Lower Withlacoochee River Environmental Analysis

Phase 3 – Data Synthesis and Recommendations for Recovery

Prepared for

Withlacoochee Aquatic Restoration

July 2021

Prepared by

Wetland Solutions Inc

Table of Contents

Table of Exhibits

Figures

Tables

Acknowledgements

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The contributions of our partners and the funds provided through grants and donations are greatly appreciated.

Abbreviations

ac	Acre
As-T	Arsenic, Total
BDL	Below Detection Limit
BMAP	Basin Management Action Plan
Ca-T	Calcium, Total
CFBC	Cross-Florida Barge Canal
cfs	Cubic Feet per Second
Chl-a corr	Chlorophyll a, corrected for pheophytin
Cl-T	Chloride, Total
CR	Community Respiration
Cu-T	Copper, Total
DO	Dissolved Oxygen
EPT	Ephemeroptera/Plecoptera/ Trichoptera
FC	Fecal Coliform
FDEP	Florida Department of Environmental Protection
Fe-T	Iron, Total
FLUCCS	Florida Land Use, Cover and Form Classification System
ft	Feet
FWC	Florida Fish and Wildlife Conservation Commission
g $O_2/m^2/d$	Grams Oxygen per Meters Squared per Day
GPP	Gross Primary Productivity
HA	Habitat Assessment
ha	Hectare
HBI	Hilsenhoff Biotic Index
Kd	Diffuse Attenuation Coefficient
km	Kilometer
lbs/d	Pounds per Day
LOESS	Locally-Weighted Scatterplot Smoothing
LWR	Lower Withlacoochee River
m	Meters
M	Million
mg/L	Milligrams per Liter
MGD	Million Gallons per Day

Mg-T	Magnesium, Total
NGVD29	National Geodetic Vertical Datum of 1929
NH4-N	Ammonia Nitrogen
NOx-N	Nitrate + Nitrite Nitrogen
NPP	Net Primary Productivity
NTU	Nephelometric Turbidity Units
OrgN	Organic Nitrogen
OrthoP	Orthophosphorus
P/R	Productivity / Respiration Ratio
PAR	Photosynthetically-Active Radiation
pcu	Platinum-Cobalt Units
Pheo-a	Pheophytin-a
ppt	Parts per Thousand
s.u.	Standard Units
SCI	Stream Condition Index
SO4	Sulfate, Total
SpCond	Specific Conductance
SR	State Road
SWFWMD	Southwest Florida Water Management District
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
Turb	Turbidity
USGS	United States Geological Survey
WAR	Withlacoochee Aquatic Restoration
WR-DSRR	Withlacoochee River Downstream of the Rainbow River
WR-US41	Withlacoochee River Upstream at US 41
WR-USRR	Withlacoochee River Upstream of the Rainbow River
WSI	Wetland Solutions, Inc.
Wtr Temp	Water Temperature
µg/L	Micrograms per Liter
µS/cm	Microsiemens per Centimeter

Executive Summary

A local citizens advocacy group, Withlacoochee Aquatic Restoration (W.A.R., Inc.) contracted with Wetland Solutions, Inc. (WSI) to conduct a three-phase environmental assessment and restoration planning effort in response to perceived ecosystem changes and environmental degradation in the Lower Withlacoochee River. The study area included the Withlacoochee River from just upstream of Dunnellon and the Rainbow River confluence, downstream through Lake Rousseau and the historic river channel to the Gulf of Mexico, and proceeded in three phases:

- Phase 1 was a review of existing environmental conditions and data relevant to the health of the Lower Withlacoochee River. Key among the preliminary conclusions was that the Lower Withlacoochee River has been significantly altered by human activities over the past 100+ years. Major impacts include historic timber extraction, dredging, ditching, current and historic phosphate and limerock mining, construction of dams and spillways, construction of the Cross-Florida Barge Canal, regional groundwater extractions, aquatic weed management in Lake Rousseau, and agricultural and urban development in the surface and groundwater basin that supplies water to the river.
- Phase 2 was conducted to update environmental information through current conditions and to fill existing data gaps, including collection of environmental data over a four-year period from November 2015 through October 2020. Monthly monitoring took place from November 2015 through October 2017; and supplemental quarterly monitoring was conducted from October 2019 through October 2020. For Phase 2 the Southwest Florida Water Management District (SWFWMD) provided staff support and the Florida Department of Environmental Protection (FDEP) provided all analytical chemical analyses. Sampling of fish populations in the Lower Withlacoochee River was conducted by the Florida Fish & Wildlife Conservation Commission (FWC) staff.
- Phase 3 is the conclusion of this study, including preparation and publication of this report. This report describes the existing environmental impairments that negatively affect the environmental health of the Lower Withlacoochee River Study Area and recommends practical management and capital improvement actions that will reduce or eliminate impairments and increase overall environmental, economic, and aesthetic vitality to the project study area.

Phase 3 Key Findings and Recommendations

Key Findings

Urban, commercial, and agricultural development have replaced natural land cover in large areas of the surface and groundwater basins that contribute water to the Lower Withlacoochee River Study Area. These intensive human activities occupy a combined 25% of the contributing surface water basin affecting this portion of the river and 60% of the groundwater basin feeding water to the Rainbow River. These land use changes have resulted in both direct and indirect impacts to the Lower Withlacoochee River, including reduced water inflows and impaired water quality that have contributed to altered river conditions.

Since the construction of the Cross-Florida Barge Canal in the late 1960s, the Lower Withlacoochee River has been deprived of peak flows in excess of approximately 1,450 cfs. Before the late 1960s periodic higher flows in the Lower Withlacoochee River had the potential to flush out accumulated sediment and filamentous algae and contributed to a productive aquatic food chain supporting a healthy recreational fishery.

Historically, baseflows in the Lower Withlacoochee River were dominated by upstream springs, including the Gum Slough spring system, Blue Spring in Citrus County, and most importantly the spring-fed Rainbow River. Historic discharge data document significant long-term reductions in average and low flows in these springs and in the Lower Withlacoochee River, on the order of 20 to 40%.

Upstream of the confluence with the Rainbow River, the Withlacoochee River is characterized as a blend of surface runoff and spring inflows, with low turbidity and suspended solids, some tannic color, and relatively low concentrations of nitrogen and phosphorus nutrients. The low concentrations of nitrogen in the Withlacoochee River increase downstream of the river's confluence with the Rainbow River. Rainbow Springs has experienced a significant increase in nitrate-nitrogen concentrations over the past four decades due to increasing fertilizer use and wastewater discharges throughout the groundwater basin. Nitrate-nitrogen concentrations in the Rainbow River increased from 0.08 mg/L in March 1927 to consistently above 2.2 mg/L currently, a more than 25-fold increase.

The Lower Withlacoochee River water quality, downstream of the confluence with the Rainbow River, reflects the blending of these two rivers. During periods with low water levels in the Withlacoochee River, water quality conditions downstream of the confluence are similar to conditions in the Rainbow River. Increased water clarity and nitrogen entering Lake Rousseau fuel growth of invasive aquatic plants and planktonic algae, increasing concentrations of chlorophyll-a, and requiring annual herbicide treatments to maintain boating access. This cultural eutrophication of Lake Rousseau likely contributes to water quality degradation in the downstream segment of the Lower Withlacoochee River when water is discharged from the lake to the river.

Historic herbicide treatments in Lake Rousseau may be partially or wholly responsible for the near eradication of aquatic plants that formerly grew in the Lower Withlacoochee River. Continuing herbicide treatments in Lake Rousseau contribute periodic elevated herbicide concentrations to the lower river. The potential chronic toxicity of these residual herbicides, combined with the documented reduction is water clarity due to reduced spring-fed base flows and increased incoming particulates from Lake Rousseau, may have limited the recovery of the former native plant communities in the Lower Withlacoochee River.

With few exceptions, aquatic habitat in the Lower Withlacoochee River is considered "marginal" or "suboptimal" and macroinvertebrate populations are indicative of polluted water conditions. These small organisms are a critical link in the aquatic food web that supports healthy fish and wildlife populations. Existing fish populations in the Lower Withlacoochee River are dominated by non-game species indicative of impaired water quality conditions. Due to the apparent absence of submerged aquatic vegetation in the Lower Withlacoochee River, primary productivity is low and wildlife habitat is largely dependent on organic inputs from Lake Rousseau.

Human recreational use of the Lower Withlacoochee River also appears to be low. Although more than 200 boats were typically moored to docks along the river, only 134 individuals and 12 fishermen were documented during the 28 Phase 2 sampling trips.

Restoration Recommendations

A plan for restoration of the Lower Withlacoochee River must mitigate many of the impacts that have occurred to-date and must also include measures to offset inevitable future impacts resulting from additional development activities.

Partial restoration of the original river flows may be possible by decreasing consumptive uses in the groundwater basin feeding the Rainbow and Lower Withlacoochee Rivers, while increasing recharge of high-quality water to the Floridan Aquifer. Regulatory minimum flows and minimum levels (MFLs) for the Rainbow River and Gum Slough and the upcoming MFL for the Lower Withlacoochee River must be set at levels that provide adequate flows needed to support healthy environmental systems.

A direct and achievable alternative for environmental enhancement of the Lower Withlacoochee River is restoration of historic peak flows from Lake Rousseau to the lower river. This could be accomplished in one of two ways: either by increasing the flow capacity of the Inglis Bypass Channel and the control gate to between 2,500 and 4,500 cfs, or by reconnecting the dam to the historic channel of the lower river by installing a new lock in the Cross-Florida Barge Canal, downstream of a restored connection between the two natural sections of the Lower Withlacoochee River. The proposed new lock connecting the lower river to upstream Lake Rousseau could also be designed to allow facilitated passage of fish and manatees into the upstream springs and river.

An additional recommended structural improvement is elimination of the approximately 105-167 cfs leakage that currently occurs under or around the Inglis Dam to the Barge Canal. This repair is expected to measurably increase flows to the Lower Withlacoochee River. This additional inflow is particularly critical during droughts when it constitutes 20% or more of the total flow in the Lower Withlacoochee River.

Reducing water quality problems in the Lower Withlacoochee River will require efforts to eliminate both direct and indirect sources of nitrogen to surface and groundwaters. Indirect pollution impacts from thousands of septic tanks affecting the lower river requires septic-to-sewer conversion for most residences and businesses with a new wastewater treatment plant. This new wastewater treatment system should include advanced wastewater treatment with nitrogen removal and groundwater recharge within the springshed to recycle highly-treated effluent to the Floridan Aquifer.

Other indirect sources of nitrogen pollution affecting the Rainbow River and ultimately Lake Rousseau and the Lower Withlacoochee River need to be reduced by more than 80% as identified by the state’s Rainbow River Basin Management Action Plan (BMAP). Achieving this level of nutrient load reduction is expected to require the replacement of thousands of single-family septic systems throughout the 737 square mile Rainbow Springshed and nutrient reduction on tens of thousands of acres of intensive farmland. These efforts are expected to require significant state and federal funding support.

Use of fertilizers and pesticides on urban and commercial properties should be regulated within a riverine buffer zone through a city, county, or state ordinance. Herbicide use on Lake Rousseau should be limited lake wide and eliminated within close proximity to outflow structures to reduce downstream acute and chronic impacts. Periodic drawdowns of water levels in the lake should be considered in conjunction with limited mechanical harvesting as an alternative approach for lake management.

Finally, limits should be considered for further shoreline development along the Lower Withlacoochee River, including docks and seawalls, that allow a maximum length of hard, vertical seawall combined with a more environmentally-friendly option such as living shorelines or natural shorelines for the remaining shoreline length.

Introduction

The Withlacoochee River (south) is located in West Central Florida. The river drains surface water runoff from the Green Swamp near the City of Lakeland in Polk County, northwest to Citrus County, and then west to the Gulf of Mexico near Yankeetown (Figure 1). In addition to surface water the Withlacoochee River intercepts and conveys significant quantities of groundwater from a large area of karst terrain that extends east and south through Pasco, Sumter, Citrus, Marion, and Levy counties. One primary source of this spring flow is the Rainbow River/Springs System that drains into the Withlacoochee River near Dunnellon. The approximate length of the Withlacoochee River is 157 miles with a surface watershed of about 2,060 square miles (Southwest Florida Water Management District, 2010).

In its lower reaches (below Dunnellon and the Rainbow River confluence) the Lower Withlacoochee River (LWR) has been highly altered by human activities. The most significant structural changes to the river were the closing of the Inglis Dam on the river in 1909 that impounded Lake Rousseau; the construction of the Cross-Florida Barge Canal (CFBC) and lock system just east of US 19 and south of Inglis in the 1960s; and the dredging of the lower river to accommodate boat traffic for mining and power generation. These alterations, in conjunction with other environmental stresses resulting from conversion from natural to developed land uses in the river's watershed have changed the physical, chemical, biological, and aesthetic conditions in the Lower Withlacoochee River.

In response to perceived changes and degradation, a local citizens' advocacy group, Withlacoochee Aquatic Restoration (W.A.R., Inc.) contracted with Wetland Solutions, Inc. (WSI) to conduct a three-phase environmental assessment and restoration planning effort for the Lower Withlacoochee River Study Area (Figure 2). This river segment extends from just upstream of the confluence with the Rainbow River, downstream through Lake Rousseau, the Cross-Florida Barge Canal segment that discharges to the Gulf of Mexico, and approximately 10 miles of the historic river channel that receives bypass water from Lake Rousseau and empties into the Gulf.

The three study phases included: Phase 1 – a summary of existing information concerning historical environmental conditions, Phase 2 – a monitoring and data collection effort to fill some data gaps and provide a current baseline of environmental conditions, and Phase 3 (this report) to synthesize historical and current information concerning known impairments to the environmental health of the Lower Withlacoochee River Study Area and to provide recommendations for reducing existing impairments and restoring the lower river to an environmentally and economically healthy condition.

Phase 1 Summary of Existing Data

WSI's Phase 1 review of existing environmental data from the Lower Withlacoochee River provided the following preliminary conclusions (Wetland Solutions, Inc., 2013b):

- The Lower Withlacoochee River has been significantly altered by human activities over the past 100+ years and likely since the first colonization of the Gulf Coastal Plain by Europeans. Major impacts include historic timber extraction, dredging, ditching, current and historic phosphate and limerock mining, construction of dams and spillways, construction of the Cross-Florida Barge Canal, aquatic weed management, and agricultural and urban development in the surface and groundwater basin that supplies water to the river.

- Specific documented impacts affecting the existing environment in the Lower Withlacoochee River Study Area include the following:
    - Creation and maintenance of a dredged channel connecting the mouth of the lower river to the Gulf of Mexico.
    - Construction of the Inglis Dam in 1909.
    - Alterations in water quality and the physical aquatic environment with the conversion of 5.7 miles of the historic river and floodplain wetlands to Lake Rousseau.
    - Diversion of historic high peak flows from the lower river to the Cross-Florida Barge Canal since December 1969.
    - Significant long-term flow reduction in all portions of the system on the order of 20 to 40%.
    - Increasing concentrations of nitrate nitrogen, a plant-growth nutrient, entering the Rainbow River from groundwater sources and traveling downstream to Lake Rousseau and the lower river.
    - Proliferation of native and non-native aquatic plants in the Lower Withlacoochee River, the Rainbow River, and Lake Rousseau, leading to chemical and physical eradication efforts.
    - Releases of dead plant matter, herbicides, and planktonic algae from Lake Rousseau through the Inglis Bypass Channel to the remaining natural segment of the lower river, with creation of eutrophic conditions, and wide swings in concentrations of dissolved oxygen and pH; and
    - Apparent eradication of submerged aquatic vegetation in the Lower Withlacoochee River with associated declines in fish, manatees, and other wildlife.

Studies by Frazer *et al*. (2001) from the University of Florida indicate that there was little to no submerged aquatic vegetation in the Lower Withlacoochee River for at least the past 15 years, if not longer. However, with the exception of the UF study there was a paucity of historical biological data from the lower river. No algal, macroinvertebrate, fish, reptile/amphibian, bird, or mammal population data were located for the Phase 1 analysis. This biological data gap, both past and present, limits conclusions concerning the causation of current conditions and environmental health.

Phase 2 Updated Baseline of Environmental Conditions

The purpose of Phase 2 was to update the baseline with time-varying environmental conditions for the Lower Withlacoochee River including flow and water quality, and to fill some of the existing data gaps. Additional data collection during Phase 2 and a supplemental monitoring period helped to augment the understanding of the current physical, chemical, and biological conditions in the Lower Withlacoochee River study area.

Phase 2 included collection of environmental data over a four-year period from November 2015 until October 2020 (Phase 2 monthly monitoring: November 2015 – October 2017; Supplemental quarterly monitoring: October 2019 – October 2020). Partners during the Phase 2 study included the Southwest Florida Water Management District (SWFWMD) who provided shared staff resources, the Florida Department of Environmental Protection (FDEP) who provided analytical chemistry and biological sampling support, and the Florida Fish and Wildlife Conservation Commission (FWC) who provided fish population data and information on aquatic weed control activities.

Phase 3 Assessment of Environmental Impairments and Restoration Recommendations

This report is the final deliverable of the Lower Withlacoochee River Study Area environmental analysis. Phase 3 of this study describes the existing environmental impairments that negatively affect the environmental health of the Lower Withlacoochee River Study Area and recommends practical management and capital improvement actions that will reduce or eliminate existing impairments and increase overall environmental, economic, and aesthetic vitality to the Study Area.

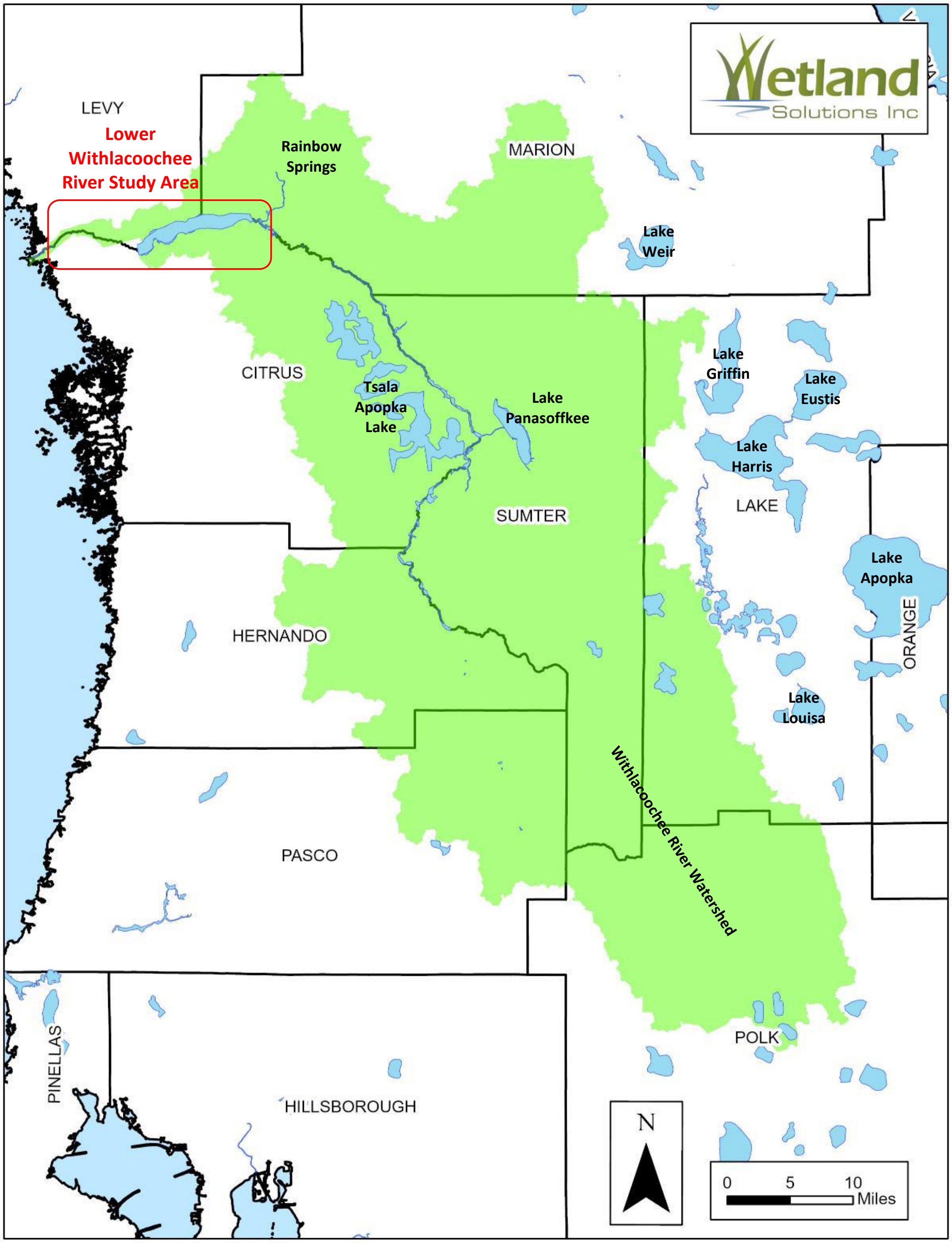


Figure 1. Extent of the Withlacoochee River surface watershed and location of the Lower Withlacoochee River Study Area

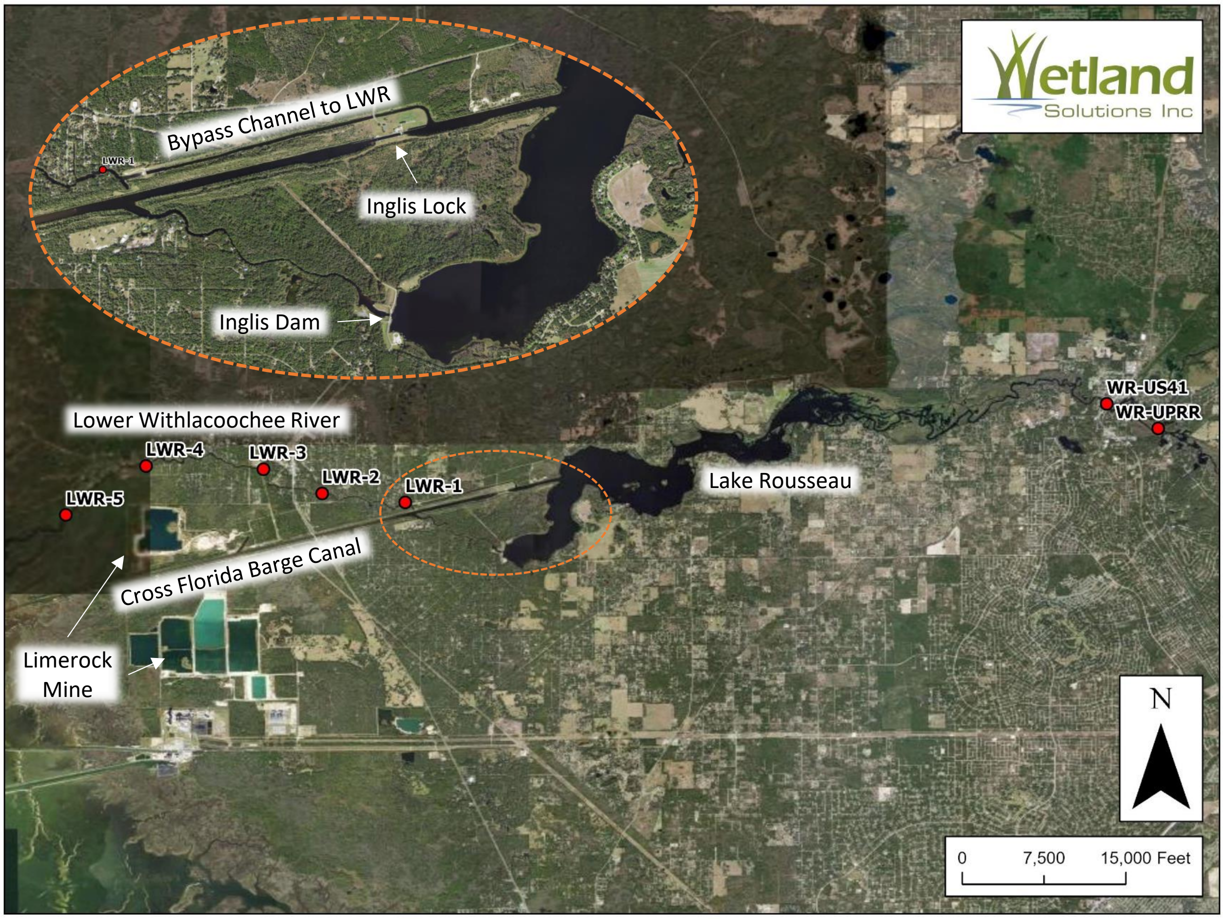


Figure 2. Lower Withlacoochee River Study Area

Environmental Setting

The Lower Withlacoochee River Study Area, in the context of this report, is the section of the Withlacoochee River from just above its confluence with the Rainbow River to the Gulf of Mexico. This includes Lake Rousseau, the Inglis Bypass Channel, the Inglis Lock and Dam, the Cross-Florida Barge Canal from the Inglis Dam to the Gulf, and the isolated Lower Withlacoochee River segment from the dam back to the Cross-Florida Barge Canal. The section of river from the Inglis Bypass Channel to the Gulf receives all of its upstream flow through the Bypass Channel, with the quantity of this inflow controlled by the gate design and operations. The lower river then flows through a mostly natural, meandering channel, for about ten miles before emptying into the Gulf of Mexico. Additional water sources to the Lower Withlacoochee River Study Area include seeps from the surficial aquifer and Floridan Aquifer leakage from fissures in the limestone river channel. In the entire lower river, tidal cycles cause significant changes in water levels and flows, with river flows slowed or even reversed under strong incoming tides, especially during periods of low river inflows.

Location

The Lower Withlacoochee River Study Area is located along the borders of Marion, Citrus, and Levy Counties in West Central Florida. The lower-most portion of the river begins at the spillway on the Inglis Bypass Channel that was designed to provide flow to the lower river after it was disconnected by construction of the west terminus of the Cross-Florida Barge Canal at a lock to Lake Rousseau. The Cross-Florida Barge Canal was constructed beginning in 1964 and was terminated in 1971. Within the Lower Withlacoochee River Study Area, the Cross-Florida Barge Canal created an artificial connection between the Gulf of Mexico and Lake Rousseau, south of the natural outlet of the Lower Withlacoochee River. This connection to Lake Rousseau split and cut off the historic channel of the Withlacoochee River about two miles downstream of the historic connection to Lake Rousseau at the southwest terminus of the lake, Figure 2.

Climate

Regional rainfall was evaluated using a data set prepared by the SWFWMD[1] for Citrus, Hernando, Lake, Levy, Marion, Pasco, Polk, and Sumter counties. This data set provides annual rainfall totals for the period-of-record from 1915 through 2020 as shown in Figure 3. These data show an average precipitation of 53 inches per year over the 106-year period-of-record. The LOESS (locally-weighted scatterplot smoothing) procedure was used to better understand the long-term trends in rainfall. Area precipitation generally increased for the first half of the record from an average of about 50 inches per year in the early 1900s to a maximum average of about 56 inches per year in the 1970s, to about 50 inches per year in the late 1990s, to an average of about 55 inches per year over the past decade. Low and high annual rainfall totals in the area range from 33 to 73 inches per year for the period of record.

The average daily temperature for this area is approximately 72°F, with average summer temperatures in the lower 80s °F and average winter temperatures in the upper 50s °F (Southwest Florida Water Management District, 2010). Estimated annual average evapotranspiration in this portion of the SWFWMD is 38.5 inches per year (Knowles, Jr., 1996)

[1] https://www.swfwmd.state.fl.us/resources/data-maps/rainfall-summary-data-region

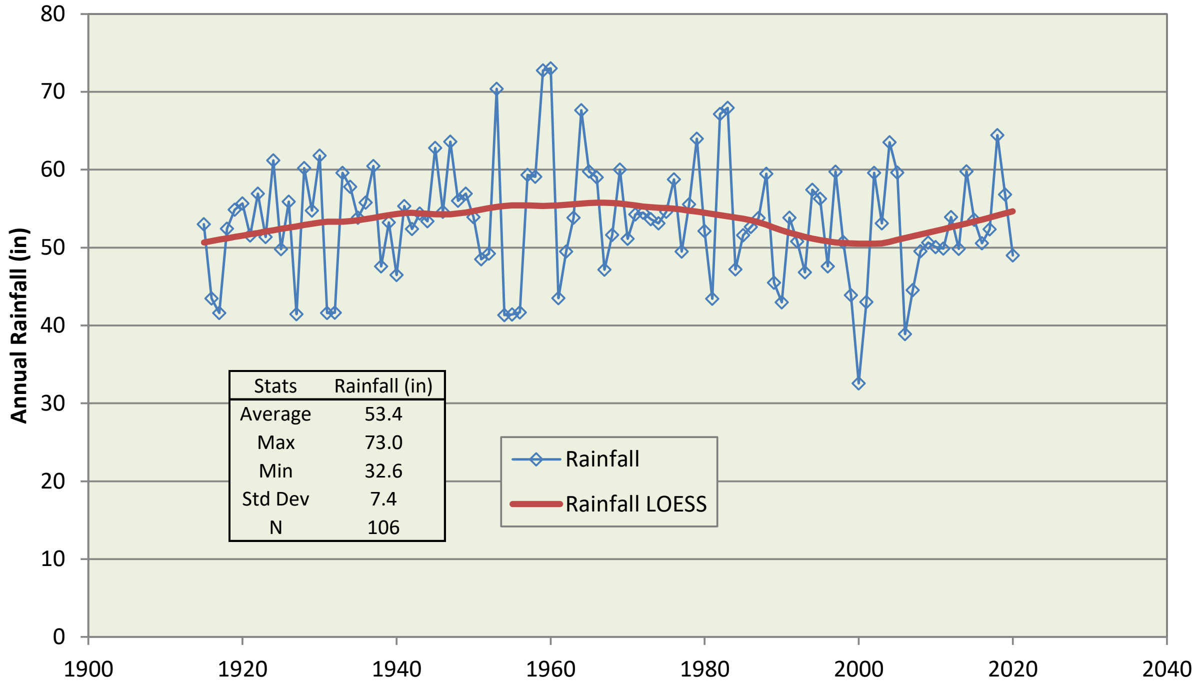


Figure 3. Annual Rainfall Summary for Withlacoochee Watershed Counties (Citrus, Hernando, Lake, Levy, Marion, Pasco, Polk, and Sumter) with LOESS Curve (data provided by SWFWMD)

Physiography

Topography

The Lower Withlacoochee River lies within the Coastal Lowlands Physiographic Region (Figure 4). Elevations within the surface watershed for the Lower Withlacoochee River Study Area range from 0 to 243 ft above mean sea level (U.S. Geological Survey, 2018).

River Bathymetry

Lake Rousseau is a man-made impoundment on the Withlacoochee River created through construction of the Inglis Dam. Figure 5 provides a bathymetric map of the impoundment (University of Florida, 2007). The historic river channel is evident on this map with measured depths up to 22 feet. The area of Lake Rousseau is approximately 2,900 acres with an estimated volume of 22,340 ac-ft. The mean water depth in Lake Rousseau is about 7.8 ft (2.4 m) with the deepest areas located in the original Withlacoochee River channel (Figure 5).

Within the Lower Withlacoochee River Study Area, the natural river channel averages approximately 150 ft (45.7 m) wide with a range of depths from about 2.0 to 46.8 ft (0.6 to 14.3 m). Figure 6 provides approximate bottom elevations along the Lower Withlacoochee River below the Inglis Bypass Channel. In general, shallower depths occur in the portion of the river immediately below the Inglis Bypass Channel with deeper depths further downstream in the river. At normal water level, the length of this river segment is 6.5 miles with an estimated volume of 1,540 ac-ft, and a mean depth of 13.0 ft (4.0 m). Water elevations in the cut-off portion of the historic river channel below the Inglis Dam are approximately 26 ft (7.9 m) lower than elevations in Lake Rousseau and fluctuate over an 11 ft range (-1.90 to 9.25 ft NGVD29) with an average of 1.3 ft NGVD29 (Wetland Solutions, Inc., 2013b).

