Southwest District • Peace River Basin

Final Report

Nutrient TMDLs for Lakes Lulu (WBID 1521), Eloise (WBID 1521B), Shipp (WBID 1521D), May (WBID 1521E), Howard (WBID 1521F), Cannon (WBID 1521H), Hartridge (WBID 1521I), Idylwild (WBID 1521J), and Jessie (WBID 1521K) and Documentation in Support of the Development of Site-Specific Numeric Interpretations of the Narrative Nutrient Criterion

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Executive Summary

This report presents the total maximum daily loads (TMDLs) developed to address the nutrient impairments in the Winter Haven Southern Chain of Lakes (WHSCL), located in the Peace River Basin. Lakes Lulu, Eloise, Shipp, May, Howard, Cannon, Hartridge, Idylwild, and Jessie have exceedances of the applicable lake numeric nutrient criteria (NNC) in Subsection 62-302.531(2), F.A.C. Lakes Eloise and Hartridge were verified as impaired for nutrients and were included on the Verified List of impaired waters for the Sarasota Bay–Peace River–Myakka River Group 3 Basin in Assessment Cycle 3 adopted by Secretarial Order in October 2016. Lakes Cannon, Howard, Idylwild, Jessie, Lulu, May, and Shipp were verified as impaired for nutrients and were included on the Cycle 1 Verified List of impaired waters for the Peace River Basin adopted by Secretarial Order in June 2005.

Pursuant to Paragraph 62-302.531(2)(a), F.A.C., the nutrient TMDLs will, upon adoption, constitute the site-specific numeric interpretation of the narrative nutrient criterion set forth in Paragraph 62-302.530(48)(b), Florida Administrative Code (F.A.C.), that will replace the otherwise applicable NNC in Subsection 62-302.531(2), F.A.C.

TMDLs for total nitrogen (TN) and total phosphorus (TP) have been developed. **Table EX-1** lists supporting information for the TMDLs. The TMDLs were developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by the U.S. Environmental Protection Agency.

Table EX-1. Summary of TMDL supporting information for Lakes Lulu, Eloise, Shipp, May, Howard, Cannon, Hartridge, Idylwild, and Jessie

Type of Information	Description
Waterbody name (waterbody identification [WBID] number)	Lake Lulu (1521), Lake Eloise (1521B), Lake Shipp (1521D), Lake May (1521E), Lake Howard (1521F), Lake Cannon (1521H), Lake Hartridge (1521I), Lake Idylwild (1521J), and Lake Jessie (1521K)
Hydrologic Unit Code (HUC) 8	03100101
Use classification/ Waterbody designation	Class III Freshwater
Targeted beneficial uses	Fish consumption; recreation; and propagation and maintenance of a healthy, well-balanced population of fish and wildlife
303(d) listing status	Verified List of impaired waters for the Group 3 basins (Sarasota Bay–Peace River–Myakka River) adopted via Secretarial Order dated June 2005 (Lakes Lulu, Shipp, May, Howard, Cannon, Idylwild, and Jessie) and October 2016 (Lakes Eloise and Hartridge).
TMDL pollutants	Total nitrogen (TN) and total phosphorus (TP)
TMDLs and site-specific interpretations of the narrative nutrient criterion	**Lake Lulu (WBID 1521), Lake Eloise (WBID 1521B), Lake Shipp (WBID 1521D), Lake May (WBID 1521E), Lake Howard (WBID 1521F), Lake Cannon (WBID 1521H), Lake Hartridge (WBID 1521I), Lake Idylwild (WBID 1521J), and Lake Jessie (WBID 1521K):** **TN:** 1.07 milligrams per liter (mg/L), expressed as an annual geometric mean (AGM) not to be exceeded. **TP:** 0.03 mg/L, expressed as an AGM not to be exceeded.
Load reductions required to meet the TMDLs	**Lake Lulu (WBID 1521):** 35 % TN reduction and 0 % TP reduction to achieve a chlorophyll *a* target of 20 micrograms per liter (µg/L) **Lake Eloise (WBID 1521B):** 33 % TN reduction and 0 % TP reduction to achieve a chlorophyll *a* target of 20 µg/L **Lake Shipp (WBID 1521D):** 49 % TN reduction and 0 % TP reduction to achieve a chlorophyll *a* target of 20 µg/L **Lake May (WBID 1521E)**: 44 % TN reduction and 57 % TP reduction to achieve a chlorophyll *a* target of 20 µg/L **Lake Howard (WBID 1521F):** 39 % TN reduction and 0 % TP reduction to achieve a chlorophyll *a* target of 20 µg/L **Lake Cannon (WBID 1521H):** 20 % TN reduction and 0 % TP reduction to achieve a chlorophyll *a* target of 20 µg/L **Lake Hartridge (WBID 1521I):** 36 % TN reduction and 0 % TP reduction to achieve a chlorophyll *a* target of 20 µg/L **Lake Idylwild (WBID 1521J):** 31 % TN reduction and 0 % TP reduction to achieve a chlorophyll *a* target of 20 µg/L **Lake Jessie (WBID 1521K):** 12 % TN reduction and 0 % TP reduction to achieve a chlorophyll *a* target of 20 µg/L

Acknowledgments

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Acronyms and Additional Abbreviations Used in Report

AGM	Annual Geometric Mean
BMP	Best Management Practice
CFR	Code of Federal Regulations
CWA	Clean Water Act
DEP	Florida Department of Environmental Protection
EPA	Environmental Protection Agency
F.A.C.	Florida Administrative Code
FDOH	Florida Department of Health
F.S.	Florida Statutes
FWRA	Florida Watershed Restoration Act
FWS	U.S. Fish and Wildlife Service
GIS	Geographic Information System
HUC	Hydrologic Unit Code
in/yr	Inches Per Year
IPaC	Information for Planning and Conservation
IWR	Impaired Surface Waters Rule
LA	Load Allocation
mg/L	Milligrams/Liter
MOS	Margin of Safety
N	Nitrogen
NA	Not Applicable
MS4	Municipal Separate Storm Sewer System
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NNC	Numeric Nutrient Criteria
NPDES	National Pollutant Discharge Elimination System
OFW	Outstanding Florida Water
OSTDS	Onsite Sewage Treatment and Disposal System
P	Phosphorus
STORET	Storage and Retrieval
SWFWMD	Southwest Florida Water Management District
SWIM	Surface Water Improvement and Management
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
WBID	Waterbody Identification
WHSCL	Winter Haven Southern Chain of Lakes
WLA	Wasteload Allocation
WQS	Water Quality Standards
WWTF	Wastewater Treatment Facility

Chapter 1: Introduction

1.1 Purpose of Report

This report presents the total maximum daily loads (TMDLs) developed to address the nutrient impairments of Lakes Eloise and Hartridge, located in the Peace River Basin. Additionally, the report identifies revised nutrient TMDLs for Lakes Lulu, Shipp, May, Howard, Cannon, Idylwild, and Jessie.

Pursuant to Paragraph 62-302.531(2)(a), Florida Administrative Code (F.A.C.), the nutrient TMDLs will also constitute the site-specific numeric interpretation of the narrative nutrient criterion set forth in Paragraph 62-302.530(48)(b), F.A.C., that will replace the otherwise applicable numeric nutrient criteria (NNC) in Subsection 62-302.531(2), F.A.C. Lakes Eloise and Hartridge were verified as impaired for nutrients using the methodology in the Identification of Impaired Surface Waters Rule (IWR) (Chapter 62-303, F.A.C.), and were included on the Verified List of impaired waters for the Sarasota Bay–Peace River–Myakka River Group 3 Basin in Assessment Cycle 3 adopted by Secretarial Order in October 2016.

Lakes Cannon, Howard, Idylwild, Jessie, Lulu, May, Mirror, and Shipp were verified as impaired for nutrients using the methodology in the 2001 version of the IWR and were included on the Cycle 1 Verified List of impaired waters for the Peace River Basin adopted by Secretarial Order in June 2005. In 2007, the Florida Department of Environmental Protection (DEP) developed TMDLs for total phosphorus (TP) to address the nutrient impairments in these eight waterbodies in the Winter Haven Southern Chain of Lakes (WHSCL) system (Florida Department of Environmental Protection [DEP] 2007).

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and provides water quality targets needed to achieve compliance with applicable water quality criteria based on the relationship between pollutant sources and water quality in the receiving waterbody. The TMDLs establish the allowable loadings to Lakes Lulu, Eloise, Shipp, May, Howard, Cannon, Hartridge, Idylwild, and Jessie that would restore the waterbodies so that they meet their applicable water quality criteria for nutrients.

1.2 Identification of Waterbodies

The WHSCL includes Lakes Hartridge, Jessie, Idylwild, Cannon, Mirror, Spring, Howard, May, Shipp, Lulu, Roy, Eloise, Summit, and Winterset. Lakes Mariana, Blue, and Deer can flow into the other lakes in the Southern Chain when the lakes are at higher seasonal water levels.

For assessment purposes, DEP divided the Peace River Basin (Hydrologic Unit Code [HUC] 03100101) into watershed assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or surface water segment. Lake Lulu is WBID 1521, Lake Eloise is WBID 1521B, Lake Shipp is WBID 1521D, Lake May is WBID 1521E, Lake Howard is WBID 1521F, Lake Cannon is WBID 1521H, Lake Hartridge is WBID 1521I, Lake Idylwild is WBID 1521J, and Lake Jessie is WBID 1521K. These nine lakes had exceedances of the applicable NNC during the most recent Cycle 3 assessment period.

The lakes in the WHSCL not exceeding the applicable NNC are Lakes Mirror (WBID 1521G), Spring (WBID 1521G1), Roy (WBID 1521O), Summit (WBID 1521M), and Winterset (WBID 1521A).

Figure 1.1 shows the location of the lake WBIDs in the basin and major geopolitical and hydrologic features in the region, and **Figure 1.2** contains a more detailed map of the WBIDs. The WHSCL is located in north-central Polk County in or around the City of Winter Haven and near the Cities of Auburndale, Lake Alfred, and Eagle Lake (**Figure 1.2**). The nine lakes where exceedances of the NNC occur, along with Lakes Winterset, Mirror, Spring, Summit, and Roy, are interconnected by navigable canals. **Table 1.1** lists the characteristics of each lake in the WHSCL system.

Historical sources of nutrients to the WHSCL include discharges from chemical fertilizer plants, citrus packing, soft drink and milk bottling waste, and domestic sewage effluent. **Table 1.2** lists information on the former point source dischargers. Water flow through the canal system tended to distribute introduced materials throughout the chain (Riedinger-Whitmore et al. 2005). The facility discharges in the watershed have been removed, but the lakes continue to receive stormwater runoff from the watershed, which now primarily consists of urban development.

The WHSCL can discharge to Lake Lulu Run, which flows into the Wahneta Farms Drainage Canal, from a structure on the south side of Lake Lulu. The Wahneta Farms Drainage Canal flows into the Peace Creek Drainage Canal, which, along with Saddle Creek, makes up the headwaters of the Peace River.

Table 1.1. Characteristics of the WHSCL

[1] Data from Polk County Water Atlas 2019. ac = acres; ac-ft = acre-feet; ft = feet
Note: Lakes in shaded rows do not exceed the applicable NNC.

Lake Name	WBID	Lake Surface Area (ac)[1]	Lake Volume (ac-ft)[1]	Mean Depth (ft)[1]	Maximum Depth (ft)[1]	Watershed Area (ac)	Hydrologically connected to
Lulu	**1521**	315	1,514	5.0	13.7	768	Eloise, Roy, Shipp
Eloise	**1521B**	1,174	12,645	10.0	18.0	995	Lulu, Summit, Winterset
Shipp	**1521D**	276	1,533	4.0	14.0	610	May, Lulu
May	**1521E**	49	132	3.0	8.0	429	Howard, Shipp
Howard	**1521F**	624	6,968	11.0	19.0	1,416	May, Cannon
Cannon	**1521H**	333	3,486	10.0	17.0	859	Idylwild, Howard, Spring
Hartridge	**1521I**	433	4,114	5.0	22.0	479	Idylwild, Conine
Idylwild	**1521J**	95	747	5.0	18.0	259	Jessie, Cannon, Hartridge
Jessie	**1521K**	189	1,546	5.0	12.0	2,203	Idylwild
Winterset	**1521A**	556	8,846	13.0	30.0	478	Eloise
Mirror	**1521G**	123	1,045	11.0	14.0	154	Cannon, Spring
Spring	**1521G1**	24	240	3.0	19.0	92	Mirror
Summit	**1521M**	66	758	15.0	26.0	115	Eloise
Roy	**1521O**	74	896	14.0	23.0	321	Lulu

Table 1.2. Former point source discharges to the WHSCL

Information from PBS&J 2010

Lake Name	WBID	Point Source Discharger	Type of Discharger	Year Discharges Ended
Lulu	**1521**	City of Winter Haven	Domestic WWTF	1977
Lulu	**1521**	Bordo's Citrus Processing Plant	Industrial WWTF	Unknown
Lulu	**1521**	Snively Plant	Industrial WWTF	Unknown
Lulu	**1521**	Swift Fertilizer Plant	Industrial WWTF	Unknown
Eloise	**1521B**	Cypress Gardens	Domestic WWTF	1975
Shipp	**1521D**	Robert Brothers vegetable processing	Industrial WWTF	Unknown
Shipp	**1521D**	Bordo's Citrus Processing Plant	Industrial WWTF	Unknown
May	**1521E**	Imhoff Plant	Industrial WWTF	1949
May	**1521E**	Citrus	Industrial WWTF	Unknown
May	**1521E**	Velda Farms Dairy	Industrial WWTF	Unknown
Howard	**1521F**	Jan-Phyl Village	Domestic WWTF	1977
Jessie	**1521K**	Unknown	Domestic WWTF	Unknown

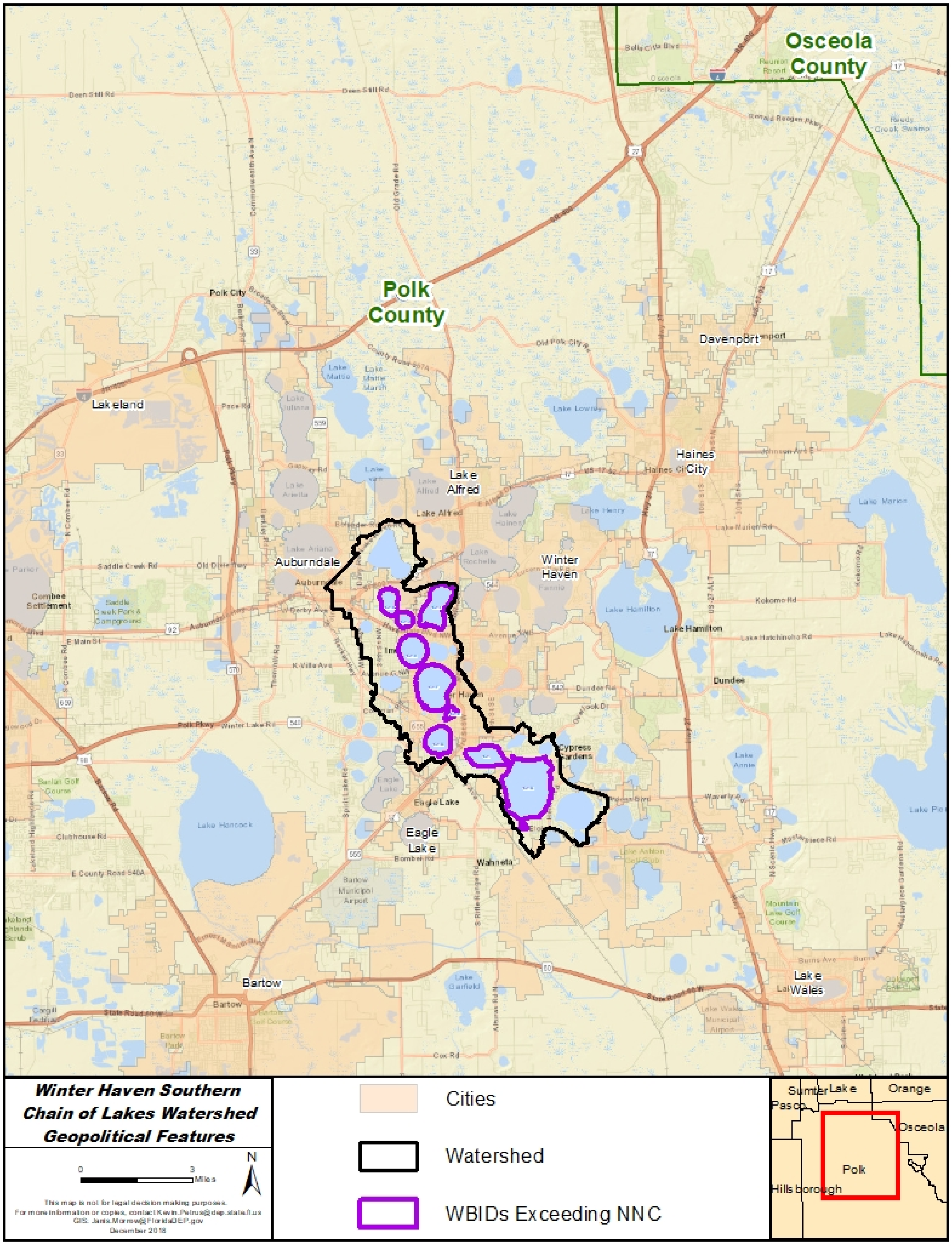

Figure 1.1. Location of the WHSCL Watershed in the Peace River Basin and major hydrologic and geopolitical features in the region

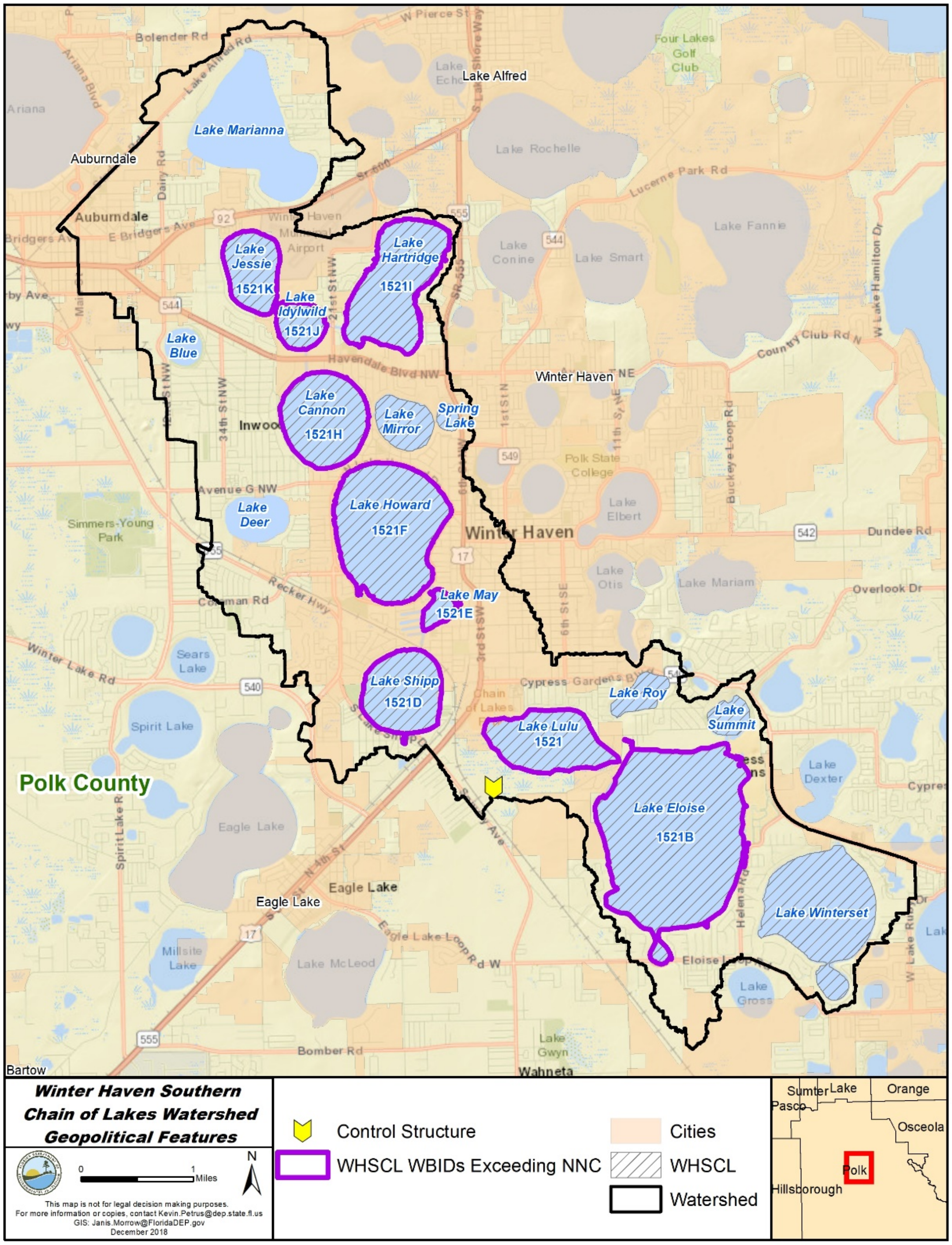

Figure 1.2. Closer view of Lakes Lulu (WBID 1521), Eloise (WBID 1521B), Shipp (WBID 1521D), May (WBID 1521E), Howard (WBID 1521F), Cannon (WBID 1521H), Hartridge (WBID 1521I), Idylwild (WBID 1521J), and Jessie (WBID 1521K) in the WHSCL Watershed and major hydrologic and geopolitical features in the area

1.3 Watershed Information

1.3.1 Population and Geopolitical Setting

The WHSCL is located in north-central Polk County in or around the City of Winter Haven and near the Cities of Auburndale, Eagle Lake, and, Lake Alfred (**Figure 1.2**). Polk County had a population of 686,483 in 2017 (U.S. Census Bureau July 2017). The City of Winter Haven had a population of 41,280 in 2017 (U.S. Census Bureau July 2017). The Cities of Auburndale, Eagle Lake, and, Lake Alfred had populations of 15,973, 2,570, and 5,941 in 2017, respectively (U.S. Census Bureau July 2017).

