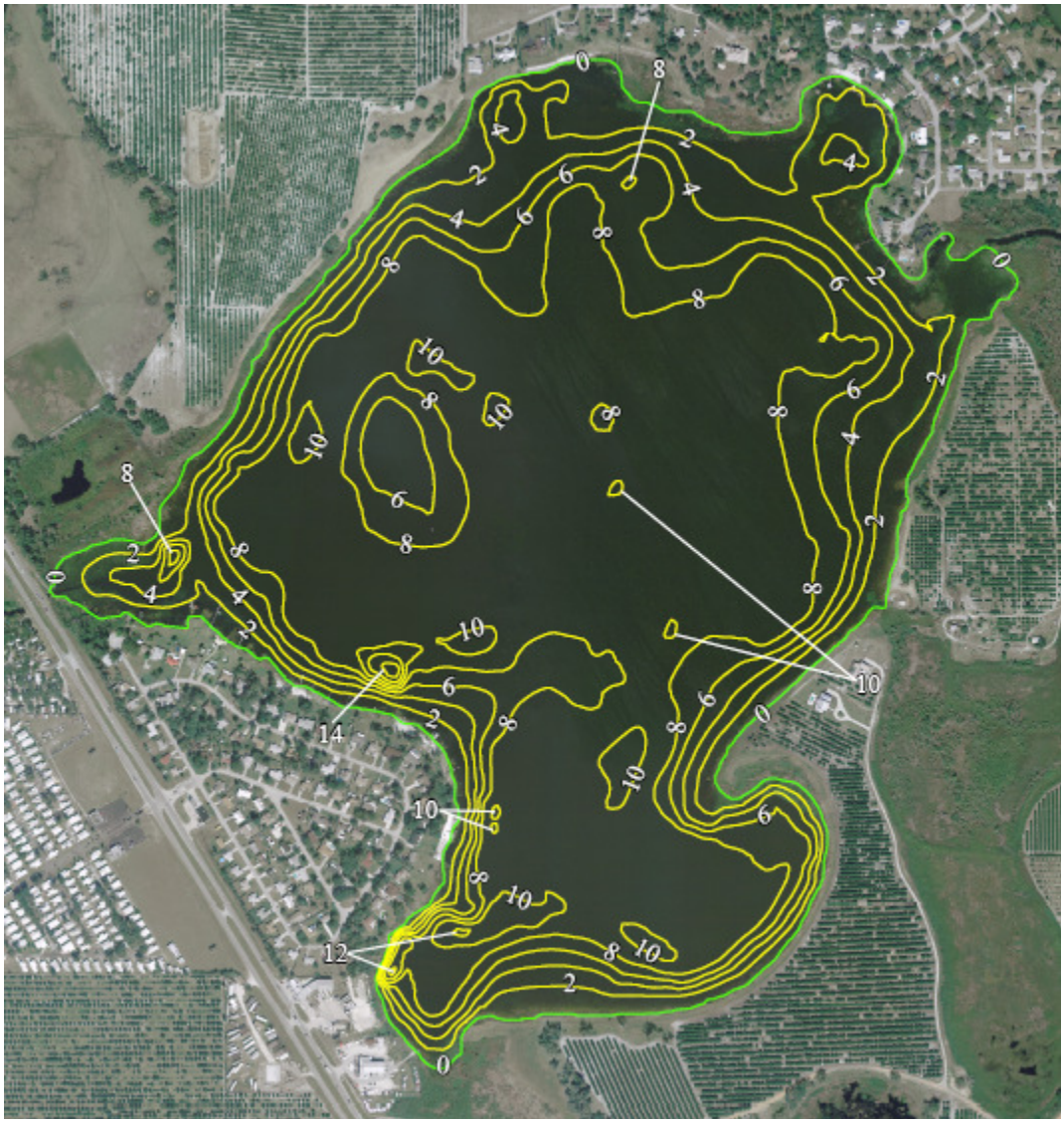
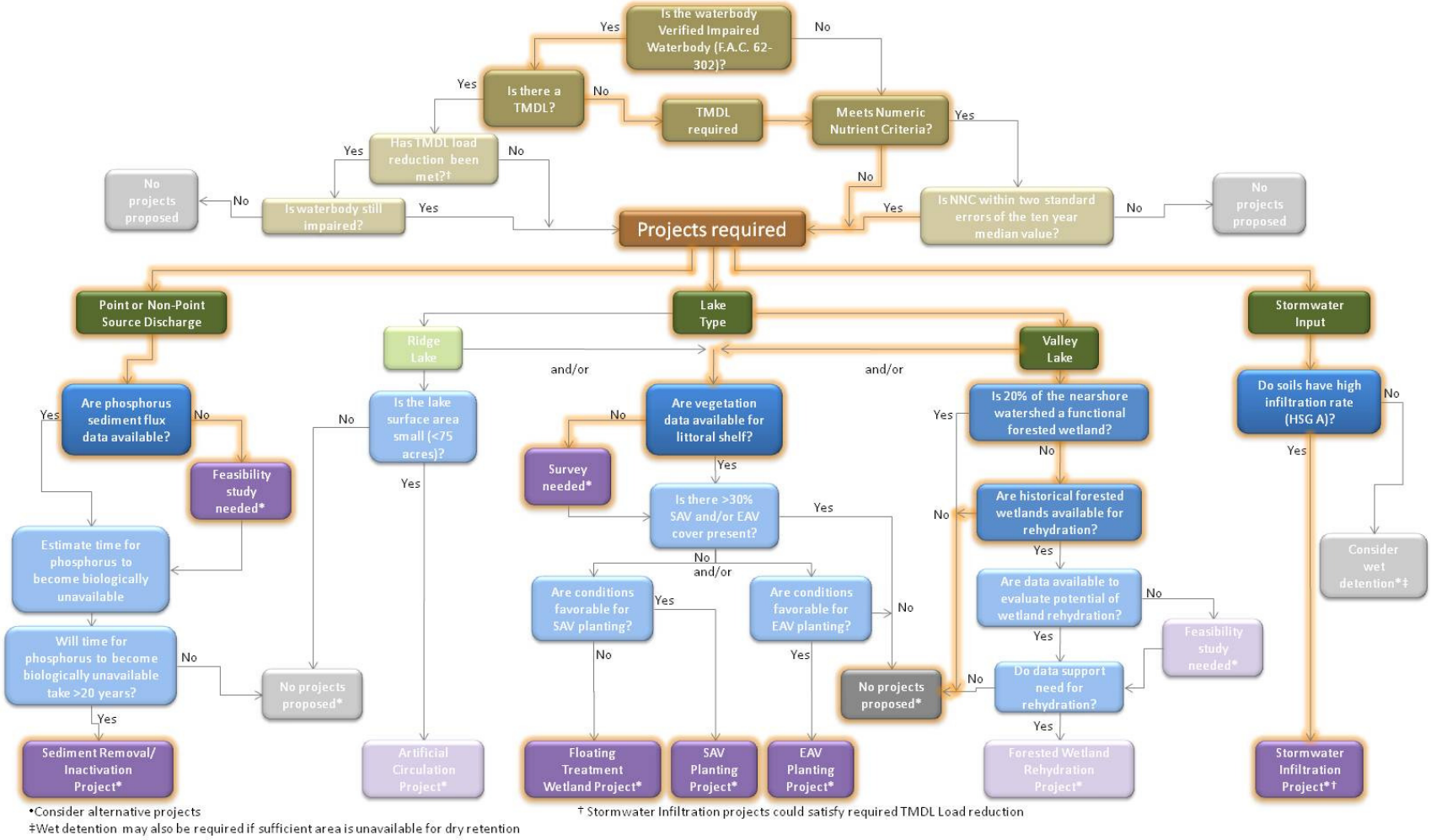


Figure 4-54. Little Lake Hamilton decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Little Lake Hamilton watershed has approximately 938 acres (82 percent of the watershed) classified as high infiltration soils. The Northern Chain was not included in the PLRG study (USF 2005), therefore a TMDL has not been completed for Little Lake Hamilton and data to estimate SIA acres for TP load reduction are not available at this time. SIA implementation could have the additional benefit of increasing storage to supplement dry season lake levels and a reduction in stormwater loads that can be later applied to the required TMDL TP load reduction. As such, SIA design should be focused on recharging the surficial aquifer.

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Little Lake Hamilton may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

Hydrilla infestations have not been a chronic problem in Little Lake Hamilton. A survey of existing SAV cover in Little Lake Hamilton is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth.

Based on the median secchi depth (3.2 feet) from 1997-2007, plants would not be planted in water depths greater than 4 feet. The maximum planting effort for Little Lake Hamilton cannot be calculated until the electronic bathymetry data are acquired.

Cost Estimate: A cost estimate will be generated upon receipt of the bathymetry data.

FTWs

If the feasibility study indicates that more than 30 percent of Little Lake Hamilton has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing shoreline vegetation surrounding Little Lake Hamilton is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.14. Lake Lulu

Background

Physical and chemical characteristics specific to Lake Lulu are presented here in the context of relevant regulatory criteria and requirements (Table 4-28). Lake Lulu (WBID 1521), the terminal lake in the WHCL Southern Chain, is hydrologically connected to lakes Shipp, Roy and Eloise via constructed navigable canals (Photo 4-17, Figure 4-55). In 2005, Lake Lulu was declared verified impaired based on elevated TSI values (>60). A TMDL was adopted for the Southern Chain of the WHCL, including Lake Lulu (FDEP 2007), and Lake Lulu was subsequently delisted from impairment by FDEP in 2010. Based on the modeled external TP load to Lake Lulu, a 55 percent reduction in TP load (84 kg TP/year) is required to comply with the TSI criteria of 60 (FDEP 2007). The TP, TN, and chlorophyll *a* geometric mean for Lake Lulu for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-28. To comply with the NNC, concentration reductions of 39 percent for TP, 19 percent for TN, and 48 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Lulu is presented in Table 4-29. Lake Lulu historically received point source discharges from four WWTF (City of Winter Haven, Bordo's citrus processing plant, Snively, and Swift Fertilizer). While the effluent discharges have been eliminated, the discharges resulted in nutrient and sediment accumulation in the lake bottom. An inverse relationship between lake levels and TP concentrations may suggest sediment resuspension resulting in a decline in water quality. In response to the TMDL, the City of Winter Haven and SWFWMD implemented a stormwater alum injection project (Figure 4-56). Based on TP load reduction estimates for projects constructed on Lake Lulu (193 kg/year), the TMDL required TP load reductions (84 kg/year) have been accomplished. After the implementation of the stormwater retrofit project in 2005, the chlorophyll *a* values continue to exceed 20 µg/liter, indicating that TSI_{CHLA} values less than or equal to 60 (which would require chlorophyll *a* levels to be below 20 µg/L) were not reached. Since 1996, *Hydrilla* eradication projects have been completed annually, treating over 40 percent of the lake surface area in some years. The median chlorophyll *a*, TN and TP concentrations continue to exceed the NNC targets provided by EPA for Lake Lulu. A statistically significant trend in chlorophyll *a* concentrations from 1983 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). Lake Lulu is a terminal lake, therefore, improvements in water quality of the lake would result in no benefit farther downstream.

The Lake Lulu watershed is 547 acres in size and includes 303 acres (55 percent) of developed lands compared to 244 acres (45 percent) of undeveloped lands (Table 4-28). The 2000-2007 median color value (20 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 129 feet in June 2007 (Table 4-28). Bathymetry data are available for Lake Lulu for the June 2007 water level elevation (Figure 4-57). A water level of 130 feet was reported in August 2010, reflecting a 1.0 foot increase in water elevation when compared to 2007. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Lulu water quality and the surrounding watershed characteristics, five potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-58). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Sediment Removal/Inactivation
- Project 2: Stormwater Infiltration Areas (SIAs)
- Project 3: Forested Wetland Rehydration
- Project 4: SAV Planting/Management or FTWs
- Project 5: EAV Planting/Management

Table 4-28. Physical, chemical, and regulatory characteristics of Lake Lulu.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	292 (53 percent)
Relation to other lakes	Terminal	**Developed land (acres)**	303 (55 percent)
Watershed area (acres)	547	**Undeveloped land (acres)**	244 (45 percent)
Lake area (acres)*	318	**Median water depth (feet)***	5.0
Perimeter (feet)*	24,471	**Maximum water depth (feet)***	13.7
Surface area: lake volume ratio*	0.21	**Volume (acre-feet)***	1,514
Watershed to surface area ratio*	1.72		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	39	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.24	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.049	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required†
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	39 percent

*at a water level elevation of 129 feet †TMDL adopted
**presented in section 5.0

Photo 4-17. Southern view of Lake Lulu.

Table 4-29. Lake Lulu water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	223	1	42	66
Color (PCU)	27	5	20	25
Conductivity (µmhos/cm)	28	185	247	326
Dissolved oxygen (mg/L)	28	7	8.72	10.26
pH	28	6.83	8.04	9.07
Secchi depth (feet)	226	1.2	1.8	3.7
Total nitrogen (mg/L)	225	0.0	1.22	1.89
Total phosphorus (mg/L)	218	0.00	0.050	0.080

Figure 4-55. Lake Lulu and associated watershed.

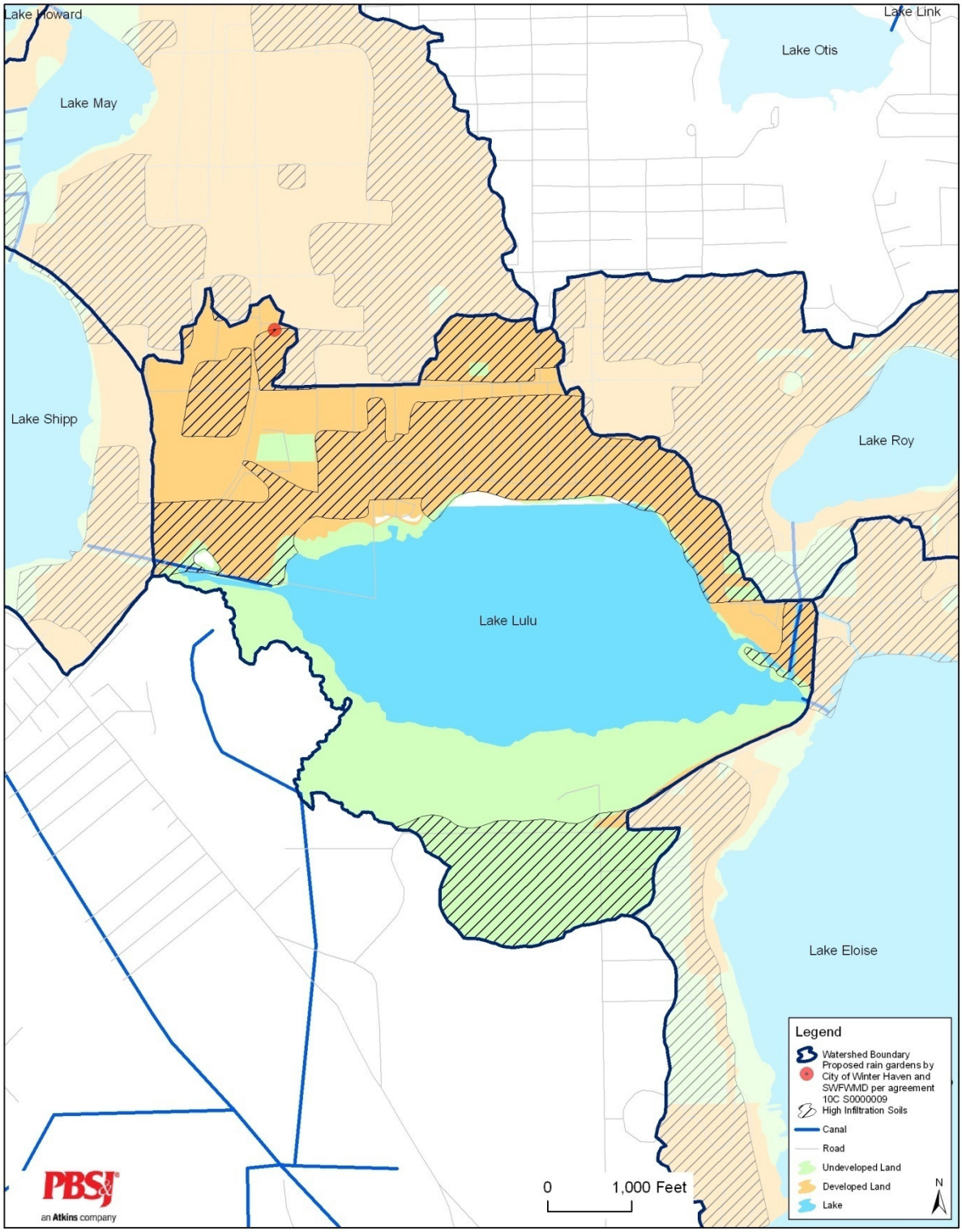


Figure 4-56. Lake Lulu chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

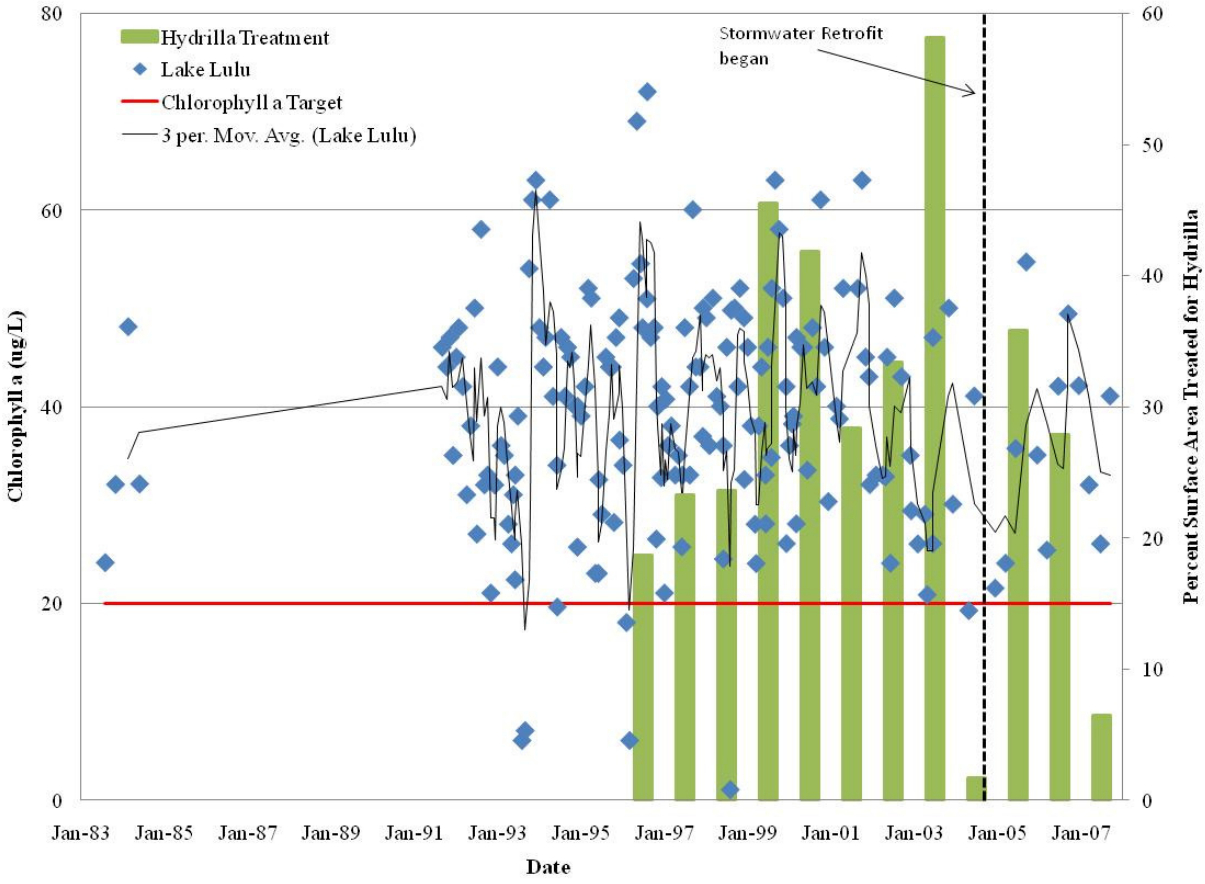
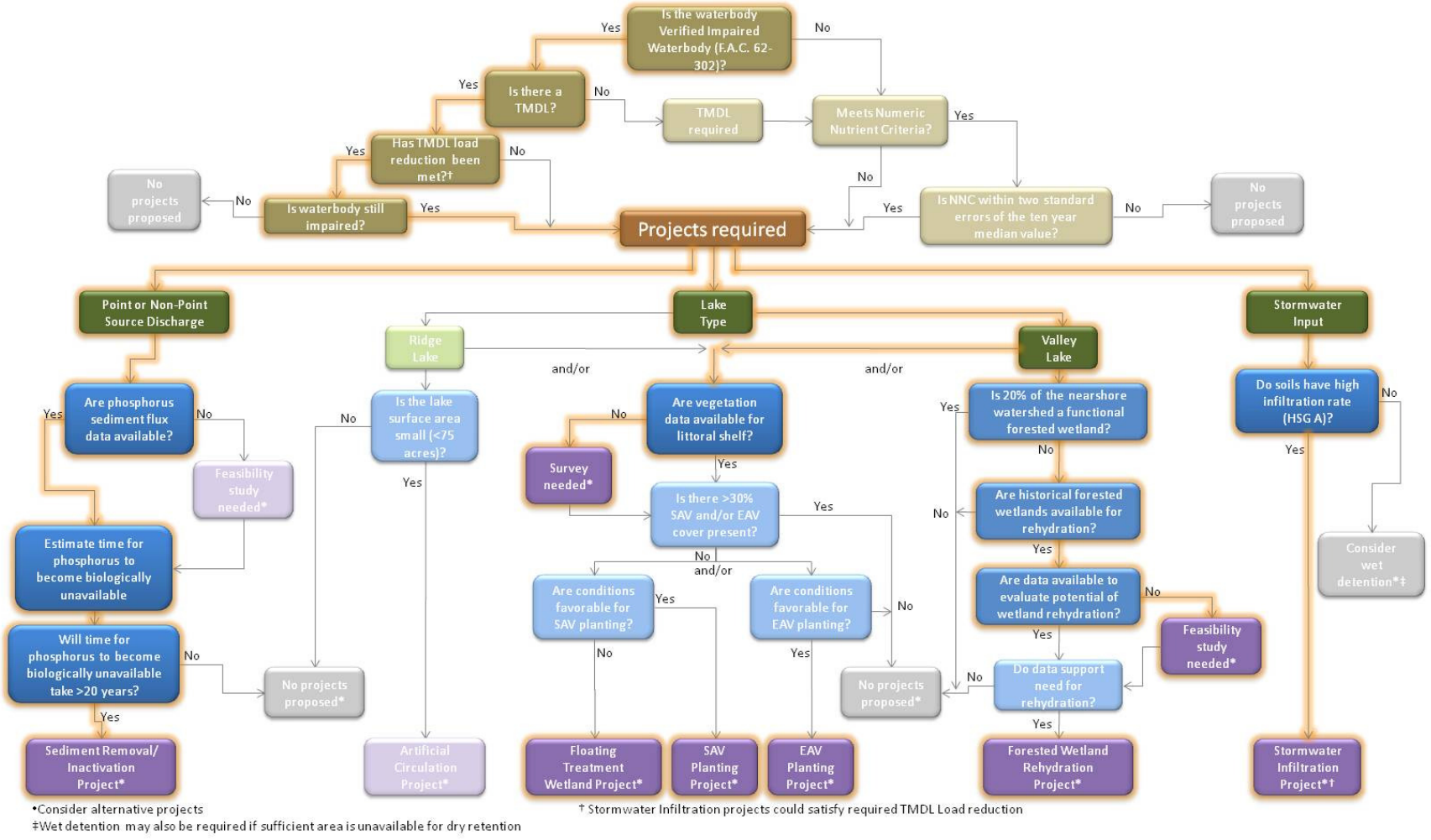


Figure 4-57. Lake Lulu bathymetry (June 2007) at water level elevation = 129 feet (Polk County Water Atlas).

Figure 4-58. Lake Lulu decision key: highlighted path shows decision process.



Project 1: Sediment Removal/inactivation

Historical point source discharges to Lake Lulu from WWTFs require further evaluation of the potential internal phosphorus load from the lake bottom sediments. The City of Winter Haven funded a Sediment Removal Feasibility Study performed by ERD to evaluate the sediment characteristics, phosphorus flux, and volume (ERD 2010). An estimate of the length of time until the pool of available phosphorus within the bottom sediments returns to background conditions was calculated using TP concentration in the sediments, the percent of available phosphorus and bulk density. Approximately 142 years are required for phosphorus concentrations to return to background conditions. Therefore, sediment removal/inactivation is recommended to address internal phosphorus loads. A cost estimate for sediment removal/inactivation has been completed by ERD (2010).

Sediment Removal: Costs associated with hydraulic dredging can be highly variable depending upon a variety of factors such as dredge capacity, availability of disposal areas, and distance to disposal areas, sludge dewatering requirements, booster pump requirements, and final sediment disposal. Since none of these factors have been fully evaluated at this time, a general sediment dredging cost of approximately $10.00 per cubic yard is assumed for this analysis. This value assumes that a shoreline dewatering facility would be used. A summary of estimated costs for hydraulic dredging in Lake Lulu, based on the previously determined organic sediment volumes, is $13,665,000. An estimated 847 ac-ft (1,366,493 cubic yards) of organic material would be removed.

Sediment Inactivation: A summary of estimated application costs for sediment inactivation in Lake Lulu is given based on an application of 10:1 Al:P ratio. This estimate assumes an alum volume of 728,023 gallons and a sodium aluminate volume of 128,006 gallons would be applied over two applications within a 6-12 month time period. It is assumed that the alum and sodium aluminate are purchased at a government contract price. Planning and mobilization costs are estimated to be approximately $5000 per application, which includes initial planning, mobilization of equipment to the site, demobilization at the completion of the application process, and clean-up. A labor rate of $125/hour is assumed which includes labor costs, water quality monitoring, expenses, equipment rental, insurance, mileage, and application equipment fees. The estimated cost for sediment inactivation in Lake Lulu is $1,412,239 or approximately $706,119 per application.

Project 2: Stormwater Infiltration Areas (SIAs)

The Lake Lulu watershed has approximately 292 acres (53 percent of the watershed) classified as high infiltration soils. A TMDL has been established for Lake Lulu, and as such, the SIA design should be focused on satisfying the TMDL requirements. SIA projects would need to encompass approximately 7 percent (38 acres) of the watershed in order to accomplish an annual 84 kg reduction in TP loads to Lake Lulu. Acres of SIA estimated to meet the TP NNC was 32 (6 percent of the watershed) for a 39 percent phosphorus reduction in Lake Lulu to meet its NNC. Fifty-three percent of the watershed is characterized by high infiltration soils; therefore, it may be feasible to satisfy the TMDL load reductions through SIA implementation.

Presently, the City of Winter Haven has preliminarily identified one rain garden project within the contributing drainage basin for Lake Lulu as part of SWFWMD funded agreement (Figure 4-59). The rain garden is 500 feet^2 providing treatment to 4,000 feet^2. A brief description of the project is identified below as provided by the City of Winter Haven.

Site 29: South side of Post Ave. SW east of Third Street SW at the WH Water Plant:

Type of Project:	Rain Garden along Post Ave. SW.
Objective:	To capture and percolate the runoff coming down the south side of Post Ave. SW. The runoff can be easily directed into the depressional area/rain garden at this location as the area is lower than the adjacent edge of pavement.
Drainage Area:	4,000 SF
Rain Garden:	500 SF
Treatment Volume:	360 CF (provided)
Cost Estimate:	$ 2,850

Project 3: Forested Wetland Rehydration

Approximately 45 percent of the land cover within the 500 foot buffer surrounding Lake Haines is classified as wetlands using the 2006 FLUCS data. Forested wetlands encompass 30 percent of the total wetland area, which is within the 10 to 20 percent recommended forested wetland cover required to maintain color levels above 50 PCU. While FLUCS classifies the land cover as forested wetland, the hydrologic connection between the lake and adjacent land might not be present as is observed along the southern rim of the Lake.

One proposed project area was identified adjacent to Lake Lulu along the southern rim and is expected to rehydrate approximately 167 acres (Figure 4-60). The feasibility study is recommended in order to evaluate the proposed project area for inundation.

Feasibility study cost estimate: $75,000.

Figure 4-59 . Proposed forested wetland rehydration project areas for Lake Lulu.

Project 4: SAV Planting or FTWs

SAV Planting

In Lake Lulu, *Hydrilla* eradication has been completed over as much as 58 percent of the lake surface area attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Lulu is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

SAV plants should not be planted in water depths greater than 2 feet based on the median secchi depth values (1.8 feet). The maximum planting effort could result in vegetation cover of approximately 14 percent of the lake bottom (45 acres). Due to the extensive organic material located in Lake Lulu, it is recommended that SAV planting be performed after sediment removal/inactivation, if completed. If sediment removal is completed, the planting area would need to be recalculated using updated bathymetry data.

Cost Estimate: $220,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance).

FTWs

If the feasibility study indicates that more than 30 percent of Lake Lulu has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 5: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Lulu is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.15. Lake Mariana

Background

Physical and chemical characteristics specific to Lake Mariana are presented here in the context of relevant regulatory criteria and requirements (Table 4-30). Lake Mariana (WBID 1521L) is hydrologically connected to the Southern Chain of the WHCL and discharges water to Lake Jessie via a structure and constructed outflow ditch (non-navigable) (Photo 4-18, Figure 4-60). In 2010, Lake Mariana was declared verified impaired based on elevated TSI values (>60). A TMDL is required for Lake Mariana to calculate load reductions necessary to satisfy the TSI criteria. The TP, TN, and chlorophyll *a* geometric mean for Lake Mariana for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-30. To comply with the NNC, concentration reductions of 3 percent for TP, 9 percent for TN and 12 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Mariana is presented in Table 4-31. The median chlorophyll *a*, TN and TP concentrations exceed the NNC targets provided by EPA for Lake Mariana. Chlorophyll *a* concentrations in Lake Mariana fluctuate with values regularly elevated above 20 µg/L (Figure 4-61). A statistically significant increase in chlorophyll *a* concentrations from 1992 to 2007 was observed (seasonal Kendall-Tau, $p<0.02$). *Hydrilla* has not been treated in Lake Mariana since there is no public access. A significant water quality improvement project has been implemented for Lake Mariana in an effort to restore water quality. In 2005, a wetland treatment project was constructed by Polk County in the southwest corner of the lake that treated 546 acres of an urban watershed. Lake Mariana is a headwater lake; therefore, improvements in water quality of the lake could result in some benefit farther downstream.

The Lake Mariana watershed is 1,445 acres in size and includes 896 acres (62 percent) of developed lands compared to 548 acres (38 percent) of undeveloped lands. The 2000-2007 median color value (17 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 136 feet in October 2009. Bathymetry data are available for Lake Mariana for the October 2009 water level (Figure 4-62).

A water level of 138 feet was reported in August 2010, reflecting a 2.0 foot increase in water elevation when compared to 2009. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Mariana water quality and the surrounding watershed characteristics, four potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-63). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management

Table 4-30. Physical, chemical, and regulatory characteristics of Lake Mariana.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	765 (53 percent)
Relation to other lakes	Headwater	**Developed land (acres)**	896 (62 percent)
Watershed area (acres)	1,145	**Undeveloped land (acres)**	548 (38 percent)
Lake area (acres)*	518	**Median water depth (feet)***	8.0
Perimeter (feet)*	29,366	**Maximum water depth (feet)***	18.4
Surface area: lake volume ratio*	0.11	**Volume (acre-feet)***	4,725
Watershed to surface area ratio*	2.21		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	23	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.10	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.031	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required
Chlorophyll *a* trend	Increasing**	**TP concentration reduction required**	3 percent

*at a water level elevation of 136 feet
**presented in section 5.0

Photo 4-18. Lake Mariana.

Table 4-31. Lake Mariana water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	46	10	23	57
Color (PCU)	32	5	17	40
Conductivity (µmhos/cm)	30	183	212	262
Dissolved oxygen (mg/L)	30	5.36	8.43	11.17
pH	30	6.25	7.62	9.3
Secchi depth (feet)	47	1.2	2.4	3.9
Total nitrogen (mg/L)	50	0.74	1.09	1.81
Total phosphorus (mg/L)	45	0.006	0.034	0.093

Figure 4-60. Lake Mariana and associated watershed.