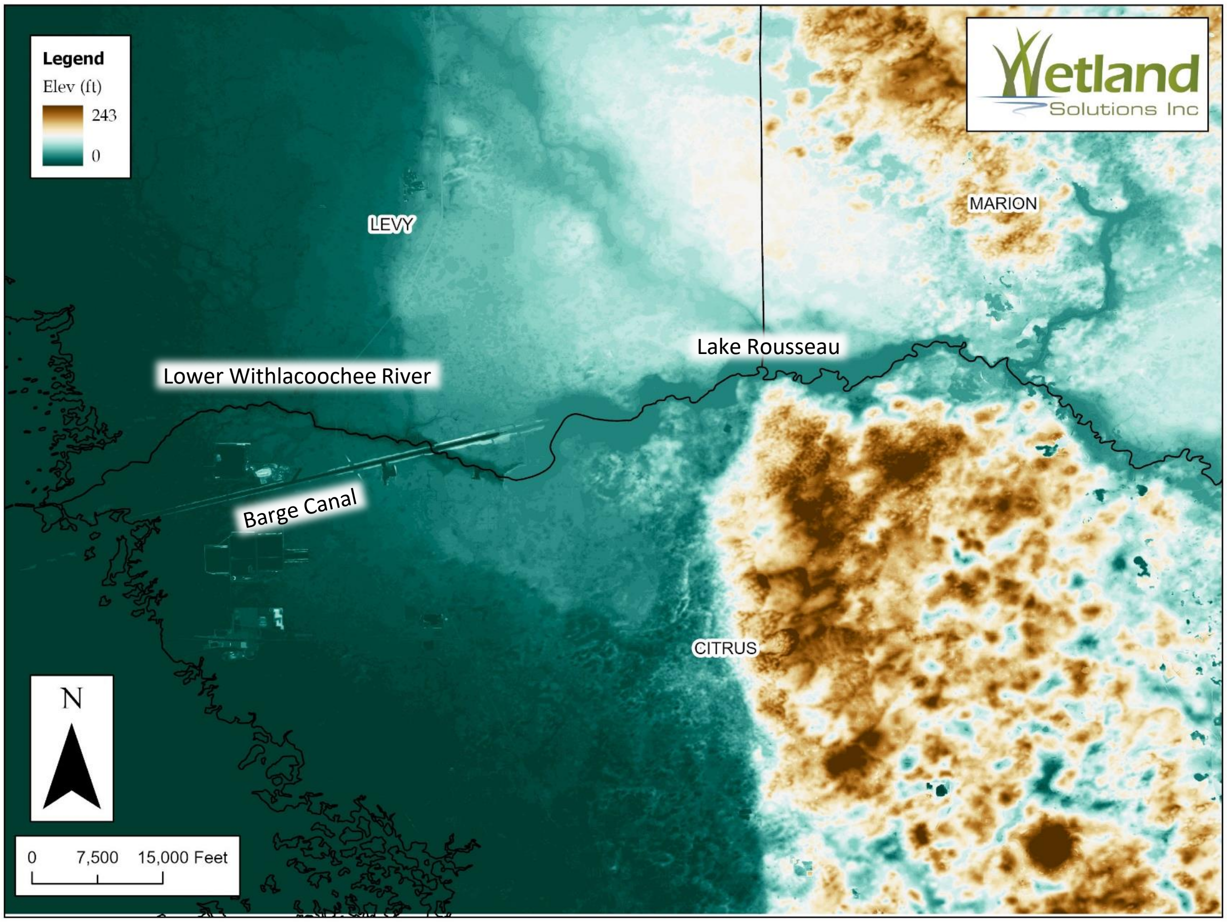
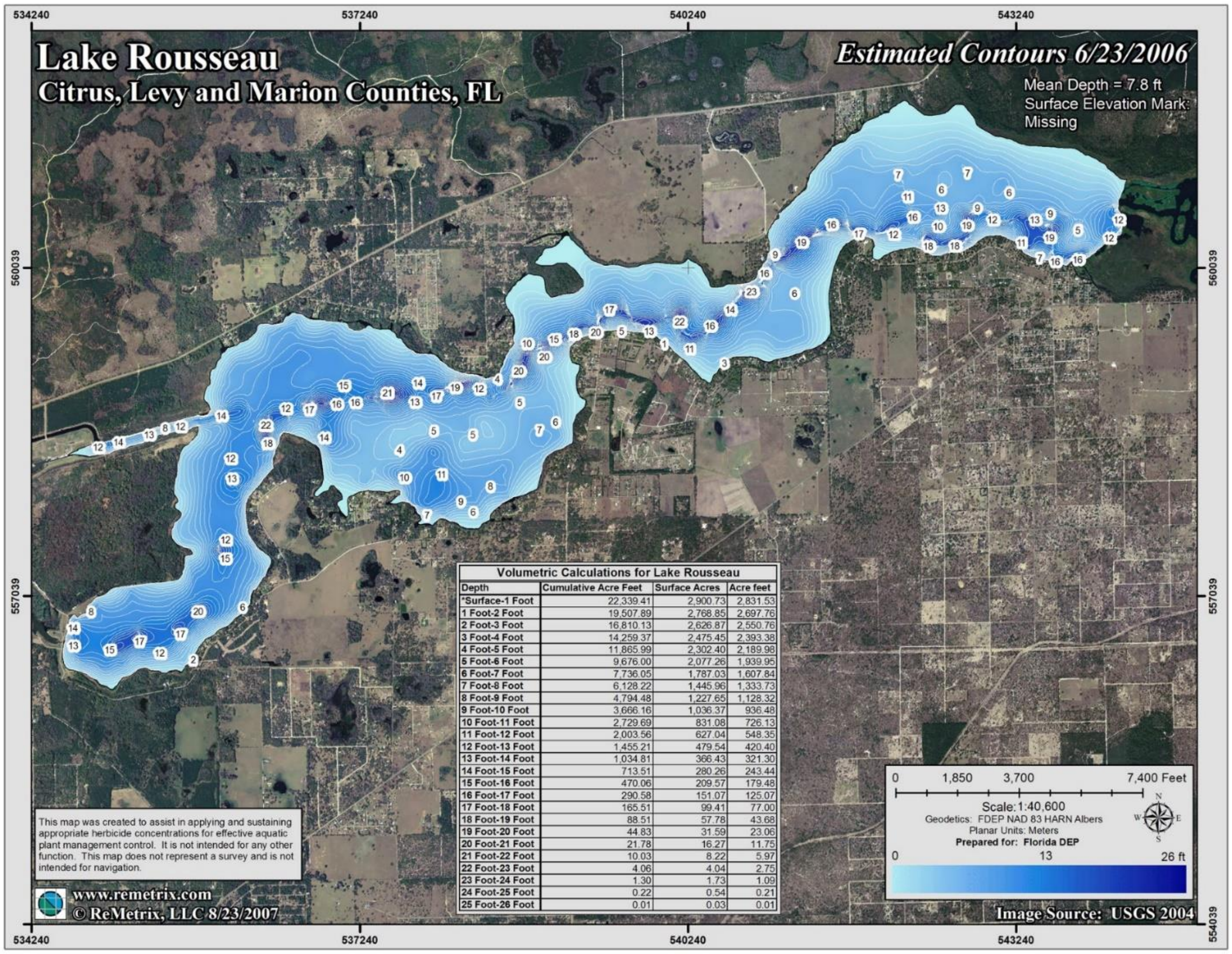


Figure 4. Elevations within the Lower Withlacoochee River Study Area



Volumetric Calculations for Lake Rousseau

Depth	Cumulative Acre Feet	Surface Acres	Acre feet
*Surface-1 Foot	22,339.41	2,900.73	2,831.53
1 Foot-2 Foot	19,507.89	2,768.85	2,697.76
2 Foot-3 Foot	16,810.13	2,626.87	2,550.76
3 Foot-4 Foot	14,259.37	2,475.45	2,393.38
4 Foot-5 Foot	11,865.99	2,302.40	2,189.98
5 Foot-6 Foot	9,676.00	2,077.26	1,939.95
6 Foot-7 Foot	7,736.05	1,787.03	1,607.84
7 Foot-8 Foot	6,128.22	1,445.96	1,333.73
8 Foot-9 Foot	4,794.48	1,227.65	1,128.32
9 Foot-10 Foot	3,666.16	1,036.37	936.48
10 Foot-11 Foot	2,729.69	831.08	726.13
11 Foot-12 Foot	2,003.56	627.04	548.35
12 Foot-13 Foot	1,455.21	479.54	420.40
13 Foot-14 Foot	1,034.81	366.43	321.30
14 Foot-15 Foot	713.51	280.26	243.44
15 Foot-16 Foot	470.06	209.57	179.48
16 Foot-17 Foot	290.58	151.07	125.07
17 Foot-18 Foot	165.51	99.41	77.00
18 Foot-19 Foot	88.51	57.78	43.68
19 Foot-20 Foot	44.83	31.59	23.06
20 Foot-21 Foot	21.78	16.27	11.75
21 Foot-22 Foot	10.03	8.22	5.97
22 Foot-23 Foot	4.06	4.04	2.75
23 Foot-24 Foot	1.30	1.73	1.09
24 Foot-25 Foot	0.22	0.54	0.21
25 Foot-26 Foot	0.01	0.03	0.01

Figure 5. Lake Rousseau Bathymetric Map

The Withlacoochee River enters the lake on the east and exits to the west into the Lower Withlacoochee River channel and the Cross Florida Barge Canal

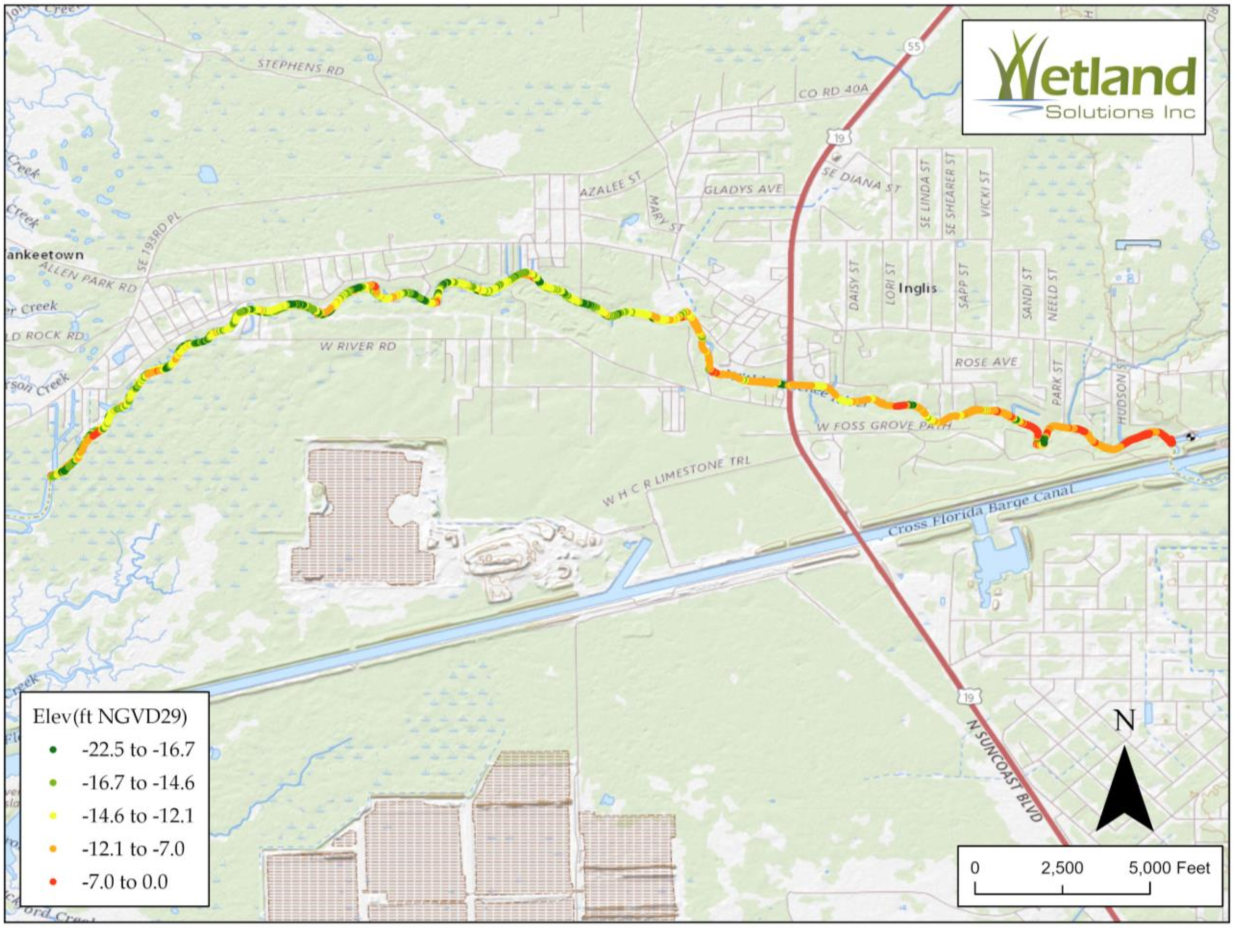


Figure 6. Lower Withlacoochee River Bottom Elevations Based on Sonar Depths Collected on November 12, 2015

Land Use

Land use within the Lower Withlacoochee River Study Area surface watershed was evaluated based on the most recent published data from 2017 (Southwest Florida Water Management District, 2019). Land use mapping is based on the Florida Land Use, Cover and Form Classification System (FLUCCS) as a standard across the state. Within this classification system there are four levels of land use specificity with increasing detail at each level. Figure 7 provides a simplified summary of dominant land uses in the Lower Withlacoochee River watershed. The area of each of the defined FLUCCS land use classes is shown in Table 1. This breakdown of land uses shows that the surface watershed is dominated by water and wetlands (10,585 acres), upland forests (10,439 acres), urban and built-up (5,045 acres), agricultural and rangeland (1,986 acres), and other human-altered land uses (322 acres). This surface watershed has a combined developed area of about 25%.

Existing land uses in the 737 square mile Rainbow River springshed that contributes flows to the Lower Withlacoochee River in 2004 were estimated to include about 60% urban and agricultural development (Wetland Solutions, Inc., 2013a).

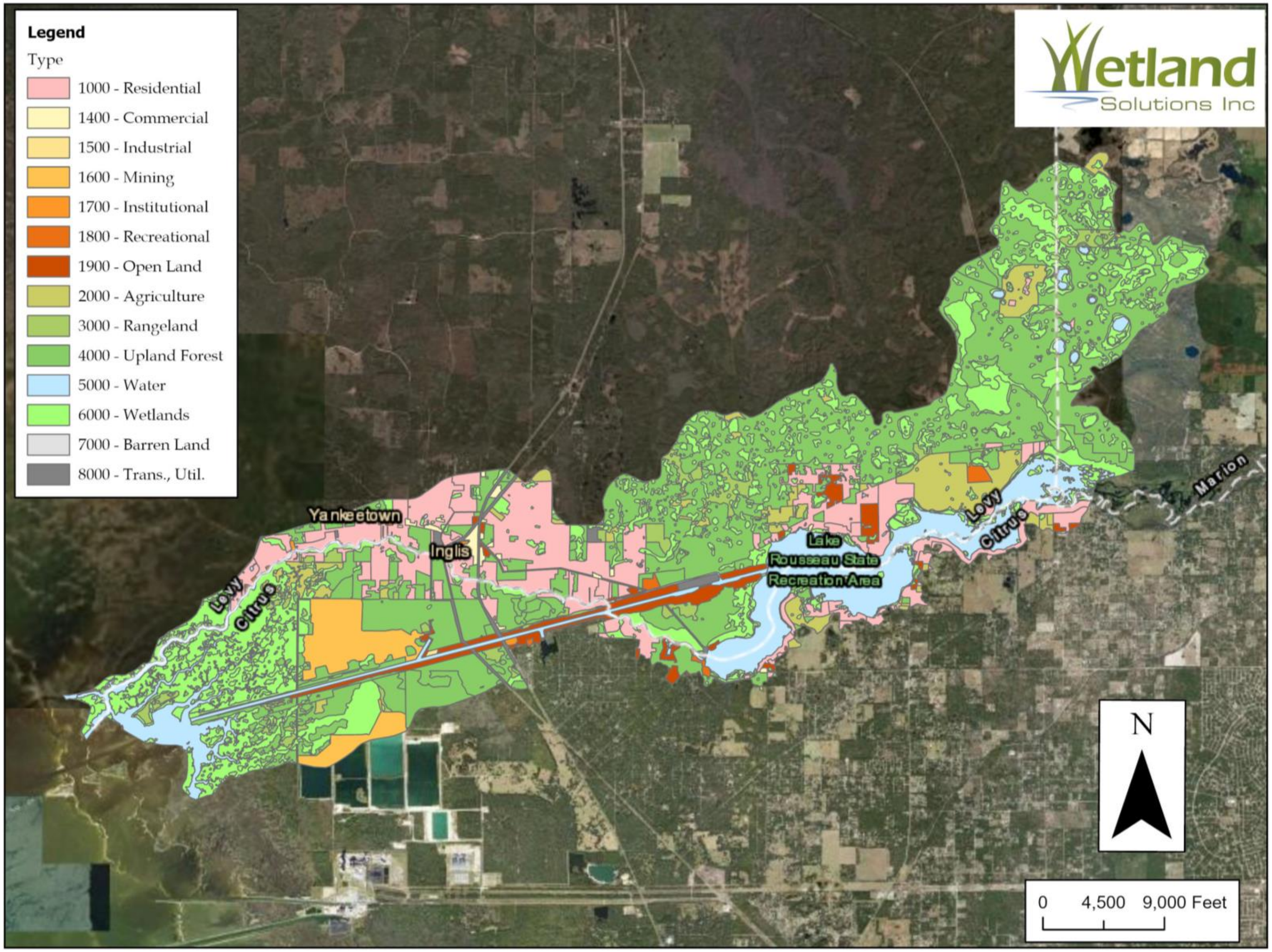


Figure 7. Land Use within the Lower Withlacoochee River Study Area Watershed (2017)

Table 1. Land Use Areas for the Lower Withlacoochee River Study Area Watershed (2017)

Type	Detailed FLUCCS Description		Area (ac)
1000 - Residential	1100	Residential Low Density < 2 Dwelling Units per Acre	2,685
	1200	Residential Med Density 2 To 5 Dwelling Units per Acre	1,119
	1300	Residential High Density	38.5
1400 - Commercial	1400	Commercial and Services	132
1500 - Industrial	1500	Industrial	6.8
1600 - Mining	1600	Extractive	927
1700 - Institutional	1700	Institutional	37.7
1800 - Recreational	1800	Recreational	98.7
1900 - Open Land	1900	Open Land	820
2000 - Agriculture	2100	Cropland and Pastureland	1,001
	2500	Specialty Farms	35.2
	2600	Other Open Lands	315
3000 - Rangeland	3200	Shrub and Brushland	567
	3300	Mixed Rangeland	67.9
4000 - Upland Forest	4100	Upland Coniferous Forest	609
	4110	Pine Flatwoods	352
	4120	Longleaf Pine - Xeric Oak	882
	4340	Upland Hardwood - Coniferous Mix	2,053
	4400	Tree Plantation	6,543
5000 - Water	5100	Streams and Waterways	436
	5200	Lakes	109
	5300	Reservoirs	2,318
	5400	Bays and Estuaries	776
	5720	Gulf of Mexico	7.6
6000 - Wetlands	6150	Stream and Lake Swamps (Bottomland)	327
	6200	Wetland Coniferous Forests	115
	6210	Cypress	1,528
	6300	Wetland Forested Mixed	2,000
	6400	Vegetated Non-Forested Wetlands	86.1
	6410	Freshwater Marshes	1,319
	6420	Saltwater Marshes	1,391
	6430	Wet Prairies	48.3
	6440	Emergent Aquatic Vegetation	118
	6530	Intermittent Ponds	6.1
7000 - Barren Land	7400	Disturbed	1.8
8000 - Trans., Util.	8100	Transportation	106
	8300	Utilities	214

Septic Systems

Figure 8 provides a map of known and suspected on-site treatment and disposal systems (septic systems) in the historic groundwater basin (Ursin, 2016). This inventory, provided by the Florida Department of Health, was completed in 2016 and is known to include data gaps. The majority of the residential and commercial properties not identified on this map, located south of the lower river and in the towns of Inglis and Yankeetown proper, are also reliant on septic systems. Based on Florida Department of Health records there are about 2,200 single-family septic systems in the Lower Withlacoochee River Study Area.

To support the Rainbow Springs BMAP effort FDEP (Eller & Katz, 2015) estimated that there are about 21,772 septic systems in the Rainbow Springs priority focus area (smaller than the springshed).

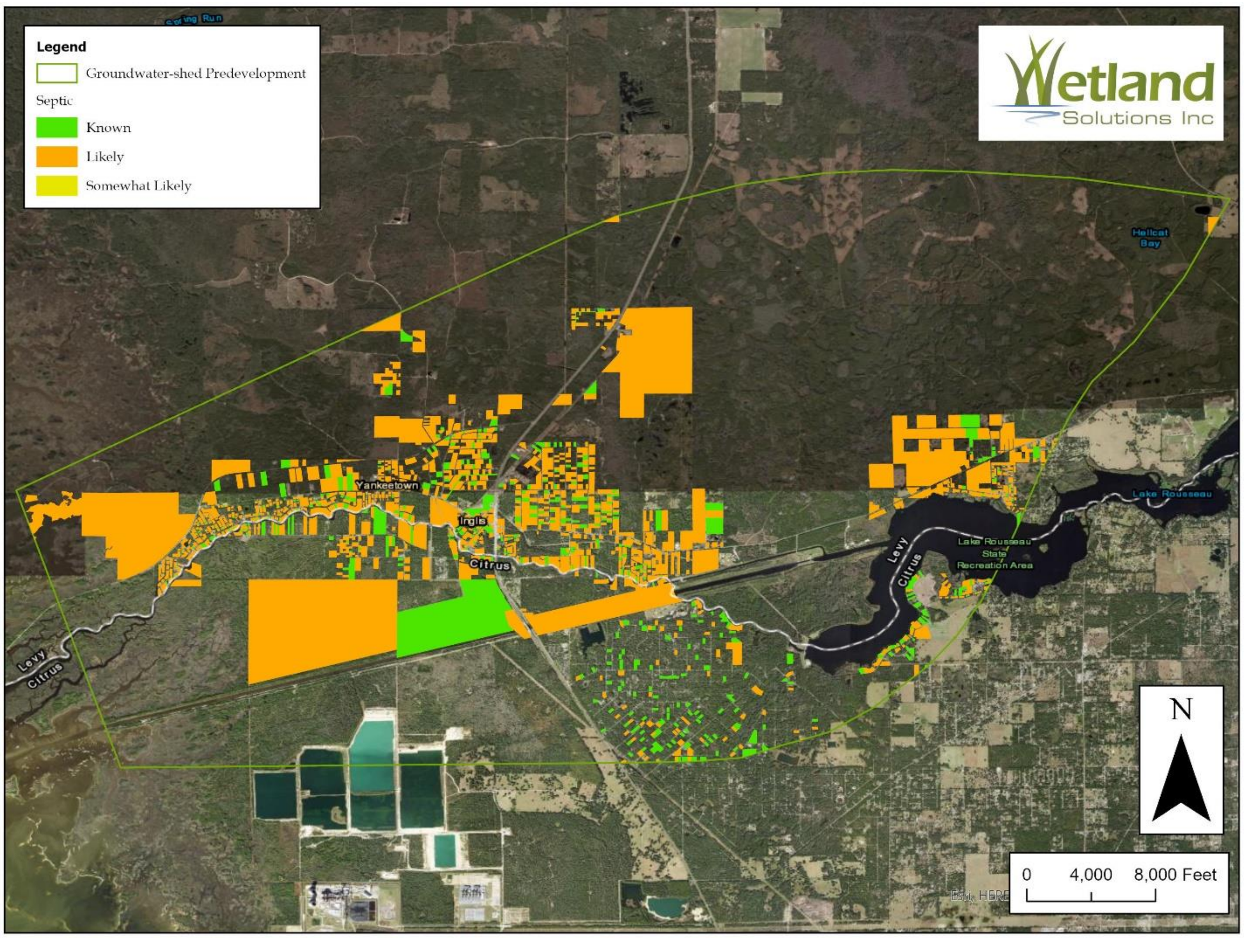


Figure 8. Onsite Sewage Treatment and Disposal Systems within the Lower Withlacoochee River Study Area (2016)

Surface Hydrology

Surface Watersheds

The entire Withlacoochee River watershed (8-digit HUC, 03100208) includes 1,332,593 acres, or 2,082 square miles. The Lower Withlacoochee River watershed evaluated for this project was the USGS 12-digit hydrologic unit code (HUC) 031002081103, including Lake Rousseau. This watershed is approximately 29,195 acres, or 46 square miles (Figure 9). This area is only a small portion of the larger Withlacoochee River watershed and encompasses only 2.2% of the overall Withlacoochee River surface watershed area. Based on the karst geology of this area, the Lower Withlacoochee Watershed contributes minimally via surface waterbodies because of the relatively high infiltration rates. This is evidenced by the small number of contributing streams and the ephemeral flow classification for a portion of these streams.

The locations of USGS stage and discharge stations within and upstream of the Lower Withlacoochee River Study Area are illustrated in Figure 10.

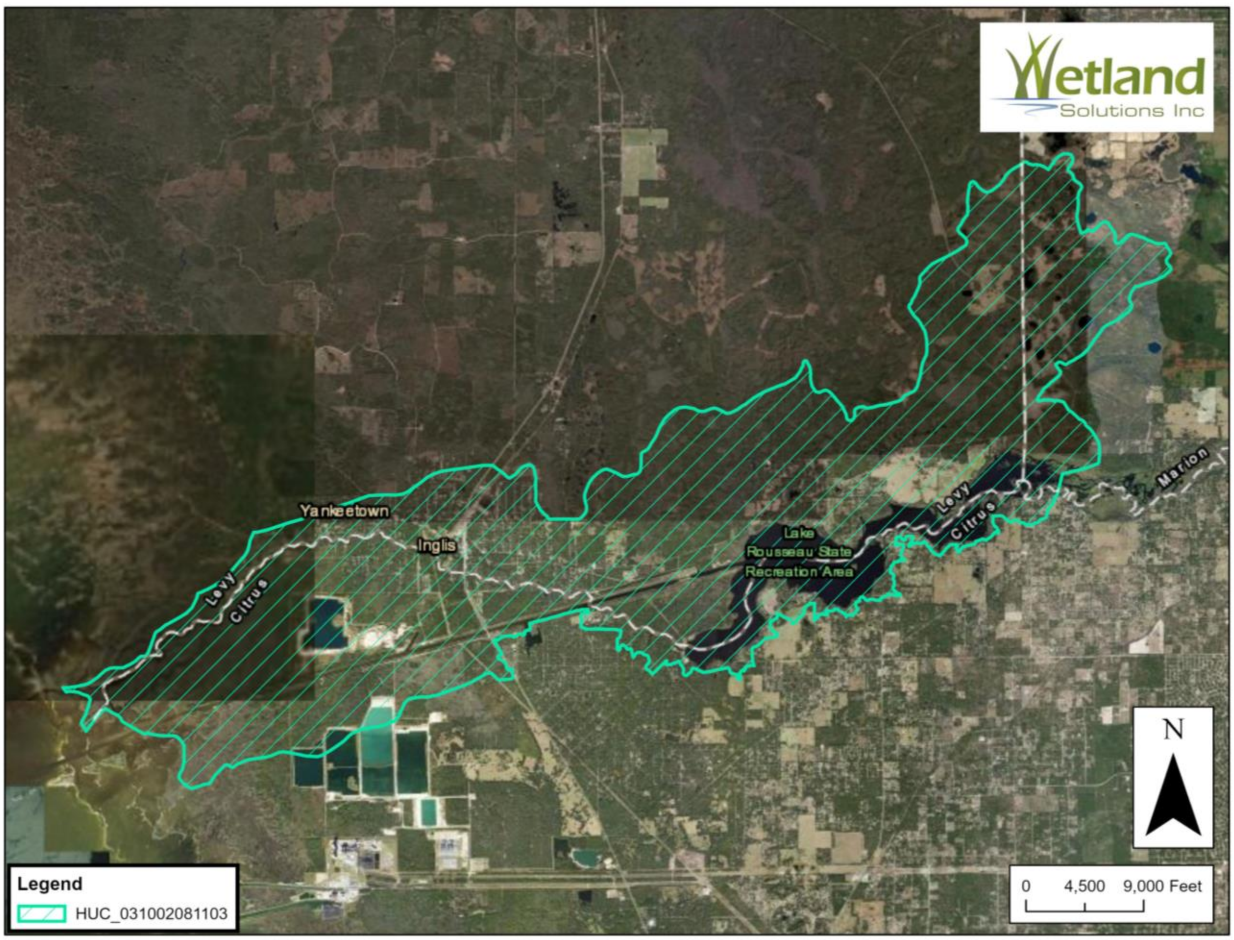


Figure 9. Lower Withlacoochee River Sub-Watershed

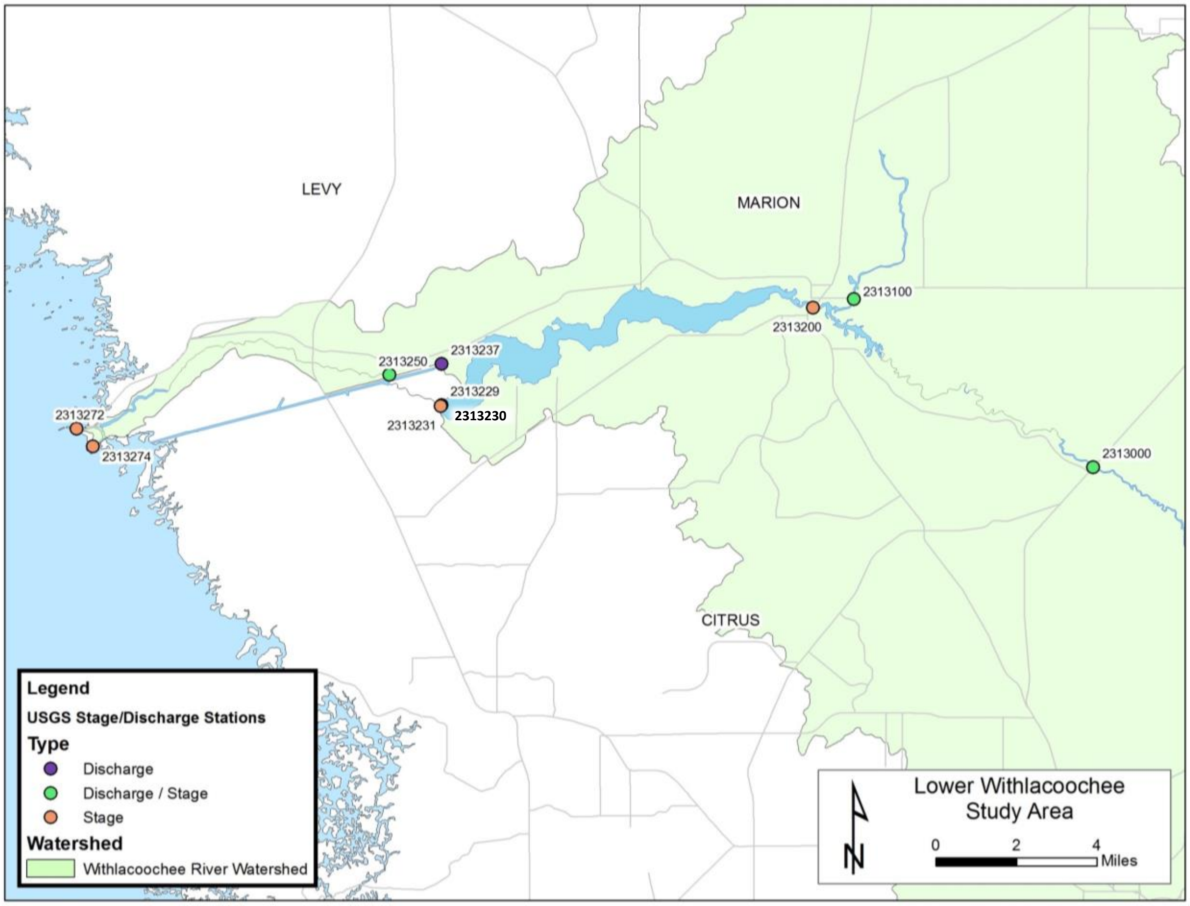


Figure 10. USGS Stage/Discharge Stations within the Lower Withlacoochee River

Upper Withlacoochee River

The Green Swamp, located in northern Polk County, forms the headwaters of the 157-mile-long Withlacoochee River. From Polk County, the river generally flows northwest and then west, ultimately discharging into the Withlacoochee Bay Estuary in the Gulf of Mexico near Yankeetown. The entire river and its connected lakes and tributaries have been designated as Outstanding Florida Waters (Florida Department of Environmental Protection, 2006).

Figure 11 provides a summary of 92 years of published discharge data at the State Road (SR) 200 station (USGS 2313000). The long-term average annual flow at this station through 2020 was 934 cfs with a range of annual averages from 110 to 3,561 cfs. Daily flow at this station varied widely during wet and dry seasons with a long-term average daily flow of 945 cfs with a reported range of daily flows from 33 to 8,660 cfs. Annual average flow in the Upper Withlacoochee River at the SR200 gage was 675 cfs post-2000, approximately 36% lower (374 cfs) than the pre-2000 average flow of 1,049 cfs.

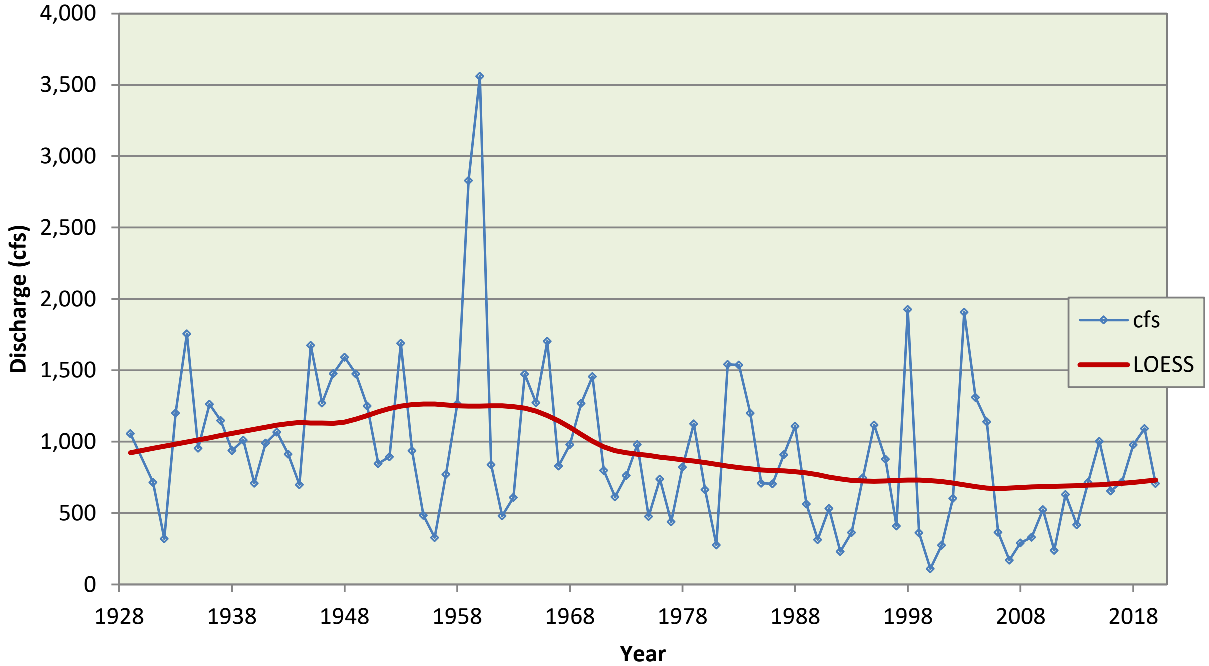


Figure 11. Annual Average Withlacoochee River Discharge at State Road 200 (USGS 0231300)

Rainbow Springs and River

The Rainbow River is entirely spring fed and, based on average annual flow, is the largest tributary to the Withlacoochee River. The long-term average flow in the Rainbow River through 2020 was 697 cfs with a range of recorded annual flow rates between 502 and 911 cfs (Figure 12). Average annual flow in the Rainbow River was 609 cfs post-2000, approximately 16% lower (114 cfs) than the pre-2000 average flow of 723 cfs.

Based on discharge data, lower flows are evident at both of the upstream stations (Rainbow River and Withlacoochee River at SR200) during the past two decades. The difference in the combined average historic flow in the Withlacoochee River feeding Lake Rousseau and the lower river was 406 cfs (24%) over the past two decades.

Lake Rousseau

Lake Rousseau is a man-made reservoir that was originally created by construction of the Inglis Dam between 1905 and 1909 to provide navigation for the commercial development (timber, phosphate, and citrus) of the Withlacoochee River. The dam also provided hydroelectric power generation by the Florida Power Corporation. Lake Rousseau is approximately 5.7-miles (9.2 km) long and has a surface area of about 2,900 ac (1,174 ha). The flow of water over the Inglis Dam produced electric power until 1965 (Florida Department of Environmental Protection, 2006). The Withlacoochee and Rainbow Rivers are the two major tributaries that contribute surface water flows to Lake Rousseau.

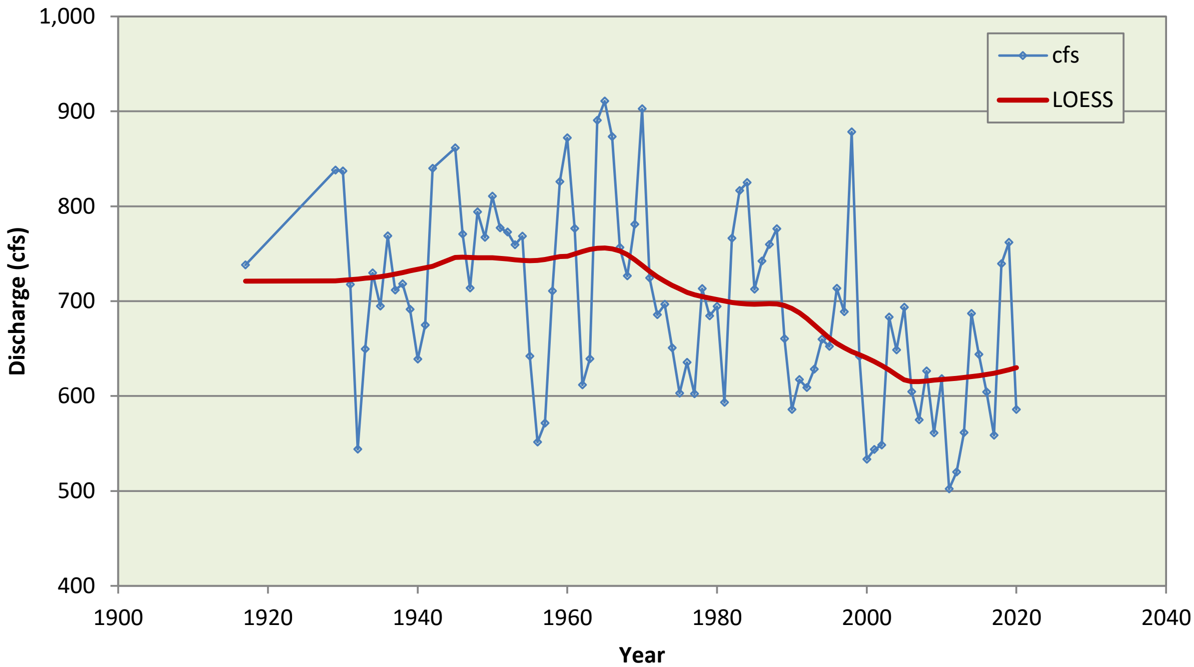


Figure 12. Annual Average Rainbow River Discharge (USGS 02313100)

Discharges from Lake Rousseau to the Lower Withlacoochee River and Barge Canal are measured at three stations: the Inglis Bypass Channel, the Inglis Lock, and the Inglis Dam spillway (Inglis Structural Complex, Figure 13). Figure 14 provides a summary of 51 years of USGS published discharge data at these structures. Combined long-term average flows at these stations through 2020 were 1,397 cfs with a range of annual averages from 599 to 2,923 cfs. Compared to historic annual average pre-2000 flow measurements of about 1,484 cfs, the combined discharges from Lake Rousseau over the past two decades have declined by 213 cfs (14%). Approximately 27% of this combined outflow from Lake Rousseau was discharged at the Inglis Dam and down the historic channel of the Lower Withlacoochee River to the Cross Florida Barge Canal to the Gulf.