Historically the area around the lakes has been used for agriculture (improved pasture) and citrus production (PBS&J 2010). In the 1920s, numerous navigable canals were constructed to link the lakes. The lakes are situated in a rapidly urbanizing region. Most of the urbanization has taken place on soils with high infiltration rates and has resulted in increased runoff to the lakes where previously infiltration and aquifer recharge would have occurred (PBS&J 2010).

1.3.2 Topography

The lakes in the Southern Chain and other lakes in the vicinity lie in the Trail Ridge/Lake Wales Ridge (75-31) lake region (Griffith et al. 1997), which runs north-south through Polk County. This system is the oldest and highest of a series of sand ridges (relict beaches of ancient sea levels) that parallel the present coastlines (Southwest Florida Water Management District [SWFWMD] 1998). The dominant natural vegetation is longleaf pine and xerophytic oak. The lakes in the area are sinkhole features caused by the collapse of dissolution cavities of the underlying limestone (Sinclair and Reichenbaugh 1981).

The elevation in the watershed ranges from 180 feet (ft) (North American Vertical Datum 29) above sea level (ASL) on the ridge east of Lake Howard to 130 ft ASL at the outlet of Lake Lulu. From 2008 to 2016, the average lake levels of the 14 lakes in the WHSCL were 130 ft ASL.

1.3.3 Hydrogeological Setting

The greater hydrogeological context in which these lakes function is determined in part by the topography, but also by their similar soil geology, aquifer/groundwater interactions, and climate.

The climate of the watershed area is subtropical, with an annual average temperature of 73° F. Annual rainfall in or near the Peace River Basin averages 50 to 56 inches, and 60 % of the rainfall occurs from June through September (SWFWMD 2004). The long-term average annual rainfall for Polk County, based on SWFWMD records from 1915 to 2017, is 52 inches/year (in/yr).

The entire WHSCL Watershed is underlain by the Cypresshead Formation (Pliocene), which consists of reddish brown to reddish orange, unconsolidated to poorly consolidated, fine to very coarse grained, clean to clayey sands where the surficial aquifer system is located (Scott 2001; Spechler and Kroening 2007). Below this formation are a series of limestone formations of Miocene through Eocene age where the intermediate aquifer system and Floridan aquifer system are located.

Soils are classified by the National Cooperative Soil Survey into four hydrologic soil groups (HSGs)—Types A, B, C, and or D—based on their runoff potential. "A" type soils are typically well-drained, have deep water tables, and consist of sandy textured soils with relatively low runoff potential. "B" type soils are typically loamy with some silt component, a moderately coarse texture, and a lower infiltration rate than Type A soils and are therefore classed as moderately well drained. "C" type soils are sand, clay, and loam with more fine textures and lower infiltration rates, especially when wet. "D" type soils are variable in texture but generally have a greater clay component and are often found at lower topography with higher water tables that generate a higher hydrologic runoff response. Multi-classed soils vary in their hydrologic response depending on in situ drainage improvements.

The soils in the area are for the most part composed of various sands and sandy clay, with high infiltration rates (6.0 inches/hour) (U.S. Department of Agriculture Soil Conservation Service 1990), with the water table at least 6 ft below the surface. **Figure 1.3** displays the distribution of soil types in the WHSCL Watershed. The majority of soils in the watershed areas for the 14 lakes consists of a mix of well-drained and variable soil with higher clay content ("A/D" soils) and Type A soils (**Table 1.3**), which by virtue of their infiltration characteristics and the watershed elevation are principally recharge areas for the Floridan aquifer.

Table 1.3. Soil type acreage and percent in the WHSCL regression set watershed

N/A = Not applicable because the area is unclassified lake bottom. Hybrid soil types are A/D, B/D, and C/D.

Soil	Watershed Total (ac)	Watershed Total (%)
N/A	5,837	41
A	4,121	29
A/D	3,977	28
B	24	<1
B/D	222	2
C	38	<1
C/D	34	<1
D	0	0
Total	**14,253**	**100**

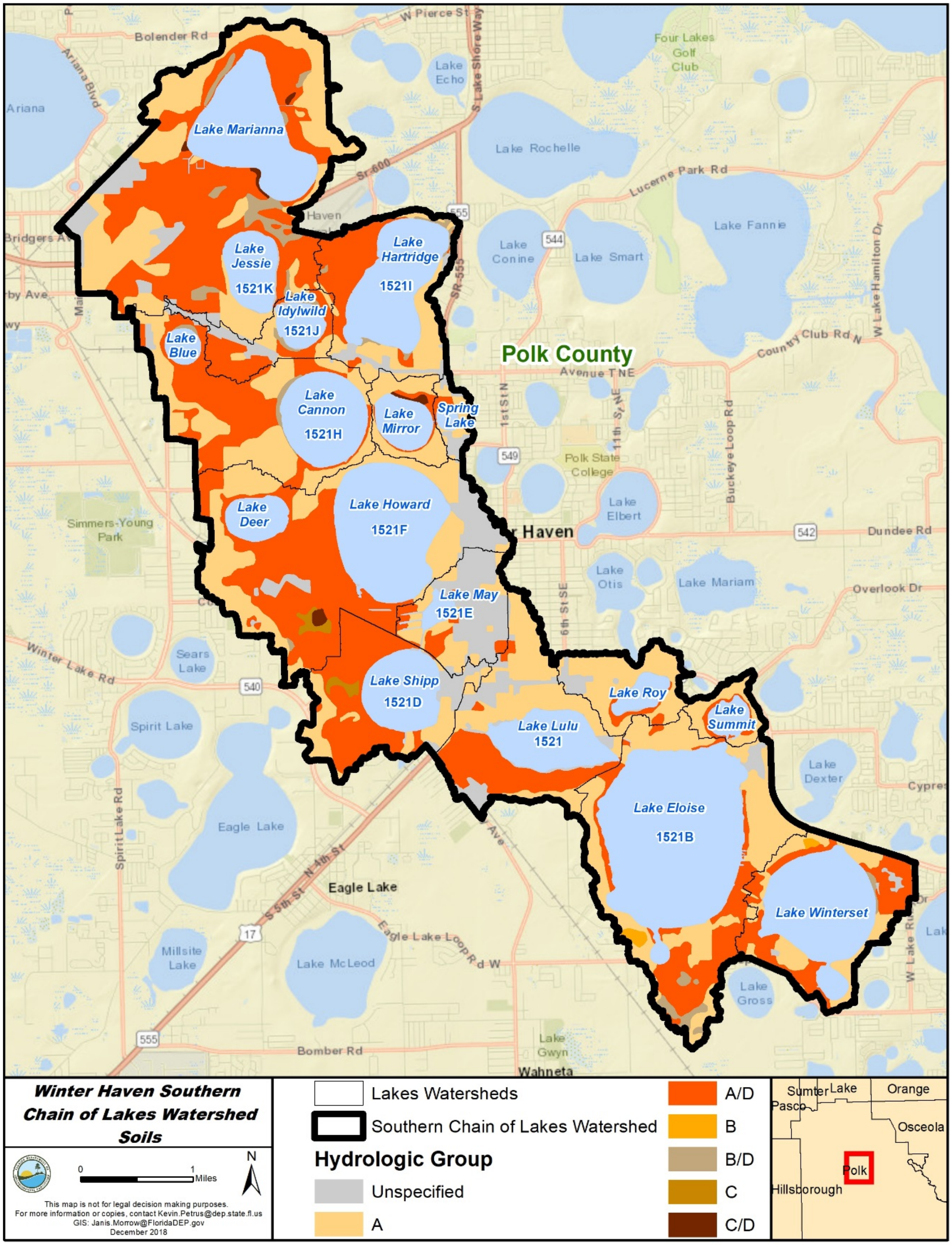

Figure 1.3. Hydrologic soil groups in the WHSCL regression set watershed

Chapter 2: Water Quality Assessment and Identification of Pollutants of Concern

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the federal Clean Water Act (CWA) requires states to submit to the U.S. Environmental Protection Agency (EPA) lists of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant causing the impairment of listed waters on a schedule. DEP has developed such lists, commonly referred to as 303(d) lists, since 1992.

The Florida Watershed Restoration Act (FWRA) (Section 403.067, Florida Statutes [F.S.]) directed DEP to develop, and adopt by rule, a science-based methodology to identify impaired waters. The Environmental Regulation Commission adopted the methodology as Chapter 62-303, F.A.C. (the IWR), in 2001. The rule was amended in 2006, 2007, 2012, 2013, and 2016.

The list of impaired waters in each basin, referred to as the Verified List, is also required by the FWRA (Subsection 403.067[4], F.S.). The state's 303(d) list is amended annually to include basin updates.

2.2 Classification of the Waterbody and Applicable Water Quality Standards

Lakes Eloise, Lulu, Shipp, May, Howard, Cannon, Hartridge, Idylwild, and Jessie are Class III (fresh) waterbodies, with a designated use of fish consumption, recreation, and propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the verified impairment (nutrients) for these waterbodies is Florida's nutrient criterion in Paragraph 62-302.530(48)(b), F.A.C. Florida adopted NNC for lakes, spring vents, and streams in 2011. These were approved by the EPA in 2012 and became effective in 2014.

The applicable lake NNC are dependent on alkalinity, measured in milligrams per liter as calcium carbonate (mg/L $CaCO_3$), and true color (color), measured in platinum cobalt units (PCU), based on long-term period of record (POR) geometric means (**Table 2.1**). For the 9 lakes exceeding the NNC, the POR alkalinity geometric means ranged from 43 mg/L $CaCO_3$ in Lake Hartridge to 64 mg/L $CaCO_3$ in Lake Lulu. The POR geometric means for color ranged from 12 PCU in Lake Hartridge to 20 PCU in Lake Lulu.

The geometric means were calculated based on the results in the IWR Run 55 database. Using this methodology, the lakes in the southern chain that exceed NNC are classified as low-color (≤40 PCU), high-alkalinity (> 20 mg/L $CaCO_3$) lakes. The five other lakes that do not exceed the NNC (Lakes Mirror, Spring, Roy, Summit, and Winterset) are also classified as low-color, high alkalinity lakes.

The chlorophyll *a* NNC for low-color, high alkalinity lakes is an annual geometric mean (AGM) value of 20 micrograms per liter (µg/L), not to be exceeded more than once in any consecutive 3-year period. The associated total nitrogen (TN) and TP criteria for a lake can vary annually, depending on the availability of data for chlorophyll *a* and the concentrations of chlorophyll *a* in the lake. If there are sufficient data to calculate an AGM for chlorophyll *a* and the mean does not exceed the chlorophyll *a* criterion for the lake type listed in **Table 2.1**, then the TN and TP numeric interpretations for that calendar year are the AGMs of lake TN and TP samples, subject to the minimum and maximum TN and TP limits in the table.

If there are insufficient data to calculate the AGM for chlorophyll *a* for a given year, or the AGM for chlorophyll *a* exceeds the values in the table for the lake type, then the applicable numeric interpretations for TN and TP are the minimum values in the table. **Table 2.1** lists the NNC for Florida lakes specified in Subparagraph 62-302.531(2)(b)1., F.A.C.

Table 2.1. Chlorophyll *a*, TN, and TP criteria for Florida lakes (Subparagraph 62-302.531[2][b]1., F.A.C.)

* For lakes with color > 40 PCU in the West Central Nutrient Watershed Region, the maximum TP limit is the 0.49 mg/L TP streams threshold for the region.

Long-Term Geometric Mean Lake Color and Alkalinity	AGM Chlorophyll *a* (µg/L)	Minimum Calculated AGM TP NNC (mg/L)	Minimum Calculated AGM TN NNC (mg/L)	Maximum Calculated AGM TP NNC (mg/L)	Maximum Calculated AGM TN NNC (mg/L)
>40 PCU	20	0.05	1.27	0.16*	2.23
≤ 40 PCU and > 20 mg/L $CaCO_3$	20	0.03	1.05	0.09	1.91
≤ 40 PCU and ≤ 20 mg/L $CaCO_3$	6	0.01	0.51	0.03	0.93

2.3 Determination of the Pollutant of Concern

2.3.1 Data Providers

The sources of lake nutrient data used in the most recent assessment period, beginning in 2008, are stations sampled by Polk County (21FLPOLK…) and DEP (21FLTPA…, and 21FLGW…). The majority of the nutrient data comes from the monitoring conducted by Polk County. **Figure.1** shows the lake sampling locations, and **Table 2.2** lists the monitoring stations for each lake with chlorophyll *a*, TN, and TP data in the period from 2008 to 2016. The water quality results for the 14 lakes in the southern chain in this period were used in the regression analysis, described in **Chapter 5**.

The county started routine monitoring of the WHSCL in the mid-1990s. In 1999, the county began sampling for corrected chlorophyll *a*, the more common form of chlorophyll *a* used in assessing surface water quality. Other sampling organizations have conducted lake monitoring intermittently. The water quality measurements discussed in this report are available in IWR Run 56 database and are available on request.

Table 2.2. WHSCL stations monitored from 2008 to 2016

[1] Boldface type indicates stations with the majority of data in each lake.
Note: Lakes in shaded rows do not exceed the applicable NNC.

Lake Name	WBID	Station Name[1]
Lulu	1521	**21FLPOLKLULU1** 21FLTPA 25020144
Eloise	1521B	**21FLPOLKLTL ELOISE1** **21FLPOLKELOISE1** 21FLGW 47185 21FLGW 41148 21FLGW 40268
Shipp	1521D	**21FLPOLKSHIPP1** 21FLTPA 25020355
May	1521E	**21FLPOLKMAY1**
Howard	1521F	**21FLPOLKHOWARD1** 21FLGW 45441 21FLTPA 25020267
Cannon	1521H	**21FLPOLKCANNON1** 21FLGW 41626
Hartridge	1521I	**21FLPOLKHARTRIDGE1** 21FLTPA 25020070
Idylwild	1521J	**21FLPOLKIDYLWILD1**
Jessie	1521K	**21FLPOLKJESSIE1**
Winterset	1521A	**21FLPOLKWINTERSET1** **21FLPOLKLTL WINTERSET1**
Mirror	1521G	**21FLPOLKMIRROR1** 21FLTPA 25020356 21FLTPA 28021688144296
Spring	1521G1	**21FLPOLKSPRING1** 21FLGW 39661 21FLGW 40396 21FLGW 42523 21FLGW 44512 21FLTPA 28021618144058
Summit	1521M	**21FLPOLKSUMMIT1**
Roy	1521O	**21FLPOLKROY1**

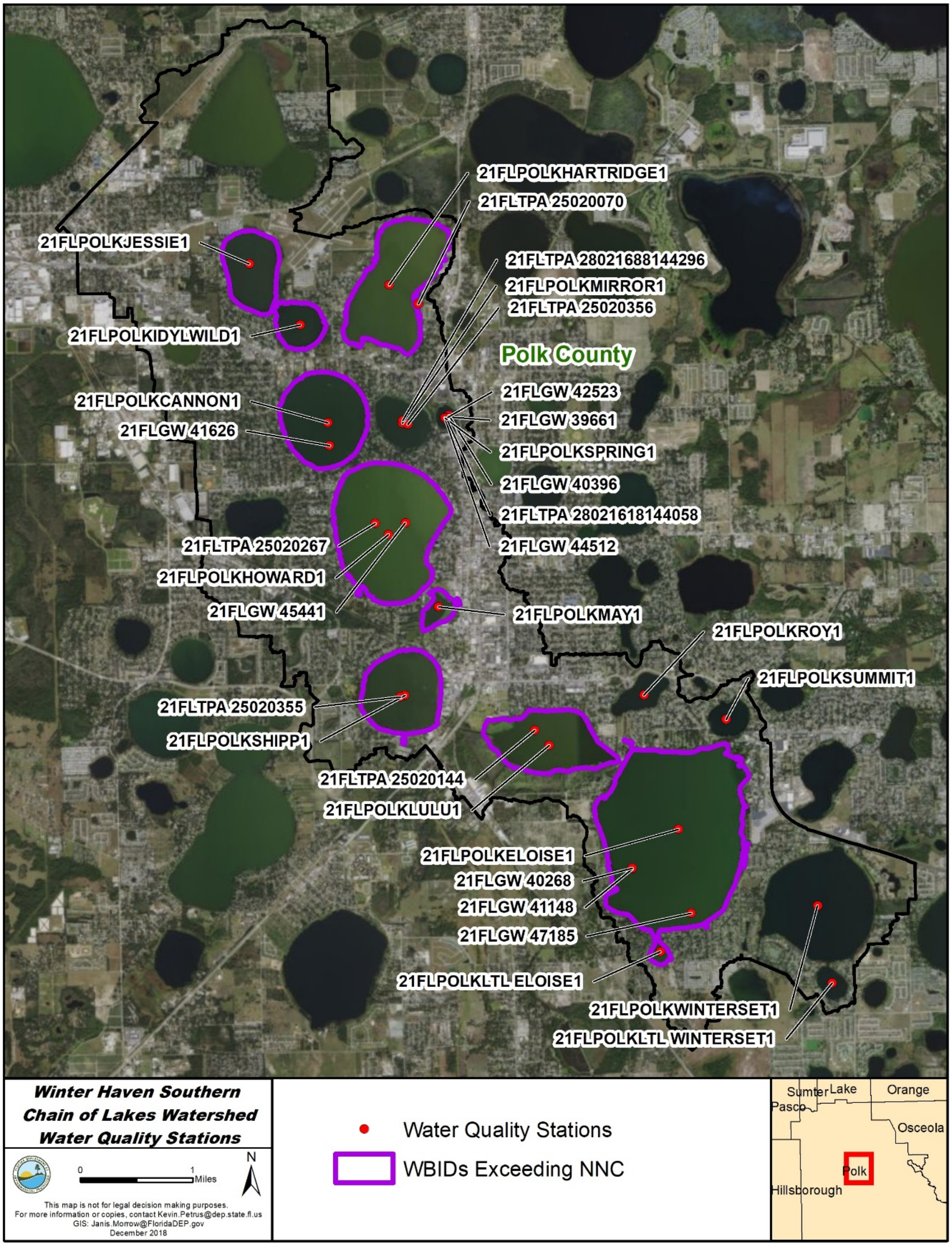

Figure 2.1. Monitoring stations in the WHSCL (2008–16)

2.3.2 Information on Verified Impairment

For the Group 3 basin assessment completed in 2016, the NNC were used to assess the lakes during the verified period (January 1, 2008–June 30, 2015), based on data from the IWR Run 52 database. Lake Eloise was assessed as impaired (Category 5) for chlorophyll *a* and TN, and Lake Hartridge was assessed as impaired for chlorophyll *a*, TN, and TP because the AGMs exceeded the NNC more than once in a three-year period. The waterbodies were added to the Verified List for these parameters. Lake Eloise was assessed as not impaired for TP (Category 2).