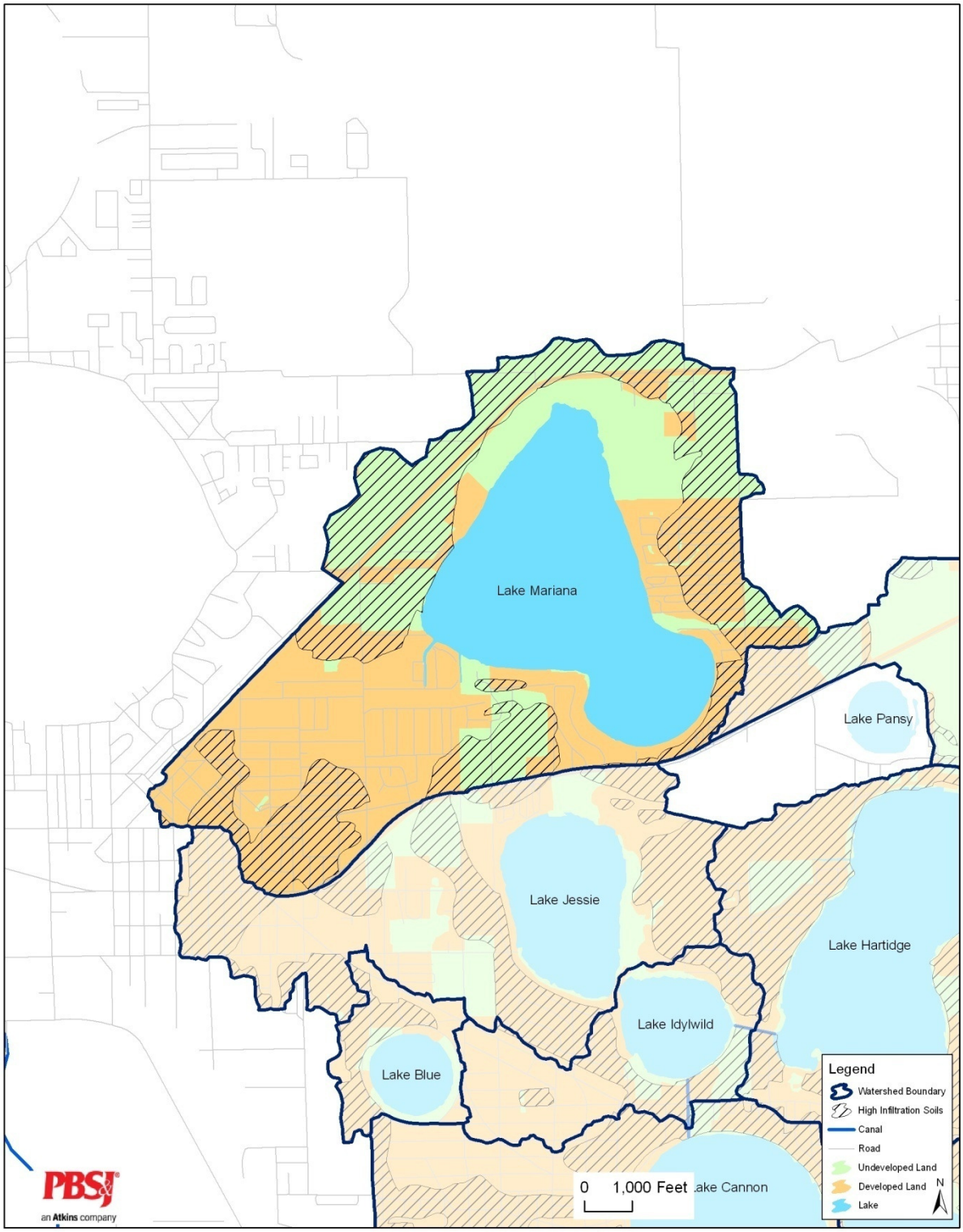


Figure 4-61. Lake Mariana chlorophyll *a* concentrations using available data from 1992 to 2007.

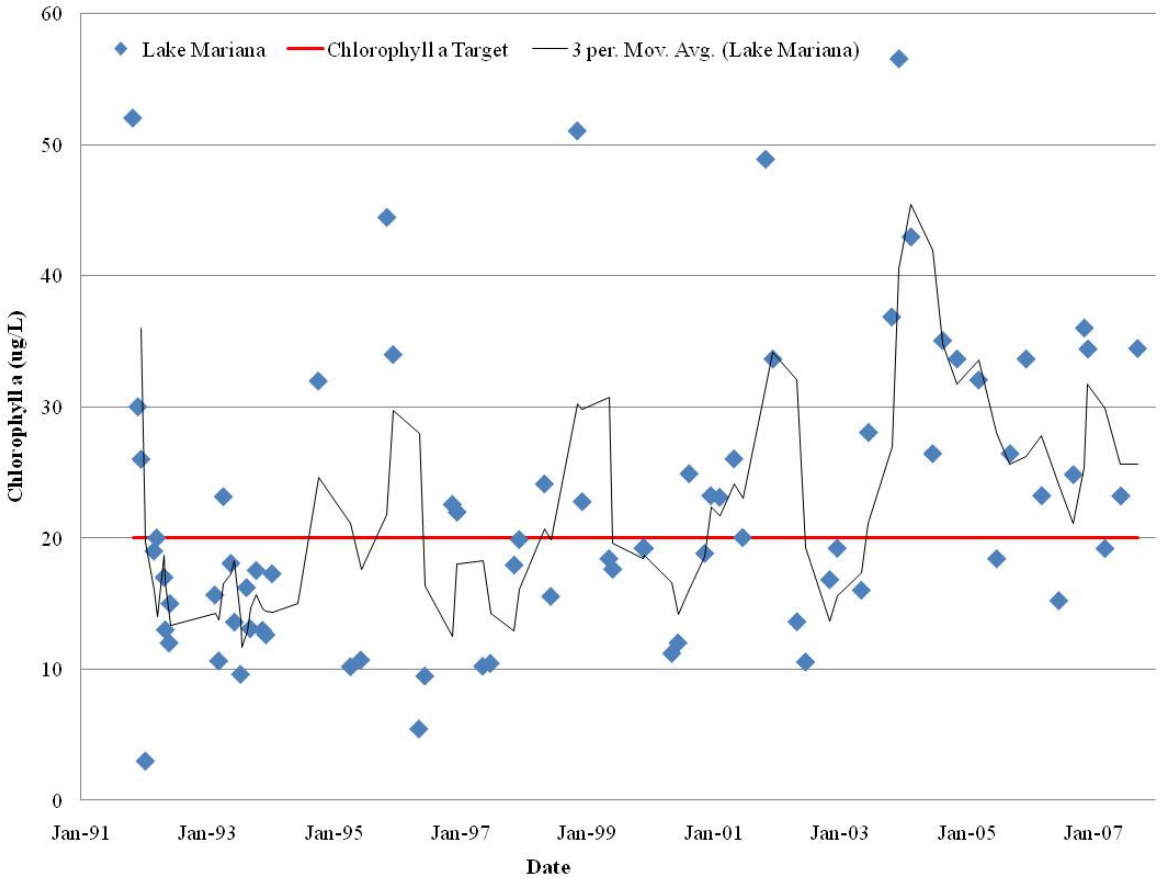


Figure 4-62. Lake Mariana bathymetry (October 2009) at water level elevation = 136 feet (Polk County Water Atlas).

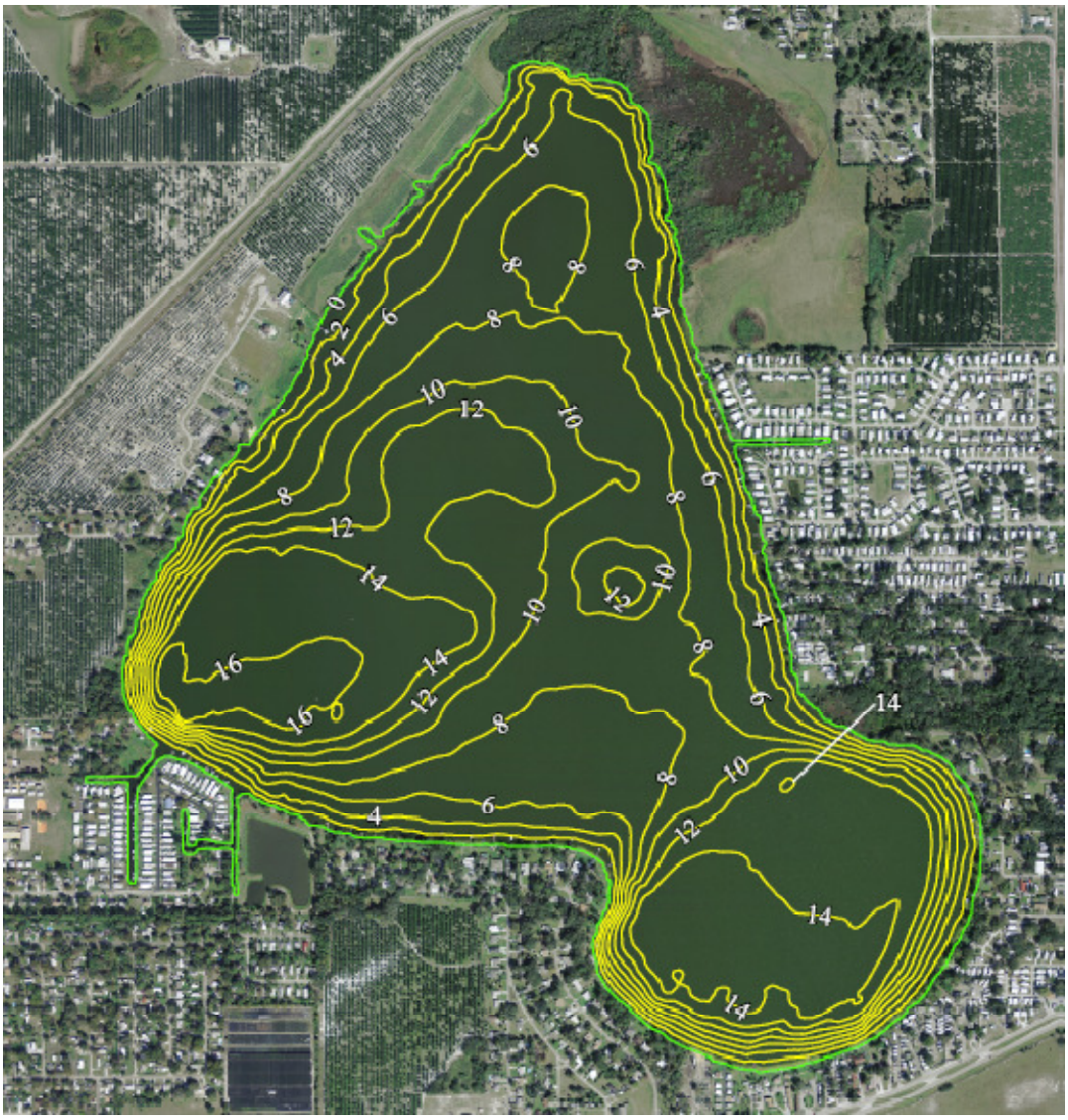
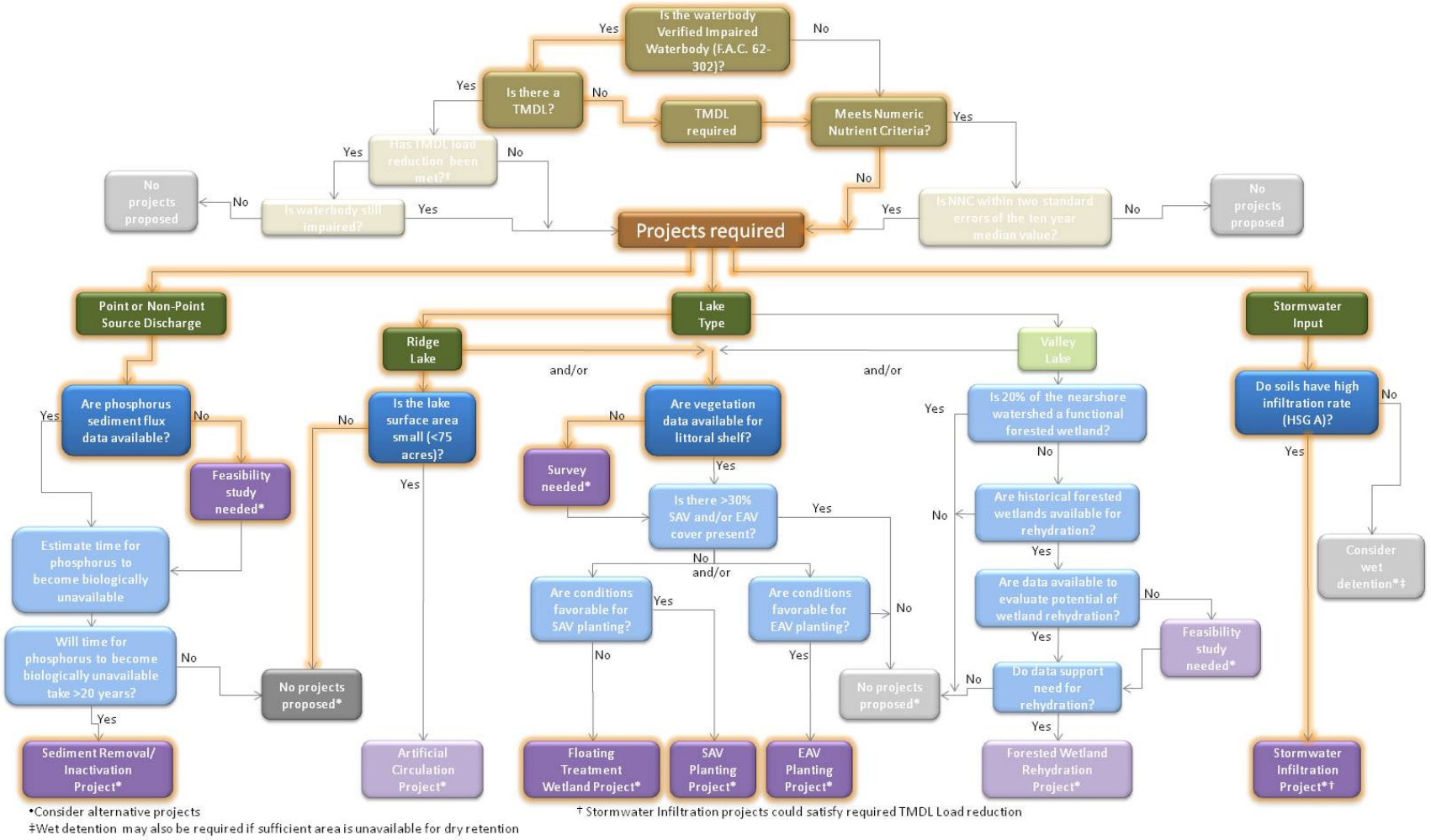


Figure 4-63. Lake Mariana decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Mariana watershed has approximately 765 acres (53 percent of the watershed) classified as high infiltration soils. Lake Mariana does not have a TMDL, therefore, SIA acres estimates were calculated using data from the PLRG (USF 2005). The SIA estimate for Lake Mariana was 31 acres (approximately 3 percent of the watershed) to meet a 17 percent PLRG. Acres of SIA estimated to meet the TP NNC was 7 (one percent of the watershed) for an 3 percent phosphorus reduction in Lake Mariana to meet its NNC. Fifty-three percent of the watershed is characterized by high infiltration soils; therefore, it may not be feasible to satisfy the load reductions through SIA implementation.

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Lake Mariana may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

Hydrilla infestations have not been a chronic problem in Lake Mariana. However, *Hydrilla* eradication was necessary in 2008. A survey of existing SAV cover in Lake Mariana is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth.

Based on the median secchi depth (2.4 feet) from 1997-2007, plants would not be planted in water depths greater than 2 feet. The maximum planting effort could result in vegetation cover of approximately six percent of the lake bottom (32 acres).

Cost Estimate: $165,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance)

FTWs

If the feasibility study indicates that more than 30 percent of Lake Mariana has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Mariana is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.16. Lake May

Background

Physical and chemical characteristics specific to Lake May are presented here in the context of relevant regulatory criteria and requirements (Table 4-32). Lake May (WBID 1521E), a lake in the WHCL Southern Chain, is hydrologically connected to Lake Howard to the north and to Lake ship to the south via navigable canals (Photo 4-19, Figure 4-64). In 2005, Lake May was declared verified impaired based on elevated TSI values (>60). A TMDL was adopted for the Southern Chain of the WHCL, including Lake May (FDEP 2007), and Lake May was subsequently delisted from impairment by FDEP in 2010. Based on the modeled external TP load to Lake May, a 57.5 percent reduction in TP load (97 kg TP/year) is required to comply with the TSI criteria of 60 (FDEP 2007). The TP, TN, and chlorophyll *a* geometric mean for Lake May for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-32. To comply with the NNC, concentration reductions of 47 percent for TP, 26 percent for TN, and 53 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake May is presented in Table 4-33 Lake May historically received point source discharges from three WWTF (Imhoff, Citrus, and Velda). While the effluent discharges have been eliminated, the discharges resulted in nutrient and sediment accumulation in the lake bottom. An inverse relationship between lake levels and TP concentrations may suggest sediment resuspension resulting in a decline in water quality. In response to the TMDL, the City of Winter Haven and the SWFWMD implemented a stormwater alum injection treatment project. Based on TP load reduction estimates for projects constructed on Lake May (357 kg/year), it appears that required TP load reductions (97 kg/year) have already been accomplished. There is no clear evidence of water quality improvement after the implementation of the stormwater retrofit project in 2005. The chlorophyll *a* values consistently exceed 20 µg/liter, indicating that TSI_{CHLA} values less than or equal to 60 (which would require chlorophyll *a* levels to be below 20 µg/L) were not reached (Figure 4-65). A statistically significant trend in chlorophyll *a* concentrations from 1983 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). The median chlorophyll *a*, TN and TP concentrations continue to exceed the NNC targets provided by EPA for Lake May. *Hydrilla* eradication projects have been completed annually since 2001 treating up to 20 percent of the lake surface area. Lake May is an intermediate lake so improvements in water quality could result in some benefit farther downstream.

The Lake May watershed is 610 acres in size and includes 563 acres (92 percent) of developed lands compared to 47 acres (8 percent) of undeveloped lands (Table 4-32). The 2000-2007 median color value (20 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 130 feet in September 2009 (Table 4-32). Bathymetry data are available for Lake May for the September 2009 water level elevation (Figure 4-66). A water level of 130 feet was reported in August 2010, indicating similar water elevations when compared to 2009. Changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake May water quality and the surrounding watershed characteristics, five potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-67). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Sediment Removal/Inactivation
- Project 2: Stormwater Infiltration Areas (SIAs)
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management
- Project 5: Artificial Circulation

Table 4-32. Physical, chemical, and regulatory characteristics of Lake May.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	279 (46 percent)
Relation to other lakes	Intermediate	**Developed land (acres)**	563 (92 percent)
Watershed area (acres)	610	**Undeveloped land (acres)**	47 (8 percent)
Lake area (acres)*	52	**Median water depth (feet)***	3.4
Perimeter (feet)*	15,008	**Maximum water depth (feet)***	8.4
Surface area: lake volume ratio*	0.39	**Volume (acre-feet)***	132
Watershed to surface area ratio*	11.73		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	42	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.35	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.057	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required†
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	47 percent

*at a water level elevation of 130 feet
**presented in section 5.0
†TMDL adopted

Photo 4-19. View of Lake May during incubation study.

Table 4-33. Lake May water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	101	22	46	92
Color (PCU)	27	5	20	25
Conductivity (µmhos/cm)	32	191	227	365
Dissolved oxygen (mg/L)	32	5.85	8.59	10.27
pH	32	6.8	7.79	8.71
Secchi depth (feet)	102	0.8	1.4	3.2
Total nitrogen (mg/L)	103	0.09	1.41	2.58
Total phosphorus (mg/L)	98	0.01	0.058	0.139

Figure 4-64. Lake May and associated watershed.

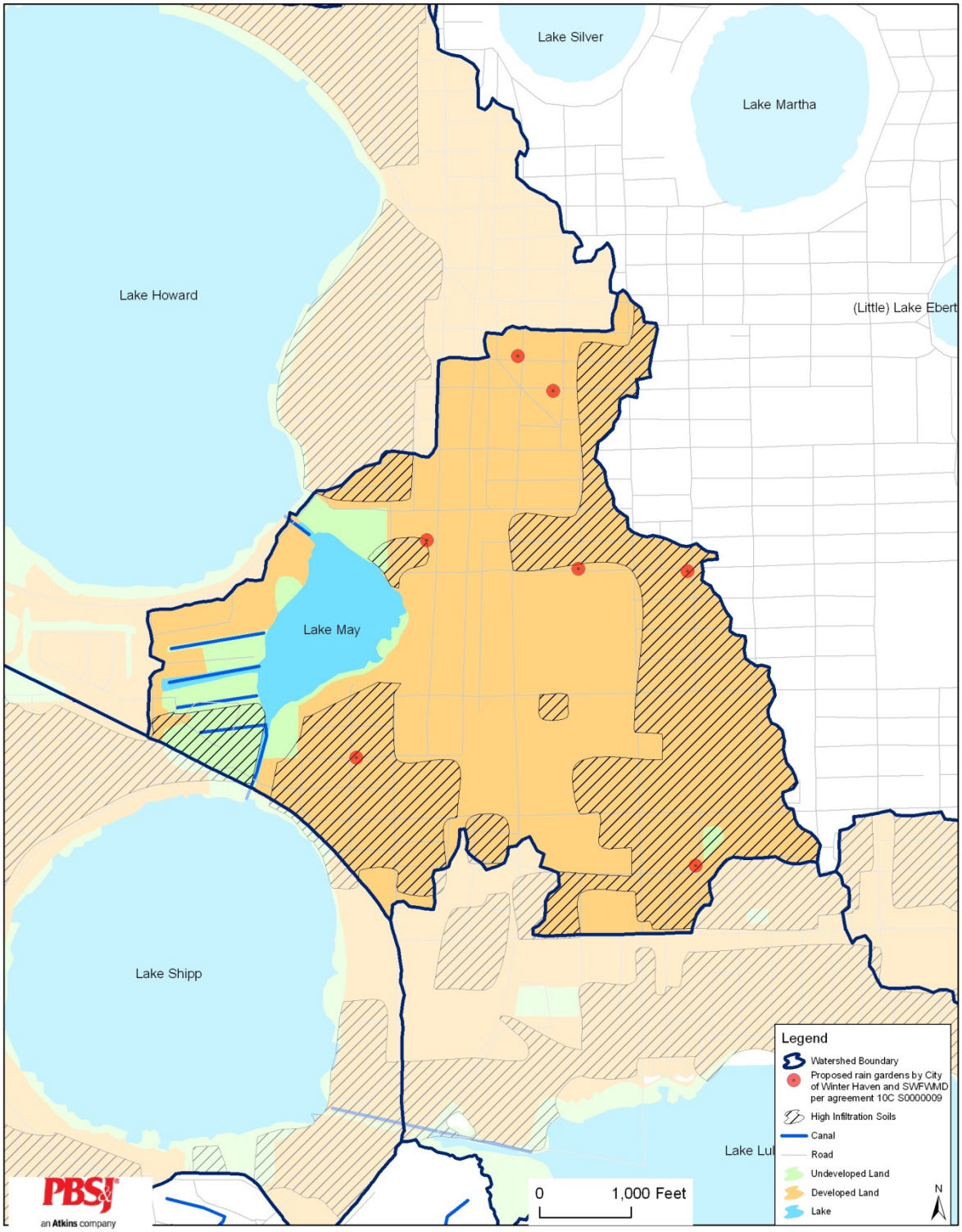


Figure 4-65. Lake May chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

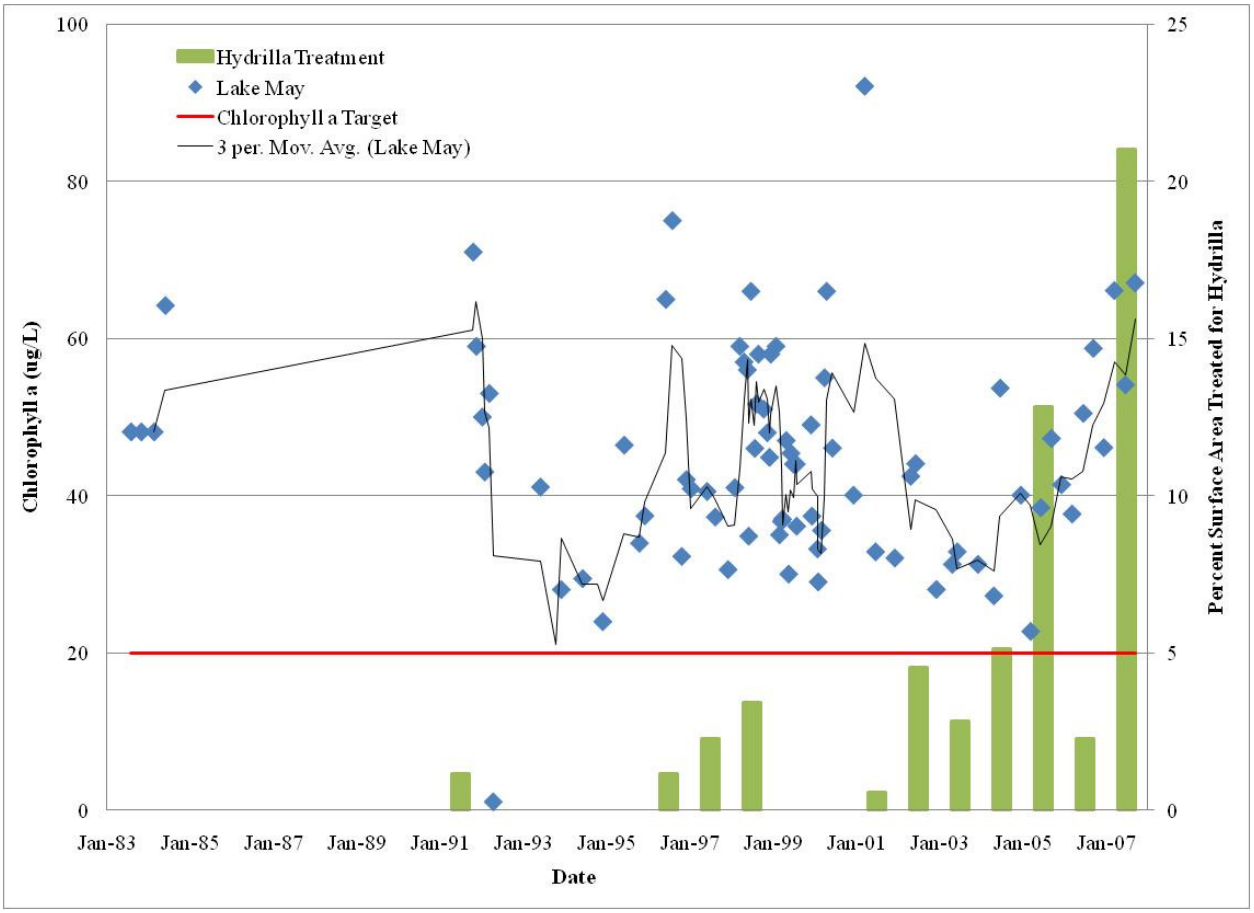
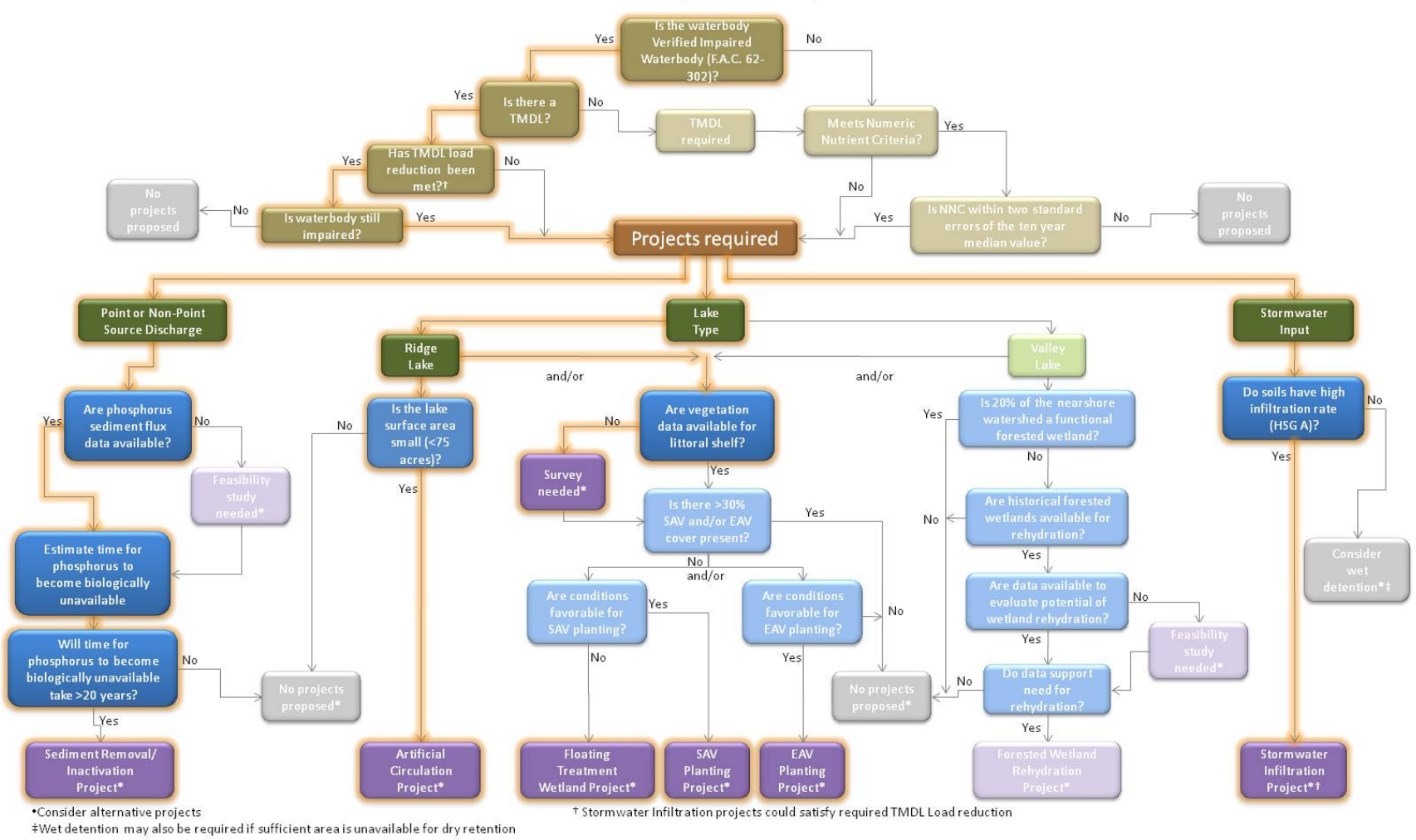


Figure 4-66. Lake May bathymetry (September 2009) at water level elevation = 130 feet (Polk County Water Atlas).

Figure 4-67. Lake May decision key: highlighted path shows decision process.



Project 1: Sediment Removal/inactivation

The City of Winter Haven and the SWFWMD recognized the potential issues associated with the organic sediments in Lake May and funded the Sediment Removal Feasibility Study performed by ERD to evaluate the sediment characteristics, phosphorus flux, and volume (ERD 2010). An estimate of the length of time until the pool of available phosphorus within the bottom sediments returns to background conditions was calculated using TP concentration in the sediments, the percent of available phosphorus and bulk density. Approximately 403 years are required for phosphorus concentrations to return to background conditions. Therefore, sediment removal/inactivation is recommended to address internal phosphorus loads. A cost estimate for sediment removal/inactivation has been completed by ERD (2010). The use of alum for sediment inactivation is not recommended for Lake May due to shallow water depths increasing the possibility of wind/wave action resuspension of the extensive organic sediment material in the lake. Resuspension of the organic material may allow of the incorporation of the alum material thereby reducing its efficiency to remove phosphorus.

Sediment Removal: Costs associated with hydraulic dredging can be highly variable depending upon a variety of factors such as dredge capacity, availability of disposal areas, and distance to disposal areas, sludge dewatering requirements, booster pump requirements, and final sediment disposal. Since none of these factors have been fully evaluated at this time, a general sediment dredging cost of approximately $10.00 per cubic yard is assumed for this analysis. This value assumes that a shoreline dewatering facility would be used. A summary of estimated costs for hydraulic dredging in Lake May based on the previously determined organic sediment volumes, estimated dredging costs is $4,872,300. An estimated 302 ac-ft (487,227 cubic yards) of organic material would be removed.

Project 2: Stormwater Infiltration Areas (SIAs)

The Lake May watershed has approximately 279 acres (46 percent of the watershed) classified as high infiltration soils. A TMDL has been established for Lake May, and as such, the SIA design should be focused on satisfying the TMDL requirements. In order to calculate the percentage of the Lake May watershed for SIA construction, a modification to the PLRG runoff statistic was required. The University of South Florida will be contacted to verify the modification. SIA projects would need to encompass approximately six percent (34 acres) of the watershed in order to accomplish an annual 97 kg reduction in TP loads to Lake May. Acres of SIA estimated to meet the TP NNC was 33 (5 percent of the watershed) for a 47 percent phosphorus reduction in Lake May to meet its NNC. Forty-six percent of the watershed is characterized by high infiltration soils; therefore, it may be feasible to satisfy the TMDL load reduction through SIA implementation.

Presently, the City of Winter Haven has preliminarily identified seven rain garden projects within the contributing drainage basin for Lake May as part of SWFWMD funded agreement. The rain garden size ranges from 200 to 1,000 feet^2 providing treatment to 3,000 to 12,500 feet^2. A brief description of the project is identified below as provided by the City of Winter Haven.