The average annual discharge from the Bypass Channel (USGS 2313250) for the period from 1970 to 2020 was 1,020 cfs with a maximum recorded annual average flow of 1,405 cfs and a minimum of 483 cfs. The average annual discharge through the Inglis Lock (USGS 2313237) for the period from 1970 to 1992 was 11.9 cfs with a maximum recorded annual average flow of 20.2 cfs and a minimum of 5.2 cfs. The average annual discharge at the Inglis Dam spillway (USGS 2313230) for the period from 1970 to 2020 was 371 cfs with a maximum recorded annual average flow of 1,643 cfs and a minimum of 6.9 cfs. The combined outflow from Lake Rousseau through these three gaged outlets averaged 1,397 cfs during the period-of-record.

Comparison of daily combined flow data upstream of Lake Rousseau and downstream for the overlapping period-of-record from 1970 through 2020 indicates a measured inflow of 1,415 cfs and a measured outflow of 1,396 cfs, for a net loss of about 19 cfs on average.

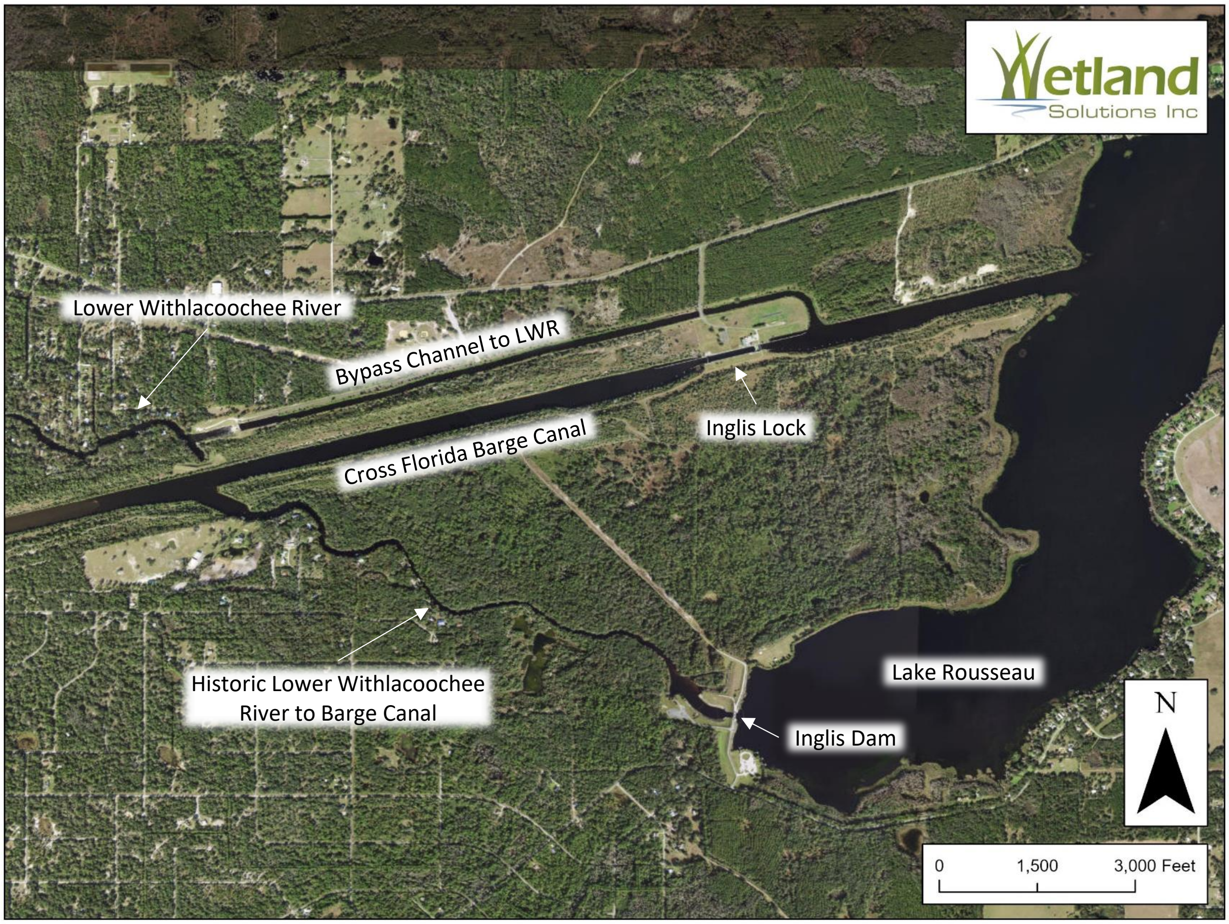


Figure 13. Lake Rousseau Inglis Structural Complex including the Inglis Dam, Bypass Channel, and Inglis Lock

Cross-Florida Barge Canal

The Lower Withlacoochee River, the natural channel west of Lake Rousseau, was significantly altered with the construction of the Cross Florida Barge Canal in the 1960s. The Cross Florida Barge Canal project was de-commissioned in 1990 before it was completed. The Barge Canal bisected the Withlacoochee River approximately two miles (3.2 km) downstream of the Inglis Dam, cutting off this river segment and re-routing all outflows from Lake Rousseau above about 1,450 cfs to the Barge Canal and the Gulf of Mexico (Figure 15).

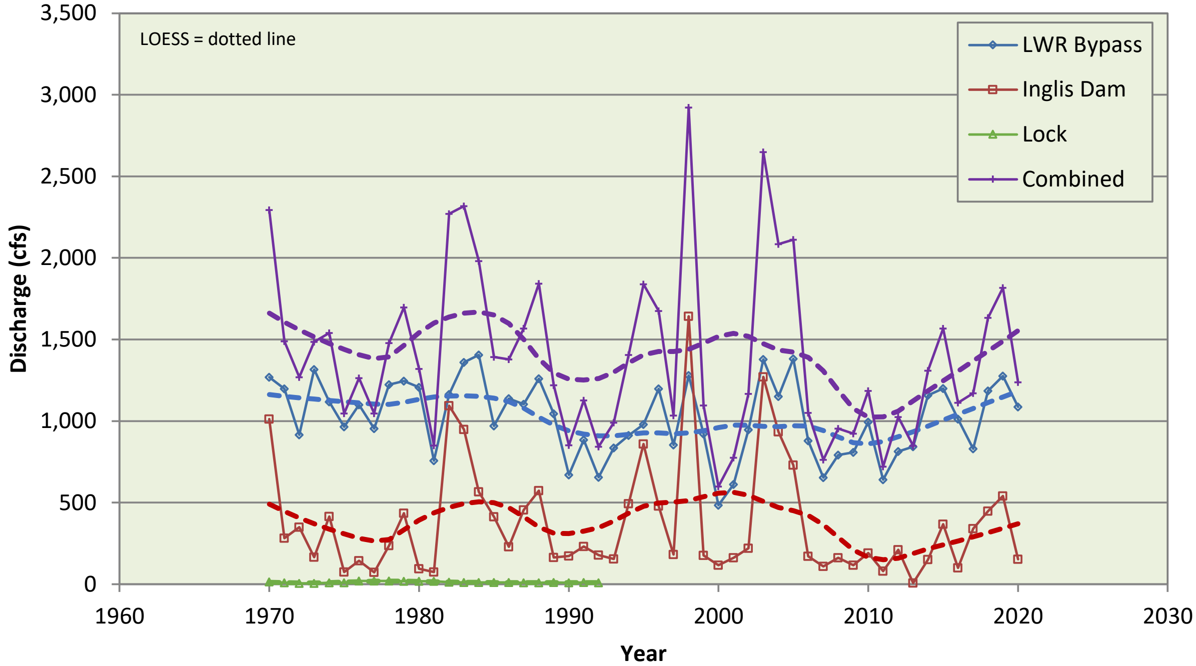


Figure 14. Annual Average Inglis Dam (USGS 02313230), Bypass Channel (USGS 02313250), and Inglis Lock (USGS 02313237) Discharges

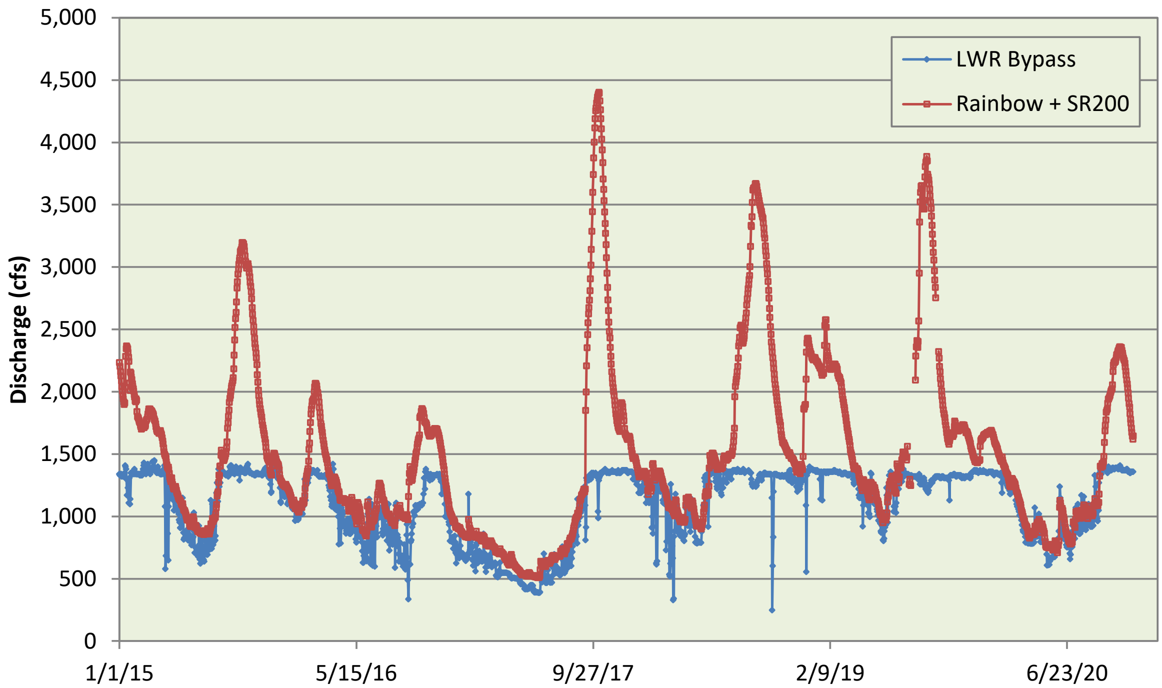


Figure 15. Daily Average Combined Flows (Rainbow River and Withlacoochee River at SR200) and Bypass Channel Discharges to the Lower Withlacoochee River

Lower Withlacoochee River (Below the Inglis Bypass Channel)

The flow regime within the Lower Withlacoochee River study segment is dominated by upstream inflows from Lake Rousseau through the Inglis Bypass Channel, unquantified groundwater inflows, and within the lower sections of the river by tidal fluctuations from the Gulf of Mexico. Along the entire length of the Lower Withlacoochee River tidal fluctuations range several feet under normal conditions.

At the upstream end of the lower river, an under-flow gate directs water from the Inglis Bypass Channel to the lower river. This bypass discharge structure is design-limited to a maximum flow of approximately 1,450 cfs (Figure 15). This makes management of water levels in Lake Rousseau and the lower river complex since lowering the lake level by a small amount can cause significant reductions in the maximum flow to the Lower Withlacoochee River (Florida Department of Environmental Protection, 2006).

Since the construction of the Cross-Florida Barge Canal in the late 1960s, the Lower Withlacoochee River has been deprived of peak flows, in excess of approximately 1,450 cfs. Discharge to the Lower Withlacoochee River from Lake Rousseau can only be routed via the Inglis Bypass Channel. These structural modifications resulted in reduced average and peak flows to the remaining Lower Withlacoochee River segment. Flows of up to about 6,000 cfs have been discharged through the Inglis Dam (USGS 2313230) to the Cross-Florida Barge Canal which diverts available high flows directly to tide and away from the remaining section of the Lower Withlacoochee River.

Annual average flow data measured in the Bypass Channel are illustrated in Figure 14. During the 50-year period-of-operation, the dam spillway was operated across a wide range of levels. This is illustrated by initially higher flows diverted through the Bypass Channel to the Lower Withlacoochee River in the 1970s and early 1980s averaging about 1,150 cfs, followed by much lower flows averaging about 950 cfs until 2010, when average flows were gradually increased to the current average of about 1,200 cfs. This additional water for the Lower Withlacoochee River came as a result of reduced discharges to the Cross Florida Barge Canal during the 50-year period of declining inflows to Lake Rousseau. In 1970, roughly 65% of the Lake Rousseau discharge was released through the Bypass Channel to the Lower Withlacoochee River. By 2020, while the average flow to the Lower Withlacoochee River had only increased slightly (4%) to about 1,199 cfs, the fraction of the total Lake Rousseau discharge through the Bypass Channel had been increased from 65% to about 73%.

Hydrogeology

Groundwater Basin

Groundwater basins can be delineated based on potentiometric levels (water levels measured in wells) in the Floridan Aquifer. In a spatial context, these potentiometric levels produce a map of higher and lower water levels within the aquifer. Since water flows from higher pressure to lower pressure (i.e., downhill); springshed basins can be delineated by approximating where a drop of water at a given point would move. All areas that would contribute water to the same lower area are then included in a given groundwater basin.

Figure 16 illustrates the estimated predevelopment groundwater basin based on mapped potentiometric levels prior to any pumping impacts for the Lower Withlacoochee River Study

Area. The delineated area is about 37,100 acres and extends from the Levy/Marion County line on the northeast to the Gulf of Mexico on the southwest.

A portion of the rain that falls on these highly permeable karst areas recharges the underlying Floridan Aquifer. In topographically lower areas, groundwater discharges to the land surface through springs. Estimated average annual groundwater discharge/recharge rates have been mapped by hydrogeologists (Aucott 1988) in Florida and are shown on Figure 16. Multiplying the estimated discharge/recharge rates (in/yr) by the land area within the groundwater basin, results in an overall estimated average annual recharge of 6.8 cfs (4.4 MGD), a discharge of 9.6 cfs (6.2 MGD), for a net discharge of 2.8 cfs (1.8 MGD) from the groundwater basin.

Figure 17 shows the extent of the current groundwater basin based on potentiometric surface maps from 2015. The area delineated in this figure is 26,000 acres, approximately 11,100 acres smaller than the pre-development groundwater basin. Based on this smaller groundwater basin the estimated annual recharge is 2.6 cfs (1.7 MGD), the discharge is 7.6 cfs (4.9 MGD), and the net discharge is about 5.0 cfs (3.2 MGD) or 76% more than estimated for predevelopment conditions.

Since there are no named springs within the discharge zone of the Lower Withlacoochee River springshed, it can be assumed that these flows contribute a portion of the downstream flows in the river segment, in the Cross-Florida Barge Canal, and potentially in springs/seeps in the Gulf of Mexico. Bush (1973) and Faulkner (1972) estimated that some diffuse groundwater inflows (about 7 cfs) formerly entering the lower river are intercepted by the Barge Canal.

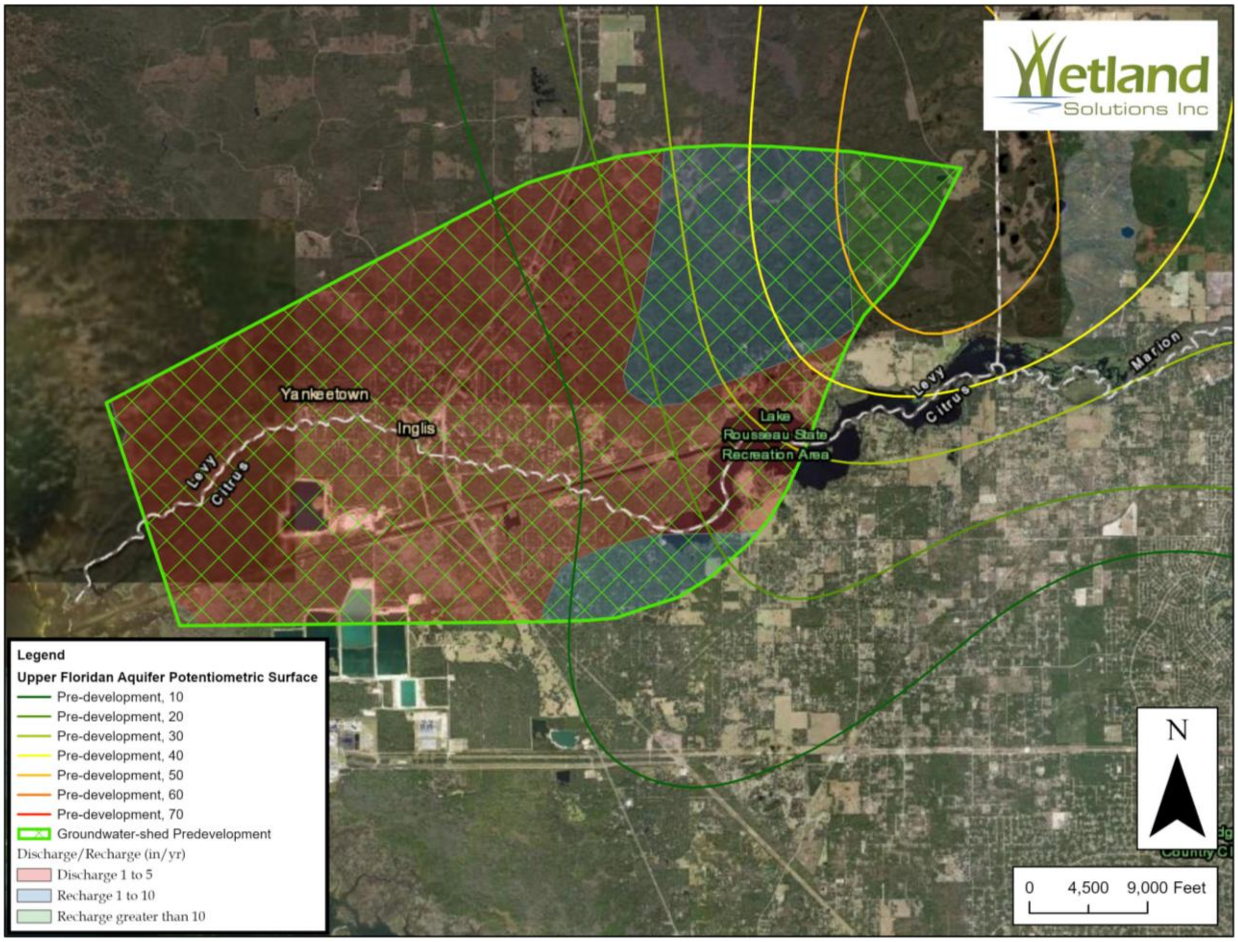


Figure 16. Pre-Development Groundwater Basin in the Vicinity of the Lower Withlacoochee River

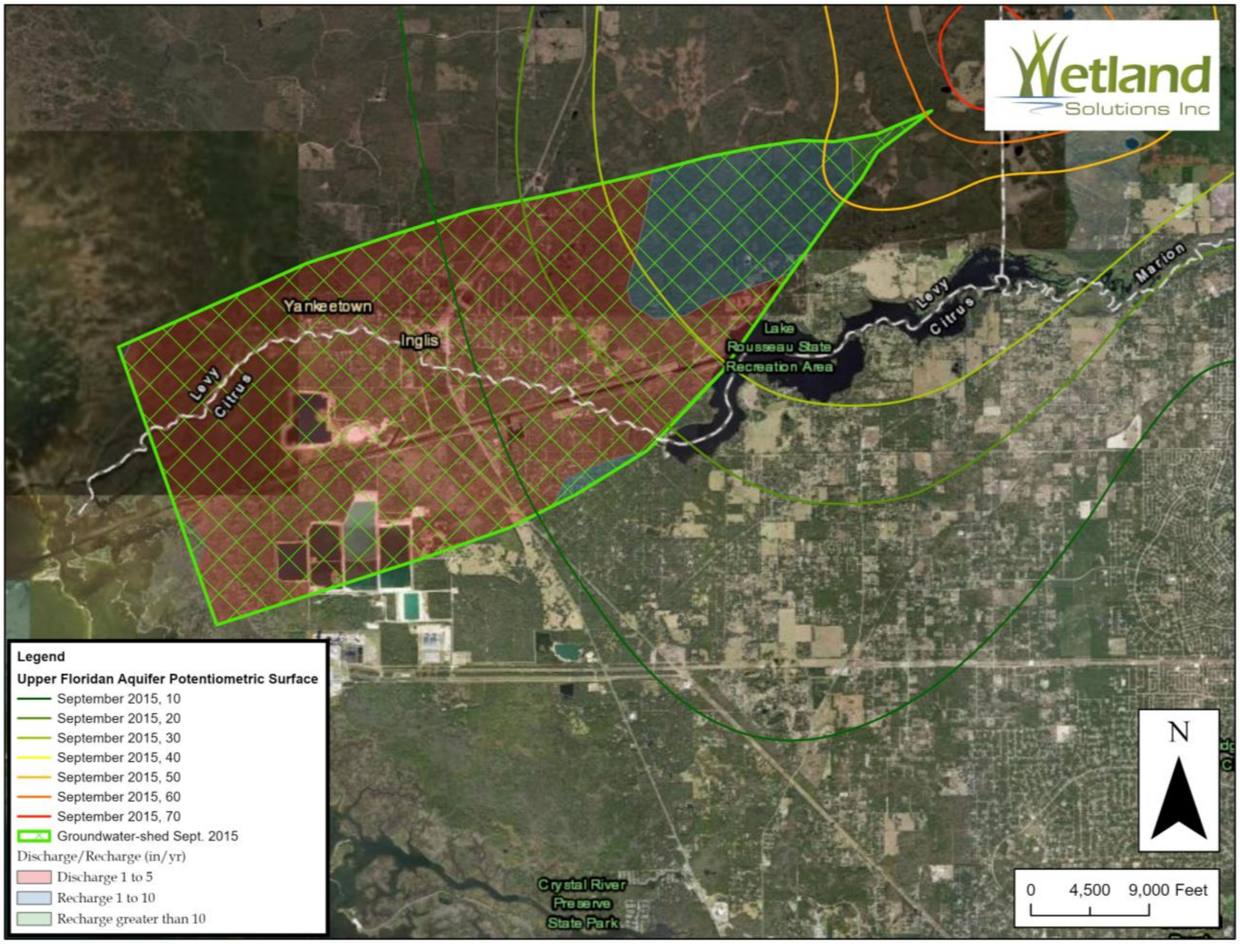


Figure 17. September 2015 Groundwater Basin in the Vicinity of the Lower Withlacoochee River

Cross-Florida Barge Canal Groundwater Flows

An ancillary study to quantify groundwater releases through the Cross-Florida Barge Canal was conducted in November 2020. Flows were measured approximately half-way down the Cross-Florida Barge Canal during a 17-hour intensive monitoring period on November 2, 2020. Flows were measured twice each hour through a full tidal cycle using a Sontek River Surveyor M9 flow meter. On November 6, 2020, Barge Canal flows were measured within the dam spillway and just downstream in the historic natural channel of the Lower Withlacoochee River.

Figure 18 provides a summary of the November 2, 2020, Cross-Florida Barge Canal flow data. Average flows through a full tidal cycle were 695 cfs. During the same interval, the average flow recorded at the Inglis Dam was 437 cfs, for a net gain of 258 cfs.

It was reported by the USGS that there appears to be a "spring" adjacent to the dam, downstream from the control structure[2]. This flow, estimated by the USGS to be approximately 105 cfs, is considered to be due to leakage of surface waters from Lake Rousseau. A newspaper article from the time of the dam construction reported that some portion of this leakage may be due to groundwater discharge from karst features that were intersected as part of the construction of the

[2] https://nwis.waterdata.usgs.gov/nwis/wys_rpt/?site_no=02313230&agency_cd=USGS

dam ("An Immense Undertaking," 1909). Measurements on November 6, 2020, indicated that this leakage was about 167 cfs. Based on difference, these data and the USGS remark indicate an estimated net gain of between 91 and 153 cfs (59-99 MGD) of groundwater inputs to the upper half of the Cross-Florida Barge Canal excluding leakage in the vicinity of the dam. Visual examination of the shoreline of the canal during low tide revealed many groundwater discharge locations (Figure 19).

Specific conductance was measured in the Barge Canal (surface and bottom) continuously during the flow study (Figure 20) and synoptically sampled at five of the groundwater vents. Specific conductance recorded in the Barge Canal ranged from about 3,700 to 33,000 µS/cm with an average of 9,870 µS/cm at the water surface and 21,370 µS/cm near the bottom. Specific conductance measured in the five sampled spring vents ranged from 2,047 to 6,111 µS/cm with an average of 3,599 µS/cm. These results indicate that a substantial fraction of the spring flows measured during the Barge Canal flow study were derived from fresh groundwater leakage.

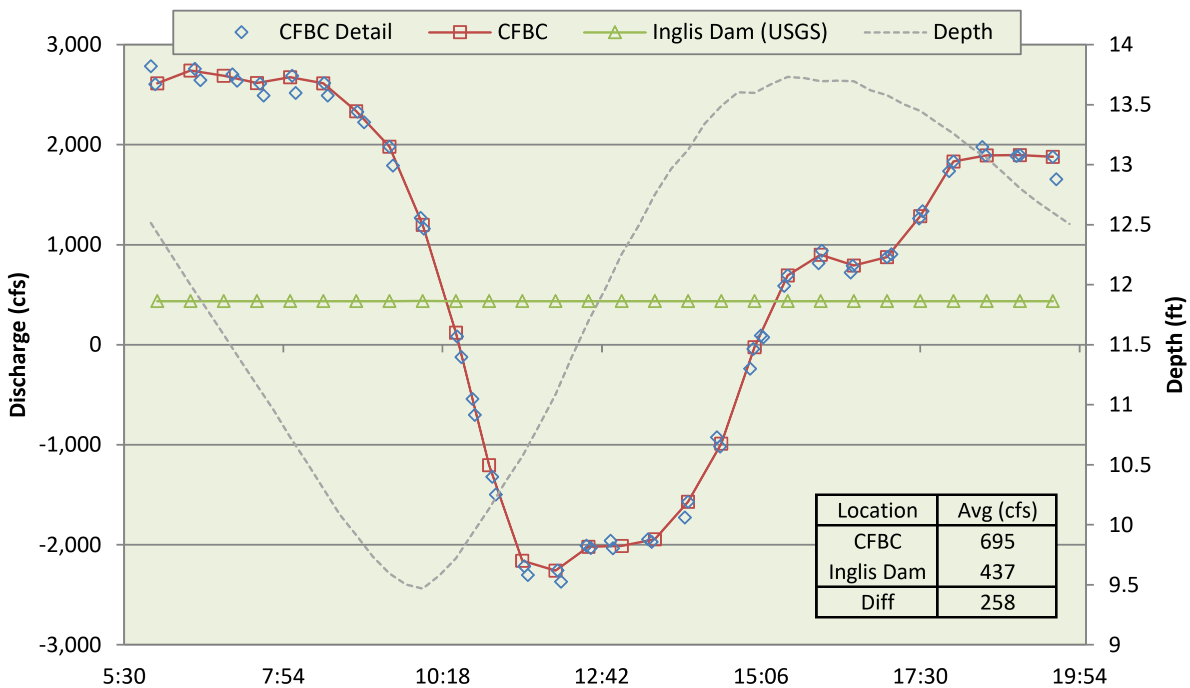


Figure 18. Measured Discharge in the Cross-Florida Barge Canal Through a Full Tidal Cycle on November 2, 2020

Figure 19. Groundwater Discharge Example Along the Cross-Florida Barge Canal

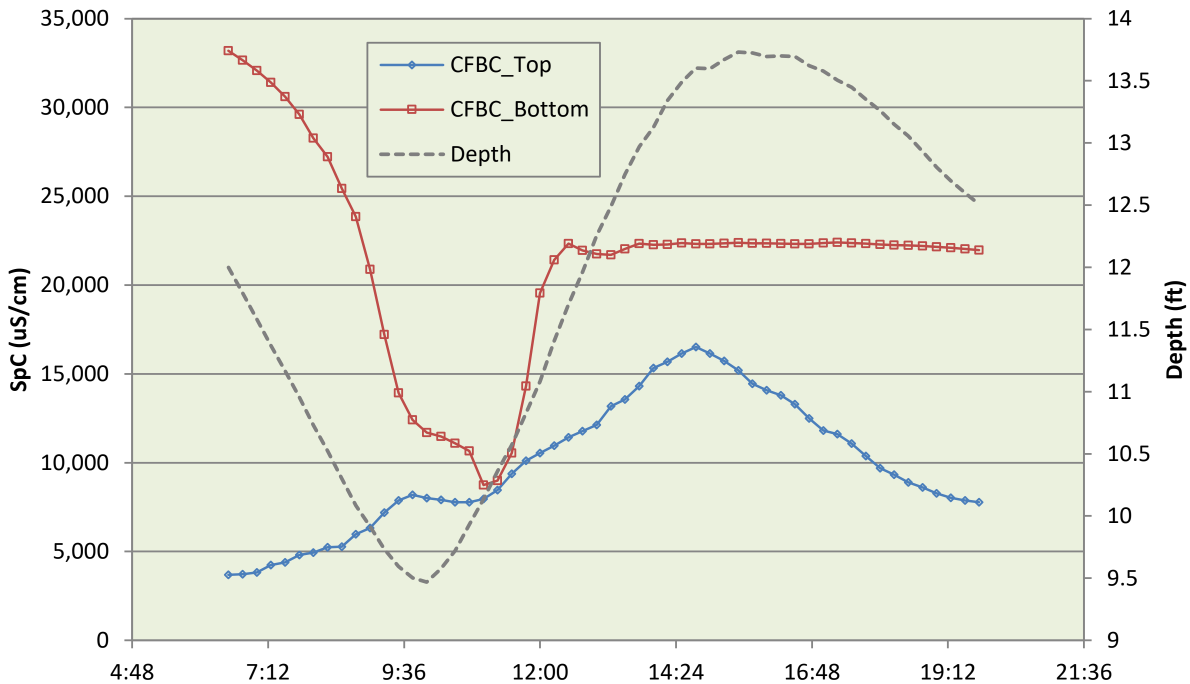


Figure 20. Measured Specific Conductance in the Cross-Florida Barge Canal Through a Full Tidal Cycle on November 2, 2020

Water and Sediment Quality

Water Quality

Historic water quality data were reviewed from a total of 79 reported sampling stations within the Lower Withlacoochee River Study Area. Those data were reported in the Phase 1 report (Wetland Solutions, Inc., 2013b). The historic water quality data were spatially grouped into eleven functional segments and summarized by decade since the 1950s (Figure 21). A brief summary of historic water quality and observed trends in the study area includes:

- Upstream of the confluence with the Rainbow River, the Withlacoochee River is characterized as a blend of surface runoff and spring inflows, with some tannic color (82 pcu), relatively low nutrients (TN = 0.84 mg/L, TP = 0.06 mg/L), and an average specific conductance of 319 µS/cm. Average turbidity and suspended solids were low at 1.8 NTU and 3.1 mg/L, respectively. Observed trends included rising specific conductance and color, presumably due to lower upstream groundwater inflows from springs and increased urbanization stormwater contributions.
- Rainbow Springs has experienced a significant increase in nitrate concentrations over the past four decades (Southwest Florida Water Management District, 2008). Nitrate concentrations reported from the main spring pool during March 1927 were 0.08 mg/L (Ferguson et al., 1947). Recent nitrate concentrations at Rainbow Springs were consistently above 2.2 mg/L, a more than 25-fold increase.

- Withlacoochee River water quality below the confluence with the Rainbow River reflects the blending of these two sources. During periods with low water levels in the Withlacoochee River, water quality conditions downstream of the confluence are similar to conditions in the Rainbow River. In comparison to the upstream river segment stations, a decrease was observed in color (60 pcu), turbidity (0.9 NTU), suspended solids (1.6 mg/L), and specific conductance (293 µS/cm) over the period-of-record. During the past decade, the average total phosphorus concentration remained the same (TP = 0.06 mg/L) but total nitrogen increased to 1.2 mg/L, due to the observed increase in nitrate-nitrogen from 0.22 to 0.96 mg/L, largely driven by the observed increases in the Rainbow River.

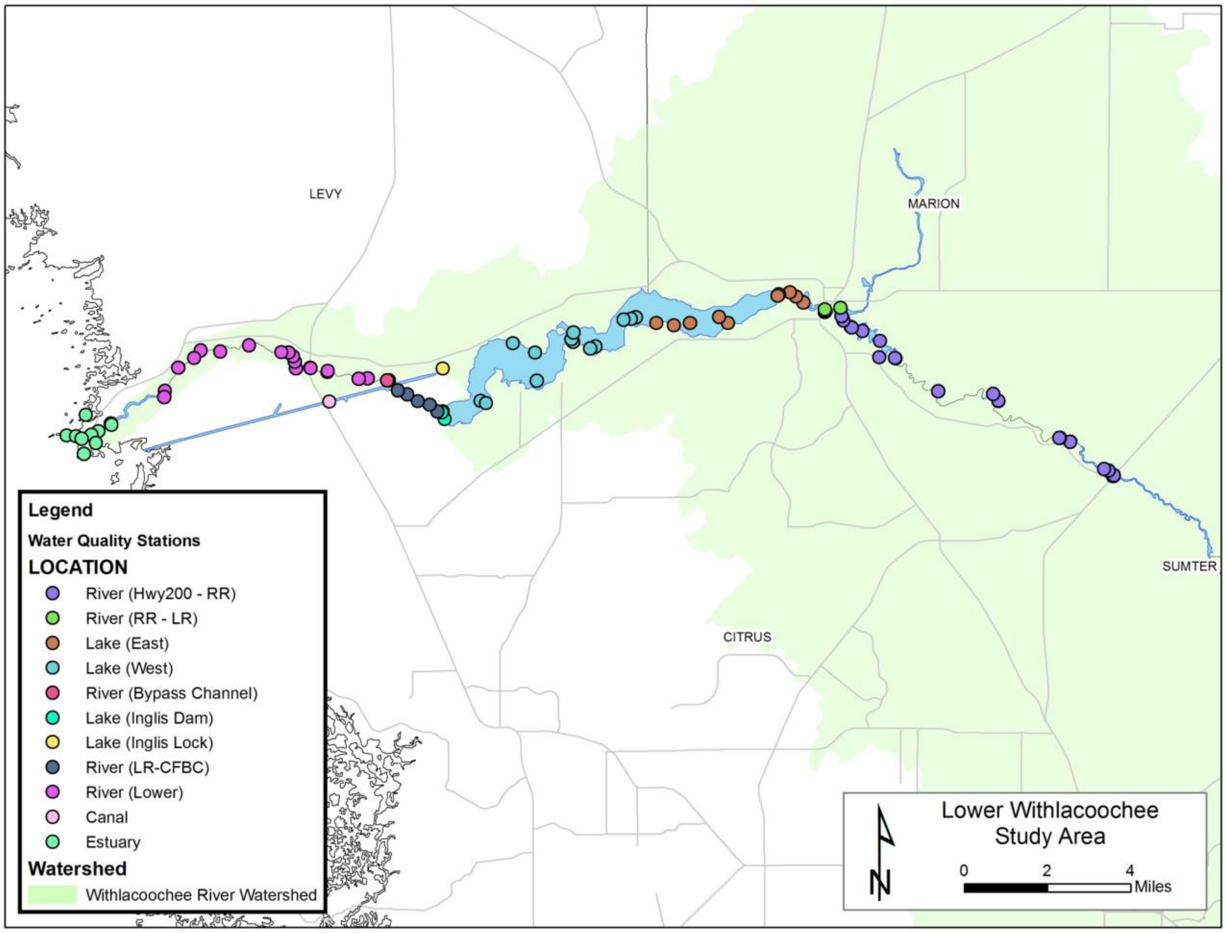


Figure 21. Water Quality Stations with Historic Data Identified by Station Type and Location within the Lower Withlacoochee River

- Water quality in Lake Rousseau is altered by the transition from a riverine to a reservoir system. Chlorophyll-a concentrations in the lake appear to increase through the lake (East – 28 µg/L and West - 35 µg/L) while nitrate-nitrogen is reduced (East - 0.73 mg/L, West – 0.29 mg/L, Dam – 0.07 mg/L) in comparison to upstream river stations. Mean total nitrogen concentrations decreased through the lake from 0.91

mg/L (East) to 0.68 mg/L (Dam). Total phosphorus concentrations increased through Lake Rousseau (East = 0.049 mg/L, West = 0.061 mg/L, Dam = 0.077 mg/L).