Lakes Cannon, Howard, Idylwild, Jessie, Lulu, May, Mirror, and Shipp were verified as impaired for nutrients in the Cycle 1 assessment period and were included on the Verified List for the Peace River Basin adopted by Secretarial Order in June 2005. For the Cycle 1 (2005) and Cycle 2 (2010) basin assessments, the Trophic State Index (TSI), a calculation based on nutrient and chlorophyll *a* concentrations, was the primary means of assessing nutrient impairment in lakes.

For the most recent basin assessment in 2016, Lakes Cannon, Howard, Idylwild, Jessie, Lulu, May, and Shipp had AGMs exceeding the applicable NNC for chlorophyll *a* and TN. The TP AGMs for Lake May also exceeded the applicable NNC. **Tables 2.3**, **2.4**, and **2.5** list the chlorophyll *a*, TN, and TP AGMs, respectively, calculated using the most recent results found in the IWR Run 56 database, for the lakes exceeding the NNC from 2008 to 2016. Lake Mirror, identified as impaired for nutrients in Cycles 1 and 2, is not impaired for nutrients using the applicable NNC.

Table 2.3. WHSCL chlorophyll *a* AGM values (µg/L), 2008–16

Note: Values shown in boldface type and shaded are greater than the NNC for lakes. Rule 62-302.531, F.A.C., states that the applicable numeric interpretations for TN, TP, and chlorophyll *a* shall not be exceeded more than once in any consecutive three-year period.

Year	Lake Lulu	Lake Eloise	Lake Shipp	Lake May	Lake Howard	Lake Cannon	Lake Hartridge	Lake Idylwild	Lake Jessie
2008	**35**	**31**	**30**	**51**	**42**	**24**	14	**28**	**25**
2009	**31**	**27**	**50**	**47**	**33**	**32**	**23**	**37**	**31**
2010	**30**	**31**	**39**	**32**	**25**	**28**	**24**	**33**	**32**
2011	**25**	**39**	**38**	**35**	**30**	**29**	**28**	**23**	**25**
2012	**23**	**27**	**36**	**37**	**33**	**23**	**28**	**21**	**24**
2013	**23**	**36**	**32**	**33**	**27**	**30**	**31**	**27**	**27**
2014	17	**34**	**23**	**24**	**27**	**27**	**30**	**22**	**27**
2015	**21**	**31**	**25**	19	**26**	16	**28**	17	20
2016	**25**	**37**	**27**	**29**	**28**	19	**27**	14	15

Table 2.4. WHSCL TN AGM values (mg/L), 2008–16

Note: Values shown in boldface type and shaded are greater than the NNC for lakes. Rule 62-302.531, F.A.C., states that the applicable numeric interpretations for TN, TP, and chlorophyll *a* shall not be exceeded more than once in any consecutive three-year period.

Year	Lake Lulu	Lake Eloise	Lake Shipp	Lake May	Lake Howard	Lake Cannon	Lake Hartridge	Lake Idylwild	Lake Jessie
2008	**1.64**	**1.13**	**2.08**	**1.90**	**1.76**	1.05	1.03	**1.22**	**1.06**
2009	**1.45**	**1.17**	**1.95**	**1.73**	**1.65**	**1.31**	**1.25**	**1.54**	**1.14**
2010	**1.50**	**1.34**	**1.69**	**1.55**	**1.38**	**1.21**	**1.23**	**1.33**	**1.20**
2011	**1.46**	**1.59**	**1.87**	**1.73**	**1.63**	**1.33**	**1.42**	**1.29**	**1.21**
2012	**1.34**	**1.31**	**1.72**	**1.69**	**1.64**	**1.13**	**1.45**	**1.26**	**1.16**
2013	**1.15**	**1.56**	**1.45**	**1.49**	**1.46**	**1.33**	**1.64**	**1.30**	**1.13**
2014	1.04	**1.56**	**1.23**	**1.32**	**1.36**	**1.29**	**1.66**	**1.24**	**1.17**
2015	**1.08**	**1.36**	**1.17**	**1.20**	**1.26**	0.93	**1.36**	0.96	0.95
2016	**1.22**	**1.54**	**1.29**	**1.41**	**1.44**	1.06	**1.43**	0.97	0.90

Table 2.5. WHSCL TP AGM values (mg/L) from 2008 to 2016

ID = Insufficient data
Note: Values shown in boldface type and shaded are greater than the NNC for lakes. Rule 62-302.531, F.A.C., states that the applicable numeric interpretations for TN, TP, and chlorophyll *a* shall not be exceeded more than once in any consecutive three-year period.

Year	Lake Lulu	Lake Eloise	Lake Shipp	Lake May	Lake Howard	Lake Cannon	Lake Hartridge	Lake Idylwild	Lake Jessie
2008	**0.05**	0.02	**0.05**	**0.07**	0.03	0.02	0.02	0.02	**0.05**
2009	0.03	0.02	**0.04**	**0.07**	0.02	0.02	0.02	0.02	0.02
2010	0.03	0.02	0.03	**0.06**	ID	ID	ID	ID	ID
2011	0.02	0.02	0.03	**0.06**	0.02	0.02	0.02	0.02	0.02
2012	0.02	0.02	0.02	**0.05**	0.02	0.02	0.02	0.02	0.02
2013	0.02	0.02	0.02	**0.05**	0.02	0.02	0.02	0.02	0.02
2014	0.02	0.02	0.02	**0.04**	0.02	0.02	0.02	0.02	0.02
2015	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2016	0.02	0.03	0.02	**0.04**	0.02	0.02	0.02	0.02	0.02

Chapter 3: Site-Specific Numeric Interpretation of the Narrative Nutrient Criterion

3.1 Establishing the Site-Specific Interpretation

Pursuant to Paragraph 62-302.531(2)(a), F.A.C., the nutrient TMDLs presented in this report will, upon adoption into Chapter 62-304.625, F.A.C., constitute the site-specific numeric interpretation of the narrative nutrient criterion set forth in Paragraph 62-302.530(48)(b), F.A.C., that will replace the otherwise applicable NNC in Subsection 62-302.531(2), F.A.C. **Table 3.1** lists the elements of the nutrient TMDLs that constitute the site-specific numeric interpretation of the narrative nutrient criterion. **Appendix B** summarizes the relevant details to support the determination that the TMDLs provide for the protection of Lakes Lulu, Eloise, Shipp, May, Howard, Cannon, Hartridge, Idylwild, and Jessie, and for the attainment and maintenance of water quality standards in downstream waters (pursuant to Subsection 62-302.531[4], F.A.C.), and to support using the nutrient TMDLs as the site-specific numeric interpretations of the narrative nutrient criterion.

When developing TMDLs to address nutrient impairment, it is essential to address those nutrients that typically contribute to excessive plant growth. In Florida waterbodies, nitrogen and phosphorus are most often the limiting nutrients. The limiting nutrient is defined as the nutrient(s) that limit plant growth (both macrophytes and algae) when it is not available in sufficient quantities. A limiting nutrient is a chemical necessary for plant growth, but available in quantities smaller than those needed for the optimal growth of algae, represented by chlorophyll *a*, and macrophytes.

In the past, management activities to control lake eutrophication focused on phosphorus reduction, as phosphorus was generally recognized as the most limiting nutrient in freshwater systems. Recent studies, however, have supported the reduction of both nitrogen and phosphorus as necessary to control algal growth in aquatic systems (Conley et al. 2009; Paerl 2009; Lewis et al. 2011; Paerl and Otten 2013). Furthermore, the analysis used in the development of the Florida lake NNC support this idea, as statistically significant relationships were found between chlorophyll *a* values and both nitrogen and phosphorus concentrations (DEP 2012).

3.2 Site-Specific Response Variable Target Selection

The generally applicable chlorophyll *a* criteria for lakes were established by taking into consideration multiple lines of evidence, including an analysis of lake chlorophyll *a* concentrations statewide, comparisons with a smaller population of select reference lakes, paleolimnological studies, expert opinions, user perceptions, and biological responses. Based on the evidence, DEP concluded that an annual average chlorophyll *a* of 20 µg/L in colored, high-alkalinity lakes is protective of the designated uses of recreation and aquatic life support (DEP

2012). Color and alkalinity were used as morphoedaphic factors to predict the natural trophic status of lakes. Colored (>40 PCU), high-alkalinity (>20 mg $CaCO_3$/L) lakes are naturally mesotrophic or eutrophic.

The generally applicable chlorophyll *a* criteria are assumed to be protective of individual Florida lakes, absent information that shows either (1) more sensitive aquatic life use (i.e., a more responsive floral community), or (2) a significant historical change in trophic status (i.e., a significant increasing trend in color and/or alkalinity). Long-term datasets of color, alkalinity, and nutrients in the WHSCL suggest that they do not differ from the population of lakes used in the development of the NNC. Therefore, DEP has determined that the generally applicable chlorophyll *a* criterion for low-color, high-alkalinity lakes is appropriate for the lakes in the WHSCL, will serve as the TMDL water quality target, and will remain the applicable water quality criterion.

3.3 Numeric Expression of the Site-Specific Numeric Interpretation

An empirical equation describing the relationships between chlorophyll *a* and nutrient concentrations (TN and TP), using the AGM values for all 14 lakes in the WHSCL, was applied in the TMDL development approach, explained in detail in **Chapter 5**. This approach uses the regression relationships between nutrients and chlorophyll *a* to assist in setting restoration target concentrations. The site-specific numeric interpretation of the narrative criterion and TMDL target for TP (0.03 mg/L, not to be exceeded in any year) is based on paleolimnological study results conducted on select lakes in the WHSCL (Whitmore and Brenner 1995; 2002) (see **Chapter 5**).

The site-specific numeric interpretation of the narrative criterion and TMDL target for TN (1.07 mg/L, not to be exceeded in any year) was determined using a regression approach, based on the relationship between nutrients (TN and TP) and chlorophyll *a*. The TN concentration, along with the lake TP concentration set at the criterion, would achieve the applicable chlorophyll *a* criterion (20 µg/L, not to be exceeded more than once in any consecutive 3-year period). The target concentrations are then used to determine the percent reductions in in-lake concentrations necessary to meet the targets, for the period from 2008 to 2016.

The nutrient criteria are all expressed as AGM concentrations in these lakes. The chlorophyll *a* concentration is expressed as an AGM concentration not to be exceeded more than once in any consecutive three-year period. The TN and TP concentrations are expressed as AGM concentrations never to be exceeded. **Table 3.1** summarizes the nutrient concentration targets for the lakes.

Table 3.1. Site-specific interpretations of the narrative nutrient criterion

Note: Frequency refers to the time interval not to be exceeded. Chlorophyll *a* shall not be exceeded more than once in any consecutive three-year period. TN and TP are never to be exceeded.

Waterbody/ WBID	AGM Chlorophyll *a* (µg/L)	Chlorophyll *a* Frequency	AGM TN (mg/L)	TN Frequency	AGM TP (mg/L)	TP Frequency
Lake Lulu/ 1521	20	Once in a three-year period	1.07	No exceedance	0.03	No exceedance
Lake Eloise/ 1521B	20	Once in a three-year period	1.07	No exceedance	0.03	No exceedance
Lake Shipp/ 1521D	20	Once in a three-year period	1.07	No exceedance	0.03	No exceedance
Lake May/ 1521E	20	Once in a three-year period	1.07	No exceedance	0.03	No exceedance
Lake Howard/ 1521F	20	Once in a three-year period	1.07	No exceedance	0.03	No exceedance
Lake Cannon/ 1521H	20	Once in a three-year period	1.07	No exceedance	0.03	No exceedance
Lake Hartridge/ 1521I	20	Once in a three-year period	1.07	No exceedance	0.03	No exceedance
Lake Idylwild/ 1521J	20	Once in a three-year period	1.07	No exceedance	0.03	No exceedance
Lake Jessie/ 1521K	20	Once in a three-year period	1.07	No exceedance	0.03	No exceedance

3.4 Downstream Protection

The Southern Chain of Lakes can discharge to Lake Lulu Run (WBID 1521C) from a structure on the south side of Lake Lulu. Lake Lulu Run flows into the Wahneta Farms Drainage Canal (WBID 1580). The Wahneta Farms Drainage Canal flows into the Peace Creek Drainage Canal, which, along with Saddle Creek, makes up the headwaters of the Peace River.

The Peace River Basin is located in the West Central Nutrient Watershed Region. The generally applicable NNC for streams in this region, including Lake Lulu Run, Wahneta Farms Drainage Canal, and Peace Creek Drainage Canal, set forth in Subparagraph 62-302.531(2)(c)2., F.A.C., are a TN concentration of 1.65 mg/L and a TP concentration of 0.49 mg/L. These nutrient thresholds, which are expressed as AGMs not to be exceeded more than once in a 3-year period, are higher than the AGM site-specific interpretations of the narrative nutrient criterion for the WHSCL.

Lake Lulu Run is verified as impaired for DO and nutrients (chlorophyll *a*). There are limited nutrient data available for this segment. In the most recent, Cycle 3, assessment period the chlorophyll *a* stream threshold for impairment (20 µg/L expressed as an AGM), was exceeded in one of the three years when sufficient data were available to calculate AGMs (AGM = 23 µg/L in 2008). Likewise, the applicable stream TN threshold was exceeded in one of the three years when sufficient data were available to calculate AGMs (AGM = 1.81 mg/L in 2008). The applicable TP threshold was not exceeded in 2003 and 2008, the only years with sufficient data to calculate AGMs. Lake Lulu Run is primarily fed by outflow from Lake Lulu. The Lake Lulu outlet channel passes through an extensive wetland area on the south side of the lake, upstream of the control structure, **Figure 1.2**. The wetlands is the likely source of the lower DO levels in the Run.

The Wahneta Farms Drainage Canal and Peace Creek Drainage Canal are not on the verified list of impaired waters. During the Cycle 3 assessment period, the TN and TP AGMs in the Wahneta Farms Drainage Canal were all less than the applicable stream thresholds. In the Peace Creek Drainage Canal, the TN and TP AGMs did not exceed the stream thresholds more than once in a 3-year period.

The reductions in nutrient concentrations prescribed in the TMDLs are not expected to cause nutrient impairments downstream and will actually improve water quality in waterbody segments downstream by reducing algal biomass and associated nutrients transported downstream.

3.5 Endangered Species Considerations

Section 7(a)(2) of the Endangered Species Act requires each federal agency, in consultation with the services (i.e., the U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, and National Marine Fisheries Service), to ensure that any federal action authorized, funded, or carried out is not likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat. The EPA must review and approve changes in water quality standards (WQS) such as setting site-specific criteria.

Prior to approving WQS changes for aquatic life criteria, the EPA will prepare an Effect Determination summarizing the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action. The EPA categorizes potential effect outcomes as either (1) "no effect," (2) "may affect, not likely to adversely affect," or (3) "may affect: likely to adversely affect."

The service(s) must concur on the Effect Determination before the EPA approves a WQS change. A finding and concurrence by the service(s) of "no effect" will allow the EPA to approve an otherwise approvable WQS change. However, findings of either "may affect, not likely to adversely affect" or "may affect: likely to adversely affect" will result in a longer consultation process between the federal agencies and may result in a disapproval or a required modification to the WQS change.

DEP is not aware of any endangered aquatic species present in the WHSCL. Furthermore, water quality improvements resulting from these restoration efforts are expected to positively affect aquatic species living in the lakes and their respective watersheds.

Chapter 4: Assessment of Sources

4.1 Types of Sources

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of the pollutant of concern in the target watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either point sources or nonpoint sources. Historically, the term "point sources" has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, agriculture, silviculture, and mining; discharges from septic systems; and atmospheric deposition.

However, the 1987 amendments to the CWA redefined certain nonpoint sources of pollution as point sources subject to regulation under the EPA's National Pollutant Discharge Elimination System (NPDES) Program. These nonpoint sources included certain urban stormwater discharges, such as those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see **Appendix A** for background information on the federal and state stormwater programs).

To be consistent with CWA definitions, the term "point source" is used to describe traditional point sources (such as domestic and industrial wastewater discharges) and stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (see **Section 6.1** on **Expression and Allocation of the TMDL**). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2 Point Sources

4.2.1 Wastewater Point Sources

There are no NPDES-permitted domestic or industrial wastewater facilities discharging in the WHSCL Watershed. **Table 1.2** lists former dischargers to the lakes in the WHSCL system.

4.2.2 Municipal Separate Storm Sewer System (MS4) Permittees

The WHSCL Watershed is covered by a Polk County NPDES MS4 Phase I permit (FLS000015). The Florida Department of Transportation (FDOT) District 1 and the Cities of Winter Haven and Auburndale are co-permittees in the MS4 permit. For additional information on MS4 facilities in the watersheds, email npdes-stormwater@dep.state.fl.us. **Table 4.1** lists the permittees/co-permittees and their MS4 permit numbers.

Table 4.1. NPDES MS4 permits with jurisdiction in the WHSCL Watershed

Permit Number	Permittee/Co-Permittee	Phase
FLS000015	Polk County	I
FLS266604	City of Auburndale	I
FLS266761	City of Winter Haven	I
FLS266779	FDOT District 1 – Polk	I

4.3 Nonpoint Sources

Pollutant sources that are not NPDES wastewater or stormwater dischargers are generally considered nonpoint sources. Nutrient loadings to the WHSCL are primarily generated from nonpoint sources. Nonpoint sources addressed in this analysis primarily include loadings from surface runoff, groundwater seepage entering the lake, and precipitation directly onto the lake surface (atmospheric deposition).

4.3.1 Land Uses

Land use is one of the most important factors in determining nutrient loadings from a watershed. Nutrients can be flushed into a receiving water through surface runoff and stormwater conveyance systems during stormwater events. Both human land use areas and natural land areas generate nutrients. However, human land uses typically generate more nutrient loads per unit of land surface area than natural lands can produce. **Table 4.2** lists land use in the WHSCL in 2011, and **Figure 4.1** shows the information graphically.

The WHSCL Watershed covers an area of 14,253 acres (22.3 square miles), and 51 % of the area consists of urban land. Medium-density residential is the predominant urban land use, covering one-quarter of the watershed. Water covers 35 % and agriculture makes up 6 % of the watershed area.

In most of the individual lake watersheds, medium-density residential is the predominant anthropogenic land use. The highest percentages of medium-density residential land (46 %) are found in the Lake Cannon and Lake Summit Watersheds. In the Lake Lulu, May, and Spring Watersheds, the predominant anthropogenic land use is commercial and services, comprising 16 %, 37 %, and 51 %, respectively, of the basin areas.

Agricultural activities occur in 10 of the individual lake watersheds, but overall, agricultural land uses are a relatively low percentage of the watershed. The largest percentages of agriculture are found in the Lake Jessie, Shipp, and Eloise Watersheds, at 16 %, 10 %, and 5 %, respectively. **Appendix C** contains watershed land use information for the individual lake watersheds.