Site 13: City of Winter Haven Utility Services parking lot along Ave. F SW:

Type of Project:	Rain Garden
Objective:	To capture and percolate the runoff coming from the roof of the building and parts of the adjacent parking lot. An area of the parking lot would be removed and a rain garden constructed in its place. The runoff would be directed into the rain garden at this location as the site generally slopes down to that area.
Drainage Area:	10,000 SF
Rain Garden:	1,000 SF
Treatment Volume:	720 CF (provided).
Cost Estimate:	$ 9,200

Site 14: The Federal Building at the northeast corner of Third Street SW and Ave. A SW:

Type of Project:	Rain Gardens (two), one along Third Street and one along Ave. A.
Objective:	To capture and percolate the runoff coming from the roof of the building and the adjacent area. The runoff can be easily directed into the depressional areas/rain gardens at these two locations as the existing down spouts discharge to those areas.
Drainage Area:	5200 SF
Rain Garden:	2 x 200 SF
Treatment Volume:	290 CF (provided)
Cost Estimate:	$ 2,350

Site 27: Southwest corner of Second Street SW and Ave. B SW:

Type of Project:	Rain Garden (open cut the curb and dig out to depression).
Objective:	To capture and percolate the runoff coming down the south side of Ave. B SW. The runoff would be directed into the depressional area/rain garden at this location by creating an opening in the existing curb and constructing a concrete flume.
Drainage Area:	3,000 SF
Rain Garden:	200 SF
Treatment Volume:	150 CF (provided)
Cost Estimate:	$ 2,200

Site 30: Northwest corner of Third Street SE and Post Ave. SE:

Type of Project:	Storm Inlet and perforated pipe (French Drain)
Objective:	To capture and percolate the runoff coming down the west side of Third Street SE. In addition to increasing the percolation/infiltration into the ground, this would help reduce the runoff coming down onto the adjacent roads.

Drainage Area:	5,400 SF
Perforated Pipe:	60 L.F. of 18 inch pipe surrounded by 1 foot thick stone layer.
Treatment Volume:	580 CF
Cost Estimate:	$ 5,350

Site 42: Southwest corner of Second Street SE and Ave. G SE at Grace Baptist Church:

Type of Project:	Rain Garden (remove existing paved area to create a rain garden).
Objective:	To capture and percolate the runoff coming down the south side of Ave. G SE. The runoff can be easily directed into the depressional area/rain garden at this location as the area is the low point at that corner of the intersection.
Drainage Area:	11,300 SF
Rain Garden:	650 SF
Treatment Volume:	470 CF (provided)
Cost Estimate:	$ 5,700

Site 43: East side of Second Street SW at Ave. G SW:

Type of Project:	Rain Garden along Second Street SW.
Objective:	To capture and percolate the runoff coming down the east side of Second Street SW. The runoff can be easily directed into the depressional area/rain garden at this location as the area is lower than the adjacent edge of pavement.
Drainage Area:	5,000 SF
Rain Garden:	750 SF
Treatment Volume:	540 CF (provided)
Cost Estimate:	$ 4,175

Site 45: South side of Ave. M SW between Seventh St. SW and Eighth St. SW adjacent to Southside Baptist Church:

Type of Project:	Rain Garden along Ave. M SW.
Objective:	To capture and percolate the runoff coming down the south side of Ave. M SW. The runoff can be easily directed into the depressional area/rain garden at this location as the area is lower than the adjacent edge of pavement.
Drainage Area:	12,500 SF
Rain Garden:	750 SF
Treatment Volume:	540 CF (provided)
Cost Estimate:	$ 4,175

Project 3: SAV Planting or FTWs

SAV Planting

In Lake May, *Hydrilla* eradication has been completed over as much as 26 percent of the lake surface area attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake May is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

SAV plants should not be planted in water depths greater than 2 feet based on the median secchi depth values (1.4 feet). The maximum planting effort could result in vegetation cover of approximately 30 percent of the lake bottom (15 acres). Due to the extensive organic material located in Lake May, it is recommended that SAV planting be performed after sediment removal/inactivation, if completed. If sediment removal is completed, the planting area would need to be recalculated using updated bathymetry data.

Cost Estimate: $100,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance).

FTWs

If the feasibility study indicates that more than 30 percent of Lake May has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing shoreline vegetation surrounding Lake May is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

Project 5: Artificial Circulation

Due to the shallow water depths recorded in Lake May (median of 3.4 feet), artificial circulation is not initially recommended as a restoration project for the Lake (ERD 2010). After sediment removal, conditions in Lake May could be conducive for artificial circulation. A reevaluation of water quality conditions should be performed prior to the project design for artificial circulation.

4.17. Middle Lake Hamilton

Background

Physical and chemical characteristics specific to Middle Lake Hamilton are presented here in the context of relevant regulatory criteria and requirements (Table 4-34). Middle Lake Hamilton (WBID 15002), located in the WHCL Northern Chain, is hydrologically connected to lakes Hamilton and Little Lake Hamilton via constructed navigable canals (Photo 4-20, Figure 4-68). Middle Lake Hamilton has not been declared verified impaired; therefore, a TMDL is not required. However, the NNC are performance based, and an exceedance more than once every three years results in non-compliance. The annual geometric chlorophyll *a* and TN mean in 2005 through 2007 were above the NNC. Insufficient data were available to evaluate TP in comparison to the NNC target based on the EPA data requirements. The TN and chlorophyll *a* geometric mean for Middle Lake Hamilton for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-34. To comply with the NNC, concentration reductions of 18 percent for TN and 33 percent for chlorophyll *a* are required.

A summary of water quality statistics for Middle Lake Hamilton is presented in Table 4-35. Median chlorophyll *a*, TN and TP concentrations exceed the NNC targets provided by EPA for Middle Lake Hamilton. Chlorophyll *a* concentrations in Lake Haines have fluctuated but have remained consistently elevated above 20 µg/L (Figure 4-69). A statistically significant trend in chlorophyll *a* concentrations from 1994 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). Lack of eradication projects in Middle Lake Hamilton suggest that *Hydrilla* infestations do not appear to be a problem. Middle Lake Hamilton is adjacent to a terminal lake, therefore, improvements in water quality of the lake would result in little benefits farther downstream.

The Middle Lake Hamilton watershed is 1,072 acres in size and includes 199 acres (19 percent) of developed lands compared to 873 acres (81 percent) of undeveloped lands. The 2000-2007 median color value (115 PCU) was above 40 PCU indicating the lake is a colored lake. Using the adopted EPA NNC for Florida lakes, characterization of alkalinity or acidity is not necessary based on the colored classification of Middle Lake Hamilton. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 118 feet in February of 2010. Bathymetry data are available for Middle Lake Hamilton for the February 2010 water level elevation (Figure 4-70). Changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Middle Lake Hamilton water quality and the surrounding watershed characteristics, five potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-71). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: Forested Wetland Rehydration
- Project 4: SAV Planting/Management or FTWs
- Project 5: EAV Planting/Management

Table 4-34. Physical, chemical, and regulatory characteristics of Middle Lake Hamilton.

Physical			
Location in chain	Northern	**High infiltration soils (acres)**	332 (31 percent)
Relation to other lakes	Adjacent to Terminal	**Developed land (acres)**	199 (19 percent)
Watershed area (acres)	1,072	**Undeveloped land (acres)**	873 (81 percent)
Lake area (acres)*	101	**Median water depth (feet)***	3.7
Perimeter (feet)*	10,932	**Maximum water depth (feet)***	5.7
Surface area: lake volume ratio*	0.28	**Volume (acre-feet)***	359
Watershed to surface area ratio*	10.61		
Water Chemistry			
Locally-derived: acidic or alkaline	NA	**Clear or colored**	Colored
Geometric mean chlorophyll *a* (µg/L)	30	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.51	**NNC TN target (mg/L)**	1.23
Geometric mean TP (mg/L)	ID	**NNC TP target (mg/L)**	0.050
Regulatory Data			
Impaired	Yes	**TMDL status**	NA
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	ID

*at a water level elevation of 118 feet
**presented in section 5.0
NA- Not Applicable
ID- Insufficient Data

Photo 4-20. Fisherman on Middle Lake Hamilton.

Table 4-35. Middle Lake Hamilton water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	26	3	27	54
Color (PCU)	19	50	115	200
Conductivity (µmhos/cm)	19	169	204	271
Dissolved oxygen (mg/L)	19	4.98	7.5	9.46
pH	19	6.21	7.24	7.91
Secchi depth (feet)	26	1.1	2.1	3.0
Total nitrogen (mg/L)	26	1.05	1.56	2.46
Total phosphorus (mg/L)	21	0.043	0.070	0.167

Figure 4-68. Middle Lake Hamilton and associated watershed.

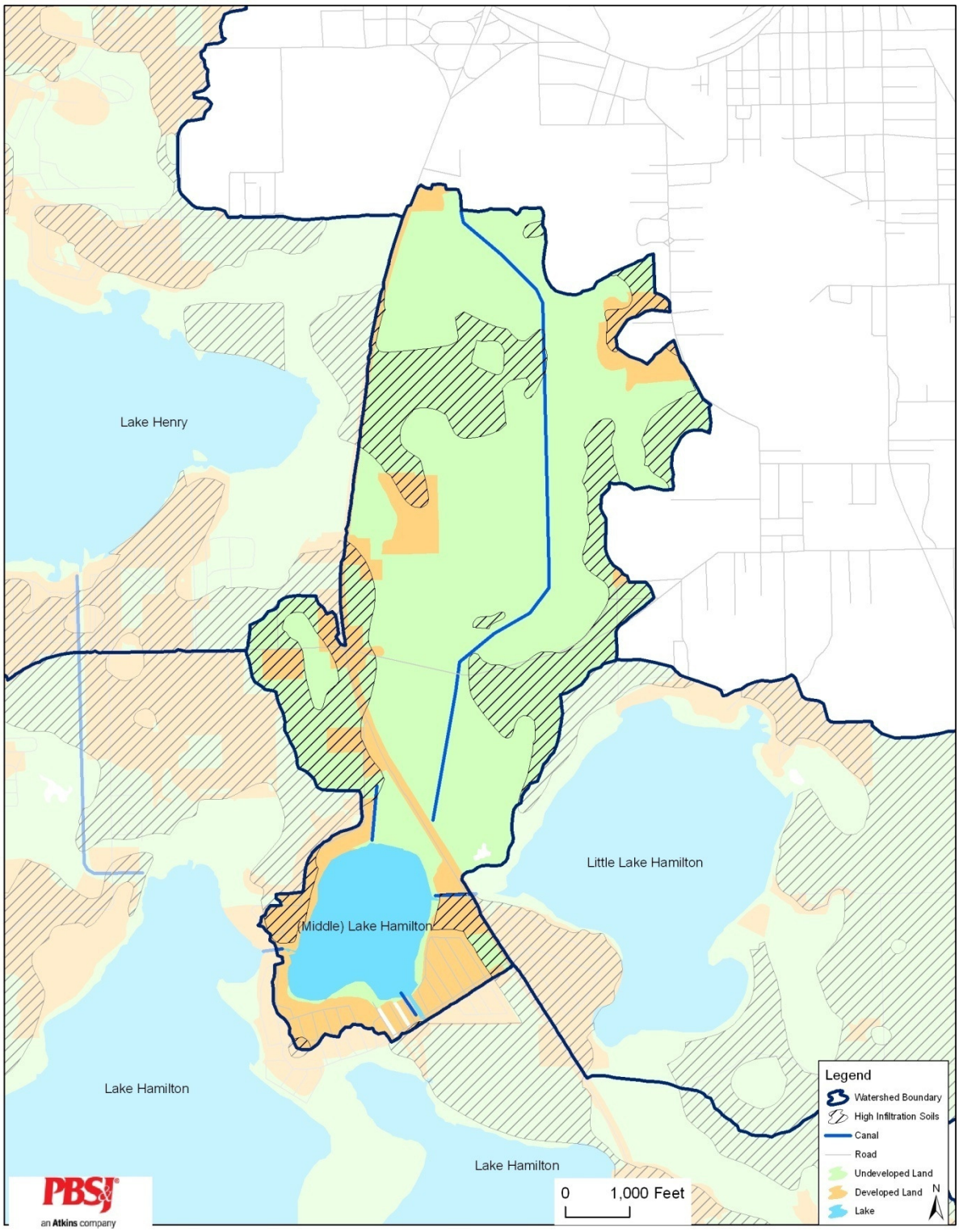


Figure 4-69. Middle Lake Hamilton chlorophyll *a* concentrations using available data from 1993 to 2007.

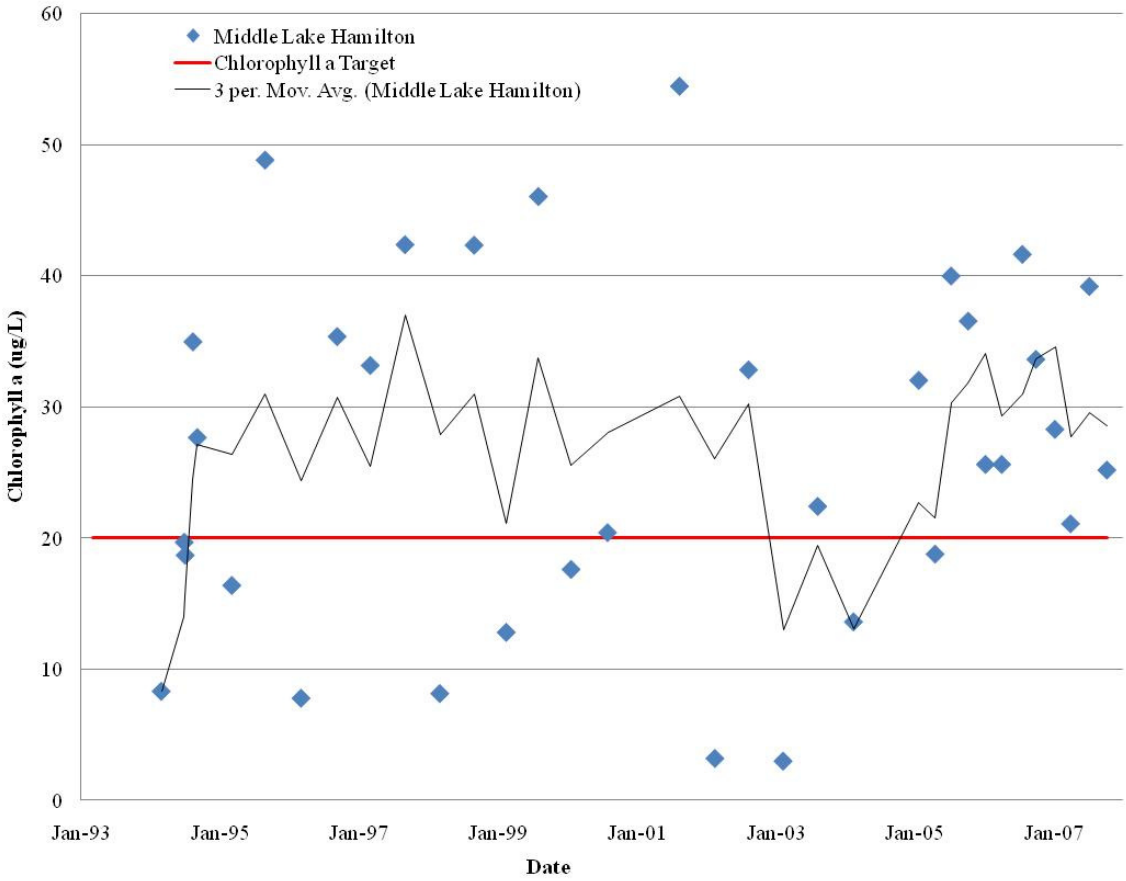
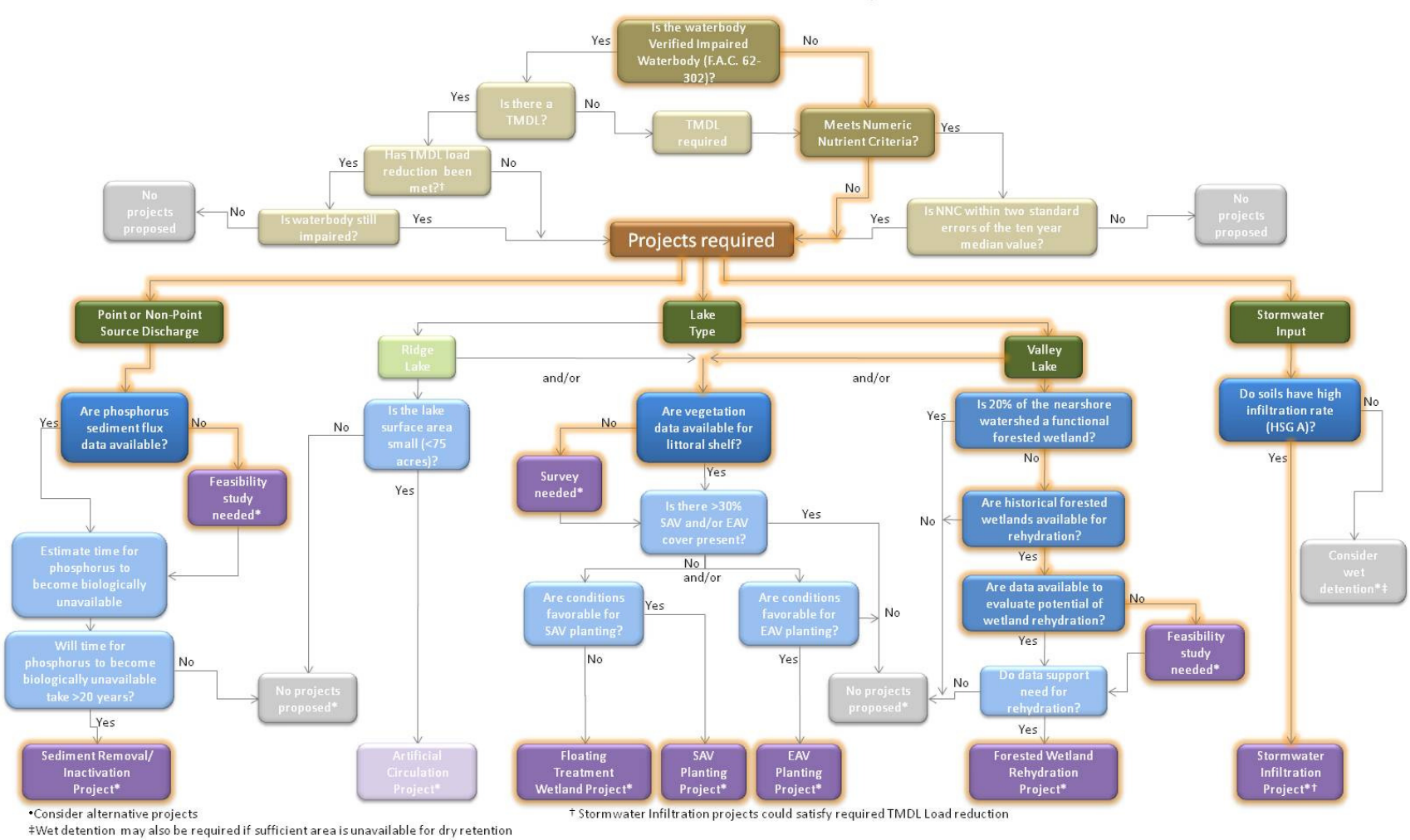


Figure 4-70. Middle Lake Hamilton bathymetry (February 2010) at water level elevation = 118 feet (Polk County Water Atlas).

Figure 4-71. Middle Lake Hamilton decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Middle Lake Hamilton watershed has approximately 332 acres (31 percent of the watershed) classified as high infiltration soils. A TMDL is not required for Middle Lake Hamilton and the Northern Chain was not included in the PLRG study (USF 2005), therefore data to estimate SIA acres for TP load reduction are not available at this time. The SIA design should be focused on recharging the surficial aquifer. SIA implementation could have a double benefit of increasing storage to supplement dry season lake levels and a reduction in stormwater loads that can be later applied to the required TMDL TP load reduction.

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Middle Lake Hamilton may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: Forested Wetland Rehydration (and Restoration)

Approximately 19 percent of the land cover within the 500 foot buffer surrounding Middle Lake Hamilton is classified as wetlands using the 2006 FLUCS data. Forested wetlands encompass five percent of the total wetland area, which is not within the 10 to 20 percent recommended forested wetland cover required to maintain color levels above 50 PCU.

Middle Lake Hamilton has a watershed area of 1,072 acres draining into the 101-acre lake (watershed to lake ratio of 10.61). Also, a relatively large portion of the watershed is undeveloped (81 percent) and has low percolation soils (84 percent).

One proposed project is to rehydrate (restore) approximately 350 acres (Figure 4-72) of historically low lying lands that have been drained by the Haines City Drainage Canal. This project would treat stormwater runoff from a substantial portion of the watershed before it enters the lake and has been recommended by the Sustainable Water Resource Management Plan for re-creating lost storage in the watershed. A feasibility study is recommended to evaluate the proposed project area for inundation.

Feasibility study cost estimate: $100,000.

Project 4: SAV Planting or FTWs

SAV Planting

Middle Lake Hamilton does not have a history of *Hydrilla* infestations. A survey of existing SAV cover in Middle Lake Hamilton is recommended due to the lack of sufficient data to

calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth.

SAV plants should not be planted in water depths greater than 2 feet based on the median secchi depth values (2.1 feet). The maximum planting effort for Middle Lake Hamilton cannot be calculated until the electronic bathymetry data are acquired.

Cost Estimate: A cost estimate will be generated upon receipt of the bathymetry data.

FTWs

If the feasibility study indicates that more than 30 percent of Middle Lake Hamilton has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 5: EAV Planting

A survey of existing shoreline vegetation surrounding Middle Lake Hamilton is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

Figure 4-72. Proposed forested wetland rehydration project area for Middle Lake Hamilton.

4.18. Lake Mirror

Background

Physical and chemical characteristics specific to Lake Mirror are presented here in the context of relevant regulatory criteria and requirements (Table 4-36). Lake Mirror (WBID 1521G) is located in the Southern Chain of the WHCL and is hydrologically connected to lakes Cannon and Spring via constructed navigable canals (Photo 4-21, Figure 4-73). In 2005, Lake Mirror was declared verified impaired based on elevated TSI values (>60). A TMDL was adopted for the Southern Chain of the WHCL, including Lake Mirror (FDEP 2007), and Lake Mirror was subsequently delisted from impairment by FDEP in 2010. Based on the modeled external TP load to Lake Mirror, a 27.5 percent reduction in TP load (15.9 kg TP/year) is required to comply with the TSI criteria of 60 (FDEP 2007). The TP, TN, and chlorophyll *a* geometric mean for Lake Mirror for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-36. To comply with the NNC, concentration reductions of 44 percent for TP, 24 percent for TN, and 48 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Mirror is presented in Table 4-37. The median recorded chlorophyll *a*, TN, and TP concentrations exceed the NNC targets provided by EPA for Lake Mirror. Chlorophyll *a* concentrations in Lake Mirror have fluctuated but have remained consistently elevated above 20 µg/L (Figure 4-74). A statistically significant trend in chlorophyll *a* concentrations from 1983 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). No water quality improvement projects have been implemented in Lake Mirror to restore water quality. *Hydrilla* eradication projects have been implemented in Lake Mirror treating greater than 40 percent of the lake surface area in some years. Lake Mirror is an intermediate lake so improvements in water quality of the lake could result in some benefit farther downstream.

The Lake Mirror watershed is 163 acres in size and includes 144 acres (88 percent) of developed lands compared to 19 acres (12 percent) of undeveloped lands. The 2000-2007 median color value (17 PCU) was below 40 PCU indicating it is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 129 feet in December 2009. Bathymetry data are available for Lake Mirror for the December 2009 water level elevation (Figure 4-75). A water level of 130 feet was reported in July 2010, reflecting a 1.0 foot increase in water elevation when compared to 2009. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Mirror water quality and the surrounding watershed characteristics, four potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-76). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management

Table 4-36. Physical, chemical, and regulatory characteristics of Lake Mirror.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	138 (84 percent)
Relation to other lakes	Intermediate	**Developed land (acres)**	144 (88 percent)
Watershed area (acres)	163	**Undeveloped land (acres)**	19 (12 percent)
Lake area (acres)*	127	**Median water depth (feet)***	10.7
Perimeter (feet)*	9,189	**Maximum water depth (feet)***	13.6
Surface area: lake volume ratio*	0.12	**Volume (acre-feet)***	1,045
Watershed to surface area ratio*	1.28		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	38	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.32	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.054	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required†
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	44 percent

*at a water level elevation of 129 feet
**presented in section 5.0
† TMDL adopted

Photo 4-21. View of north shoreline of Lake Mirror.

Table 4-37. Lake Mirror water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	35	9	32	85
Color (PCU)	27	10	17	80
Conductivity (µmhos/cm)	25	190	209	240
Dissolved oxygen (mg/L)	25	6.68	8.73	11.34
pH	25	7.11	8.16	9.36
Secchi depth (feet)	38	0.9	2.1	4.4
Total nitrogen (mg/L)	38	0.86	1.41	2.24
Total phosphorus (mg/L)	34	0.006	0.040	0.080

Figure 4-73. Lake Mirror and associated watershed.

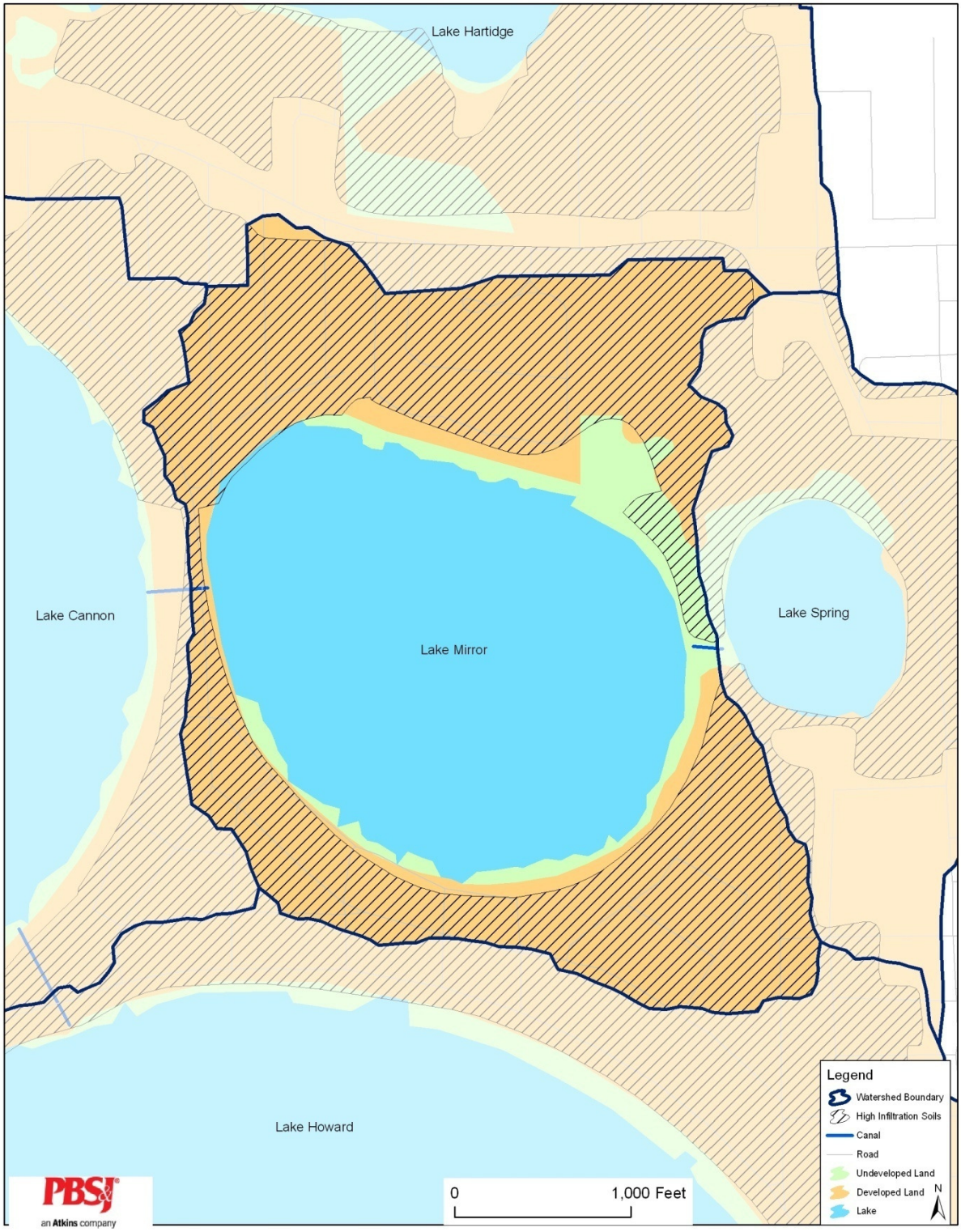


Figure 4-74. Lake Mirror chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

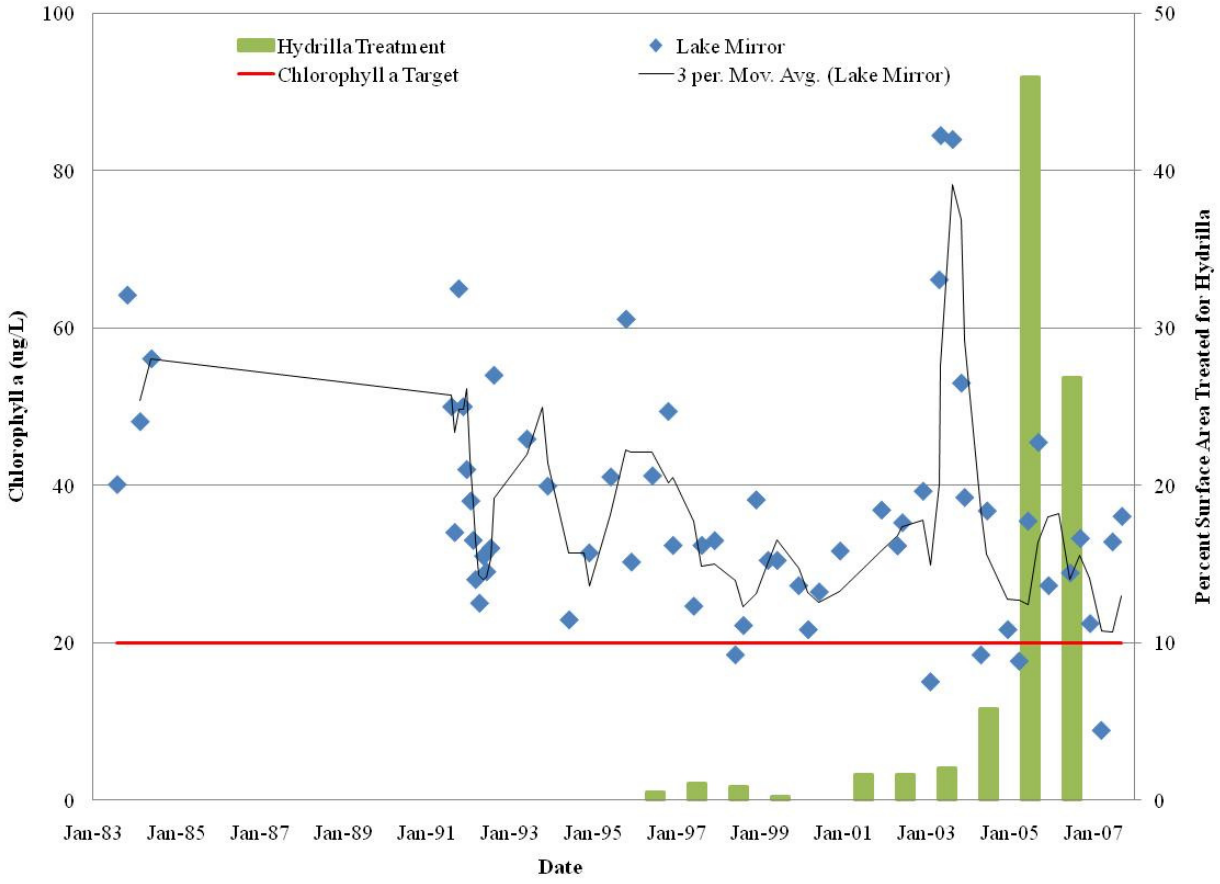


Figure 4-75. Lake Mirror bathymetry (December 2009) at water level elevation = 129 feet (Polk County Water Atlas).