- Lower Withlacoochee River water quality data had an observed decrease in chlorophyll-a compared to Lake Rousseau (5.5 µg/L), an increase in specific conductance (506 µS/cm) and salinity (2.0 ppt), and little change in nutrients (TN = 0.66 mg/L, TP = 0.047 mg/L) over the period-of-record.
- As freshwater from the Lower Withlacoochee River flows into Withlacoochee Bay Estuary, lower nitrate concentrations (0.20 mg/L) and higher total phosphorus concentrations (0.071 mg/L), specific conductance (18,900 µS/cm), salinity (7.6 ppt), turbidity (7.5 NTU), and suspended solids (8.6 mg/L) were observed.

The Phase 2 water quality update included a total of seven monitoring stations (Figure 22). Field parameter data are briefly summarized as follows with detailed timeseries and statistics available in Appendix A.

- Water temperature was seasonal with highest temperatures (about 30°C) recorded during July/August of each year and lowest temperatures (15 to 18°C) recorded in December/January.
- Hydrogen ion (pH) showed a slight seasonal variation with higher values (basic) recorded in summer months (8 to 8.5 s.u.) and lower values (neutral) recorded in the fall and winter (7 to 7.5 s.u.). Hydrogen ion varied diurnally despite limited aquatic productivity in the Lower Withlacoochee River, and most likely as a result of photosynthesis in Lake Rousseau upstream.
- Specific conductance readings showed the influence of upstream groundwater inputs and were higher downstream due to the proximity of the estuary waters, especially during periods of low river flow.
- Dissolved oxygen was generally high (above 6 mg/L) at most stations and showed diurnal variability despite limited primary productivity in the Lower Withlacoochee River, and most likely as a result of photosynthesis in Lake Rousseau. Lowest dissolved oxygen concentrations were observed in response to Hurricane Irma in September 2017.

Detailed data for 36 analytical parameters were sampled by WSI during Phase 2 and analyzed by the Florida Department of Environmental Protection's Laboratory in Tallahassee. A summary of the results for selected parameters follows with detailed timeseries and statistics available in Appendix A. Figure 23 provides a summary of select water quality parameters sampled during Phase 2.

- Chlorophyll-a, a measure of planktonic algal populations, peaked in the Lower Withlacoochee River each year during summer at about 20 µg/L.
- There was an increase in total arsenic concentrations in the Withlacoochee River upstream of US 41 and Rainbow River following the passage of Hurricane Irma. This increase was also visible in the Lower Withlacoochee River study area. The highest arsenic value of 2.5 µg/L did not exceed the water quality criterion of 50 µg/L. Total

iron also peaked in the river during that same time period at about 2.5 mg/L, about two and one-half times higher than the state standard of 1 mg/L.

- Nitrate-nitrogen was elevated in all stations below the Rainbow River due, at least in part, to spring inputs. While upstream nitrate-nitrogen concentrations were generally less than 0.2 mg/L, the US 41 station averaged about 1 mg/L over the two-year study and downstream stations in the Lower Withlacoochee River study area averaged between 0.4 and 0.5 mg/L.
- A number of herbicides were detected in the Lower Withlacoochee River study area. The most significant concentrations of an aquatic herbicide fluridone (the active ingredient in SONAR® a broad spectrum and very persistent herbicide typically used for hydrilla control) was detected at all downstream stations with peaks during each summer growing season. Elevated concentrations of 2,4-D, a systemic, organic herbicide, also appeared at the Lower Withlacoochee River stations from June through August 2017. This herbicide was not detected at the US 41 station downstream of the Rainbow River, indicating that it may have been associated with herbicide application events in Lake Rousseau. The algicide Diuron was also detected at the Lower Withlacoochee River stations in July 2016 and July 2017.
- The presence of sucralose (artificial sweetener) at all seven stations, may show evidence of inflows from local septic systems or regional wastewater systems within the Lower Withlacoochee watershed. Phase 2 average concentrations were generally low (ranged from 0.030 to 0.043 µg/L) with 85% of samples reported above the detection limit of 0.01 µg/L.
- A recording multi-parameter data sonde deployed in the Lower Withlacoochee River recorded periods of high turbidity in the river in early February 2016, the first half of March 2016, and a few days in June 2016. The specific cause of this increased turbidity is not clear but could be the result of aquatic weed control (June 2016, Figure 24) or operations in Lake Rousseau.
- Light transmittance (a measure of water clarity) in the Lower Withlacoochee River varied widely during the duration of the project. During late-2016 and early-2017, water clarity and transmittance increased substantially as rainfall was low and the proportion of the water in the Lower Withlacoochee River from the Rainbow River increased.

Sediment Chemistry

During Phase 2 investigations, arsenic, copper, and iron concentrations in the river sediments were sampled and were found to have higher concentrations at station LWR-3, near the former powerplant, in comparison to the other stations sampled (Wetland Solutions, Inc., 2018).

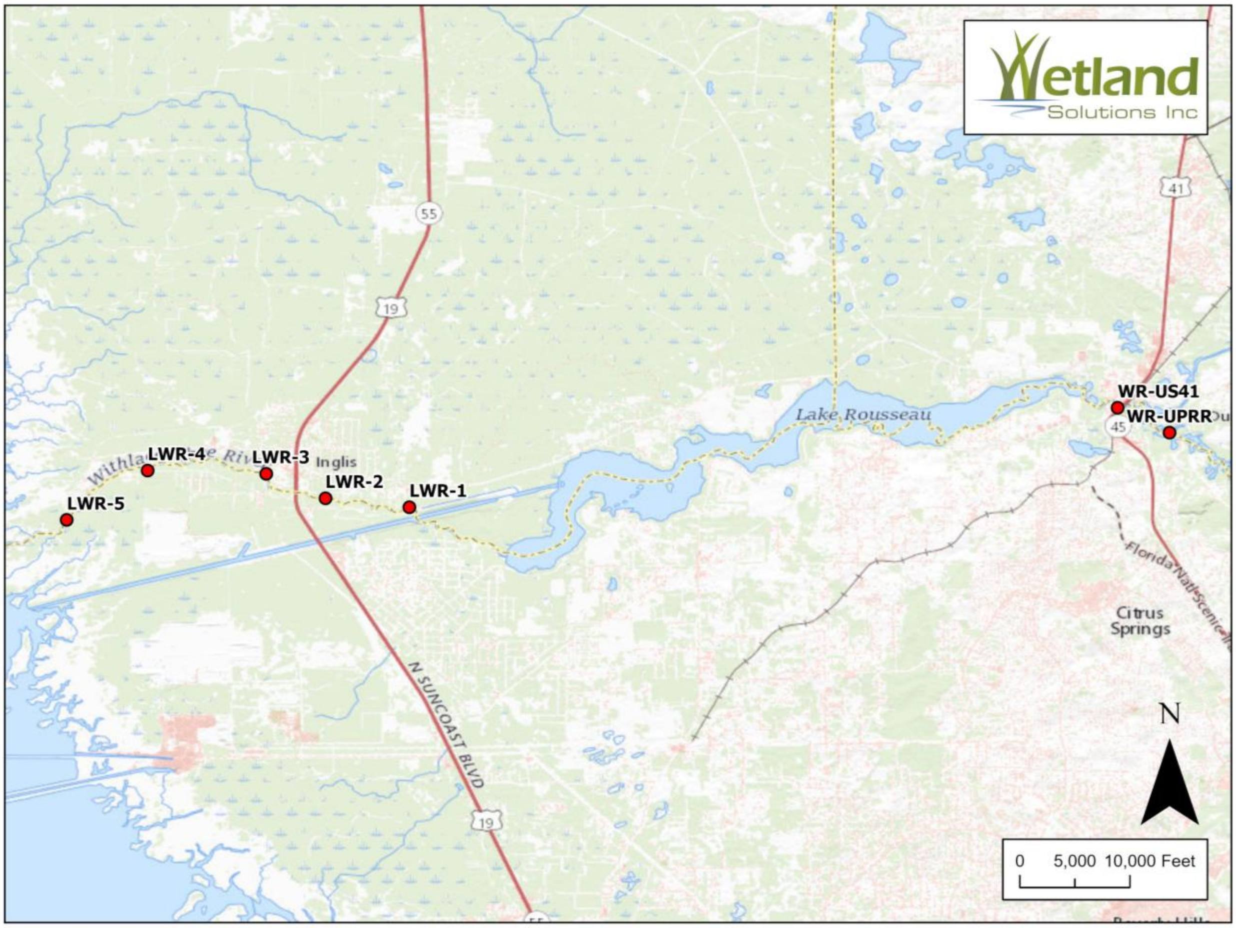


Figure 22. Phase 2 Monitoring Stations within the Lower Withlacoochee River

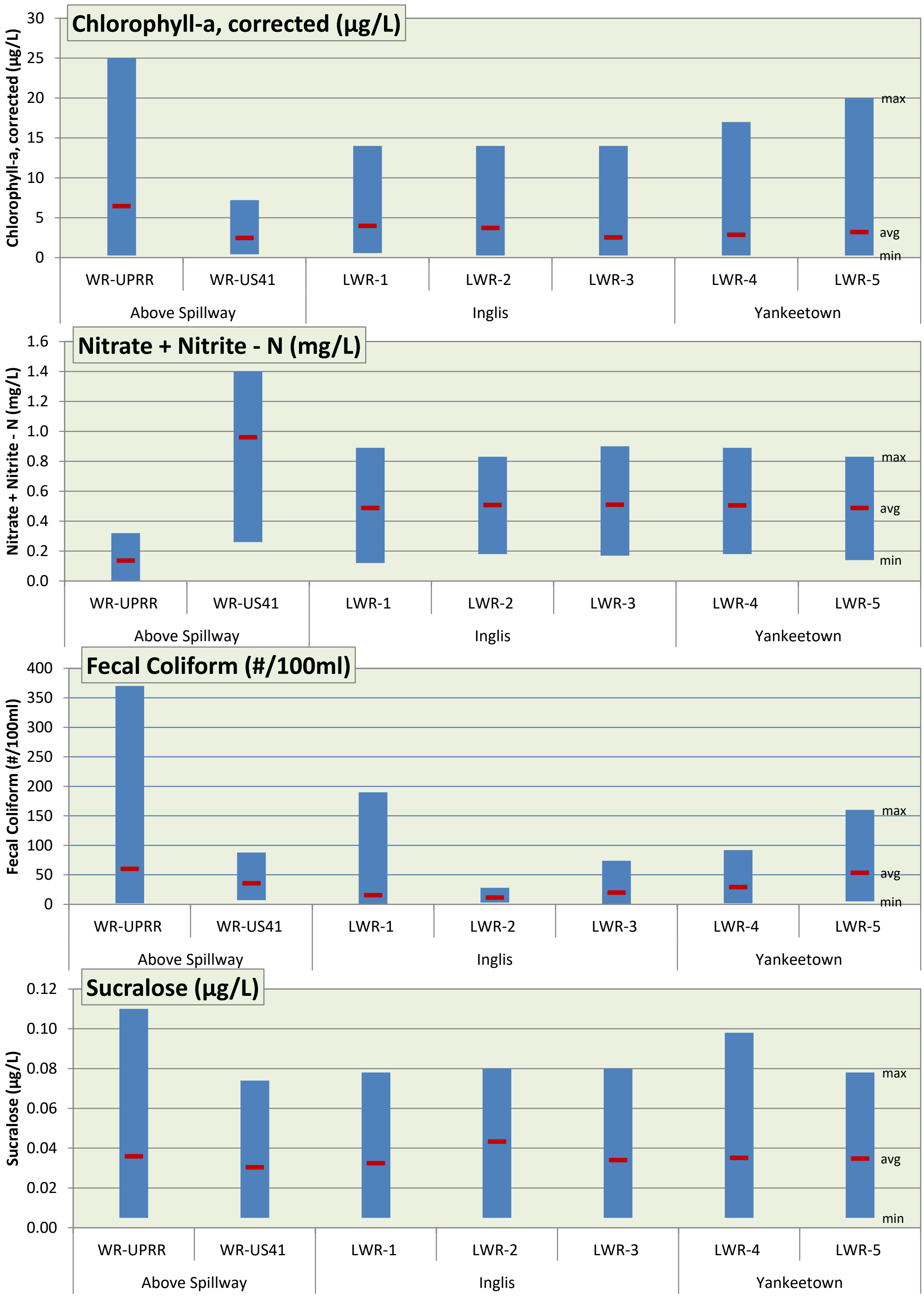


Figure 23. Phase 2 Water Quality Summary (Average and Range) for Select Parameters

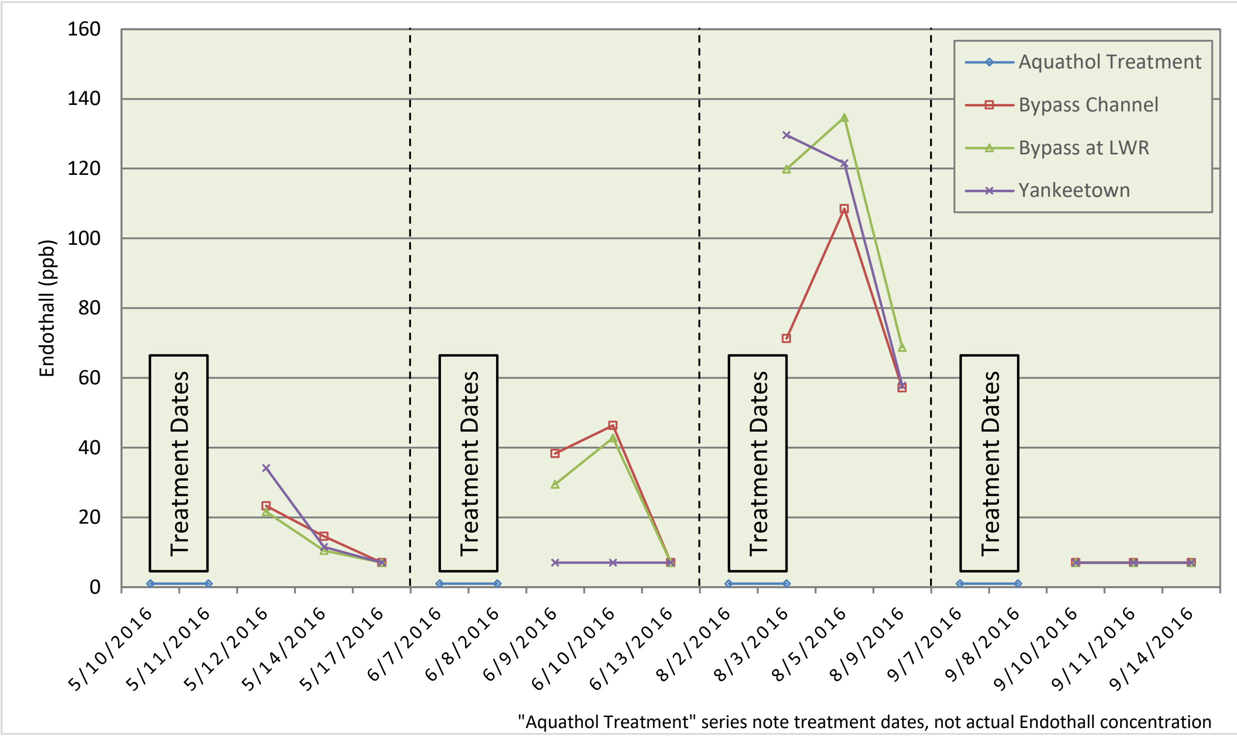


Figure 24. Aquathol Treatments in Lake Rousseau with Endothall Sample Results (FWC data)

Ecological Health

The health of the Lower Withlacoochee River aquatic ecosystems was assessed by collection and review of biological data concerning the structure and function of the submerged plant communities and water-dependent faunal populations.

Aquatic Plants

Lake Rousseau contains nuisance aquatic weed growth, including hydrilla (*Hydrilla verticillata*) and water hyacinth (*Eichhornia crassipes*), and periodically receives herbicide treatments by FWC and their contractors to reduce vegetation coverage and maintain boat access. Between fiscal years 2002 and 2017 available data indicate that on average 1,018 acres were treated to kill hydrilla, water hyacinth, and water lettuce (*Pistia stratiotes*) per year (Figure 25). The largest treated area occurred during fiscal year 2005-2006 with a total herbicide treatment area of 2,533 acres. This coincides with historic imagery of Lake Rousseau in May 2005 when the majority of the reservoir can be seen covered with aquatic vegetation presumed to be topped-out hydrilla. During both phases of the WSI study, fragmented macrophytes including hydrilla, water lettuce, coontail (*Ceratophyllum demersum*), and water hyacinth were observed floating downstream, after coming under the gate from Lake Rousseau.

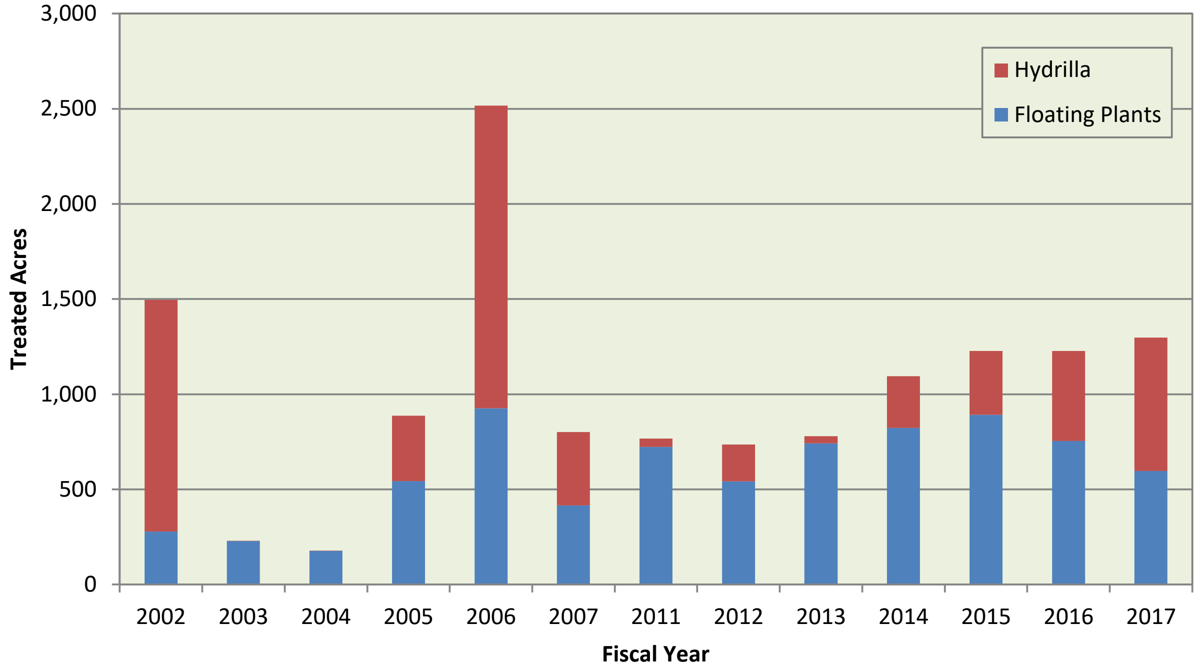


Figure 25. Herbicide Application in Lake Rousseau by Year

Submerged aquatic plants listed in the Lower Withlacoochee River in the mid-1970s by Hartman, (1974) included abundant: hydrilla, milfoil (*Myriophyllum spicatum*), coontail, and widgeon grass (*Ruppia maritima*); additionally there was a presence of four varieties of pondweed (*Potamogeton spp.*) and southern naiad (*Najas guadalupensis*). Floating aquatic plants that were listed included a presence of water hyacinth, common salvinia (*Salvinia minima*), water lettuce, and duckweed (*Lemna spp.*) (Hartman, 1974). At the time of the Outstanding Florida Water petition for the Lower Withlacoochee River (1987), the lower river was described to "support an astounding variety of wildlife and plant systems" (W.A.R., Inc., 1987). By the late 1990s, Frazer *et al*. (2001) reported a lack of submerged aquatic plants in the river segment, and infrequent occurrences of filamentous algae growing attached to rocks. W.A.R., Inc. prepared a report that included photos of manatee activity in 2001 that appears to show the presence of either filamentous algae or submerged aquatic plants in portions of the river under clear water conditions (W.A.R., Inc., 2008).

No submerged aquatic plants were observed in the Lower Withlacoochee River segment below the Inglis Bypass Channel during Phase 1 field visits in 2013 or during Phase 2 field visits between 2015 and 2017. During Phase 2 of the project some attached algae was observed at station LWR-1 during a low-flow event when water was particularly clear in the lower river.

Particulate Export

During Phase 2, a plankton net was used to quantitatively sample particulate export at two stations (LWR-1 and LWR-4) in the Lower Withlacoochee River during March and July 2020 (Table 2). Samples collected just below the spillway averaged 242 lbs/d of dry matter (134 lbs/d organic). Samples collected further downstream had a lower average of 134 lbs/d of dry matter (92 lbs/d of organic matter). Microscopic examination indicated that the majority of the particulate matter during the March event was pseudoplankton, consisting of fragmented algal filaments with a few zooplankton organisms, while the July samples included a mix of fragmented algae and intact zooplankton.

Table 2. Lower Withlacoochee River Particulate Export Samples Collected with a Plankton Net

			Total Sample							
Date	Station	% Ash	Dry Wt. (g)	Ash-Free Dry Wt. (g)	Dry Matter (g/m^3)	Organic Matter (g/m^3)	Dry Matter (g/d)	Organic Matter (g/d)	Dry Matter ($g/m^2/d$)	Organic Matter ($g/m^2/d$)
3/18/2020	LWR-1	43.1	0.557	0.317	0.041	0.023	101,332	57,657	---	---
	LWR-4	42.1	0.057	0.033	0.007	0.004	16,919	10,159	---	---
	Segment	42.6	-0.500	-0.283	-0.034	-0.019	-84,413	-47,498	-0.291	-0.164
7/22/2020	LWR-1	45.7	0.605	0.359	0.053	0.030	118,563	64,380	---	---
	LWR-4	28.3	0.536	0.382	0.048	0.034	104,704	73,302	---	---
	Segment	37.0	-0.069	0.023	-0.005	0.004	-13,859	8,922	-0.048	0.031

Segment Area (m^2) = 289,783; Segment Length (m) = 7,612; Average Width (m) = 38.1
March Flow (m^3/s) = 28.6; July Flow (m^3/s) = 28.6; Net Area (m^2) = 0.1886

Benthic Macroinvertebrates

Historic data on benthic macroinvertebrates were not available for the Lower Withlacoochee River. More recent Stream Condition Index (SCI) and Habitat Assessment (HA) data were reported by the FDEP Aquatic Ecology and Quality Assurance Section between 2007 and 2018 for the locations identified in Figure 26. The SCI and HA were summarized by station and grouped into the following zones: Withlacoochee River upstream of the Rainbow River (WR-USRR), Withlacoochee River downstream of the Rainbow River (WR-DSRR), Bypass Channel, and Lower Withlacoochee River (Figure 27 and Figure 28).

The SCI is a biological assessment procedure that measures the degree to which flowing fresh waters support a healthy, well-balanced biological community, as indicated by benthic macroinvertebrates (Florida Department of Environmental Protection, 2011). Overall biota habitat quality is determined using HA scoring for primary (substrate diversity and availability, velocity, and habitat smothering) and secondary (artificial channelization, bank stability, riparian buffer width, and vegetation quality) habitat parameters, each component ranging from 1 to 20[3], with 20 being the highest quality. Primary and secondary habitat parameter components are summed to result in a total HA score.

All stations, with the exception of the Withlacoochee River, immediately downstream of the Rainbow River, had SCI scores indicating "impaired" biological health (<40). The Withlacoochee River stations immediately downstream of the Rainbow River (WR-DSRR) had SCI scores considered "healthy" (40-63), while none of the stations were considered "exceptional" (64-100).

All stations upstream of Lake Rousseau had HA scores in the "optimal" (120-160) and "suboptimal" (80-119) range, while downstream stations, in the bypass channel and Lower Withlacoochee River, were in the "marginal" (40-79) and "suboptimal" (80-119) range. The lowest

[3] with the exception of 3 secondary habitat components (bank stability, riparian buffer width, and vegetation quality) which range from 1 to 10, with 10 being the highest quality.

HA score observed was from the most recent assessment in the Lower Withlacoochee River (LOWERWITH station, July 2017).

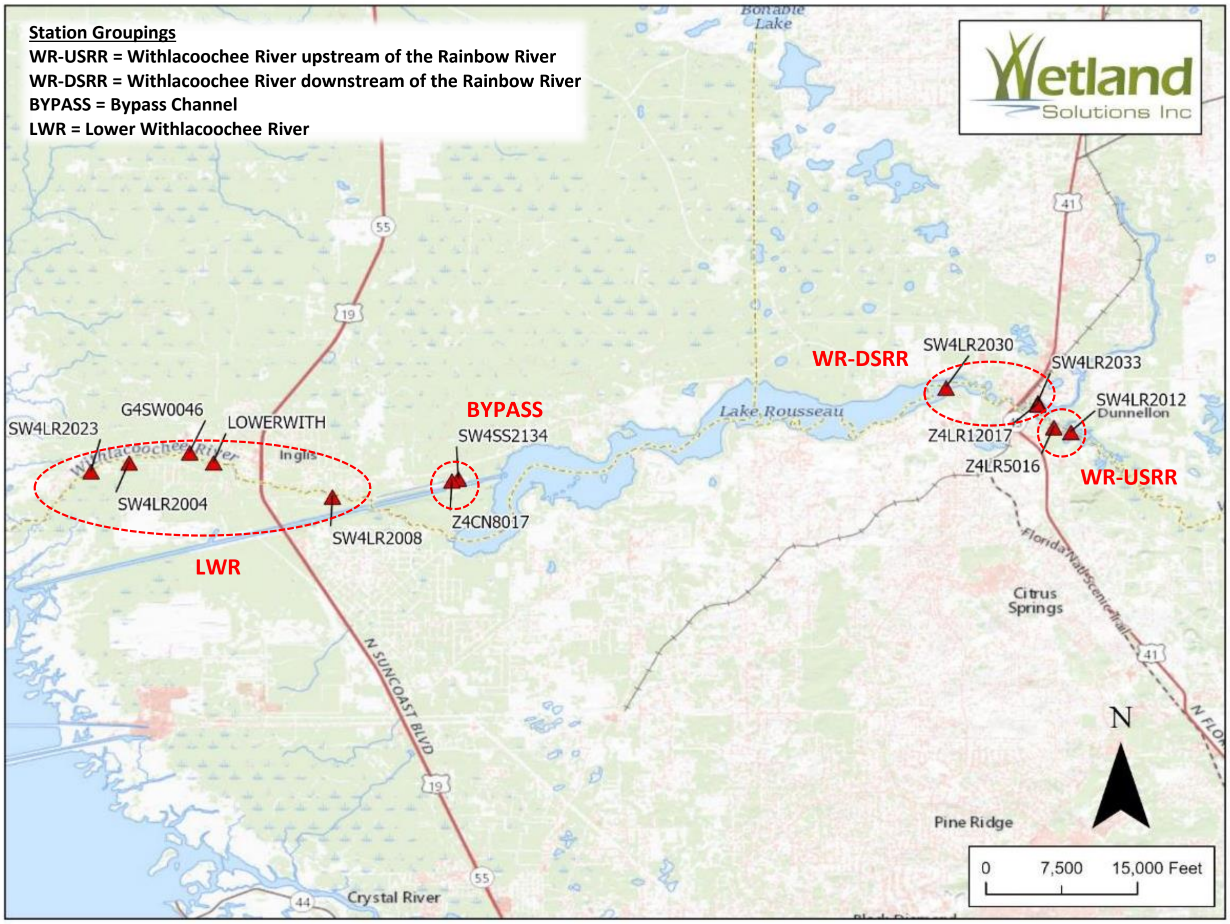


Figure 26. Stream Condition Index and Stream Habitat Assessment Monitoring Stations (FDEP)

During Phase 2 sampling, FDEP scientists concluded that submerged habitat in the Lower Withlacoochee River (LOWERWITH station, July 2017) was "marginal" (Figure 23, HA score of 64) and unsuitable for SCI benthic macroinvertebrate sampling[4]. WSI subsequently conducted limited macroinvertebrate community sampling in March and July 2020. Two stations were sampled, LWR-1, the Lower Withlacoochee River just below the Inglis Bypass Channel spillway and WR-US41, the upriver station just below the confluence with the Rainbow River (Figure 22). While species diversity was slightly higher at the LWR-1 station, the Ephemeroptera/ Plecoptera/Trichoptera (EPT) richness index, indicative of better water quality, was twice as high at the upstream US 41 station than in the lower river below Lake Rousseau (Table 3). For the combined sampling events, the Hilsenhoff Biotic Index (HBI) indicated "poor" water quality at both stations with the likelihood of "very substantial organic pollution"(Hilsenhoff, 1988). There was also a greater frequency of pollution-tolerant macroinvertebrate species at LWR-1 (Figure 29). During the July 2020 sampling event, the HBI for WR-US41 indicated "good" water quality with the likelihood of "some organic pollution probable". While these data indicate seasonal and

[4] SCI sampling only conducted with a HA score above 80 (suboptimal or optimal range)

spatial variability in macroinvertebrate populations, they also indicate a greater level of water quality impairment in the Lower Withlacoochee River, downstream of Lake Rousseau, compared to the station upstream of Lake Rousseau.

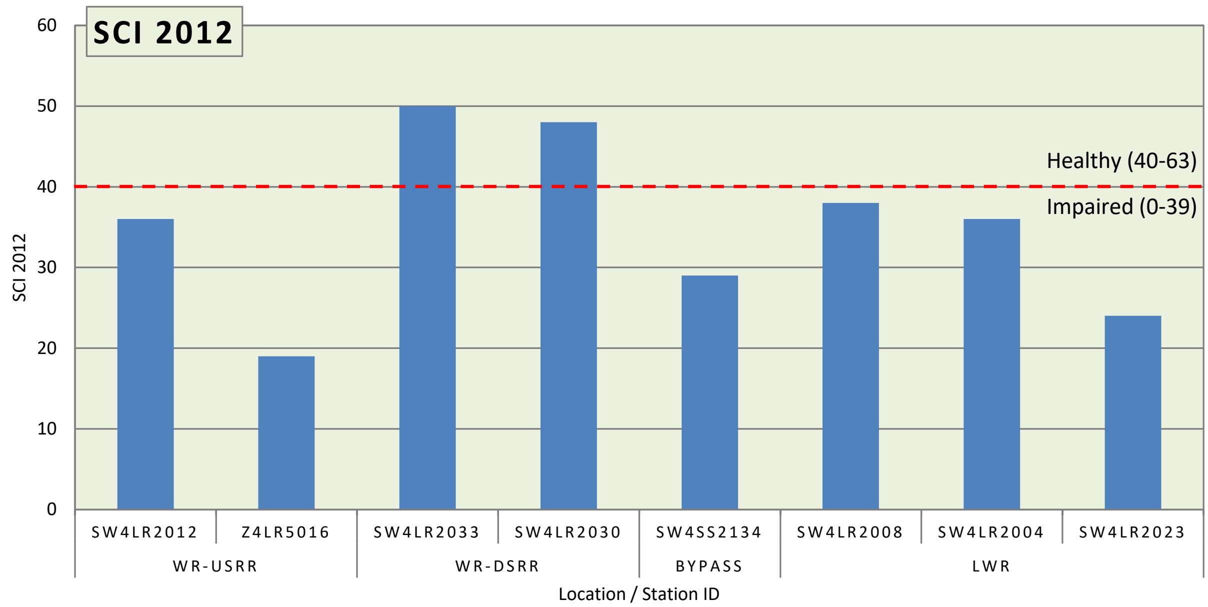


Figure 27. FDEP Stream Condition Index Results (All station from 2007, with the exception of Z4LR5016 from 2011)

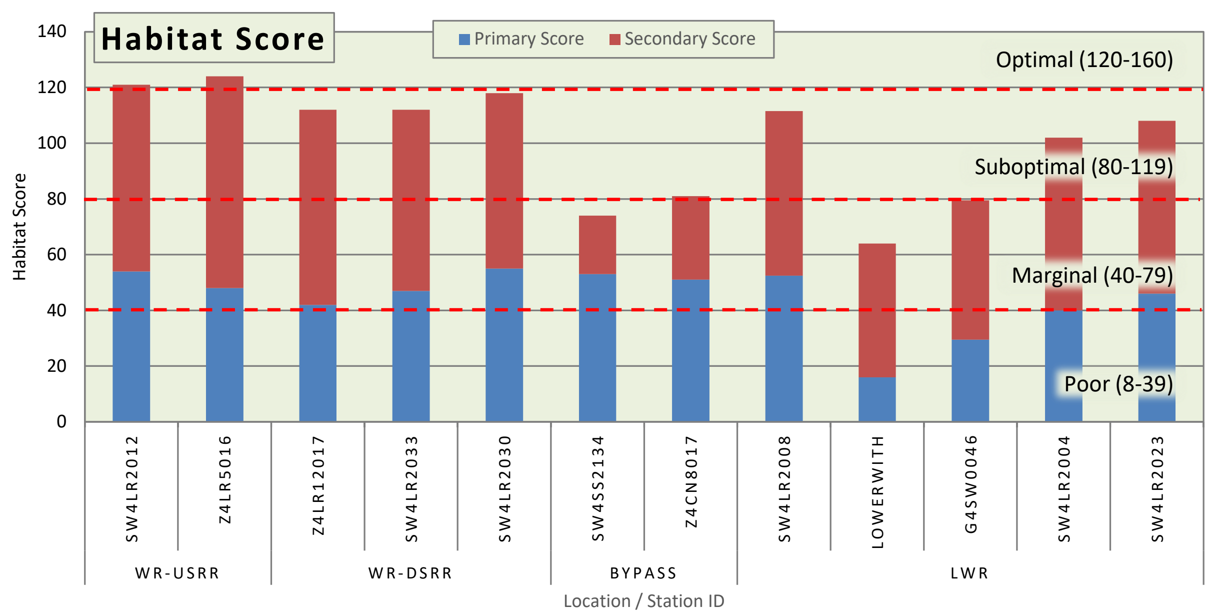


Figure 28. FDEP Stream Habitat Assessment Results (2007 - 2018)

Table 3. Benthic Macroinvertebrate Population Summary within the Withlacoochee River

Station	Total No. of Organisms	Density (#/m^2)	Taxa Richness (S)	Shannon Wiener Diversity Index (H')	Evenness (J')	Simpson's Diversity Index (D)	EPT Richness Index (%)	Hilsenhoff Biotic Index (HBI)
March 18, 2020								
LWR-1	832	273	28	3.727	0.775	0.88	3.6	7.22
WR-US41	4,480	1,470	29	3.083	0.635	0.77	17.2	7.41
July 22, 2020								
LWR-1	3,340	1,096	41	3.183	0.594	0.71	12.2	7.18
WR-US41	960	315	28	4.087	0.850	0.93	25.0	4.76
Total								
LWR-1	4,172	1,369	60	3.918	0.663	0.80	10.0	7.19
WR-US41	5,440	1,785	52	3.897	0.684	0.84	21.2	7.15

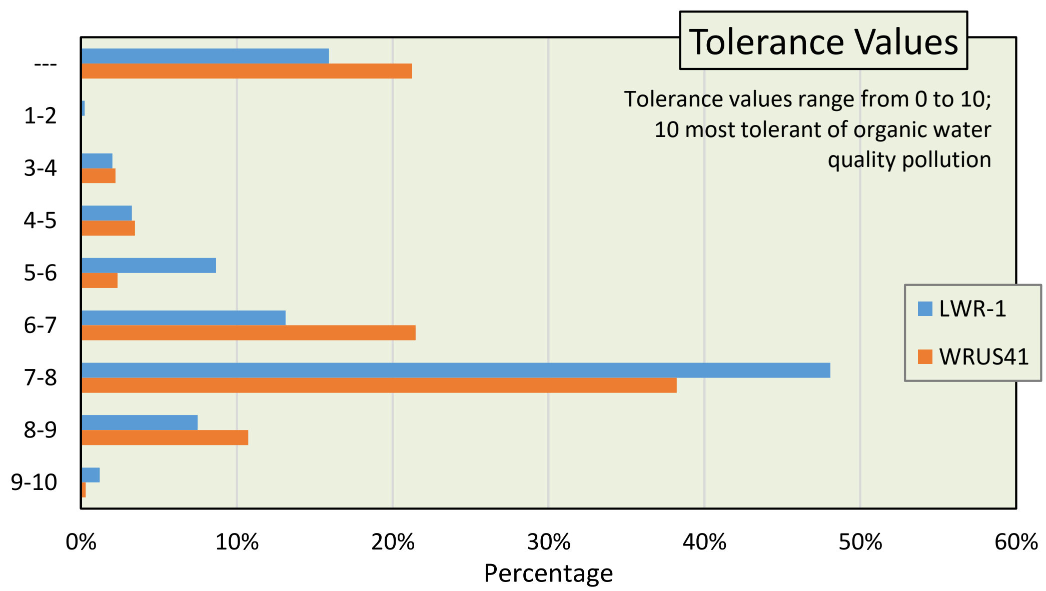


Figure 29. Pollution Tolerance Values for Benthic Macroinvertebrates Collected within the Withlacoochee River (2020). Reported as Percentage of Total Organisms Collected.