Table 4.2. SWFWMD land use in the WHSCL Watershed in 2011

Land Use Code	Land Use Classification	Acres	% of Watershed
1100	Low-Density Residential	361	2.5
1200	Medium-Density Residential	3,541	24.8
1300	High-Density Residential	810	5.7
1400	Commercial and Services	1,317	9.2
1500	Industrial	381	2.7
1700	Institutional	278	1.9
1800	Recreational	273	1.9
1900	Open Land	339	2.4
2000	Agriculture	799	5.6
3000	Rangeland	70	0.5
4110	Upland Forest	158	1.1
5000	Water	4,956	34.8
6000	Wetlands	578	4.1
8000	Transportation, Communication, and Utilities	393	2.8
Total		**14,254**	**100**

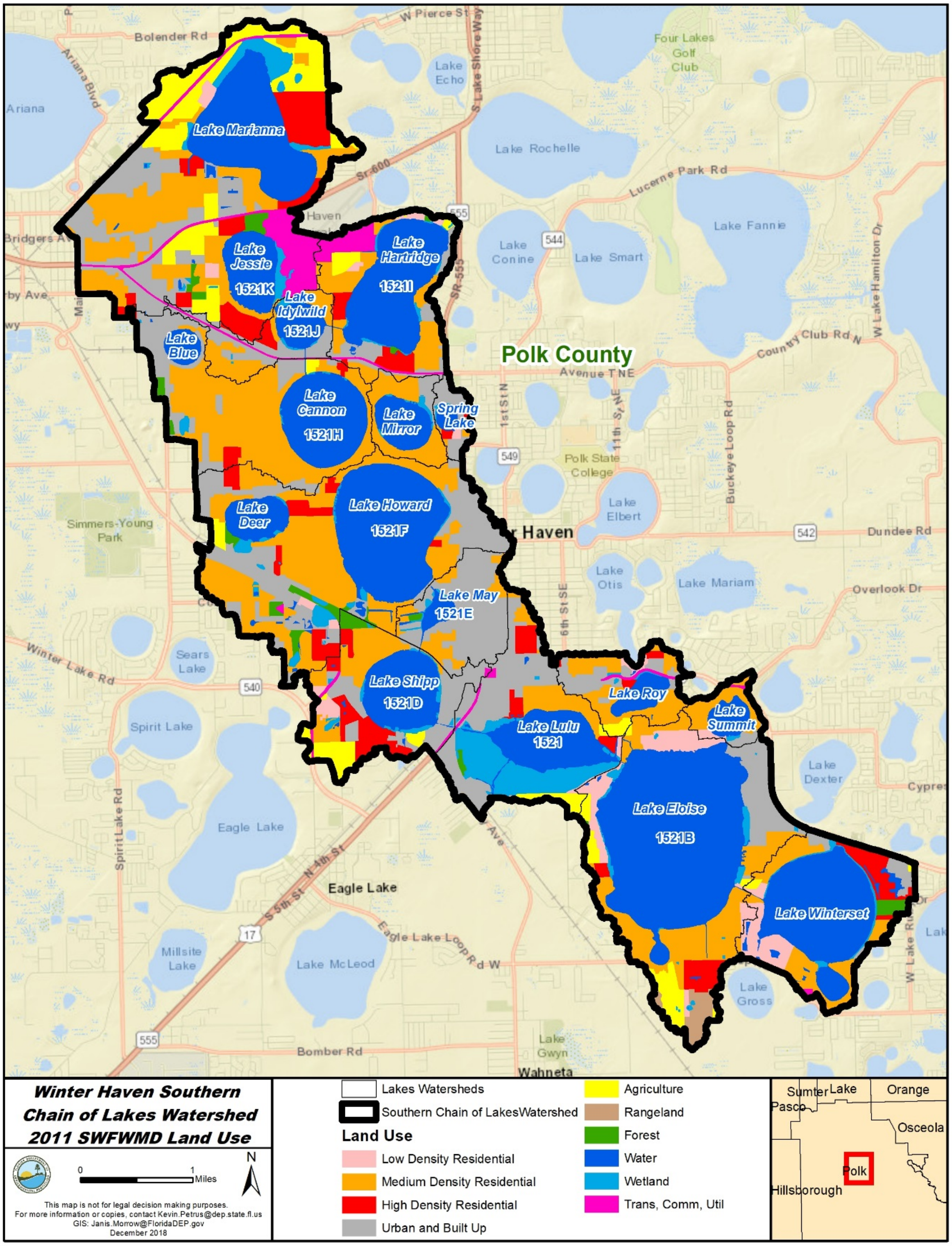

Figure 4.1. Land use in the WHSCL Watershed in 2011

4.3.2 Onsite Sewage Treatment and Disposal Systems (OSTDS)

OSTDS, including septic tanks, are commonly used where providing central sewer service is not cost-effective or practical. When properly sited, designed, constructed, maintained, and operated, OSTDS are a safe means of disposing of domestic waste. The effluent from a well-functioning OSTDS is comparable to secondarily treated wastewater from a sewage treatment plant. OSTDS can be a source of nutrients (nitrogen and phosphorus), pathogens, and other pollutants to both groundwater and surface water. **Figure 4.2** shows the locations of OSTDS in the watershed, and **Table 4.3** lists the OSTDS counts by lake watershed.

The Florida Department of Health (FDOH) maintains a list of septic systems by county, and the Polk County database was used to determine the number of septic systems in the area. The number of septic tanks calculated for the WHSCL was 5,502. The Lake Cannon Watershed has the largest number of systems at 1,493, and the Lake Mirror and Spring Watersheds have the fewest, with 4 systems each.

Table 4.3. Number of OSTDS in the WHSCL Watershed

Lake Watershed	Number of OSTDS
Cannon	1,493
Eloise	529
Hartridge	202
Howard	474
Idylwild	366
Jessie	1,345
Lulu	146
May	40
Mirror	4
Roy	294
Shipp	255
Spring	4
Summit	144
Winterset	206
Total	**5,502**

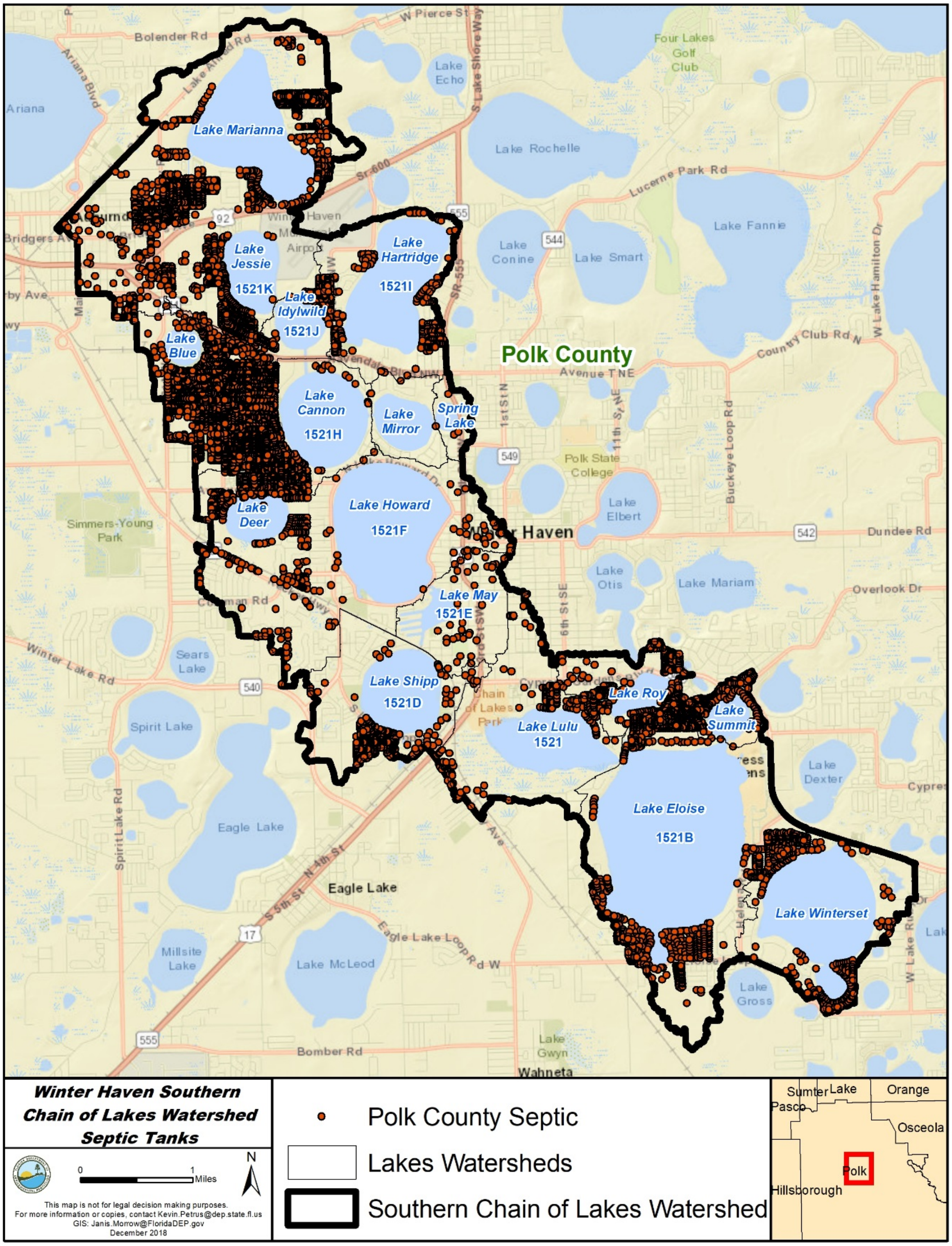

Figure 4.2. OSTDS in the WHSCL Watershed

Chapter 5: Determination of Assimilative Capacity

5.1 Determination of Loading Capacity

Nutrient enrichment and the resulting problems related to eutrophication tend to be widespread and are frequently manifested far (in both time and space) from their sources. Addressing eutrophication involves relating water quality and biological effects such as photosynthesis, decomposition, and nutrient recycling as acted on by environmental factors (rainfall, point source discharge, etc.) to the timing and magnitude of constituent loads supplied from various categories of pollution sources. Assimilative capacity should be related to some specific hydrometeorological condition during a selected period or to some range of expected variation in these conditions.

The goal of this TMDL analysis is to determine the assimilative capacity of Lakes Lulu, Eloise, Shipp, May, Howard, Cannon, Hartridge, Idylwild, and Jessie and to identify the maximum allowable TN and TP lake concentrations and the associated nutrient source reductions, so that the lakes will meet the TMDL targets and thus maintain their function and designated use as Class III freshwaters.

5.2 Evaluation of Water Quality Conditions

Water quality monitoring for nutrients in recent years has been performed primarily by Polk County (Organization Code 21FLPOLK), and DEP (Organization Codes 21FLGW and 21FLTPA). Most of the available nutrient data come from monitoring conducted by Polk County, which has routinely sampled the lakes since the mid-1990s. In 1999, the county began sampling for corrected chlorophyll *a*, the more common form of chlorophyll *a* used in assessing surface water quality. Only the corrected chlorophyll *a* results were used for TMDL development. Other sampling organizations have conducted monitoring intermittently for short periods.

For the water quality analysis conducted for TMDL development, AGMs were used to be consistent with the expression of the adopted NNC for lakes. For the purpose of this analysis, AGMs were calculated using a minimum of four sample results per year, with at least one of the samples collected in the May to September period and at least one sample collected from other months. Values with an "I" qualifier code were used as reported. Values with "U" or "T" qualifier codes were changed to the minimum detection limit (mdl) divided by the square root of 2. Values with "G" or "V" qualifier codes were removed from the analysis for quality control purposes. Negative values and zero values were also removed. Multiple sample results collected in the same day at the same station were averaged. The AGM calculation method for this purpose is somewhat different than the one used to calculate AGMs for performing water quality assessments, following the methodology in Chapter 62-303, F.A.C. Therefore, the AGMs listed in **Chapter 2** may not exactly match the AGMs used for TMDL development.

Figure 5.1 shows the chlorophyll *a* AGM values from 1999 to 2016 for the lakes in the southern chain that exceeded the NNC. From 1999 to 2005, Lake Shipp had the highest chlorophyll *a* results, ranging from 40 to 54 µg/L. From 1999 to 2002, Lake Hartridge had the lowest chlorophyll *a* results, between 5 and 13 µg/L. More recently, Lake Eloise has had the highest chlorophyll *a* results, ranging from 31 to 37 µg/L from 2013 to 2016. In recent years, Lakes Hartridge, Howard, Lulu, and Eloise chlorophyll *a* AGMs have increased, while chlorophyll *a* AGMs for Lakes May, Shipp, Idylwild, Jessie and Cannon have decreased.

Figure 5.2 shows the chlorophyll *a* AGM values from 1999 to 2016 for the lakes in the southern chain that do not exceed the NNC. From 2000 to 2003, Lake Mirror had the highest chlorophyll *a* results, between 28 and 49 µg/L, while over the same period Lake Summit had the lowest, with AGMs from 7 to 11 µg/L. More recently, Spring Lake chlorophyll *a* results have varied considerably, from 6 µg/L in 2013 to 21 µg/L in 2015 and back to 7 µg/L in 2016. Since 2007, the chlorophyll *a* AGMs have declined.

Figure 5.3 shows the TN AGM values from 1999 to 2016 for the lakes exceeding the NNC. From 1999 to 2005, Lake Shipp had the highest TN results, from 1.17 to 2.09 mg/L, while over the same period Lake Hartridge had the lowest, between 0.41 and 0.84 mg/L. In general, most of the lakes exhibited decreases in TN AGMs since 2008, with the exception of Lakes Eloise and Hartridge.

Figure 5.4 shows the TN AGM values over the 1999 to 2016 period for the lakes not exceeding the NNC. From 1999 to 2000 Lake Winterset had the lowest TN results, ranging from 0.80 to 0.90 mg/L, while from 2002 to 2003 Lake Mirror had the highest TN results at 1.79 mg/L. In general, these lakes exhibited decreases in TN AGMs from 2008 to 2016.

Figure 5.5 shows the TP AGM values from 1999 to 2016 for the lakes exceeding the NNC. Between 1999 and 2004, the TP AGM values of the lakes varied from year to year with no upward or downward pattern. Beginning in 2008, however, AGM values decreased in Lakes May, Lulu, Shipp, and Jessie, with the largest declines occurring in Lake May. Between 2008 and 2016, Lake May had the highest TP results, ranging between 0.07 and 0.03 mg/L.

Figure 5.6 shows the TP AGM values from 1999 to 2016 for the lakes not exceeding the NNC. Between 1999 and 2003, the lake AGMs varied between 0.01 and 0.06 mg/L. Since 2008, the lake TP AGM values have ranged from 0.01 to 0.03 mg/L.

Figure 5.7 shows the color AGM values from 1999 to 2016 for the lakes exceeding the NNC. The lake color varied between 8 and 26 PCU. In general, Lakes Eloise, Howard, and Hartridge had some of the lowest color AGMs, while Lakes Jessie, Lulu, and Idylwild had some of the highest.

Figure 5.8 shows the color AGM values during the 1999 to 2016 period for the lakes not exceeding the NNC. The lake AGMs varied between 6 and 22 PCU, with the exception of Lake Mirror, which had a much higher color AGM in 2003 (44 PCU). In general, Lake Winterset consistently had the lowest color, while Spring Lake and Lake Mirror had some of the highest color of this group of lakes.

Using the AGM results, the relationships between water quality and lake levels were evaluated. **Figure 5.9** shows chlorophyll *a* AGM values and annual average lake levels from 1999 to 2016 for the lakes that exceeded the NNC. Lakes Lulu, Shipp, May, Howard, Cannon, Idylwild, and Jessie chlorophyll *a* AGM values tended to decrease with increased annual lake levels, while the other lakes did not display a trend.

Figure 5.10 shows chlorophyll *a* AGM values and average annual lake levels from 1999 to 2016 for the lakes not exceeding the NNC. Chlorophyll *a* in Lakes Mirror, Summit, and Roy decreased with increased annual lake levels, while Spring Lake chlorophyll *a* increased with increased annual lake levels.

Figures 5.11 and **5.12** show color AGM values and annual average lake levels from 1999 to 2016 for the lakes exceeding and not exceeding the NNC, respectively. All the lakes in the southern chain exhibited an increase in color AGM values with increases in annual average lake levels.

The relationships of chlorophyll *a* and TN AGMs (**Figure 5.13**) and chlorophyll *a* and TP AGMs (**Figure 5.14**) for all the lakes in the southern chain combined show a significant positive response of chlorophyll *a* to increased nutrient concentrations (p values < 0.001). As chlorophyll *a* responds to nutrient conditions in a similar fashion throughout the WHSCL and the applicable chlorophyll *a* target criterion appropriate for these lakes is the same (20 µg/L), the water quality results for the lakes were combined for the regression analysis.

The water quality results applied in the analysis were from the 2008–16 period, which included years with both above- and below-average precipitation. Rainfall from the SWFWMD Polk County results (**Figure 5.15**) indicate that 2008, 2012, and 2013 were years with below-average precipitation, while 2014 to 2016 had above-average precipitation.

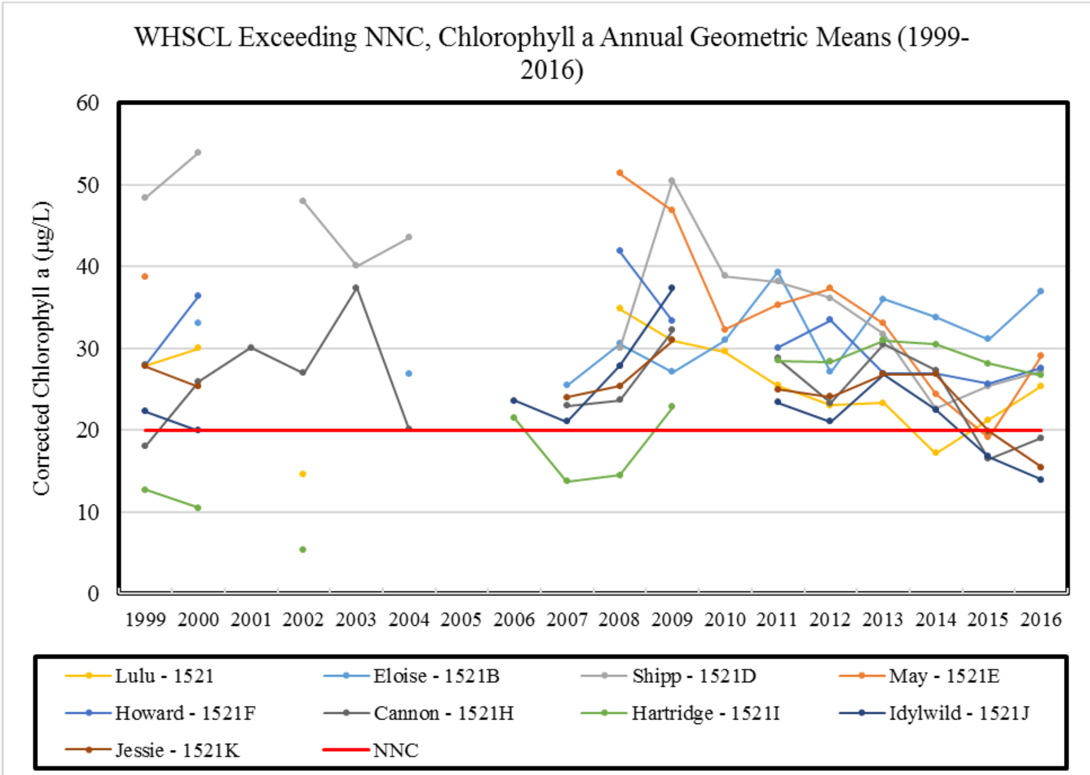

Figure 5.1. Chlorophyll *a* AGM values for lakes exceeding the applicable NNC

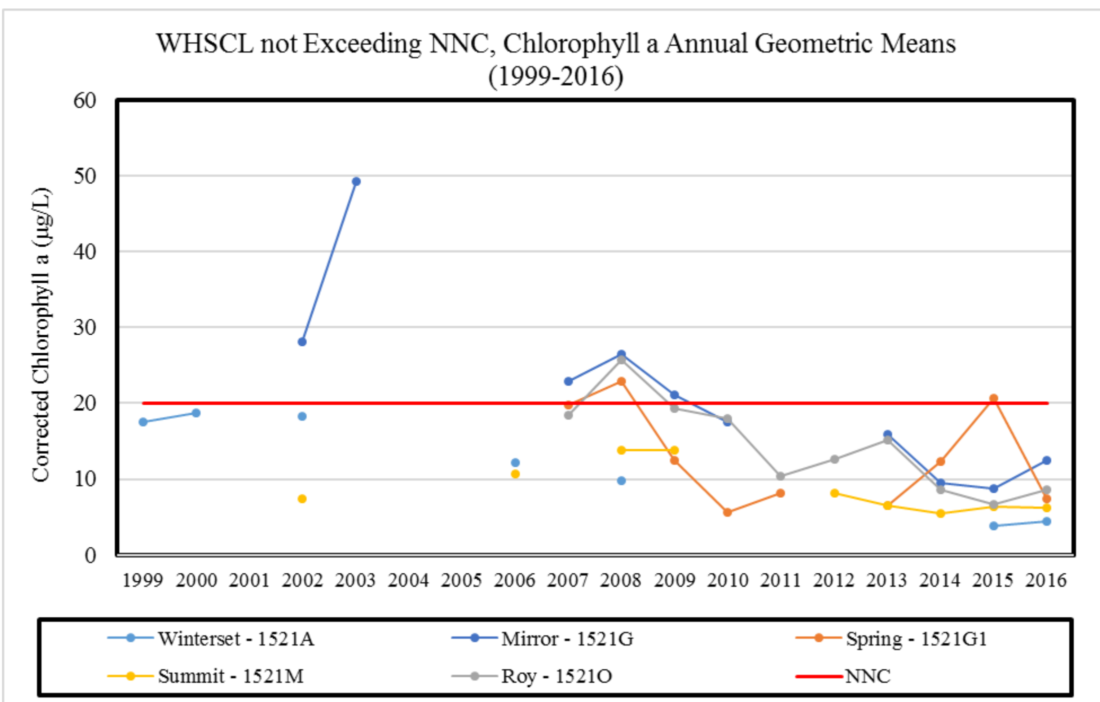

Figure 5.2. Chlorophyll *a* AGM values for lakes not exceeding the applicable NNC