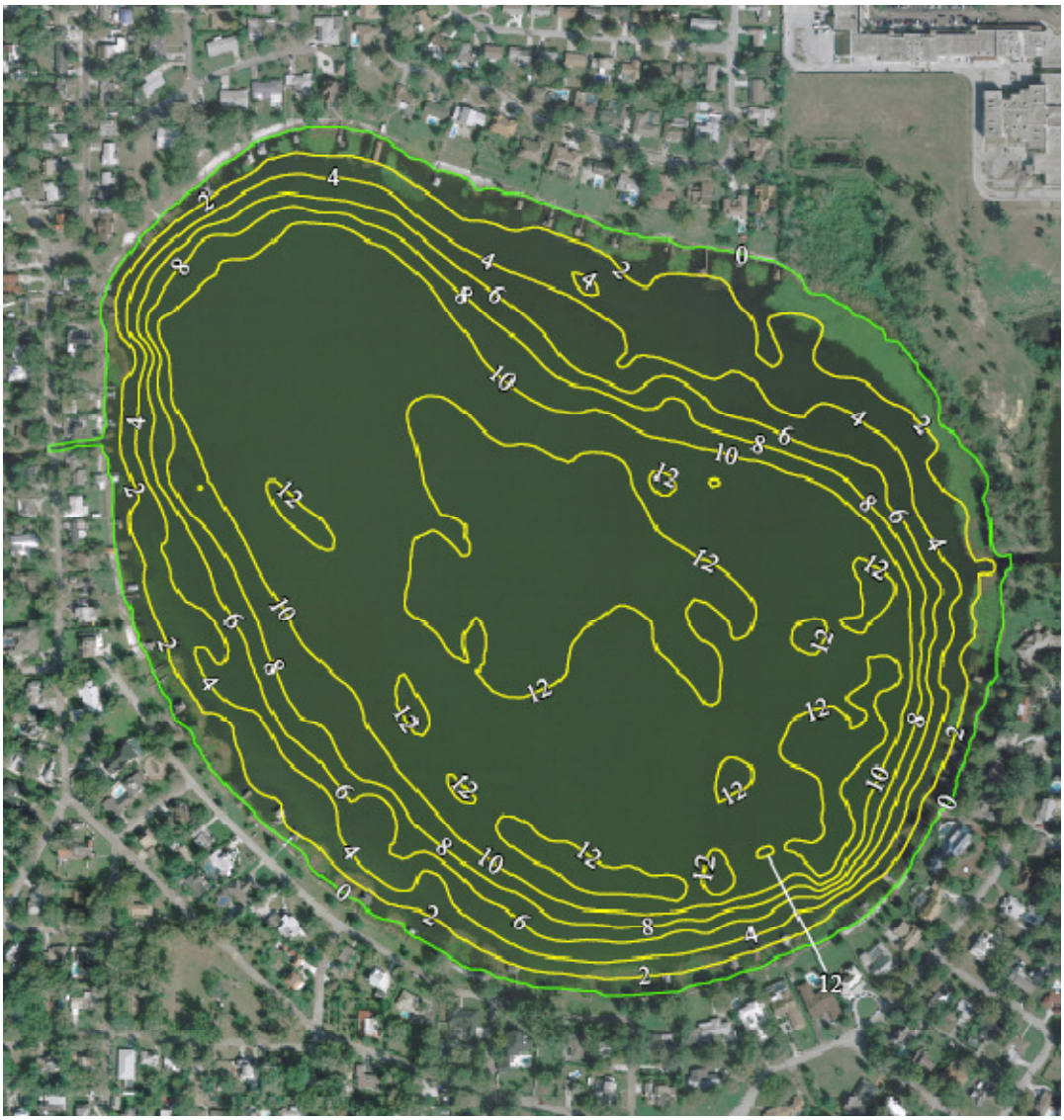
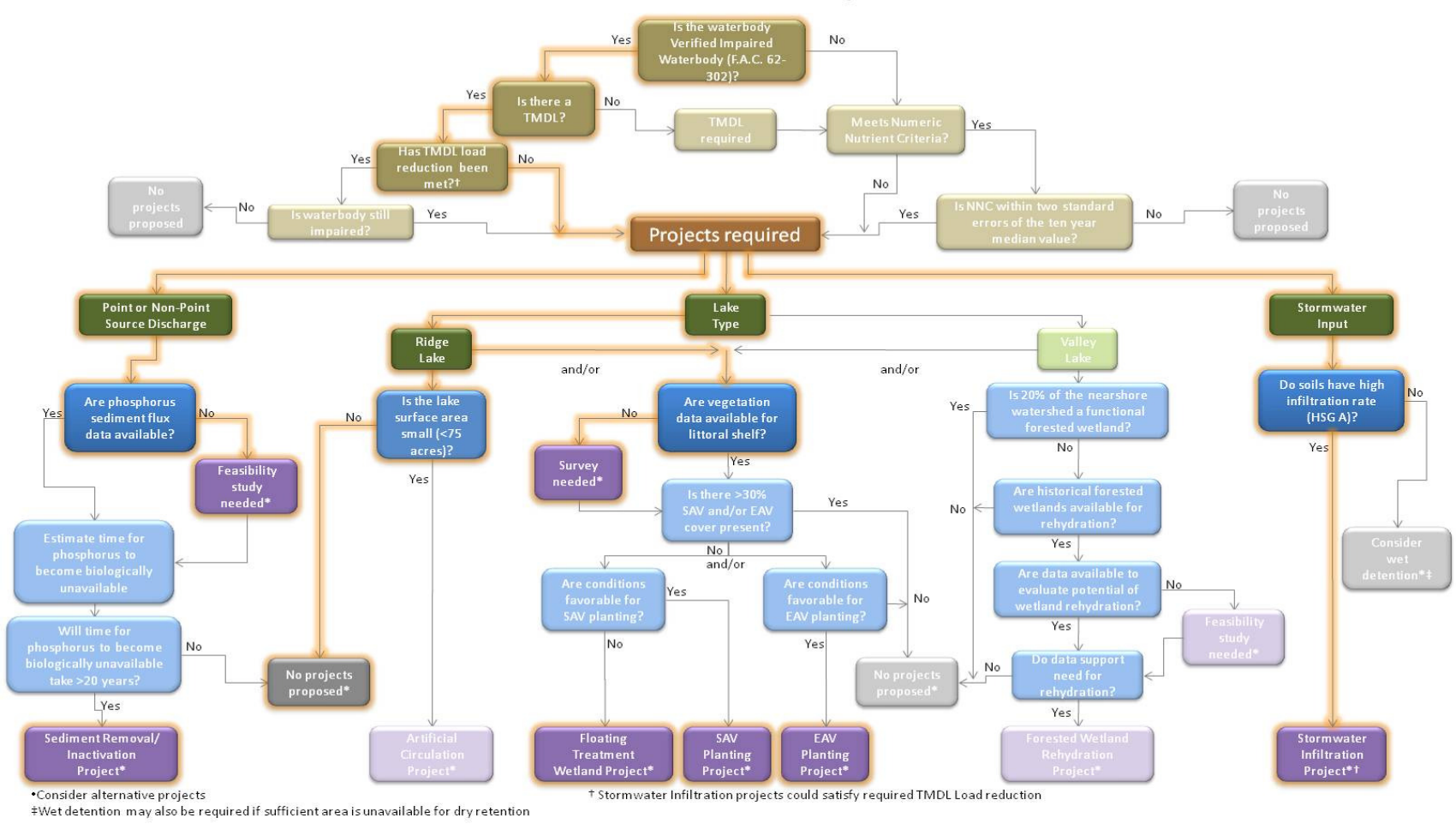


Figure 4-76. Lake Mirror decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Mirror watershed has approximately 138 acres (84 percent of the watershed) classified as high infiltration soils. A TMDL has been established for Lake Mirror, and as such, the SIA design should be focused on satisfying the TMDL requirements. SIA projects would need to encompass approximately three percent (five acres) of the watershed in order to accomplish an annual 15.9 kg reduction in TP loads to Lake Mirror. Acres of SIA estimated to meet the TP NNC was ten (six percent of the watershed) for a 17 percent phosphorus reduction in Lake Mirror to meet its NNC. Eighty-four percent of the watershed is characterized by high infiltration soils; therefore, it may be feasible to satisfy the TMDL load reductions through SIA implementation.

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Lake Mirror may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

In Lake Mirror, as much as 46 percent of the lake surface has been treated for *Hydrilla* eradication. A survey of existing SAV cover in Lake Mirror is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

The median secchi depth from 1997-2007 in Lake Mirror was 2.1 feet indicating that SAV should not be planted in water depths greater than 2 feet. The maximum planting effort should result in vegetation cover of approximately 12 percent of the lake bottom (15 acres).

Cost Estimate: $100,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance)

FTWs

If the feasibility study indicates that more than 30 percent of Lake Mirror has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Mirror is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.19. Lake Rochelle

Background

Physical and chemical characteristics specific to Lake Rochelle are presented here in the context of relevant regulatory criteria and requirements (Table 4-38). Lake Rochelle (WBID 1488B) is located in the WHCL Northern Chain and is hydrologically connected to lakes Conine and Haines via constructed navigable canals (Photo 4-22, Figure 4-77). In 2005, Lake Rochelle was declared verified impaired based on elevated TSI values (>60). A TMDL is required for Lake Rochelle to calculate load reductions necessary to satisfy the TSI criteria. The TP, TN, and chlorophyll *a* geometric means for Lake Rochelle for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-39. To comply with the NNC, concentration reductions of 37 percent for TP, 7 percent for TN and 22 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Rochelle is presented in Table 4-39. Median chlorophyll *a*, TN and TP concentrations exceed the NNC targets provided by EPA for Lake Rochelle. Chlorophyll *a* concentrations in Lake Rochelle have fluctuated but have remained consistently elevated above 20 µg/L (Figure 4-78). A statistically significant trend in chlorophyll *a* concentrations from 1986 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). Multiple *Hydrilla* eradication projects have been completed in the past several years, with greater than 60 percent of the lake being treated in 2002 and 2006. No water quality improvement projects have been implemented in Lake Rochelle to restore water quality. Lake Rochelle is adjacent to a headwater lake; therefore, improvements in water quality of the lake could result in benefits farther downstream.

The Lake Rochelle watershed is 1,162 acres in size and includes 290 acres (25 percent) of developed lands compared to 872 acres (75 percent) of undeveloped lands. The 2000-2007 median color value (25 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate that the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 128 feet in October 2005. Bathymetry data are available for Lake Rochelle for the October 2005 water level elevation (Figure 4-79). A water level of 126 feet was reported in August 2010, reflecting a 2.0 foot decrease in water elevation when compared to 2005. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Rochelle water quality and the surrounding watershed characteristics, five potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-80). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: Forested Wetland Rehydration
- Project 4: SAV Planting/Management or FTWs
- Project 5: EAV Planting/Management

Table 4-38. Physical, chemical, and regulatory characteristics of Lake Rochelle.

Physical			
Location in chain	Northern	**High infiltration soils (acres)**	580 (50 percent)
Relation to other lakes	Adjacent to Headwater	**Developed land (acres)**	290 (25 percent)
Watershed area (acres)	1,162	**Undeveloped land (acres)**	872 (75 percent)
Lake area (acres)*	583	**Median water depth (feet)***	11
Perimeter (feet)*	23,179	**Maximum water depth (feet)***	22.5
Surface area: lake volume ratio*	0.09	**Volume (acre-feet)***	6,758
Watershed to surface area ratio*	1.99		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	26	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.07	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.047	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	37 percent

*at a water level elevation of 128 feet
**presented in section 5.0

Photo 4-22. Lake Rochelle.

Table 4-39. Lake Rochelle water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	177	3	30	74
Color (PCU)	51	10	25	135
Conductivity (µmhos/cm)	49	182	229	274
Dissolved oxygen (mg/L)	49	5.72	8.26	12.32
pH	49	7.03	7.96	8.98
Secchi depth (feet)	180	1.4	2.4	8.6
Total nitrogen (mg/L)	182	0.371	1.07	1.71
Total phosphorus (mg/L)	174	0.010	0.050	0.105

Figure 4-77. Lake Rochelle and associated watershed.

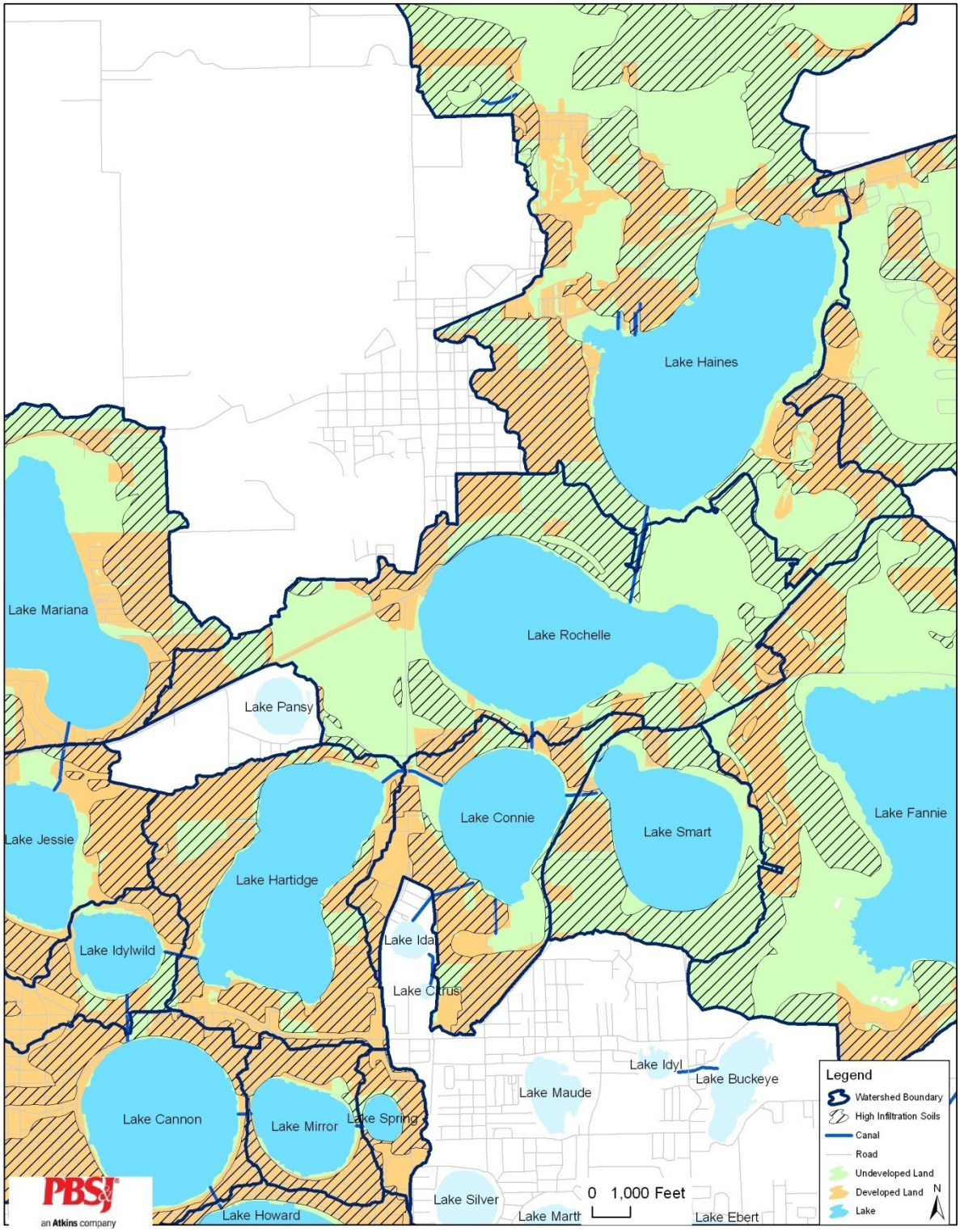


Figure 4-78. Lake Rochelle chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1986 to 2007.

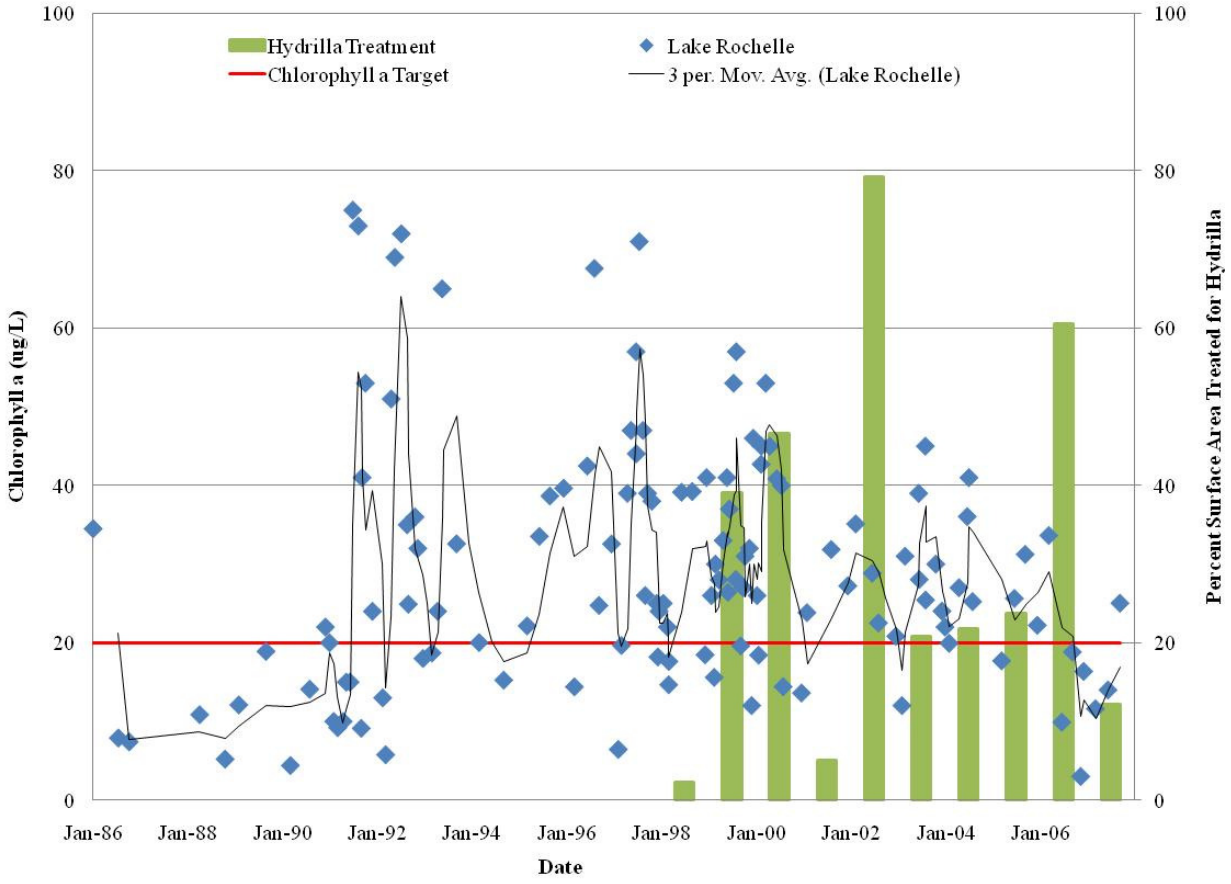


Figure 4-79. Lake Rochelle bathymetry (October 2005) at water level elevation = 128 feet (Polk County Water Atlas).

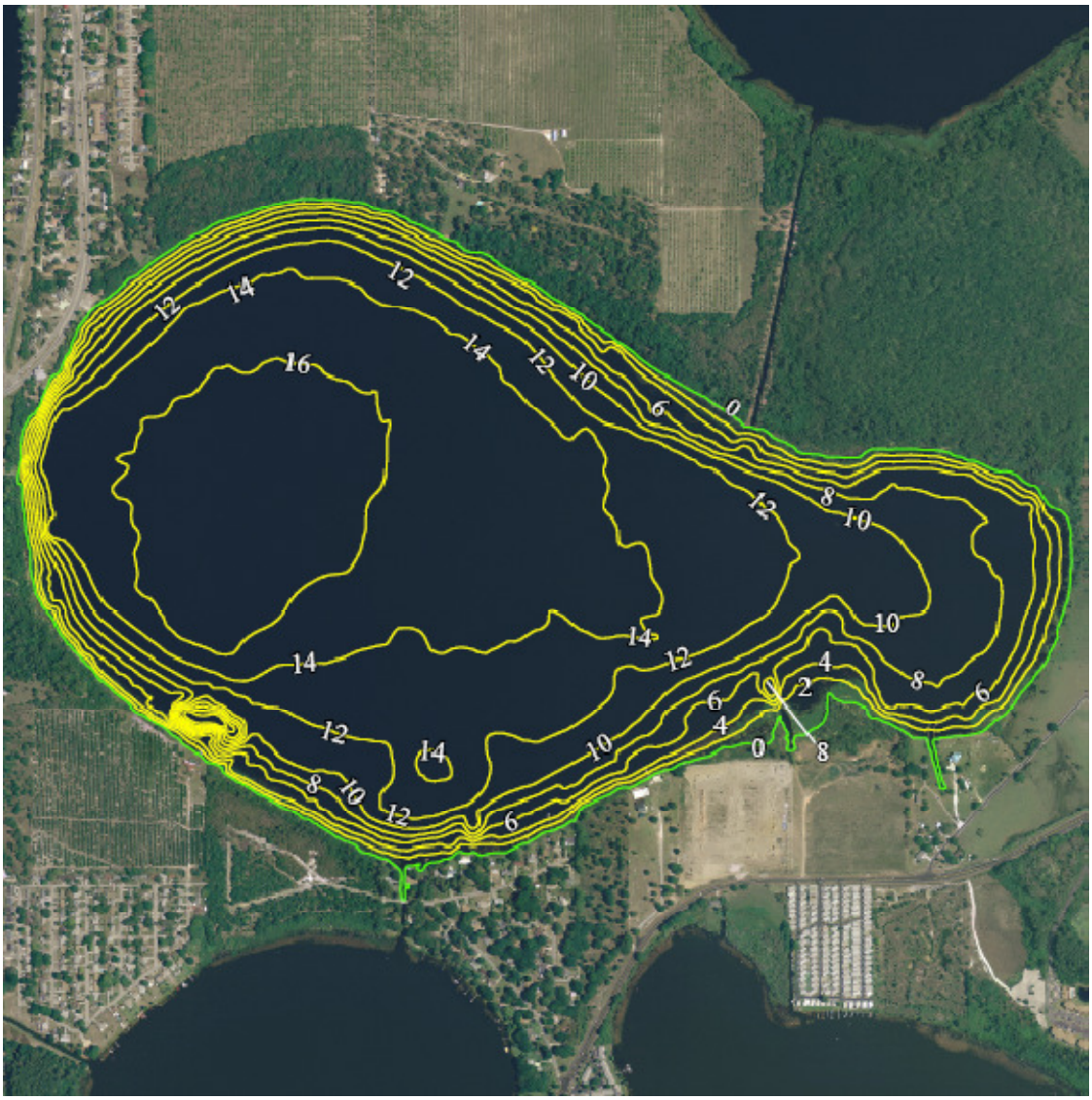
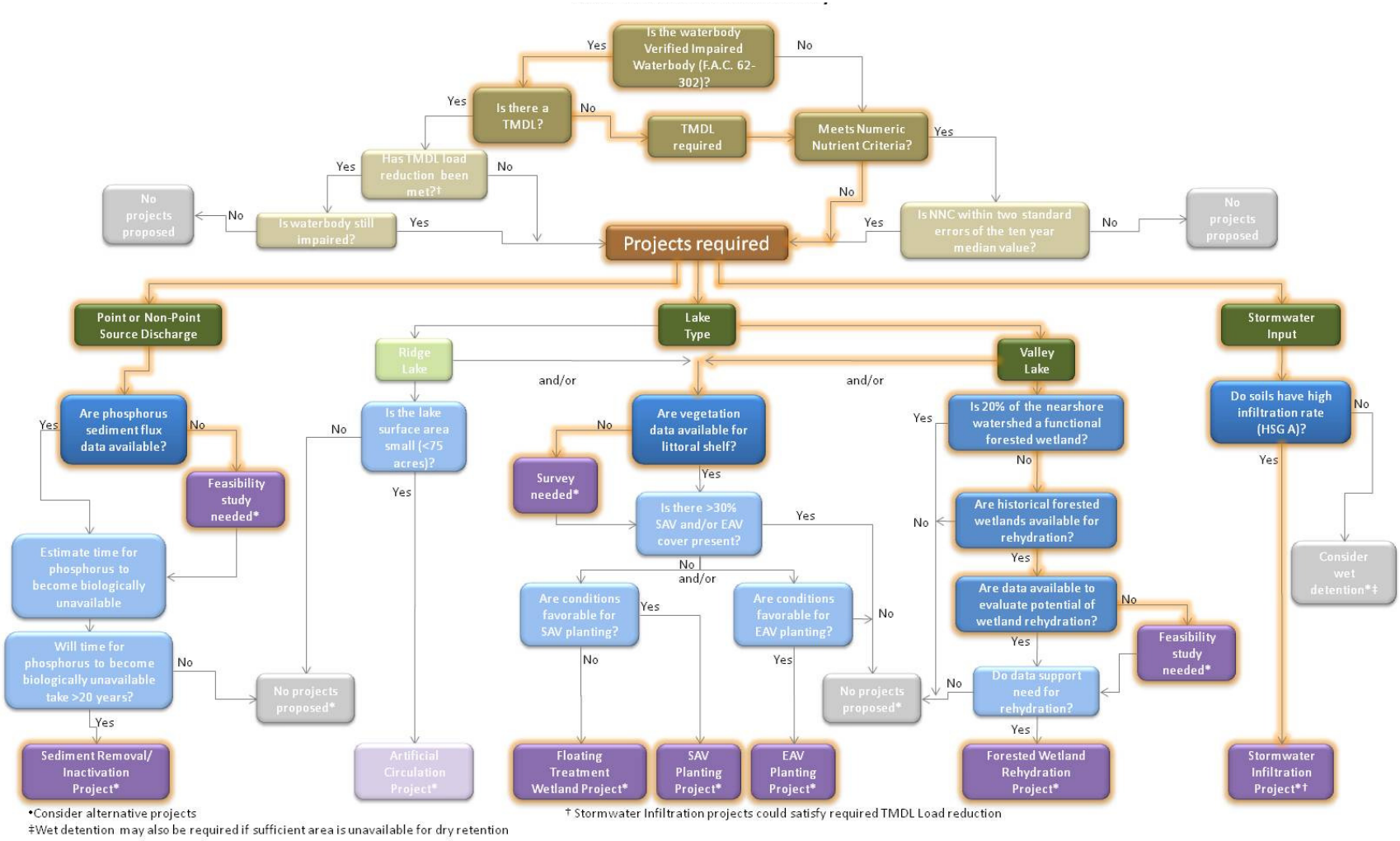


Figure 4-80. Lake Rochelle decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Rochelle watershed has approximately 580 acres (50 percent of the watershed) classified as high infiltration soils. The Northern Chain was not included in the PLRG study (USF 2005), therefore a TMDL has not been completed for Lake Rochelle and data to estimate SIA acres for TP load reduction are not available at this time. SIA implementation could have the additional benefit of increasing storage to supplement dry season lake levels and a reduction in stormwater loads that can be later applied to the required TMDL TP load reduction. As such, SIA design should be focused on recharging the surficial aquifer.

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Lake Rochelle may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: Forested Wetland Rehydration

Approximately 35 percent of the land cover within the 500 foot buffer surrounding Lake Rochelle is classified as wetlands using the 2006 FLUCS data. Forested wetlands encompass 19 percent of the total wetland area, which is within the 10 to 20 percent recommended forested wetland cover required to maintain color levels above 50 PCU. While FLUCS classifies the land cover as forested wetland, the hydrologic connection between the lake and adjacent land might not be present as is observed along the northern rim of the Lake.

Two proposed project area were identified adjacent to Lake Rochelle are expected to rehydrate approximately 310 acres (Figure 4-81). The feasibility study is recommended in order to evaluate the proposed project area for inundation.

Feasibility study cost estimate: $100,000.

Figure 4-81. Proposed forested wetland rehydration project areas for Lake Rochelle.

Project 4: SAV Planting or FTWs

SAV Planting

In Lake Rochelle, *Hydrilla* eradication occurs frequently attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Rochelle is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

SAV plants should not be planted in water depths greater than 2 feet based on the median secchi depth values (2.4 feet). The maximum planting effort could result in vegetation cover of approximately 4 percent of the lake bottom (26 acres).

Cost Estimate: $120,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance).

FTWs

If the feasibility study indicates that more than 30 percent of Lake Rochelle has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 5: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Rochelle is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.20. Lake Roy

Background

Physical and chemical characteristics specific to Lake Roy are presented here in the context of relevant regulatory criteria and requirements (Table 4-40). Lake Roy (WBID 1521O), a lake in the WHCL Southern Chain, is hydrologically connected to Lake Lulu via a constructed navigable canal (Photo 4-23, Figure 4-82). Lake Roy has not been identified as impaired; therefore, no TMDL is required. The NNC are performance based, and an exceedance more than once every three years results in non-compliance. Insufficient data are available to compare the geometric means to the EPA NNC based on the EPA data requirements. However, the NNC targets for TN and TP are within two times the standard error of the ten year median TN and TP concentrations. The results of this comparison indicate that a slight degradation in water quality in Lake Roy could result in an impairment designation. Therefore, water quality restoration projects are recommended for Lake Roy as a preventative action. The TP, TN, and chlorophyll *a* geometric mean for Lake Roy for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-41. Concentration reductions to comply with the NNC cannot be calculated due to the lack of sufficient data. A summary of water quality statistics for Lake Roy is presented in Table 4-41. The median chlorophyll *a*, TN and TP concentrations are below the NNC targets provided by EPA for Lake Roy. Chlorophyll *a* concentrations in Lake Roy are limited and fluctuate around 20 µg/L (Figure 4-83). A statistically significant trend in chlorophyll *a* concentrations from 1984 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). No water quality improvement projects have been implemented in Lake Roy to restore water quality. Several *Hydrilla* eradication projects have been implemented in Lake Roy treating greater than 40 percent of lake surface area in some years. Lake Roy is adjacent to a terminal Lake; therefore, improvements in water quality of the lake would result in little benefit farther downstream.

The Lake Roy watershed is 297 acres in size and includes 270 acres (91 percent) of developed lands compared to 26 acres (9 percent) of undeveloped lands. The 2000-2007 median color value (15 PCU) was below 40 PCU indicating it is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 129 feet in August 2009. Bathymetry data are available for Lake Roy for the August 2009 water level elevation (Figure 4-84). A water level of 130 feet was reported in July 2010, reflecting a 1.0 foot increase in water elevation when compared to 2009. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Roy water quality and the surrounding watershed characteristics, five potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-85). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management
- Project 5: Artificial Circulation

Table 4-40. Physical, chemical, and regulatory characteristics of Lake Roy.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	233 (78 percent)
Relation to other lakes	Adjacent to Terminal	**Developed land (acres)**	270 (91 percent)
Watershed area (acres)	297	**Undeveloped land (acres)**	26 (9 percent)
Lake area (acres)*	74	**Median water depth (feet)***	13.6
Perimeter (feet)*	9,695	**Maximum water depth (feet)***	23.1
Surface area: lake volume ratio*	0.08	**Volume (acre-feet)***	896
Watershed to surface area ratio*	4.01		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	ID	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	ID	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	ID	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	No	**TMDL status**	NA
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	ID

*at a water level elevation of 129 feet
**presented in section 5.0
ID- Insufficient Data
NA- Not Applicable

Photo 4-23. Beach Motel adjacent to Lake Roy.

Table 4-41. Lake Roy water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	6	7	15	31
Color (PCU)	2	15	15	15
Conductivity (µmhos/cm)	3	258	269	287
Dissolved oxygen (mg/L)	3	9.55	10.21	10.25
pH	3	8.58	8.77	9.37
Secchi depth (feet)	7	2.7	3.6	5.5
Total nitrogen (mg/L)	8	0.70	0.94	1.71
Total phosphorus (mg/L)	8	0.021	0.028	0.040

Figure 4-82. Lake Roy and associated watershed.

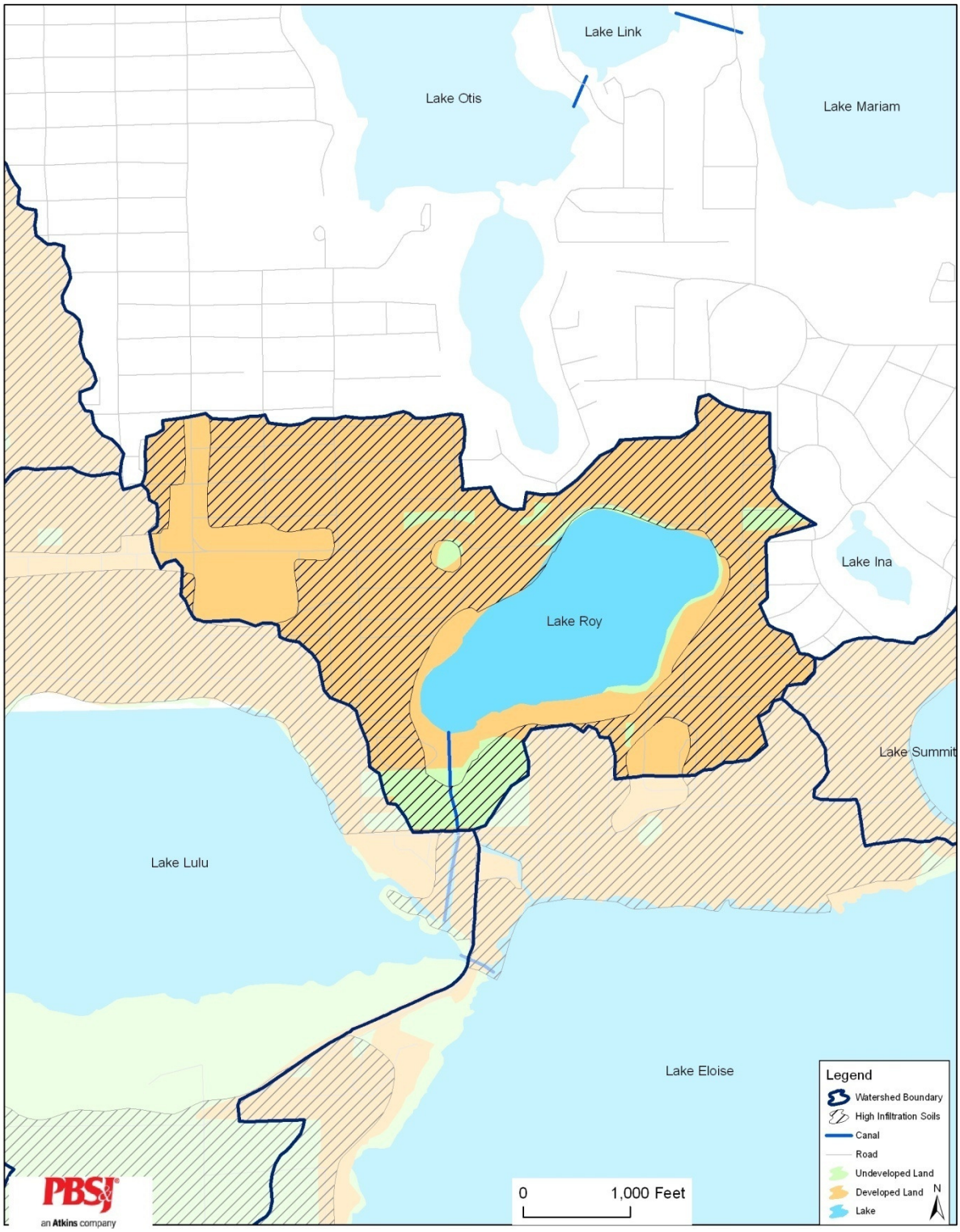


Figure 4-83. Lake Roy chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1984 to 2007.