Fish and Other Wildlife

The Florida Fish and Wildlife Conservation Commission (FWC) have reported detailed electrofishing data on two recent occasions for the Lower Withlacoochee River (Table 4). Sampling was conducted in June 2020 and February 2021 between stations LWR-1 and LWR-5.

The most abundant freshwater fish species in terms of numbers was threadfin shad (*Dorosoma petenense*), a small planktivorous species. Spotted sunfish (*Lepomis punctatus*) were second in total numbers, followed by coastal shiner (*Notropis petersoni*). In terms of live weight biomass, the lower river is dominated by gar (both Florida and longnose [*Lepisosteus sp.*]) with a measured biomass of 44.3 kg, comprising 35% of the biomass of freshwater fish species. The second-most dominant freshwater fish was bowfin (*Amia calva*) with 38.4 kg representing 30% of the freshwater fish biomass. Predominant freshwater gamefish species were largemouth bass (*Micropterus salmoides*) with 13 kg and 10% of the biomass and channel catfish (*Ictalurus punctatus*) with 5.7 kg and 4.5% of the total freshwater fish biomass. In terms of saltwater fish species, striped mullet (*Mugil cephalus*) had a measured biomass of 34.9 kg and comprised 59% of the saltwater fish biomass, followed by common snook (*Centropomus undecimalis*) at 18.1 kg total or 31% of the saltwater fish biomass. During the 2020 and 2021 sampling, FWC recorded 42 fish species with 30 native freshwater species, one freshwater exotic species (sailfin catfish), and 11 saltwater species.

Table 4. Summary of Fish Abundance and Biomass Data by Habitat Type and For Dominant Species on the Lower Withlacoochee River (FWC 2021)

Common (Scientific)	Summer 2020				Spring 2021				2020 - 2021			
	#	Count	Biomass		#	Count	Biomass		#	Count	Biomass	
	Spp		kg	% of Total	Spp		kg	% of Total	Spp		kg	% of Total
Freshwater	**23**	**1,277**	**129**	---	**26**	**1,304**	**125**	---	**31**	**1,291**	**126.9**	---
Bowfin (*Amia calva*)		15	32.4	25.1		26	44.4	35.6		21	38.4	30.2
Longnose Gar (*Lepisosteus osseus*)		25	30.4	23.5		13	15.3	12.3		19	22.9	18.0
Florida Gar (*Lepisosteus platyrhincus*)		26	18.6	14.4		38	24.3	19.5		32	21.4	16.9
Channel Catfish (*Ictalurus punctatus*)		3	11.4	8.9		0	---	0.0		1.5	5.7	4.5
Largemouth Bass (*Micropterus salmoides*)		55	7.96	6.2		55	17.9	14.3		55	12.9	10.2
Spotted Sunfish (*Lepomis punctatus*)		154	7.19	5.6		362	13.3	10.7		258	10.3	8.1
Threadfin Shad (*Dorosoma petenense*)		754	2.66	2.1		0	---	0.0		377	1.3	1.0
Coastal Shiner (*Notropis petersoni*)		54	0.04	0.03		273	0.36	0.29		164	0.20	0.2
Other		191	18.4	14.3		537	9.2	7.4		364	13.8	10.9
Saltwater	**9**	**171**	**39.2**	---	**8**	**135**	**78**	---	**11**	**153**	**59**	---
Striped Mullet (*Mugil cephalus*)		68	28.0	71.4		68	41.8	53.4		68	34.9	59.5
Common Snook (*Centropomus undecimalis*)		8	6.00	15.3		23	30.1	38.5		16	18.1	30.8
Other		95	5.19	13.2		44	6.30	8.1		70	5.7	9.8
Total	**32**	**1,448**	**168**	---	**34**	**1,439**	**203**	---	**42**	**1,444**	**186**	---

Visual counts of aquatic turtles were conducted during Phase 2 monitoring and are summarized in Figure 30. The highest counts were observed during March 2017 totaling 129 aquatic turtles observed within the Lower Withlacoochee River. Details by zone are as follows; LWR 1-2: 21, LWR 2-3: 16, LWR 3-4: 72, and LWR 4-5: 20. Due to their semi-quantitative nature these data cannot be directly compared to other healthy aquatic ecosystems.

Fish and turtle counts indicate that the Lower Withlacoochee River still retains some wildlife habitat value.

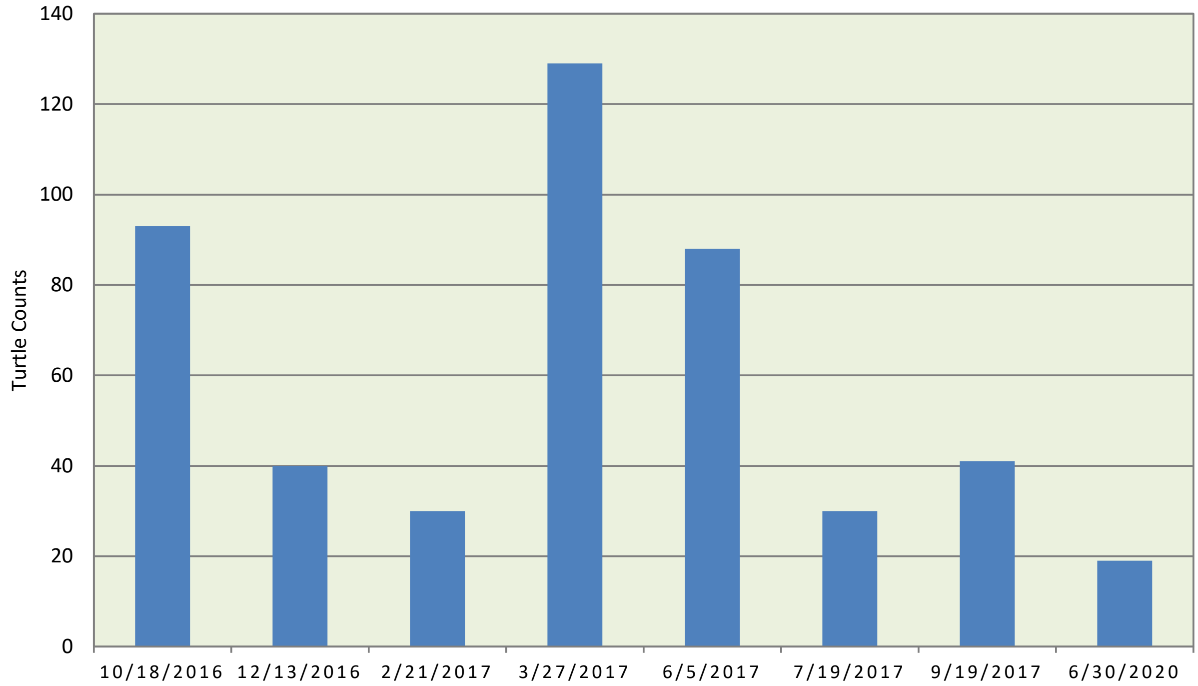


Figure 30. Visual Turtle Counts on the Lower Withlacoochee River

Ecosystem Metabolism

Aquatic ecosystem metabolism was calculated based on measured diurnal upstream-downstream oxygen changes in the freshwater portion of the Lower Withlacoochee River. Sampling was conducted during ten, month-long events between November 2015 and August 2020 (Table 5). Estimated gross primary productivity in the Lower Withlacoochee River was very low, averaging 0.69 g $O_2/m^2/d$, with a monthly high of 2.39 g $O_2/m^2/d$. Total community respiration varied from a low of -2 g $O_2/m^2/d$ and a high of 25.4 g $O_2/m^2/d$, with an average of 7.45 g $O_2/m^2/d$. This river segment was highly heterotrophic with a productivity to respiration ratio (P/R) average of 0.10. Photosynthetic efficiency (gross primary productivity divided by photosynthetically-active radiation) averaged 0.41%.

These data indicate that the Lower Withlacoochee River has a very low internal capability to support food production for macroinvertebrates and higher forms of wildlife, including fish, reptiles, and birds. It appears that the overall health of this aquatic ecosystem is diminished by the apparent depauperate submerged plant communities, and the existing animal populations are largely dependent on organic inputs from upstream Lake Rousseau.

Table 5. Aquatic Ecosystem Metabolism in the Lower Withlacoochee River (Station LWR-1 to LWR-4)

Start Date	End Date	GPP (g O_2/m²/d)	NPP (g O_2/m²/d)	CR (g O_2/m²/d)	P/R Ratio	PAR (24hr) (mol/m²/d)	PAR Efficiency (%)	PAR Efficiency (g O_2/mol)
11/13/15	12/15/15	0.09	-1.87	1.93	0.15	7.40	0.10	0.01
2/19/16	3/15/16	0.26	-6.99	7.35	0.04	9.40	0.21	0.03
5/18/16	6/21/16	1.55	-8.75	10.3	0.15	21.6	0.52	0.06
8/16/16	9/1/16	0.71	-4.98	5.63	0.12	12.5	0.40	0.05
11/16/16	12/13/16	0.10	2.18	-2.04	-0.06	5.92	0.12	0.01
2/22/17	3/27/17	0.65	-4.50	5.22	0.13	20.4	0.25	0.03
5/17/17	6/20/17	0.49	-3.58	4.12	0.12	21.7	0.14	0.02
9/20/17	10/17/17	0.18	-25.4	25.4	0.01	2.10	0.80	0.10
2/19/20	3/18/20	0.46	-2.79	3.31	0.17	12.8	0.29	0.04
7/23/20	8/16/20	2.39	-10.7	13.2	0.18	14.9	1.28	0.16
	Average	0.69	-6.75	7.45	0.10	12.9	0.41	0.05

Human Use

Shoreline Survey

A shoreline survey was conducted for each parcel on each bank of the Lower Withlacoochee River in March 2017.

Table 6 presents a summary between each LWR station (Figure 22) with an example map in Figure 31. The natural shoreline was most commonly identified, with riprap and walls increasing in prevalence with distance downstream in the Lower Withlacoochee River.

Table 6. Shoreline Survey (March 2017)

	LWR Zone				
Shoreline	1-2	2-3	3-4	4-5	Total
Natural	48%	67%	57%	44%	53%
Riprap	13%	11%	19%	27%	18%
Wall	3%	11%	10%	22%	12%
Combination	35%	12%	14%	7%	16%
Total	100%	100%	100%	100%	100%

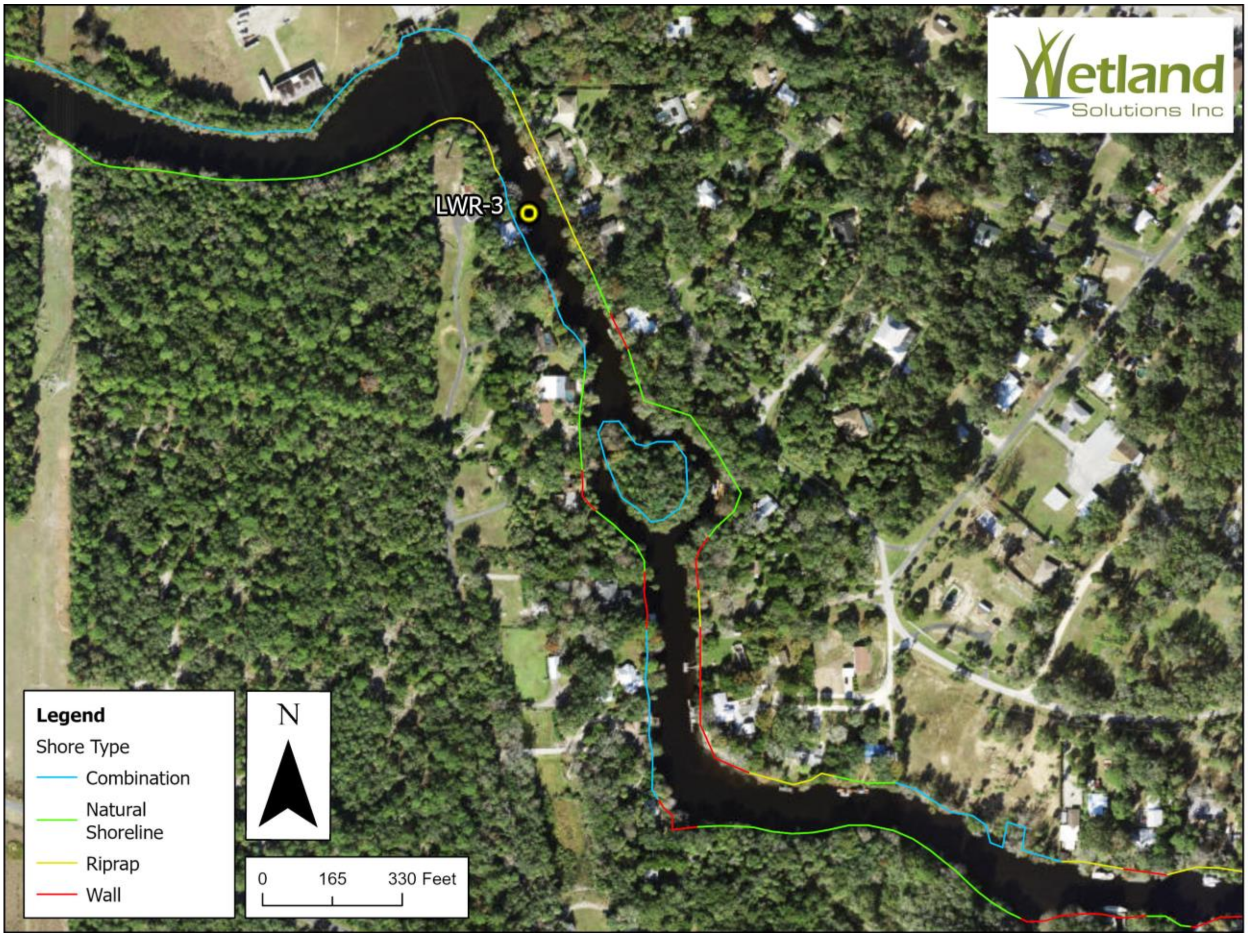


Figure 31. Shoreline Survey Example (March 2017)

Dock Survey

A dock survey was conducted on each bank of the Lower Withlacoochee River in March 2017 totaling 232 docks within the Lower Withlacoochee River. Details by zone are as follows; LWR 1-2: 46, LWR 2-3: 36, LWR 3-4: 65, and LWR 4-5: 85.

Boating Survey

A survey of inactive boats (moored to docks or shorelines) was conducted on the Lower Withlacoochee River in March 2016 totaling 237 boats within the Lower Withlacoochee River. Details by zone are as follows; LWR 1-2: 39, LWR 2-3: 42, LWR 3-4: 57, and LWR 4-5: 99. An additional survey in July 2016 identified 214 boats, with powerboats (108) being the most common, following by pontoon boats (35), sailboats (29), canoe/kayaks (26), and shrimp boats (16).

Active boating activities observed during all Phase 2 monitoring events were also documented. During Phase 2, a total of 134 individuals were observed boating on the Lower Withlacoochee River with powerboats (100) having the most people, followed by pontoon boats (19), canoe/kayaks (9), and other[5] (6). A total of 12 people were observed fishing on the Lower Withlacoochee River during Phase 2 monitoring activities.

Summary of Environmental Impairments

The Lower Withlacoochee River environmental assessment has documented a variety of hydrological, physical, chemical, biological, and structural impairments that have resulted over the past 120 years due to human development activities. These changes have increased over time and resulted in the current environmental condition documented in the Lower Withlacoochee River. The conditions and impairments noted in this study are summarized below.

Hydrological Impairments

Declining Flows and Groundwater Pumping

Average flow rates in the Withlacoochee River at SR200 have been declining since the 1950s. Average flows in the Rainbow River have also been declining since at least the 1960s. Due to the documented long-term flow reductions in its two largest tributaries, inflows to Lake Rousseau have been declining long-term with an estimated average flow reduction of about 406 cfs (262 MGD) or 24% since 2000 compared to the pre-2000s. Long-term average flows to the Lower Withlacoochee River through the Inglis Bypass Channel have also been declining since measurements began in 1970 until about 2010. The difference in average historic flow to the Lower Withlacoochee River was 105 cfs (68 MGD) or 10% over the past two decades.

The specific causes of these system-level flow declines were not determined as a part of this study. Based on the documented long-term flow declines in the Rainbow River Springs Group, and in the springs feeding Gum Slough upstream in the Withlacoochee River (Wetland Solutions, Inc., 2011), it is considered likely that the principal cause of the flow declines is a reduction in base flows in the springs that feed the Withlacoochee River. Overall groundwater consumption in the Southwest Florida Water Management District in 2015 was estimated as 773 MGD (Marella, 2020). Groundwater is the principal water source for all freshwater uses in the counties surrounding the Lower Withlacoochee River groundwater basin. Combined groundwater pumping in Citrus, Levy, Marion, and Sumter counties rose from less than 25 MGD in 1950 to about 132 MGD in 2015 (Marella, 1995, 2020). This local groundwater pumping is equal to about one half of the observed total decline of average river flows. In other parts of the state, regional pumping has been shown to shift groundwater divides and change the direction of groundwater flow (Grubbs & Crandall, 2007).

Since long-term rainfall has been relatively consistent throughout the surface and groundwater basins feeding surface flows to the Withlacoochee River, it is likely that human groundwater extractions are responsible for some of the reduction in baseflows in the Lower Withlacoochee River Study Area. Changes in surface drainage patterns, resulting from land use development, are also likely to contribute to reduced recharge and decreased baseflows. The observed decline of ecological function in the lower river is to some extent a probable result of these long-term average baseflow reductions.

[5] construction crane barge

Loss of Peak Flows and Altered Flow Regime

The flow regime within the Lower Withlacoochee River is dominated in the upstream portions by inflows from Lake Rousseau, and within the lower sections by tidal fluctuations. At the upstream end of the Lower Withlacoochee River a flow station is maintained from the Bypass Channel to the Lower Withlacoochee River. This structure is limited to a maximum flow of approximately 1,450 cfs. Figure 15 illustrates how high flows in the Lower Withlacoochee River are truncated compared to upstream flows in the river as a whole (Rainbow + SR200). The Inglis Bypass Channel flows (dark blue data points in Figure 15) illustrate how peak flows to the lower river are much lower, in some cases less than one third of the combined river flows entering Lake Rousseau. Peak flow events are a very important driver for healthy riverine ecology and their elimination is likely a significant environmental stress that is impairing the health of the Lower Withlacoochee River ecosystem (Franklin et al., 2008; Warren et al., 2008).

Physical/Chemical Impairments

FDEP Water Quality Classification and Assessment Status

The Withlacoochee River and Lake Rousseau are classified as Class III state waters (recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife). In addition to this protective classification, all of these waters are also classified as Outstanding Florida Waters where point source pollution discharges are essentially prohibited, and water quality is not allowed to be degraded. However, in 2010, FDEP determined that all the waters in the Lower Withlacoochee River Study Area were impaired under Sections 305(b) and 303(d) of the Clean Water Act (Table 7). The impaired areas of the Lower Withlacoochee River include two segments downstream of Lake Rousseau - the Lower Withlacoochee River below the Inglis Bypass Channel and the river segment between the Inglis Dam and Cross Florida Barge Canal. Each waterbody was listed as impaired for mercury in fish tissue; dissolved oxygen impairments in Lake Rousseau and the Withlacoochee River below the Inglis Dam; benthic macroinvertebrate bioassessment impairment for the Lower Withlacoochee River; and chlorophyll-a impairment in the Lower Withlacoochee River below the Inglis Dam.

Table 7. Water Quality Assessment Report – 2010 (US Environmental Protection Agency, 2010)

Waterbody	Type	Impairment	Cause
Lake Rousseau (FL1329B)	Freshwater Lake	Dissolved oxygen	Organic Enrichment / Oxygen Depletion
		Mercury in fish tissue	Mercury
Withlacoochee River (FL1337)	Stream	Benthic Macroinvertebrate Bioassessment	Cause Unknown – Impaired Biota
		Mercury in fish tissue	Mercury
Withlacoochee River - Cross Florida Barge Canal (FL1329A)	Estuary	Chlorophyll-a	Algal Growth
		Dissolved Oxygen	Organic Enrichment/Oxygen Depletion
		Mercury in Fish Tissue	Mercury

Increasing Anthropogenic Pollutant Concentrations

The review of historical data and collection of additional water quality data during Phases 1 and 2 of this study documented increasing concentrations of the biologically-available inorganic forms of nitrogen and phosphorus. These elevated nutrient levels are likely the chief cause of the elevated chlorophyll-a concentrations in Lake Rousseau and the Lower Withlacoochee River.

Other pollutants detected in the Lower Withlacoochee River Study Area included dissolved metals (arsenic and iron) and synthetic herbicides (fluridone and Diuron). While detected concentrations of these chemicals were below action thresholds, the potential impact of these constituents cannot be determined without further study. Long-term exposure to these classes of pollutants could result in chronic toxicity to the re-establishment of native plants and possible secondary impacts to animals that are expected to occupy the Lower Withlacoochee River (Durkin, 2008; Lee et al., 2001; Negri et al., 2015; Siemering et al., 2008; Wilkinson et al., 2015).

Reduced Light Transmittance (Water Clarity)

Aquatic plant management activities in the Rainbow River and Lake Rousseau kill aquatic vegetation, resulting in decaying plant material settling in the lake and being discharged through the Bypass Channel gate into the Lower Withlacoochee River. This dead and decaying vegetation likely contributes to impacts to the observed river water quality and aesthetics such as excessive foam generation in the Bypass Channel feeding the river.

Water transparency in natural waters can be reduced by dissolved color (plant tannins) and by various forms of turbidity, including free floating algae, zooplankton, and decomposing vegetation. The SR200 Withlacoochee River station above the Rainbow River had the lowest measured light transmittance due to the natural predominance of tannic waters in the upstream watershed. The river station downstream of Rainbow River had better water clarity due to the input of clear spring flows. However, average light transmittance was measurably reduced at the LWR-1 and LWR-2 stations below the Inglis Bypass Channel spillway after travel through Lake Rousseau. As documented by the particulate export sampling, this increase in turbidity appeared to be due to increased plankton populations and particulate organic matter originating in Lake Rousseau. Average transparency increased in the Lower Withlacoochee River further downstream, indicating that the suspended solids entering from the lake had degraded or settled to some extent, allowing greater light penetration.

Studies by Hoyer *et al.* (2004) from the University of Florida on three spring river systems (Chassahowitzka, Homosassa, and Crystal Rivers) determined that light availability was a primary factor affecting the distribution and abundance of submerged aquatic vegetation. They found that for stations where less than 10% of the incident surface light reached the substrate, little to no vegetation biomass was observed. Using a mean depth of 13.0 ft (4.0 m) for the LWR, Figure 32 provides a summary of light transmittance estimates (percent available light remaining) at the substrate during the Phase 2 and supplemental monitoring periods. This analysis indicates that at all of the monitored stations insufficient light was consistently available (less than 10% of incident sunlight) for establishment and growth of submerged aquatic vegetation in the Lower Withlacoochee River.

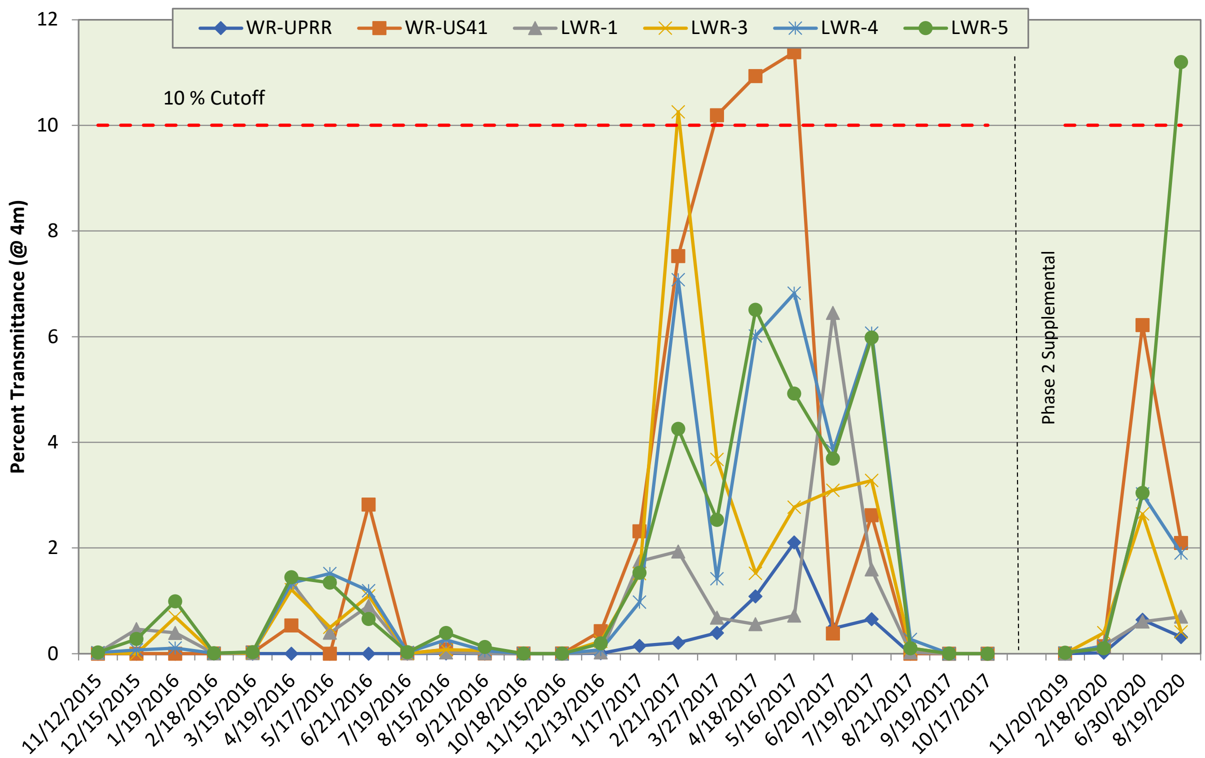


Figure 32. Light Transmittance estimates at 4 meters for the Phase 2 Monitoring Stations within the Lower Withlacoochee River

Rising Salinity

In combination with documented rising sea levels, reduced inflows of freshwater, both average and peak flows, are likely to cause increasing salinity and intrusion distance in the channel of the Lower Withlacoochee River inland from the Gulf of Mexico. Both plant and animal communities that are adapted to life in freshwater are negatively impacted by increasing salinity conditions (Hoyer et al., 2004).

Biological Impairments

Absence of Submerged Aquatic Vegetation

While historically reported in the Lower Withlacoochee River, submerged aquatic vegetation is rare or absent under current conditions. Four factors that may have contributed to this loss are a reduction in water clarity due to increased turbidity and tannic color, reduction in average and peak water velocities due to the bypass of peak flows, the unintended downstream movement of aquatic herbicides applied in Lake Rousseau and increasing exposure to upstream penetration of saltwater from the Gulf of Mexico.

There is evidence that all four of these stresses have or are currently occurring in the Lower Withlacoochee River. Increased tannic color in the lower river is a result of declining base flows (clear groundwater inputs) and eutrophication of the river as it travels through the Lake Rousseau impoundment. It is certainly not the intention of FWC for herbicides to be present in harmful concentrations in the outflow from Lake Rousseau. However, seasonal and persistent concentration increases were documented on more than one occasion at LWR-1. Furthermore, reduced average and peak freshwater flows have reduced average and peak water velocities and allowed saltwater to encroach further upstream into the historically freshwater portions of the Lower Withlacoochee River.

The general absence of submerged aquatic vegetation and the noted occurrences of benthic algae compared to historic conditions, indicate that the base of the aquatic food chain is generally diminished in the Lower Withlacoochee River. Upstream-downstream DO measurements of ecosystem primary productivity supported this observation with very low rates of gross primary productivity and negative net primary production (community respiration higher than primary productivity) in the lower river. Excessive populations of benthic filamentous algae are controlled in spring-fed rivers by high flow events (Reddy et al., 2017). Loss of peak flows may be a causative factor contributing to increased populations of benthic filamentous algae in the Lower Withlacoochee River.

The community metabolism data and the particulate export measurements documented that the Lower Withlacoochee River is heterotrophic. This means that the river's food web is dependent on external organic carbon inputs rather than on internal primary productivity. Based on field observations, these allochthonous organic carbon inputs are most likely dominated by the export of dead and rotting aquatic vegetation from Lake Rousseau and litter fall from the vegetation growing along the banks of the Lower Withlacoochee River.

Marginal to Suboptimal Aquatic Habitat for Macroinvertebrates

FDEP's habitat assessment data for the Lower Withlacoochee River indicated poor environmental conditions for supporting healthy macroinvertebrate populations. These tiny organisms include aquatic worms, insects, and other invertebrates that normally provide the first level of a healthy aquatic food web that supports fish and other vertebrate wildlife. Adequate populations of these organisms are dependent upon suitable habitat, including good water quality, adequate freshwater flows, and the presence of native submerged aquatic vegetation. The macroinvertebrate data collected in the study area indicate a lack of suitable habitat and confirm the predominance of pollution-tolerant organisms in the lower river, especially just below the discharge from Lake Rousseau through the Inglis Bypass Channel gate. Many of these organisms generally subsist on decaying organic matter and are tolerant of polluted water conditions.

Dominance by Rough Fish Tolerant of Pollution

Based on FWC electrofishing data, fresh and saltwater fish populations exist in the Lower Withlacoochee River. In terms of fish species, threadfin shad were most abundant, comprising 29% of the freshwater fish population biomass. This species of fish is a plankton feeder, presumably feeding on the abundant particulate matter (live and dead phytoplankton, pseudo-plankton, and zooplankton) entering the lower river through the Inglis Bypass Channel from Lake Rousseau. The largest fraction of freshwater fish in the lower river as indicated by biomass were non-game species, including gar and bowfin. These species are adapted to survive and dominate in low oxygen waters characterized by inputs of decaying organic matter. The most abundant saltwater fish species was striped mullet. These catadromous fish feed on benthic and attached algae in coastal, spring-fed rivers. Smaller populations of spotted sunfish, largemouth bass, and snook indicate that this impaired lower river segment still retains some habitat value for prized game fish.

Summary of Biological Impairments

Prior to construction of the Inglis Dam and eventual aging of Lake Rousseau, the predominant base flow feeding the Lower Withlacoochee River would have been spring flows from the Rainbow River and other springs upstream and downstream of the Rainbow River. A predominance of spring water with high clarity likely allowed adequate sunlight to sustain a healthy community of submerged aquatic vegetation in the lower river. The photosynthesis of this vegetative community would have served as the base of an autotrophic food web similar to the Rainbow River, with high fish and other wildlife production. Over the past 50+ years those spring-fed base flows have declined significantly, and nitrogen levels have increased. As evidenced by this study, the quality and quantity of the water feeding the Lower Withlacoochee River has likely changed markedly due to impactful human developments throughout the contributing surface and groundwater basins, the impoundment of Lake Rousseau, the lake's eutrophication and excessive growth of plants, and their subsequent chemical control.

Structural Impairments

Inglis Dam

The original impoundment of the Withlacoochee River that formed Lake Rousseau occurred more than 100 years ago. Installation of this dam would have resulted in the loss of migrating fish and manatees moving freely between the Gulf of Mexico and the upstream river and springs. Ongoing ecological research at Silver Springs comparing biological conditions in the Silver River before and after installation of the Rodman Dam on the Ocklawaha River has attributed some portion of losses of fish biomass and ecological productivity to this disconnection of the aquatic migration of these organisms (Munch et al., 2006). The same effect is expected to be the case for the longer-lived presence of the Inglis Dam.

Cross-Florida Barge Canal

While installation of the Inglis Dam resulted in impairments to the lower river segment due to the gradual water quality changes resulting from the filling and eutrophication of the lake and the restrictions on aquatic animal movement, it did not eliminate high peak flows from periodically going through the Lower Withlacoochee River. These peak flows are essential in rivers to move detritus and sediments, flush out pollutants, and maintain healthy plant and animal populations. Until the 1960s, peak flows continued to occur over the dam to the entire natural channel of the Lower Withlacoochee River. These periodic peak flood flows were eliminated with construction of the western terminus of the Cross-Florida Barge Canal and construction of the Inglis Bypass Channel. This modification resulted in the elimination of peak flood flows that could be expected to transport and flush accumulated sediments and algae in the Lower Withlacoochee River since that time (more than 50 years ago).

Residential and Commercial Development

Many structural changes have occurred throughout the Lower Withlacoochee River Study Area and the contributing surface water and groundwater basins over the past 100+ years. These changes have included installation of thousands of septic systems, landscaped lawns, impermeable building and shoreline surfaces, limerock mines, and intensive agricultural operations. Direct alterations on and adjacent to the Lower Withlacoochee River include at least 2,000 home sites and associated septic systems, over 200 docks, and conversion of nearly 50% of the shoreline of the lower river to hardened structures such as sea walls or shoreline rip-rap. These indirect and direct modifications have all contributed to changes to the physical and chemical environment of Lake Rousseau and the lower river. Environmental impacts associated with this continuing waterfront development include impaired water quality, reduced shoreline wildlife habitat, and increased stormwater runoff.

Future Impacts

Development impacts from agricultural, urban, and industrial development are expected to increase with time. At current growth rates Florida's resident and tourist population may double in the next 50 years[6]. With continuing human population increases and associated urban, agricultural, and industrial development comes more human and animal wastewaters; more nitrogen loading from fertilizer; more groundwater withdrawals; construction of additional homes, roads, and other impervious surfaces; and greater recreational impacts to navigable water bodies. A plan for the long-term restoration of the Lower Withlacoochee River must not only compensate for the impacts that have occurred up until the present but must also offset future impacts that are considered inevitable.

Goals for Environmental Restoration

Hydrological

Significant changes in regional water consumption must be made to restore protective flows to the Lower Withlacoochee River. Assuming a 10% flow reduction may be allowed by the Lower Withlacoochee River MFL analysis currently underway, an ambitious goal for flow restoration to the Lower Withlacoochee River is reestablishing at least 90% of average historical flow rates. Based on an estimated average baseflow at the dam of 1,800 cfs, and a current average flow of about 1,250 cfs, this target flow increase is estimated at about 350 cfs.