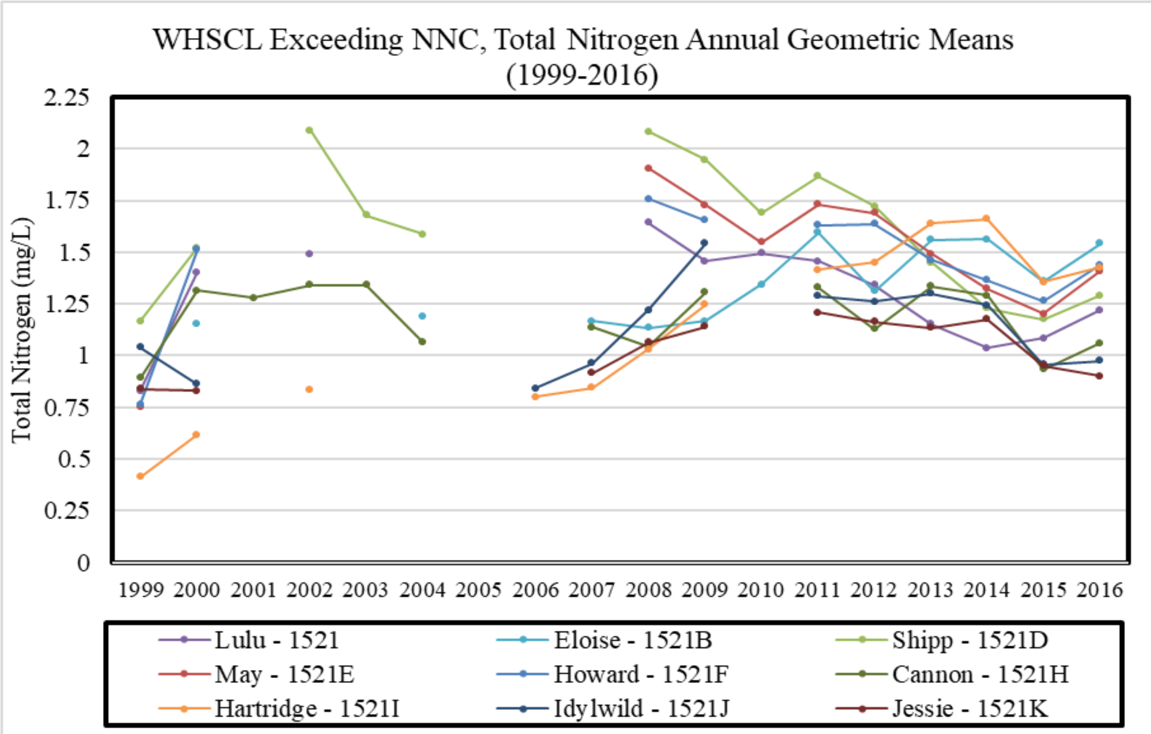

Figure 5.3. TN AGM values for lakes exceeding the applicable NNC

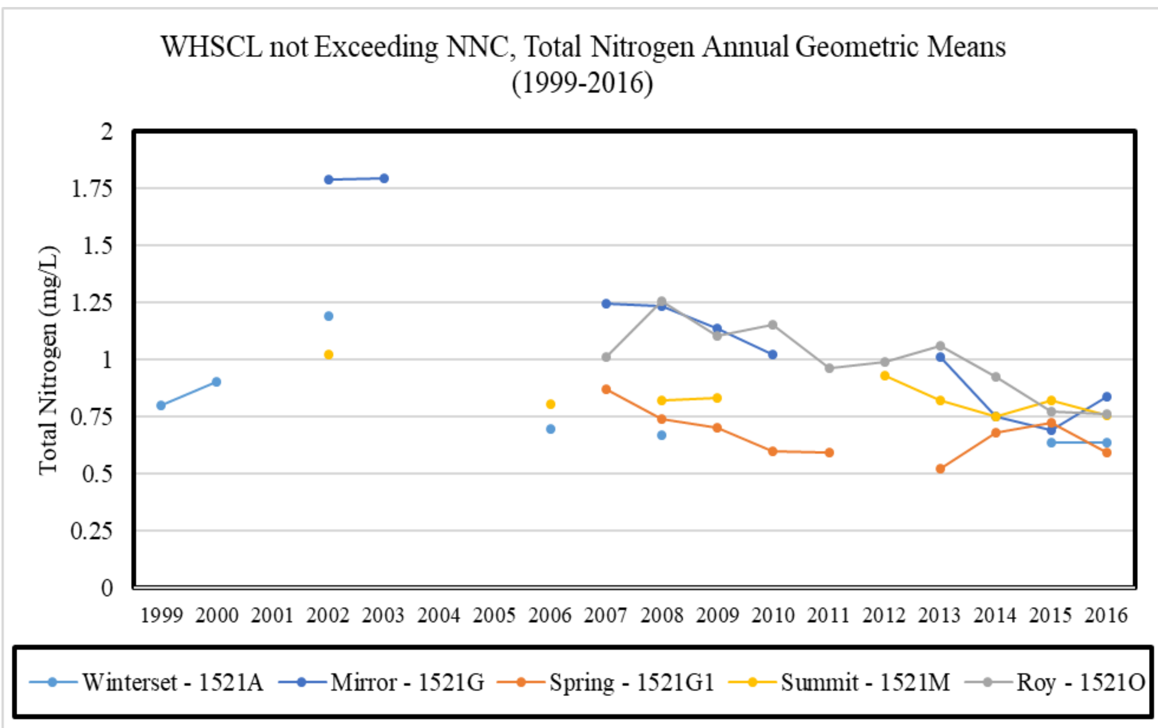

Figure 5.4. TN AGM values for lakes not exceeding the applicable NNC

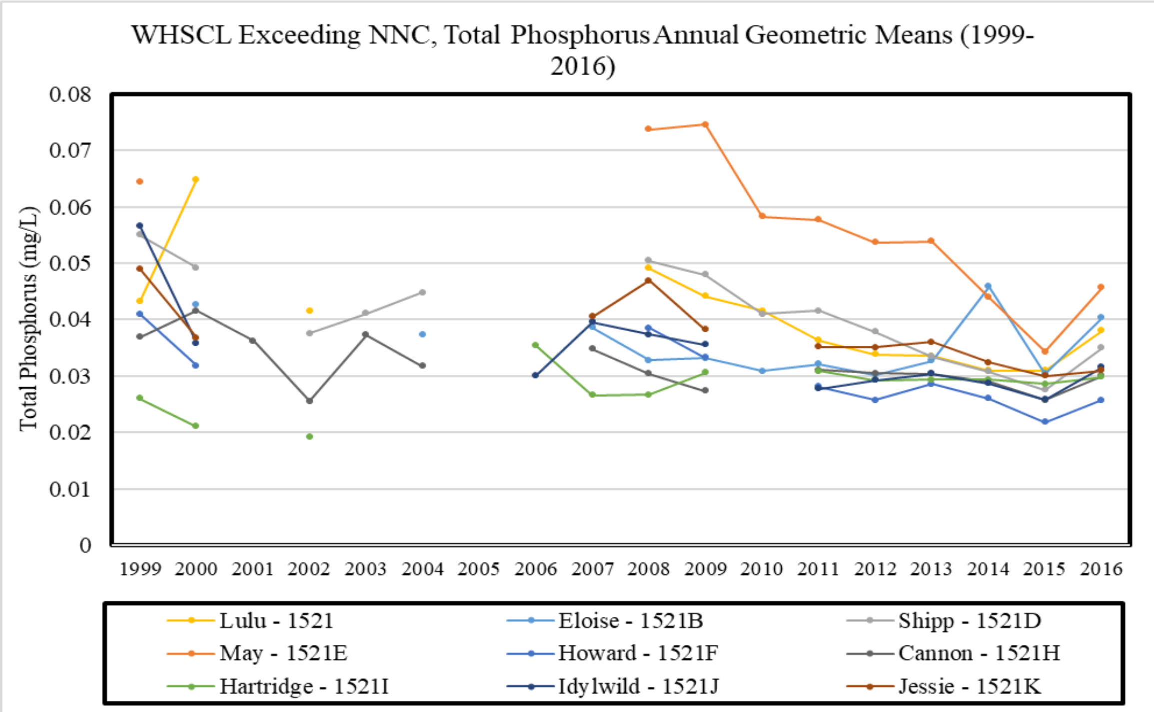

Figure 5.5. TP AGM values for lakes exceeding the applicable NNC

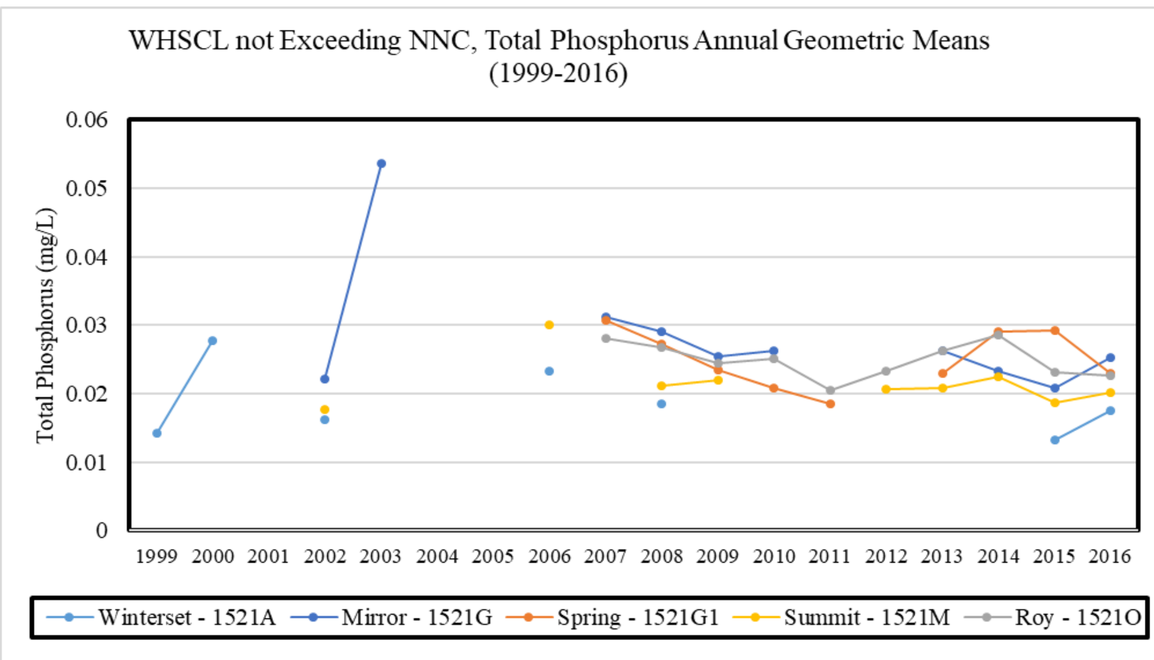

Figure 5.6. TP AGM values for lakes not exceeding the applicable NNC

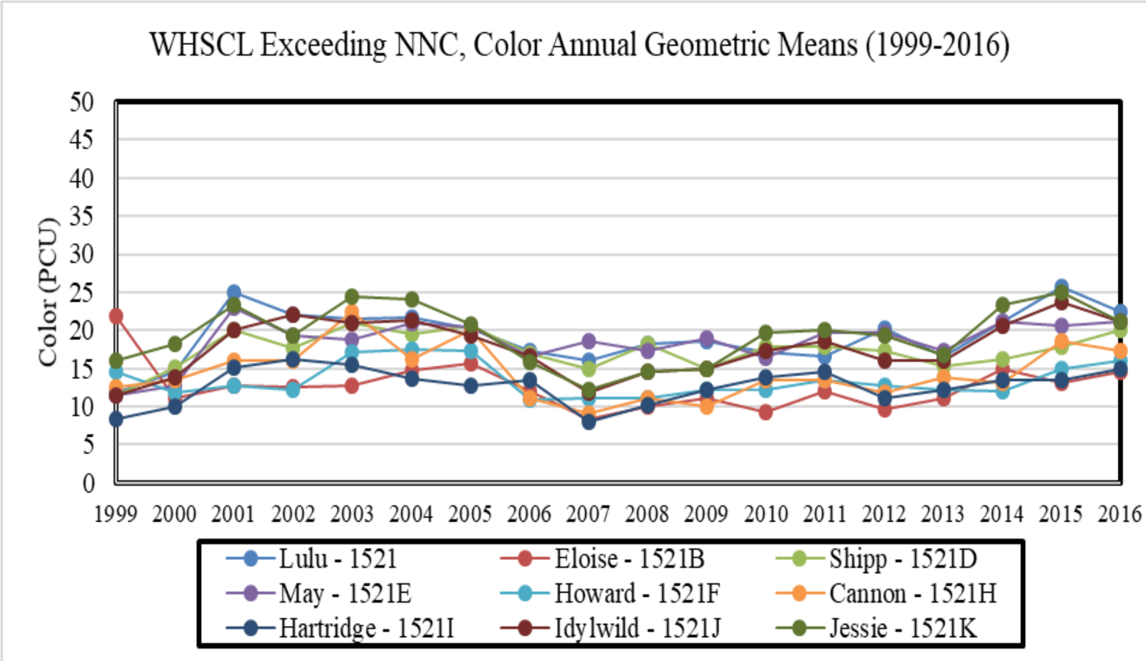

Figure 5.7. Color AGM values for lakes exceeding the applicable NNC

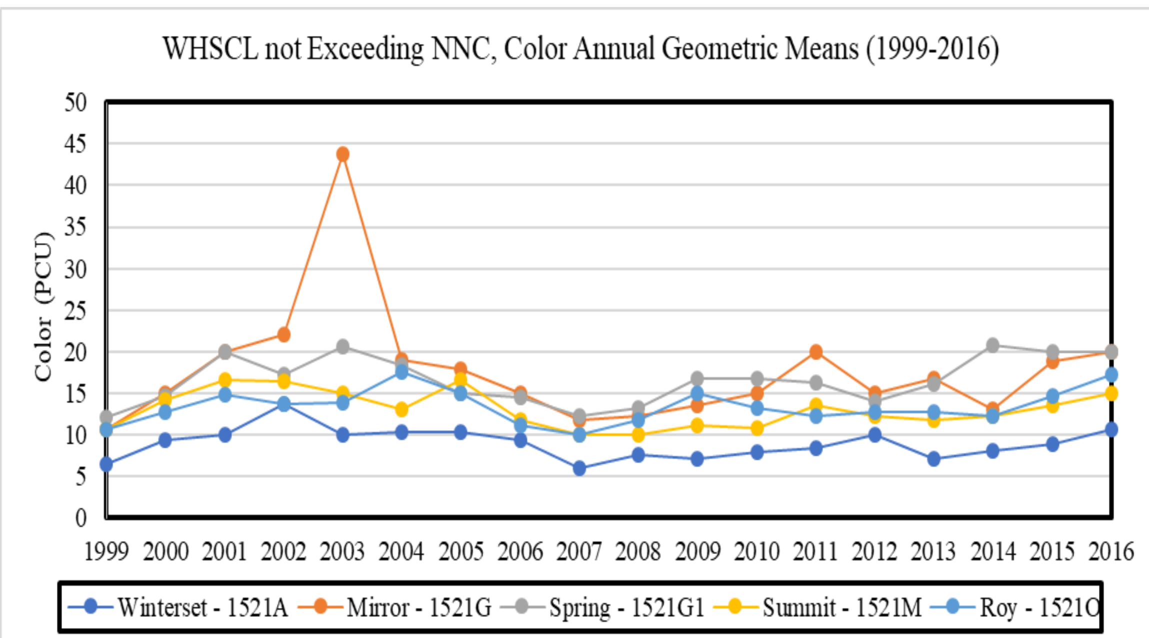

Figure 5.8. Color AGM values for lakes not exceeding the applicable NNC

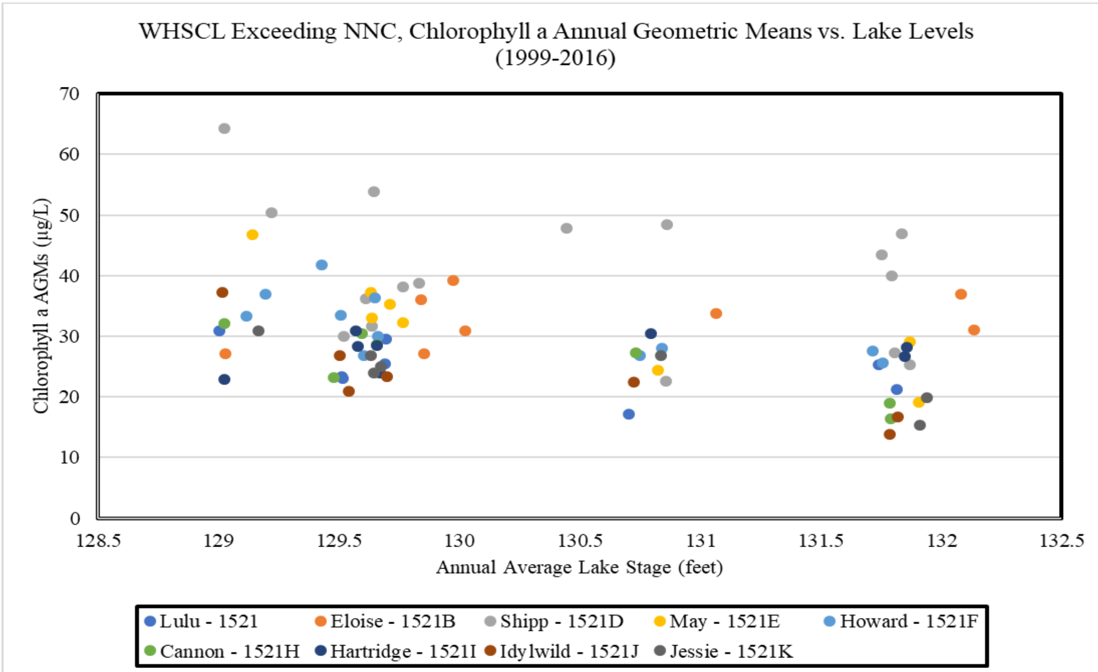

Figure 5.9. Relationship between chlorophyll *a* AGM results and lake levels for lakes exceeding the applicable NNC