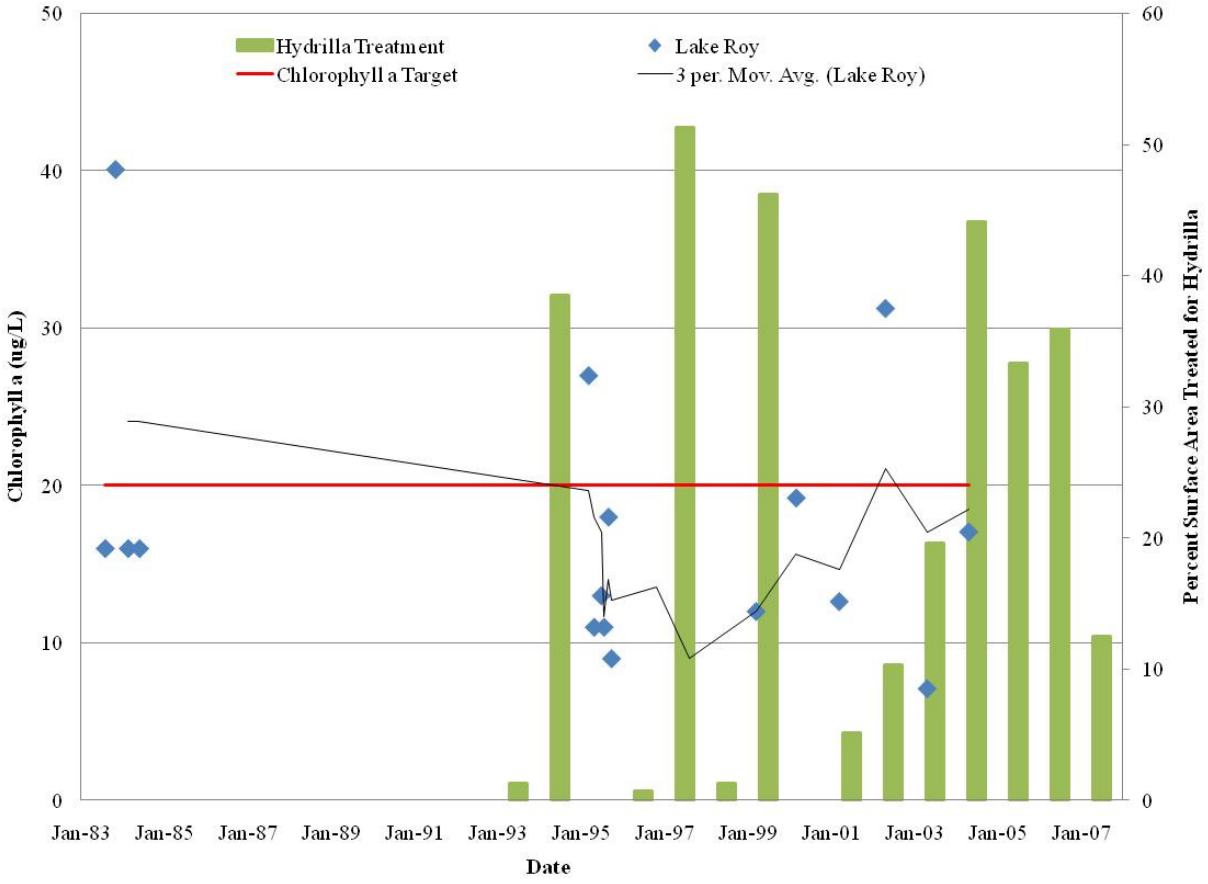


Figure 4-84. Lake Roy bathymetry (August 2009) at water level elevation = 129 feet (Polk County Water Atlas).

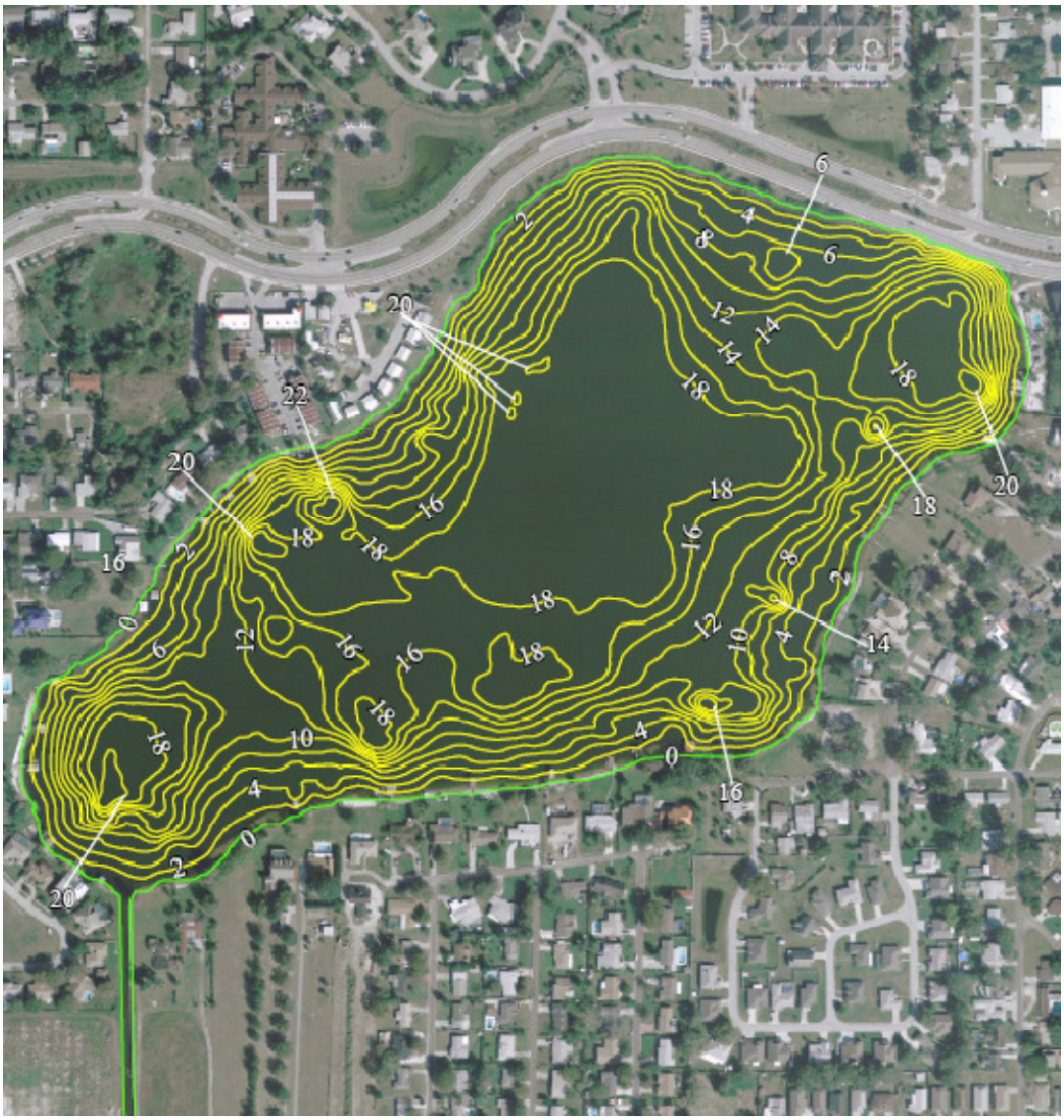
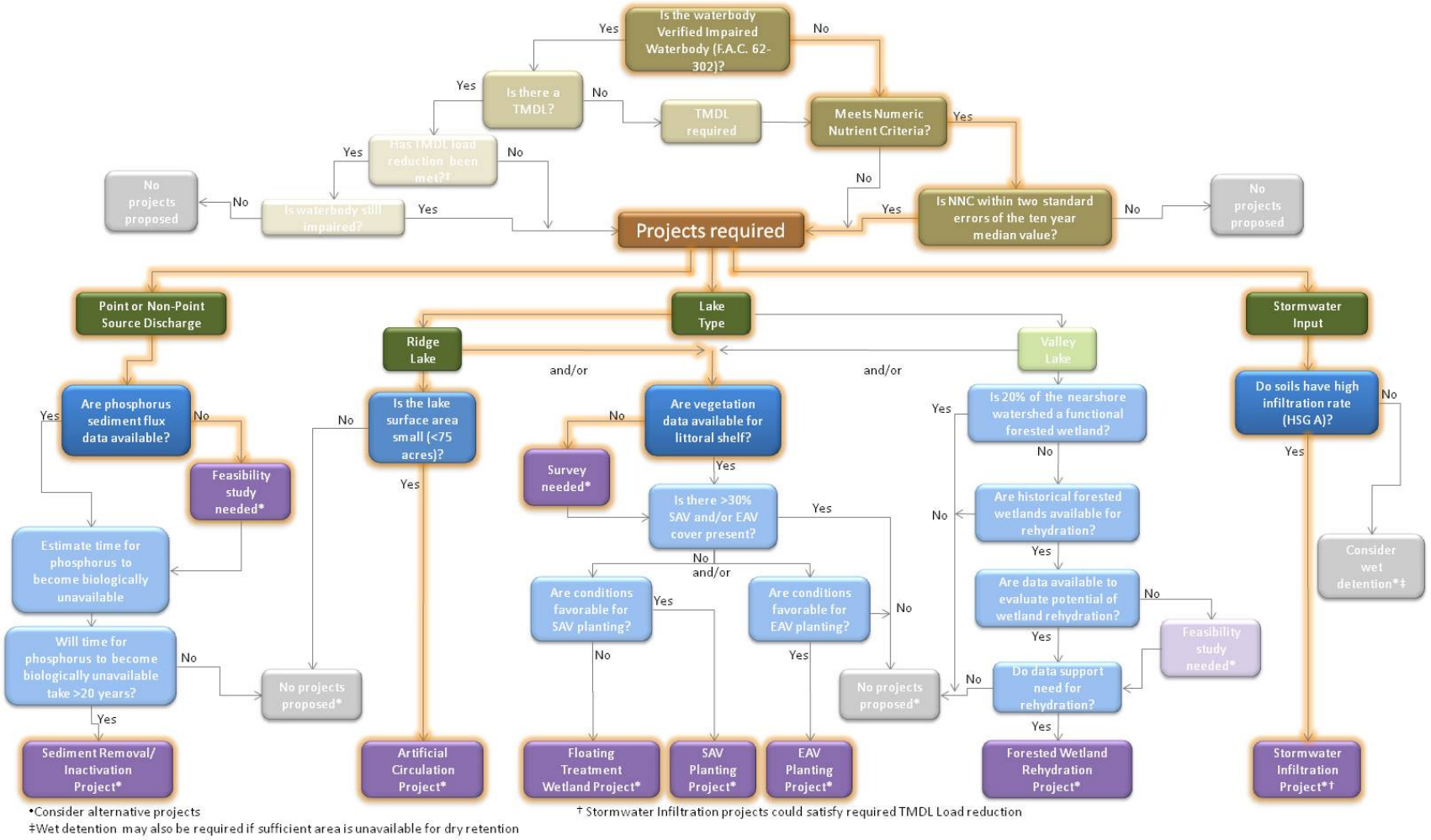


Figure 4-85. Lake Roy decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Roy watershed has approximately 233 acres (78 percent of the watershed) classified as high infiltration soils. Lake Roy does not have a TMDL based on the unimpaired status, therefore, SIA acres estimates were calculated using data from the PLRG (USF 2005). The SIA estimate for Lake Roy was 12 acres (approximately four percent of the watershed) to meet a 21 percent PLRG. Insufficient data are available to calculate the TP geometric mean for Lake Roy, therefore, acres of SIA estimated to meet the TP NNC were not calculated. SIA design should be focused on recharging the surficial aquifer. SIA implementation should have a double benefit of increasing storage to supplement dry season lake levels and a reduction in stormwater loads which can be later applied toward TMDL TP load reduction (if necessary).

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Lake Roy may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

In Lake Roy, *Hydrilla* eradication has been completed over as much as 50 percent of the lake surface area attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Roy is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

SAV plants should not be planted in water depths greater than 4 feet based on the median secchi depth values (3.6 feet). The maximum planting effort could result in vegetation cover of approximately 15 percent of the lake bottom (11 acres).

Cost Estimate: $65,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance)

FTWs

If the feasibility study indicates that more than 30 percent of Lake Roy has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Roy is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

Project 5: Artificial Circulation

The project design is based on the assumption that the system configuration developed by SolarBee® for Lake Blue is applicable for Lake Roy. Therefore, each circulation pump is assumed to effectively circulate 16 to 20 acres. The surface area of Lake is 74 acres requiring the purchase and installation of four SB10000 v 18 machines.

Cost Estimate: $215,000 (estimate based on cost provided for Lake Blue by Solar Bee®).

4.21. Lake Shipp

Background

Physical and chemical characteristics specific to Lake Shipp are presented here in the context of relevant regulatory criteria and requirements (Table 4-42). Lake Shipp (WBID 1521D), a lake in the WHCL Southern Chain, is hydrologically connected to lakes May and Lulu via constructed navigable canals (Photo 4-24, Figure 4-86). In 2005, Lake Shipp was declared verified impaired based on elevated TSI values (>60). A TMDL was adopted for the Southern Chain of the WHCL, including Lake Shipp (FDEP 2007), and Lake Shipp was subsequently delisted from impairment by FDEP in 2010. Based on the modeled external TP load to Lake Shipp, a 65 percent reduction in TP load (145 kg TP/year) is required to comply with the TSI criteria of 60 (FDEP 2007). The TP, TN, and chlorophyll *a* geometric mean for Lake Shipp for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-42. To comply with the NNC, concentration reductions of 42 percent for TP, 43 percent for TN, and 67 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Shipp is presented in Table 4-43. Lake Shipp historically received point source discharges from two WWTFs (Robert Brothers vegetable and Bordo's citrus processing plant). While the effluent discharges have been eliminated, the discharges resulted in nutrient and sediment accumulation in the lake bottom. An inverse relationship between lake levels and both TP and chlorophyll *a* concentrations may suggest sediment resuspension resulting in a decline in water quality. *Hydrilla* eradication projects are performed regularly treating up to 19 percent of the lake surface area in some years. The median chlorophyll *a*, TN and TP concentrations continue to exceed the NNC targets provided by EPA for Lake Shipp. Chlorophyll *a* concentrations in Lake Shipp are elevated above 20 µg/L consistently (Figure 4-87). A statistically significant trend in chlorophyll *a* concentrations from 1983 to 2007 was observed (seasonal Kendall-Tau, p=0.10). No water quality restoration projects have been implemented in Lake Shipp in order to improve water quality. Improvements in water quality of Lake Shipp, which is adjacent to a terminal lake, could result in little benefit farther downstream.

The Lake Shipp watershed is 534 acres in size and includes 378 acres (71 percent) of developed lands compared to 156 acres (29 percent) of undeveloped land. The 2000-2007 median color value (20 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 129 feet in June 2007. Bathymetry data are available for Lake Shipp for the June 2007 water level elevation (Figure 4-88). A water level of 130 feet was reported in August 2010, reflecting a 1.0 foot increase in water elevation when compared to 2007. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Shipp water quality and the surrounding watershed characteristics, four potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure

4-89). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management

Table 4-42. Physical, chemical, and regulatory characteristics of Lake Shipp.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	364 (68 percent)
Relation to other lakes	Adjacent to Terminal	**Developed land (acres)**	378 (71 percent)
Watershed area (acres)	534	**Undeveloped land (acres)**	156 (29 percent)
Lake area (acres)*	274	**Median water depth (feet)***	4.5
Perimeter (feet)*	15,064	**Maximum water depth (feet)***	14.5
Surface area: lake volume ratio*	0.18	**Volume (acre-feet)***	1,533
Watershed to surface area ratio*	1.95		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	60	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.76	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.052	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	Required†
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	42 percent

*at a water level elevation of 129 feet
†TMDL adopted
**presented in section 5.0

Photo 4-24. Boat docks located on Lake Shipp.

Table 4-43. Lake Shipp water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	101	22	46	92
Color (PCU)	27	5	20	25
Conductivity (µmhos/cm)	32	191	227	365
Dissolved oxygen (mg/L)	32	5.85	8.59	10.27
pH	32	6.8	7.79	8.71
Secchi depth (feet)	102	0.8	1.4	3.2
Total nitrogen (mg/L)	103	0.09	1.41	2.58
Total phosphorus (mg/L)	98	0.01	0.058	0.139

Figure 4-86. Lake Shipp and associated watershed.

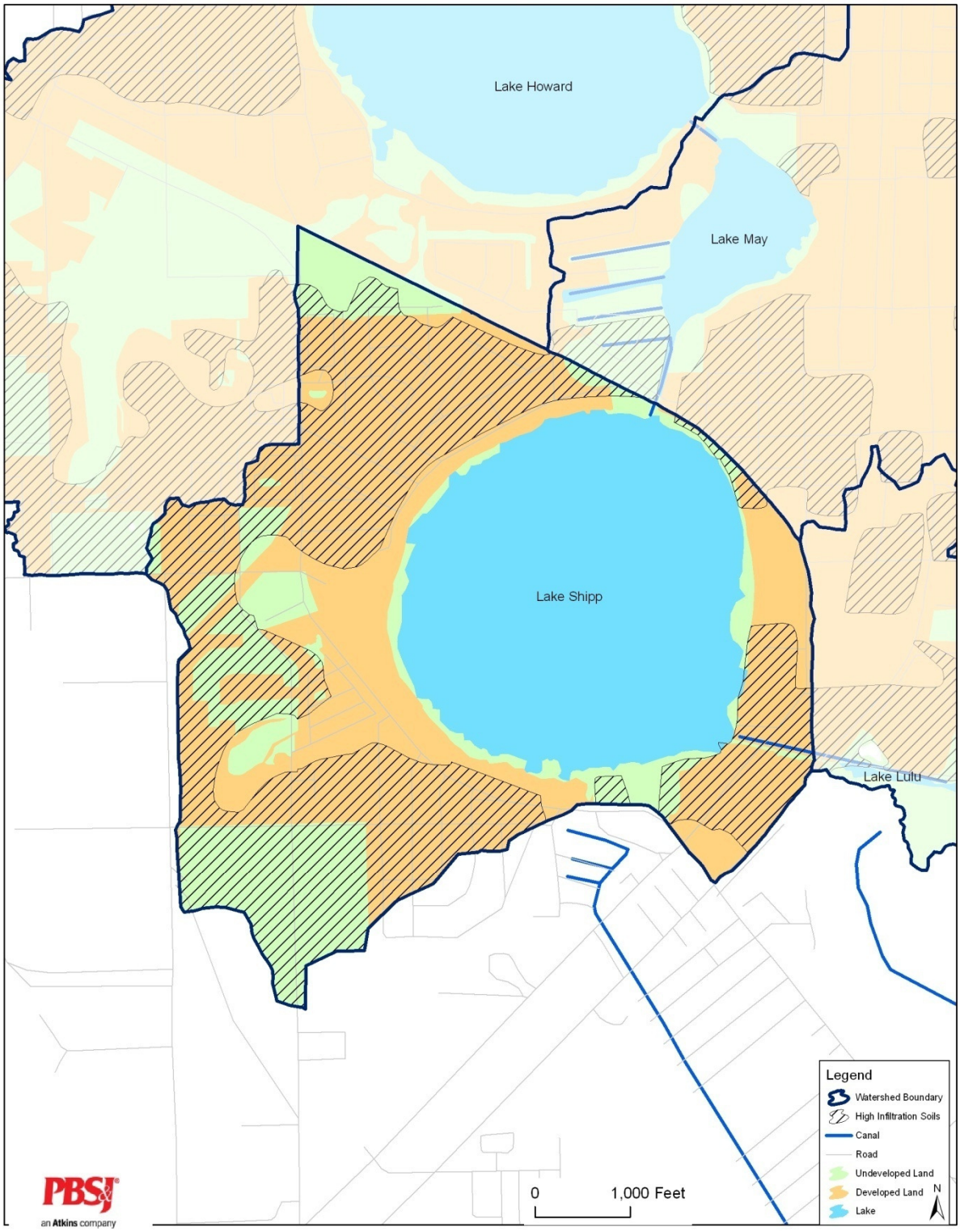


Figure 4-87. Lake Shipp chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

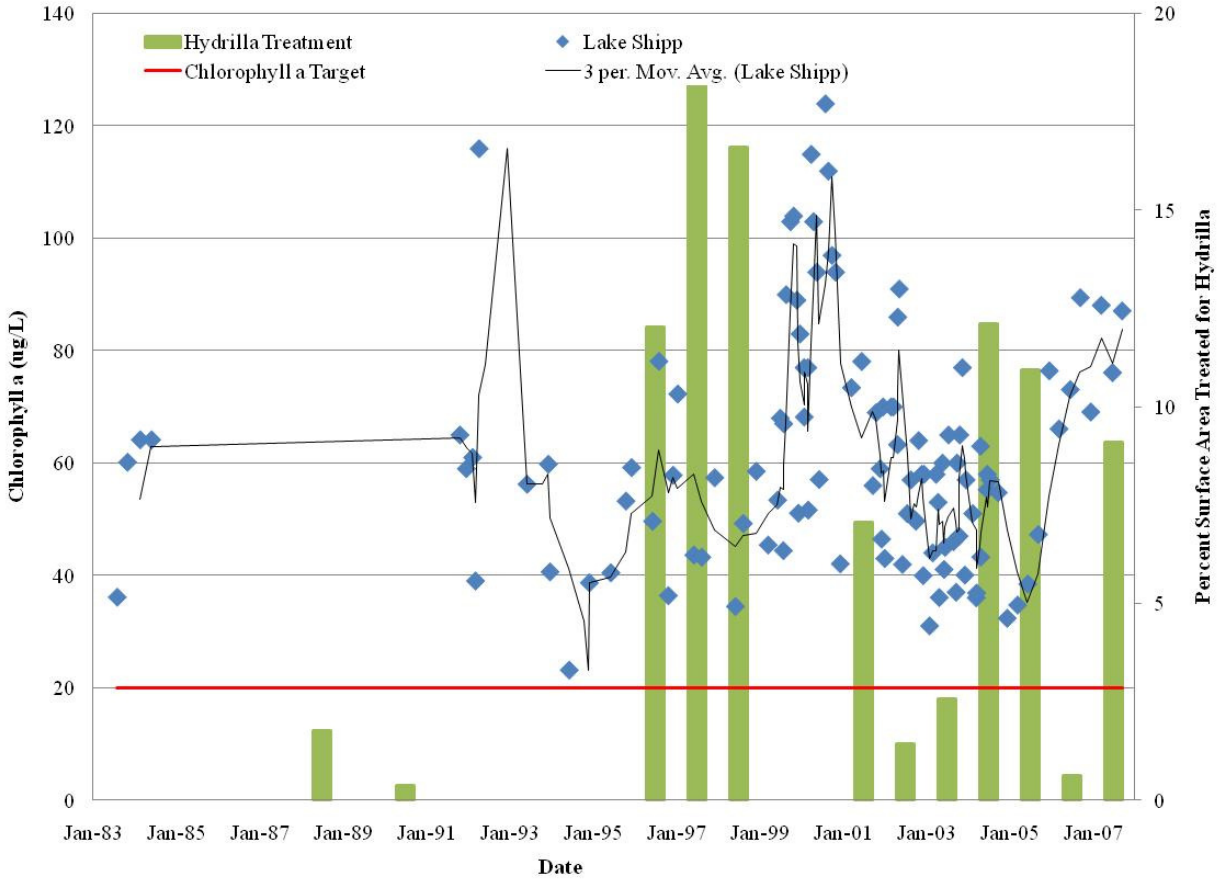
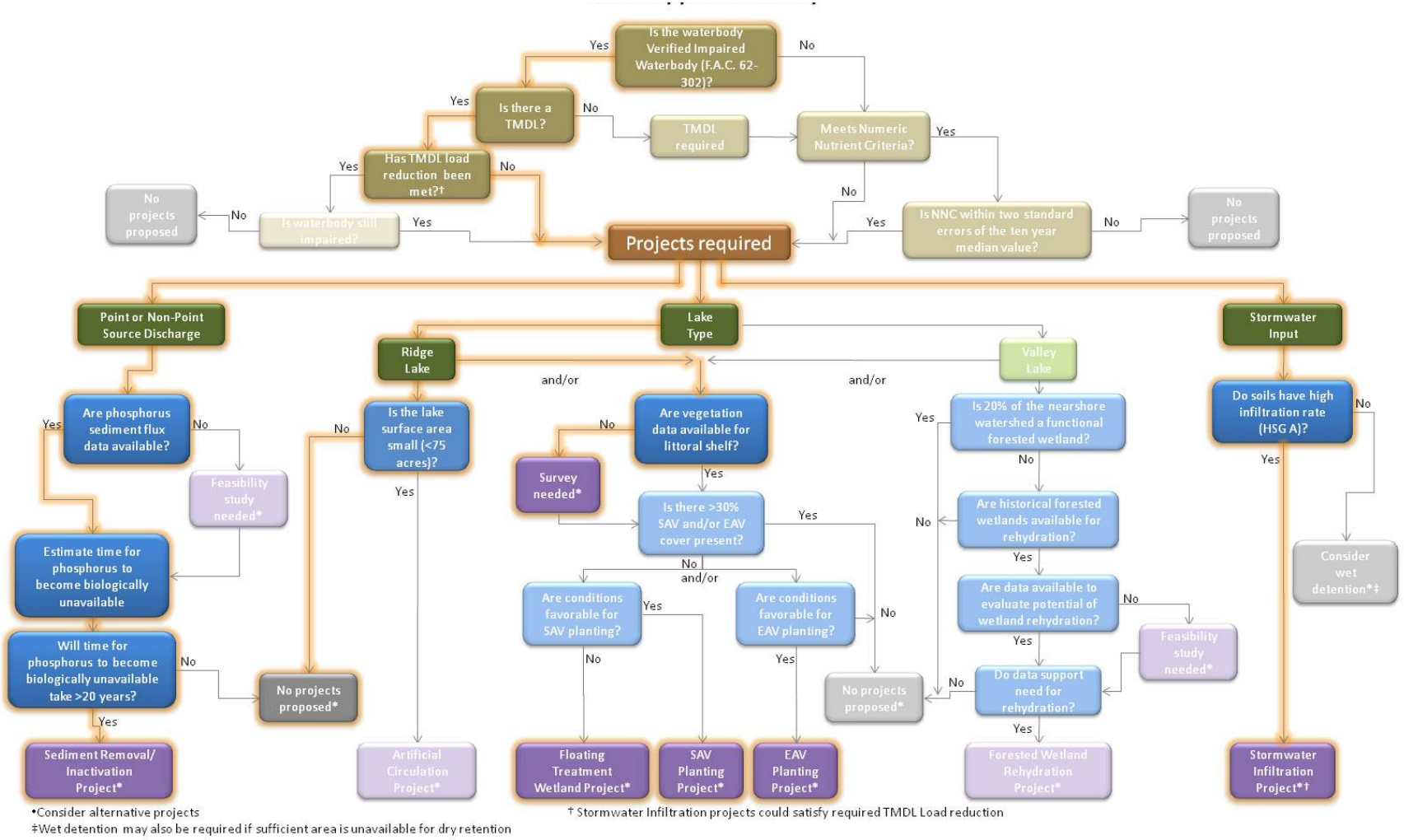


Figure 4-88. Lake Shipp bathymetry (June 2007) at water level elevation = 129 feet (Polk County Water Atlas).

Figure 4-89. Lake Shipp decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Shipp watershed has approximately 364 acres (68 percent of the watershed) classified as high infiltration soils. A TMDL has been established for Lake Shipp, and as such, the SIA design should be focused on satisfying the TMDL requirements. SIA projects would need to encompass approximately 11 percent (60 acres) of the watershed in order to accomplish an annual 145 kg reduction in TP loads to Lake Shipp. Acres of SIA estimated to meet the TP NNC was 47 (nine percent of the watershed) for a 42 percent phosphorus reduction in Lake Shipp to meet its NNC. Sixty-eight percent of the watershed is characterized by high infiltration soils; therefore, it may be feasible to satisfy the TMDL load reduction through SIA implementation.

Project 2: Sediment Removal/Inactivation

Historical point source discharges to Lake Shipp from WWTFs require further evaluation of the potential internal phosphorus load from the lake bottom sediments. The City of Winter Haven funded a Sediment Removal Feasibility Study performed by ERD to evaluate the sediment characteristics, phosphorus flux, and volume (ERD 2010). An estimate of the length of time until the pool of available phosphorus within the bottom sediments returns to background conditions was calculated using TP concentration in the sediments, the percent of available phosphorus and bulk density. Approximately 76 years are required for phosphorus concentrations to return to background conditions. Therefore, sediment removal/inactivation is recommended to address internal phosphorus loads. A cost estimate for sediment removal/inactivation has been completed by ERD (2010).

Sediment Removal: Costs associated with hydraulic dredging can be highly variable depending upon a variety of factors such as dredge capacity, availability of disposal areas, and distance to disposal areas, sludge dewatering requirements, booster pump requirements, and final sediment disposal. Since none of these factors have been fully evaluated at this time, a general sediment dredging cost of approximately $10.00 per cubic yard is assumed for this analysis. This value assumes that a shoreline dewatering facility would be used. A summary of estimated costs for hydraulic dredging in Lake Shipp based on the previously determined organic sediment volumes, estimated dredging costs is $4,872,300. An estimated 302 ac-ft (487,227 cubic yards) of organic material would be removed.

Sediment Inactivation: A summary of estimated application costs for sediment inactivation in Lake Shipp is given based on an application of 10:1 Al:P ratio. This estimate assumes an alum volume of 1,000,489 gallons and a sodium aluminate volume of 250,122 gallons would be applied over two applications within a 6-12 month time period. It is assumed that the alum and sodium aluminate are purchased at a government contract price. Planning and mobilization costs are estimated to be approximately $5000 per application, which includes initial planning, mobilization of equipment to the site, demobilization at the completion of the application process, and clean-up. A labor rate of $125/hour is assumed that includes labor costs, water quality monitoring, expenses, equipment rental, insurance, mileage, and application equipment fees. The estimated cost for sediment inactivation in Lake Shipp is $1,939,766 or approximately $969,903 per application.

A representative from Phoslock® has been contacted to provide a cost estimate for Phoslock® application to Lake Shipp to provide a cost comparison.

Project 3: SAV Planting or FTWs

SAV Planting

In Lake Shipp, *Hydrilla* eradication has been completed over as much as 49 percent of the lake surface area attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Shipp is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

SAV plants should not be planted in water depths greater than 2 feet based on the median secchi depth values (1.4 feet). The maximum planting effort could result in vegetation cover of approximately 12 percent of the lake bottom (34 acres). Due to the extensive organic material located in Lake Shipp, it is recommended that SAV planting be performed after sediment removal/inactivation, if completed. If sediment removal is completed, the planting area would need to be recalculated using updated bathymetry data.

Cost Estimate: $170,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance)

FTWs

If the feasibility study indicates that more than 30 percent of Lake Shipp has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Shipp is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

4.22. Lake Smart

Background

Physical and chemical characteristics specific to Lake Smart are presented here in the context of relevant regulatory criteria and requirements (Table 4-44). Lake Smart (WBID 1488A) is located in the WHCL Northern Chain and is hydrologically connected to lakes Conine and Fannie via constructed canals (Photo 4-25, Figure 4-90). The connection to Lake Conine is navigable, however, the connection with Lake Fannie is controlled using a gated structure and is not navigable. In 2005, Lake Smart was declared verified impaired based on elevated TSI values (>60). A TMDL is required for Lake Smart to calculate load reductions necessary to satisfy the TSI criteria. The TP, TN, and chlorophyll *a* geometric means for Lake Smart for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-44. To comply with the NNC, concentration reductions of 10 percent for TP, 13 percent for TN, and 30 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Smart is presented in Table 4-45. Median chlorophyll *a*, TN and TP concentrations exceed the NNC targets provided by EPA for Lake Smart. Chlorophyll *a* concentrations in Lake Smart fluctuate and have remained consistently elevated above 20 µg/L, but appear to decrease over time (Figure 4-91). A statistically significant decline in chlorophyll *a* concentrations from 1986 to 2007 was observed (seasonal Kendall-Tau, p=0.0019), indicating an improvement in water quality. Multiple *Hydrilla* eradication projects have been completed in the past several years, with greater than 80 percent of the lake being treated in 2003. No water quality improvement projects have been implemented in Lake Smart to restore water quality. Lake Smart is adjacent to Lake Fannie, an isolated lake with a gated structure; therefore, improvements in water quality of the lake would result in little benefits farther downstream.

The Lake Smart watershed is 352 acres in size and includes 67 acres (19 percent) of developed lands compared to 285 acres (81 percent) of undeveloped lands. The 2000-2007 median color value (46 PCU) was above 40 PCU indicating the lake is a colored lake. Using the adopted EPA NNC for Florida lakes, characterization of alkalinity or acidity is not necessary based on the colored classification of Lake Smart. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 125 feet in June 2007. Bathymetry data are available for Lake Smart for the June 2007 water level elevation (Figure 4-91). A water level of 126 feet was reported in August 2010, reflecting a 1.0 foot increase in water elevation when compared to 2007. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Smart water quality and the surrounding watershed characteristics, five potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-92). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of

priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: Forested Wetland Rehydration
- Project 4: SAV Planting/Management or FTWs
- Project 5: EAV Planting/Management

Table 4-44. Physical, chemical, and regulatory characteristics of Lake Smart.