Complete restoration of the Lower Withlacoochee River would require removal of the lake and dam to return the river to its natural channel and revegetation of its lost riverine forest plant community. This outcome is likely infeasible because of flooding concerns, property rights, and the substantial ecological changes that would occur with removing a large lake and associated habitat that has developed over the past 110 years. While complete dam removal may not be feasible, repair of the existing lock or construction of a new lock that facilitates passage of fish and manatees into the Withlacoochee River, as well as periodic drawdowns of the water levels in Lake Rousseau are possible options for further consideration.

Another achievable alternative for environmental enhancement of the Lower Withlacoochee River would be restoration of historic peak flows from Lake Rousseau to the Lower Withlacoochee River. This change could be accomplished in one of two ways. Either increasing the hydraulic capacity of the Inglis Bypass Channel and the control gate to between 2,500 and

[6] https://npg.org/specialreports/FL/fl_report.html

4,500 cfs, or reconnection of the dam to the historic channel of the lower river, by installing a new lock in the Cross-Florida Barge Canal downstream of a restored connection between the two natural sections of the Lower Withlacoochee River. Modifications to the outfall at the Bypass Channel should also change the current structure from an underflow gate to an overflow weir with a skimmer to avoid entraining and transporting decaying organic material that reduces light transmittance to the lower river.

A further improvement at Lake Rousseau that should occur is repair of the approximately 105-167 cfs leakage that currently occurs under or around the Inglis Dam to the Barge Canal. This flow constitutes more than 10% of the current average flow in the Lower Withlacoochee River and is water that should flow through the Bypass Channel to the Lower Withlacoochee River. This water is particularly critical during droughts when this could constitute 20% or more of the flow in the Lower Withlacoochee River. Furthermore, there appears to be some likelihood that this flow could be the result of dam construction that intercepted a "big spring" or "subterranean river" that was subsequently blocked up to allow for dam construction ("An Immense Undertaking," 1909).

Water Quality

The largest source of pollutants affecting the Lower Withlacoochee River currently is the nitrate-nitrogen discharging from the Rainbow River above US 41. In 2009, FDEP issued a nitrate-nitrogen Total Maximum Daily Load (TMDL) that required >80% reduction of nitrate loads to the Rainbow River and springs (Holland & Hicks, 2013). In 2018, the FDEP issued a Basin Management Action Plan (BMAP) intended to achieve that nitrate load reduction goal within the next 20 years (Florida Department of Environmental Protection, 2015). Accelerated achievement of this BMAP is essential to restoring the ecological and economic health of the Lower Withlacoochee River in a timely fashion. Greatly reducing nitrogen inputs from the Rainbow River to Lake Rousseau will likely reduce the current excessive growth of invasive plants and reduce reliance on the use of aquatic herbicides.

Additional water quality impacts to the Lower Withlacoochee River are the result of poor water quality discharging into the river channel from Lake Rousseau, and due to residential and commercial development along the lower river. Reducing water quality problems in the Lower Withlacoochee River resulting from existing and any future shoreline development should include abandonment of septic systems on lots less than one acre with connection to central sewer for all residences and businesses, with advanced wastewater treatment and groundwater recharge within the springshed for recycling highly treated effluent back to the Floridan Aquifer. Use of fertilizers and pesticides should be regulated within a riverine buffer zone through a city or county ordinance. Finally, limits should be established for further shoreline development, including docks and seawalls that allows a maximum length of hard seawall combined with a more environmentally-friendly option such as living shorelines, or natural shoreline for the remaining shoreline as implemented in the City of Dunnellon (Florida Department of Environmental Protection, 2015).

Restoration Implementation Plan

Responsible Parties

Relocating the east terminus of the Cross-Florida Barge Canal and enhancing the Lower Withlacoochee River is a worthy goal for the residents of Florida. This goal will only be realized through a partnership between the affected public and local governments on one hand, and the Governor, cabinet, legislature, and state agency heads on the other. Federal monetary support should also be sought to modify the Cross-Florida Barge Canal and to achieve the water quality improvement goals of the Clean Water Act.

Stakeholder Engagement

All affected parties will need to be involved in this proposed restoration project. This includes all landowners on the Lower Withlacoochee River and all landowners within the Rainbow Springshed. Other stakeholders will include city and county governments, local businesses, SWFWMD, FDEP, FWC, USFWS, Florida Legislature, United States Coast Guard, and United States Army Corps of Engineers.

Regulatory Enforcement

The existing water quantity and quality impairments noted at Rainbow Springs and the Rainbow River need to be fully and expeditiously addressed by state governmental agencies. This includes full implementation of the Rainbow River BMAP, completion of the Lower Withlacoochee River MFL, and development of a TMDL and BMAP for Lake Rousseau and the Lower Withlacoochee River.

Given FDEP's Rainbow River BMAP, a fertilizer ordinance should be developed for both urban and agricultural inputs and implemented throughout the 737 square mile Rainbow Springshed. In addition, sewering all septic systems on parcels of one acre or less throughout the springshed should be prioritized. Marion County Utilities has already prepared a public-private partnership concept to make these connections at no public expense (Mellinger, 2015).

Based on the observed decreases in baseflows documented in this study, efforts should be made to prioritize groundwater recharge in both the Rainbow Springshed and Withlacoochee groundwater basin. This recharge will bolster aquifer levels and increase baseflows in the Rainbow and Withlacoochee Rivers. Recharge can be provided in both existing projects and in new projects designed to recharge treated wastewater and/or stormwater.

Structural Modifications

A variety of alternatives exist to provide structural improvement and environmental enhancement on the Lower Withlacoochee River. Two primary options are discussed with a variety of sub-projects that could be a part of each. Additionally, a variety of separate projects exist that would apply in the case of either alternative. Expected conceptual cost ranges for each alternative are also defined below. Some of the restoration components were previously evaluated for the SWFWMD (URS, 2004). Where applicable, component costs for Alternative 1 and 2 were extrapolated and escalated from 2003 costs to present day values using a cost multiplier of 1.74 (Hale & R.S. Means Company, 2018). 'Other Projects' expected conceptual cost sources are identified below.

Alternative 1: Bypass Channel Modifications

- Reconstruction of the Inglis Bypass Channel to allow passage of flood flows to the lower river (an increased capacity to between 2,500 and 4,500 cfs[7]) and conversion from the existing underflow gate to an overflow gate. [$20-30 M]
- Restoration of the Inglis Lock to allow controlled passage of manatees and fish between the Gulf and the river. [$5-10 M]

Alternative 2: Re-Connection of the Lower Withlacoochee River

- Reconnection of the Inglis Dam overflow to the Lower Withlacoochee River segment by closing the Cross-Florida Barge Canal and installing a lock at or upstream of the FWC ramp and facility, and removing the earthen fill blocking the historic channel of the lower river. [$50-75 M]
- The Barge Canal channel from the new Inglis Lock to the Gulf of Mexico can be maintained as a protected inland boat harbor and boat ramp and landing for the general public, FWC, and the Florida Marine Patrol. This channel could also serve to provide flood protection under extreme events. [maintain as-is]

Other Projects

- Repair of the existing leak around the Inglis Dam. [$1–5 M]
- Provide central sewer to all homes located in the springshed. [$15,000 - 40,000/home][8]
- Establish a fertilizer ordinance for the springshed. [$250,000 - 500,000][9]
- Provide improved wastewater management and recharge throughout the springshed. [$50-75 M]
- Discontinue herbicide application within a minimum of 500' of structures that discharge to downstream waterbodies except in the immediate vicinity of structures. [minor cost savings]

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[7] A detailed hydrologic modeling of the lower river's flow capacity range should be evaluated before any improvements are made.

[8] approximate costs of septic-to-sewer projects in FDEP Springs Funding requests (https://floridadep.gov/springs/restoration-funding), accessed 5/18/2021

[9] Florida Department of Environmental Protection, 2020

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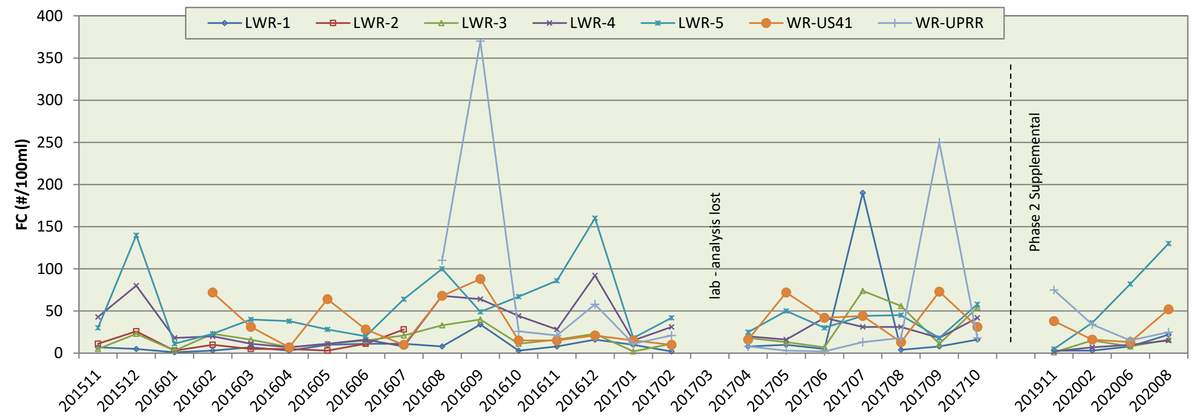
Appendix A

Phase 2 Water Quality Data Summary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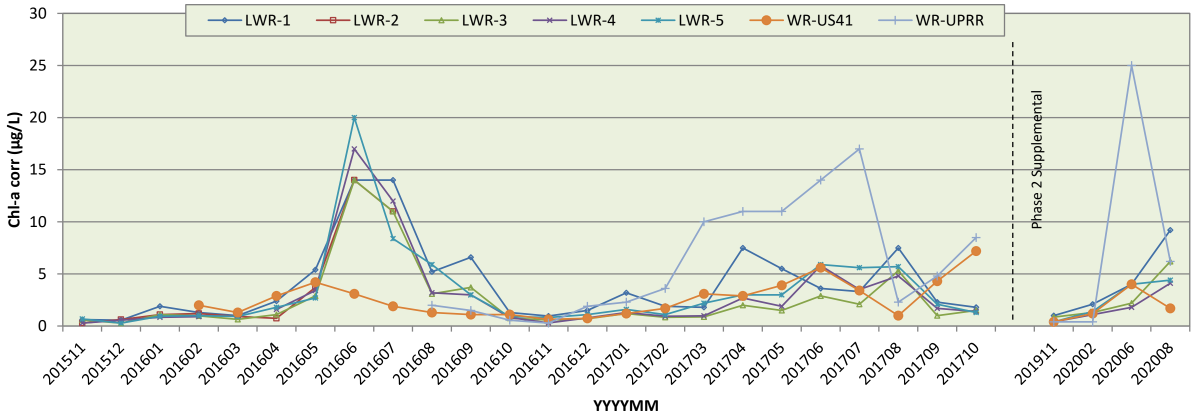
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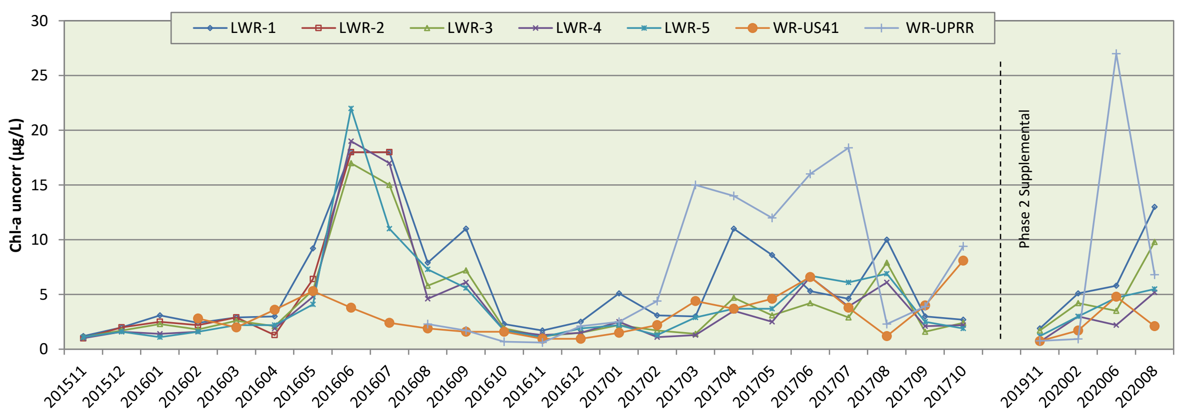
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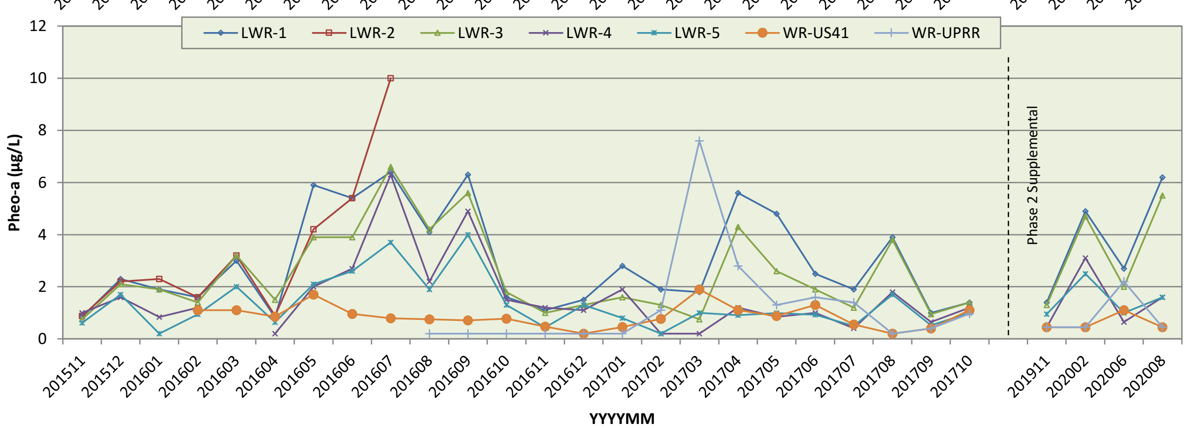
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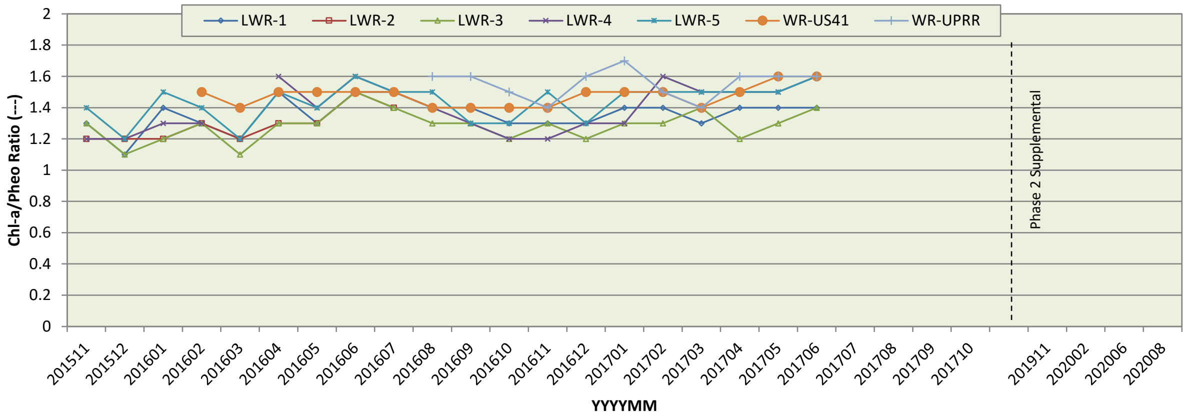
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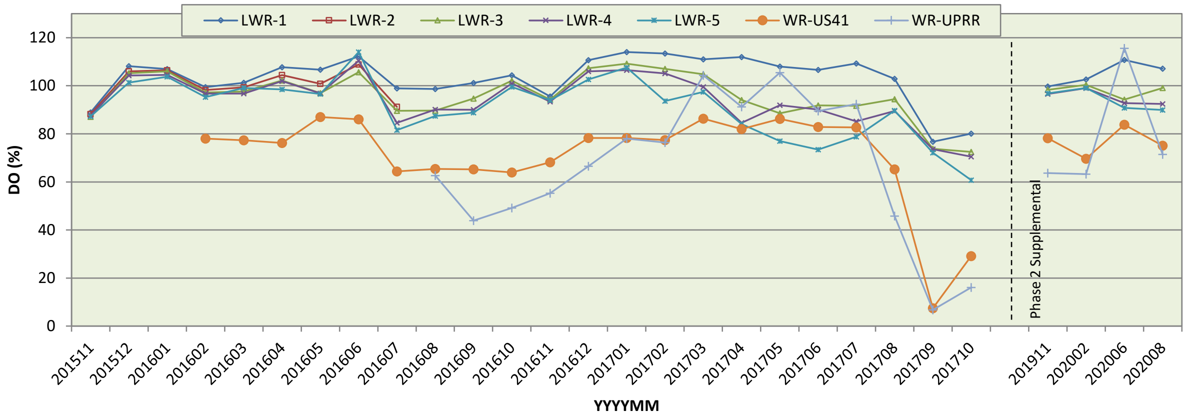
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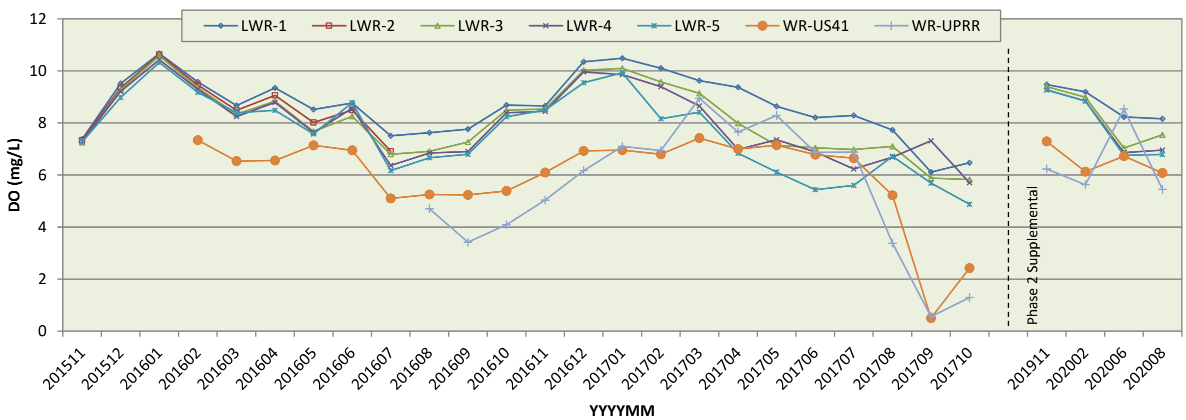
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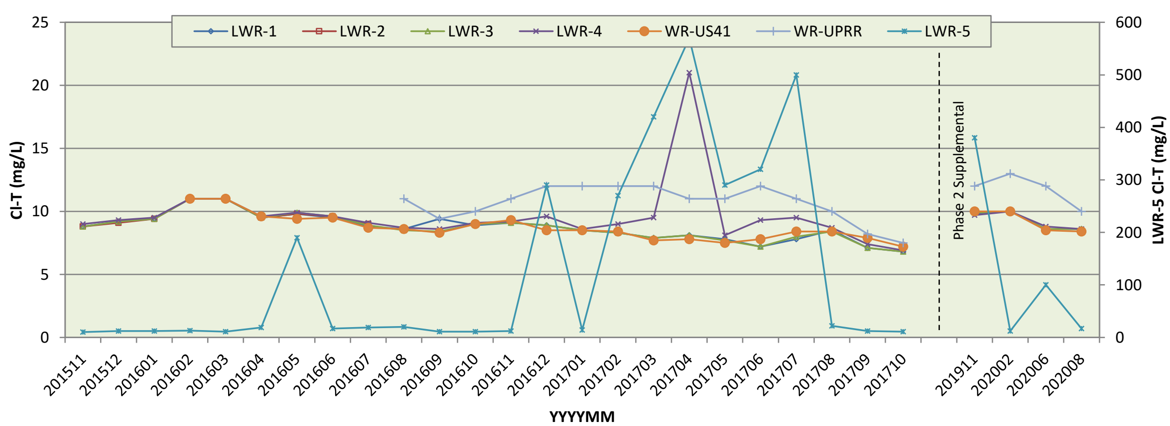
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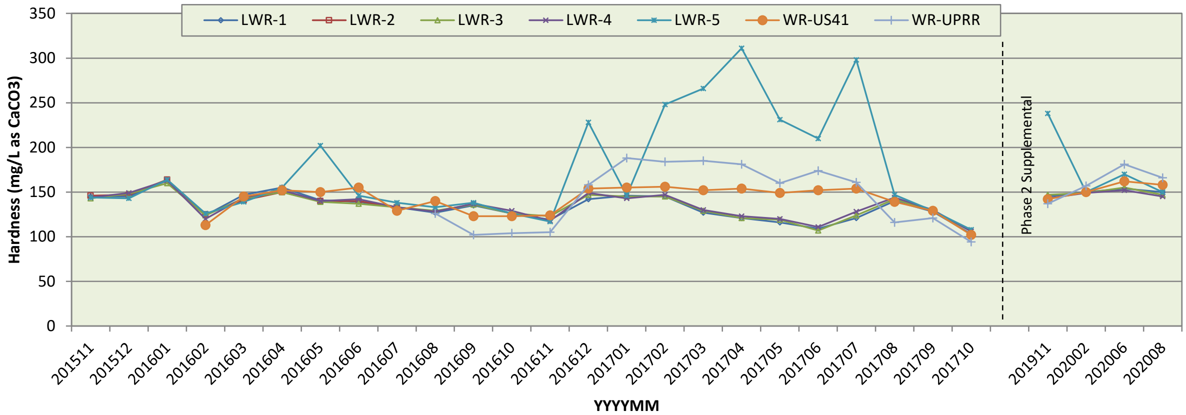
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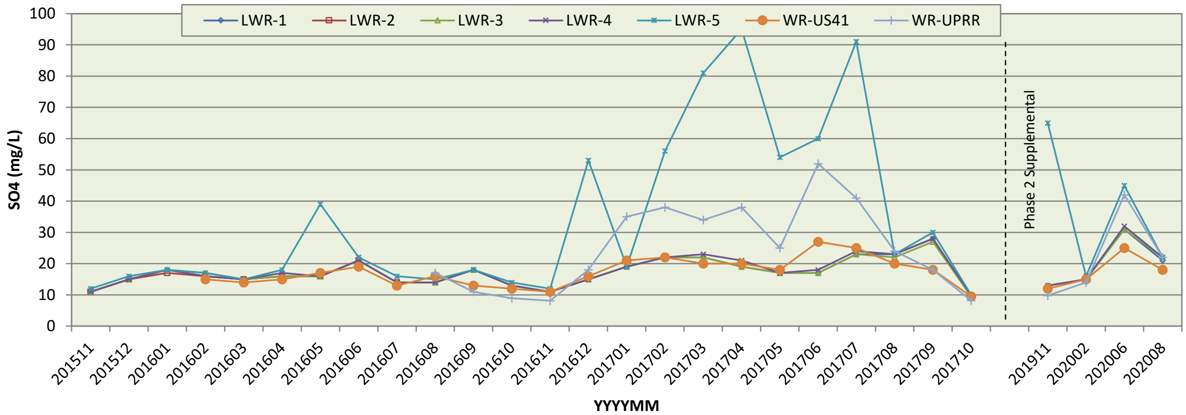
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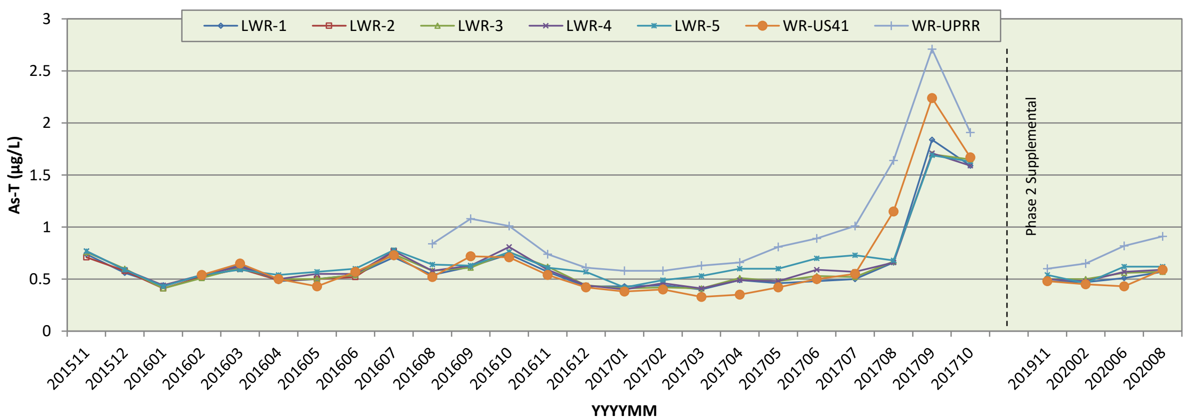
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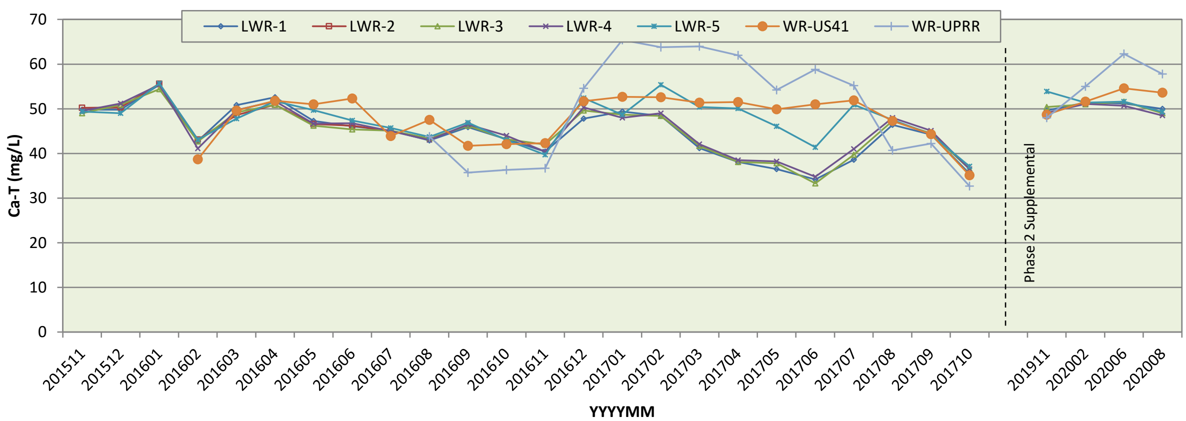
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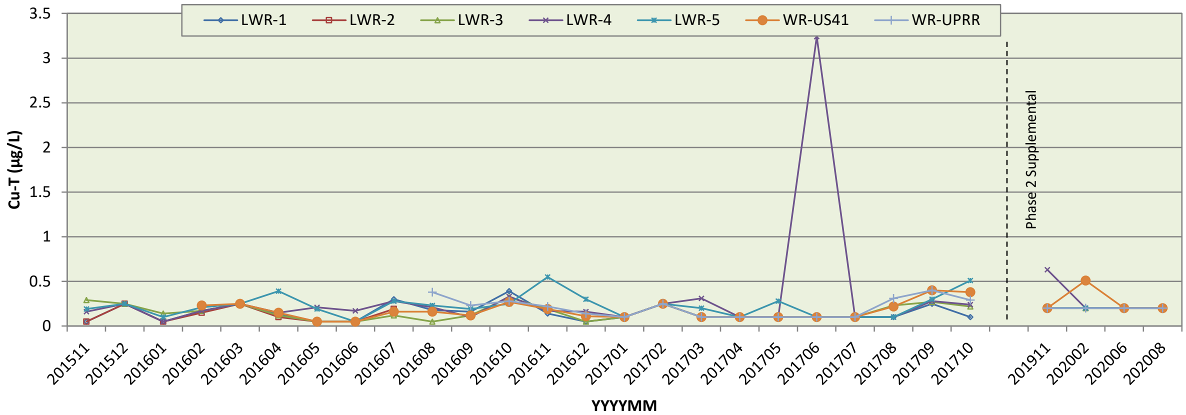
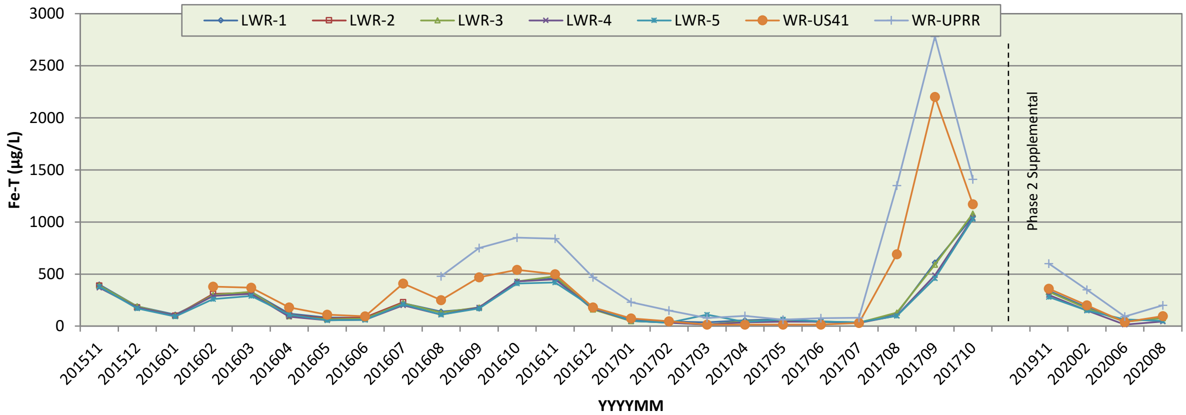
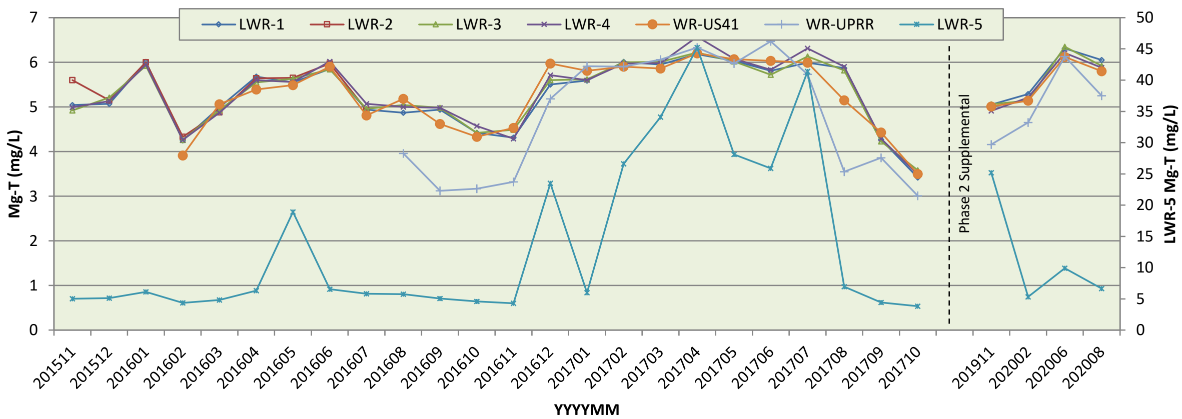
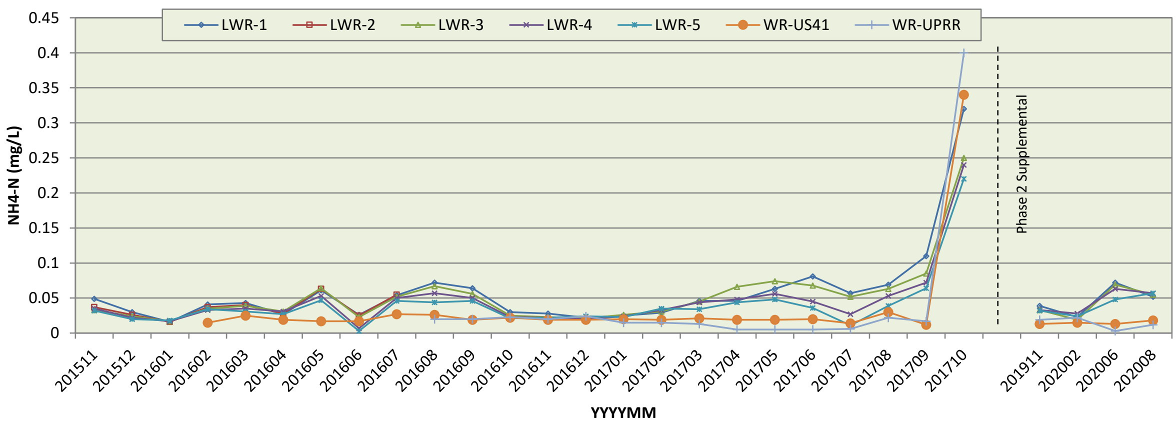
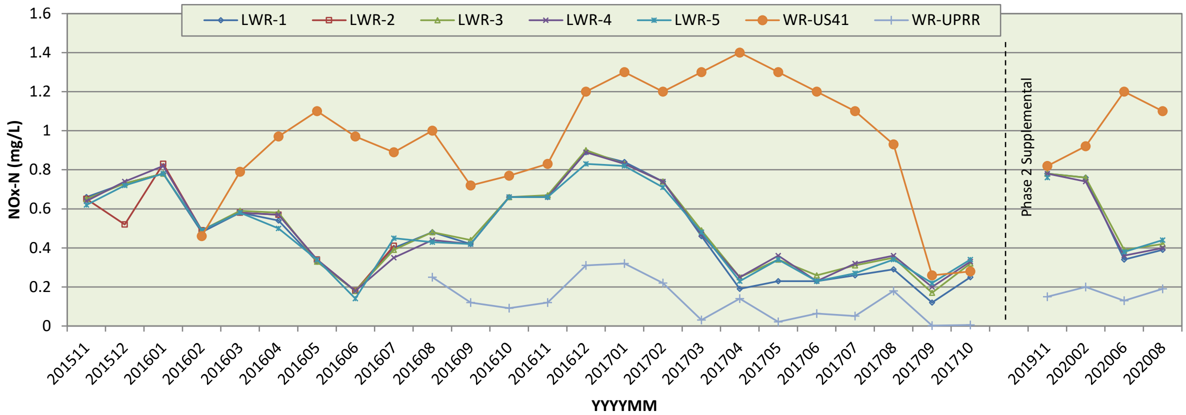
LWR-5
WR-US41
WR-UPRR
Ca-T (mg/L)
Phase 2 Supplemental
YYYYMM

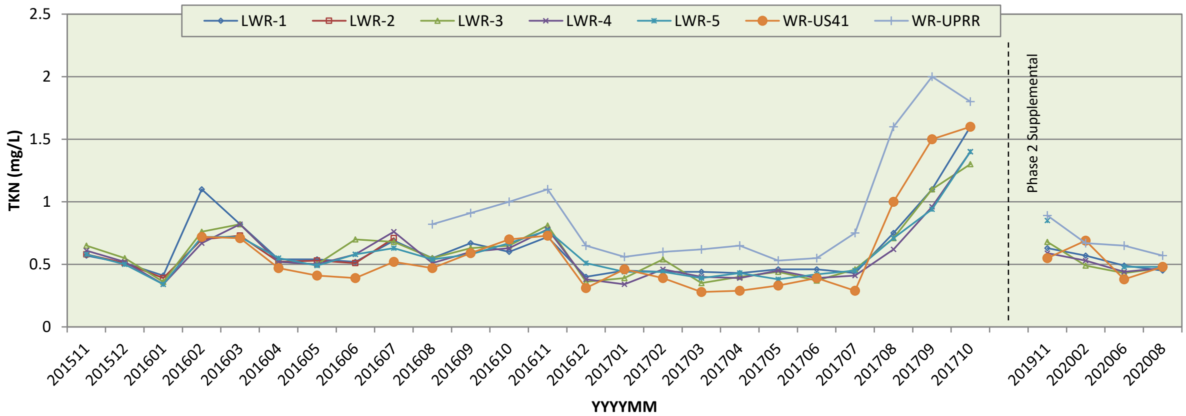

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Cu-T (µg/L)
Phase 2 Supplemental
YYYYMM