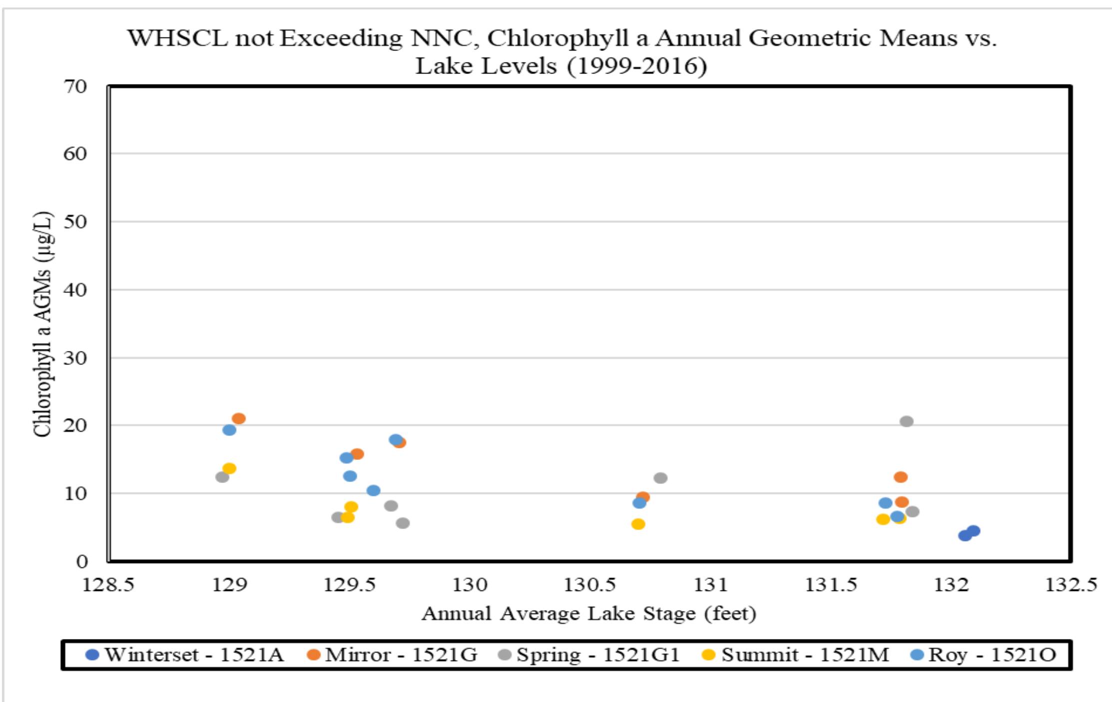

Figure 5.10. Relationship between chlorophyll *a* AGM results and lake levels for lakes not exceeding the applicable NNC

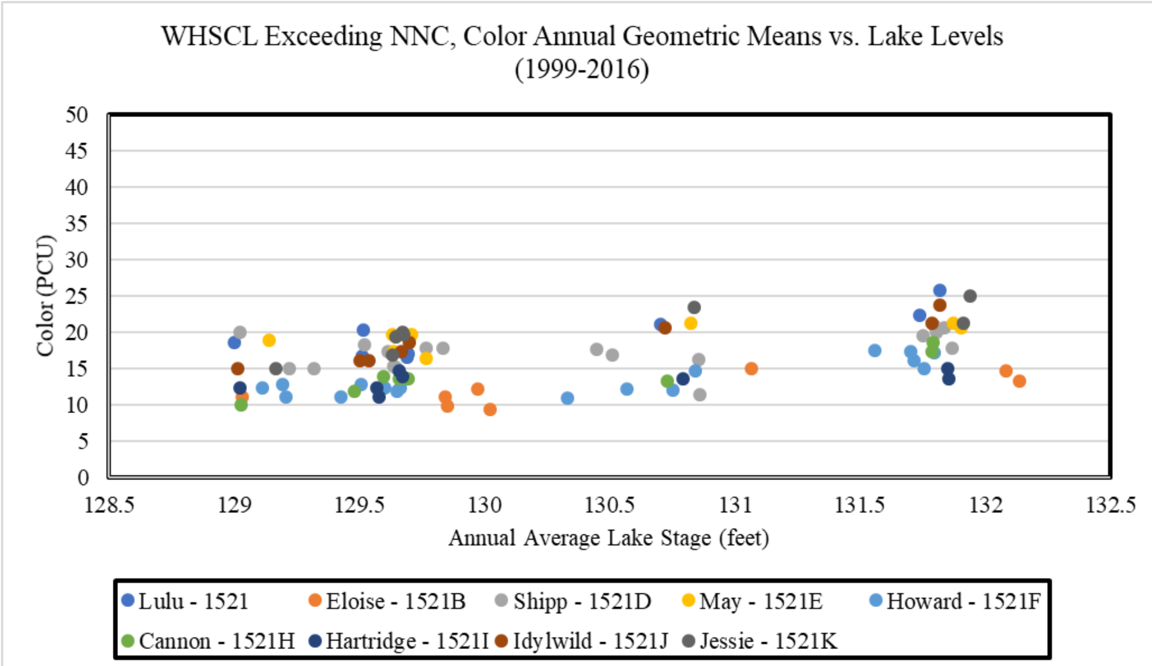

Figure 5.11. Relationship between color AGM results and lake levels for lakes exceeding the applicable NNC

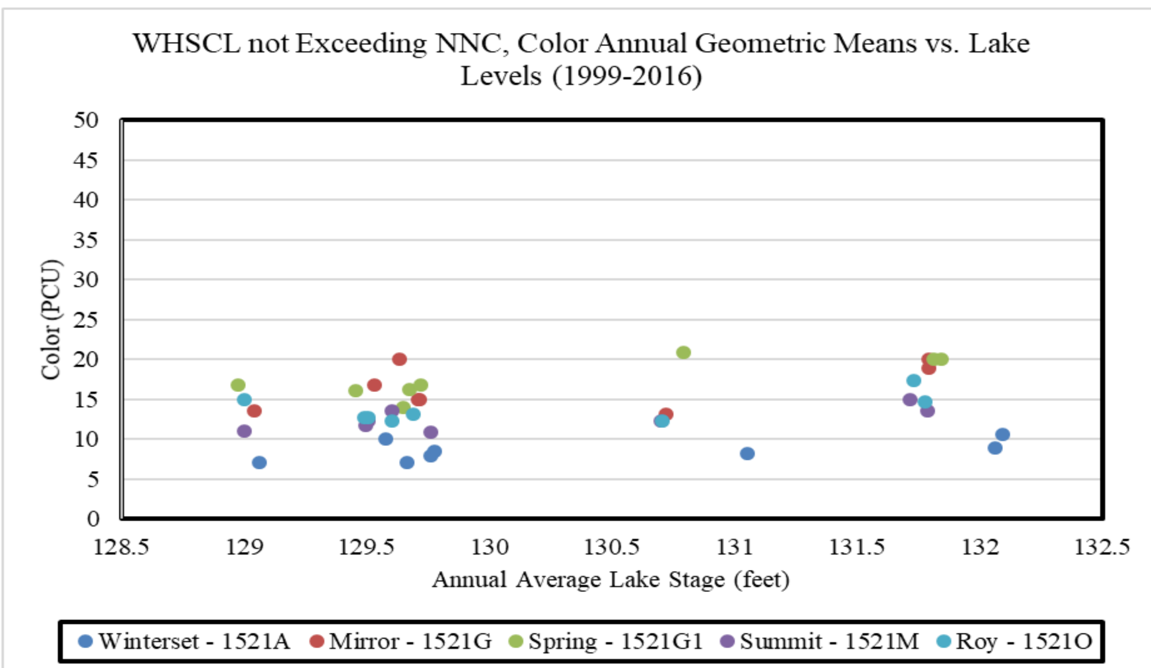

Figure 5.12. Relationship between color AGM results and lake levels for lakes not exceeding the applicable NNC

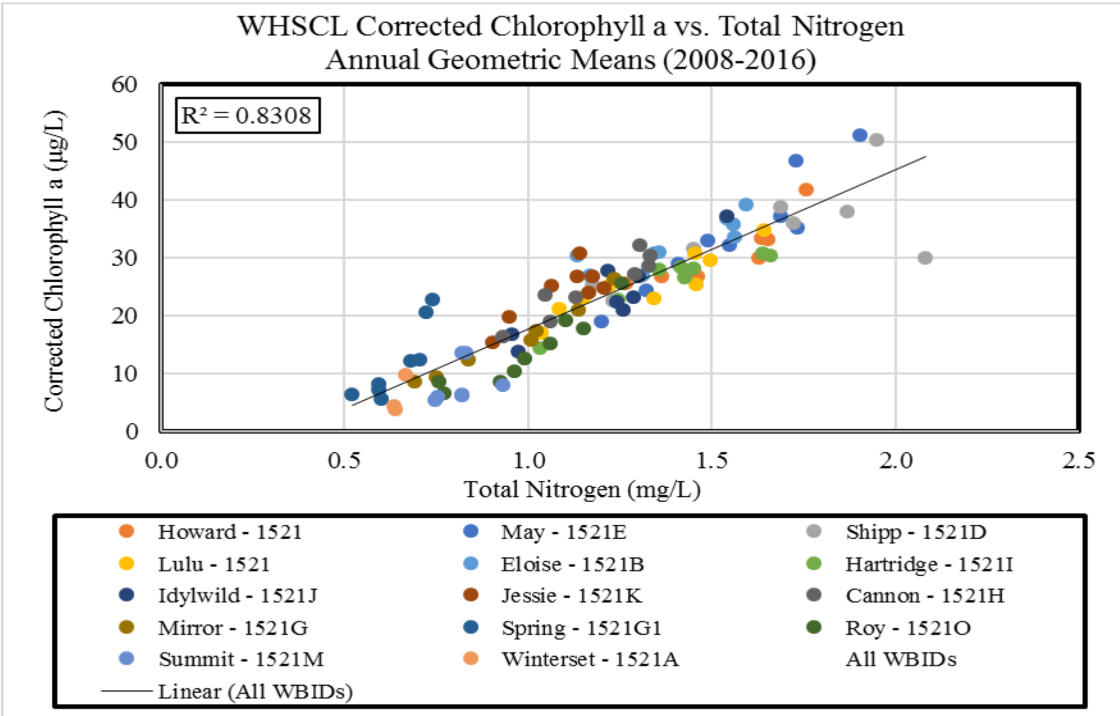

Figure 5.13. Relationship between AGM results for chlorophyll *a* and TN

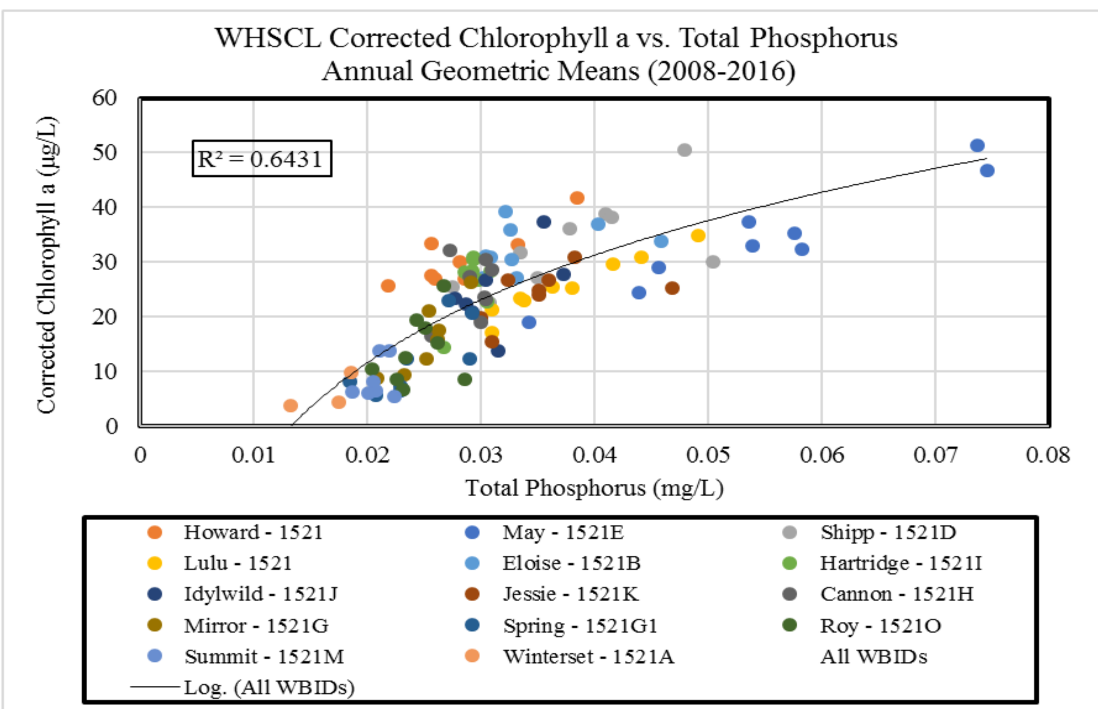

Figure 5.14. Relationship between AGM results for chlorophyll *a* and TP

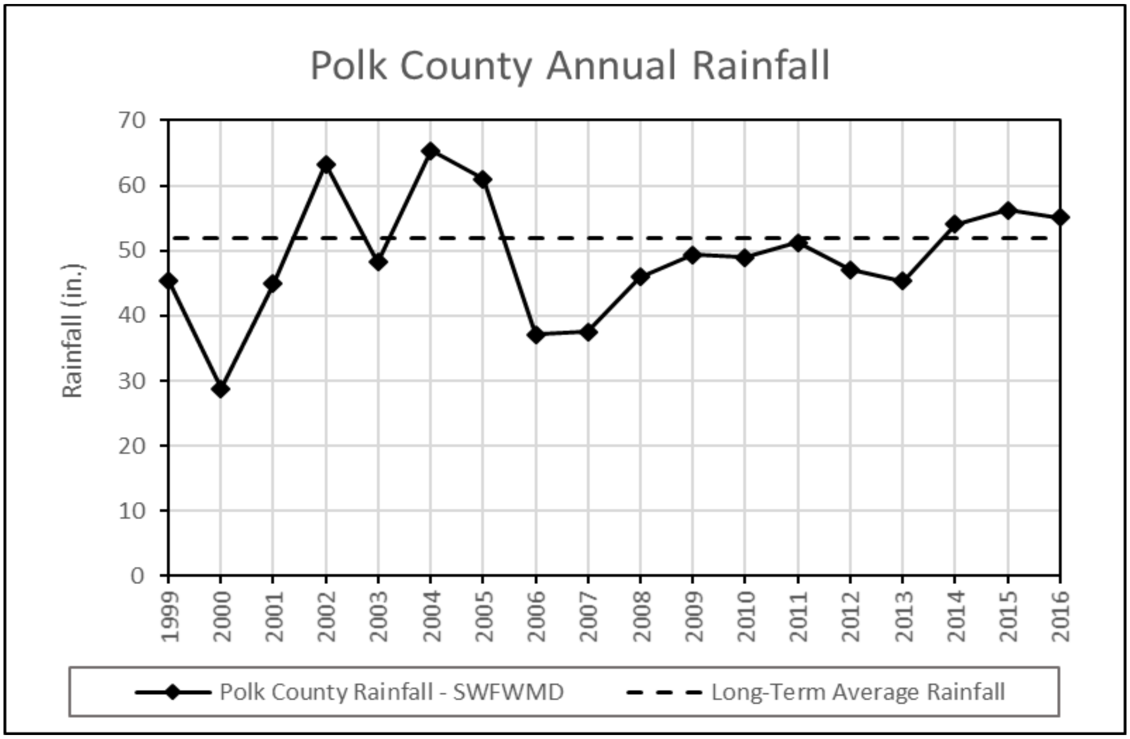

Figure 5.15. Annual rainfall in Polk County, 1999–2016

5.3 Critical Conditions and Seasonal Variation

The estimated assimilative capacity is based on annual conditions, rather than critical/seasonal conditions, because (1) the methodology used to determine assimilative capacity does not lend itself very well to short-term assessments; (2) DEP is generally more concerned with the net change in overall primary productivity in the segment, which is better addressed on an annual basis; (3) the applicable chlorophyll *a* criterion is expressed as an AGM; and (4) the assessment methodology used to determine impairment is based on AGM values.

5.4 Calculation of the TMDLs

The results collected by Polk County and DEP were used in evaluating the relationships between nutrient concentrations and chlorophyll *a* levels. The period from 2008 to 2016 had the most complete set of AGM values for evaluating surface water quality for the 14 lakes in the southern chain, as shown in **Figures 5.1** through **5.6**. The nutrient and corrected chlorophyll *a* AGMs were used in this evaluation to be consistent with the expression of the adopted NNC for lakes.

A multiple regression model was developed using the nutrient results from the 14 lakes to derive an equation that relates TN and TP AGM concentrations to chlorophyll *a* AGM concentrations. The model was developed using the chlorophyll *a*, TN, and TP AGM concentrations calculated from Polk County and DEP lake measurements recorded from 2008 to 2016. Polk County is the only organization that has routinely sampled the lakes over an extended period; therefore, most of the data used for the calculations come from the county. The results of the multiple regression analyses show a significant relationship between in-lake chlorophyll *a* and nutrient concentrations. **Appendix D** presents the results of this relationship (r squared adjusted = 0.85, p values < 0.05), and the resultant equation is as follows:

Chlorophyll *a* AGM = -11.1 + 22.75 * TN AGM + 224.5 * TP AGM

The TP water quality target for the WHSCL was derived using the predisturbance inferred water quality from paleolimnological study results measured in Lakes May, Howard, and Hartridge (Whitmore and Brenner 1995), as well as Lakes Lulu and May (Whitmore and Brenner 2002). The studies estimated predisturbance average TP levels by applying statistical models based on sedimented diatoms and calibrated using a large number of Florida lakes (Whitmore 1989; Brenner et al. 1993; Line et al. 1994). The predicted minimum average TP results for the 4 lakes from the deepest sediment core depth analyzed (90 centimeter [cm] depth), which equates to predisturbance conditions, were 30 µg/L (0.03 mg/L) for Lake Lulu and 28 µg/L (0.028 mg/L) for Lake May.

Since the predisturbance TP results represent an estimate of average conditions, a method was applied to relate averages to geometric means from the lake dataset used in NNC development. Using all the statewide lake TP data, which were applied in the development of the lake NNC thresholds (DEP 2012), the comparison of average and geometric mean values shows a strong linear relationship (**Figure 5.16**). The expression of this relationship in the form of an equation is TP geometric mean = TP average * 0.9373. In the case of Lake Lulu, the predisturbance average TP value is equivalent to a geometric mean of 0.028 mg/L. For Lake May, the predisturbance TP value, expressed as a geometric mean, is 0.026 mg/L. For TMDL development, a TP value of 0.03 mg/L expressed as a geometric mean is identified as the water quality target.

As discussed in **Chapter 3**, the NNC chlorophyll *a* threshold of 20 µg/L, expressed as an AGM, was selected as the response variable target for TMDL development. The paleolimnological results provided a TP concentration target. The regression equation explaining the relationship of chlorophyll *a* to TN and TP was then used to determine the TN concentration necessary to meet the chlorophyll *a* target of 20 µg/L. A TN geometric mean of 1.07 mg/L, associated with the TP target of 0.03 mg/L, results in a chlorophyll *a* AGM of 20 µg/L.

The lakes are expected to meet the applicable nutrient criteria and maintain their function and designated use as Class III freshwater when surface water nutrient concentrations are reduced to the target concentrations, addressing the anthropogenic contributions to the water quality impairments. The approaches used to establish the nutrient target also address meeting the chlorophyll *a* target and take into consideration the estimated predisturbance conditions in the lakes.

The method used to determine the reductions needed to attain the nutrient TMDLs is the percent reduction approach. Existing lake nutrient conditions used in the percent reduction calculations were selected by considering the nutrient concentrations measured in the 2008 to 2016 period, which includes the Cycle 3 verified period as well as the water quality measurements in 2016 following the Cycle 3 assessment period. The existing nutrient conditions used to calculate the required reductions were the maximum values of the TN and TP AGMs in each lake that exceeded the water quality targets. The geometric means were calculated from nutrient results available in the IWR Run 56 Database.