Physical			
Location in chain	Northern	**High infiltration soils (acres)**	291 (83 percent)
Relation to other lakes	Adjacent to Terminal	**Developed land (acres)**	67 (19 percent)
Watershed area (acres)	352	**Undeveloped land (acres)**	285 (81 percent)
Lake area (acres)*	282	**Median water depth (feet)***	7.2
Perimeter (feet)*	18,678	**Maximum water depth (feet)***	11.5
Surface area: lake volume ratio*	0.13	**Volume (acre-feet)***	2,227
Watershed to surface area ratio*	1.25		
Water Chemistry			
Locally-derived: acidic or alkaline	NA	**Clear or colored**	Colored
Geometric mean chlorophyll *a* (µg/L)	29	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	1.42	**NNC TN target (mg/L)**	1.23
Geometric mean TP (mg/L)	0.056	**NNC TP target (mg/L)**	0.050
Regulatory Data			
Impaired	Yes	**TMDL status**	Required
Chlorophyll *a* trend	Decreasing**	**TP concentration reduction required**	10 percent

*at a water level elevation of 125 feet
**presented in section 5.0

Photo 4-25. Lake Smart.

Table 4-45. Lake Smart water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	56	2.1	26	51
Color (PCU)	49	20	46	75
Conductivity (µmhos/cm)	41	202	214	268
Dissolved oxygen (mg/L)	41	6.72	10.48	12.72
pH	41	7.51	8.38	9.38
Secchi depth (feet)	57	0.9	2.1	4.6
Total nitrogen (mg/L)	53	0.81	1.36	2.33
Total phosphorus (mg/L)	56	0.012	0.055	0.131

Figure 4-90. Lake Smart and associated watershed.

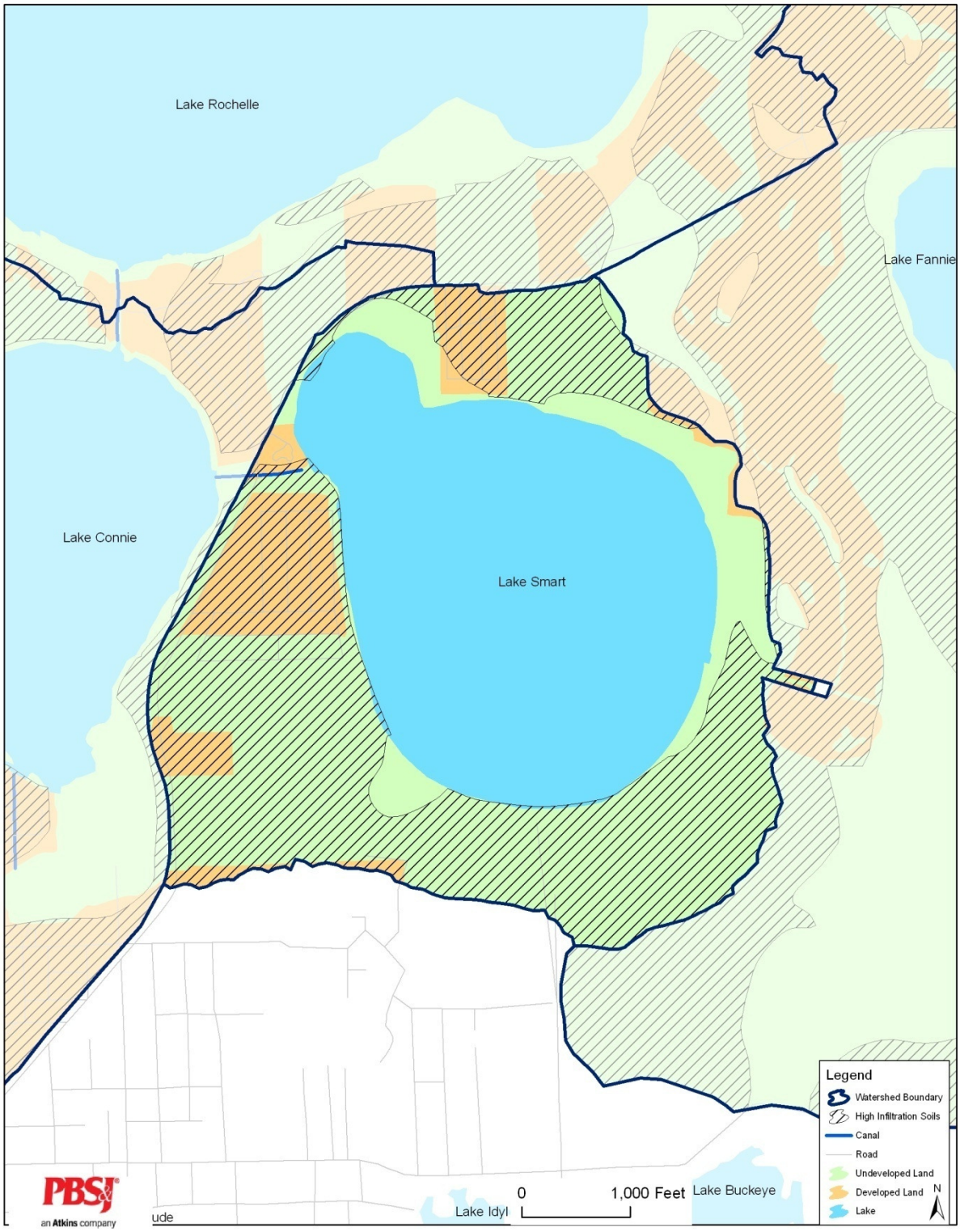


Figure 4-91. Lake Smart bathymetry (June 2007) at water level elevation = 125 feet (Polk County Water Atlas).

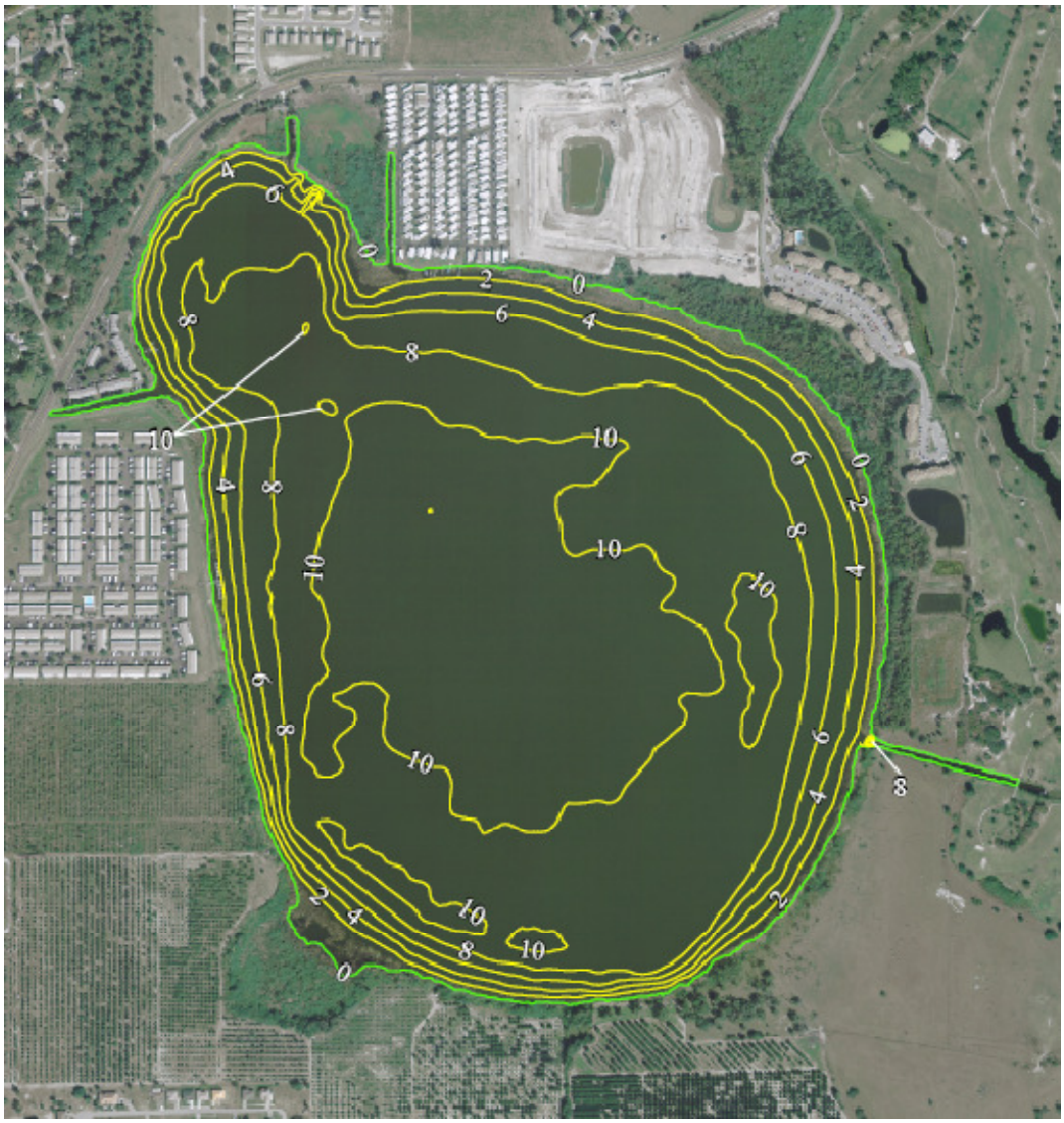
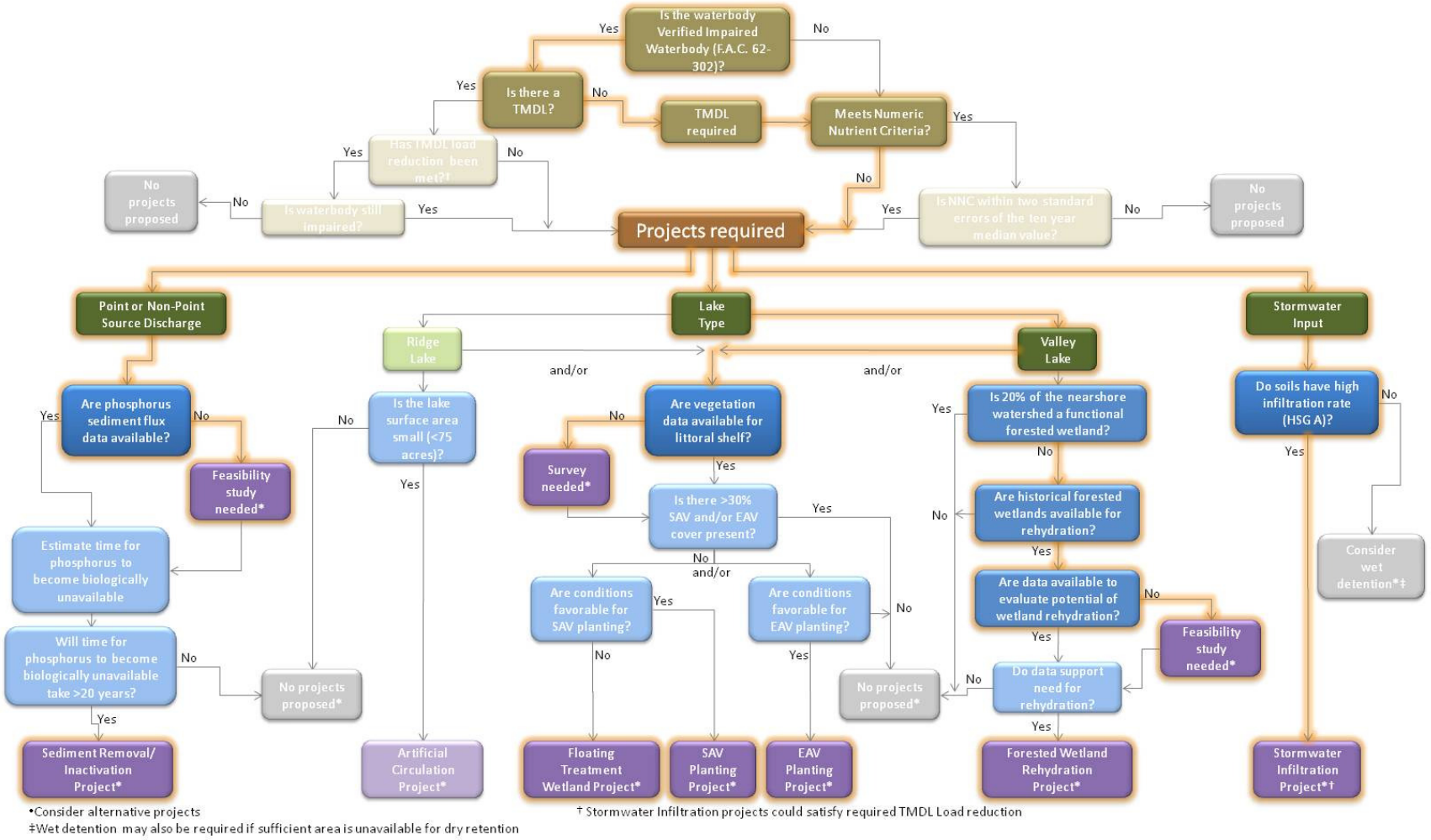


Figure 4-92. Lake Smart decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Smart watershed has approximately 291 acres (83 percent of the watershed) classified as high infiltration soils. The Northern Chain was not included in the PLRG study (USF 2005), therefore a TMDL has not been completed for Lake Smart and data to estimate SIA acres for TP load reduction are not available at this time. SIA implementation could have the additional benefit of increasing storage to supplement dry season lake levels and a reduction in stormwater loads that can be later applied to the required TMDL TP load reduction. As such, SIA design should be focused on recharging the surficial aquifer.

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Lake Smart may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: Forested Wetland Rehydration

Approximately 13 percent of the land cover within the 500 foot buffer surrounding Lake Smart is classified as wetlands using the 2006 FLUCS data. Forested wetlands encompass seven percent of the total wetland area, which does not satisfy the recommended forested wetland cover required to maintain color levels above 50 PCU.

One proposed project area was identified adjacent to Lake Smart and is expected to rehydrate approximately 15 acres (Figure 4-93). The feasibility study is recommended in order to evaluate the proposed project area for inundation.

Feasibility study cost estimate: $60,000.

Project 4: SAV Planting or FTWs

SAV Planting

In Lake Smart, *Hydrilla* eradication occurs frequently attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Smart is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

SAV plants should not be planted in water depths greater than 2 feet based on the median secchi depth values (2.1 feet). The maximum planting effort could result in vegetation cover of approximately 7 percent of the lake bottom (21 acres).

Cost Estimate: $100,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance)

FTWs

If the feasibility study indicates that more than 30 percent of Lake Smart has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 5: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Smart is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

Figure 4-93. Proposed forested wetland rehydration project area for Lake Smart.

4.23. Lake Spring

Background

Physical and chemical characteristics specific to Lake Spring are presented here in the context of relevant regulatory criteria and requirements (Table 4-46). Lake Spring (WBID 1521G1) is a headwater lake located in the WHCL Southern Chain and is hydrologically connected to Lake Mirror via a constructed navigable canal (Photo 4-26, Figure 4-94). Lake Spring has not been declared verified impaired; therefore, a TMDL is not required. However, the NNC are performance based, and an exceedance more than once every three years results in non-compliance. The annual geometric chlorophyll *a* and TN mean in 2005 and 2006 were above the NNC. Insufficient data were available to evaluate TP in comparison to the NNC target based on the EPA data requirements. The TN and chlorophyll *a* geometric mean for Lake Spring for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-46. To comply with the NNC, concentration reductions of 9 percent for chlorophyll *a* are required.

A summary of water quality statistics for Lake Spring is presented in Table 4-47. The median recorded chlorophyll *a* and TP concentrations exceed the NNC targets provided by EPA for Lake Spring while the TN concentrations are below the target. Chlorophyll *a* concentrations in Lake Spring fluctuate but have remained consistently elevated above 20 µg/L (Figure 4-95). A statistically significant trend in chlorophyll *a* concentrations from 1983 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). *Hydrilla* eradication projects have been implemented regularly since 1990 treating greater than 40 percent of the lake surface area in some years. No water quality improvement projects have been implemented in Lake Spring to restore water quality. Lake Spring is an intermediate lake hydrologically connected to Lake Mirror, therefore, improvements in water quality of the lake could result in some benefit farther downstream.

The Lake Spring watershed is 93 acres in size and includes 87 acres (93 percent) of developed lands compared to 6 acres (3 percent) of undeveloped lands. The 2000-2007 median color value (15 PCU) was below 40 PCU indicating it is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 129 feet in June 2007. Bathymetry data are available for Lake Spring for the June 2007 water level elevation (Figure 4-96). A water level of 130 feet was reported in August 2010, reflecting a 1.0 foot increase in water elevation when compared to 2007. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Spring water quality and the surrounding watershed characteristics, five potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-97). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in order of

priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management
- Project 5: Artificial Circulation

Table 4-46. Physical, chemical, and regulatory characteristics of Lake Spring.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	58 (62 percent)
Relation to other lakes	Headwater	**Developed land (acres)**	87 (93 percent)
Watershed area (acres)	93	**Undeveloped land (acres)**	6 (3 percent)
Lake area (acres)*	25	**Median water depth (feet)***	3.2
Perimeter (feet)*	4,176	**Maximum water depth (feet)***	18.7
Surface area: lake volume ratio*	0.10	**Volume (acre-feet)***	240
Watershed to surface area ratio*	3.72		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	22	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	0.93	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	ID	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	Yes	**TMDL status**	NA
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	ID

*at a water level elevation of 129 feet
**presented in section 5.0
NA- Not applicable
ID- Insufficient Data

Photo 4-26. North view of Lake Spring.

Table 4-47. Lake Spring water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	32	8.81	21	64
Color (PCU)	23	10	15	25
Conductivity (µmhos/cm)	21	185	207	244
Dissolved oxygen (mg/L)	21	4.72	8.66	10.88
pH	21	6.87	7.76	9.23
Secchi depth (feet)	34	1.1	2.7	5.3
Total nitrogen (mg/L)	34	0.57	0.94	2.2
Total phosphorus (mg/L)	30	0.014	0.039	0.094

Figure 4-94. Lake Spring and associated watershed.

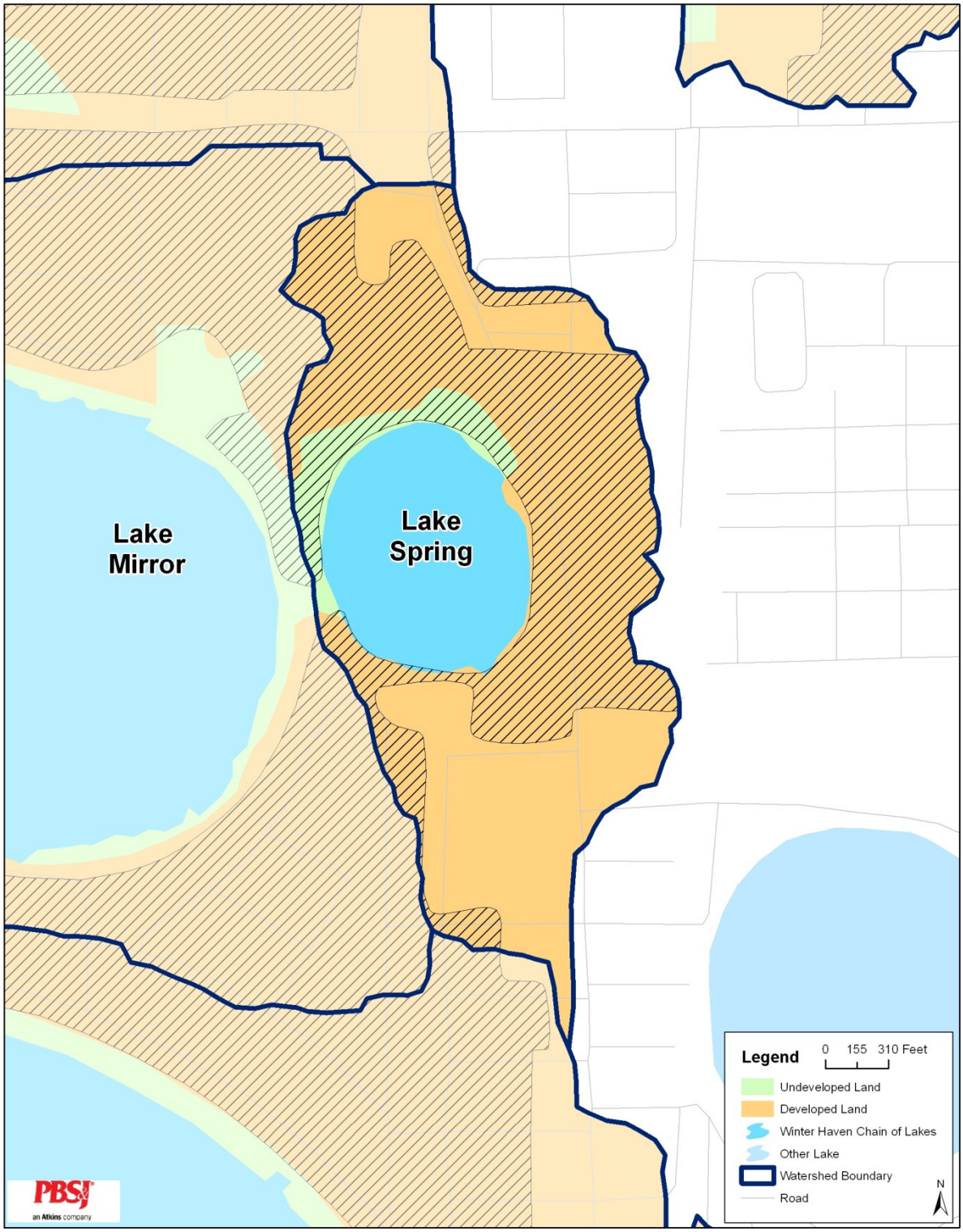


Figure 4-95. Lake Spring chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

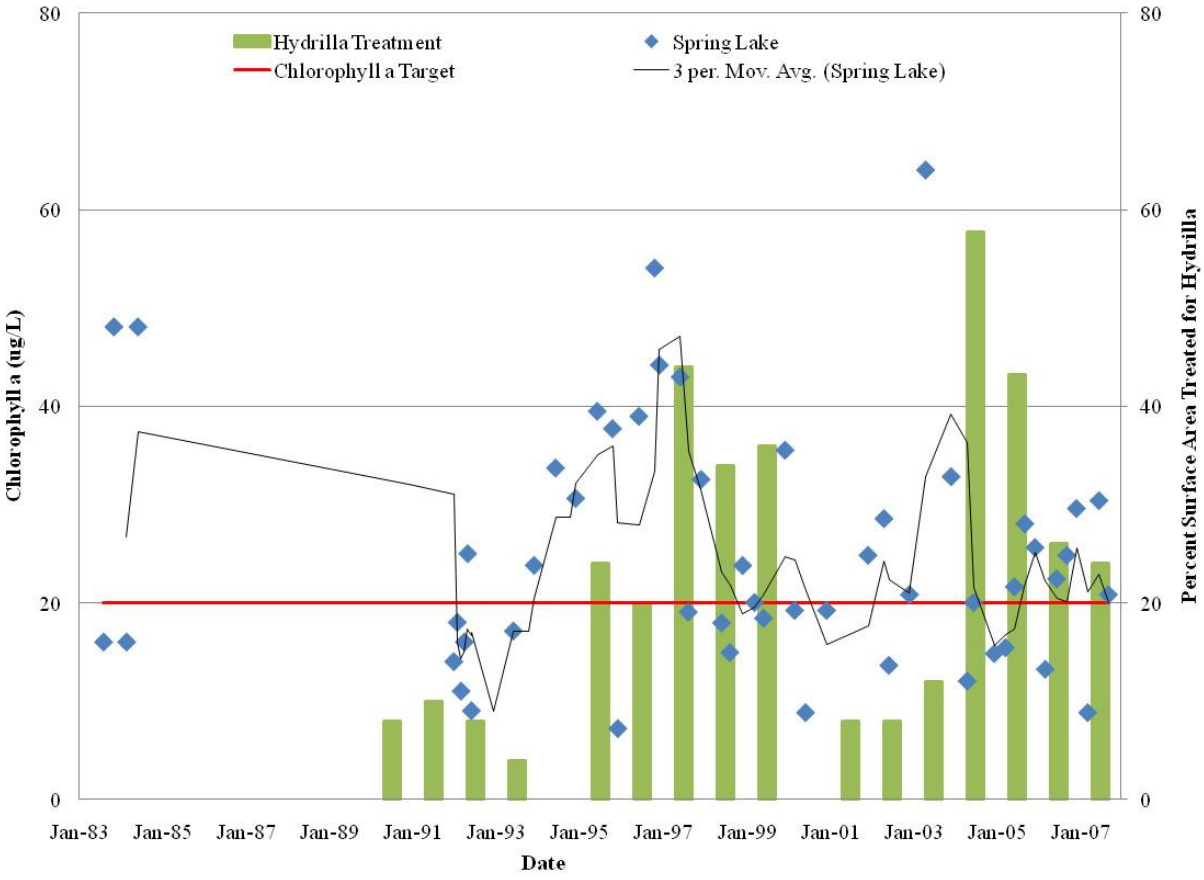


Figure 4-96. Lake Spring bathymetry (June 2007) at water level elevation = 129 feet (Polk County Water Atlas).

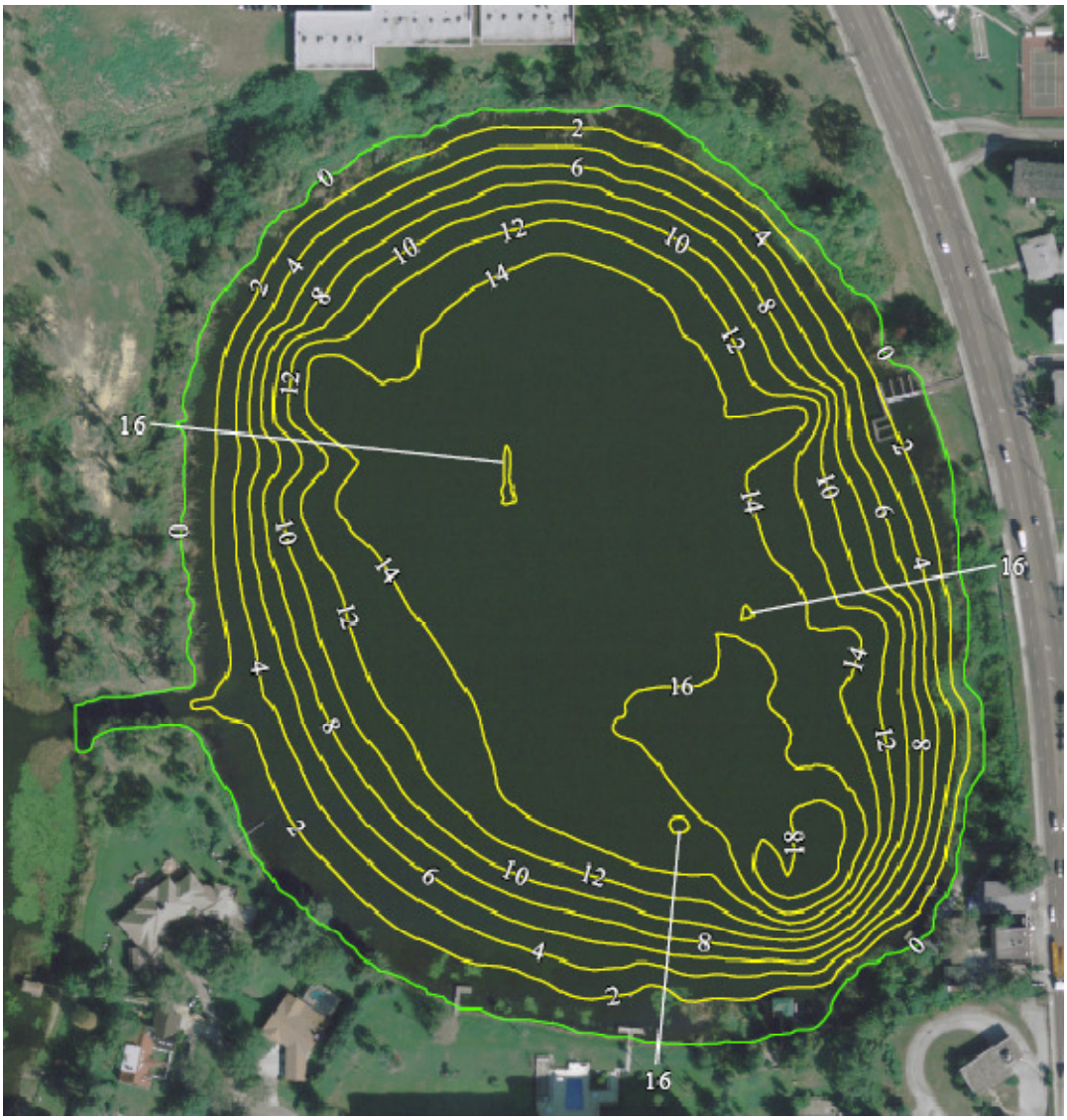
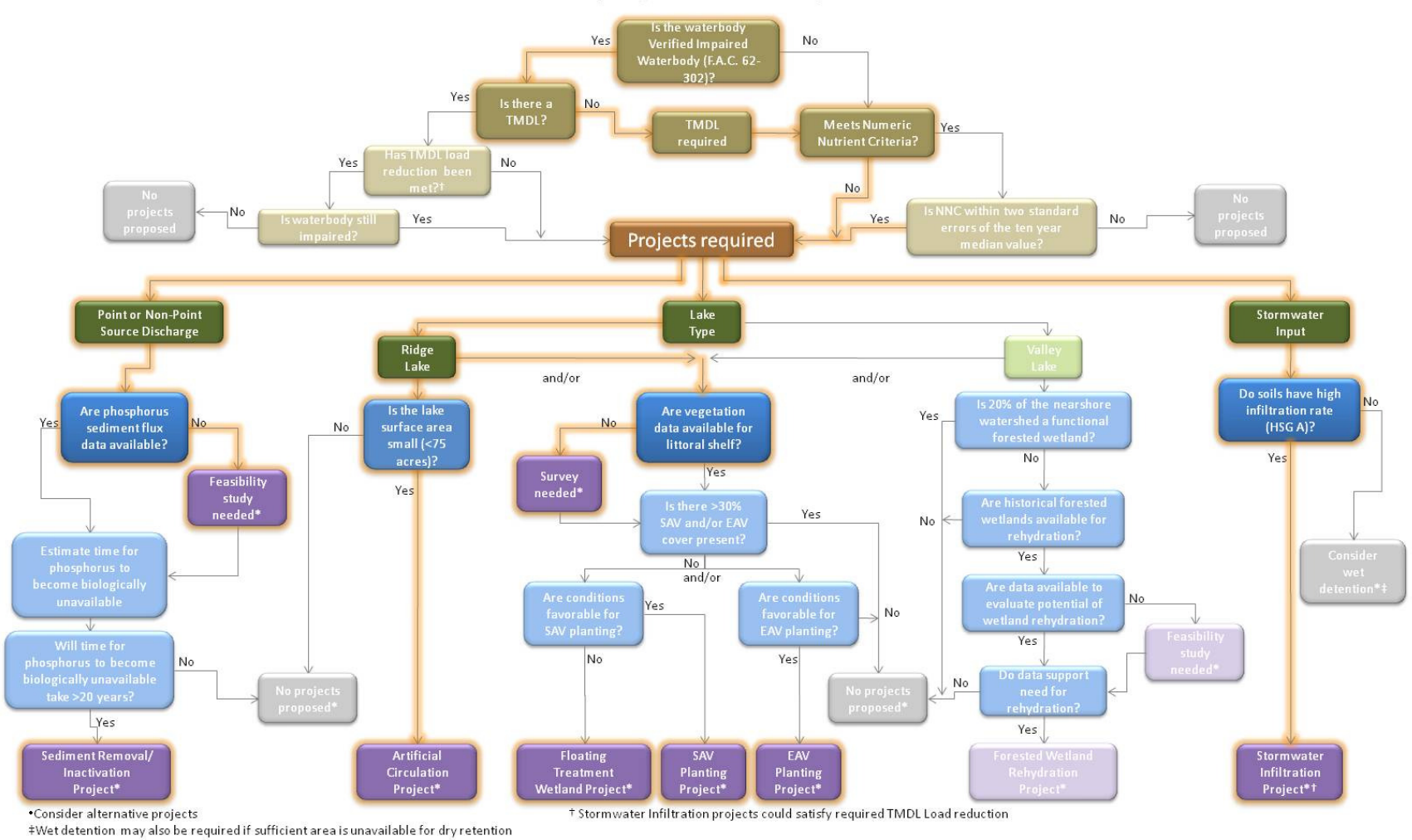


Figure 4-97. Lake Spring decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

The Lake Spring watershed has approximately 58 acres (62 percent of the watershed) classified as high infiltration soils. Lake Spring does not have a TMDL, therefore, SIA acres estimates were calculated using data from the PLRG (USF 2005). Based on the water quality conditions modeled in the PLRG, a TP load reduction for Lake Spring is not required to achieve a TSI of 60. Additionally, insufficient data were available to estimate the required load reduction to mee the NNC. As such, SIA design should be focused on recharging the surficial aquifer. SIA implementation could have the additional benefit of increasing storage to supplement dry season lake levels and a reduction in stormwater loads that can be later applied to the required TMDL TP load reduction.