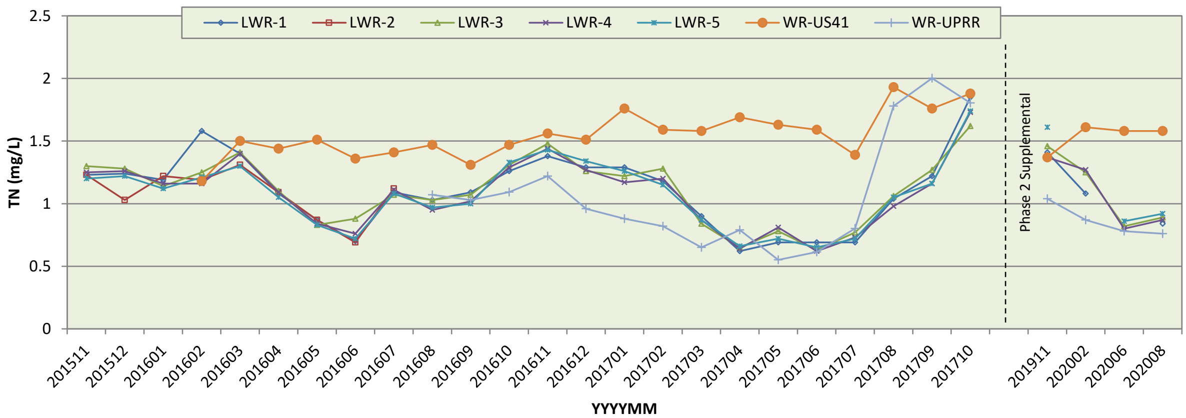

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Fe-T (µg/L)
Phase 2 Supplemental
YYYYMM

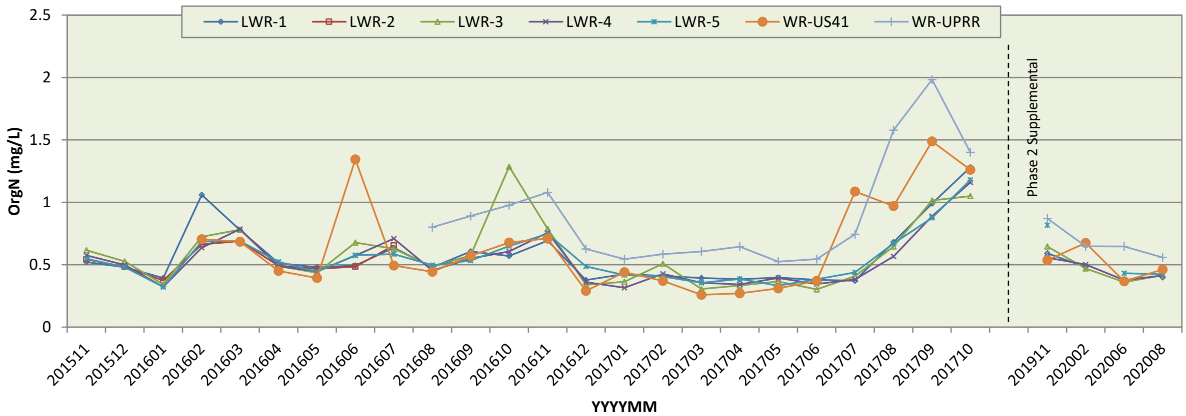

LWR-1
LWR-2
LWR-3
LWR-4
WR-US41
WR-UPRR
LWR-5
Mg-T (mg/L)
LWR-5 Mg-T (mg/L)
Phase 2 Supplemental
YYYYMM

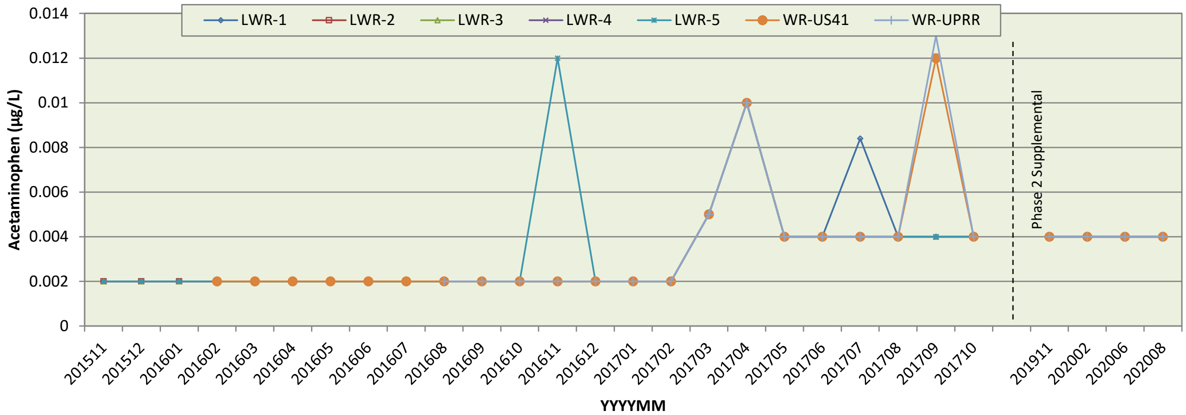

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
NH4-N (mg/L)
Phase 2 Supplemental
YYYYMM

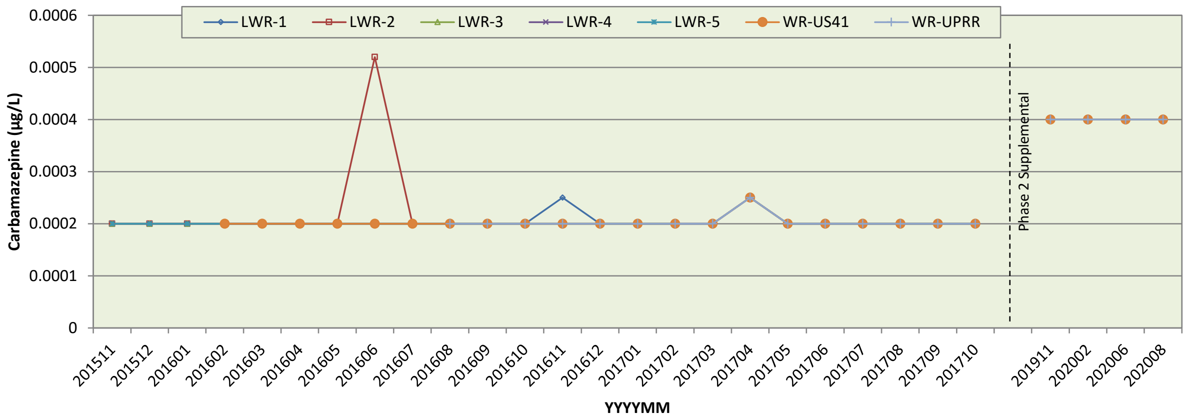

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
NOx-N (mg/L)
Phase 2 Supplemental
YYYYMM

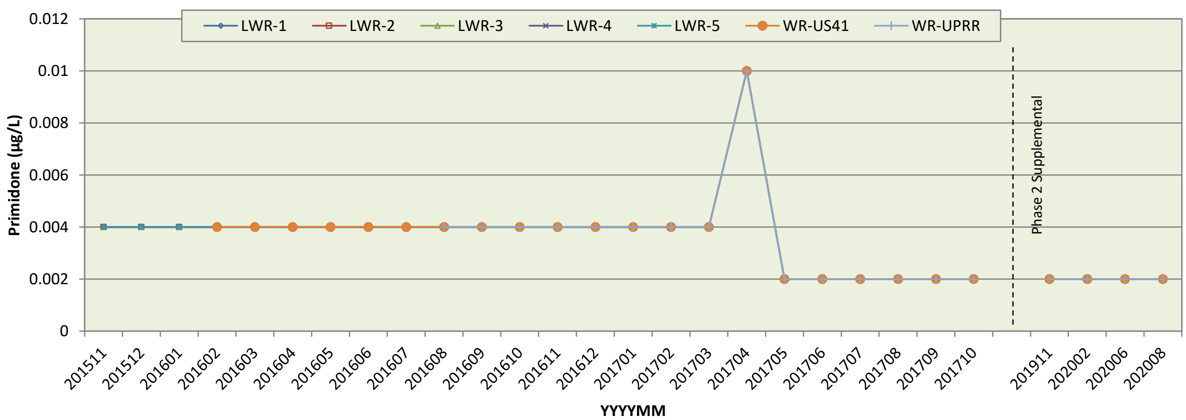

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
TKN (mg/L)
Phase 2 Supplemental
YYYYMM

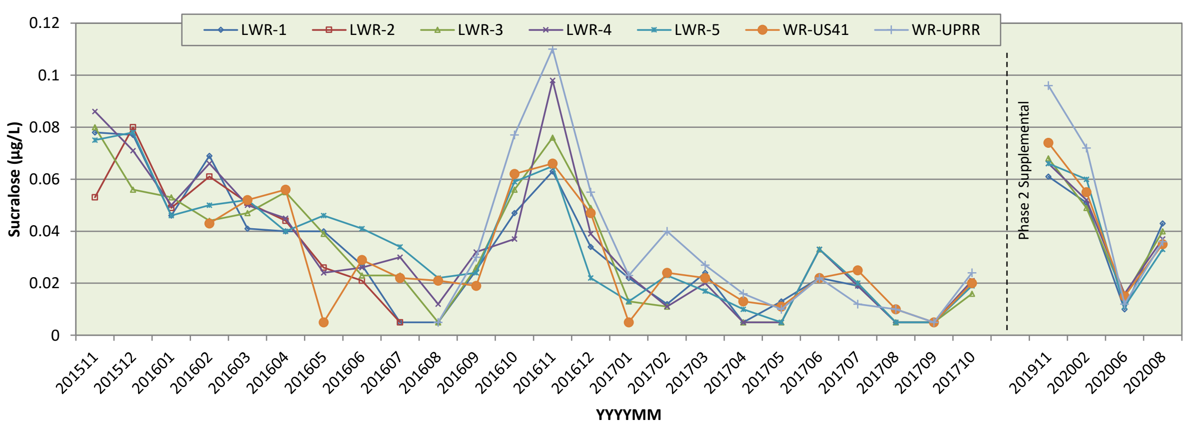

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
TN (mg/L)
Phase 2 Supplemental
YYYYMM

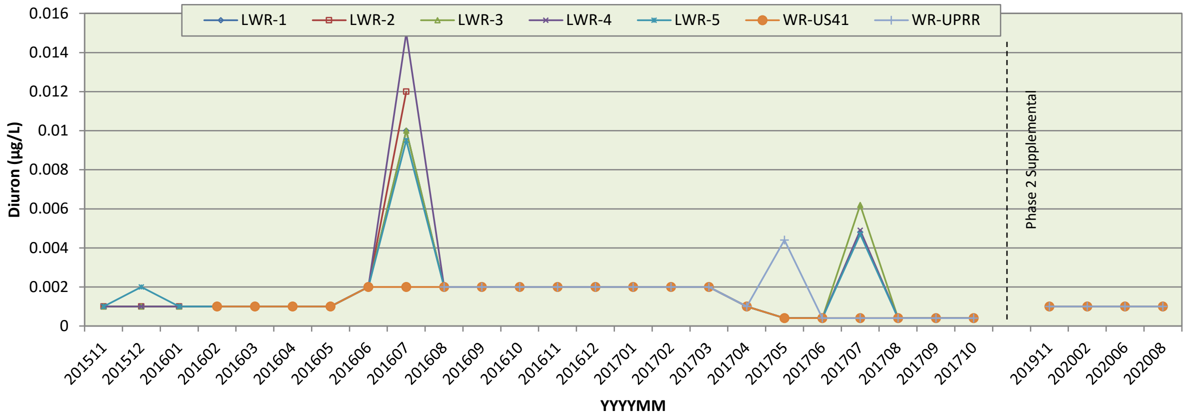

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
OrgN (mg/L)
Phase 2 Supplemental
YYYYMM

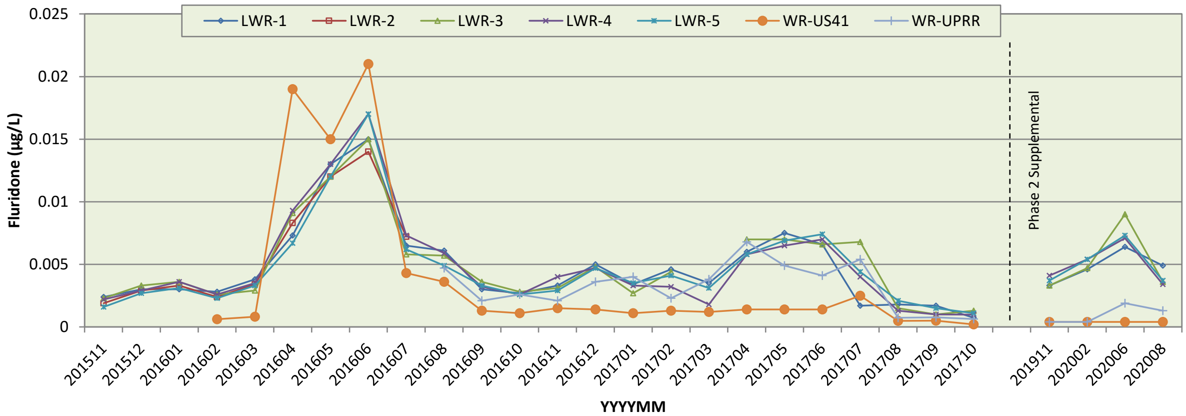

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Acetaminophen (µg/L)
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
Phase 2 Supplemental
201511 201512 201601 201602 201603 201604 201605 201606 201607 201608 201609 201610 201611 201612 201701 201702 201703 201704 201705 201706 201707 201708 201709 201710 201911 202002 202006 202008
YYYYMM

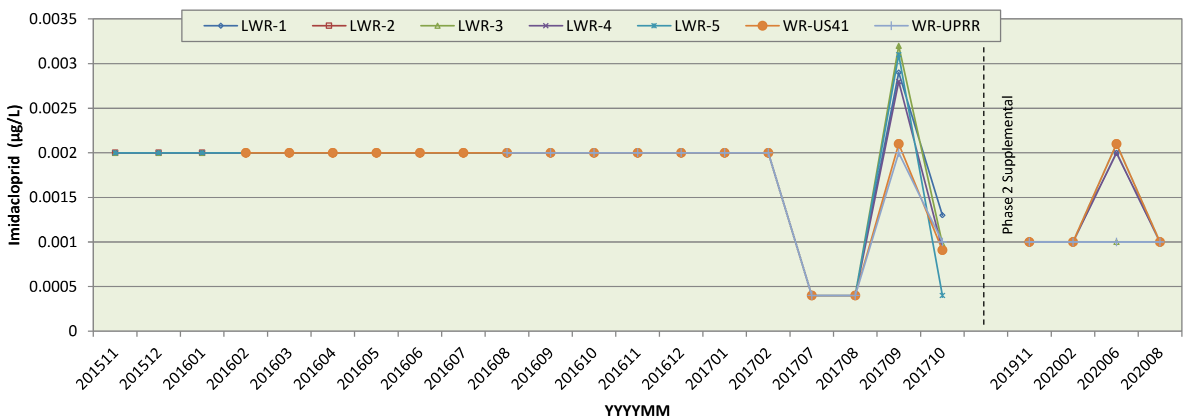

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Carbamazepine (µg/L)
0
0.0001
0.0002
0.0003
0.0004
0.0005
0.0006
Phase 2 Supplemental
201511 201512 201601 201602 201603 201604 201605 201606 201607 201608 201609 201610 201611 201612 201701 201702 201703 201704 201705 201706 201707 201708 201709 201710 201911 202002 202006 202008
YYYYMM

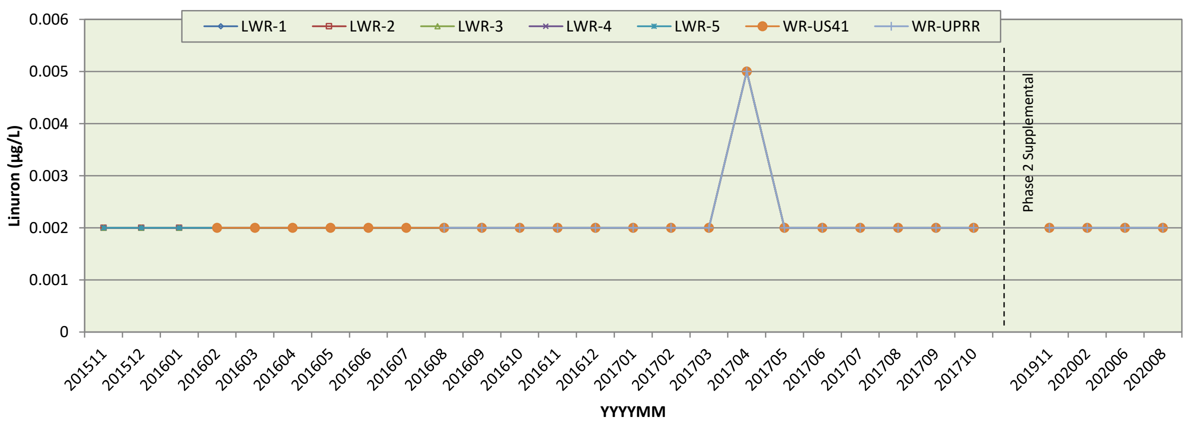

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Primidone (µg/L)
0
0.002
0.004
0.006
0.008
0.01
0.012
Phase 2 Supplemental
201511 201512 201601 201602 201603 201604 201605 201606 201607 201608 201609 201610 201611 201612 201701 201702 201703 201704 201705 201706 201707 201708 201709 201710 201911 202002 202006 202008
YYYYMM

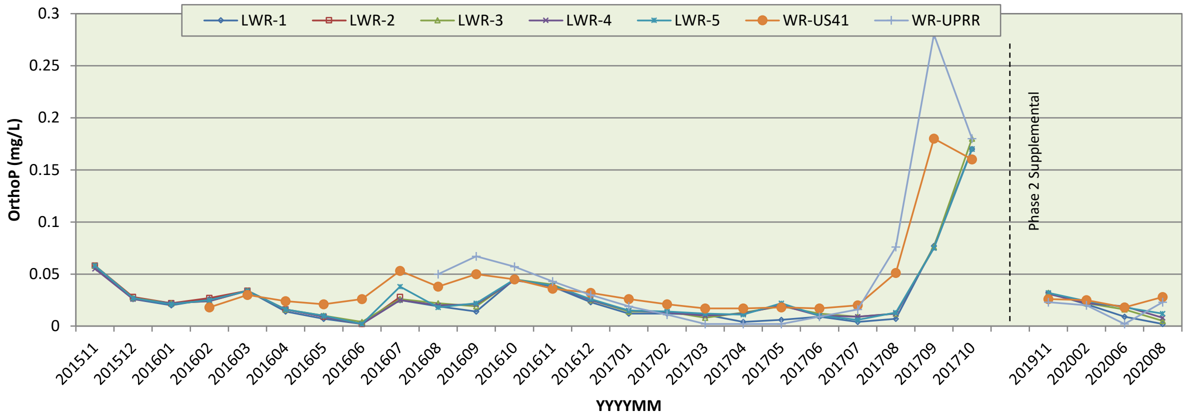

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Sucralose (µg/L)
0
0.02
0.04
0.06
0.08
0.1
0.12
Phase 2 Supplemental
201511 201512 201601 201602 201603 201604 201605 201606 201607 201608 201609 201610 201611 201612 201701 201702 201703 201704 201705 201706 201707 201708 201709 201710 201911 202002 202006 202008
YYYYMM

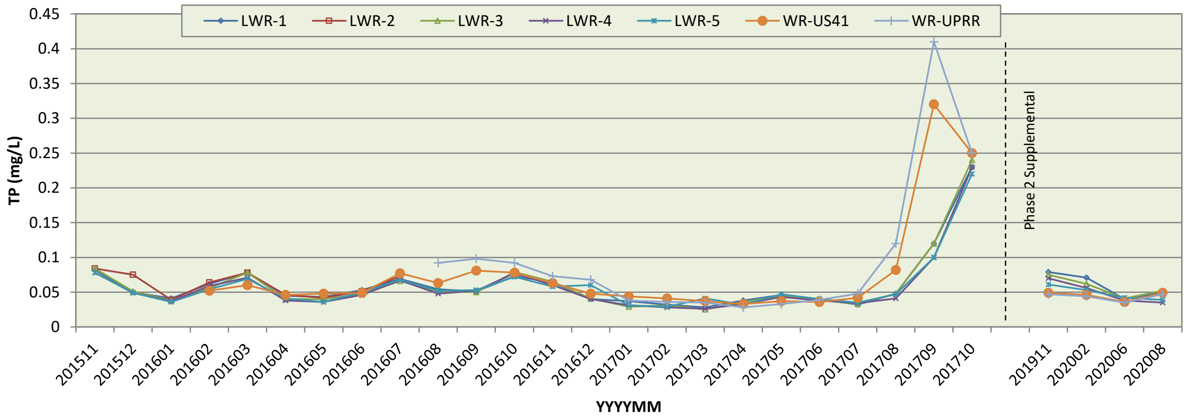

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Diuron (µg/L)
Phase 2 Supplemental
YYYYMM

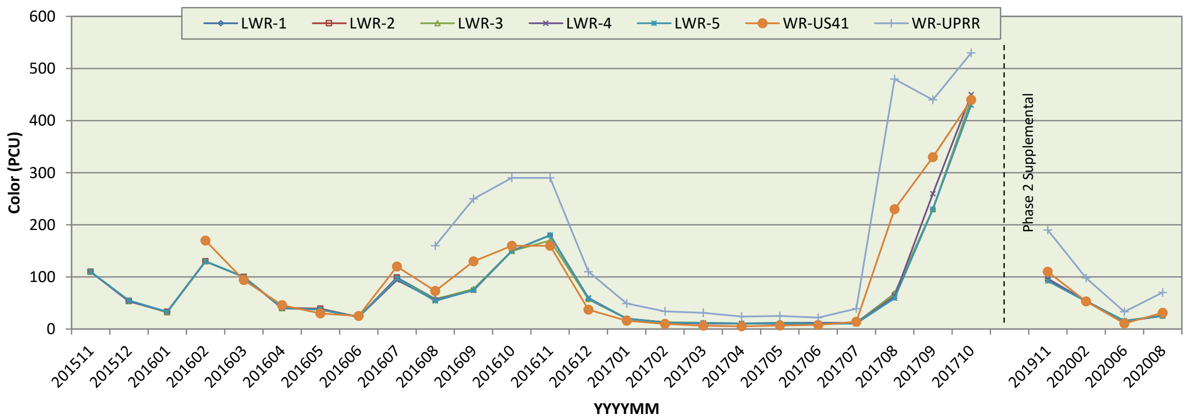

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Fluridone (µg/L)
Phase 2 Supplemental
YYYYMM

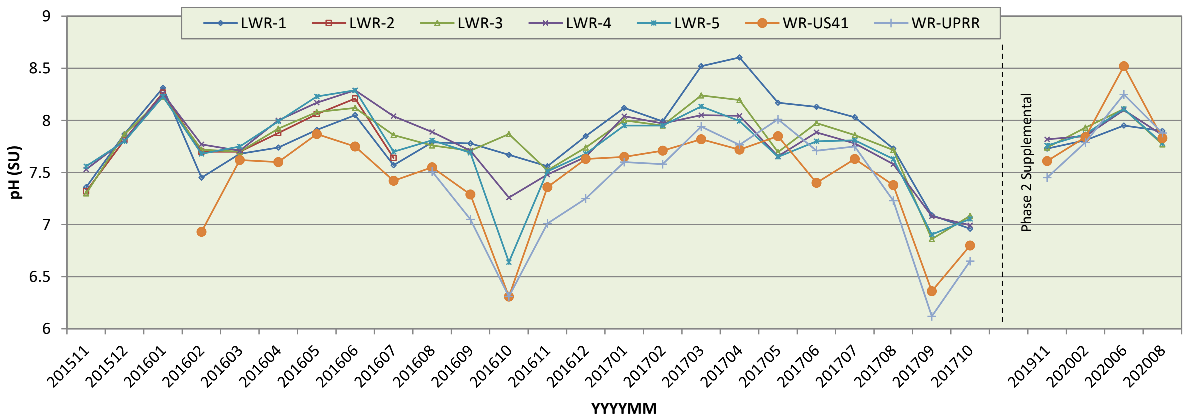

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Imidacloprid (µg/L)
Phase 2 Supplemental
YYYYMM

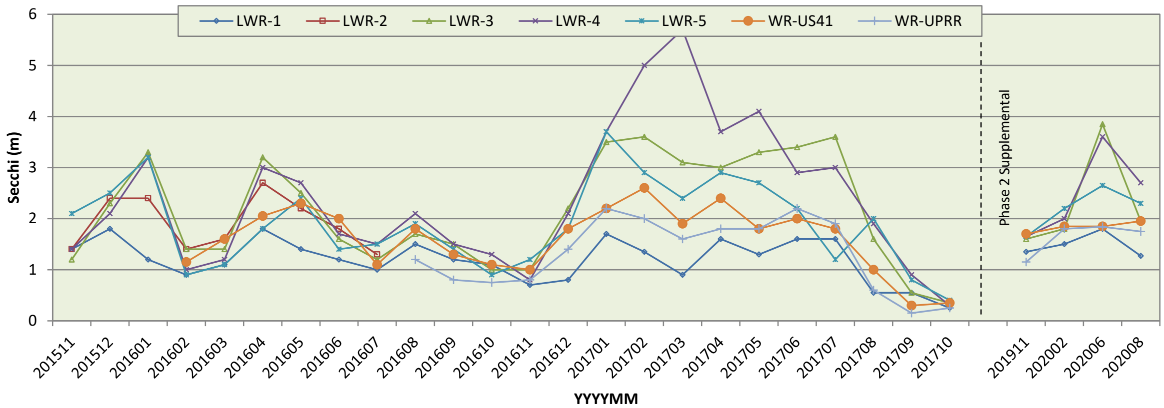

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Linuron (µg/L)
Phase 2 Supplemental
YYYYMM

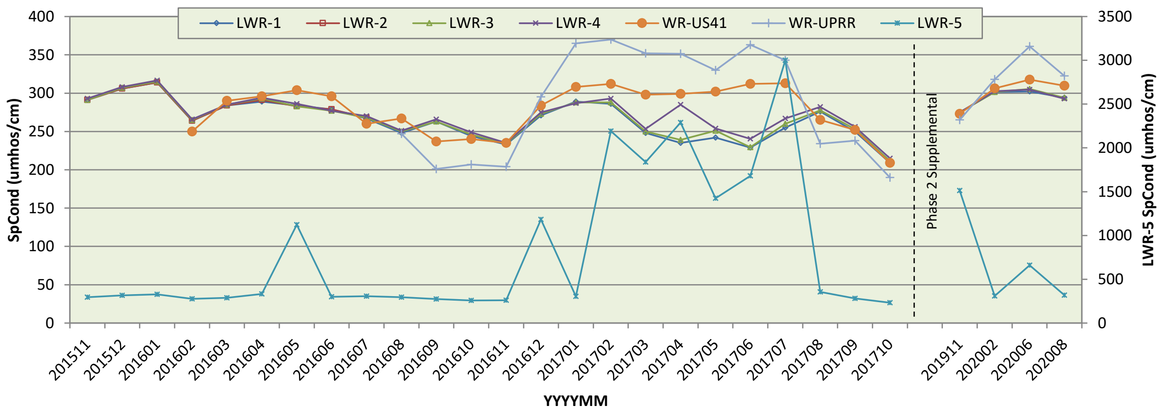

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
OrthoP (mg/L)
Phase 2 Supplemental
YYYYMM

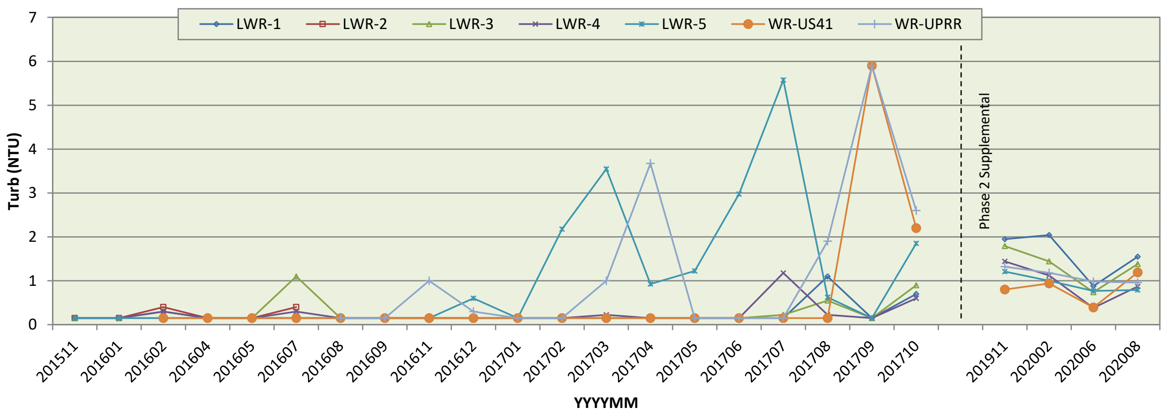

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
TP (mg/L)
Phase 2 Supplemental
YYYYMM

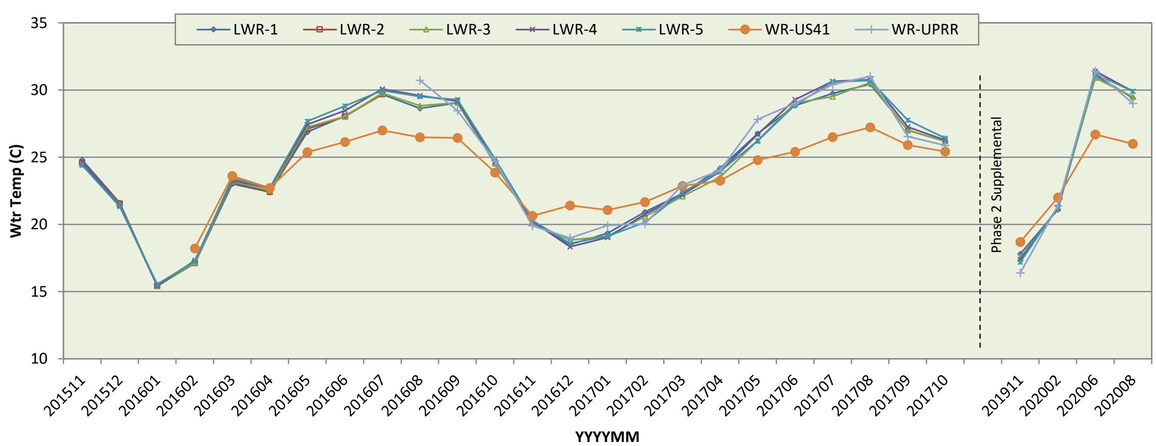

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Color (PCU)
Phase 2 Supplemental
YYYYMM

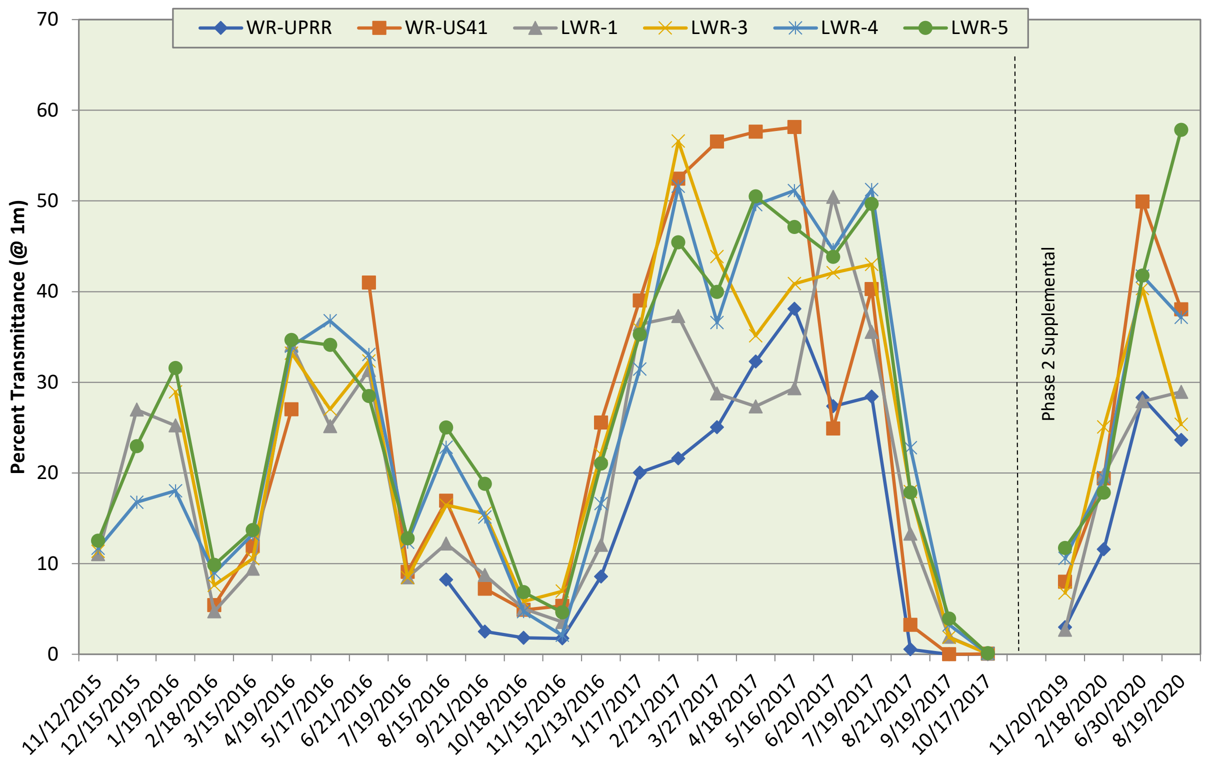

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
pH (SU)
Phase 2 Supplemental
YYYYMM

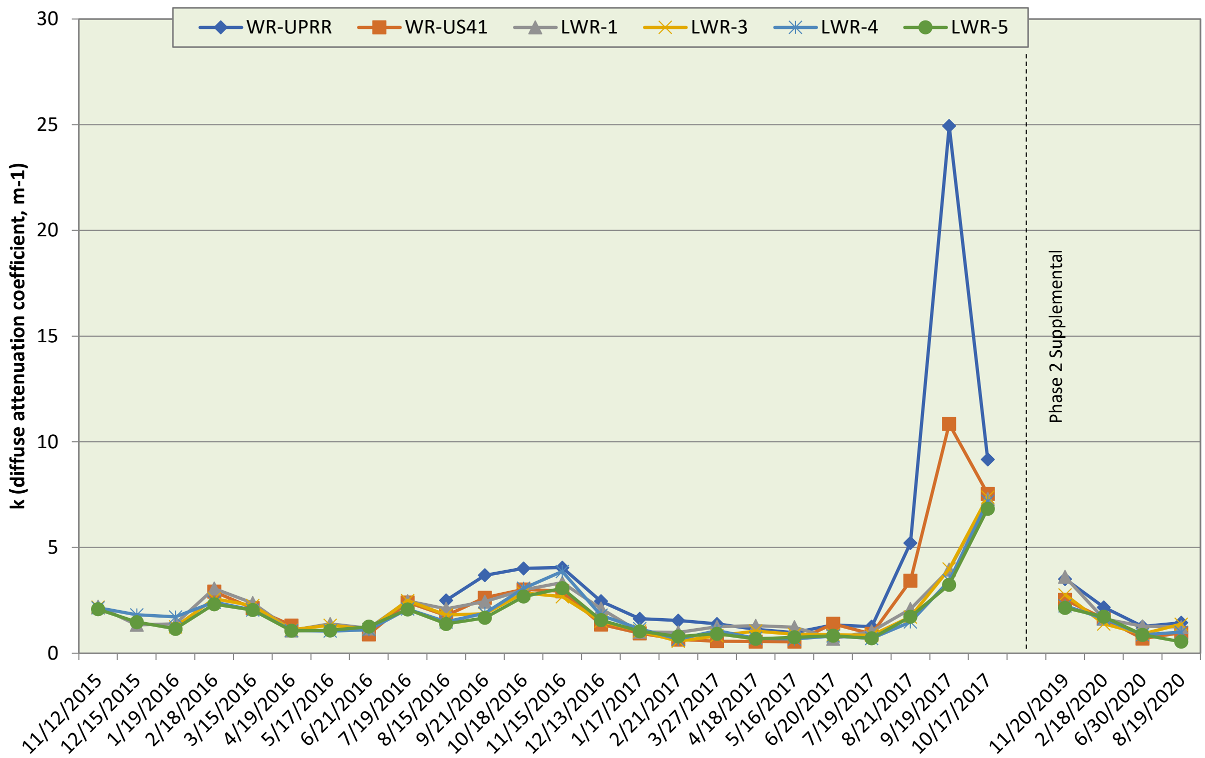

LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Secchi (m)
Phase 2 Supplemental
YYYYMM