The equation used to calculate the percent reduction is as follows:

$$\frac{[\text{measured exceedance} - \text{target}]}{\text{measured exceedance}} \times 100$$

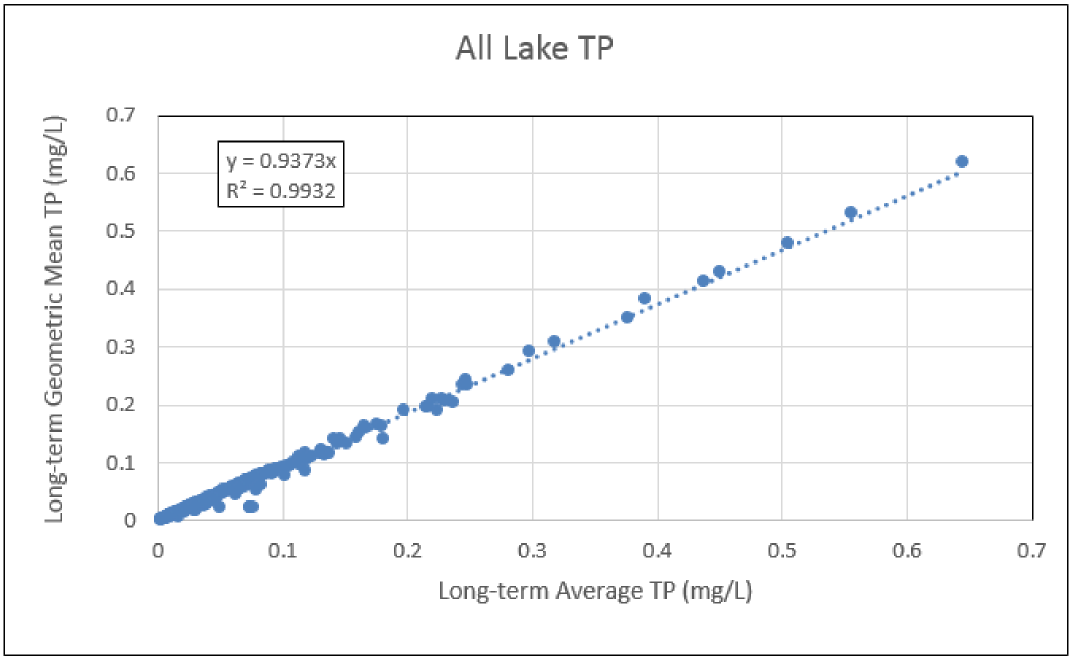

Figure 5.16. Relationship between TP AGMs and averages (arithmetic means) from lake results used in NNC development

Table 5.1 lists the percent reductions in the maximum AGMs needed to achieve the TN AGM target of 1.07 mg/L and the TP AGM target of 0.03 mg/L. The TN percent reductions range from a high of 49 % in Lake Shipp to a low of 12 % in Lake Jessie. Lake May, the only lake with exceedances of the applicable TP NNC, requires a 57 % reduction in TP to meet the target. The nutrient AGM TMDL values and the associated percent reductions address the anthropogenic nutrient inputs contributing to the exceedances of the chlorophyll *a* criterion.

Table 5.1. Reductions required in existing TN and TP concentrations to meet the water quality targets

Year	Lulu TN AGM (mg/L)	Eloise TN AGM (mg/L)	Shipp TN AGM (mg/L)	Howard TN AGM (mg/L)	Cannon TN AGM (mg/L)	Hartridge TN AGM (mg/L)	Idylwild TN AGM (mg/L)	Jessie TN AGM (mg/L)	May TN AGM (mg/L)	May TP AGM (mg/L)
2008	1.64	1.13	2.08	1.76	1.05	1.03	1.22	1.06	1.9	0.07
2009	1.45	1.17	1.95	1.65	1.31	1.25	1.54	1.14	1.73	0.07
2010	1.5	1.34	1.69	1.38	1.21	1.23	1.33	1.2	1.55	0.06
2011	1.46	1.59	1.87	1.63	1.33	1.42	1.29	1.21	1.73	0.06
2012	1.34	1.31	1.72	1.64	1.13	1.45	1.26	1.16	1.69	0.05
2013	1.15	1.56	1.45	1.46	1.33	1.64	1.3	1.13	1.49	0.05
2014	1.04	1.56	1.23	1.36	1.29	1.66	1.24	1.17	1.32	0.04
2015	1.08	1.36	1.17	1.26	0.93	1.36	0.96	0.95	1.2	0.02
2016	1.22	1.54	1.29	1.44	1.06	1.43	0.97	0.9	1.41	0.04
Maximum	**1.64**	**1.59**	**2.08**	**1.76**	**1.33**	**1.66**	**1.54**	**1.21**	**1.9**	**0.07**
TMDL Target	**1.07**	**1.07**	**1.07**	**1.07**	**1.07**	**1.07**	**1.07**	**1.07**	**1.07**	**0.03**
% Reduction to Meet Target	**35**	**33**	**49**	**39**	**20**	**36**	**31**	**12**	**44**	**57**

Chapter 6: Determination of Loading Allocations

6.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating loads to all the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (wasteload allocations, or WLAs), nonpoint source loads (load allocations, or LAs), and an appropriate margin of safety (MOS), which accounts for uncertainty in the relationship between effluent limitations and water quality:

$$\textbf{TMDL} = \sum \textbf{WLAs} + \sum \textbf{LAs} + \textbf{MOS}$$

As discussed earlier, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$\textbf{TMDL} \cong \sum \textbf{WLAs}_{\textbf{wastewater}} + \sum \textbf{WLAs}_{\textbf{NPDES Stormwater}} + \sum \textbf{LAs} + \textbf{MOS}$$

It should be noted that the various components of the revised TMDL equation may not sum up to the value of the TMDL because (1) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is also accounted for within the LA, and (2) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as "percent reduction" because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges also differs from the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the "maximum extent practical" through the implementation of best management practices (BMPs).

This approach is consistent with federal regulations (40 Code of Federal Regulations [CFR] § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or other appropriate measure. The TMDLs for Lakes Lulu, Eloise, Shipp, May, Howard, Cannon, Hartridge, Idylwild, and Jessie are expressed in terms of nutrient concentration targets and the percent reductions necessary to meet the targets, and represent the lake nutrient concentrations the waterbodies can assimilate while maintaining a balanced aquatic flora and fauna (see **Table 6.1**). These TMDLs are expressed as maximum AGM values for TN and TP not to be exceeded. The restoration goal is to achieve the generally applicable chlorophyll *a* criterion of 20 µg/L, which is expressed as an AGM not to be exceeded more than once in any consecutive 3-year period, thus protecting each lake's designated use.

Table 6.1 lists the TMDLs for the WHSCL Watershed. The TMDLs will constitute the site-specific numeric interpretation of the narrative nutrient criterion set forth in Paragraph 62-302.530(48)(b), F.A.C., that will replace the otherwise applicable NNC in Subsection 62-302.531(2), F.A.C., for these particular waters.

6.2 Load Allocation

To achieve the LA, decreases in current TN and TP loads to the lakes will be required to meet the percent reductions, as specified in **Table 6.1.** The percent reductions represent the generally needed TN and TP reductions from all sources; including stormwater runoff, groundwater contributions, and septic tanks. Although the TMDLs are based on the percent reductions from all sources to the lakes, it is not DEP's intent to abate natural conditions. The needed reduction from anthropogenic inputs will be calculated based on more detailed source information when a restoration plan is developed. The reductions in nonpoint source nutrient loads are expected to result in reduced sediment nutrient flux, which is commonly a factor in lake eutrophication.

It should be noted that the LA includes loading from stormwater discharges regulated by DEP and the water management districts that are not part of the NPDES stormwater program (see **Appendix A**).

6.3 Wasteload Allocation

6.3.1 NPDES Wastewater Discharges

As noted in **Chapter 4**, no active NPDES-permitted facilities discharge either into the waterbodies or the WHSCL Watershed. Therefore, a WLA for wastewater discharges is not applicable.

6.3.2 NPDES Stormwater Discharges

Polk County and co-permittees (FDOT District 1 and the Cities of Winter Haven and Auburndale) are covered by a Phase I NPDES MS4 permit (FLS000015). Areas within these jurisdictions may be responsible for percent reductions in current TN and TP loadings to the lakes, as indicated in **Table 6.1**.

It should be noted that any MS4 permittee is only responsible for reducing the anthropogenic loads associated with stormwater outfalls that it owns or otherwise has responsible control over, and it is not responsible for reducing other nonpoint source loads in its jurisdiction.

Table 6.1. TMDL components for nutrients in the WHSCL (WBIDs 1521, 1521B, 1521, 1521E, 1521F, 1521H, 1521I, 1521J and 1521K)

NA = Not applicable
[1] Represents the AGM lake value not to be exceeded.
[2] The required percent reductions listed in this table represent the reduction from all sources.

Waterbody Name (WBID)	Parameter	TMDL (mg/L)[1]	WLA Wastewater (% reduction)	WLA NPDES Stormwater (% reduction)[2]	LA (% reduction)[2]	MOS
Lake Lulu (1521)	TN	1.07	NA	35	35	Implicit
Lake Lulu (1521)	TP	0.03	NA	0	0	Implicit
Lake Eloise (1521B)	TN	1.07	NA	33	33	Implicit
Lake Eloise (1521B)	TP	0.03	NA	0	0	Implicit
Lake Shipp (1521D)	TN	1.07	NA	49	49	Implicit
Lake Shipp (1521D)	TP	0.03	NA	0	0	Implicit
Lake May (1521E)	TN	1.07	NA	44	44	Implicit
Lake May (1521E)	TP	0.03	NA	57	57	Implicit
Lake Howard (1521F)	TN	1.07	NA	39	39	Implicit
Lake Howard (1521F)	TP	0.03	NA	0	0	Implicit
Lake Cannon (1521H)	TN	1.07	NA	20	20	Implicit
Lake Cannon (1521H)	TP	0.03	NA	0	0	Implicit
Lake Hartridge (1521I)	TN	1.07	NA	36	36	Implicit
Lake Hartridge (1521I)	TP	0.03	NA	0	0	Implicit
Lake Idylwild (1521J)	TN	1.07	NA	31	31	Implicit
Lake Idylwild (1521J)	TP	0.03	NA	0	0	Implicit
Lake Jessie (1521K)	TN	1.07	NA	12	12	Implicit
Lake Jessie (1521K)	TP	0.03	NA	0	0	Implicit

6.4 Margin of Safety

The MOS can either be implicitly accounted for by choosing conservative assumptions about loading or water quality response, or explicitly accounted for during the allocation of loadings. Consistent with the recommendations of the Allocation Technical Advisory Committee (DEP 2001), an implicit MOS was used in the development of these TMDLs. The MOS is a required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving waterbody (CWA, Section 303[d][1][C]). Considerable uncertainty is usually inherent in estimating nutrient loading from nonpoint sources, as well as in predicting water quality response. The effectiveness of management activities (e.g., stormwater management plans) in reducing loading is also subject to uncertainty.

Consistent with the recommendations of the Allocation Technical Advisory Committee (DEP 2001), an implicit MOS was used in the development of the TMDLs because of the conservative assumptions that were applied. The TMDLs were developed using the highest TN and TP AGM values to calculate the percent reductions and require the TMDL targets not to be exceeded in any one year.

Chapter 7: Implementation Plan Development and Beyond

7.1 Implementation Mechanisms

Following the adoption of a TMDL, implementation takes place through various measures. The implementation of TMDLs may occur through specific requirements in NPDES wastewater and MS4 permits, and, as appropriate, through local or regional water quality initiatives or basin management action plans (BMAPs).

Facilities with NPDES permits that discharge to the TMDL waterbody must respond to the permit conditions that reflect target concentrations, reductions, or wasteload allocations identified in the TMDL. NPDES permits are required for Phase I and Phase II MS4s as well as domestic and industrial wastewater facilities. MS4 Phase I permits require a permit holder to prioritize and act to address a TMDL unless management actions to achieve that particular TMDL are already defined in a BMAP. MS4 Phase II permit holders must also implement the responsibilities defined in a BMAP or other form of restoration plan (e.g., a reasonable assurance plan).

7.2 BMAPs

Information on the development and implementation of BMAPs can be found in Section 403.067, F.S. (the FWRA). DEP or a local entity may initiate and develop a BMAP that addresses some or all of the contributing areas to the TMDL waterbody. BMAPs are adopted by the DEP Secretary and are legally enforceable.

BMAPs describe the fair and equitable allocations of pollution reduction responsibilities to the sources in the watershed, as well as the management strategies that will be implemented to meet those responsibilities, funding strategies, mechanisms to track progress, and water quality monitoring. Local entities—such as wastewater facilities, industrial sources, agricultural producers, county and city stormwater systems, military bases, water control districts, state agencies, and individual property owners—usually implement these strategies. BMAPs can also identify mechanisms to address potential pollutant loading from future growth and development.

Additional information about BMAPs is available on DEP's website.

7.3 Implementation Considerations for the Waterbody

Several local factors should be considered regarding restoration activities in the WHSCL Watershed. As shown in **Table 4.3**, the watersheds for Lakes Cannon and Jessie have a large (>1,300) number of septic tanks, and most of the WHSCL Watershed has sandy soils with high infiltration rates (**Table 1.3**), which could influence hydrogeologic nutrient transport.

In addition to addressing reductions in watershed pollutant contributions to the lakes during the implementation phase, it is also necessary to consider the impacts of internal sources (e.g., sediment nutrient fluxes or the presence of nitrogen-fixing cyanobacteria) and the results of any associated remediation projects on surface water quality. The WHSCL low watershed to lake-surface-area ratio may result in relatively greater load contributions from internal sources and atmospheric deposition to the lakes. Historical point source discharges to Lakes Lulu, Eloise, Shipp, May, Jessie, and Howard (see **Table 1.2**) likely have contributed additional nutrients and organic matter to the sediments in these lakes. Lake levels may also influence chlorophyll *a* and color (see **Figures 5.9** through **5.12** and their associated text for more information). Herbicide treatment is used to control the growth of invasive aquatic plants in the WHSCL, and this management activity can contribute to the cycling of nutrients in the lakes and can be a factor influencing phytoplankton growth.

Approaches for addressing both the external and internal nutrient sources should be included in a comprehensive management plan for the lakes. Best management practices focused on internal loading and nitrogen reduction should be considered in prioritizing projects to improve water quality. Additionally, the current aquatic vegetation, water quality and water level monitoring of each lake should continue and be expanded, if needed, during the implementation phase to ensure that adequate information is available for tracking restoration progress.

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Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C. In 1994, DEP stormwater treatment requirements were integrated with the stormwater flood control requirements of the water management districts, along with wetland protection requirements, into the Environmental Resource Permit regulations, as authorized under Part IV of Chapter 373, F.S.

Chapter 62-40, F.A.C., also requires the state's water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a Surface Water Improvement and Management (SWIM) Program plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, they have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka.

In 1987, the U.S. Congress established Section 402(p) as part of the federal CWA Reauthorization. This section of the law amended the scope of the federal NPDES permitting program to designate certain stormwater discharges as "point sources" of pollution. The EPA promulgated regulations and began implementing the Phase I NPDES stormwater program in 1990 to address stormwater discharges associated with industrial activity, including 11 categories of industrial activity, construction activities disturbing 5 or more acres of land, and large and medium MS4s located in incorporated places and counties with populations of 100,000 or more.

However, because the master drainage systems of most local governments in Florida are physically interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 special districts; community development districts, water control districts, and FDOT throughout the 15 counties meeting the population criteria. DEP received authorization to implement the NPDES stormwater program in 2000. The authority to administer the program is set forth in Section 403.0885, F.S.

The Phase II NPDES stormwater program, promulgated in 1999, addresses additional sources, including small MS4s and small construction activities disturbing between 1 and 5 acres, and urbanized areas serving a minimum resident population of at least 1,000 individuals. While these urban stormwater discharges are technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility, as are other point sources of pollution such as domestic and industrial wastewater discharges. It should be noted that Phase I MS4 permits issued in Florida include a reopener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

Appendix B: Information in Support of Site-Specific Interpretations of the Narrative Nutrient Criterion

Table B-1. Spatial extent of the numeric interpretation of the narrative nutrient criterion

Location	Description
Waterbody name	Lake Lulu, Lake Eloise, Lake Shipp, Lake May, Lake Howard, Lake Cannon, Lake Hartridge, Lake Idylwild, and Lake Jessie
Waterbody type(s)	Lake
WBID	Lake Lulu (1521), Lake Eloise (1521B), Lake Shipp (1521D), Lake May (1521E), Lake Howard (1521F), Lake Cannon (1521H), Lake Hartridge (1521I), Lake Idylwild (1521J), and Lake Jessie (1521K) (see **Figure 1.2** of this report)
Description	Lake Lulu, Lake Eloise, Lake Shipp, Lake May, Lake Howard, Lake Cannon, Lake Hartridge, Lake Idylwild, and Lake Jessie are part of the Winter Haven Southern Chain of Lakes (WHSCL) system, located in north central Polk County. The combined watershed area for these lakes is 14,253 acres. Lakes in the WHSCL have a combined surface area of 4,956 acres (35 % of the watershed). Medium-density residential is the predominant anthropogenic land use and makes up 3,541 acres (25 %) of the watershed. **Chapter 1** of this report provides more detail on the WHSCL system.
Specific location (latitude/longitude or river miles)	The center of Lake Lulu is located at Latitude N: 27°59'44", Longitude W: -81°43'15". The center of Lake Eloise is located at Latitude N: 27°58'54", Longitude W: -81°42'10". The center of Lake Shipp is located at Latitude N: 28°00'09", Longitude W: -81°44'31". The center of Lake May is located at Latitude N: 28°00'48", Longitude W: -81°44'13". The center of Lake Howard is located at Latitude N: 28°01'23", Longitude W: -81°44'39". The center of Lake Cannon is located at Latitude N: 28°02'17", Longitude W: -81°45'11". The center of Lake Hartridge is located at Latitude N: 28°03'21", Longitude W: -81°44'33". The center of Lake Idylwild is located at Latitude N: 28°03'02", Longitude W: -81°45'23". The center of Lake Jessie is located at Latitude N: 28°03'28", Longitude W: -81°45'48". The site-specific criteria apply as a spatial average for each lake, as defined by WBIDs 1521, 1521B, 1521, 1521E, 1521F, 1521H, 1521I, 1521J, and 1521K.
Map	**Figure 1.1** shows the general location of the lakes and the WHSCL Watershed, and **Figure 4.1** shows the land uses in the watersheds.
Classification(s)	Class III Freshwater
Basin name (HUC 8)	Peace River Basin (03100101)

Table B-2. Description of the numeric interpretation of the narrative nutrient criterion

Numeric Interpretation of Narrative Nutrient Criterion	Information on Parameters Related to Numeric Interpretation of the Narrative Nutrient Criterion
NNC summary	Lakes Lulu, Eloise, Shipp, May, Howard, Cannon, Hartridge, Idylwild, and Jessie are classified as low-color (<40 PCU), high-alkalinity (> 20 mg/L $CaCO_3$) lakes, and the generally applicable NNC, expressed as AGM concentrations not to be exceeded more than once in any 3-year period, are chlorophyll *a* of 20 µg/L, TN of 1.05 to 1.91 mg/L, and TP of 0.03 to 0.09 mg/L.
Proposed TN, TP, chlorophyll a, and/or nitrate + nitrite concentrations (magnitude, duration, and frequency)	Numeric interpretations of the narrative nutrient criterion: **Lake Lulu (1521), Lake Eloise (1521B), Lake Shipp (1521D), Lake May (1521E), Lake Howard (1521F), Lake Cannon (1521H), Lake Hartridge (1521I), Lake Idylwild (1521J), and Lake Jessie (1521K):** **TN:** 1.07 mg/L, expressed as an AGM not to be exceeded. **TP:** 0.03 mg/L, expressed as an AGM not to be exceeded.
Period of record used to develop numeric interpretations of the narrative nutrient criterion for TN and TP	AGM values for 14 lakes in the WHSCL from 2008 to 2016 were used to develop the empirical relationship used to set the TN criterion for the 9 lakes. The selection of the TP nutrient target and resultant criterion takes into consideration the results of paleolimnological studies of Lakes Lulu, May, Howard, and Hartridge. The paleolimnological results are presented in Whitmore and Brenner (1995; 2002) (see the **References** section of this report for complete bibliographical details).
How the criteria developed are spatially and temporally representative of the waterbody or critical condition	The water quality results applied in the analysis were from the 2008–16 period, which included years with both above- and below-average precipitation. Rainfall from the SWFWMD Polk countywide results indicate that 2008, 2012, and 2013 were years with below-average precipitation, while 2014 to 2016 were years with above-average precipitation. **Figure 2.1** shows the sampling stations in the WHSCL. Monitoring stations were located across the spatial extent and represent the spatial distribution of nutrient dynamics in the lakes, as follows: Polk County (21FLPOLK…) and DEP (21FLTPA …and 21FLGW). **Chapter 5** contains graphs showing water quality results for the variables relevant to TMDL development.