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Lake Spring may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

In Lake Spring, *Hydrilla* eradication has been completed over as much as 58 percent of the lake surface area attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Spring is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

SAV plants should not be planted in water depths greater than 4 feet based on the median secchi depth values. The median secchi depth from 1997-2007 in Lake Spring was 2.7 feet. The maximum planting effort could result in vegetation cover of approximately 22 percent of the lake bottom (6 acres).

Cost Estimate: $35,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance)

FTWs

If the feasibility study indicates that more than 30 percent of Lake Spring has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Spring is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

Project 5: Artificial Circulation

The project design is based on the assumption that the system configuration developed by SolarBee® for Lake Blue is applicable for Lake Spring. Each circulation pump is assumed to effectively circulate 16 to 20 acres. The surface area of Lake Spring is 25 acres requiring the purchase and installation of one SB10000 v 18 machines.

Cost Estimate: $55,000 (estimate based on cost provided for Lake Blue by SolarBee®).

4.24. Lake Summit

Background

Physical and chemical characteristics specific to Lake Summit are presented here in the context of relevant regulatory criteria and requirements (Table 4-48). Lake Summit (WBID 1521M), a lake in the WHCL Southern Chain, is hydrologically connected to Lake Eloise via a constructed navigable canal (Photo 4-27, Figure 4-98). Lake Summit has not been identified as impaired; therefore, no TMDL is required. The NNC are performance based, and an exceedance more than once every three years results in non-compliance. Limited data were available to compare the geometric means to the EPA NNC based on the EPA data requirements. However, the NNC targets for TN and TP are within two times the standard error of the ten year median TN and TP concentrations. The results of this comparison indicate that a slight degradation in water quality in Lake Summit could result in an impairment designation. Therefore, water quality restoration projects are recommended for Lake Summit as a preventative action. The TP, TN, and chlorophyll *a* geometric mean for Lake Summit for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-48.

A summary of water quality statistics for Lake Summit is presented in Table 4-49. The median chlorophyll *a*, TN and TP concentrations are below the NNC targets provided by EPA for Lake Summit. Chlorophyll *a* concentrations in Lake Summit are variable with values peaking above 20 µg/L (Figure 4-99). A statistically significant trend in chlorophyll *a* concentrations from 1983 to 2007 was not observed (seasonal Kendall-Tau, $p > 0.10$). No water quality improvement projects have been implemented in Lake Summit to restore water quality. Several *Hydrilla* eradication projects have been implemented in Lake Summit treating greater than 50 percent of lake surface area in some years. Lake Summit is an intermediate lake; therefore, improvements in water quality of the lake could result in some benefit farther downstream.

The Lake Summit watershed is 123 acres in size and includes 120 acres (98 percent) of developed lands compared to 3 acres (2 percent) of undeveloped lands. The 2000-2007 median color value (15 PCU) was below 40 PCU indicating it is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 129 feet in August 2009. Bathymetry data are available for Lake Summit for the August 2009 water level elevation (Figure 4-100). A water level of 130 feet was reported in July 2010, reflecting a 1.0 foot increase in water elevation when compared to 2009. The subsequent changes in overall surface area, water depth, and volume of the lake should be considered during the development and implementation of water quality restoration projects.

Water Quality Restoration Project Selection and Priorities

Based on Lake Summit water quality and the surrounding watershed characteristics, five potential water quality restoration projects were identified using the WHCL WQMP decision key (Figure 4-101). The decision key presents the factors on which yes/no decisions were based and used to identify and select water quality improvement projects. Projects to address water quality, nutrient and sediment loading, and reduced lake levels are proposed. The projects are listed in

order of priority, based on expected water quality improvements. A detailed discussion of the potential water quality restoration implications for each project can be found in Section 3.0.

- Project 1: Stormwater Infiltration Areas (SIAs)
- Project 2: Sediment Removal/Inactivation
- Project 3: SAV Planting/Management or FTWs
- Project 4: EAV Planting/Management
- Project 5: Artificial Circulation

Table 4-48. Physical, chemical, and regulatory characteristics of Lake Summit.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	122 (99 percent)
Relation to other lakes	Intermediate	**Developed land (acres)**	120 (98 percent)
Watershed area (acres)	123	**Undeveloped land (acres)**	3 (2 percent)
Lake area (acres)*	67	**Median water depth (feet)***	14.8
Perimeter (feet)*	9,378	**Maximum water depth (feet)***	26.1
Surface area: lake volume ratio*	0.09	**Volume (acre-feet)***	758
Watershed to surface area ratio*	1.84		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	15	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	0.89	**NNC TN target (mg/L)**	1.00
Geometric mean TP (mg/L)	0.027	**NNC TP target (mg/L)**	0.030
Regulatory Data			
Impaired	No	**TMDL status**	NA
Chlorophyll *a* trend	No trend**	**TP concentration reduction required**	NA

*at a water level elevation of 129 feet
**presented in section 5.0
NA- Not applicable

Photo 4-27. Lake Summit.

Table 4-49. Lake Summit water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	40	4	14	42
Color (PCU)	25	10	15	20
Conductivity (µmhos/cm)	24	234	265	312
Dissolved oxygen (mg/L)	24	6.98	8.89	9.83
pH	24	7.18	8.00	9.23
Secchi depth (feet)	44	1.5	4.2	11.8
Total nitrogen (mg/L)	44	0.63	0.84	1.64
Total phosphorus (mg/L)	40	0.01	0.028	0.081

Figure 4-98. Lake Summit and associated watershed.

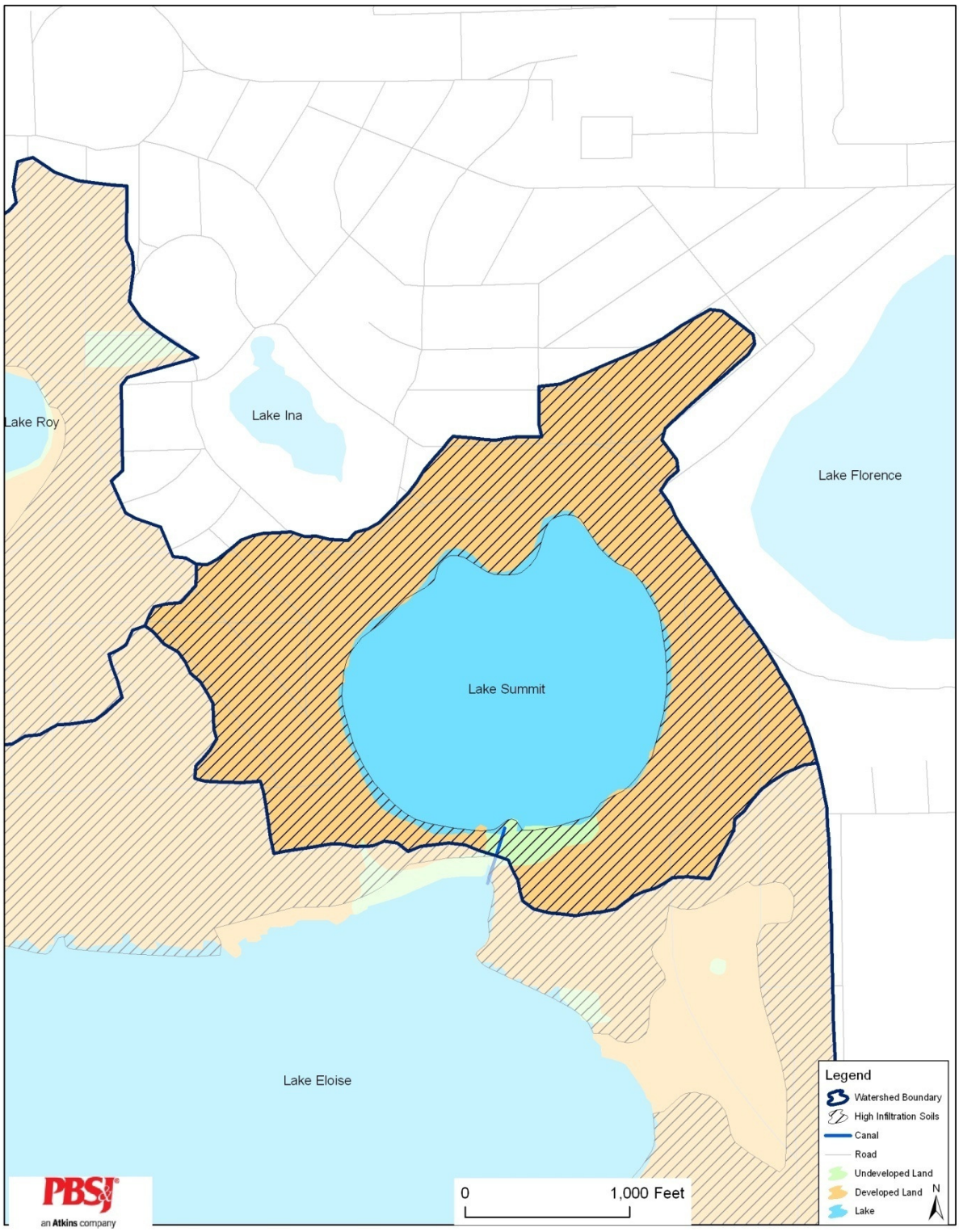


Figure 4-99. Lake Summit chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

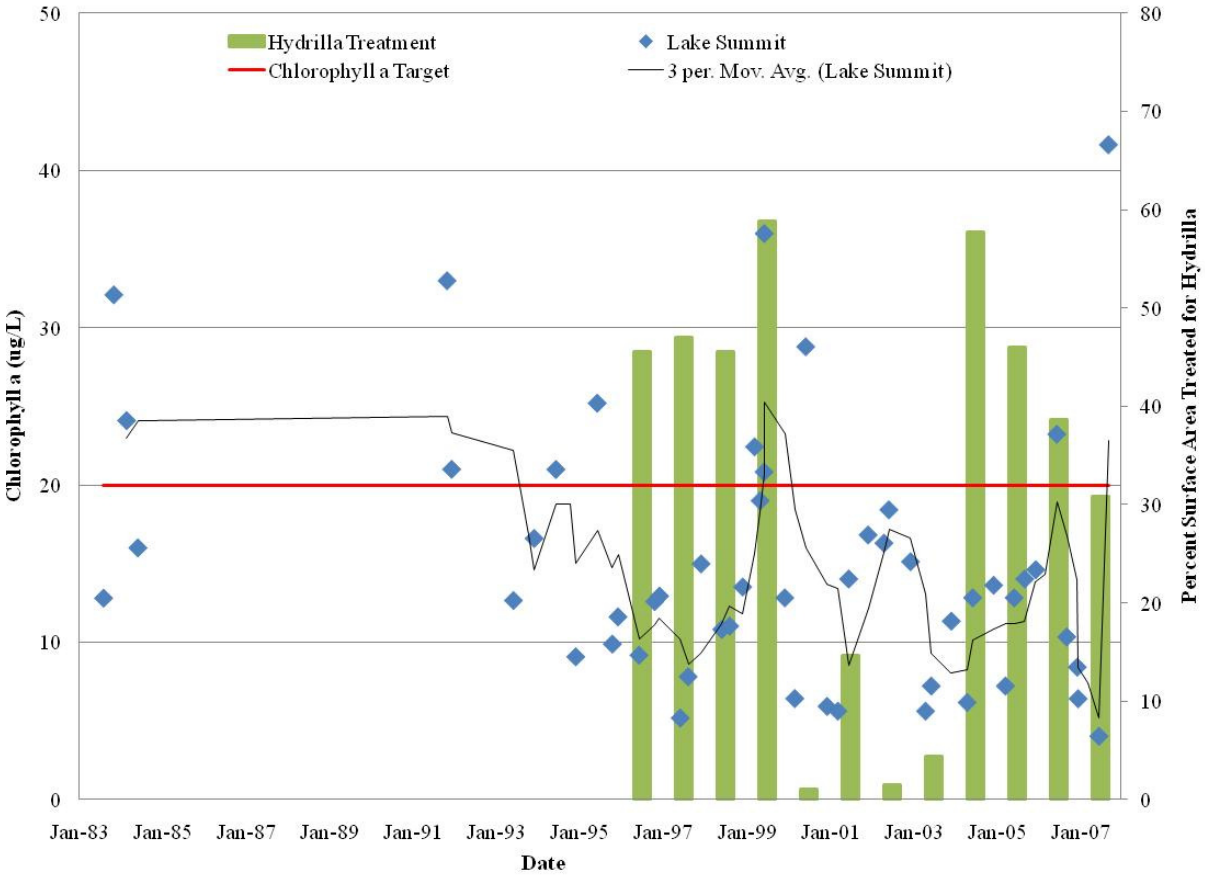


Figure 4-100. Lake Summit bathymetry (August 2009) at water level elevation = 129 feet (Polk County Water Atlas).

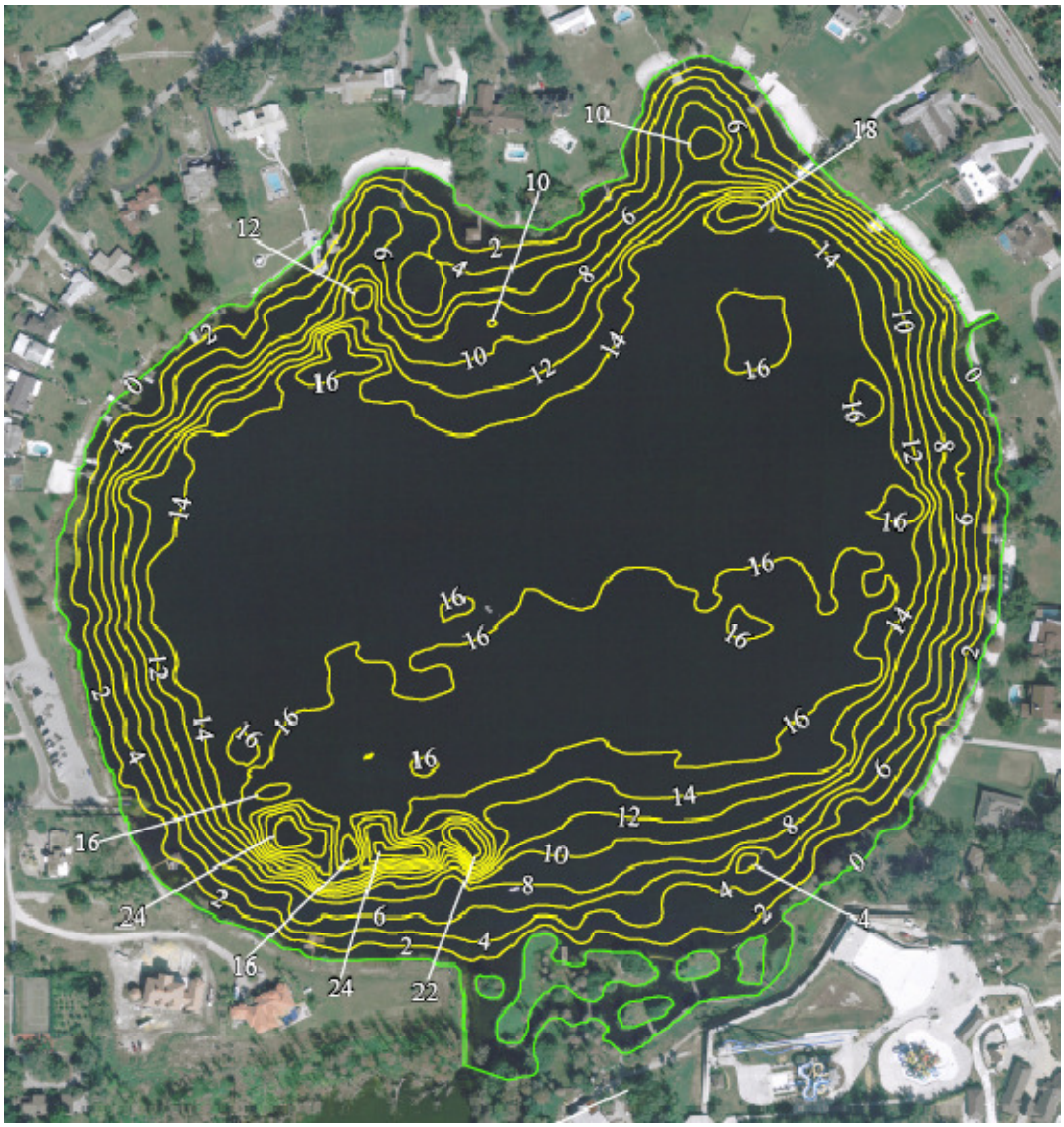
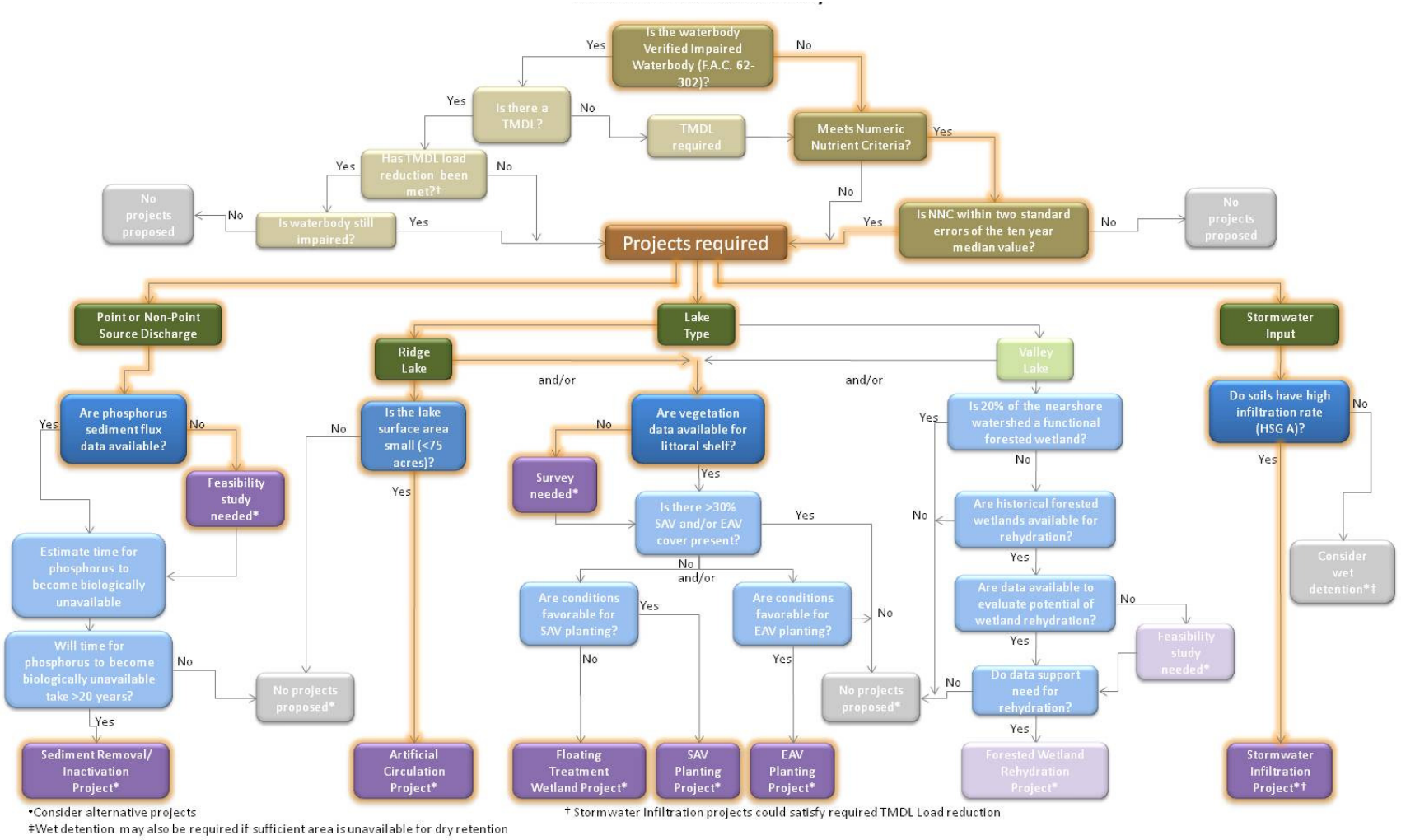


Figure 4-101. Lake Summit decision key: highlighted path shows decision process.



Project 1: Stormwater Infiltration Areas (SIAs)

Within the Lake Summit watershed has approximately 122 acres (99 percent of the watershed) classified as high infiltration soils. A TMDL is not required for Lake Summit due to the unimpaired status; therefore, SIA acres estimates were calculated using data from the PLRG (USF 2005). The SIA estimate for Lake Summit was 2 acres (approximately one percent of the watershed) to meet an 11 percent PLRG. The TP geometric mean for Lake Summit is below the NNC; therefore, acres of SIA estimated to meet the TP NNC were not calculated. SIA design should be focused on recharging the surficial aquifer. SIA implementation could have a double benefit of increasing storage to supplement dry season lake levels and a reduction in stormwater loads that can be later applied to the required TMDL TP load reduction (if necessary).

Project 2: Sediment Removal/Inactivation

Non-point source discharges to Lake Summit may have resulted in substantial internal nutrient loads due to phosphorus release from sediments. Presently, sufficient data are not available to evaluate the internal phosphorus load and calculate the phosphorus decay rate and the time at which the phosphorus will ultimately become biologically unavailable in the lake sediments. A feasibility study is required to determine whether sediment removal/inactivation is necessary to reduce internal phosphorus loads to the lake.

Cost Estimate: $10,000.

Project 3: SAV Planting or FTWs

SAV Planting

In Lake Summit, *Hydrilla* eradication has been completed over as much as 59 percent of the lake surface area attributing to the continued degradation in water quality. A survey of existing SAV cover in Lake Summit is recommended due to the lack of sufficient data to calculate percent lake cover. Based on the results of the SAV survey, conclusions regarding SAV planting can be determined. If SAV cover is less than 30 percent, lake conditions should be evaluated to assess if additional SAV is viable based on the soil condition, water clarity and water depth. *Hydrilla* harvesting may be required for successful establishment of selected SAV plants.

SAV plants should not be planted in water depths greater than 4 feet based on the median secchi depth values (4.2 feet). The maximum planting effort should result in vegetation cover of approximately 18 percent of the lake bottom (12 acres).

Cost Estimate: $70,000 (estimate based on previous purchase and installation cost of $0.90 per plant provided by EarthBalance®, additional funds included for maintenance)

FTWs

If the feasibility study indicates that more than 30 percent of Lake Summit has SAV cover, FTW may be considered. The installation of floating mats with appropriate aquatic vegetation would be expected to assimilate nutrients from the water column.

Project 4: EAV Planting

A survey of existing shoreline vegetation surrounding Lake Summit is recommended due to the lack of sufficient data at this time. Based on the results of the shoreline survey, conclusions and recommendations regarding emergent aquatic or woody vegetation planting can be determined. If limited shoreline vegetation is present, shoreline conditions should be evaluated to assess if vegetation planting is viable based on the soil conditions, slope, water level and inundation frequency and wave disturbance.

Project 5: Artificial Circulation

The project design is based on the assumption that the system configuration developed by SolarBee® for Lake Blue is applicable for Lake Summit. Each circulation pump is assumed to effectively circulate 16 to 20 acres. The surface area of Lake Summit is 67 acres requiring the purchase and installation of four SB10000 v 18 machines.

Cost Estimate: $215,000 (estimate based on cost provided for Lake Blue by Solar Bee®).

4.25. Lake Winterset

Background

Physical and chemical characteristics specific to Lake Winterset are presented here in the context of relevant regulatory criteria and requirements (Table 4-50). Lake Winterset (WBID 1521A) is located in the Southern Chain of the WHCL. It is hydrologically connected to lake Eloise via a constructed navigable canal, however the constructed canal to Little Lake Winterset is not navigable (Photo 4-28, Figure 4-102). In 2005, Lake Winterset was declared verified impaired based on elevated TSI values (>40). Later in 2005, a paleolimnological review of Lake Winterset supported the decision to remove the lake from the impaired list based on the evidence that the lake was historically eutrophic and assigned a revised TSI threshold of 60. No TMDL is required for Lake Winterset because it is not identified as an impaired waterbody. The TP, TN, and chlorophyll *a* geometric mean for Lake Winterset for the period of 1997 to 2007 and corresponding EPA NNC water quality targets are listed in Table 4-50. Concentrations reductions in chlorophyll *a*, TN, or TP are not required to comply with the NNC.

A summary of water quality statistics for Lake Winterset is presented in Table 4-51. Median chlorophyll *a*, TN and TP concentrations do not exceed the NNC targets provided by EPA for Lake Fannie. Chlorophyll *a* concentrations in Lake Winterset fluctuate but values have remained below 20 µg/L sufficiently to maintain an unimpaired status (Figure 4-103). A statistically significant decline in chlorophyll *a* concentrations from 1983 to 2007 was observed (seasonal Kendall-Tau, p=0.05). No water quality improvement projects have been implemented in Lake Winterset to restore water quality. However, several *Hydrilla* infestation eradication projects have been performed in the last ten years. Lake Winterset is an intermediate lake so improvements in water quality of the lake could result in some benefit farther downstream.

The Lake Winterset watershed is 694 acres in size and includes 527 acres (76 percent) of developed lands compared to 167 acres (24 percent) of undeveloped lands. The 2000-2007 median color value (10 PCU) was below 40 PCU indicating the lake is a clear (non-colored) lake and specific conductivity data indicate the lake is alkaline. The lake area, perimeter, water depth, and volume statistics are based on a water level elevation of 129 feet in July 2007. Bathymetry data are available for Lake Winterset for the June 2007 water level elevation (Figure 4-104). A water level of 130 feet was reported in August 2010, reflecting a 1.0 foot increase in water elevation when compared to 2007.

Water Quality Restoration Project Selection and Priorities

The water quality of Lake Winterset is characterized here in the context of relevant regulatory criteria and requirements. No water quality restoration projects are proposed for Lake Winterset at this time (Figure 4-105). However, continued water quality monitoring efforts are recommended for ongoing evaluation.

Table 4-50. Physical, chemical, and regulatory characteristics of Lake Winterset.

Physical			
Location in chain	Southern	**High infiltration soils (acres)**	542 (78 percent)
Relation to other lakes	Headwater	**Developed land (acres)**	527 (76 percent)
Watershed area (acres)	694	**Undeveloped land (acres)**	167 (24 percent)
Lake area (acres)*	549	**Median water depth (feet)***	12.7
Perimeter (feet)*	28,242	**Maximum water depth (feet)***	30.2
Surface area: lake volume ratio*	0.06	**Volume (acre-feet)***	8,876
Watershed to surface area ratio*	1.26		
Water Chemistry			
Locally-derived: acidic or alkaline	Alkaline	**Clear or colored**	Clear
Geometric mean chlorophyll *a* (µg/L)	15	**NNC chlorophyll *a* target (µg/L)**	20
Geometric mean TN (mg/L)	0.77	**NNC TN target (mg/L)**	1.81
Geometric mean TP (mg/L)	0.019	**NNC TP target (mg/L)**	0.087
Regulatory Data			
Impaired	No	**TMDL status**	NA
Chlorophyll *a* trend	Decreasing**	**TP concentration reduction required**	NA

*at a water level elevation of 129 feet
**presented in section 5.0
NA- Not applicable

Photo 4-28. Residential area along Lake Winterset shoreline.

Table 4-51. Lake Winterset water quality summary for 1997 to 2007.

Parameter	N	Minimum	Median	Maximum
Chlorophyll *a* (µg/L)	51	4	15	26
Color (PCU)	28	5	10	22
Conductivity (µmhos/cm)	26	240	266	328
Dissolved oxygen (mg/L)	26	7.29	8.96	10.6
pH	26	7.23	7.875	9.02
Secchi depth (feet)	55	1.5	3.6	11.8
Total nitrogen (mg/L)	55	0.39	0.80	1.42
Total phosphorus (mg/L)	51	0.005	0.021	0.06

Figure 4-102. Lake Winterset and associated watershed.

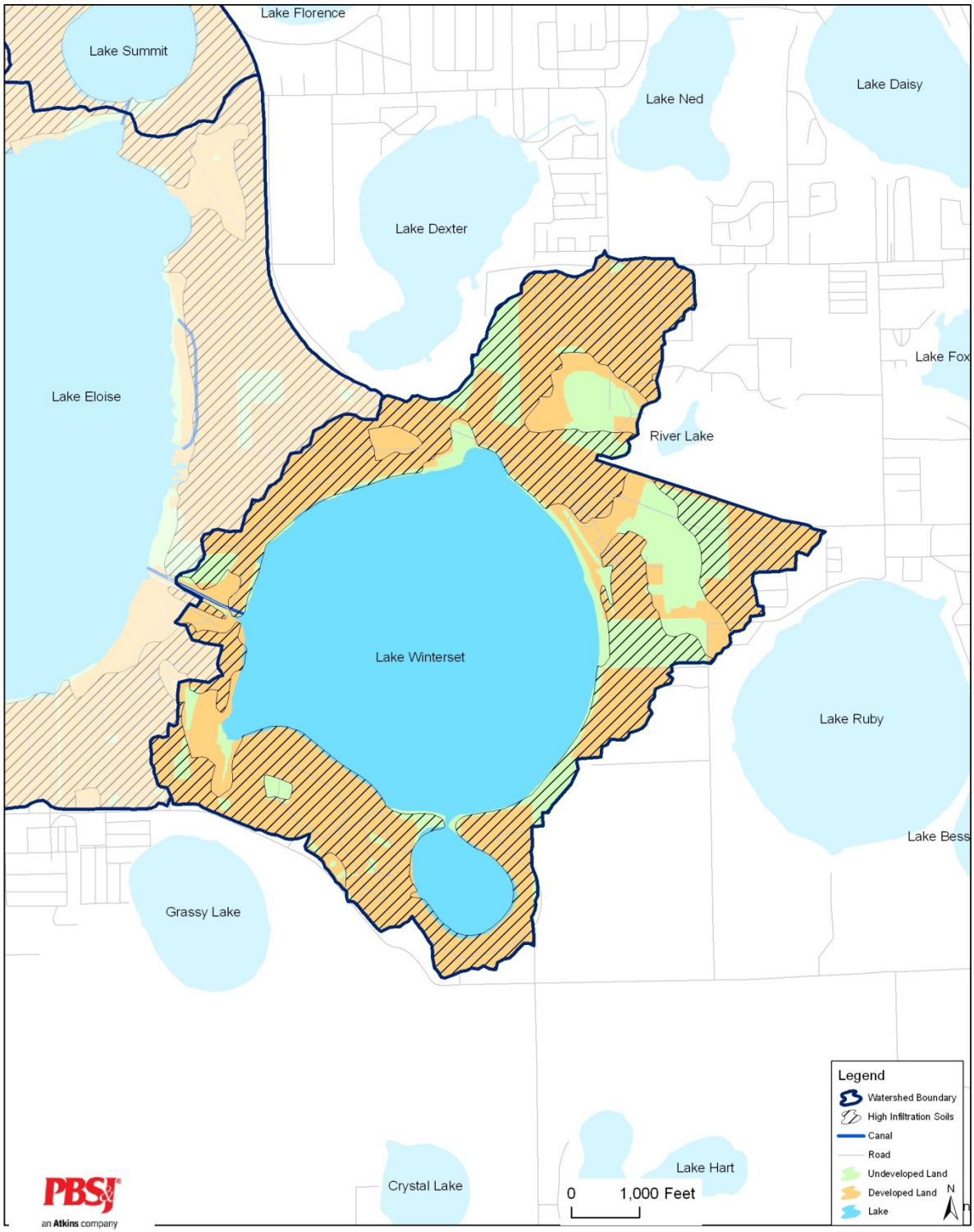


Figure 4-103. Lake Winterset chlorophyll *a* concentrations and *Hydrilla* treatment history using available data from 1983 to 2007.