LWR-1
LWR-2
LWR-3
LWR-4
WR-US41
WR-UPRR
LWR-5
SpCond (umhos/cm)
LWR-5 SpCond (umhos/cm)
Phase 2 Supplemental
YYYYMM


LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Turb (NTU)
Phase 2 Supplemental
YYYYMM


LWR-1
LWR-2
LWR-3
LWR-4
LWR-5
WR-US41
WR-UPRR
Wtr Temp (C)
Phase 2 Supplemental
YYYYMM


WR-UPRR
WR-US41
LWR-1
LWR-3
LWR-4
LWR-5
Percent Transmittance (@ 1m)
Phase 2 Supplemental
11/12/2015
12/15/2015
1/19/2016
2/18/2016
3/15/2016
4/19/2016
5/17/2016
6/21/2016
7/19/2016
8/15/2016
9/21/2016
10/18/2016
11/15/2016
12/13/2016
1/17/2017
2/21/2017
3/27/2017
4/18/2017
5/16/2017
6/20/2017
7/19/2017
8/21/2017
9/19/2017
10/17/2017
11/20/2019
2/18/2020
6/30/2020
8/19/2020


WR-UPRR
WR-US41
LWR-1
LWR-3
LWR-4
LWR-5
k (diffuse attenuation coefficient, m-1)
Phase 2 Supplemental
11/12/2015
12/15/2015
1/19/2016
2/18/2016
3/15/2016
4/19/2016
5/17/2016
6/21/2016
7/19/2016
8/15/2016
9/21/2016
10/18/2016
11/15/2016
12/13/2016
1/17/2017
2/21/2017
3/27/2017
4/18/2017
5/16/2017
6/20/2017
7/19/2017
8/21/2017
9/19/2017
10/17/2017
11/20/2019
2/18/2020
6/30/2020
8/19/2020

Lower Withlacoochee River Environmental Analysis – Phase 2 Water Quality Data Summary

Parameter Group	Parameter	Units	Station	Average	Maximum	Minimum	StdDev	Count	Count BDL	Period of Record	
BACTERIOLOGICAL	FC	#/100ml	WR-UPRR	59.9	370	2.00	97.2	18	0	8/15/2016	8/19/2020
			WR-US41	35.6	88.0	7.00	25.1	24	0	2/18/2016	8/19/2020
			LWR-1	15.4	190	1.00	35.6	27	1	11/12/2015	8/19/2020
			LWR-2	11.3	28.0	3.00	9.45	9	0	11/12/2015	7/19/2016
			LWR-3	19.7	74.0	1.00	17.7	27	1	11/12/2015	8/19/2020
			LWR-4	29.3	92.0	2.00	23.5	27	0	11/12/2015	8/19/2020
			LWR-5	53.3	160	5.00	39.9	27	0	11/12/2015	8/19/2020
BIOLOGICAL	Chl-a	µg/L	WR-UPRR	7.41	27.0	0.610	7.60	19	0	8/15/2016	8/19/2020
			WR-US41	3.05	8.10	0.750	1.87	25	0	2/18/2016	8/19/2020
			LWR-1	5.98	18.0	1.20	4.73	28	0	11/12/2015	8/19/2020
			LWR-2	6.03	18.0	0.980	6.96	9	0	11/12/2015	7/19/2016
			LWR-3	4.21	17.0	1.10	3.99	28	0	11/12/2015	8/19/2020
			LWR-4	3.94	19.0	0.680	4.41	27	0	11/12/2015	8/19/2020
			LWR-5	4.17	22.0	1.10	4.26	28	0	11/12/2015	8/19/2020
	Chl-a corr	µg/L	WR-UPRR	6.46	25.0	0.275	6.78	19	3	8/15/2016	8/19/2020
			WR-US41	2.48	7.20	0.410	1.70	25	1	2/18/2016	8/19/2020
			LWR-1	3.98	14.0	0.560	3.67	28	0	11/12/2015	8/19/2020
			LWR-2	3.73	14.0	0.275	5.13	9	1	11/12/2015	7/19/2016
			LWR-3	2.54	14.0	0.275	3.18	28	1	11/12/2015	8/19/2020
			LWR-4	2.86	17.0	0.275	3.72	27	3	11/12/2015	8/19/2020
			LWR-5	3.22	20.0	0.275	3.89	28	2	11/12/2015	8/19/2020
	Chl-a/Pheo Ratio	---	WR-UPRR	1.55	1.70	1.40	0.093	11	0	8/15/2016	6/20/2017
			WR-US41	1.48	1.60	1.40	0.066	17	0	2/18/2016	6/20/2017
			LWR-1	1.36	1.50	1.10	0.100	20	0	11/12/2015	6/20/2017
			LWR-2	1.29	1.50	1.20	0.105	9	0	11/12/2015	7/19/2016
			LWR-3	1.29	1.50	1.10	0.099	20	0	11/12/2015	6/20/2017
			LWR-4	1.39	1.60	1.20	0.151	19	0	11/12/2015	6/20/2017
			LWR-5	1.44	1.60	1.20	0.118	20	0	11/12/2015	6/20/2017
	Pheo-a	µg/L	WR-UPRR	1.16	7.60	0.200	1.73	19	11	8/15/2016	8/19/2020
			WR-US41	0.821	1.90	0.200	0.423	25	6	2/18/2016	8/19/2020
			LWR-1	3.06	6.40	0.830	1.89	28	0	11/12/2015	8/19/2020
			LWR-2	3.41	10.0	0.880	2.89	9	0	11/12/2015	7/19/2016
			LWR-3	2.59	6.60	0.750	1.67	28	0	11/12/2015	8/19/2020
			LWR-4	1.55	6.30	0.200	1.39	27	5	11/12/2015	8/19/2020
			LWR-5	1.36	4.00	0.200	0.952	28	2	11/12/2015	8/19/2020
DISSOLVED OXYGEN	DO	%	WR-UPRR	69.4	116	6.80	28.6	20	0	8/15/2016	8/19/2020
			WR-US41	71.8	87.0	7.50	18.0	25	0	2/18/2016	8/19/2020
			LWR-1	103	114	76.7	10.1	29	0	11/12/2015	8/19/2020
			LWR-2	100	109	88.2	7.07	9	0	11/12/2015	7/19/2016
			LWR-3	96.5	109	73.8	8.90	28	0	11/12/2015	8/19/2020
			LWR-4	95.6	110	72.2	8.78	28	0	11/12/2015	8/19/2020
			LWR-5	94.3	114	68.4	9.66	28	0	11/12/2015	8/19/2020
	DO	mg/L	WR-UPRR	5.74	8.95	0.560	2.31	20	0	8/15/2016	8/19/2020
			WR-US41	6.07	7.42	0.500	1.59	25	0	2/18/2016	8/19/2020
			LWR-1	8.61	10.7	6.11	1.19	29	0	11/12/2015	8/19/2020
			LWR-2	8.65	10.7	6.92	1.15	9	0	11/12/2015	7/19/2016
			LWR-3	8.14	10.7	5.88	1.27	28	0	11/12/2015	8/19/2020
			LWR-4	8.11	10.5	5.86	1.19	28	0	11/12/2015	8/19/2020
			LWR-5	7.92	10.4	5.48	1.30	28	0	11/12/2015	8/19/2020
GENERAL INORGANIC	Cl-T	mg/L	WR-UPRR	10.9	13.0	7.50	1.42	19	0	8/15/2016	8/19/2020
			WR-US41	8.78	11.0	7.20	0.996	25	0	2/18/2016	8/19/2020
			LWR-1	8.82	11.0	6.80	1.03	28	0	11/12/2015	8/19/2020
			LWR-2	9.69	11.0	8.80	0.805	9	0	11/12/2015	7/19/2016
			LWR-3	8.80	11.0	6.80	1.03	28	0	11/12/2015	8/19/2020
			LWR-4	9.58	21.0	6.90	2.40	28	0	11/12/2015	8/19/2020
			LWR-5	128	570	10.0	175	28	0	11/12/2015	8/19/2020
	Hardness	mg/L as CaCO3	WR-UPRR	147	188	94.1	32.6	19	0	8/15/2016	8/19/2020
			WR-US41	142	162	102	15.7	25	0	2/18/2016	8/19/2020
			LWR-1	136	163	103	14.7	28	0	11/12/2015	8/19/2020
			LWR-2	143	164	125	11.0	9	0	11/12/2015	7/19/2016
			LWR-3	136	160	106	13.7	28	0	11/12/2015	8/19/2020
			LWR-4	136	163	106	13.7	28	0	11/12/2015	8/19/2020
			LWR-5	175	311	108	56.4	28	0	11/12/2015	8/19/2020

Lower Withlacoochee River Environmental Analysis – Phase 2 Water Quality Data Summary

Parameter Group	Parameter	Units	Station	Average	Maximum	Minimum	StdDev	Count	Count BDL	Period of Record	
GENERAL INORGANIC	SO4	mg/L	WR-UPRR	24.4	52.0	8.10	13.6	19	0	8/15/2016	8/19/2020
			WR-US41	17.3	27.0	9.50	4.56	25	0	2/18/2016	8/19/2020
			LWR-1	17.6	31.0	9.50	4.98	28	0	11/12/2015	8/19/2020
			LWR-2	15.7	21.0	11.0	2.65	9	0	11/12/2015	7/19/2016
			LWR-3	17.6	31.0	9.50	4.89	28	0	11/12/2015	8/19/2020
			LWR-4	17.9	32.0	9.70	5.19	28	0	11/12/2015	8/19/2020
			LWR-5	34.0	95.0	10.0	25.5	28	0	11/12/2015	8/19/2020
METAL	As-T	µg/L	WR-UPRR	0.983	2.71	0.580	0.547	19	0	8/15/2016	8/19/2020
			WR-US41	0.651	2.24	0.330	0.435	25	0	2/18/2016	8/19/2020
			LWR-1	0.620	1.84	0.400	0.325	28	0	11/12/2015	8/19/2020
			LWR-2	0.567	0.770	0.410	0.113	9	0	11/12/2015	7/19/2016
			LWR-3	0.629	1.70	0.410	0.312	28	0	11/12/2015	8/19/2020
			LWR-4	0.639	1.71	0.400	0.304	28	0	11/12/2015	8/19/2020
			LWR-5	0.676	1.69	0.420	0.293	28	0	11/12/2015	8/19/2020
	Ca-T	mg/L	WR-UPRR	51.0	65.4	32.7	11.0	19	0	8/15/2016	8/19/2020
			WR-US41	48.4	54.6	35.1	5.12	25	0	2/18/2016	8/19/2020
			LWR-1	45.5	55.4	34.2	5.54	28	0	11/12/2015	8/19/2020
			LWR-2	48.5	55.6	43.1	3.75	9	0	11/12/2015	7/19/2016
			LWR-3	45.6	54.4	33.3	5.20	28	0	11/12/2015	8/19/2020
			LWR-4	45.8	55.4	34.8	5.15	28	0	11/12/2015	8/19/2020
			LWR-5	48.0	55.7	37.1	4.54	28	0	11/12/2015	8/19/2020
	Cu-T	µg/L	WR-UPRR	0.205	0.400	0.100	0.096	19	11	8/15/2016	8/19/2020
			WR-US41	0.188	0.510	0.050	0.112	25	13	2/18/2016	8/19/2020
			LWR-1	0.155	0.390	0.050	0.086	28	20	11/12/2015	8/19/2020
			LWR-2	0.127	0.250	0.050	0.086	9	6	11/12/2015	7/19/2016
			LWR-3	0.162	0.320	0.050	0.079	28	17	11/12/2015	8/19/2020
			LWR-4	0.311	3.24	0.050	0.584	28	12	11/12/2015	8/19/2020
			LWR-5	0.224	0.550	0.050	0.116	28	13	11/12/2015	8/19/2020
	Fe-T	µg/L	WR-UPRR	576	2,780	63.0	679	19	0	8/15/2016	8/19/2020
			WR-US41	338	2,200	15.0	473	25	4	2/18/2016	8/19/2020
			LWR-1	213	1,050	35.0	223	28	0	11/12/2015	8/19/2020
			LWR-2	200	390	72.0	118	9	0	11/12/2015	7/19/2016
			LWR-3	209	1,080	15.0	230	28	1	11/12/2015	8/19/2020
			LWR-4	192	1,040	15.0	219	28	2	11/12/2015	8/19/2020
			LWR-5	194	1,030	32.0	209	28	0	11/12/2015	8/19/2020
	Mg-T	mg/L	WR-UPRR	4.83	6.47	3.01	1.25	19	0	8/15/2016	8/19/2020
			WR-US41	5.29	6.20	3.50	0.750	25	0	2/18/2016	8/19/2020
			LWR-1	5.33	6.31	3.42	0.724	28	0	11/12/2015	8/19/2020
			LWR-2	5.35	6.00	4.33	0.561	9	0	11/12/2015	7/19/2016
			LWR-3	5.34	6.35	3.58	0.700	28	0	11/12/2015	8/19/2020
			LWR-4	5.37	6.57	3.49	0.741	28	0	11/12/2015	8/19/2020
			LWR-5	13.4	45.2	3.83	12.5	28	0	11/12/2015	8/19/2020
NITROGEN	NH4-N	mg/L	WR-UPRR	0.035	0.400	0.003	0.089	19	0	8/15/2016	8/19/2020
			WR-US41	0.032	0.340	0.012	0.064	25	0	2/18/2016	8/19/2020
			LWR-1	0.057	0.320	0.016	0.056	28	0	11/12/2015	8/19/2020
			LWR-2	0.036	0.063	0.016	0.015	9	0	11/12/2015	7/19/2016
			LWR-3	0.052	0.250	0.017	0.044	28	0	11/12/2015	8/19/2020
			LWR-4	0.046	0.240	0.007	0.041	28	0	11/12/2015	8/19/2020
			LWR-5	0.040	0.220	0.003	0.038	28	0	11/12/2015	8/19/2020
	NOx-N	mg/L	WR-UPRR	0.137	0.320	0.002	0.096	19	1	8/15/2016	8/19/2020
			WR-US41	0.960	1.40	0.260	0.303	25	0	2/18/2016	8/19/2020
			LWR-1	0.488	0.890	0.120	0.229	28	0	11/12/2015	8/19/2020
			LWR-2	0.508	0.830	0.180	0.187	9	0	11/12/2015	7/19/2016
			LWR-3	0.510	0.900	0.170	0.211	28	0	11/12/2015	8/19/2020
			LWR-4	0.505	0.890	0.180	0.212	28	0	11/12/2015	8/19/2020
			LWR-5	0.488	0.830	0.140	0.202	27	0	11/12/2015	8/19/2020
	OrgN	mg/L	WR-UPRR	0.855	1.98	0.525	0.400	19	0	8/15/2016	8/19/2020
			WR-US41	0.625	1.49	0.259	0.347	25	0	2/18/2016	8/19/2020
			LWR-1	0.562	1.28	0.373	0.225	28	0	11/12/2015	8/19/2020
			LWR-2	0.539	0.690	0.374	0.107	9	0	11/12/2015	7/19/2016
			LWR-3	0.567	1.29	0.302	0.244	28	0	11/12/2015	8/19/2020
			LWR-4	0.528	1.16	0.316	0.194	28	0	11/12/2015	8/19/2020
			LWR-5	0.551	1.18	0.322	0.194	27	0	11/12/2015	8/19/2020

Lower Withlacoochee River Environmental Analysis – Phase 2 Water Quality Data Summary

Parameter Group	Parameter	Units	Station	Average	Maximum	Minimum	StdDev	Count	Count BDL	Period of Record	
NITROGEN	TKN	mg/L	WR-UPRR	0.891	2.00	0.530	0.440	19	0	8/15/2016	8/19/2020
			WR-US41	0.586	1.60	0.280	0.340	25	0	2/18/2016	8/19/2020
			LWR-1	0.619	1.60	0.400	0.265	28	0	11/12/2015	8/19/2020
			LWR-2	0.576	0.730	0.390	0.115	9	0	11/12/2015	7/19/2016
			LWR-3	0.595	1.30	0.350	0.223	28	0	11/12/2015	8/19/2020
			LWR-4	0.574	1.40	0.340	0.222	28	0	11/12/2015	8/19/2020
			LWR-5	0.592	1.40	0.340	0.220	27	0	11/12/2015	8/19/2020
	TN	mg/L	WR-UPRR	1.03	2.00	0.551	0.411	19	0	8/15/2016	8/19/2020
			WR-US41	1.55	1.93	1.18	0.173	25	0	2/18/2016	8/19/2020
			LWR-1	1.11	1.85	0.620	0.299	28	0	11/12/2015	8/19/2020
			LWR-2	1.08	1.31	0.690	0.196	9	0	11/12/2015	7/19/2016
			LWR-3	1.11	1.62	0.630	0.262	28	0	11/12/2015	8/19/2020
			LWR-4	1.08	1.73	0.620	0.266	28	0	11/12/2015	8/19/2020
			LWR-5	1.08	1.74	0.650	0.282	27	0	11/12/2015	8/19/2020
OTHER	Acetaminophen	µg/L	WR-UPRR	0.004	0.013	0.002	0.003	19	18	8/15/2016	8/19/2020
			WR-US41	0.004	0.012	0.002	0.002	25	24	2/18/2016	8/19/2020
			LWR-1	0.003	0.010	0.002	0.002	28	27	11/12/2015	8/19/2020
			LWR-2	0.002	0.002	0.002	0.0000	9	9	11/12/2015	7/19/2016
			LWR-3	0.003	0.010	0.002	0.002	27	27	11/12/2015	8/19/2020
			LWR-4	0.003	0.010	0.002	0.002	28	28	11/12/2015	8/19/2020
			LWR-5	0.003	0.012	0.002	0.002	28	27	11/12/2015	8/19/2020
	Carbamazepine	µg/L	WR-UPRR	0.0002	0.0004	0.0002	0.0001	19	19	8/15/2016	8/19/2020
			WR-US41	0.0002	0.0004	0.0002	0.0001	25	25	2/18/2016	8/19/2020
			LWR-1	0.0002	0.0004	0.0002	0.0001	28	28	11/12/2015	8/19/2020
			LWR-2	0.0002	0.0005	0.0002	0.0001	9	8	11/12/2015	7/19/2016
			LWR-3	0.0002	0.0004	0.0002	0.0001	27	27	11/12/2015	8/19/2020
			LWR-4	0.0002	0.0004	0.0002	0.0001	28	28	11/12/2015	8/19/2020
			LWR-5	0.0002	0.0004	0.0002	0.0001	28	28	11/12/2015	8/19/2020
	Primidone	µg/L	WR-UPRR	0.003	0.010	0.002	0.002	19	19	8/15/2016	8/19/2020
			WR-US41	0.003	0.010	0.002	0.002	25	25	2/18/2016	8/19/2020
			LWR-1	0.004	0.010	0.002	0.002	28	28	11/12/2015	8/19/2020
			LWR-2	0.004	0.004	0.004	0.0000	9	9	11/12/2015	7/19/2016
			LWR-3	0.003	0.010	0.002	0.002	27	27	11/12/2015	8/19/2020
			LWR-4	0.004	0.010	0.002	0.002	28	28	11/12/2015	8/19/2020
			LWR-5	0.004	0.010	0.002	0.002	28	28	11/12/2015	8/19/2020
	Sucralose	µg/L	WR-UPRR	0.036	0.110	0.005	0.032	19	3	8/15/2016	8/19/2020
			WR-US41	0.030	0.074	0.005	0.021	25	4	2/18/2016	8/19/2020
			LWR-1	0.032	0.078	0.005	0.023	28	5	11/12/2015	8/19/2020
			LWR-2	0.043	0.080	0.005	0.023	9	1	11/12/2015	7/19/2016
			LWR-3	0.034	0.080	0.005	0.023	27	5	11/12/2015	8/19/2020
			LWR-4	0.035	0.098	0.005	0.025	28	4	11/12/2015	8/19/2020
			LWR-5	0.035	0.078	0.005	0.022	28	3	11/12/2015	8/19/2020
PESTICIDE	2,4-D	µg/L	WR-UPRR	0.001	0.003	0.0004	0.0007	12	11	3/27/2017	8/19/2020
			WR-US41	0.003	0.026	0.0004	0.007	12	10	3/27/2017	8/19/2020
			LWR-1	0.007	0.039	0.0004	0.012	12	7	3/27/2017	8/19/2020
			LWR-3	0.007	0.042	0.0004	0.012	11	6	4/18/2017	8/19/2020
			LWR-4	0.010	0.087	0.0004	0.024	12	8	3/27/2017	8/19/2020
			LWR-5	0.008	0.068	0.0004	0.019	12	7	3/27/2017	8/19/2020
	Bentazon	µg/L	WR-UPRR	0.004	0.048	0.0004	0.014	12	11	3/27/2017	8/19/2020
			WR-US41	0.005	0.049	0.0004	0.014	12	10	3/27/2017	8/19/2020
			LWR-1	0.005	0.049	0.0004	0.014	12	9	3/27/2017	8/19/2020
			LWR-3	0.0005	0.001	0.0004	0.0003	11	9	4/18/2017	8/19/2020
			LWR-4	0.005	0.049	0.0004	0.014	12	9	3/27/2017	8/19/2020
			LWR-5	0.004	0.048	0.0004	0.014	12	9	3/27/2017	8/19/2020
	Diquat	µg/L	WR-US41	0.500	0.500	0.500	---	1	1	8/15/2016	8/15/2016
			LWR-1	0.500	0.500	0.500	---	1	1	8/15/2016	8/15/2016
	Diuron	µg/L	WR-UPRR	0.001	0.004	0.0004	0.0010	19	18	8/15/2016	8/19/2020
			WR-US41	0.001	0.002	0.0004	0.0007	25	25	2/18/2016	8/19/2020
			LWR-1	0.002	0.010	0.0004	0.002	28	26	11/12/2015	8/19/2020
			LWR-2	0.002	0.012	0.001	0.004	9	8	11/12/2015	7/19/2016
			LWR-3	0.002	0.010	0.0004	0.002	27	25	11/12/2015	8/19/2020
			LWR-4	0.002	0.015	0.0004	0.003	28	26	11/12/2015	8/19/2020
			LWR-5	0.002	0.010	0.0004	0.002	28	25	11/12/2015	8/19/2020
	Endothall	µg/L	WR-US41	2.50	2.50	2.50	---	1	1	8/15/2016	8/15/2016
			LWR-1	2.50	2.50	2.50	---	1	1	8/15/2016	8/15/2016

Lower Withlacoochee River Environmental Analysis – Phase 2 Water Quality Data Summary

Parameter Group	Parameter	Units	Station	Average	Maximum	Minimum	StdDev	Count	Count BDL	Period of Record	
PESTICIDE	Fenuron	µg/L	WR-UPRR	0.006	0.008	0.004	0.002	7	7	7/19/2017	8/19/2020
			WR-US41	0.006	0.008	0.004	0.002	7	7	7/19/2017	8/19/2020
			LWR-1	0.009	0.027	0.004	0.008	7	6	7/19/2017	8/19/2020
			LWR-3	0.007	0.014	0.004	0.004	7	6	7/19/2017	8/19/2020
			LWR-4	0.006	0.008	0.004	0.002	7	7	7/19/2017	8/19/2020
			LWR-5	0.006	0.008	0.004	0.002	7	7	7/19/2017	8/19/2020
	Fluridone	µg/L	WR-UPRR	0.003	0.007	0.0004	0.002	19	2	8/15/2016	8/19/2020
			WR-US41	0.003	0.021	0.0002	0.006	25	5	2/18/2016	8/19/2020
			LWR-1	0.005	0.015	0.0007	0.003	28	0	11/12/2015	8/19/2020
			LWR-2	0.006	0.014	0.002	0.004	9	0	11/12/2015	7/19/2016
			LWR-3	0.005	0.015	0.001	0.003	27	0	11/12/2015	8/19/2020
			LWR-4	0.005	0.017	0.0010	0.004	28	0	11/12/2015	8/19/2020
			LWR-5	0.005	0.017	0.001	0.003	28	0	11/12/2015	8/19/2020
	Imidacloprid	µg/L	WR-UPRR	0.001	0.002	0.0004	0.0007	19	17	8/15/2016	8/19/2020
			WR-US41	0.002	0.002	0.0004	0.0007	25	22	2/18/2016	8/19/2020
			LWR-1	0.002	0.003	0.0004	0.0007	28	25	11/12/2015	8/19/2020
			LWR-2	0.002	0.002	0.002	0.0000	9	9	11/12/2015	7/19/2016
			LWR-3	0.002	0.003	0.0004	0.0007	27	25	11/12/2015	8/19/2020
			LWR-4	0.002	0.003	0.0004	0.0007	28	25	11/12/2015	8/19/2020
			LWR-5	0.002	0.003	0.0004	0.0007	28	26	11/12/2015	8/19/2020
	Linuron	µg/L	WR-UPRR	0.002	0.005	0.002	0.0007	19	19	8/15/2016	8/19/2020
			WR-US41	0.002	0.005	0.002	0.0006	25	25	2/18/2016	8/19/2020
			LWR-1	0.002	0.005	0.002	0.0006	28	28	11/12/2015	8/19/2020
			LWR-2	0.002	0.002	0.002	0.0000	9	9	11/12/2015	7/19/2016
			LWR-3	0.002	0.005	0.002	0.0006	27	27	11/12/2015	8/19/2020
			LWR-4	0.002	0.005	0.002	0.0006	28	28	11/12/2015	8/19/2020
			LWR-5	0.002	0.005	0.002	0.0006	28	28	11/12/2015	8/19/2020
	MCPP	µg/L	WR-UPRR	0.001	0.002	0.001	0.0004	12	12	3/27/2017	8/19/2020
			WR-US41	0.001	0.002	0.001	0.0004	12	12	3/27/2017	8/19/2020
			LWR-1	0.001	0.002	0.001	0.0004	12	12	3/27/2017	8/19/2020
			LWR-3	0.001	0.002	0.001	0.0003	11	11	4/18/2017	8/19/2020
			LWR-4	0.001	0.002	0.001	0.0004	12	12	3/27/2017	8/19/2020
			LWR-5	0.001	0.002	0.001	0.0004	12	12	3/27/2017	8/19/2020
	Triclopyr	µg/L	WR-UPRR	0.003	0.005	0.002	0.001	12	12	3/27/2017	8/19/2020
			WR-US41	0.003	0.005	0.002	0.001	12	12	3/27/2017	8/19/2020
			LWR-1	0.003	0.005	0.002	0.001	12	12	3/27/2017	8/19/2020
			LWR-3	0.003	0.007	0.002	0.002	11	10	4/18/2017	8/19/2020
			LWR-4	0.003	0.005	0.002	0.001	12	12	3/27/2017	8/19/2020
			LWR-5	0.003	0.005	0.002	0.001	12	12	3/27/2017	8/19/2020
PHOSPHORUS	OrthoP	mg/L	WR-UPRR	0.048	0.280	0.002	0.070	19	4	8/15/2016	8/19/2020
			WR-US41	0.040	0.180	0.017	0.041	25	0	2/18/2016	8/19/2020
			LWR-1	0.026	0.170	0.002	0.033	28	2	11/12/2015	8/19/2020
			LWR-2	0.025	0.058	0.002	0.016	9	1	11/12/2015	7/19/2016
			LWR-3	0.029	0.180	0.004	0.034	28	0	11/12/2015	8/19/2020
			LWR-4	0.028	0.170	0.002	0.032	28	1	11/12/2015	8/19/2020
			LWR-5	0.029	0.170	0.002	0.032	28	1	11/12/2015	8/19/2020
	TP	mg/L	WR-UPRR	0.086	0.410	0.028	0.094	19	0	8/15/2016	8/19/2020
			WR-US41	0.071	0.320	0.033	0.067	25	0	2/18/2016	8/19/2020
			LWR-1	0.061	0.230	0.028	0.039	28	0	11/12/2015	8/19/2020
			LWR-2	0.061	0.084	0.039	0.017	9	0	11/12/2015	7/19/2016
			LWR-3	0.059	0.240	0.025	0.041	28	0	11/12/2015	8/19/2020
			LWR-4	0.056	0.230	0.026	0.039	28	0	11/12/2015	8/19/2020
			LWR-5	0.057	0.220	0.029	0.036	28	0	11/12/2015	8/19/2020
PHYSICAL	Color	PCU	WR-UPRR	167	530	22.0	168	19	0	8/15/2016	8/19/2020
			WR-US41	92.7	440	5.20	110	25	0	2/18/2016	8/19/2020
			LWR-1	77.4	440	11.0	90.5	28	0	11/12/2015	8/19/2020
			LWR-2	69.9	130	23.0	39.6	9	0	11/12/2015	7/19/2016
			LWR-3	76.9	440	10.0	90.2	28	0	11/12/2015	8/19/2020
			LWR-4	78.2	450	10.0	94.2	28	0	11/12/2015	8/19/2020
			LWR-5	76.3	430	9.70	89.2	28	0	11/12/2015	8/19/2020
	Depth, 1% Light	m	WR-UPRR	2.14	4.37	0.237	1.30	19	0	8/15/2016	8/19/2020
			WR-US41	3.45	8.10	0.382	2.45	24	0	2/18/2016	8/19/2020
			LWR-1	2.55	6.13	0.504	1.30	28	0	11/12/2015	8/19/2020
			LWR-2	2.59	4.21	1.58	0.996	9	0	11/12/2015	7/19/2016
			LWR-3	2.97	5.71	0.469	1.49	27	0	11/12/2015	8/19/2020
			LWR-4	3.17	6.24	0.499	1.73	28	0	11/12/2015	8/19/2020
			LWR-5	3.27	6.33	0.488	1.71	28	0	11/12/2015	8/19/2020

Lower Withlacoochee River Environmental Analysis – Phase 2 Water Quality Data Summary

Parameter Group	Parameter	Units	Station	Average	Maximum	Minimum	StdDev	Count	Count BDL	Period of Record	
PHYSICAL	Kd (PAR)	m-1	WR-UPRR	3.88	24.9	0.966	5.47	19	0	8/15/2016	8/19/2020
			WR-US41	2.27	10.8	0.543	2.36	24	0	2/18/2016	8/19/2020
			LWR-1	2.07	7.30	0.685	1.35	28	0	11/12/2015	8/19/2020
			LWR-2	1.76	2.38	1.02	0.579	9	0	11/12/2015	7/19/2016
			LWR-3	1.88	7.39	0.569	1.37	27	0	11/12/2015	8/19/2020
			LWR-4	1.83	7.18	0.662	1.34	28	0	11/12/2015	8/19/2020
			LWR-5	1.70	6.83	0.547	1.24	28	0	11/12/2015	8/19/2020
	Light Trans (1m)	%	WR-UPRR	14.9	38.1	0.000	12.9	19	0	8/15/2016	8/19/2020
			WR-US41	25.1	58.1	0.002	20.2	24	0	2/18/2016	8/19/2020
			LWR-1	19.9	50.4	0.068	13.5	28	0	11/12/2015	8/19/2020
			LWR-2	20.0	36.0	9.24	11.2	9	0	11/12/2015	7/19/2016
			LWR-3	23.7	56.6	0.062	15.4	27	0	11/12/2015	8/19/2020
			LWR-4	24.9	51.6	0.076	16.4	28	0	11/12/2015	8/19/2020
			LWR-5	26.4	57.8	0.112	16.3	28	0	11/12/2015	8/19/2020
	pH	SU	WR-UPRR	7.43	8.25	6.12	0.565	20	0	8/15/2016	8/19/2020
			WR-US41	7.50	8.52	6.31	0.479	25	0	2/18/2016	8/19/2020
			LWR-1	7.80	8.60	6.90	0.395	29	0	11/12/2015	8/19/2020
			LWR-2	7.84	8.27	7.32	0.300	9	0	11/12/2015	7/19/2016
			LWR-3	7.82	8.30	6.86	0.315	28	0	11/12/2015	8/19/2020
			LWR-4	7.82	8.29	6.94	0.329	28	0	11/12/2015	8/19/2020
			LWR-5	7.77	8.29	6.64	0.369	28	0	11/12/2015	8/19/2020
	Secchi	m	WR-UPRR	1.37	2.20	0.150	0.644	19	0	8/15/2016	8/19/2020
			WR-US41	1.64	2.60	0.300	0.586	25	0	2/18/2016	8/19/2020
			LWR-1	1.23	1.80	0.250	0.408	28	0	11/12/2015	8/19/2020
			LWR-2	1.91	2.70	1.30	0.523	9	0	11/12/2015	7/19/2016
			LWR-3	2.17	3.85	0.350	1.04	28	0	11/12/2015	8/19/2020
			LWR-4	2.38	5.70	0.300	1.30	28	0	11/12/2015	8/19/2020
			LWR-5	1.97	3.70	0.400	0.804	29	0	11/12/2015	8/19/2020
	SpCond	umhos/cm	WR-UPRR	295	370	190	64.9	20	0	8/15/2016	8/19/2020
			WR-US41	281	318	209	30.5	25	0	2/18/2016	8/19/2020
			LWR-1	267	314	209	28.3	29	0	11/12/2015	8/19/2020
			LWR-2	287	314	264	16.2	9	0	11/12/2015	7/19/2016
			LWR-3	270	315	212	25.7	28	0	11/12/2015	8/19/2020
			LWR-4	274	316	214	24.2	28	0	11/12/2015	8/19/2020
			LWR-5	788	3,000	231	778	28	0	11/12/2015	8/19/2020
	Turb	NTU	WR-UPRR	1.34	7.20	0.150	1.97	19	8	8/15/2016	8/19/2020
			WR-US41	0.628	5.90	0.150	1.28	22	16	2/18/2016	8/19/2020
			LWR-1	0.471	2.04	0.150	0.587	25	17	11/12/2015	8/19/2020
			LWR-2	0.233	0.400	0.150	0.129	6	4	11/12/2015	7/19/2016
			LWR-3	0.438	1.79	0.150	0.506	24	17	11/12/2015	8/19/2020
			LWR-4	0.311	1.44	0.150	0.344	24	17	11/12/2015	8/19/2020
			LWR-5	0.589	5.10	0.150	1.05	25	17	11/12/2015	8/19/2020
TEMPERATURE	Wtr Temp	C	WR-UPRR	25.1	31.4	16.4	4.59	20	0	8/15/2016	8/19/2020
			WR-US41	24.0	27.2	18.2	2.62	25	0	2/18/2016	8/19/2020
			LWR-1	24.5	31.1	15.4	4.46	29	0	11/12/2015	8/19/2020
			LWR-2	23.2	29.7	15.4	4.79	9	0	11/12/2015	7/19/2016
			LWR-3	24.4	30.9	15.4	4.56	28	0	11/12/2015	8/19/2020
			LWR-4	24.6	31.4	15.5	4.75	28	0	11/12/2015	8/19/2020
			LWR-5	24.7	31.2	15.6	4.77	28	0	11/12/2015	8/19/2020

BDL = below detection limit