Table B-3. Summary of how designated use(s) are protected by the criterion

Designated Use Requirements	Information Related to Designated Use Requirements
History of assessment of designated use support	During the Cycle 3 assessment, the NNC were used to assess the lakes during the verified period (January 1, 2008–June 30, 2015) based on data from IWR Database Run 52. Lakes Eloise and Hartridge were assessed as impaired for chlorophyll *a* and TN because the AGMs exceeded the NNC more than once in a three-year period, and the waterbodies were added to the 303(d) list for chlorophyll *a* and TN. These lakes were found not to be impaired for TP. When the Cycle 1 assessment was performed, Lakes Cannon, Howard, Idylwild, Jessie, Lulu, May, Mirror, and Shipp were verified as impaired for nutrients and were included on the Verified List of impaired waters for the Peace River Basin that was adopted by Secretarial Order in June 2005. During the Cycle 1 assessment, the TSI, a calculation based on nutrient and chlorophyll *a* concentrations, was the primary means of assessing nutrient impairment in lakes. For the most recent assessment, Lakes Cannon, Howard, Idylwild, Jessie, Lulu, and Shipp had AGMs that exceeded the applicable NNC for chlorophyll *a* and TN. Lake May had AGMs that exceeded the applicable NNC for chlorophyll *a*, TN, and TP.
Basis for use support	The basis for use support is the NNC chlorophyll *a* concentration of 20 µg/L, which is protective of designated uses for low-color, high-alkalinity lakes. Based on the available information, there is nothing unique about the lakes that would make the use of the chlorophyll *a* threshold of 20 µg/L inappropriate.
Approach used to develop criteria and how it protects uses	The methods used to address the nutrient impairment included (1) the development of a regression equation that relates the lake TN and TP concentrations to the AGM chlorophyll *a* levels, and (2) the evaluation of paleolimnological results to establish a TP target consistent with predisturbance conditions. The criteria are expressed as maximum AGM concentrations not to be exceeded in any year. Establishing the frequency as not to be exceeded in any year ensures that the chlorophyll *a* NNC, which are protective of designated use, is achieved.
How the TMDL analysis will ensure that nutrient-related parameters are attained to demonstrate that the TMDLs will not negatively impact other water quality criteria	The method indicated that the chlorophyll *a* concentration target for the lake will be attained at the TMDL in-lake TN and TP concentration, frequency, and duration, while taking into consideration the estimated predisturbance phosphorus condition in the lake. DEP notes that there were no impairments for nutrient-related parameters (such as dissolved oxygen [DO] or un-ionized ammonia). The proposed reductions in nutrient inputs will result in further improvements in water quality.

Table B-4. Documentation of the means to attain and maintain water quality standards for downstream waters

Protection of Downstream Waters and Monitoring Requirements	Information Related to Protection of Downstream Waters and Monitoring Requirements
Identification of downstream waters: List receiving waters and identify technical justification for concluding downstream waters are protected	The WHSCL can discharge to the stream segments of Lake Lulu Run (WBID 1521C) and Wahneta Farms Drainage Canal (WBID 1580) from a structure on the south side of Lake Lulu. The Wahneta Farms Drainage Canal flows into the Peace Creek Drainage Canal, which, along with Saddle Creek, makes up the headwaters of the Peace River. The Peace River Basin is located in the West Central Nutrient Watershed Region. The generally applicable NNC for streams in this region, set forth in Subparagraph 62-302.531[2][c]2., F.A.C., are a TN concentration of 1.65 mg/L and a TP concentration of 0.49 mg/L. These nutrient thresholds, which are also expressed as AGMs, are higher than the AGM site-specific criteria for the WHSCL. The reductions in nutrient loads described in this TMDL analysis are not expected to cause nutrient impairments downstream and will improve water quality in downstream waters (see **Section 3.4** of this report).
Summary of existing monitoring and assessment related to the implementation of Subsection 62-302.531(4), F.A.C., and trends tests in Chapter 62-303, F.A.C.	Polk County and DEP conduct routine monitoring of WHSCL. The data collected through these monitoring activities will be used to evaluate the effect of BMPs implemented in the watershed on lake TN and TP concentrations in subsequent water quality assessment periods.

Table B-5. Documentation of endangered species consideration

Administrative Requirements	Information for Administrative Requirements
Endangered species consideration	DEP is not aware of any endangered aquatic species present in the WHSCL. Furthermore, it is expected that improvements in water quality resulting from these restoration efforts will positively impact aquatic species living in the lakes and their respective watersheds.

Table B-6. Documentation that administrative requirements are met

Administrative Requirements	Information for Administrative Requirements
Notice and comment notifications	DEP published a Notice of Development of Rulemaking on March 29, 2019, to initiate TMDL development for impaired waters in the Peace River Basin. A rule development public workshop for the TMDLs was held on May 7, 2019.
Hearing requirements and adoption format used; responsiveness summary	Following the publication of the Notice of Proposed Rule, DEP will provide a 21-day challenge period and a public hearing that will be noticed no less than 45 days prior.
Official submittal to EPA for review and General Counsel certification	If DEP does not receive a rule challenge, the certification package for the rule will be prepared by the DEP program attorney. DEP will prepare the TMDLs and submittal package for the TMDLs to be considered a site-specific interpretation of the narrative nutrient criterion, and will submit these documents to the EPA.

Appendix C: SWFWMD Land Use by Lake Watershed in 2011

Lake	Code	Land Use	Acres	Lake Watershed %
Cannon	1100	Low-Density Residential	0	0
Cannon	1200	Medium-Density Residential	579.79	46.45
Cannon	1300	High-Density Residential	25.77	2.06
Cannon	1400	Commercial and Services	52.53	4.21
Cannon	1500	Industrial	69.91	5.6
Cannon	1600	Extractive	0	0
Cannon	1700	Institutional	62.4	5
Cannon	1800	Recreational	10.78	0.86
Cannon	1900	Open Land	22.31	1.79
Cannon	2000	Agriculture	7.82	0.63
Cannon	3000	Rangeland	0	0
Cannon	4000	Upland Forest	16.92	1.36
Cannon	5000	Water	385.83	30.91
Cannon	6000	Wetlands	11.56	0.93
Cannon	7000	Barren Land	0	0
Cannon	8000	Transportation, Communication and Utilities	2.67	0.21
Eloise	1100	Low-Density Residential	143.14	6.61
Eloise	1200	Medium-Density Residential	392.95	18.51
Eloise	1300	High-Density Residential	68.91	3.18
Eloise	1400	Commercial and Services	6.6	0.3
Eloise	1500	Industrial	0	0
Eloise	1600	Extractive	0	0
Eloise	1700	Institutional	2.79	0.13
Eloise	1800	Recreational	144.39	6.67
Eloise	1900	Open Land	10.58	0.49
Eloise	2000	Agriculture	113.64	5.25
Eloise	3000	Rangeland	69.57	3.21
Eloise	4000	Upland Forest	1.39	0.06
Eloise	5000	Water	1,163.56	53.76
Eloise	6000	Wetlands	38.97	1.8
Eloise	7000	Barren Land	0	0
Eloise	8000	Transportation, Communication and Utilities	8.04	0.37
Hartridge	1100	Low-Density Residential	18.23	1.95
Hartridge	1200	Medium-Density Residential	187.55	20.1
Hartridge	1300	High-Density Residential	54.65	5.86
Hartridge	1400	Commercial and Services	60.6	6.49
Hartridge	1500	Industrial	0	0
Hartridge	1600	Extractive	0	0
Hartridge	1700	Institutional	20.42	2.19
Hartridge	1800	Recreational	0	0

Lake	Code	Land Use	Acres	Lake Watershed %
Hartridge	1900	Open Land	15.1	1.62
Hartridge	2000	Agriculture	33.79	3.62
Hartridge	3000	Rangeland	0	3.21
Hartridge	4000	Upland Forest	6.65	0.71
Hartridge	5000	Water	437.86	46.92
Hartridge	6000	Wetlands	13.86	11.49
Hartridge	7000	Barren Land	0	0
Hartridge	8000	Transportation, Communication and Utilities	84.48	9.05
Howard	1100	Low-Density Residential	13.22	0.61
Howard	1200	Medium-Density Residential	734.06	33.69
Howard	1300	High-Density Residential	98.49	4.52
Howard	1400	Commercial and Services	283.7	13.02
Howard	1500	Industrial	18.91	0.87
Howard	1600	Extractive	0	0
Howard	1700	Institutional	51.17	2.35
Howard	1800	Recreational	21.5	0.99
Howard	1900	Open Land	84.24	3.87
Howard	2000	Agriculture	19.03	0.87
Howard	3000	Rangeland	0	0
Howard	4000	Upland Forest	45.58	2.09
Howard	5000	Water	744.3	34.16
Howard	6000	Wetlands	62.39	2.86
Howard	7000	Barren Land	0	0
Howard	8000	Transportation, Communication and Utilities	2.42	0.11
Idylwild	1100	Low-Density Residential	0	0
Idylwild	1200	Medium-Density Residential	112.05	31.05
Idylwild	1300	High-Density Residential	18.13	5.02
Idylwild	1400	Commercial and Services	75.86	21.02
Idylwild	1500	Industrial	0	0
Idylwild	1600	Extractive	0	0
Idylwild	1700	Institutional	6.85	1.9
Idylwild	1800	Recreational	0	0
Idylwild	1900	Open Land	27.01	7.48
Idylwild	2000	Agriculture	0.04	0.01
Idylwild	3000	Rangeland	0	0
Idylwild	4000	Upland Forest	0	0
Idylwild	5000	Water	93.42	25.88
Idylwild	6000	Wetlands	8.77	2.43
Idylwild	7000	Barren Land	0	0
Idylwild	8000	Transportation, Communication and Utilities	18.78	5.2
Jessie	1100	Low-Density Residential	28.1	0.96
Jessie	1200	Medium-Density Residential	612.69	21.02

Lake	Code	Land Use	Acres	Lake Watershed %
Jessie	1300	High-Density Residential	269.57	9.25
Jessie	1400	Commercial and Services	261.06	8.96
Jessie	1500	Industrial	103.49	3.55
Jessie	1600	Extractive	0	0
Jessie	1700	Institutional	35.42	1.22
Jessie	1800	Recreational	5.13	0.18
Jessie	1900	Open Land	53.44	1.83
Jessie	2000	Agriculture	473.58	16.25
Jessie	3000	Rangeland	0	0
Jessie	4000	Upland Forest	33.67	1.16
Jessie	5000	Water	704.64	24.18
Jessie	6000	Wetlands	114.92	3.94
Jessie	7000	Barren Land	0	0
Jessie	8000	Transportation, Communication and Utilities	218.81	7.51
Lulu	1100	Low-Density Residential	9.3	0.86
Lulu	1200	Medium-Density Residential	115.94	10.68
Lulu	1300	High-Density Residential	57.35	5.28
Lulu	1400	Commercial and Services	171.35	15.78
Lulu	1500	Industrial	45.82	4.22
Lulu	1600	Extractive	0	0
Lulu	1700	Institutional	34.47	3.17
Lulu	1800	Recreational	45.31	4.17
Lulu	1900	Open Land	21.15	1.95
Lulu	2000	Agriculture	41.54	3.82
Lulu	3000	Rangeland	0	0
Lulu	4000	Upland Forest	6.18	0.57
Lulu	5000	Water	280.27	25.81
Lulu	6000	Wetlands	245.68	22.62
Lulu	7000	Barren Land	0	0
Lulu	8000	Transportation, Communication and Utilities	11.69	1.08
May	1100	Low-Density Residential	0	0
May	1200	Medium-Density Residential	91.1	18.95
May	1300	High-Density Residential	0	0
May	1400	Commercial and Services	178.93	37.22
May	1500	Industrial	88.25	18.35
May	1600	Extractive	0	0
May	1700	Institutional	27.85	5.79
May	1800	Recreational	0	0
May	1900	Open Land	38.13	7.93
May	2000	Agriculture	0	0
May	3000	Rangeland	0	0
May	4000	Upland Forest	4.09	0.85

Lake	Code	Land Use	Acres	Lake Watershed %
May	5000	Water	41.83	8.7
May	6000	Wetlands	10.62	2.21
May	7000	Barren Land	0	0
May	8000	Transportation, Communication and Utilities	0	0
Mirror	1100	Low-Density Residential	0	0
Mirror	1200	Medium-Density Residential	124.7	44.39
Mirror	1300	High-Density Residential	0.01	0
Mirror	1400	Commercial and Services	16.78	5.97
Mirror	1500	Industrial	0	18.35
Mirror	1600	Extractive	0	0
Mirror	1700	Institutional	0.02	0.01
Mirror	1800	Recreational	0	0
Mirror	1900	Open Land	10.28	3.66
Mirror	2000	Agriculture	0	0
Mirror	3000	Rangeland	0	0
Mirror	4000	Upland Forest	0	0
Mirror	5000	Water	120.22	42.79
Mirror	6000	Wetlands	8.94	3.18
Mirror	7000	Barren Land	0	0
Mirror	8000	Transportation, Communication and Utilities	0	0
Roy	1100	Low-Density Residential	13.42	3.4
Roy	1200	Medium-Density Residential	171.35	43.39
Roy	1300	High-Density Residential	15.71	3.98
Roy	1400	Commercial and Services	71.74	18.17
Roy	1500	Industrial	0	0
Roy	1600	Extractive	0	0
Roy	1700	Institutional	16.59	4.2
Roy	1800	Recreational	0	0
Roy	1900	Open Land	0	0
Roy	2000	Agriculture	16.48	4.17
Roy	3000	Rangeland	0	0
Roy	4000	Upland Forest	0	0
Roy	5000	Water	72.32	18.31
Roy	6000	Wetlands	4.39	1.11
Roy	7000	Barren Land	0	0
Roy	8000	Transportation, Communication and Utilities	12.93	3.27
Shipp	1100	Low-Density Residential	28.06	3.17
Shipp	1200	Medium-Density Residential	151.78	17.17
Shipp	1300	High-Density Residential	118.14	13.36
Shipp	1400	Commercial and Services	64.79	7.33
Shipp	1500	Industrial	54.45	6.16
Shipp	1600	Extractive	0	0

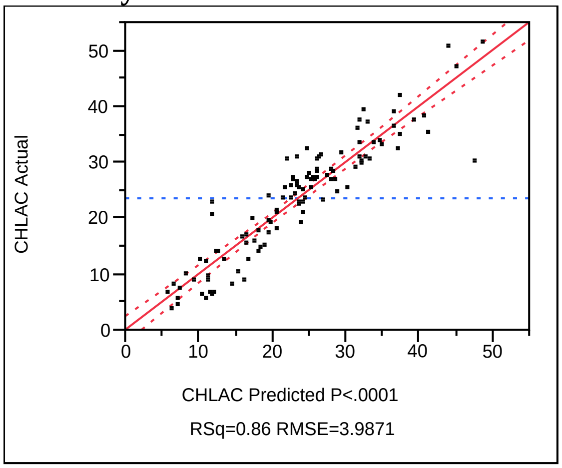
Lake	Code	Land Use	Acres	Lake Watershed %
Shipp	1700	Institutional	12.57	1.42
Shipp	1800	Recreational	26.35	2.98
Shipp	1900	Open Land	17.39	1.97
Shipp	2000	Agriculture	83.68	9.46
Shipp	3000	Rangeland	0	0
Shipp	4000	Upland Forest	19.63	2.22
Shipp	5000	Water	262.72	29.71
Shipp	6000	Wetlands	28.66	3.24
Shipp	7000	Barren Land	0	0
Shipp	8000	Transportation, Communication and Utilities	16.02	1.81
Spring	1100	Low-Density Residential	4.78	4.08
Spring	1200	Medium-Density Residential	7.23	6.17
Spring	1300	High-Density Residential	7.08	6.04
Spring	1400	Commercial and Services	59.81	51
Spring	1500	Industrial	0	0
Spring	1600	Extractive	0	0
Spring	1700	Institutional	6.84	5.83
Spring	1800	Recreational	1.85	1.58
Spring	1900	Open Land	2.83	2.41
Spring	2000	Agriculture	0	0
Spring	3000	Rangeland	0	0
Spring	4000	Upland Forest	0	0
Spring	5000	Water	23.58	20.11
Spring	6000	Wetlands	3.27	2.79
Spring	7000	Barren Land	0	0
Spring	8000	Transportation, Communication and Utilities	0	0
Summit	1100	Low-Density Residential	8.46	4.66
Summit	1200	Medium-Density Residential	83.99	46.28
Summit	1300	High-Density Residential	0	0
Summit	1400	Commercial and Services	0	0
Summit	1500	Industrial	0	0
Summit	1600	Extractive	0	0
Summit	1700	Institutional	0	0
Summit	1800	Recreational	17.28	9.52
Summit	1900	Open Land	0	1.97
Summit	2000	Agriculture	0	0
Summit	3000	Rangeland	0	0
Summit	4000	Upland Forest	0	0
Summit	5000	Water	65.48	36.06
Summit	6000	Wetlands	2.85	1.57
Summit	7000	Barren Land	0	0
Summit	8000	Transportation, Communication and Utilities	3.53	1.81

Lake	Code	Land Use	Acres	Lake Watershed %
Winterset	1100	Low-Density Residential	94.47	9.2
Winterset	1200	Medium-Density Residential	175.91	17.13
Winterset	1300	High-Density Residential	76.54	7.45
Winterset	1400	Commercial and Services	13.72	1.34
Winterset	1500	Industrial	0	0
Winterset	1600	Extractive	0	0
Winterset	1700	Institutional	0.38	0.04
Winterset	1800	Recreational	0	0
Winterset	1900	Open Land	36.73	3.58
Winterset	2000	Agriculture	9.21	0.9
Winterset	3000	Rangeland	0	0
Winterset	4000	Upland Forest	23.86	2.32
Winterset	5000	Water	559.92	54.51
Winterset	6000	Wetlands	22.98	2.24
Winterset	7000	Barren Land	0	0
Winterset	8000	Transportation, Communication and Utilities	13.41	1.31

Appendix D: Multiple Regression Model Results

Response CHLAC AGM: WHSCL 2008–16
Results
Whole Model

Actual by Predicted Plot



Summary of Fit

Calculation	Result
RSquare	0.8564
RSquare Adj	0.853716
Root Mean Square Error	3.98711
Mean of Response	23.49668
Observations (or Sum Wgts)	110

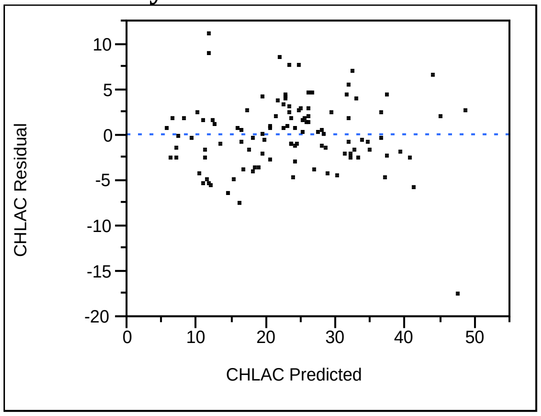
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	10144.29	5072.14	319.0621
Error	107	1700.984	15.9	Prob > F
C. Total	109	11845.27		<.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	-11.1131	1.424239	-7.8	<.0001*	
TN	22.74647	1.555162	14.63	<.0001*	1.9773
TP	224.4959	51.44272	4.36	<.0001*	1.9773

Residual by Predicted Plot



Prediction Expression

-11.113129407946 + 22.7464651852925 * TN AGM + 224.495931620453 * TP AGM