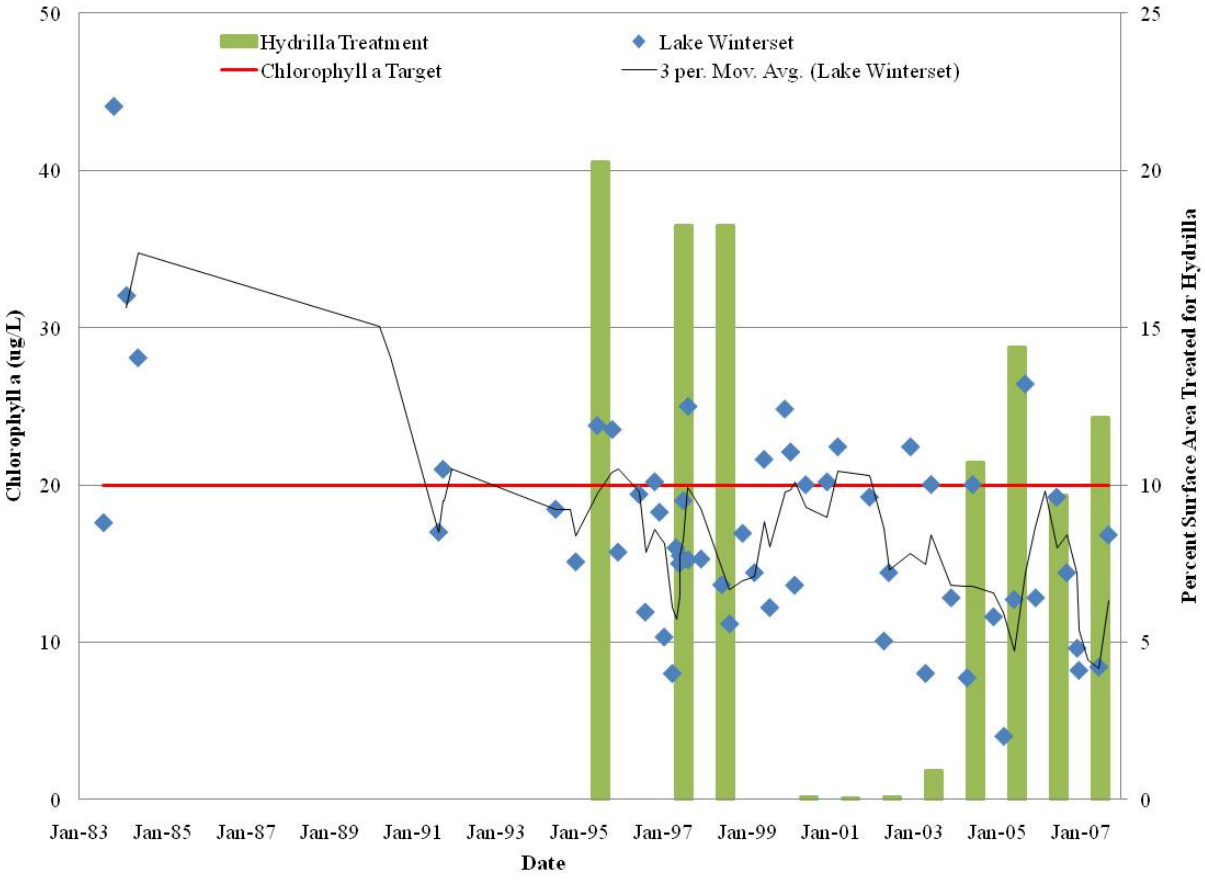


Figure 4-104. Lake Winterset bathymetry (June 2007) at water level elevation = 129 feet (Polk County Water Atlas).

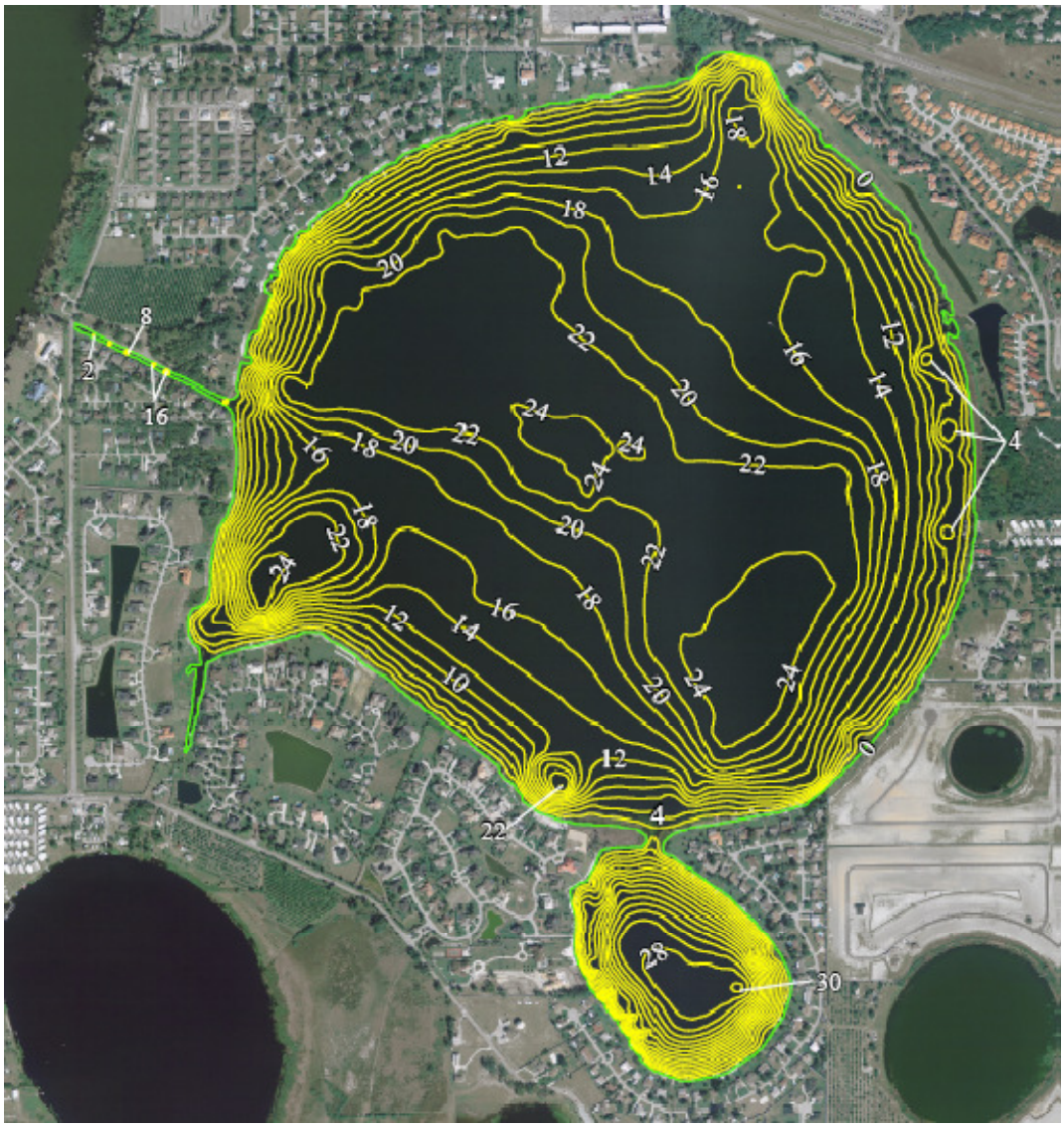
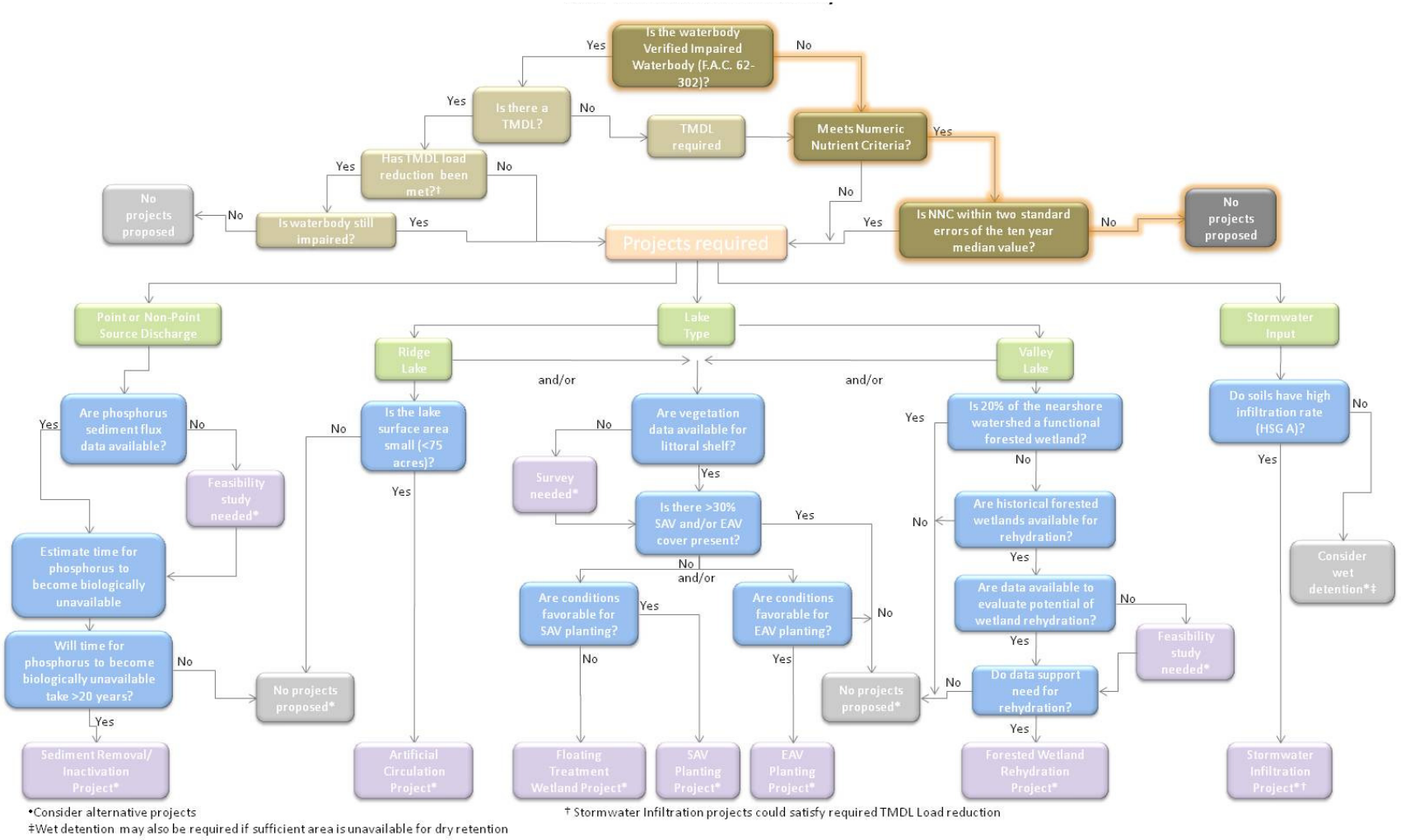


Figure 4-105. Lake Winterset decision key.



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5.0 Priorities for Lake Restoration Projects

Priorities were developed for lake-specific water quality restoration projects as part of this WQMP. Factors considered in the ranking approach included water quality status (e.g. impairment status and chlorophyll trends), magnitude of required phosphorus concentration reduction, and relative lake location. Lake priority rankings are based on relative importance of a project to improving water quality in a lake. Project priorities are also assigned, but on a lake by lake basis. Cost was not included in the rankings, but relative magnitudes of restoration costs are listed with rankings as a means of comparison.

5.1. Lake Ranks

Lake priority rankings were developed using higher ranks for higher priorities and lower ranks for lower priorities. The ranking factors and scales used to assign priority to lakes are listed in Table 5-1. Individual ranks for water quality status, TP reduction required, and location were summed and averaged to provide an average rank for each lake (Table 5-2). Projects were examined and described in Section 4.0 and are listed by priority for each lake in Table 5-3.

Water Quality Status

Lakes were first ranked by water quality status using three criteria: impaired status, water quality in relation to NNC, and trends in chlorophyll *a*. For example, a lake designated as impaired that exhibited an increasing trend in chlorophyll *a* over time was ranked 5, while a lake designated as impaired but with a decreasing trend in chlorophyll *a* was ranked 4. Trends in chlorophyll *a* are presented for each lake in Section 4. A higher rank indicates higher restoration priority. For lakes that are unimpaired, water quality status was ranked based on trends in chlorophyll *a* and the likelihood of water quality reaching the NNC threshold (i.e. two standard errors (SE) below the NNC). The four unimpaired lakes that have TP and TN water column concentrations more than two standard errors below the NNC were assigned a rank of 1.

Required Phosphorus Reduction

The second factor for ranking lakes was required phosphorus reductions, based on the percent reduction required to meet targeted TP concentrations designated by the NNC (Figure 5-1). Higher ranked lakes have higher restoration priority. The highest priority lakes are those with the least (< 20 percent, e.g. Lake Haines) and greatest (> 50 percent, e.g. Lake Blue) phosphorus reduction required and were assigned a rank of 4. Water quality restoration projects completed on lakes with less than a 20 percent required TP reduction are likely to produce the most notable improvements in water quality. In contrast, lakes with greater than 50 percent TP reduction might require more time before substantial water quality improvements are observed, therefore, projects should be implemented sooner rather than later. Lakes with 20 to 40 percent TP concentration reduction, or with a standard error associated with the median TP concentration that is within two standard errors of the NNC, are ranked 3 for TP reduction. Lakes with 40 to 50 percent TP concentration reduction are ranked 2. Finally, lakes with no reduction in TP required were ranked 1.

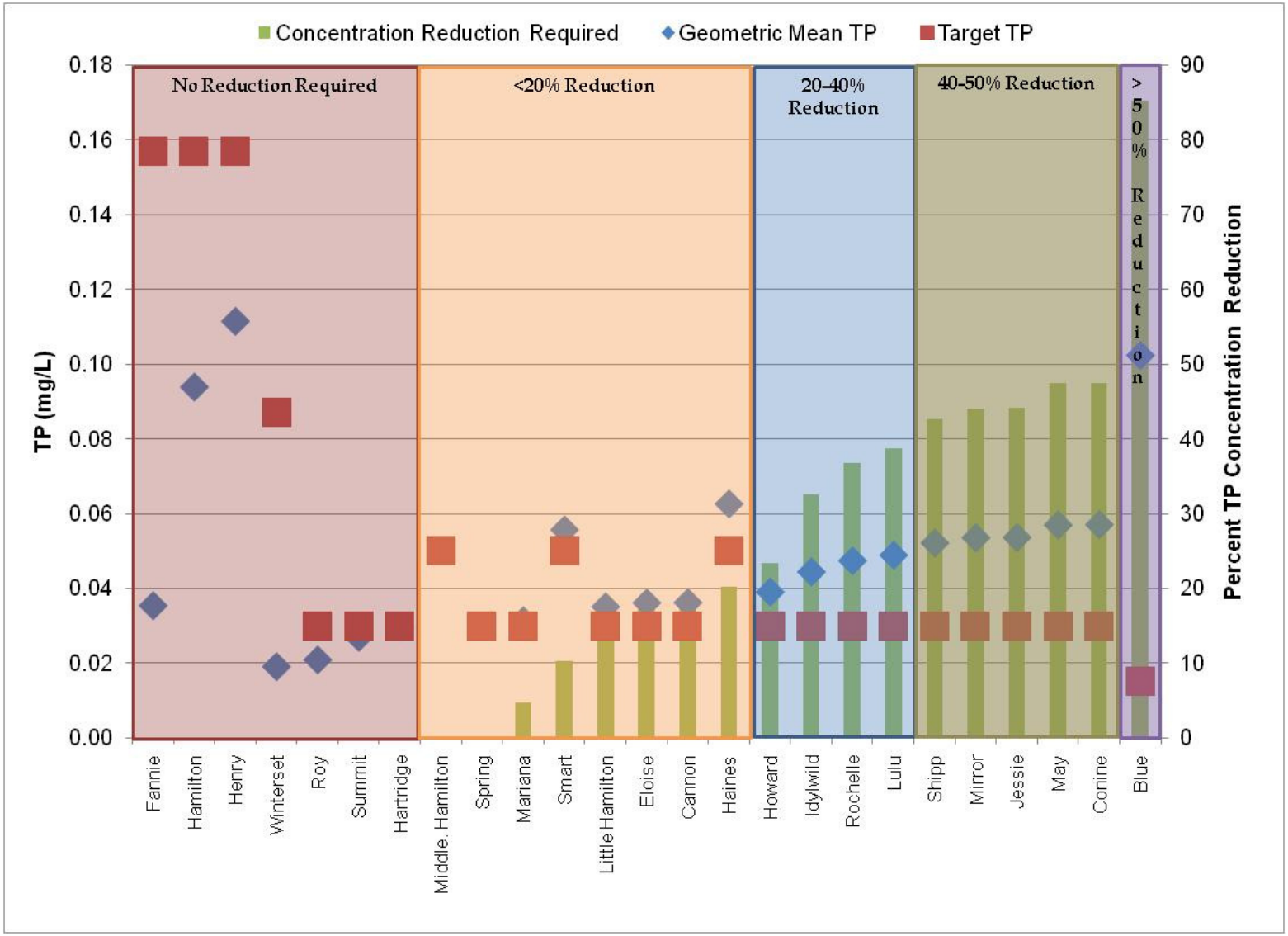
Table 5-1. Ranking scale used to assign priority to lakes for the WHCL.

Factor Used in Ranking	Rank
Water Quality Status	
Impaired, increasing or no trend in chlorophyll *a*	5
Impaired, decreasing trend in chlorophyll *a*	4
Unimpaired (<2SE), increasing or no trend in chlorophyll *a*	3
Unimpaired (<2SE), decreasing trend in chlorophyll *a*	2
Unimpaired (>2SE)	1
TP Reduction Required	
<20 percent or >50 percent	4
20-40 percent or within NNC 2SE	3
40-50 percent	2
No reduction	1
Location Relative to other Lakes	
Headwater lakes or proximate to headwater lake	4
Intermediate location	3
Discharge lake or adjacent	2
Hydrologic isolation due to gated structures	1
Estimated Restoration Cost	
<$500,000	$
$500,000-$1,000,000	$$
>$1,000,000	$$$

2SE= twice the standard error of the ten year median chlorophyll *a* data

The average percent reduction in phosphorus required for lakes with an adopted TMDL was 52 percent and an average 56 acres of SIAs is required to treat the external load associated with the TMDL (refer section 3.4 for detail). Percent phosphorus reductions required to meet NNC targets (Figure 5-1) for lakes with TMDLs averaged 66 percent with a corresponding average of 71 acres of SIAs to treat external phosphorus loads. In contrast, the average percent reduction required for lakes without an adopted TMDL to meet their NNC was an estimated 33 percent, with a corresponding average of 30 acres of SIA required to meet that reduction, approximately half that of lakes with TMDLs. As described previously, internal phosphorus loads are not a component of these estimates.

Figure 5-1. Required TP reductions, geometric mean TP concentrations, and targeted TP concentrations for the WHCL.



Lake Location

Lake location relative to the entire WHCL was also included in the rankings because of the potential influence of upstream projects on downstream lakes. For example, a project implemented in the headwaters of the WHCL would likely have a positive influence on the lakes downstream from the headwaters and are assigned a rank of 4, while a project at the "terminus" of the Southern Chain would not be expected to influence any of the other lakes and was assigned a rank of 1.

Rankings

As described earlier, rankings were assigned based on the importance and/or potential success of a project. Therefore, cost estimates are included in the summary tables and provide an estimate of the magnitude of the cost associated with projects but was not a component in ranking projects.

Individual lakes in the WHCL, associated TMDL status, and recommended projects are listed in Table 5-2. Lakes are grouped into tiers, based on relative importance (rank) of needed restoration. Recommended restoration projects should be implemented first in the first (red) tier lakes, followed by implementation in the second, third, and fourth tiers of lakes.

Priority rankings for restoration lakes ranged from 4.3 (highest importance) to 0.7 (least importance) and were grouped into five tiers based on average ranking values. All lakes in the first three tiers are designated impaired and therefore ranked either 4 or 5 for water quality status.

Total phosphorus values relative to NNC were also used to rank lakes for water quality status. TP values less than two standard errors below the TP NNC for a particular lake suggests that a relatively small decline in water quality could lead to impairment. For example, only Lakes Summit, Roy, and Hartridge ranked 3 under water quality status, indicating no impairment but TP values within two standard errors of the TP NNC. Therefore, projects were proposed for these lakes even though they are not designated as impaired. No lakes ranked 2 under water quality status, i.e. unimpaired, more than two standard errors below the TP threshold, and a decreasing trend in chlorophyll *a*.

Required reductions in TP were also used to rank lakes from 1 (no reduction required) to 4 (<20 percent or > 50 percent required). The first two tiers of lakes consistently ranked 3 or 4, while tiers three and four ranked 2 or 3 (with the single exception of Lake Blue). No phosphorus reductions are required for the unimpaired tier five lakes.

Relative location in the chain of lakes ranked lakes from 4 (headwaters) to 1 (isolated). The first tier of lakes were ranked 3 (intermediate location) and 4, compared with the second tier in which lakes ranked 2 (a discharge lake or adjacent to a discharge lake) and 3. There was no consistent pattern in the remaining tiers and lakes generally ranged from 1 to 4 in each tier.

Little Lake Hamilton is in the first tier (highest priority) of lakes. The lake is impaired, exhibits no trend in chlorophyll *a,* and is connected to Lake Hamilton. The median total phosphorus (TP) concentration in the lake exceeds the NNC established by EPA, but by less than 20 percent,

suggesting that implementing a water quality improvement project may have enough influence to reduce TP to below the NNC target, allowing the lake to be de-listed (no longer impaired).

Table 5-2 . Priority rankings for lakes in the WHCL (higher numbers indicate greater priority and same color shading indicates equal priority).

Lake	WBID Number	WQ Status	TP Reduction Required	Location	Average Rank	Estimated Restoration Cost
Mariana	1521L	5	4	4	4.3	$
Spring	1521G1	5	4	4	4.3	$
Idylwild	1521J	5	3	4	4.0	$
Little Hamilton	15001	5	4	3	4.0	$
Haines	1488C	4	4	4	4.0	$$$
Rochelle	1488B	5	3	4	4.0	$$
Cannon	1521H	4	4	3	3.7	$
Smart	1488A	4	4	3	3.7	$$
Middle Hamilton	15002	5	4	2	3.7	$$
Howard	1521F	5	3	3	3.7	$$$
Eloise	1521B	5	4	2	3.7	$$$
Mirror	1521G	5	2	3	3.3	$
Blue	1521Q	5	4	1	3.3	$
Jessie	1521K	4	2	4	3.3	$$$
May	1521E	5	2	3	3.3	$$$
Lulu	1521	5	3	2	3.3	$$$
Summit	1521M	3	3	3	3.0	$
Conine	1488U	4	2	3	3.0	$$$
Shipp	1521D	5	2	2	3.0	$$$
Roy	1521O	3	3	2	2.7	$$
Hartridge	1521I	3	3	4	2.3	$$
Winterset	1521A	1	1	4	2.0	NA
Henry	1504A	1	1	4	1.7	NA
Hamilton	15041	1	1	2	1.0	NA
Fannie	14882	1	1	1	0.7	NA

In contrast, Lake Blue is impaired, shows no trend in chlorophyll *a*, and requires a large TP reduction (85 percent). It is not connected to (i.e. has no influence on) to another lake and ranked in the third tier of lakes. Lake Conine ranks in the fourth tier of lakes. It is impaired but has a declining trend in chlorophyll *a*, therefore water quality may be improving in response to whole lake alum treatment (sediment inactivation) in the mid-1990s. The lake needs a 40 to 50 percent reduction in phosphorus, compared, for instance, to 85 percent needed in Lake Blue and less than 20 percent in Little Lake Hamilton. Lake Conine ranks in the fourth tier (lower priority).

Lakes Mariana, Idlylwild, Little Hamilton, Spring, Haines, and Rochelle were the highest ranked lakes for water quality restoration projects (ranked from 4.0 to 4.3). The five lakes are designated as impaired. Lake Haines exhibited a decreasing trend in chlorophyll *a*, while the remaining five lakes exhibited increasing (or no) trends in chlorophyll *a*.

The second tier of lakes includes Lakes Cannon, Smart, Middle Hamilton, Howard, and Eloise, each with a 3.7 rank and all designated as impaired. Chlorophyll *a* trended downward in Lakes Cannon and Smart for the period examined, but increased or had no trend for the other three lakes. The third tier of lakes (ranked 3.3) are also all designated as impaired and only one of the lakes (Jessie) exhibited a decreasing trend in chlorophyll *a*, while Lakes Mirror, Blue, May, and Lulu all exhibited a decreasing chlorophyll *a* trend.

The fourth tier of lakes includes Lakes Summit, Conine, Shipp, Roy, and Hartridge (ranked from 2.3 to 3.0). Only Lakes Conine and Shipp are designated impaired. Chlorophyll trends indicated an increase or no change in chlorophyll *a* in Lake Shipp and a decrease in chlorophyll *a* in Lake Conine. The fifth tier of lakes includes Lakes Henry, Winterset, Hamilton, and Fannie (ranked 1 to 1.7), none of which are designated impaired and none of which exhibit trends in chlorophyll *a*.

5.2. Project Ranks

Projects were listed (and ranked) for each lake in Section 4.0 and ranks are presented here as part of the overall restoration ranking matrix Table 5-3. Sediment removal or sediment inactivation projects, SIAs, and SAV and EAV planting projects are proposed for all lakes with impairment designations and for all lakes with a required and/or adopted TMDL. Sediment removal/inactivation is recommended for Lakes May, Lulu, and Shipp without a feasibility study because available data indicated it will be more than 20 years before sediment phosphorus in the three lakes is biologically unavailable in the three lakes. Sediment removal, rather than inactivation, is recommended for Lake May because of the shallow lake depth. Forested wetland rehydration is proposed for four lakes (Haines, Rochelle, Middle Hamilton, Smart, and Lulu) and artificial circulation is proposed for four other lakes (Blue, May, Spring, Summit, and Roy). Project priorities are outlined below.

- If external loads have not yet been addressed, stormwater projects to reduce nutrient loading are a priority project for a lake to reduce external nutrient loads to the lakes.

- If stormwater reduction projects have already been implemented for external nutrient loading and the lake has a history of point source loads, a sediment inactivation or removal feasibility study is recommended to evaluate the internal phosphorus loads to the lake. If internal nutrient loads are such that the time to phosphorus steady state without a project is more than 20 years, the sediment inactivation/removal project becomes a priority. If/once internal and external pollutant loads are addressed, aquatic vegetation projects (e.g. SAV, EAV, FTWs) may provide the only sustainable removal mechanism for phosphorus in these lake systems by facilitating the microbial activities responsible for permanent phosphorus burial.

- If/once internal and external pollutant loads are addressed, forested wetland rehydration is proposed for valley lakes in which high water color ameliorates the impacts of phosphorus on chlorophyll by reducing the light available to algae.

- Artificial circulation is another means to address in-lake phosphorus loads but is recommended only for small lakes.

Table 5-3. Restoration project ranking matrix for lakes in the WHCL.

Lake	TMDL Status	Sediment Removal or Inactivation	Stormwater Infiltration Areas	Forested Wetland Rehydration	SAV Planting or Floating Treatment Wetland	EAV Planting	Artificial Circulation
Mariana	R	2	1		3	4	
Spring		2	1		3	4	5
Idylwild	A	2	1		3	4	
Little Hamilton	R	2	1		3	4	
Haines	R	2	1	3	4	5	
Rochelle	R	2	1	3	4	5	
Cannon	A	2	1		3	4	
Smart	R	2	1	3	4	5	
Middle Hamilton		2	1	3	4	5	
Howard	A	1	2		3	4	
Eloise	R	2	1		3	4	
Mirror	A	2	1		3	4	
Blue	R	2	1		3	4	5
Jessie	A	2	1		3	4	
May	A	1	2		3	4	5
Lulu	A	1	2	3	4	5	
Summit		2	1		3	4	5
Conine	R	2	1		3	4	
Shipp	A	2	1		3	4	
Roy		2	1		3	4	5
Hartridge		1	2		3	4	
Hamilton							
Fannie							
Henry							
Winterset							

project not selected or TMDL not required

A = TMDL adopted; R = TMDL required;

6.0 Conclusions and Recommendations

Water quality data in the WHCL and results of water quality improvement projects in the WHCL were examined as part of the development of this WQMP. The findings of this WQMP are summarized below.

- Much of the WHCL watershed is urbanized and most urbanization occurred in the years before modern stormwater treatment rules were in place.

- Historic phosphorus loading into the WHCL via point and nonpoint sources has resulted in long term phosphorus accumulation in sediments in some lakes and subsequent internal phosphorus loading.

- Until/unless the "legacy" sediment phosphorus is appropriately addressed, water quality improvement projects that address stormwater loading and other external loadings will have little success.

- Development of the watershed has included replacement of natural infiltration areas with impervious surfaces such as roads and buildings.

- Most of the WHCL lake water levels are lower in elevation (by about five feet) than historical data indicate.

- Lower dry season lake levels in ridge lakes can be associated with degraded water quality, perhaps due to increased re-suspension of nutrient-enriched sediments.

- Lower wet season lake levels in valley lakes can be associated with a hydrologic disconnect between the lakes and their adjacent swamp shoreline.

- Tannin levels in valley lakes are more important when compared with ridge lakes due to their influence on chlorophyll *a* levels.

- Traditional large-scale stormwater retrofit projects have reduced external nutrient loads and improved water quality in the WHCL, however, further reductions in external nutrients loads are still necessary.

- Whole-lake alum treatment appears to be a potential means of improving water quality in lakes in the WHCL.

- Sediment removal projects have been successful in some lakes (Hollingsworth and Trafford) but it may not work for extremely hypereutrophic lakes (e.g. Banana Lake).

- Water quality restoration projects other than sediment removal and/or inactivation that may offer additional water quality improvements in some of the lakes in the WHCL include:

Stormwater infiltration areas can be used to reduce direct runoff of stormwater and associated nutrients into lakes and increase surface water infiltration into the ground water.

Forested wetland rehydration in valley lakes can increase lake water color and subsequently reduce availability of sunlight for phytoplankton productivity.

SAV can improve water quality in lakes in the WHCL and Hydrilla eradication efforts may adversely impact water quality.

FTWs can provide nutrient removal through aboveground plant biomass production.

EAV establishment will slow the flow of stormwater runoff into lakes and increase the filtration and assimilation of nutrients in the water column.

Whole-lake aeration may be a useful tool for water quality improvement for smaller lakes in the WHCL by increasing oxygen in the water column and displace phytoplankton to water depths where they are less productive.

Based on these findings, several recommendations have been developed as part of the WHCL WQMP and can be grouped into recommendations for ridge and valley lakes.

Ridge and Valley Lakes Recommendations

- Additional alkalinity data are necessary to develop a more locally-appropriate threshold value for clear alkaline lakes and a subsequent NNC assessment.

- Maximize native submerged aquatic vegetation communities, in coordination with efforts to control *Hydrilla*, maintain native SAV cover over 30 percent of the lake bottom, and establish EAV along 50 to 75 percent of the shoreline.

- Evaluate legacy phosphorus fluxes from sediments into the water column and time until sediment-water column phosphorus flux reaches steady state.

Ridge Lake Recommendations

- Calculate appropriate targets for TP and TN using the EPA (2010) guidance, after re-classifying most low color lakes into their appropriate category of clear and alkaline based on the use of a 164 µmhos/cm threshold for specific conductance.

- Implement sediment inactivation or sediment removal projects to minimize internal nutrient loads for lakes with documented prior point source impacts.

- Maximize surficial aquifer recharge using dry retention basins such as rain gardens and decrease the impervious areas in the watershed to increase ground water storage and maximize dry season lake levels via ground water discharge to the lakes.

Valley Lake Recommendations

- Calculate appropriate targets for TP and TN using the EPA (2010) guidance.
- Use a target color level of 50 PCU or higher or base target on historic color levels.
- Increase the hydrologic connection between lakes and swamp shoreline to a minimum of 10 to 20 percent of the shoreline to function as a wet season tannin source.

More detailed analysis of the costs of such projects, and project details, will be developed as part of project feasibility studies. The projects listed in Section 5 would supplement efforts to minimize stormwater runoff and maximize ground water recharge, as outlined in the Sustainable Water Resources Management Plan for the Peace Creek Watershed and City of Winter Haven (PBS&J 2009). Projects to increase surface water infiltration to the surficial aquifer would benefit water quality by increasing lake levels in the dry season via infiltration and eventual discharge from the surficial aquifer, and reducing stormwater pollutant loads via treatment processes of a typical dry retention pond. These types of appropriately located SIAs can be used in conjunction with large, regional stormwater treatment systems to reduce phosphorus loadings to lakes.

Sediment inactivation and/or removal projects would focus on lakes with documented prior point source impacts; such prior impacts appear to be capable of severely impacting water quality via internal loading processes.

Hydrilla control efforts should be better coordinated with other ongoing and/or planned lake management activities to minimize the potential of implementing projects with conflicting purposes. For all lakes, particularly low color lakes, an interim goal of maintaining at least 30 percent cover of the lake bottom with desirable SAV and/or 50 to 75 percent of the lake edge with EAV would be appropriate.

Lake aeration projects would focus on the smallest lakes within the WHCL, with emphasis placed on monitoring system responses both in terms of water quality and also monitoring of sediment composition.

For all water quality restoration projects, continued long-term and multi-parameter water quality monitoring programs are critical. While water quality monitoring programs may not receive the publicity and public awareness of large restoration projects, they are the only sources of information that can be relied upon to determine whether or not various restoration projects have performed successfully and whether additional projects should be considered.

Economic and Recreation Considerations

The City of Winter Haven will use the data, analyses, rankings, and recommendations developed for this WQMP to make decisions regarding selection and implementation of projects for the WHCL. Although quantitatively ranking the lakes based on factors other than water quality is beyond the scope of this WQMP, the City of Winter Haven cannot overlook the recreational and economic value of the WHCL in making these decisions. For example, Lakes Howard, May,

Shipp, Lulu, and Eloise may be considered of greater importance because of previously implemented water quality improvement projects and relatively high recreation use.

Clean lakes maintain lakeshore property values, contribute to the economic status of entire communities, provide lower cost drinking water, and offer intrinsic, aesthetic value for recreation. Defining the value of lakes can provide a means of evaluating the risk of degrading water quality and the cost of protecting our lakes in perspective. Sorting through restoration projects that compete for scarce funding means that having information about the use and passive use values of the restoration project can aid decision-makers in selecting restoration projects that provide the greatest benefits to society as a whole (Loomis 2008).

Monitoring

Importantly, water quality monitoring should continue in all lakes to provide a means of evaluating lake status in terms in terms of impairment or improvements. Success or failure of restoration projects cannot be evaluated in the absence of water quality monitoring. Alkalinity data should be collected for all lakes in the WHCL to adequately classify lakes based on the EPA NNC alkalinity/acidity designation.

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